MULTIDISCIPLINARY INTERNATIONAL RESEARCH JOURNAL OF GUJARAT TECHNOLOGICAL UNIVERSITY

Gujarat Technological University
www.gtu.ac.in

ESTD - 2007

About GTU

Gujarat Technological University is a premier academic and research institution which has driven new ways of thinking and working, since its inception in 2007, by Government of Gujarat vide Gujarat Act No. 20 of 2007. Today, GTU is an intellectual destination that draws inspired scholars to its campus, keeping GTU at the nexus of ideas that challenge and change the world. GTU is a State University with 427 affiliated colleges operating across the state of Gujarat through its five zones at Ahmedabad, Gandhinagar, Vallabh Vidyanagar, Rajkot and Surat. The University caters to the fields of Engineering, Architecture, Management, Pharmacy and Computer Science. The University has about 4, 00,000 students enrolled in a large number of Diploma, Under Graduate, Post Graduate programs along with the robust Doctoral program.

VISION

To make Gujarat Technological University a World Class University

MISSION

Every single stakeholder of the University should find pleasure in working with GTU.

OBJECTIVES

 i. Make our operations transparent and acceptable to all stakeholders.
 ii. To provide quality education, training, vocation and research facilities to our students.
 iii. To continuously organize and manage Faculty Development Programs (FDPs), Seminars and Conferences.
 iv. Affiliate and Coordinate with Colleges for an effective education delivery mechanism.
 v. Timely and efficient conduct of the Examination process.
 vi. To facilitate student's placements into suitable and meaningful careers and future of their choice.

GTU has emerged as an International Innovative University in its pursuit of bringing innovation and internationalization in professional education. Within a really short span it has achieved several national accolades for its endeavor in bringing excellence in professional education. GTU is a pioneer in introducing some innovative learning methodology like "Active Learning", a classroom created online. GTU has the largest International Experience Program in collaboration with the universities of US, Canada, Bulgaria and Germany, which offers a unique opportunity to the students to enhance their capabilities and capacities in a global perspective. GTU's Research Week, a unique concept, is an evaluation process of dissertations of Master's and Doctoral Program students involving experts from the Universities across the globe.

From the Desk of Editor-in-Chief

MESSAGE

I feel pride in publishing the fifth issue of 'Multidisciplinary International Research Journal of Gujarat Technological University'.

This issue concentrates on Engineering and Pharmacy disciplines in which articles are written in different areas such as Construction Industry, Thermal Storage System, Solar Distillation Systems, Pneumatic Double Acting Rifles, LFSR Design, Urban Heat Island, Regenerative Braking in Electrical Vehicles, Ant colony optimization and Carbon Nanotubes as a Drug Delivery System etc.

I hope all these articles will be useful for their range of applications and will also open up new directions for further research.

I take this opportunity to thank the GTU editorial board members & international editorial board members for their efforts in upgrading the articles in this issue.

Dr. Pankajray Patel
Professor & Director
Graduate School of Management Studies
Gujarat Technological University

INDEX

IMPACT AND IMPORTANCE OF LEADERSHIP SKILLS AS A PART OF PROJECT SUCCESS IN CONSTRUCTION INDUSTRY

Mr. Vismay Amishkumar Shah

L.J. Institute Of Engineering & Technology

ABSTRACT

Leadership is one of the most subjective matter of all the time. It changes from head to head, company to company, people to people. The Ahmedabad construction industry is growing faster day by day; you will see development in every sector - Private as well as government. The general tendency of measuring the project success is mainly depending on 3 criteria: 1. Does project completed on time? 2. Does project completed within budget? 3. Does project achieved its predefined quality? Because of rivalry among the companies and high competition in market the field of Project management has expanded and attained unavoidable importance. With the technical advancement and increased level of complexity; the project success is largely depending on how it is managed or you can say how it has been led by the project manager. To observe and define importance of leadership skill, leadership style and few project success factors in the accordance with the leadership - A questionnaire survey was conducted to answer specifics like what is leadership according to the people who are in working in industry, which are the important skills which leader must possess, what are the project success factors in accordance with leadership skills etc. which were actually derived from background study and literature review. Total 43 responses were received covering all the positions like senior project manager, Project manager, Assistant project manager and Assistant project manager. 3 case studies were also included as a part of research work with the aim of to go in the detail that how leader acts or applies their leadership skills in certain phase or situation of the project. The analysis shown that the leadership skills and project success are intermediately correlated to each other with the use of SPSS software. The research also showed that there is a much need of leadership training module for the employees working at different levels.

Key words: Leadership skills, Project Management, Construction Industry, Project Success.

1 INTRODUCTION

Leadership is one of the most subjective matter of all the time. It changes from head to head, company to company. The Ahmedabad construction industry is growing faster day by day; you will see development in every sector - Private as well as government. The general tendency of measuring the project success is mainly depending on 3 criteria: 1. Does project completed on time? 2. Does project completed within budget? 3. Does project achieved its predefined quality?

Rivalry among the companies and high competition in market the field of Project management has expanded and attained unavoidable importance. With the technical advancement and increased level of complexity; the project success is largely depending on how it is managed or you can say how it has been led by the project manager. The traditional view of leadership is getting changed & will be changing dramatically in the next five to ten years.

The type of leadership or the leadership skill has become one of the important factor of project success on which there is little research is done. If we look at Ahmedabad construction industry, a person has greater chances of becoming a project manager who has great technical skills/abilities and/or has vast

experience (in years) of construction field. It is a project manager who is responsible for entire project, he is the one who needs to get things done. With only technical skills it is bit difficult to lead the project towards success as the medium scale or big scale project involves various contractors, specialized contractors, Vendors, Engineers, clients, users, consultants, designers etc. Project manager has to work combine and in accordance with all of them. The importance of Leadership skills is as equal as technical skills here.

2 LITERATURE REVIEW

There is a research gap between Best practice books and on field in the matter of who should be considered as leader? & what skills he must possess to make a project success. There are many questions and factors which affects a person's leadership skills. Here are few of the literature & what they have to say about Leaders.

Berry Benator & Albert Thumann (Author of Project Management & Leadership skills for Engineering & construction projects) initiate about leadership skills with asking a question "Are Leaders born or made?" According to them almost anyone can become a respectable front-runner with hard-work, coaching and practice. Like any other job function, leadership proficiency can be learned. And just as almost anyone can improve a skill with practice, so can leadership skills can be learned and improved upon with practice.

Professional engineers need to be exposed to different leadership skills and styles to be better prepared for future projects. By implementing leadership qualities, professionals in the industry can become more versatile and more prepared to move up to project management positions. To make these changes, numerous methods to achieve these leadership skills will have to be reviewed. To start the discussion about the development of leadership classes, the following terms are defined:

- Definition of Leaders: People who recognize the need for and implement change, establish direction, align people, motivate and inspire, give away as opposed to hoard power, communicate a vision of where the organization is headed, build teams and share decision making, mentor and coach subordinates, and demonstrate a high degree of integrity in their professional interactions (Skipper and Bell 2006).
- Definition of Leadership: Process of influencing others to understand and agree about what needs to be done and how it can be done effectively, and the process of facilitating individual and collective efforts to accomplish stated objectives (Yukl 2002).

The 3rd Addition of the PMBOK includes leadership skill into the head of interpersonal skill.

- Leadership – Developing a vision & strategy, and motivating people to achieve that vision and strategy.

The 4th Addition of the PMBOK also includes leadership skills in the head of interpersonal skill.

- Leadership is something which has more involvement in focusing on the efforts of the team towards a single goal. The key elements of it are: Admiration and faith not anxiety and obedience. Leadership is bit of critical in the early phases of the project when you have to shape the vision & have to inspire all the project stakeholders especially project team.

The 5th Addition of the PMBOK also includes leadership skills in the head of interpersonal skills.

- Successful project requires strong leadership skills. Leadership is important through all phases of the project life cycle. There are multiple leadership theories defining leadership styles that should be used as needed for each situations or team. It is especially important to communicate the vision and inspire the project team to achieve high performance.

3 OBJECTIVES OF THE STUDY

The present study is conducted with the following objectives:

- To study different factors and skills in leadership in the context of construction project management.
- To improve the current style of leadership trends so as it contributes to the project success.

4 HYPOTHESIS FORMATION:

H_1: Project Success and Leadership skills are highly correlated to each other.

H_2: Leaders can be created.

H_3: Leaders requires training at every phase of their job. (Assistant Project Manager to Senior Project Manager)

5 METHODOLOGY & DATA COLLECTION

The data was collected in the form of Questionnaire survey which was sent to almost every professional who is connected to civil engineering – Contractors, Developers, Project Management Consultants, and Academicians. Total 43 Respondents and 3 case studies were conducted from different 22 Companies.

5.1 Data Analysis

Out of 43 respondent**s** 35% were working in the project management consultancy, while 37% were associated with contracting firm. Remaining respondent were majorly Developer firm and Educational Institute.

Graph 1 Type of organization (Total No. of respondents – 43)
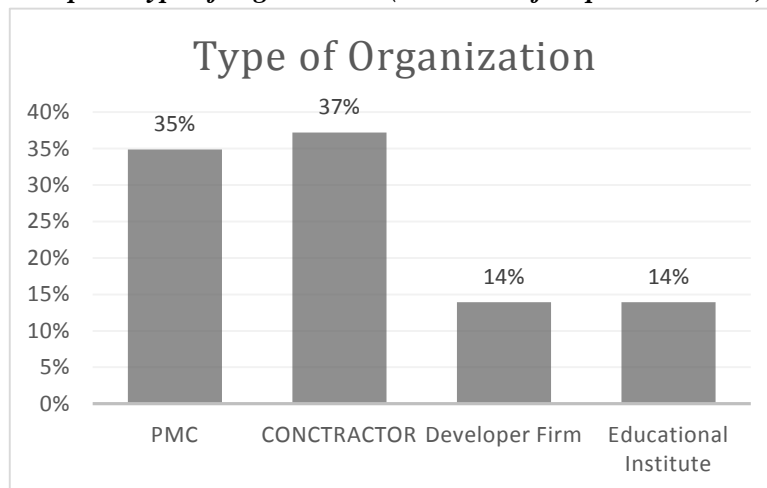
Surprisingly almost 46% respondents were having experience between 3 to 10 years. While 12% respondents were having more than 15 years of experience. Other 38% were the respondents who had just started their careers having experience 2 years or less.

Graph 2 Experience (Total No. of respondents – 43)
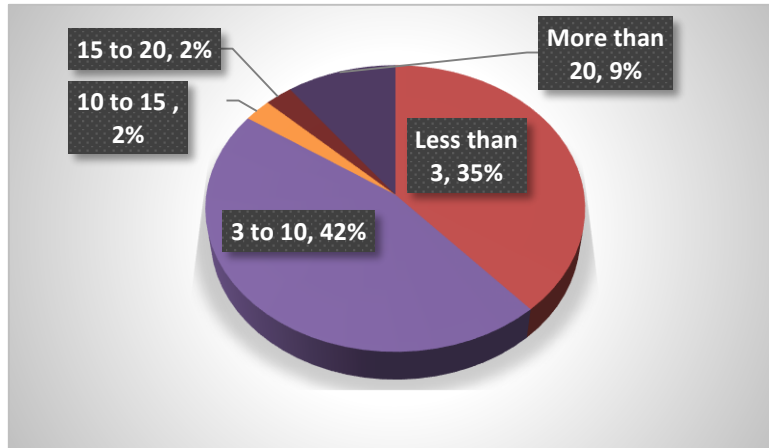
When respondent asked about that "Do they feel like a leader while managing a project?" In response to that almost 53% people partially agreed the statement while about 40% strongly felt that they act as a leader in project. Only 10% disagreed and said NO. That simply concludes that market has always demand of being leader from a project manager.

Graph 3 Are you a Leader, while managing a project? (Total No. of respondents – 43)

In the next question when they were asked that "Leaders are born or created; what is their view on that!" almost 60 – 40 situation was there. Nearly 60% respondents felt that leaders can be created while remaining were in the opinion of leaders can be born.

Graph 4 Leaders are Born or Created? (Total No. of respondents – 43)
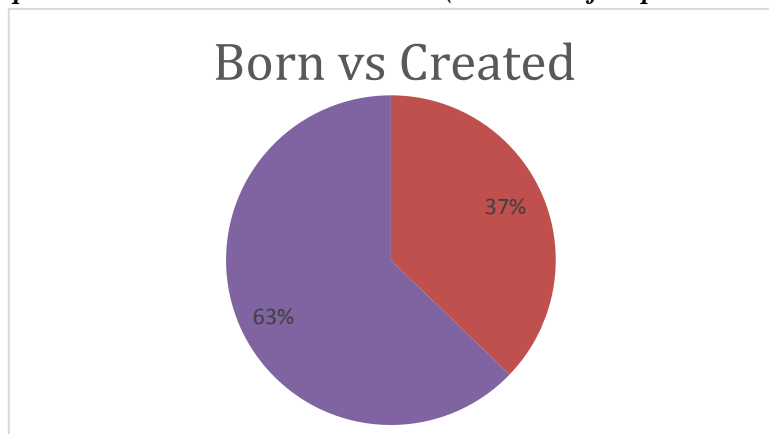
A biggest paradox was found in the analysis, which was when respondent asked that "Has he/she attended any leadership Programme?" and "Does leadership skills are require to complete the project successfully?"

On one hand 70% respondents felt that Leadership skills are require to complete the project successfully while 60% of the same respondents haven't attended any leadership Programme. Which also conflict and questions that if 63% people feels that leaders must be created but same 60% haven't attended any leadership module.

Graph 5 Have you attended any leadership Programme? (Total No. of respondents – 43)

5.2 Rank Analysis of Leadership Skills for Senior Project Managers

When in an interaction with top management – Following findings were concluded as their perception to the importance of leadership skills in construction.

Graph 6 Perception of senior project manager on leadership skills
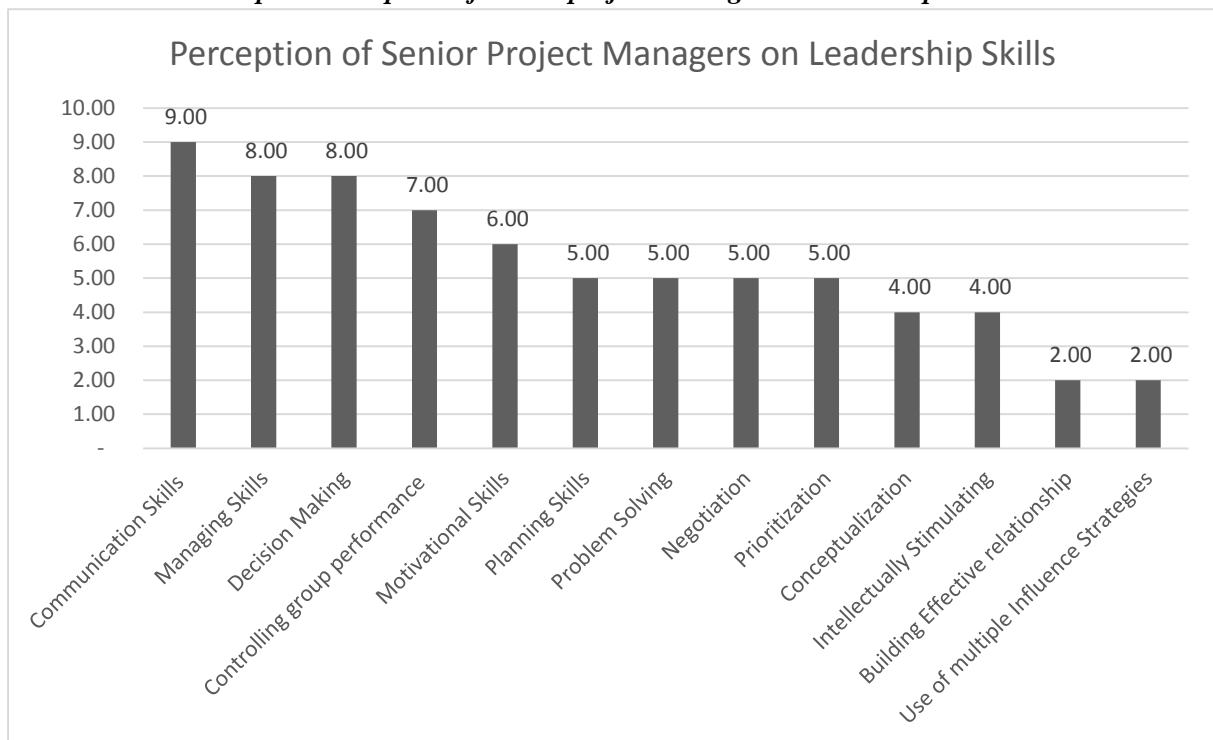
Graph 7 Perception of project manager on leadership skills

Perception of Project Managers on Leadership Skill
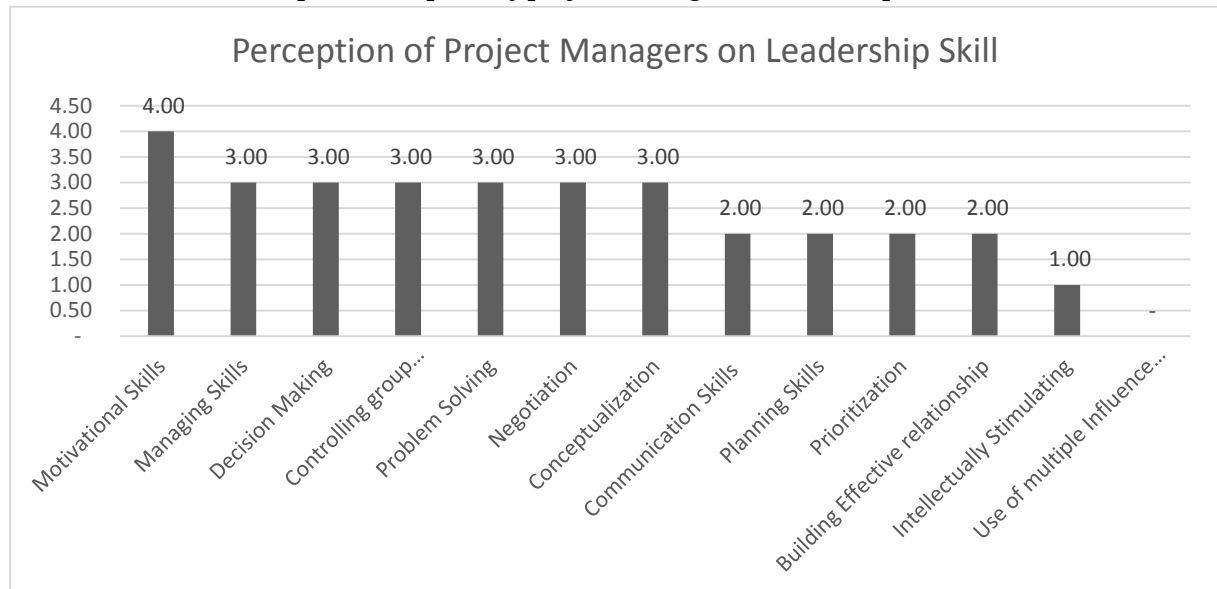
6 CONCLUSION AND RECOMMENDATION FOR FUTURE RESEARCH

Hereby, with all the collected data, analysis and findings we can conclude that leadership what PMBOK or other project management books write are nearly same to the what current construction industry or may be construction industry is turning more towards project leaders rather project managers. On the other hand, construction industry demands of leadership training modules.

A biggest paradox was found in the analysis, which was when respondent asked that "Has he/she attended any leadership programme?" and "Does leadership skills are require to complete the project successfully?"

On one hand 70% respondents felt that Leadership skills are require to complete the project successfully while 60% of the same respondents haven't attended any leadership programme. Which also conflict and questions that if 63% people feels that leaders must be created but same 60% haven't attended any leadership module.

Following training module must be applied in order to turn the project manager into a leader.

1. First there should be assessment of project manager's current skill so that area of improvement can be identified.
2. There should be Event sharing programme for senior project managers and project manager where they can share different project stories regarding leadership skills.
3. There should be training of strategy building, strategy implementation, control of group performance and other such tool which gets the project towards success.

Other Topics Include: Building greater leadership confidence and presence; understanding leadership and corporate accountability; and improving communication skills and cultural awareness. There should be training module of Authentic Leadership: They are the people whose inner breath guides their work and earn the trust of their team.

REFERENCES:

Alex Opoku, 2013, Heather Cruickshank, Vian Ahmed, Organizational leadership role in the delivery of sustainable construction projects, Built Environment Project and Asset Management

Benita Zulch, 2014, Leadership communication in project management, University of the Free State, Bloemfontein, 9300, South Africa.

Elin Elfwering & Johanna S., 2016, Leadership Competencies as success factors for project performance a case study at Skanska Sweden, Chalmers university of technology – Gothenburg Sweden.

James T. Kariuki, 2015, Project Manager Leadership Style, Teamwork, Project Characteristics and Performance of Water Projects in Kenya, Business Administration of the University of Nairobi.

Kene Christopher Lawrence,2014, Assessment of Organizational Leadership for Knowledge Management Practice in The Nigerian Construction Industry, Ahmadu Bello University, Zaria, Nigeria.

Marca ATENCIO, 2013, A Critical Success Factors Framework That Includes Leadership Competencies for Successful Delivery of Projects, university of Stanford, UK.

Mart- Mari Archer, Jacobus J.P. Verster & Benita G. Zulch, 2010, Leadership in Construction Project Management: Ignorance and Challenges, Department of Quantity Surveying and Construction Management University of the Free State, R.S.A.

Prof.P.P. Bhangale, May 2013, Study The Importance of Leadership in Construction Projects, International Journal of Latest Trends in Engineering and Technology, Maharashtra, India.

Ron garland, 1991, The Mid-Point on a Rating Scale: Is it Desirable? Marketing Bulletin.

Shamas-ur- Rehman Toor, George Ofori, 2012, Leadership and Construction Industry Development in Developing Countries, Journal of Construction in Developing Countries, Supp.

Sorrel Brown, Dec 2010, Likert scale example for surveys, lowa state university extension.

Berry Benator & Albert Thunmann,2003, Project Management & Leadership skills for Engineering & construction project, Chap 7, 102-105.

C.R. Kothari, 2004, Research Methodology – Methods and Technologies, pg. 100.

PMBOK,2004, A guide of project management body of knowledge (Third ed.). USA: Project Management Institute.

PMBOK,2008, A guide of project management body of knowledge (Fourth ed.). USA: Project Management Institute.

PMBOK,2013, A guide of project management body of knowledge (Fifth ed.). USA: Project Management Institute.

SOLAR DRYING BY USING PHASE CHANGE MATERIAL: A REVIEW

Avdhoot N. Jejurkar
Dr. Jivraj Mehta Institute of Engineering and Technology, Mogar

Anjali R. Nair
Dr. Jivraj Mehta Institute of Engineering and Technology, Mogar

Nijith Mathew
Dr. Jivraj Mehta Institute of Engineering and Technology, Mogar

ABSTRACT

Solar energy is one of the purest form of energy which we get from nature. Solar energy is hazel free from of energy. It does not create any type of pollution in environment. Many methods are used to collect solar radiation into useful form. Usage of collectors integrated to any system can enhance the already efficient working of a solar energy utilizing system. This solar energy is used for various form during day time. During off sunshine time like cloudy day or night time, when solar radiations are not present it is difficult to use it. To overcome this disadvantage research is being carried out in this field for many years. A method to overcome this problem is usage of thermal storage systems. This paper contains the different solar dryer collector study, the study of solar dryer heat storage system and solar dryer techno economic study. For eatable like vegetables, fruit like potato, onion, cashew, raisin, banana paraffin wax is considered as best option for using as Phase change material. Some research also includes study of solar dryer of vegetables and fruits using PCM. Also comparison is made without using PCM. Paraffin wax is better choice as thermal storage material. But there is a disadvantage of Paraffin wax that is low thermal-conductivity (K), to improve that many research paper have technology like metal beads, metal fins, metal foam, graphite foam, usage of metal powder etc.

Keywords: phase change materials, dryer, solar, paraffin.

1. INTRODUCTION:

Due to increase in the population of the world there is a large demand of energy. Continuous use of conventional energy can extinguish it early. This shortage of energy can only be fulfilled by renewable form of energy like solar energy. One of the most prominent way of using solar energy is by drying process. Use of solar radiation in drying can be done for vegetable, fruit etc. It reduces the total cost, efforts, uses less space, reduces use of nonrenewable energy and saves time. Earlier drying process was carried out by keeping things in open sun or by burning wood and passing that energy (heat) in drying chamber. But this methods have its own disadvantages as open drying cause hygiene problems, large open space for drying purpose **Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.**burning cause fuel extenuation as well as pollution.

2. STUDY OF VARIOUS TYPES OF SOLAR COLLECTOR

Solar collectors are used since ages, among them some of the type of collectors are flat plate collector, parabolic collector, scheffler collector, evacuated tube collector, Fresnel lens collector etc. Among the collector flat plate collector can be made of glazed material or of collector absorbing plate. Sun tracking collectors are also available like parabolic trough collector, linear Fresnel lens collector, parabolic dish reflector, heliostat field collector. Thermal and economic analyses of this collector are carried out and accordingly application is being decided. This solar collector was used in different area like solar water heating, solar refrigeration, solar drying, solar desalination, solar thermal based power plant etc. each place the collector can be selected according to the need. Like in drying only 60 to 70 ºC is needed so we can use flat plate collector but for solar power plant we need more temperature so we can use

scheffler or Fresnel lens. So this was review about solar collector its type and usage by kalogirous (2004)[14]

[15] Ayompe (2011) presented work of a year record of observation of data and result of two solar water heaters with 5 m^2**flat plate** and 4 m^2 **evacuated tube** collectors which were kept under same atmospherically condition. The reading of the two heaters was recorded on daily, monthly and yearly basis. After year it was calculated that flat plate collector produced energy of about 489 kWh/m^2 and evacuated tube collector produced 678 kWh/m^2. The yearly average collector efficiencies of flat plate collector were 45% and 61% of evacuated tube collector. Hence it was observed that the ETC are more efficient in water heating then Flat plate collector.

Tyagi (2012) [16] Research was done using paraffin wax and without using wax in different items like oil. Efficiency were calculated based on the experimental data. It was seen that efficiencies in case of heat storage material/fluid are significantly higher than the efficiency of heater of without Heat storage device. Efficiency of solar heater in which thermal storage material was used as paraffin wax was more than then material in which hytherm oil was used.

Tain Zhao (2013) had provided information on a review of various solar collectors and thermal storage methods. Information on the existing and future solar power stations was also given. According to the paper in solar collector thermal energy is absorbed from the radiation by the working fluid which can be air, wax, water or oil. Usually paraffin is used as thermal storage material but it is not so effective as the thermal conductivity of wax is very less. Tain has suggested to enhance this thermal property by adding metal powder, metal beads or metallic fins in collector. Graphite composite or metal foams are used to enhance thermal conductivity. [17]

Drying of food material also depends upon different drying kinematics. The thickness of the banana slices which will be efficient for drying purpose was mentioned in [26]. According to [28] for optimal drying or removal of moisture banana should be slices of 20 mm thickness.

Normally according to the study it is clear that active drying of materials are giving more result quick. [29] [30] [31] [32] Describes that how by drying red chilies through solar fan near collector inlet helps to enhance drying process.

3. PHASE CHANGE MATERIAL (PCM) IN SOLAR DRYER

The solar energy is only available during day time. There is no technic to store the large amount of sun energy which we are getting in conventional way like we us electricity. But there is a way to store it in thermal storage materials. PCMs are used as thermal storage materials **Error! Reference source not found.**.

Thermal energy storage devices are used for storing solar energy in night and cloudy days. The PCMs absorbs the surplus amount of the radiation which is been delivered by sun. the best thermal storage device is made by latent heat storage devices like PCMs. The only disadvantage of using PCMs are its higher volume change. Study are carried on inorganic and organic materials as PCM **Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.**. The higher price of PCM is again a draw back.

[8] Also shown experimental study of solar dryer in which sensible heat storage device and phase changing material was used. It was observed that 12.30 pm pebble temperature was 65ºC were as Paraffin temperature was 60 ºC.

PCMs are the material which absorbs and releases energy by melting and solidifying respectively. The PCMs absorbs and releases energy in form of latent heat of a substance. PCMs are seen to be more effective and better then sensible heat storage material. They are more convenient to use as they provide high energy storage density per unit volume.

```
                        ┌─────────────────┐
                        │ Phase Changing  │
                        │   materials     │
                        └─────────────────┘
        ┌───────────────────┬───────────────────┐
┌─────────────┐     ┌─────────────┐     ┌─────────────────┐
│   Organic   │     │  Inorganic  │     │ Eutectic liquids│
│ substances  │     │ substances  │     │                 │
└─────────────┘     └─────────────┘     └─────────────────┘
        │                   │
┌─────────────┐     ┌─────────────┐
│ Paraffin wax│     │Salt Hydrates│
│             │     │    H₂S      │
└─────────────┘     └─────────────┘
┌─────────────┐     ┌─────────────┐
│Non Paraffin │     │  Metallics  │
│   object    │     │   product   │
└─────────────┘     └─────────────┘
```

Salt Hydrates H_2S
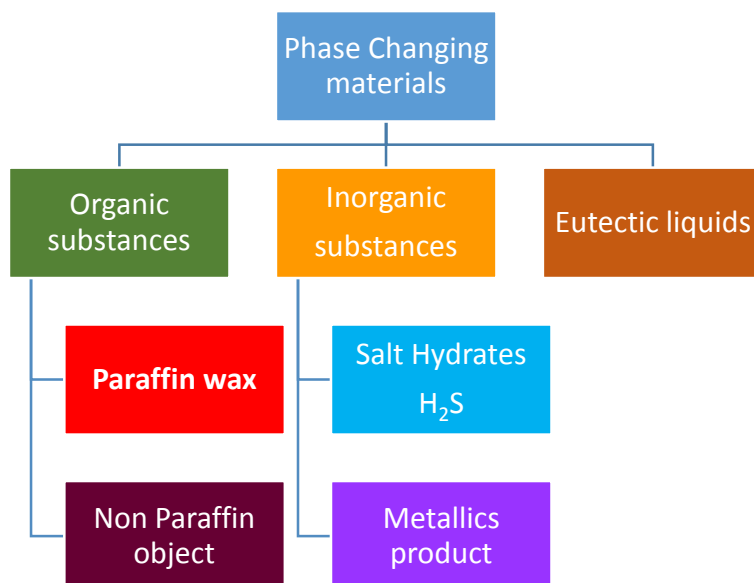
3.1 Comparison between different PCM.

| TYPE	ADVANTAGE	DISADVANTAGE
Organic	**Super cooling is not seen.** Thermal conductivity is moderately good when it is in liquid state. **It melts as well as freezes evenly.** Availability in large temperature range **Chemical properties are stable at high temperature also.** Normally heat of fusion is high. **Materials are less reactive and safe to use even for food items drying.** It can be reused mostly.	**In solid state thermal conductivity is very low.** Water cannot dissolve many organic materials. **It can catch fire easily, so at high temperature there is a risk.** It has low density, so we ned more volume to fill more mass. Hence the size of dryer increases. **If the chamber is not closed properly it can easily vaporise as it is mostly volatile.** It costly than other TES materials.
Inorganic	**Thermal conductivity is normally high.** Specific heat storage capacity is higher. **Inorganic materials are less expensive and easily available** It cannot catch fire even at high temperature. **Material can be recycled for many time.**	**High degree of super cooling** Melting takes place unevenly. **Materials like stone contains heavy weight.** Many times material like water can corrode the other metallic part of dryer. **Proper container is needed for filling and keeping material.**
Eutectic	Sharp melting temperature High volumetric thermal storage density No phase segregation and congruent phase change	Lack of currently available test data of thermo-physical properties Low total latent heat capacity Some of eutectics suffer from super-cooling effect Strong Odour Costly

3.2   Use of PCM in Solar Dryer
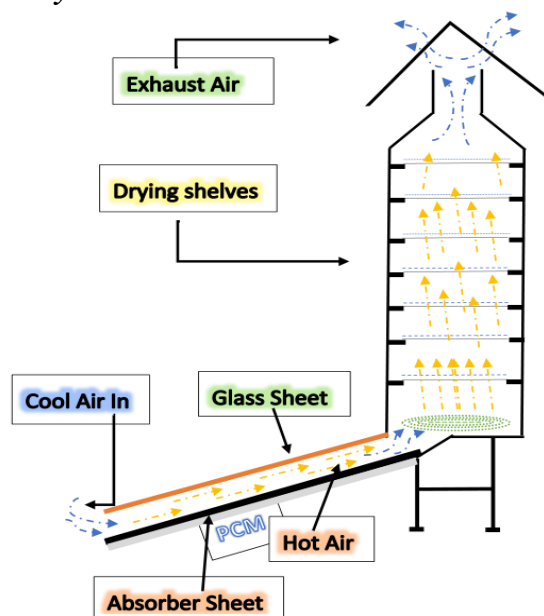
Fig. 1: -Sketch diagram of a solar dryer using PCM

As we see in above fig [1]. the sun radiation is absorbed by the pcm which is stored in collector area. This phase change material will change its state from phase solid state to liquid state this results in melting of phase changing material. At that point a large amount of thermal energy is stored in it. And during evening time this energy is released and the pcm will convert into solid this released energy will come in contact with collector air and that air will go in dryer chamber and it will remove moisture even in absence of solar radiation.

Aiswarya.M.S, Divya.C.R[18] in 2015, has published paper on in which study of solar dryer was carried out using latent heat storage device as well as sensible heat storage device also using with and without pcm was done. The solar dryer was developed with a thermal storage system as paraffin.

Research was carried out on Potato chips and other Vegetables. It was seen that quality of the food was maintained even color was maintained as direct sunlight was not falling on sample.

Result also says that inclusion of conductivity materials like aluminum improve the thermal conductive of the paraffin wax. The trays are made of aluminum mesh to avoid rusting. The area has a temperature of 33-36ºC.

The day-time thermal efficiency of the heaters with PCM is high for 0.032, 0.04, and 0.048 kg/s while it is low for 0.008, 0.016 and 0.024 kg/s regarding the heater without PCM. Thus, the use of the PCM in Solar dryer at a **flow rate of 0.032 kg/s** and more is energy-efficient and usable.

Based on the experiment carried out by [19] few conclusions were derived. Author used **honeycomb** structure for improving thermal conductivity of the heat storage device.

The daytime temperature of PCM material in the heater with honeycomb increased between by **8.8 and 2.0 °C**, respectively in reverse proportion to the increasing the air mass flowing rate.

Besides the PCM heaters, the highest peak lasts about 6 h, and the lowest peak is close to 10 h.

In the PCM heaters, equalizing the outlet air temperature with the inlet air temperature is shorter than 1 h to 16 min in favour of the honeycomb heater according to the increase in air mass flow rate.

As the air mass flow rate increases, the equalization times of the inlet and outlet air temperature of the heaters with heat storage were shortened.

The use of honeycomb has significantly shortened charge–discharge times.

The PCM were more efficient when the mass flow rate was higher between 2.6 to 22.3 %.

The use of honeycomb is suitable for applications where charge discharge times are essential, as well as for applications with high panel thicknesses.

[33] Shows the design of the solar dryer with nocturne which was great for increasing the drying rate. [34]The need to use a nocturnal-shutter to reduce the air temperature drop at night-time with an adverse night effect has emerged.

Different parameters of drying were taken into consideration like drying rate, moisture content from [22]. For banana internal moisture absorbing coefficient was 0.6.

3.3   Selection of PCM material:

Table 1: Physical Properties of PCMs. [20]

Properties	Organic		Inorganic	
	PCM	Non PCM	H_2S	Metallic material
Fusion enthalpy	More	More	More	Medium
Conductivity of material	Less	Less	More	Most
Temperature of fusion	-19 to 104+	6 to 120+	0 to 200	156 to 850+
Latent Heat of material(KJ/Kg)	199 to 281	91 to 251	61 to 301	26 to 301
Melting and solidifying cycle	Cycle is uniform	Non uniform during melting	Non Uniform of offend	Uniform
Density of PCM	Medium	Medium	Less	More
Effect of environment	Non corrosive	Mildly corrosive	Corrosive	Varies

Author [20] many more application of PCM was seen in paper in which solar air drying was used. The drying process for each food items is different. Like the temperature of drying can change from 45 to 90 degree. This drying can be done using solar dryer of same kind by varying phase changing material amount.

The different aspects considered for **selection** of PCM,
- Mainly economically feasible and viable
- The melting point of the material
- The high latent heat of fusion

By doing Literature review it seems that paraffin was due to its specific functions is proofed as the most useable latent heat storage materials. Paraffin comes in different type they can be melting at 40 to Paraffin has a large melting point selection options. Degree hence gives a wide range for customer to choose temperature.

Study is ongoing on increasing the quality of the PCM and also increasing the efficiency of the solar dryer.

- To increase the heat transfer capacity
- To increase the air mass flow rate in dryer

More over recent research also carried on increasing the thermal conductivity of paraffin wax by inclusion of nano particles. The temperature and heat transfer rate depends upon air flow also. Hence overall efficiency of solar dryer is increased.

By the paper review can be done that using phase changing material as best option for enhancing the efficiency. Using PCM can also make 24 hours working solar dryer. Some of the paper also uses active type of solar dryer by installation of induction fans used by solar panels. Phase changing material can bring a revolution in drying industry if used properly. Study also says that using phase changing material for initial drying increases efficiency of drying product.

3.4 *Measurement of PCM Parameters:*

For recording melting point of any type of PCM thermal analysis techniques are used. Differential scanning calorimetric abbreviated as (DSC) is a device which can measure latent heat of fusion and melting point of PCM. DSC was developed by Watson in 1962. According to **Error! Reference source not found.** the qualitative measured are based on exothermic as well as endothermic process. According to **Error! Reference source not found.** differential scanning calorimeter are used to measure amount of heat absorbed or released with the change in temperature, different samples measurement is taken out at same time and thermal action with a linear temperature ramp.

Before designing any solar thermal appliance the proper study of different Latent heat storage materials are very important. [10].

3.3 *Paraffin Wax*

Paraffin wax is an organic compound. It is mainly coming under natural alkane series. Paraffin wax are of many variety, the melting point of paraffin wax ranges from 41 to 100 ºC. Paraffin wax are very cheap, more reliable, when it is melted the change in volume when it is melting is very less. Paraffin wax also have low vapor pressure. In drying process specially items which are eatables like vegetables, fruit etc. the drying temperature is ranged between 40 to 60 º C Normally.**Error! Reference source not found.**.

For calculation of water content present in different type of fruits [24] was refereed. According to [24] raw banana has moisture content of 70 %.

Paraffin wax has received considerable attention in thermal energy storage because of its good thermal physical properties, including a suitable melting temperature, high latent heat energy, negligible super cooling, and stable chemical and thermal performance [20]. Paraffin wax (C_nH_{2n+2}) generally has a linear, cyclic, or branched structure. The melting point of paraffin wax is between **30 and 90 ◦C** [20], and its specific melting enthalpies are **180–270 kJ/kg**, which is determined by the chain length of the alkane. In general, the melting point of these types of materials increases with increasing average molecular weight, as shown

Table 2. Thermal physical properties of some paraffin materials [21].

Materials	Melting Point (∘C)	Latent Heat (kJ/kg)
Tetradecane	5.9	258
Pentadecane	9.9	193.9
Hexadecane	18.1	236
Heptadecane	20.8	171
Icosane	36.7	246
Tricosane	47.5	232
Hexacosane	56.3	256
Nonacosane	63.4	240
Dotriacontane	69.5	170
Tetratriacontane	75.9	269

4. CONCLUSION:

From the literature review commercial paraffin wax is found to be most appropriate PCM for solar dryer applications. Usually paraffin is used as thermal storage material but it is not so effective as the thermal conductivity of wax is very less. Tain has suggested to enhance this thermal property by adding metal powder, metal beads or metallic fins in collector. Graphite composite or metal foams are used to enhance thermal conductivity [39]. Overall the paper provides an idea about the methodology of why paraffin wax is considered as suitable PCM for solar drying.

After undergoing research review experiments were performed on solar dryer. The solar drying of banana chips was done with the use of Phase change material.

A natural convective drying system is developed along with thermal storage material as paraffin wax. The system is able to generate hot air at constant temperature throughout the drying period almost. [38]

Dimension of the solar dryer was selected based on the models presented by [35] [36] [37].

Banana Chips were dried within 16 hrs. from the moisture content of **72% to 15 %.**

The Heat utilization factor varied in the range of 0.12 to 0.91. The average heat utilization factor average was calculated **0.49.**

For drying process, the exergy efficiency varied in range of 28.5% to 100 % and the average exergy efficiency was calculated **67.61**%.

So at the end of the paper it is reviewed that if proper inclusion is carried on then paraffin is a good material for thermal storage.

5. COMPARISION OF THE WORK DONE WITH EXISTING WORK:

Comparison of Moisture content with other model found during literature survey

A — Indirect type solar dryer (Egypt)

B — Solar dryer using PCM performed in Rajasthan [7]

C — MOISTURE CONTENT OF DRYER

Comparison of temperature Profile with models found during literature survey

A — Temperature Profile of Dryer using paraffin wax as PCM (Egypt) [31]

B — Temperature profile of dryer using paraffin wax (Rajasthan)

C

Here A refers to be the reading of [27] and B refers to [29]. C refers to experiment done by me.

6. REFERENCES:

1. Fudholi A, Sopian K, Gabbasa M, Bakhtyar B, Yahya M, Ruslan MH, Mat S (2015) Techno-economic of solar drying systems with water based solar collector in Malaysia: A review. Renew sustain energy rev 51:809-820.

2. Kant K, Shukla A, Sharma A, Kumar A, Jain A (2016) Thermal energy storage based solar drying system: A review. Innovative Food Sci Emerg technol 34:86-99.

3. Prakash O, Kumar A (2014) Solar greenhouse drying: A Review. Renew sustain energy Rev 29:905-910.

4. Sharma A, Tyagi VV, Chen CR, Buddhi D (2009) Review on thermal energy storage with phase change materials and applications. Renew sustain energy Rev 13:318-345.

5. Alkan C, Sari A (2008) Fatty acid/ Poly(methyl methacrylate) PMMA blends as form-stable Phase change materials for latent heat thermal energy storage. Solar Energy 82:118-124.

6. Karaipekli A, Sari A (2008) Capric-myristic acid/expanded perlite composite as form-stable phase change material for latent heat thermal energy storage. Renew sustain energy Rev 33:2599-2605.

7. Tuncbilek K, Sari A, Tarhan S, Ergunes G, Kaygusuz K (2005) Lauric and Palmitic acid eutectic mixture as latent heat storage material for low temperature heating application. Energy 30:677-692.

8. David D, Johannes K, Roux J-J, Kuznik F (2011) a review on phase change materials integrated in building walls. Renew Sustain Energy Rev 15:379-391.

9. DSC (2010) Differential scanning calorimeter operator's manual.

10. Agarwal A, Sarviya R (2017) Characterization of commercial grade paraffine wax as latent heat storage material for solar dryers. Science direct materials today 4:779-789.

11. Agrawal A, Sarviya R (2014) a review of research and development work on solar dryers with heat storage. International Journal of Sustainable Energy 1-23.

12. Craig R, Powers J, Peyton F (1967) Differential thermal analysis of commercial and dental waxes. Journal of Dental Research 46:1090-97.

13. Hatakeyama T, Quinn F (1994) Thermal Analysis: Fundamentals and Applications to Polymer Science. John Wiley & Sons, New York 158

14. Soteris A. Kalogirou (2004) solar thermal collectors and applications. Progress in Energy and Combustion Science 30 (2004) 231–295

15. L.M. Ayompe a,*, A. Duffy a,*, M. Mc Keever c , M. Conlon c , S.J. McCormack b (2011) Comparative field performance study of flat plate and heat pipe evacuated tube collectors (ETCs) for domestic water heating systems in a temperate climate. Energy. Volume 36, Issue 5, May 2011, Pages 3370-3378

16. V. V. Tyag et. Al. (2011) Comparative study based on exergy analysis of solar air heater collector using thermal energy storage. Int. J. Energy Res. 2012; 3.

17. Y. Tian a , C.Y. Zhao b (2013) A review of solar collectors and thermal energy storage in solar thermal applications. Applied Energy, Volume 104, April 2013, Pages 538-553

18. Agrawal, A. & Sarviya, R.M. (2014). A review of research and development work on solar dryers with heat storage. International Journal of Sustainable Energy, 35, 583-605

19. Rabha, D. K. & Muthukumar, P. (2017). Performance studies on a forced convection solar dryer integrated with a paraffin wax–based latent heat storage system. Solar Energy, 149, 214-226.

20. Shalaby, S. M. & Bek, M. A. (2014). Experimental investigation of a novel indirect solar dryer implementing PCM as energy storage medium. Energy Conversion and Management, 83, 1-8

21. Guijun Yang, Yoon-Ji Yim, Ji Won Lee, Young-Jung Heo and Soo-Jin Par Carbon-Filled Organic Phase-Change Materials for Thermal Energy Storage: A Review

22. Erbay, Z. & Icier, F. (2009). A review of thin layer drying of foods: theory, Modelling, and experiments results. Critical Review of Food, Science and Nutrient, 50, 441-464.

23. Esakkimuthu, S., Hassabou, A.H., Palaniappan, C., Spinnler, M., Blumenberg, J. &Velraj, R. (2013). Experimental investigation on phase change material based thermal storage system for solar air heating applications. Solar Energy, 88, 144-153.

24. Karathanos, V. T. (1999). Determination of water content of dried fruits by drying Kinetics. Journal of Food Engineering, 39, 337-344.

25. Liu, Q., & Bakker-Arkema, F. W. (1997). Stochastic Modelling of grain drying, part 2: Model development. Journal of Agricultural Engineering Research, 66, 275-280.

26. Midilli, A., Kucuk, H. & Yapar, Z. (2002). A new Model for single-layer drying. Drying Technology, 20, 1503-1513.

27. Pakhare, V. V. & Salve, S. P. (2016). Design and development of solar dryer cabinet with thermal energy storage for drying chilies. International Journal of Current Engineering and Technology, 5, 2347-5161.

28. Panchariya, P. C., Popovic, D. & Sharma, A. L. (2002). Thin-layer modelling of black teadrying process. Journal of Food Engineering, 52, 349-357.

29. Pangavhane, D. R. & Sawheny, R.L., Sarsavadia, P.N. (2002). Design, development andperformance testing of a new natural convection solar dryer. Energy, 27, 579-590.

30. Parakash, S., Jha, S. K., & Datta, N. (2004). Performance evaluation of balanced carrots dried by three different driers. Journal of Food Engineering, 62, 305-313.

31. Rabha, D. K. & Muthukumar, P. (2017). Experimental investigation of thin layer drying kinetics of ghost chilli pepper (Capsicum Chinese Jacq.) dried in a forced convection solar tunnel dryer. Renewable Energy, 105, 583-589.

32. Rabha, D. K. & Muthukumar, P. (2017). Performance studies on a forced convection solar dryer integrated with a paraffin wax–based latent heat storage system. Solar Energy, 149, 214-226.

33. Shalaby, S. M. & Bek, M. A. (2014). Experimental investigation of a novel indirect solar dryer implementing PCM as energy storage medium. Energy Conversion and Management, 83, 1-8

34. Sharaf-Elden, Y. I., Blaisdell, J. L., Hamdy, M. Y. (1980). A Model for ear corn drying. Journal of Agricultural Engineering Research, 5, 1261-1265.

35. Steinfield, A., & Segal, I. (1986). A simulation Model for solar thin layer drying process. Drying Technology, 4, 535-542.

36. Tunde-Akintunde, T.Y. (2011). Mathematical Modeling of sun and solar drying of chilli pepper. Renewable Energy, 36, 2139-2145.

37. Tyagi, V.V., Panwarb,N.L., Rahim,N.A. & Kotharic, R. (2012). Review on solar air heating system with and without thermal energy storage system. Renewable and Sustainable Energy Reviews, 16, 2289-2303.

38. Togrul, I. T. & Pehlivan, D. (2004). Modelling of thin layer drying kinetics of some fruits under open-air sun drying process. Journal Food Engineering, 65, 413-425.

39. Yaldiz, O., Ertekin, C. & Uzun, H.I. (2001). Mathematical Modelling of thin layer solardrying of sultana grapes. Energy, 26, 457-465.

40. Soteris A. Kalogirou (2004) solar thermal collectors and applications. Progress in Energy and Combustion Science 30 (2004) 231–295

41. L.M. Ayompe a,*, A. Duffy a,*, M. Mc Keever c , M. Conlon c , S.J. McCormack b (2011) Comparative field performance study of flat plate and heat pipe evacuated tube collectors (ETCs) for domestic water heating systems in a temperate climate. Energy. Volume 36, Issue 5, May 2011, Pages 3370-3378

42. V. V. Tyag ET. Al. (2011) Comparative study based on exergy analysis of solar air heater collector using thermal energy storage. Int. J. Energy Res. 2012; 3.

43. Y. Tian a, C.Y. Zhao b (2013) A review of solar collectors and thermal energy storage in solar thermal applications. Applied Energy, Volume 104, April 2013, Pages 538-553

A REVIEW ON EXISTING SOLAR DISTILLATION SYSTEMS

Nijith Mathew
Dr. Jivraj Mehta Institute of
Technology, Mogar

Avdhoot N. Jejurkar
Dr. Jivraj Mehta Institute of
Technology, Mogar

Prashant S. Nair
Dr. Jivraj Mehta Institute of
Technology, Mogar

ABSTRACT

Desalination is the science of removing salt and impurities from saline or sea water for potable water, which has been used from ancient times till present day. Studies are conducted on various desalination systems to enhance the design and efficiency. Recorded and known history till date is a proof of the prominence that Desalination holds as a science. Among the various methods of desalination, Solar Distillation holds a special place due to its dependence on a renewable source of energy. Solar Distillation is further divided into active and passive, from which passive systems are more nature friendly due to lack of electrical or mechanical integration and total dependence on solar radiation. Passive systems have seen a lot of innovation in design, from a Conventional solar still to the most modern commercially sold conical stills. A Pyramid shaped solar has comparatively more productivity with respect to the basin area. A Thermal modelling to show its reduced heat loss coefficients confirms its dominance among other systems. A Thermo-economic comparison of all the major types of solar distillation systems, which takes into account all the economic and technical factors from construction to final output, furthermore asserts this claim.

Keywords: Desalination, Solar distillation, Passive System, Pyramid Solar Still.

1. INTRODUCTION

Water is a universally consumed commodity; it is necessary for both, sustenance and domestic use. The desired quality of consumed potable water is lack of impurities. Water quality is measured in TDS (Total Dissolved Solids) whose unit is PPM (Parts Per Million) or PPT (Parts per Trillion) and TSS (Total Suspended Solids) whose unit is mg/l. Most of the water on the surface is in oceans and seas (97.5%) but it has very high amount of salinity and impurities [1]. Currently the amount of water that is available for potable use is very low (0.014%) in comparison to the actual amount of water on the surface of the Earth. If the potable water on the surface depletes due to global warming and other man-made calamities, then there is no other option than to use this Saline water from the large water bodies. But the increased salt level is very harmful to the human body when consumed in a larger amount. For this problem there is only one solution, Desalination [2].
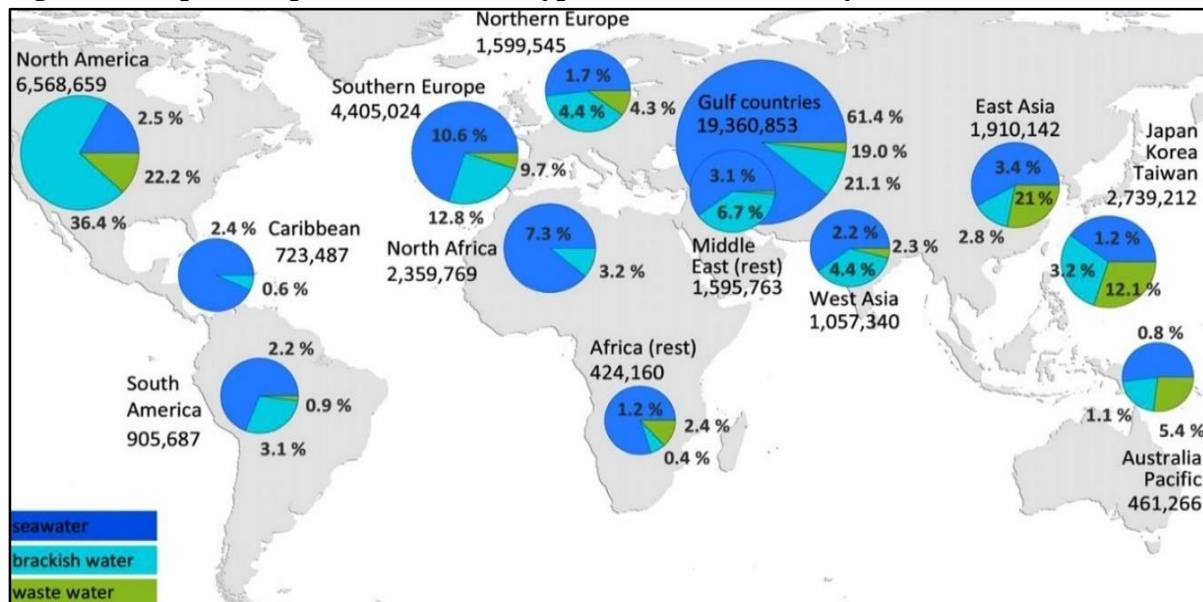
2. DESALINATION

Desalination can be traced back to a very long time ago, almost around the Egyptian Era. During the fourth century B.C. Aristotle, during his time, had described a method to desalinate impure water by evaporation and condensation. Potable water was a matter of concern when long distance ships were built. About this Alexander of Aphrodisias accounted in 200 A.D. that early Greek sailors used to boil sea water in brass utensils and collected the evaporate from the mouth of the utensil with the help of sponges or cloth to obtain sweet water [4]. Many different civilisations came up with similar ideas to desalinate water by observing the water cycle in the nature. With the rise in globalisation through ships and long distance travels the use of desalination spread throughout the remaining civilisations.

In the modern world many different types of desalination were invented and applied. Today there are many types of desalination that are prevalent and are major sources of desalinated water. Desalination systems use different types of feed water are selected according to the capacity and principle of the

desalination process involved. The main three types of water are Seawater, Brackish water and waste water. The daily desalination capacities of various countries are given in l/day in the figure 1. The percentage indicated nearby shows the percent of usage from total global usage [3]. Today there are different types of desalination systems adopted in the industry. Some of the prominent methods used in the industry are Reverse Osmosis, Multistage Flash Distillation, Multiple-effect Distillation, Electrodialysis Membrane, Membrane Distillation and Solar Distillation.

Figure 1: Graphical representation of the type of feed water used by different countries

Source: Reference Number 3

2.1 Reverse Osmosis (RO):

Reverse Osmosis is the main source of desalinated water because of its hassle free functioning, low maintenance and higher output flow. It is also preferred more in urban areas because it runs on electricity which is easily available.RO accounts for more than 22.4 Million m^3 of desalinated water per day which is 51% of the total daily output of all the desalination systems in the world [3]. The principle of a RO system is based on the natural osmosis effect -flow of liquid from higher concentration to lower concentration- found in nature, which occurs without any external force. But in RO systems the direction of flow is reversed with the help of an external force -usually a pump- and a semi permeable membrane, through which only water can flow thus entrapping salts and minerals [5]. On an average a RO system purifies only one third of the input water and rejects the remaining water in concentrate form [6] [7]. Places having water scarcity cannot afford to lose this precious water.

2.2 Multi-Stage Flash Distillation (MSF):

This is the second most used technology for desalination, after RO systems. It globally produces 14 Million m^3 of desalinated water per day which is 32% of the total daily output [3]. This technology is mostly used in Arab countries where power plants having steam generation convert steam energy to useful fuel for the MSF systems. A Multi-Stage Flash Distillation uses steam as its fuel of operation. The steam is used to increase the temperatures of the seawater and this seawater flows through consecutive chambers which have reduction in temperature. In each chamber evaporation occurs and the vapours are collected with the help of an outlet channel. The temperature decreases in each stage

while moving away from the first chamber and because of this change, the internal pressure and condensate varies successively [7] [8].

2.3 Multiple-Effect Distillation (MED):

In 1961 R. V. Dunkle published the first research paper on a roof type solar distillation unit. In that paper he discussed in detail about a Multiple Effect Diffusion Still [9]. Today MED provides more than 3.7 Million m^3 of desalinated water per day, which is 8% of the total daily output [3]. This technology is becoming obsolete day by day because of the increased amount of energy required for its functioning. Some of the major users of MED systems are Saudi Arabia, The United Arab Emirates and Kuwait (Kuwait is a country totally dependent on desalinated water and desalinates 100% of its water) [6]. The principle that a MED system runs on is similar to that of a simple Distillation System [9]. The main fuel of the system is steam that is obtained from a boiler installed for the exclusive purpose of the MED system or is the by-product of some other system [6] [7]. Saline water enters the system as hot water and passes through different chambers where the temperature increases. Evaporation occurs due to the heat of the input saline water, the reduced ambient pressures and the vapour of the previous chamber [8]. The number of chambers is dependent of the type the system. New MED systems are not installed anywhere due to its complex construction and the high installation and operating costs [10].

2.4 Electrodialysis Membrane (ED):

Most of the desalinated water in the world (c. 90%) is obtained from the above said three systems. Electrodialysis membrane produces 1.6 Million m^3 of desalinated water per day, it is 4% of the total global output [3]. Electrodialysis Membrane system is limited to desalinate only brackish water [7]. An Electrodialysis Membrane System runs on direct current flowing through parallel channels divided by positive and negative membranes which act like An-ion membrane and Cat-ion membrane. When water passes through this electric field molecules of water and molecules of salts are separated [7]. The system functions due to an electric current, so only ionic compounds can be removed from the water, whereas RO and Distillation systems can remove all types of impurities [8].

2.5 Membrane Distillation:

Membrane Distillation is also one the types of desalination which doesn't have a widespread application due to its novelty and lack of research in the field [7]. The contribution due to MD is also very low in global desalination (less than 0.5%) due to these factors [8]. In a Membrane Distillation System, a hydrophobic, microporous membrane is used to separate impurities from water. Being hydrophobic in nature the membrane will pass out water vapour molecules, but it will capture the impurities in its pores [11]. Due to the temperature gradient between the feed water and the permeate flux is created in a direction which flow occurs [12].

2.6 Solar Distillation:

Desalination of water, with the help of solar energy (Renewable energy) is called Solar Distillation. A Solar Distillation Unit or a Solar Still utilises Irradiance which passes through a transparent cover to heat the water in the basin. This water starts evaporating due to increasing temperature and controlled pressure inside the still. Water vapour rises upwards and starts to condensate on the inner side of the condensing cover and it is collected through outlet channels. The most basic type of Solar still is a Conventional solar still, also known as Single slope solar still, which has one basin and one condensing cover. Many variations were further invented to enhance the output of the solar still.

2.7 Other Technologies:

Freeze Thaw:

In this system the feed water is fed through the heat exchanger. The ice in the form of crystals are separated or washed in a cycle outside the main refrigeration cycle. A counter flow of freshwater is forced on that mixture to further clean the ice from remaining brine. This ice then enters the Melter and freshwater is obtained from it [13] [8].

Wave Powered Distillation:

A Wave powered system uses a pump that is powered with the help of the waves forming in oceans or seas. The work required to be done on the system is mainly mechanical for a RO system so to fulfil this demand of work instead of using an electrical pump, a pump that can utilize the forces of the waves and convert it to useful mechanical work is applied [14].

Vacuum Distillation:

Vacuum distillation is a part of Membrane Distillation which uses vacuum to enhance the productivity of the membrane distillation system [13]. A vacuum pressure is maintained in the side having permeate and is most suitable when volatile substances needs to be removed from the freshwater [12].

Vapour-Compression Distillation:

A Vapour Compression Distillation system utilizes the heat from the vapour compression to evaporate the seawater, sometimes even at 70^0. With the reduced pressure, the temperature required for boiling also reduces, this principle is utilized for a VCD system [13].

3. SOLAR DISTILLATION

The oldest report of using solar energy to desalinate water goes back to the time of Cleopatra the Wise, the Greek alchemist from Alexandria. He mentioned various distillers to obtain extracts from herbs and medicines using Alembics. Later on, Arab alchemists adopted these methods and found out new designs. Giambattista Della Porta (1535 -1615) wrote plenty of books in Italian. Many of those were translated to French and English, where he discusses about more than ten methods of desalination. Most significant among them was the method of desalination of water by using earthen pots exposed to sun rays to evaporate water and using vases to collect fresh water from underneath. Also, French chemist Lavoisier, in 1774, described a method of concentrating the sunrays with the help of crystal onto the distillation flasks for improved desalination [4].

In 1870, Norman W. Wheeler and Walton W. Evans were successfully granted a patent for a solar distillation unit based on their experimental works for distillation of alcohol and water. The complete design, functioning and the problems arising in the still were mentioned in detail in the patent, which can be said was very much progressive to be achieved at that time. In 1872, Carlos Wilson, a Swedish engineer built from his own designs, the first solar distillation unit in Las Salinas, Chile to obtain freshwater (22.70 m^3) and was functional for almost 40 years.

With the boom in technology during the 20th Century many more scientists, engineers and organizations further developed solar distillation. Some of the notable names are Mouchat, Maria Telkes, Louis Pasteur, C. G. Abbot, G. O. G. Loef, Everett D. Howe, V. A. Baum and some important organisations are Massachusetts Institute of Technology (MIT), Office of Saline Water (OSW) – USA, McGill University – Canada, Technical University of Athens, Commonwealth Scientific and Industrial Research Organization (CSIRO) – Melbourne. Indian organisations are National Physical Laboratory – New Delhi and CSIR – Central Salt and Marine Chemical Research Institute in Bhavnagar.

3.1 Passive Solar – Distillation Systems

A passive solar distillation system utilizes only the direct radiation that is absorbed by its inner surface. No integrated system is used that augments its input irradiance. Such systems are only preferred when the economics of the systems are of much importance, usually when the system is a commodity that can be used in domestic purposes by people of low-income generating populations. There exist methods by which a distillation system, while remaining passive, can increase its productivity. For this design considerations are applied to the system which includes, creating grooves or segments in the basin, using wick to increase evaporation, using different types of polymer paints/materials to increase irradiance absorption, minimizing heat and mass loss or using nanoparticles in water to increase their temperature holding capacity.

Thermal Storage Materials are also used to increase the productivity of a still during off sunshine hours. There are two divisions of thermal storage materials. Sensible heat storage materials absorb heat but do not change phase while doing so. Some of the material used are pebbles, marble, granite stones, metallic cubes. Latent heat storage materials absorb heat while changing phase. A few materials used are Phase Change Materials, wax, water, ammonia, eutectic salts.

3.1.1 Single Slope Solar Still (Conventional Solar Still)

A Single Slope Solar Still is the first type of Solar Still that was designed and incorporated foe freshwater production. That is why it gets the name Conventional Solar Still. Its basic design features are that it has a Single condensing cover and a single basin. Conventional Still holds an important place in the history of Stills as most of the modelling are based on the Conventional Still, but it became obsolete with increase in new designs and its low productivity.

A Single Slope Solar Still is placed in such a way that it always faces the Sun. The still uses the radiation from the Sun, which it collects in the Absorber plate as the source of input energy. This Absorber plate is usually painted black to absorb maximum insolation [15]. The Solar Still, being a covered box with controlled internal pressure starts boiling the water even at comparatively lower temperature. Due to boiling, evaporation occurs and those vapours rise above in the still and come in contact with the inner part of the condensing cover and undergo Dropwise Condensation in the beginning and eventually turn into Filmwise Condensation. The condensate is collected in the product line through which it is collected outside the still. The water collected from a distillation unit theoretically has zero PPM of TDS or TSS.

Figure 2: Working principle of a Conventional solar still
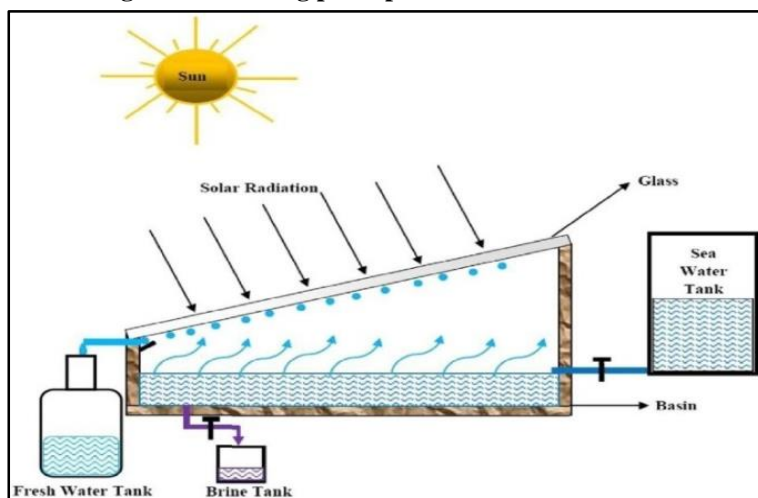
Source: Reference Number 15

3.1.2 Double Slope Solar Still

A double slope solar still works on the same principle as that of a single slope solar still. The only difference is in the shape of the condensing cover. In a double slope solar still two condensing covers of same dimensions are placed on the top of the still, with joined edges giving, it an isosceles triangle type of design. This still is placed in such a way that the line joining the condensing covers are parallel to the longitude and the covers face east and west direction respectively [16].

3.1.3 Triangular Pyramid Solar Still

A Triangular Pyramid Solar Still has three sheets of triangle shaped condensing covers joined together at the top edges. There are usually three product lines to collect the distillate output. The main benefit of a Triangular shaped cover is that the direction of the still does not matter as sunrays can incident on the absorber plate from all around the still. So, usually, not always, the still is placed in such a way that one of the covers is facing the opposite hemisphere [17].

3.1.4 Pyramid Solar Still

A Pyramid shaped solar still is shaped like the Square Pyramids of Giza, i.e. it has four triangular condensing covers of the same dimensions joined together at the top. The distillate is collected from 1, 2 or even 4 product lines as per the necessity. The benefit of such a cover is that sunrays can be incident on the absorber plate from every side of the still and if a lower basin depth is selected then almost entire absorber plate can get direct sunlight. Other importance is the increased productivity due to less distance between condensing cover and basin water and the increased condensing cover area.

Figure 3: Working principle of a Pyramid solar still
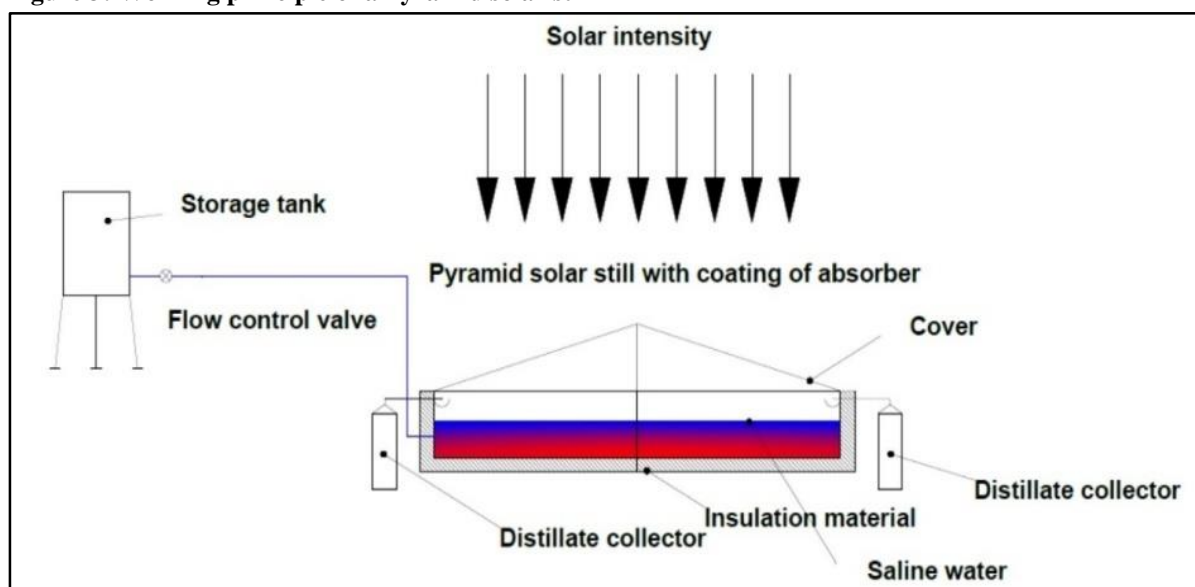
Source: Reference Number 18

3.1.5 Conical Solar Still

A Conical Solar Still has an inverted cone as the condensing cover. A conical still also has the same benefits as that of a Pyramid still. It has a common product line which is a circular ring inside the cover at the bottom part. The productivity of this solar still is comparatively less because due to the complex shape of the condensing cover only plastic or fibrous materials can be used as and the heat transfer properties of these materials are very weak in comparison to glass [1]. Because of this reason the use of conical solar still is very limited.

3.1.6 Hemispherical Solar Still

A Hemispherical Solar Still has a spherical dome type condensing cover, usually in an exact hemispherical shape or a section of hemisphere [19]. The dome is usually made of Plastic or fibrous material and so has the same limitations as that of a conical solar still. Distillate can be collected from one product line but if need arises the number is increased.
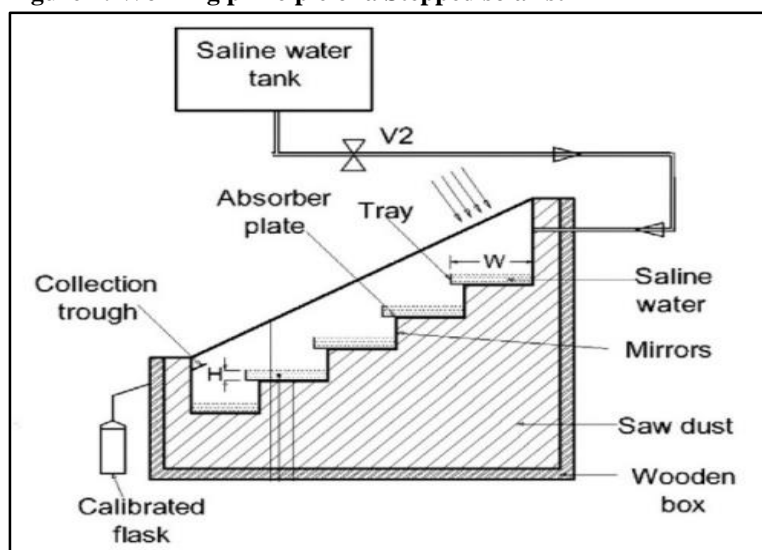
3.1.7 Spherical Solar Still

A Spherical solar still is a complete hollow sphere made of glass or transparent materials. It is supported with the help of a stand affixed on both the poles around the diameter. An open container filled with saline water and having an absorber plate at the bottom is suspended inside the sphere. Sunrays fall on the absorber plate to heat the water and its vapours rise inside the sphere and condense on the inner surface. This condensate is collected by a product line given exactly at the lowest point in the bottom hemisphere [20]. The productivity can be increased if a glass condensing cover is used, as the amount of direct radiation the absorber plate receives is of higher levels.

3.1.8 Stepped Solar Still

A Stepped solar still has a similar plain condensing cover as that of a Conventional Solar Still, but the difference is in the basin. The basin is inclined at the same angle as the condensing cover and has equidistant containments to separate water in sections. A Stepped solar still is proven to be one of the best methods of distillation for domestic and small-scale purposes [21]. It has Water inlet at the top part and a product line at the lower end of the condensing cover. Most of the radiation can be rapidly converted into heat for the water because of the separated water masses which can gain heat easily due to lesser quantity.

Figure 4: Working principle of a Stepped solar still

Source: Reference Number 21

3.1.9 Tubular Solar Still

A Tubular Solar Still, like a Spherical Solar Still, is completely transparent and is a long hollow cylinder with a similarly long water basin suspended in the centre. The radiation heats the water in the basin and this initiates evaporation. The condensing cover being a tube traps and condenses the vapour which in turn slides down towards the lower end of the slightly tilted tube. These still have only one product outlet [20].

3.2 Active Solar – Distillation Systems

Active solar distillation systems use integration of other irradiance absorbing/enhancing systems to increase the productivity of the system. These types of systems are comparatively costly and thus are used by Governments, advanced institutions and by very few domestic users who can afford such higher cost for better productivity. The key types of systems of integration to enhance the productivity are discussed below.

3.2.1 (Reflecting) Mirror

Mirrors have been used to reflect solar radiation in solar and various other systems where just reflection is needed, not concentration. Mirrors are used solely to reflect radiation which in turn increases the irradiance on an absorbing surface. Mirrors are attached in solar distillation systems at an angle so that the radiation can be reflected on the absorber plate and the angle is changed according to the time of the day or the time of the year [22].

3.2.2 Flat Plate Collector

Flat Plate Collectors are used to increase the absorber plate area of any given system without changing the design of the existing system. They are simple boxes with glass or fibrous material as the cover and have a basin of black colour to absorb more heat for the system. The Fluid (usually Air or Water) is streamed through the flat plate collector through Natural convection (gravity) or Forced convection (pump). This extra heated fluid is the used for the system, thus increasing the temperature of the inlet fluid and increasing the productivity of the system [23].

3.2.3 Evacuated Tubular Collector

An Evacuated tube collector is the modernized design of a collector which is applied broadly in the industry because of its great efficiency. An ETC contains two concentric glass cylinders separated by vacuum in which the inner cylinder has a reflective coating which traps all the solar radiation inside it and the vacuum acts as insulation to prevent heat losses [24]. Generally, an array of ETCs kept parallel to each other, are integrated to a system. Because of vacuum insulation the capacity of the ETC increases to a much higher level in comparison to other collector systems.

3.2.4 Concentrators

Concentrators come in various designs in which reflecting materials (generally mirror) are used to focus all the incident radiation to one specific point or line [25]. Sections of various shapes like, sphere, ellipse, parabola, cylinder, etc. are used as concentrators [26].

3.2.5 Solar Tracking

Solar tracking can enhance the yield a solar system by rotating the entire system or just the radiation absorbing/reflecting surface according to the movement of the sun across the sky [27]. The benefit of solar tracking is that the radiation falling on the system is always incident at the equivalent or optimum angle which is subjected to the maximum irradiation.

From the above-mentioned systems, it is suitable to select a passive system, as the cost and the number of components of the system while being passive is the least. Also, environmental safety is promoted through passive solar systems. A Pyramid shaped solar still proves to be efficient among the passive systems as it has the maximum output-to-basin area ratio [18].

4. PYRAMID SHAPED SOLAR DISTILLATION UNIT

A Pyramid Shaped Solar Still, as discussed earlier has four triangular condensing covers of equal dimensions joined at the top vertices in the shape of a Pyramid. This increases the condensing cover area as well as provides means for more radiation to enter the basin. When various still configurations were compared, Pyramid solar still was at top of the list with 4.3 l/m^2 productivity [2]. For Pyramid solar stills the productivity is maximum when the glass cover inclination angle is equal to the latitude angle of that particular geographical location and it tends to decrease with change in the angle [19].

As the system functions due to heat, a thermal analysis best describes the effects of heat on various components and the water in the system -which undergoes phase change multiple times. A thermal modelling, best describes the system in terms of heat and mass transfer. While a pyramid still is selected as the better option in evaluation, its thermal modelling will further add to its qualities of better candidature.

A Thermal/Theoretical model for Pyramid shaped solar still was claimed, which is hugely dependent on the thermal modelling of a double slope solar still [28]. Most of the calculations for the basin area and the hourly output were based on those of a double slope solar still. There is lack of a real thermal modelling which takes into account the complex shape of the inner side of the pyramid shaped condensing cover and the rate of heat and mass transfer to and from that complex surface.

4.1 Thermal Modelling of Pyramid Shaped Solar Still

The most conventional method of coining a thermal modelling is through segmenting the main surfaces in whose contact heat and mass transfer occur. In any solar still the surfaces through which heat/mass transfer occur are (i) Basin, (ii) Saline water and (iii) Condensing cover. After segmentation, the energy balance equations are defined to find out heat loss and its coefficient [28]. With the help of these values efficiency of the solar distillation system and its hourly output is also calculated. The energy balance equations are:

4.1.1 Energy balance equation for still basin

Solar energy absorbed by the basin = Energy stored in the basin + energy lost to the water mass by convection + total energy lost to the surroundings [28]

$$I(t) A_b \alpha'_b \quad = \quad m_b C_b \frac{dT_b}{dt} + Q_{conv,\,b-w} + Q_{loss} \tag{1}$$

Where,

$I(t)$ is incident solar energy for solar still,

A_b is area of the basin,

α'_b is the fraction of solar radiation absorbed by the basin,

$m_b C_b$ is heat capacity of the basin material and

$\frac{dT_b}{dt}$ is temperature gradient with respect to time in the basin.

Energy transfer by convection from basin to saline water in the basin is,

$$Q_{conv,\,b-w} \qquad = h_{conv,\,b-w} \, A_b (T_b - T_w) \tag{1.1}$$

Energy loss to the surroundings from the basin is,

$$Q_{loss} \qquad = U_b A_b (T_b - T_a) \tag{1.2}$$

Overall heat transfer coefficient for the basin is,

$$Ub = \left(\frac{y_{ins}}{k_{ins}} + \frac{1}{h_{t,b-a}} \right)^{-1} \tag{1.3}$$

Where, y_{ins} and k_{ins} are the thickness of insulation and thermal conductivity of insulation material.

4.1.2 Energy balance equation for salt water surface

Solar energy absorbed by the saline water + energy absorbed from the basin by convection = Energy stored in the saline water + energy loss to the inner surface of the condensing cover [28]

$$I(t)\, A_w\, \alpha'_w + Q_{conv,\, b-w} = m_w C_w \frac{dT_w}{dt} + Q_{t,\, w-c} \tag{2}$$

Where,
  A_w is area of the water surface that absorbs solar radiation,
  α'_w is fraction of solar radiation absorbed by the saline water,
  $m_w C_w$ is the heat capacity of saline water and
  $\frac{dT_w}{dt}$ is temperature gradient with respect to time in saline water.

The heat transfer for the saline water is in three modes, viz. convection, evaporation and radiation. It is evident from the following equation,

$$Q_{t,w-c} = h_{t,w-c}\, A_w\, (T_w - T_c)$$

$$= (h_{conv,w-c} + h_{rad,w-c} + h_{evp,w-c})\, A_w\, (T_w - T_c) \tag{2.1}$$

Where,

$$h_{conv,w-c} = 0.884\, X \left[(T_w - T_c) + \frac{(p_w - p_c) \cdot T_w}{268{,}900 - p_w} \right]^{\frac{1}{3}} \tag{2.2}$$

$$h_{evp,w-c} = 16.273\, X\, 10^{-3} \cdot h_{c,w-c} \cdot \frac{(p_w - p_c)}{(T_w - T_c)} \tag{2.3}$$

$$p = e^{\left[25.317 - \frac{5144}{T} \right]} \tag{2.3.1}$$

$$h_{rad,w-c} = \varepsilon_{eff}\, \sigma\, (T_w + T_c)(T_w^{\,2} + T_c^{\,2}) \tag{2.4}$$

$$\varepsilon_{eff} = \left(\frac{1}{\varepsilon_w} + \frac{1}{\varepsilon_c} - 1 \right)^{-1} \tag{2.4.1}$$

4.1.3 Energy balance equation for condensing cover (Top Cover)

Solar energy absorbed by the condensing cover + total energy received from the saline water by convection, evaporation and radiation = Energy stored in condensing cover + total energy lost to the surroundings [28]

$$I(t)\, A_c\, \alpha'_c + Q_{t,\, w-c} = m_c C_c \frac{dT_c}{dt} + Q_{t,c-a} \tag{3}$$

Where, A_c is area of condensing cover that absorbs the solar radiation,
  α'_c is fraction of solar radiation absorbed by condensing cover,
  $m_c C_c$ is heat capacity of the cover material and
  $\frac{dT_c}{dt}$ is temperature gradient of condensing cover with respect to time.

The energy transfer of the condensing cover takes place by convection between the cover and the surroundings and by radiation from the sky,

$$Q_{conv,c-a} = h_{conv,c-a} A_c (T_c - T_a) \tag{3.1}$$

$$Q_{rad,c-sky} = h_{rad,c-sky} A_c (T_c - T_{sky}) \tag{3.2}$$

$$T_{sky} = T_a - 6 \tag{3.2.1}$$

Where,

$$h_{rad,c-sky} = \varepsilon_g \sigma (T_c + T_{sky})(T_c{}^2 + T_{sky}{}^2) \tag{3.3}$$

4.2 Results from the Thermal Modelling

From the thermal modelling important theoretical quantities of a solar still system is obtained. One such quantity is the theoretical values of temperatures at any given time, T_w, T_c and T_a which are the temperature of the saline water, condensing cover and the atmosphere respectively. These values become important in finding out the theoretical mass of distillate hourly obtained from the system. Which in turn helps define the overall efficiency of the passive system as well as the instantaneous efficiency of the system. [29]

$$\begin{aligned} m_{DW|Theoretical} = {} & 0.012 (T_w - T_c) (T_c - T_a) - 3.737 \times 10^{-3} T_w (T_c - T_a) - 5.144 \times 10^{-3} T_c (T_c - T_a) + \\ & 5.365 \times 10^{-3} (T_c - T_a)^2 + 0.212(T_c - T_a) - 3.828 \times 10^{-3} T_w (T_w - T_c) - 5.015 \times 10^{-3} T_c \\ & (T_w - T_c) + 2.997 \times 10^{-3} (T_w - T_c)^2 + 0.217 (T_w - T_c) + 1.182 \times 10^{-3} T_c T_w + 1.663 \times \\ & 10^{-3} T_c{}^2 - 0.106 T_c - 0.065 T_w + 8.352 \times 10^{-4} T_w{}^2 + 1.992 \end{aligned} \tag{4}$$

$$\eta_i = \frac{\dot{m}_w L}{I(t) As} \tag{5}$$

$$\eta_{passive} = \left[\frac{\Sigma \dot{m}_w L}{A_s \int I(t)dt} \right] X 100 \tag{6}$$

Where,
  $m_{DW|Theoretical}$ is the theoretical mass of hourly distillate output
  L is the latent heat of evaporation of water
  η_i is the instantaneous efficiency of the system
  $\eta_{passive}$ is the overall efficiency of the system

4.3 Techno-Economic Comparison of Various Solar Still Designs

All the important designs of solar stills were taken into consideration for the techno-economic evaluation to rank the stills according to their efficiency. To obtain design efficiency of the solar still various components of the manufactured still are considered. The components taken into consideration here are skilled labour (SL), land area requirement (LA), productivity (P), economic impact (EI), fabrication (FC), and commercial potential (CP) and technical complexity (TC). All these were found out using Multi-criteria Decision Model (MCDM). The following table is made using MCDM based on various input and output criteria with the help of a fuzzy analytical hierarchy process (AHP) model integrated with a Data Envelopment Analysis (DEA) [6].

Table 1: Comparison of all the discussed types of solar stills

Sr. No.	Type of Solar Still (S.S.)	Efficiency	Efficiency Decomposition							Rank
			SL	FC	LA	EI	CP	P	TC	
1	S.S. with wick and fin	0.5504	0.8253	0.6034	0.3883	0.3129	0.4621	0.191	0.0341	12
2	Transportable hemispherical S.S.	0.2533	0.531	2.5976	0.8192	0.0748	0.1584	0.5804	0.1864	20
3	Stepped S.S. with wick and sponge	0.5277	0.6909	0.7273	0.4767	0.1573	0.1666	0.6107	0.0654	15
4	Stepped S.S. with sun tracking system	0.5269	0.1887	1.054	0.6551	0.0797	0.1689	0.6189	0.1325	16

5	Weir type S.S.	0.6905	0.5712	0.4827	0.3942	0.1951	0.1378	0.5049	0.1622	8
6	S.S. with sponge and pond	0.5468	0.5591	0.5723	0.6973	0.0985	0.5549	0.3058	0.0409	13
7	S.S. with shallow solar pond	0.7279	0.3214	0.4512	0.6012	0.1477	0.1564	0.5732	0.1227	7
8	S.S. with condenser	0.6342	0.4821	0.4935	0.6012	0.1477	0.1564	0.5732	0.1227	10
9	Single slope S.S.	0.5809	0.6034	0.3657	0.7524	0.2218	0.1175	0.4304	0.2304	11
10	Single slope S.S. with PVT	1	0.1758	0.3856	0.4385	0.0399	0.1349	0.0372	0.7881	**1**
11	S.S. with collector	0.4858	0.5638	0.7914	0.7031	0.0496	0.5595	0.3083	0.0825	19
12	S.S. with concentrator	0.6368	0.5026	0.441	0.6268	0.2309	0.1631	0.4781	0.1279	9
13	S.S. with sun tracking	0.5129	0.624	0.5474	0.7781	0.3451	0.5096	0.0702	0.0752	17
14	Pyramid shape S.S.	1	0.4053	0.3087	0.286	0.3855	0.226	0.2941	0.0944	**2**
15	Pyramid shape S.S. with collector	0.5304	0.3157	1.1804	0.3891	0.0518	0.5836	0.3216	0.043	14
16	S.S. with fin	0.7437	0.6542	0.3826	0.3078	0.5344	0.1115	0.1795	0.1746	6
17	S.S. with PCM	0.7693	0.6806	0.2671	0.3522	0.2325	0.1231	0.4512	0.1932	5
18	S.S. with Nano-PCM (paraffin+TiO_2)	0.8846	0.5105	0.2677	0.3522	0.2325	0.1231	0.4512	0.1932	4
19	S.S. with Nano-PCM (paraffin + GO)	0.487	0.4704	0.801	0.7821	0.0704	0.1491	0.5465	0.234	18
20	S.S. with Nano-PCM (paraffin + CO)	0.8847	0.5105	0.2676	0.3522	0.2325	0.1231	0.4512	0.1932	**3**

Source: Reference Number 6

The results show that, single slope solar still integrated with a PVT has the highest efficiency taking into consideration all the thermo-economic aspects. And second is Pyramid shaped solar still, because of its higher output and lower cost of production and maintenance. But when looking for a system without integration, the Pyramid solar still will be the best system from all the discussed topics.

5. CONCLUSION

All dominant types of desalination were studied and among them Solar distillation was selected to be the topic of this review paper on the basis of an ecological point of view. Solar distillation has two sub categories, active and passive, which describe its integration with an electrical or mechanical component while increasing principal cost. From all methods of solar distillation discussed, pyramid shaped solar still had more distillate output. This is the reason for it to be discussed in detail in terms of thermal modelling and thermo-economic comparison. This highlights why the pyramid shaped solar still is more preferred in scientific terms with proven facts and figures.

REFERENCES
1. Gad, Helmy & El-Din, Sh & Hussien, A. & Ramzy, Khaled. (2015). Thermal analysis of a conical solar still performance: An experimental study. Solar Energy. 122. 900-909. *10.1016/j.solener.2015.10.016.*
2. Kabeel, Abd Elnaby & Abdelgaied, Mohamed & Almulla, Nouaf. (2016). Performances of pyramid-shaped solar still with different glass cover angles: Experimental study. 1-6. *10.1109/IREC.2016.7478869.*
3. Lattemann, Sabine & Kennedy, Maria & Schippers, Jan & Amy, Gary. (2010). Chapter 2 Global Desalination Situation. Sustainability Science and Engineering. 2. *10.1016/S1871-2711(09)00202-5.*

4. Tiwari, G. & Sahota, Lovedeep. (2017). Advanced Solar-Distillation Systems: Basic Principles, Thermal Modeling, and Its Application. *10.1007/978-981-10-4672-8.*

5. Elimelech, Menachem & Phillip, William. (2011). The Future of Seawater Desalination: Energy, Technology, and the Environment. Science (New York, N.Y.). 333. 712-7. *10.1126/science.1200488.*

6. Mezher, Toufic & Fath, Hassan & Abbas, Zeina & Khalid, Arslan. (2010). Techno-economic assessment and environmental impacts of desalination technologies. Desalination. 266. *10.1016/j.desal.2010.08.035.*

7. Eltawil, Mohamed & Zhao, Zhengming & Yuan, Liqiang. (2009). A review of renewable energy technologies integrated with desalination systems. Renewable and Sustainable Energy Reviews. 13. 2245-2262. *10.1016/j.rser.2009.06.011.*

8. Miller, James. (2003). Review of Water Resources and Desalination Technologies. *10.2172/809106.*

9. Dunkle, R.V... (1961). Solar Water Distillation-the Roof Type Still and Multiple Effect Diffusion Still. Heat Transfer Conference, Proceedings. International Developments in Heat Transfer. 895-902.

10. Jones, Edward & Qadir, Manzoor & van Vliet, Michelle & Smakhtin, Vladimir & Kang, Seong-mu. (2019). The state of desalination and brine production: A global outlook. Science of The Total Environment. 657. *10.1016/j.scitotenv.2018.12.076.*

11. Shaffer, Devin & Chavez, Laura & Ben-Sasson, Moshe & Romero-Vargas Castrillón, Santiago & Yip, Ngai & Elimelech, Menachem. (2013). Desalination and Reuse of High-Salinity Shale Gas Produced Water: Drivers, Technologies, and Future Directions. Environmental science & technology. 47. *10.1021/es401966e.*

12. Subramani, Arun & Jacangelo, Joseph. (2015). Emerging desalination technologies for water treatment: A critical review. Water research. 75. 164-187. *10.1016/j.watres.2015.02.032.*

13. Khawaji, Akili & Kutubkhanah, Ibrahim & Wie, Jong-Mihn. (2008). Advances in Seawater Desalination Technologies. Desalination. 221. 47-69. *10.1016/j.desal.2007.01.067.*

14. Burn, S. & Hoang, Manh & Zarzo, Domingo & Olewniak, Frank & Campos, Elena & Bolto, Brian & Barron, Olga. (2015). Desalination techniques — A review of the opportunities for desalination in agriculture. Desalination. 364. *10.1016/j.desal.2015.01.041.*

15. Sharshir, S.W. & Yang, Nuo & Peng, Guilong & Kabeel, Abd Elnaby. (2016). Factors affecting solar stills productivity and improvement techniques: A detailed review. Applied Thermal Engineering. 100. *10.1016/j.applthermaleng.2015.11.041.*

16. Kumar, Mahesh & Manchanda, Himanshu. (2015). A comprehensive decade review and analysis on designs and performance parameters of Passive Solar Still. 2. 1-24. *10.1186/s40807-015-0019-8.*

17. Sathyamurthy, Ravishankar & Nagarajan, Pk & Dharmaraj, Vijayakumar. (2015). Experimental Validation of Fresh Water Production Using Triangular Pyramid Solar Still with PCM Storage. International Journal of Engineering Research in Africa. 20. 51-58. *10.4028/www.scientific.net/JERA.20.51.*

18. Kabeel, Abd Elnaby & Sathyamurthy, Ravishankar & Sharshir, S.W. & Muthumanokar, A. & Panchal, Hitesh & Nakka, Prakash & Chandran, Prasad & Nandakumar, S. & Kady, M.S.. (2019). Effect of water depth on a novel absorber plate of pyramid solar still coated with TiO2 nano black paint. Journal of Cleaner Production. 213. 185-191. *10.1016/j.jclepro.2018.12.185.*

19. Thirugnanasambantham, Arunkumar & Rajan, Jayaprakash & Ahsan, Amimul. (2012). A comparative experimental testing in enhancement of the efficiency of pyramid solar still and hemispherical solar still. IIRE Int J Renew Energy. 7. 1-7. *10.14456/iire.2012.7.*

20. Thirugnanasambantham, Arunkumar & Kandasamy, Vinoth Kumar & Ahsan, Amimul & Rajan, Jayaprakash & Kumar, Sanjay. (2012). Experimental Study on Various Solar Still Designs. ISRN Renewable Energy. 2012. *10.5402/2012/569381.*

21. Omara, Z.M. & Kabeel, Abd Elnaby & Younes, Mohamed. (2013). Enhancing the stepped solar still performance using internal reflectors. Desalination. 314. 67–72. *10.1016/j.desal.2013.01.007.*

22. P. Prakash and V. Velmurugan. (2015). Experimental Analysis of a Solar still with Reflectors and Sensible Heat Storage Mediums. Applied Mechanics and Materials. Vol. 787. 107-111. *10.4028/www.scientific.net/AMM.787.107*

23. Tiwari, G. & Shukla, S.K & Singh, I.P. (2003). Computer modeling of passive/active solar stills by using inner glass temperature. Desalination. 154. 171-185. *10.1016/S0011-9164(03)80018-8.*

24. Nagarajan, Selvakumar & Barshilia, Harish & Rajam, K. (2010). Review of sputter deposited mid- to high- temperature solar selective coatings for Flat Plate/Evacuated tube collectors and solar thermal power generation applications.

25. Elashmawy, Mohamed. (2017). an experimental investigation of a parabolic concentrator solar tracking system integrated with a tubular solar still. Desalination. 411. 1-8. *10.1016/j.desal.2017.02.003.*

26. Thirugnanasambantham, Arunkumar & Velraj, R. & Ahsan, Amimul & Khalifa, Abdul Jabbar & Shams, Shahriar & Denkenberger, David & Sathyamurthy, Ravishankar. (2015). Effect of parabolic solar energy collectors for water distillation. Desalination and water treatment. *10.1080/19443994.2015.1119746.*

27. Kabeel, Abd Elnaby & Hamed, Ahmed & El-Agouz, S.A... (2010). A.E. Kabeel, A. M. Hamed and S. A. El-Agouz, Cost Analysis of Different Solar Still Configurations, Energy 35(2010)2901-2908. Energy. 35. *10.1016/j.energy.2010.03.021.*

28. Nayi, Kuldeep & Modi, Kalpeshkumar. (2019). Thermal Modeling of Pyramid Solar Still. Green Energy and Technology. *10.1007/978-981-13-6887-5_9.*

29. Kalidasa Murugavel K, Sivakumar S, Riaz Ahamed J, Chockalingam Kn KSK, Srithar K (2010). Single basin double slope solar still with minimum basin depth and energy storing materials. Appl Energy. 87:514–523. *10.1016/j.apenergy.2009.07.023.*

DESIGN AND FABRICATION OF PRE-CHARGED PNEUMATIC DOUBLE ACTING RIFLES

Taher Qj Patrawala
Bhagwan Mahavir College of Engineering and Technology, GTU, Gujarat

ABSTRACT

This invention correlates to CO2 air rifles and air pistols, where air rifles being filled with carbon dioxide gas, allowing to adjust the muzzle velocity according to the preference of the user, by manually adjusting the pressure at which they can shoot pellets reducing the recoil formed during the shoot and thereby preserving the shot accuracy of the rifle. This design-based on a double-acting cylinder which pushes the pellet inside the chamber and then releases in the retraction stroke. This is not a high-pressure model which runs at around 850 Psi-900 Psi, it can run on low pressure such as 60 psi to 145 psi hence it is safe to use for anyone.

Keywords – Sequence Valve; Pneumatic components; Magazine; Barrel; Stock; Pellet, double acting cylinder;

I.   INTRODUCTION

Pre-charged pneumatic (PCP) air guns represent one of the oldest air gun power plants of all time. They have been around since at least the early 1600s and most likely a bit longer. With air rifles lead soft pellets are used which are less harmful in comparison to the traditional firearms and with that they are less prone to hurt someone in a lethal way unless intended otherwise. [4]...

With black powder, speed is directly dependent on barrel length. The same is true for compressed air. Both power sources continue to accelerate a projectile as long as the pressure behind the projectile is higher than the pressure in front of it (ambient air pressure, plus the pressure wave in front of the accelerating projectile). Of course, in this example, it must be understood that friction is also always a reason to contend with. [4]

What we get from these two facts is a simple rule: A longer barrel in a pneumatic gun increases speed (to a point), and higher air pressure also increases speed (to a point). As those points are approached, the gains from longer barrels and higher pressures have diminishing returns, so designers must balance that against making a gun too long or using pressures too high for safe and convenient operation [4]…

II.   CONCEPT & METHODOLOGY

The concept of the project is to use make a pneumatic rifle based on an air gun by using CO2 gas as a pressurized gas to a junction where a projectile (Diablo pellets) in the air like a bullet. This is a trial and error method in which multiple designs have been made and tested out to meet a desired effect/result. Usage of already existing devices has been made which has been altered to our desired form to meet the desired effects.

This is done to make a modern pneumatic weapon that can be used for target practice which acts and works as a modern automatic rifle. Modern air guns have a magazine of about 20-30 bb's in them which are in a cylindrical shape and not Diablo. Making a magazine that feeds about 10-25 diablo pellets into the pneumatic rifle so that an air gun would work in a consecutive manner without the need for reloading (Traditional one by one-shot).

Existing devices are used and modified for the sole reason that they exist in the market and work properly without any problems, the price of the pneumatic rifle is also low because of this reason. A double-acting cylinder is used in this system which works at a maximum pressure of 10 bars now since its double-acting cylinder would have two ports for extraction and retraction. During the retraction period, the gas inside the pneumatic cylinder would go back to exhaust port 2 and during extraction, it would come out from exhaust port 1. So using the exhaust energy and then combining them together injunction by a Male Y pneumatic fitting we would be able to launch a projectile at a constant pressure. [11]
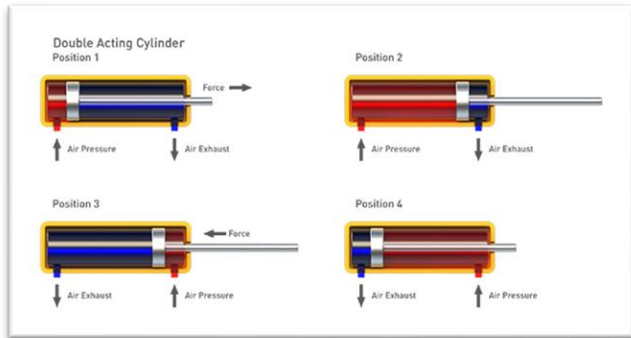
Fig.1: Double Acting Cylinder Concept

Air pressure is applied alternately to the opposite ends of the piston. Application of air pressure produces a thrust in the positive (push) stroke and thrust in the negative (pull) stroke. [11] Double-acting cylinders are typically used in all applications where the thrusts and stroke lengths required are in excess of those available from single-acting cylinders. [11]

III. DESIGN AND IMPLEMENTATION

1. *Pressure release valve*

A high-pressure tank which is capable of 2500 PSI pressure or a higher tank can be used for this modeling. We have used a 1.3kg clear line 140 bar pressure tank in our modeling that is having a poppet type valve. To bring out the pressure from the tank a soda machine (Co2) is used which is then cut and modified to make the system compact and made the soda machine valve accordingly.

Fig.2: Soda machine

Fig.3: Modified Soda Machine Valve

2. Support Structure & Arm Rest

A structure is required to support the weight of the pressurized tank which is when full (1.6 KG), and along with a support structure, it also requires looking as a pneumatic gun and gives an aesthetic feel as well. A stainless steel plate has been used for the support of the tank which has been brazed onto the soda machine valve firmly. Below the plate, an aluminum channel has been installed which works and acts like a channel (guide) for the Stock which is used to give a firm position on our shoulder.
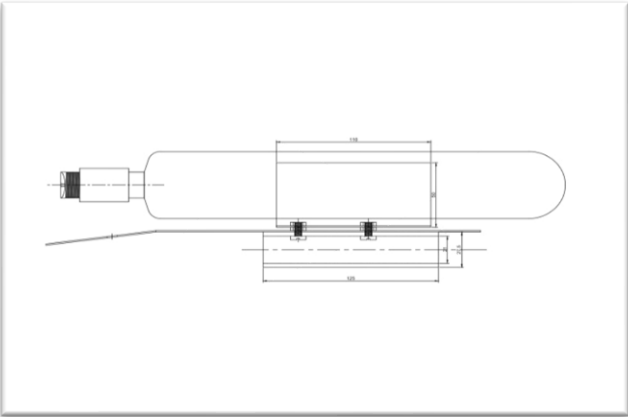
Fig.4: Support plate with the channel
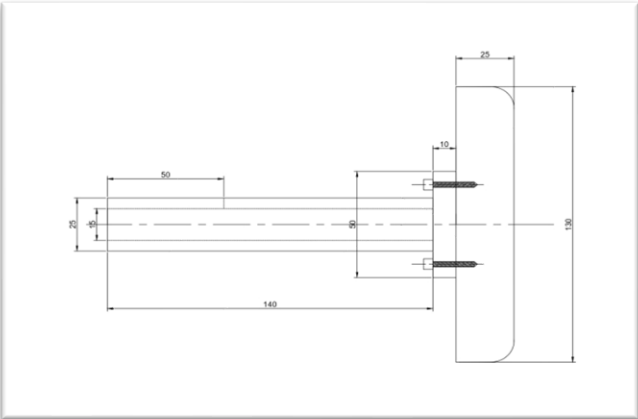
Fig.5: Arm rest

3. *Pressure Regulator*

The pressure coming out of the tank is unregulated at this stage, and to bring it to a controllable level (10bar pressure) a pressure regulator has to be installed but as in the market there were no such device available to drop the pressure from 140 bars to 10 bars and that also which are compact in size. So space was created and utilized around the PCV pipe and trigger [shown in Fig. 2]. A hole was created and using a 6mm bolt and some springs a pressure regulator was made around the space which used a winged nut as a knob [as shown in Fig 3].
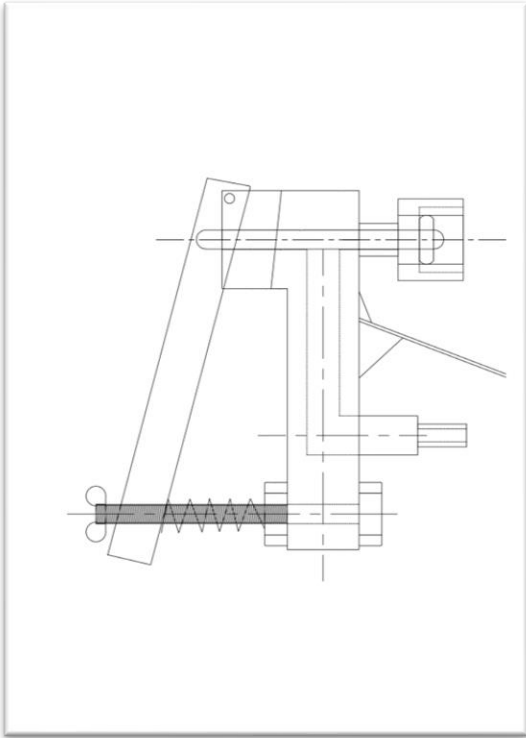
Fig.6: Pressure Regulator

A limit switch is also installed which can be seen in Fig 3. That is a bolt, now the length of the bolt can be adjusted to the degree of high pressure we require but since almost all pneumatic components work on 10 bar pressure, the bolt was set accordingly so that the regulator cannot be pressed more than that.
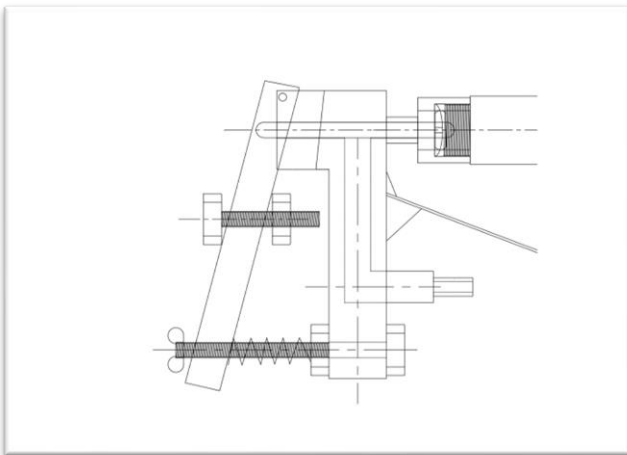
Fig.7: Pressure Regulator

4. *Pressure gauge*

To achieve an accurate flow of the pneumatic fluid (CO_2) a required pressure was installed near the spacing of the soda machine valve, the reason behind using a CO_2 tank was that with compactness it also cools the system further to sub temperature as it works more. Like a pneumatic system longer it works, cooler it runs [8] in a CO_2 operated tank the temperature decreases to subcool temperatures.

Fig.8: Pressure Regulator & Pressure Gauge

5. *Sequence Valve*

Sequence valves can improve the operation, efficiency, performance, and safety of fluid power circuits in which they are used. Sequence valves are normally closed and usually allow bidirectional flow when equipped with a bypass check valve. Sequence valves always have an external drain connected directly to the tank. [9]
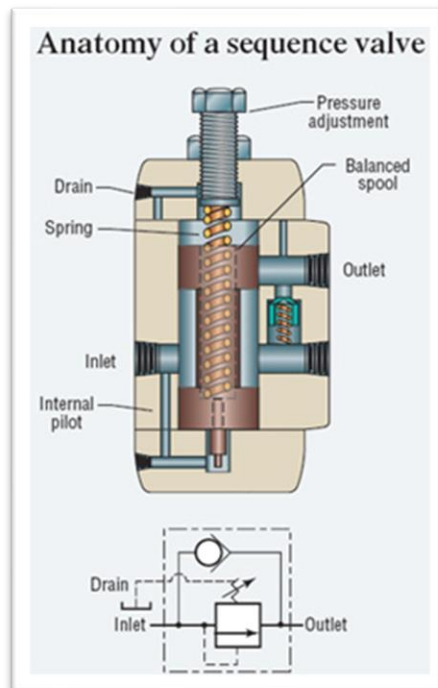
Fig.9: Anatomy of a sequence valve

When two or more cylinders operating in a parallel circuit must move in sequence, the only positive way to do this is with separate directional control valves and limits switches or limit valves. This setup ensures the first cylinder reaches a positive location before the second one begins to move. When safety or product quality will not be compromised if the first cylinder does not complete its cycle before the second one starts, a sequence valve can be a simple way of controlling cylinder actuation. [9]

A sequence valve is the best choice for a pneumatic system but due to lack of availability of it in a compact size, a double-acting cylinder and a 5/2 mechanical push-pull valve were used in the system instead of a sequence valve. A sequence valve opens up the port 2 (in the figure) when a set pressure has been achieved and when the pressure exceeds that amount a sitting valve opens and pressure is directed towards the port 2 hence in our the system when the single-acting spring return cylinder extension rod would move forward due to port 1 being normally open after the desired pressure is set the port 2 would open and the pressurized air would flush out of the port assembled together 2 which is connected to the barrel. But due to lack of availability of it in size two more components have been used.

A 5/2 Solenoid valve can also be used in this but it is not that feasible because of the solenoid being 24V DC, the system would require 2 car batteries to operate it as it needs to be compact and portable. The weight of 1 car battery is around 1.8KG which would only increase the system weight and make it heavier nothing else. Hence the solenoid valve is not feasible for this system.

6. Pneumatic Components

Since it's a Pneumatic rifle is it only understandable that Pneumatic components would be involved, the pneumatic components used in this system are mentioned as below [10];

- Techno 16*100 Double Acting miniature Cylinder
- Male Studs Mini Fitting
- Techno 5/2 Mechanical Push Pull Valve
- Male Stud - Parallel Thread
- Male Stud Taper Thread
- Push Male Y
- Push Elbow Union
- Push Union Tee
- Swivel Elbow – Taper Thread
- Male Push Connectors
- Miniature Dial Gauge
- Blanking Plug
- 4 mm Polyurethane Tubing
- 6 mm Polyurethane Tubing

These above pneumatic systems were purchased and assembled together and infused in the pneumatic system. All the pneumatic fittings are having a maximum pressure capacity of 145 Psi handling capacity.

Steps to assemble the pneumatic components in a sequence is given as below.
1) In the Techno 16*100 double-acting miniature cylinder insert the Male studs after applying some Teflon to it for a firm grip. Use a spanner to tighten the fittings to prevent air leaks.
2) In the Techno 5/2 Mechanical, the push-pull valve insert the Male Stud in them using Teflon tape and

use the spanner to tighten the fittings.

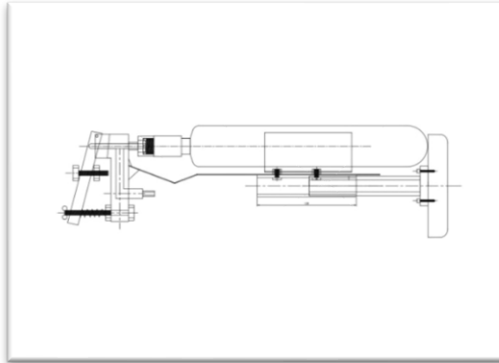3) Cut the Polyurethane tubing (6mm, 4mm) according to the size and length required.
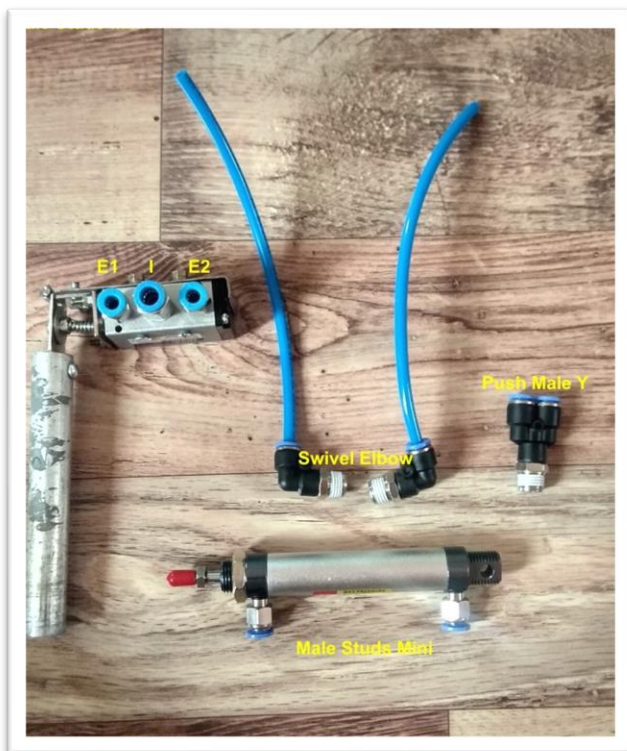

Fig.10: Pressure Regulator

Fig. 11: Pneumatic Fittings

4) Assemble the pneumatic fittings according to the image shown in Fig. 7
   o Fit the Swivel Elbow fittings in the Port A and Port B of the 5/2 mechanical valve.
   o And in the E1 port & E2 port connect the Male studs and in the Input port (I) also, connect the Male stud.
   o In the Input port (I) connect the 6mm Polyurethane tube and in E1, E2 use the 4mm Polyurethane tube which in turn is connected to the Push Male Y.
   o On port A & port B use the 4mm Polyurethane tube to connect the male stud mini fittings.

5) Use the spanner to tight the pneumatic fitting in their place as any gaps or untighten fitting would lead to leakages and pressure loss.

Fig. 12: Pneumatic Assembly

7. *Junction*

The junction is designed in AutoCAD (2D) and PTC Creo wildfire 6.00 (3D). It is a component in which the pellet falls in a slot and then taken ahead towards the chamber of the barrel and inserted at the entrance of the barrel. Where the Male Y fitting is also attached to the junction from whom the compressed gas comes out and flushes the pellet out of the barrel with velocity.

The junction component is like a pipe which allows the gas/fluid to flow from point A to point B. On point A the gas enters which when reaches to the point B meets the pellet at the exit of the component and entrance from the barrel which pushes the pellet with velocity out of the barrel.
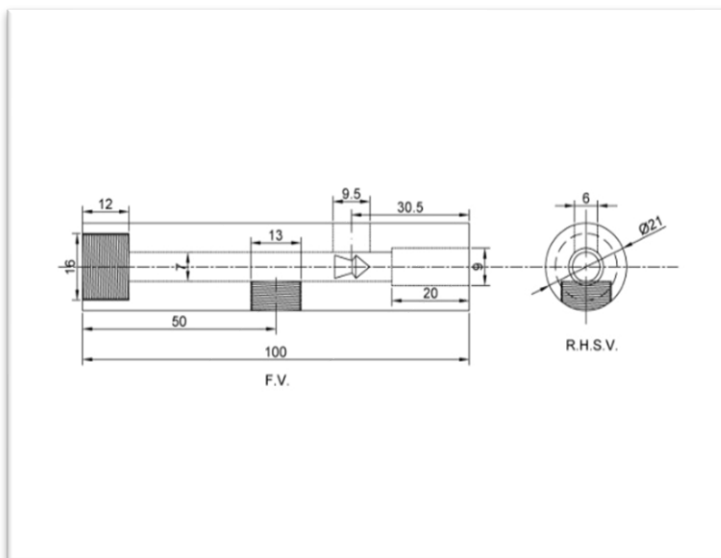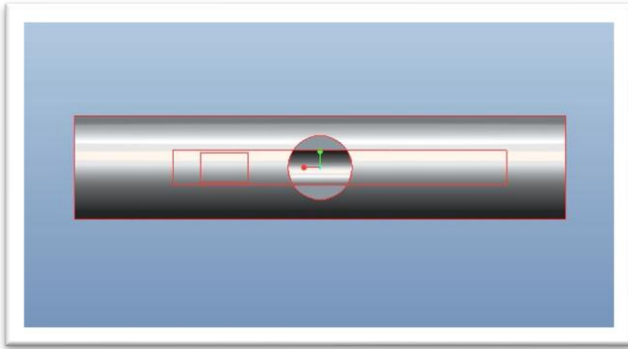

Fig. 13: Junction 2D (AutoCAD)
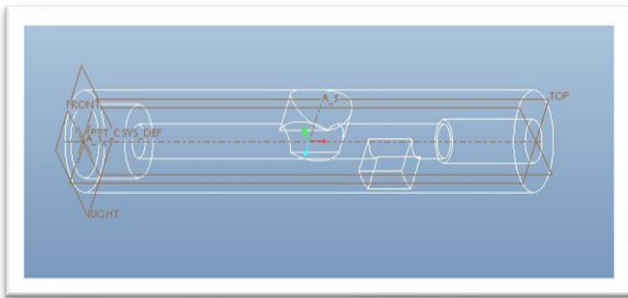
Fig. 14: Junction 3D (PTC Creo)

Fig. 15: Junction 3D Wireframe (PTC Creo)

Barlow's Formula –

Barlow's formula relates to the internal pressure that a pipe can withstand to its dimensions and the strength of its material.

Formula – $P = \dfrac{2St}{D}$

Where, P = Pressure in psi
S = Allowable stress in psi
t = Nominal wall thickness, in inches
D = Outside Diameter in inches

Data present – P = 200 Psi
S = 36259.4 Psi
T =?
D = 0.82 inch

Formula - $P = \dfrac{2St}{D}$ [Input the above data]

$\therefore 200 = \dfrac{2 \times 36259.4 \times t}{0.82} = 0.0022$ inch ~ 0.058 mm

Considering minimum thickness to be 7mm + Re-boring allowance + safety we have taken all the internal dimensions < 10mm

Material selected - Aluminum 6082 T6 [12]

Properties and specification of material;

Density   2.70 g/cc
Hardness, Brinell   95 HB
Tensile Strength, Ultimate   290 MPa
Tensile Strength, Yield   250 MPa
Elongation at Break   10 %
Thermal Conductivity   170 W/m-K
Modulus of Elasticity   70 GPa
Melting Point   555 °C
Workability   Cold: Good
Machinability   Good
Shape   Round Bar

The above image represents how the Junction being all assembled and how it would take shape after assembly. The component is designed in such a way that the stroke length of 100mm from the pneumatic cylinder would end exactly on the entrance of the barrel delivering the pellet from the slot into the barrel for launch. Due to this very integration, this component is named Junction.

8. *Pellet Magazine*

The magazine is also another crucial part of the Pneumatic Rifle, to give it a continuous and consecutive pellet delivery into the slot of the Junction below designs were make;
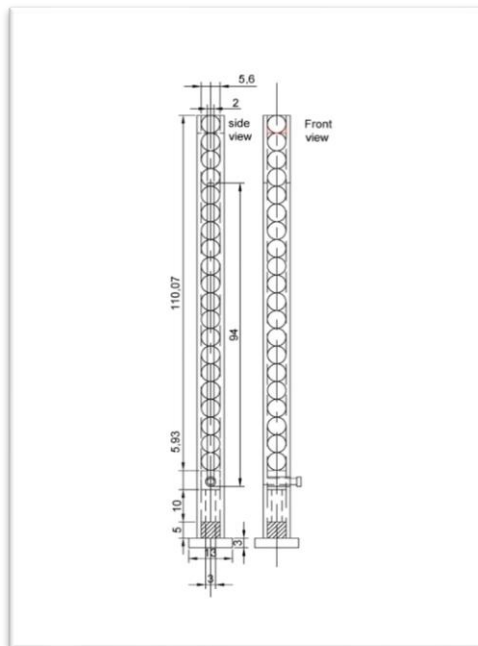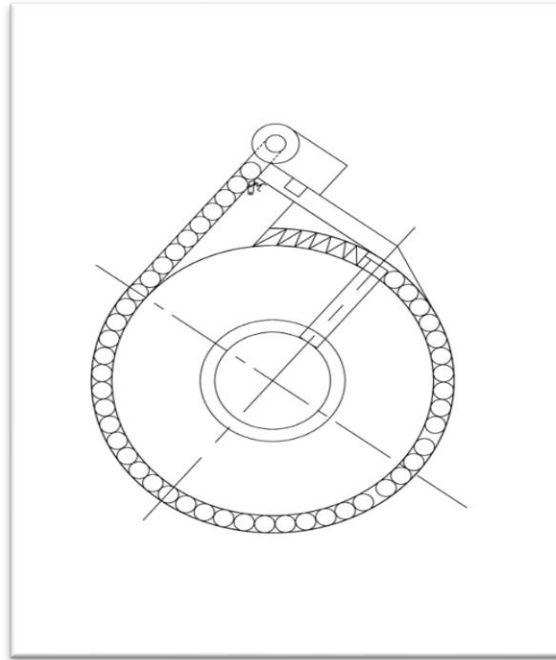

Fig. 16: Magazine Design

Fig. 17: Drum Magazine Design

Since the pellet size was small to manufacture, aluminum channels are used as magazines. The outer casing and the inner case make it a perfect selection for the 5.5 Diablo double head pellets.
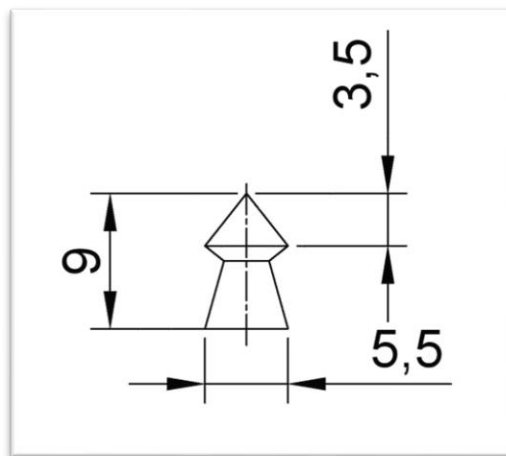

Fig. 18: Pellet

The springs used in this were manufactures and the specification for it is below;

Spring Material – Stainless Steel
Spring Thickness – 0.5 MM, 0.6 MM
Spring OD – 5.5 MM
Spring Length – 14 MM (Cut it if required)

Fig. 19: Channel Magazine

9. Trigger System and Barrel

The trigger system is attached on the 5/2 Mechanical push and pull valve, the idea is to utilize the push-pull mechanism, and adding a spring in the system would make it a spring return system. Short springs are used to give enough force to push back the connecting rod out again like a spring return system which in turn would act as a trigger mechanism.

A Stainless steel plate is used to make an attachment on the 5/2 mechanical valve as it has three holes in that it makes it easier to attach it on the plate horizontally by nut and bolts.
A hinge-like mechanism is used to provide an extension to the aluminum rod which is the trigger handle attached
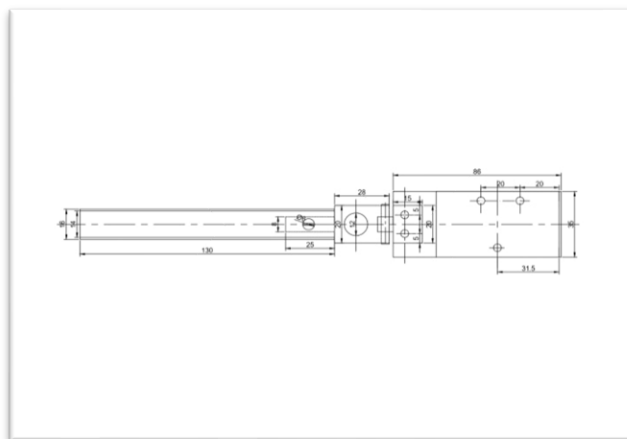
to the hinge by a nut and bolt.

Fig. 20: Trigger Mechanism

The Barrel for the pneumatic rifle is an aluminum pipe of OD 9mm and ID 5.5mm which is highly suitable for this pneumatic as for two primary reasons.
1) The weight of the pipe is low as the material is aluminum.
2) The ID of the pipe is 5.5MM which of the same size as the pellet diameter making it a good choice of the barrel for this system. The length of the barrel is 200mm and OD is 9mm.
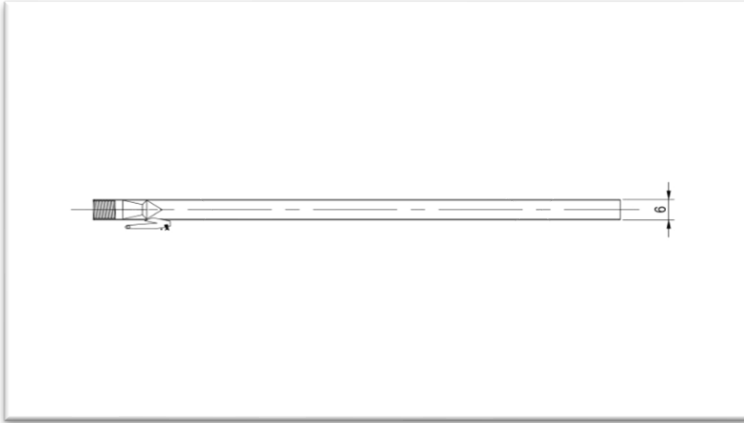

Fig. 21: Barrel

IV.   TESTING

The testing was carried out and it was determined that the system does work as intended but it also exhibits few troubles such as the slot for the magazine from which the pellet is dropped has become a source for leakage since the inner rod can't be an exact fit hence there has to be given tolerance for it to move properly without being jammed in the system.

Fig. 22: Testing the Rifle

A test has been conducted on effects on the pellet at a different pressure from a fixed parameters set. Below is the information is given;

Distance – 16.5 feet
Pellets – Marvelous shot (double head pellets)
Weight – 14.3 grains – 0.9 grams
Pellet Material - Lead
Target – 18mm Plywood
Gas used – Carbon dioxide
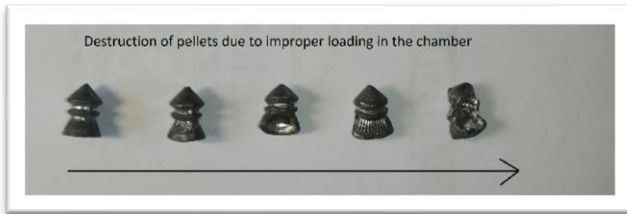
Fig. 23: Effects of different pressure on the pellet

Fig. 24: Destruction of pellet due to improper loading

1. *Muzzle Energy*

Definition - Muzzle energy is the kinetic energy of a bullet as it is expelled from the muzzle of a firearm. Without consideration of factors such as aerodynamics and gravity for the sake of comparison, muzzle energy is used as a rough indication of the destructive potential of a given firearm or cartridge.

Formulae – $E_{k} = 1/2\ MV^2$

Where M = mass of bullet

V = velocity of bullet

Air guns formula [13] –

$$\frac{(\text{Weight of the pellet in grains}) \times \text{Velocity}^2}{\text{Constant}}$$

Where, Constant - 450240

Conversion to joules - 1 foot-pound = 1.35 joules

Pellet weight in grain – 14.3

Muzzle energy at different pressure				
Pressure (Psi)	60	80	100	120
Velocity (ft./sec)	422	519	626	742
Energy (Joules)	7.67	11.61	16.88	23.71
foot-pounds	5.65	8.55	12.44	17.48

The above table has been constructed on the based formula of air gun muzzle energy and done using the above parameters.

V.   CONCLUSION

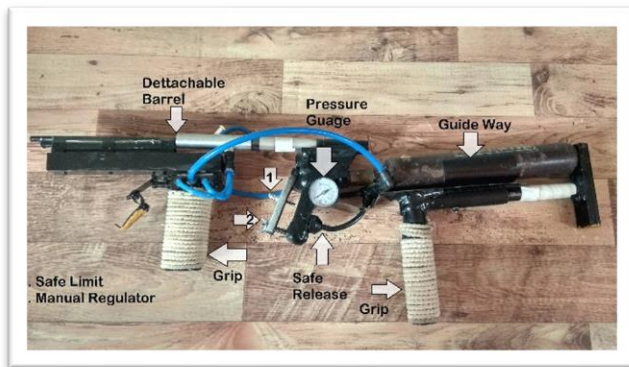To conclude; following things were observed and mention as below;

Fig. 25: Features

We can build an Air rifle based on double the acting cylinder in which the pellet enters the barrel in outwards stroke of the cylinder rod and during the retraction of the cylinder rod the gas from port E1 can push the projectile out of the barrel at a certain velocity.

We also noticed that using a double-acting the cylinder in an air rifle has a higher consumption of gas to fire a single shot, for example in normal air rifles only a single time the air is coming out of the barrel end; but in double-acting rifle the consumption is almost double for a single shot as it has to first have an outwards stroke and then during retraction stroke, it fires the round, which consumes double the energy. Even though the tank is of 300 gram of CO_2 which is much larger than the 12 grams of CO_2 canisters which are used in modern pre-charged pneumatics still given the exhaustion of the tank is on a similar rate due to the double consumption and manual on and off of the tank valve.

We have also noticed that during the testing if a pellet is improperly loaded it would jam the system and needs to be removed from the junction, a more refined design should be able to solve this problem.

VI.   REFERENCES

[1]   Solenoid valve, Patent (US5029807A) by Franz Fuchs.

[2]   Air gun Magazine, Patent (US4986251A) by Stephen J. Lilley, Sawston, England

[3]   History and Basic Principles of Air Rifles by Bikram SINGH SEKHON

[4]   https://www.pyramydair.com/

[5]   https://www.motherearthnews.com/homesteading-and-livestock/compressed-air-gun-zmaz81mjzraw

[6]   https://www.pyramydair.com/articles

[7]   https://www.sciencedirect.com/science/article/pii/S2214914717301459

[8]   https://www.kitz.co.jp/english2/material_index.html

[9]   https://www.hydraulicspneumatics.com/technologies/hydraulic-valves/article/21885033/are-you-taking-advantage-of-sequence-valves

[10]   https://pneumax.co.uk/wp-content/uploads/2013/12/pneumax-fittings-accessories-catalog.pdf

[11]   http://blog.parker.com/know-your-pneumatics-single-or-double-acting-choosing-the-right-cylinder

[12]   http://www.matweb.com/search/datasheet_print.aspx?matguid=fad29be6e64d4e95a241690f1f6e1eb7

[13]   https://www.pyramydair.com/article/What_is_Muzzle_Energy_August_2003/5#:~:text=For%20exampl
         e%2C%20many%20big%20bore,projectile%20they%20shoot%20in%20grains.&text=Take%20the%20
         energy%20times%20the,that%20number%20is%20your%20velocity.

REVIEW OF LOW POWER LFSR DESIGN TECHNIQUES

Simoni Shah
Department of Electronics
and Communication
Vishwakarma Govt.
Engineering College
Ahmedabad,Gujarat,India

Anuj Gundani
Department of Electronics
and Communication
Vishwakarma Govt.
Engineering College
Ahmedabad,Gujarat,India

Jayesh Diwan
Department of Electronics
and Communication
Vishwakarma Govt.
Engineering College
Ahmedabad, Gujarat,India

ABSTRACT

Nowadays in the VLSI domain, testing has become inextricable due to the increasing number of transistors on a chip. On the other hand, the chip area is decreasing vastly and low power consumption has become one of the top priorities in testing the chip as well as in the normal operation of the chip. Several techniques to test the chip have been introduced since the 1940s and the evolution of new and efficient testing techniques is increasing day by day. Out of the three methods discussed, the Low Transition LFSR method achieved Low consumption of power in a 32-bit pattern generator using LFSR and reduced switching activity between the test vector. In the Sub-threshold method, four different LFSR architectures are proposed using a combination of different D-Flipflop like true-single phase clock (TSPC) and transmission gate based with X-OR gate (static CMOS or Transmission gate). Moreover, another method using LFSR based on a multiplexer, specially designed for low power Design for Testability (DFT) approaches to EX-OR the single input change patterns generated by a counter and a gray code generator.

Keywords— low power, testing, LFSR.

1. INTRODUCTION

According to Moore's law, the density of transistors on the chip is increasing exponentially every 1.5-2 years. With increasing density manufactures of VLSI chips are mainly concerned about high speed, low size, and minimum power consumption. VLSI technology is currently functioning in nanometre and is aiming to reduce power consumption especially while testing the chip. High power dissipation results in heat loss and apparently to data loss. Conventionally, various testing techniques are being used like ADHOC, BIST, exhaustive etc. These techniques use LFSR to generate a random pattern that is fed to the circuit as input and examine the output.

Section 2 gives the brief about types of power consumption in a chip and LFSR, Section 3 discusses three different LFSR techniques aimed to reduce power, Section 4 draws a comparison between those techniques and shows simulation results and Section 5 gives the conclusion of this paper.

I. POWER CONSUMPTION & LFSR

A. Power Consumption

Power consumption and LFSR:
Mainly power consumption is of two types:
1) Static power or leakage power
2) Dynamic power or switching power

In smaller geometries i.e less than 90nm, leakage power is dominant whereas in larger geometries switching power is more dominant. Various techniques try to incorporate power reducing strategies.

Total power dissipation in CMOS is a function of switching activity, capacitance, voltage, and the transistor structure itself. Charging and discharging of capacitances in the circuit results in switching power dissipation. In any instance when gate switches state, there is a direct connection between the Vdd and ground, resulting in a short-circuit current.

$P_{(switching)} = a.f.\ Ceff.Vdd^2$
a = switching activity,
f = switching frequency
C_{eff} = the effective capacitance
V_{dd} = the supply voltage.

$P_{(short\text{-}circuit)} = I_{sc}.V_{dd}.$
I_{sc} = the short-circuit current during switching.

Controlling the switching activity, clock frequency, and also by reducing capacitance and V_{dd} can result in the reduction of dynamic power.

Also, the equation of leakage power is:
$P_{(Leakage)} = f\ (V_{dd},\ V_{th},\ W/L)$
V_{th} = the threshold voltage,
W = the transistor width,
L = the transistor length.
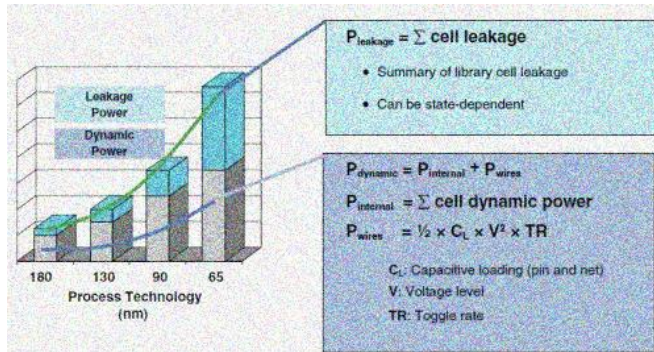Leakage power is because of the leakage current.

Fig.1 Graphical representation of leakage power and dynamic power in nanometer technology

B. LFSR

LFSR has vast applications in VLSI such as in DFT (Design for Testability), cryptography etc. A simple structure of LFSR is presented here. LFSR generates pseudo random patterns for testing. It is made up of several D - flipflops and an ex-or gate or ex-nor gate. The first input pattern fed to the circuit is known as seed. The first input cannot be 0000 if EX-OR is used and 1111 if EX-NOR is used.
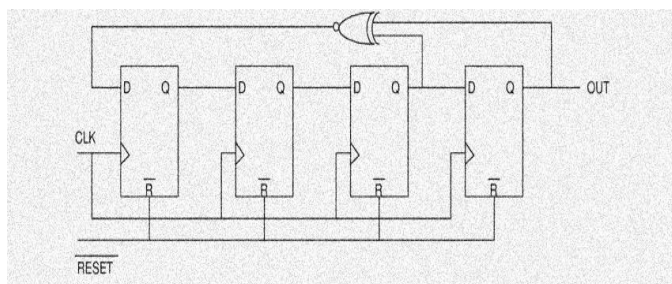
Fig.2. LFSR Structure

II. DIFFERENT LOW POWER LFSR TECHNIQUES

A. Low Transition LFSR

[1] Proposed a method to reduce the transition between two successive test pattern inputs i.e. the switching activity by injecting intermediate patterns. The given method can be used for both combinational and sequential circuits. The power consumed can be reduced by reducing the switching activity between unique test pattern generators. The normal architecture of LFSR is revised such that intermediate patterns can be injected between the two input patterns. The above-mentioned idea is implemented by two schemes:

1)Random injection (RI)
2) Bipartite LFSR

The above two schemes are discussed in detail in the presented paper with example. In Random Injection a new test vector P+ is inserted between two successive test vectors P1 and P2. The transition between P1 and P+ and between P+ and P2 is less than the transition between P1 and P2 separately.

P1:

1	0		0	1	0	0	0	1	1	1	0	1	0	1	0	1

P+:

1		R		0		R		R		R		0		R		R		1		0		R		0		1		0		R

P2:

1	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0

Fig.3.1 Example of RI Injection

As shown in figure the transition can be reduce by putting RI in between. We can put R= 0 or 1, as per the requirement.

In Bipartite LFSR two non-overlapping clocks are used to separate LFSR into two equal parts i.e. when one half of the LFSR is working the other half is deactivated and vice versa. The described process is explained in detail with example and steps. The simulation results are obtained in Xilinx 13.1 ISE design suite using Verilog HDL.
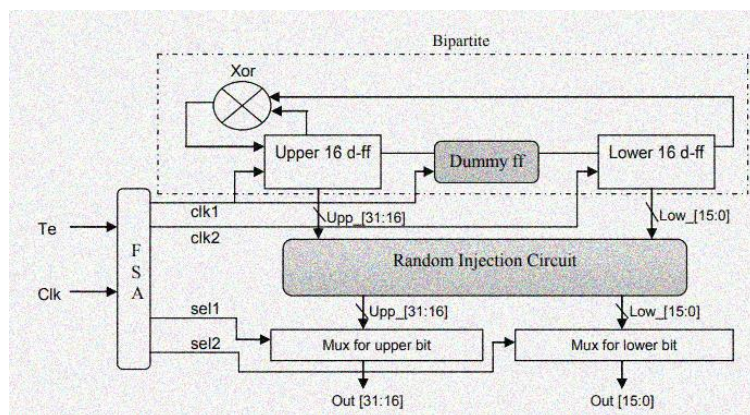
B. Sub Threshold

[2] proposed to use the advantage of digital subthreshold circuits that achieve minimized power consumption. In the subthreshold region, the transistors operate with the supply voltage (V_{DD}) less than the transistor threshold voltage (V_{TH}). The equation of operating current in the subthreshold region:

$$I = I_0 \frac{W}{L} e^{\frac{Vgs - Vth}{nV_t}} \left[1 - e^{\frac{-V_{Ds}}{V_L}} \right]$$

The proposed design uses LFSR in subthreshold regions. The conventional LFSR is made up of D-FLIPFLOP (used as shift registers) and EX-OR/EX-NOR gate (used to send feedback). The presented paper explains in detail two different architectures for both D-Flip Flop and X-OR gate. The two discussed architectures for D-Flip Flop are:

1) Transmission Gate Based Master-Slave D Flip Flop

2) True Single-Phase Clock (TSPC) D Flip Flop

The first architecture takes into account the cascaded master-slave configuration of D Flip Flop. When the clock is "0" the master D - latch is activated and samples the input to the flip flop whereas when the clock is "1" the slave D - latch in activated and passes the value stored by the master to the output. The second architecture uses four inverters which are controlled by the clock. When the clock is at "0" the first inverter samples the inverted D input to its output node and the second inverter is precharged to V_{DD}. The third inverter is OFF and holds the value of the previous inverted D input. When the clock transitions from "0" to "1" the output of the second inverter is passed to the third inverter which gets ON and the fourth inverter is used to get the non-inverted input D. Similarly, two different architectures are presented for the X-OR gate as well:

1) EX-OR Implementation in Static CMOS Logic Style
2) Transmission Gate EX-OR Gate

In the first method, twelve transistors are used from which eight transistors are for the X0R gate and the other two transistors each for two inverters. Whereas the second method needs only six transistors in all.

All the above four architectures are explained in detail with the respective diagrams in the paper. Using the amalgamation of the above discussed two architectures each of D flip flop and XOR gate, four designs of LFSR are presented.

a) Implementation of LFSR using TSPC Positive Edge Triggered D Flip Flop and Static CMOS EX-OR
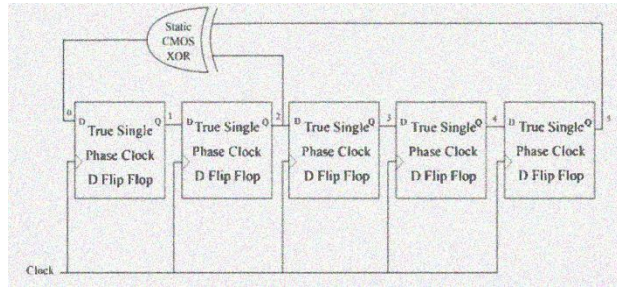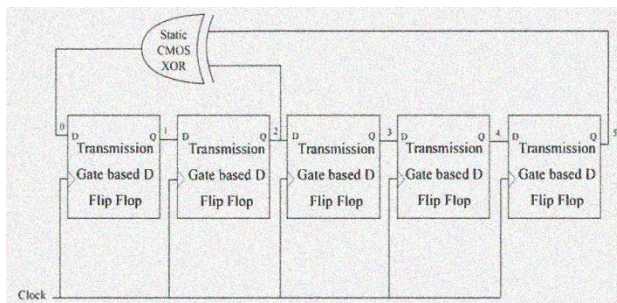

LFSR using TSPC Positive Edge Triggered D Flip Flop and Static CMOS EX-OR Fig.3.3 [2]

b) Implementation of LFSR using TSPC based positive edge-triggered D Flip Flop and transmission gate based EX-OR gate.
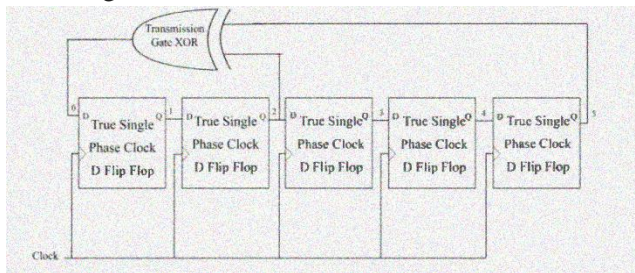
LFSR using TSPC based positive edge-triggered D Flip Flop and transmission gate based EX-OR gate Fig 3.4 [2]

c) Implementation of LFSR using transmission gate master-slave positive edge-triggered D Flip Flop and Static CMOS EX-OR.

LFSR using transmission gate master-slave positive edge-triggered D Flip Flop and Static CMOS EX-OR Fig 3.5 [2]

d)Implementation of LFSR using the transmission gate-based implementation of both D Flip Flop and EX-OR gate.
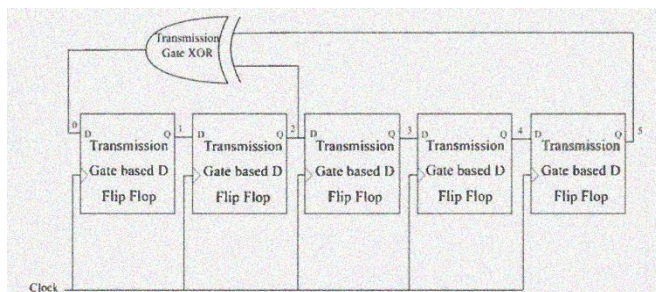
LFSR using the transmission gate-based implementation of both D Flip Flop and EX-OR gate. Fig 3.6 [2]

A comparison of the highest operating frequency and its corresponding power consumption of all the proposed architectures are shown in the paper. The functionality of all the proposed architectures is verified in the SPICE simulation.

C. MUX based LFSR

[3] proposed a multiplexer based low power design technique for testing. This method explained and illustrated when input change patterns generated by a gray code generator and a counter are EX-ORed along with the seed generated by multiplexer based on LFSR. Low power can be achieved better when single input change generators are used. The paper focuses on reducing the switching activities in the test patterns by replacing an EX-OR gate with a multiplexer. This MUX-LFSR consists of other logical circuits like m-bit counter, gray counter, NOR-gate structure, and EX-OR -array. The m bit counter generates 2m test pattern sequences when initialized with all zeros. The output of m bit counter is directly fed to the gray code generator and NOR gate. The NOR gate output is one only when the output of the counter is all zero which activates LP-LFSR to generate the next seed. The seed from MUX-LFSR and data from gray code generator are   EX-ORed and the output is the final output pattern.
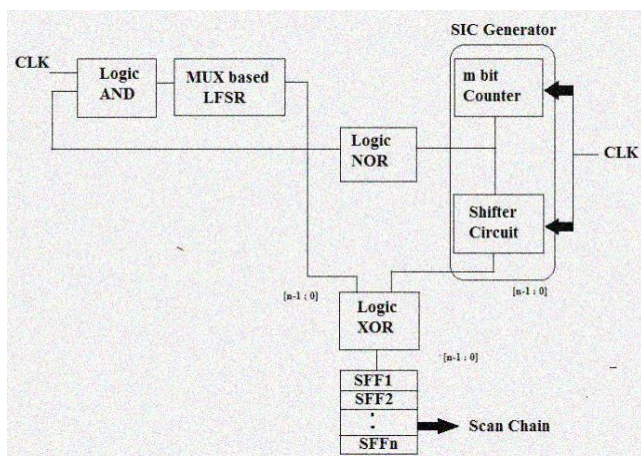

Fig. 3.7 Low Power Test Pattern Generator [3]

The paper also discusses in brief about the Array Multipliers. At last, the paper is concluded with a comparison between EX-OR LFSR and MUX-LFSR in terms of power consumption.

III. DESIGN REVIEW AND RESULT ANALYSIS

A. *For low transition LFSR method[1]*

EDA Tool: Xilinx Product Version: ISE 13.1 Target Device: xc6slx16-3csg324		
Parameter	Type of Random Sequence generator	
	32-bit LFSR	32-bit LT-LFSR
No. of Slices Register	32	28
No. of LUT's	12	9
No. of bounded IOBs	34	36
Total Power (mW)	49.00	23.00
Latency (ns)	3.668	5.194

Table I: Comparison Conventional for LFSR and LT-LFSR [1]

While testing the device, ultimately there is a reduction in power due to a decrease in the number of transitions. Hence power is consumed more efficiently in LT-LFSR as a transition between two successive test patterns is reduced. For the experimental simulation, they used the expression $X^{32}+X+1$ for both LT-LFSR and LFSR to generate 32-bit different test patterns. The results show that the total power is 50.06% less than conventional LFSR.

B. *For Subthreshold LFSR Technique[2]*

Proposed Architecture	Power Consumed at 0.181 MHz (nW)
1	73.3
2	69.9
3	211.7
4	196.2

Table II:Power Consumption at Frequency 0.181MHz [2]

The characteristic polynomial $x^5 + x^2 + 1$ is chosen. The maximal length of 5-bit LFSR is $2^5-1=31$, that is the reason LFSR covers all possible states in 31 clock cycles. All the four proposed architectures are compared in terms of power consumption using power simulation. A common frequency of 0.181 MHZ is taken into consideration. It can be noted from the table that architecture-2 LFSR consumes the least power of 69.9 nW,

followed by the architecture-1 LFSR at 73.3 nW. Architecture 3 and architecture 4 have higher power consumption. The paper also highlights that even though architecture 2 has low power dissipation, architecture 1 is also compatible to operate at double the frequency of former. Hence, depending on the priority of the desired application i.e. low power consumption or high-speed operation, any of the two architectures constructed with TSPC D Flip Flop can be used.

C. *For MUX Based LFSR*[3]

The conclusion is drawn from the comparison of different parameters like area, power consumption, and performance between normal EX-OR based LFSR and Multiplexer based LFSR. Keeping the clock frequency, the same for both the architecture it is noted that the proposed method is better in terms of area, usage and power. The dynamic power is reduced from 113 mW to 107 mW, though the static power remains constant. Logic elements in the circuit are downed to 125 from 127. The paper shows simulation at 113.4 MHZ frequency using Xilinx and X Power analyzer Tool. Using this method power is reduced in the range of 6% to 23%.
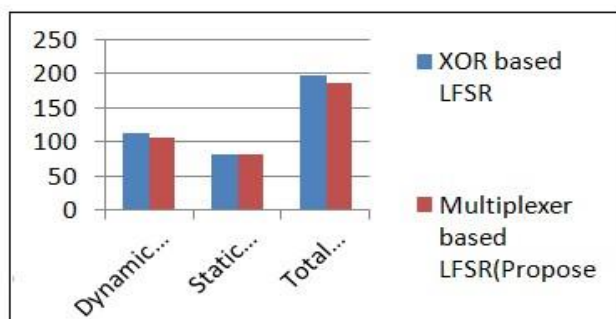

Fig.4 Power Analysis [3]

IV. CONCLUSION

After reviewing all the above-mentioned techniques, the low transition technique reflects power reduction up to 50.06% compared to conventional LFSR. Moreover, the Mux-based LFSR technique brings a little power reduction ranging from 6% to 23% without affecting its clock frequency. Using LFSR in the sub-threshold region, it corresponds to better power reduction in the highest operating frequency. To conclude, in case of low frequency, the sub-threshold techniques using different structures of EX-OR and D Flip Flop is a better option to implement. The Mux-based LFSR is very helpful especially in testing IoT Hub devices. But low transition LFSR technique reduces the highest amount of power dissipation. All the three papers taken into consideration propose different ideas to reduce the power consumption while testing the chip

REFERENCES

1. Tejas Thubrikar, Sandeep Kakde, Shweta Gaidhani, Shailesh Kamble and Nikit Shah Design and Implementation of Low Power Test Pattern Generator Using Low Transitions LFSR ("International Conference on Communication and Signal Processing, April 6-8, 2017, India", Publisher :IEEE)
2. Kirti Gupta , Prayanshu Sharma and Neeta Pandey Design of Low Power Subthreshold Linear Feedback Shift Registers ("1st IEEE International Conference on Power Electronics. Intelligent Control and Energy Systems (ICPEICES-2016")

3. Dr Sabir Hussain Design of Low Power Multiplexer based LFSR for testing IoT Devices ("Journal of Information and Computational Science – 2019")

4. Roshni Oommen, Merin K George, Sharon Joseph Study and Analysis of Various LFSR Architectures ("©2018 IEEE")

5. Jayasanthi M, Kowsalyadevi AK Low Power Implementation of Linear Feedback Shift Registers ("International Journal of Recent Technology and Engineering (IJRTE)-2019")

6. Sung-Mo Kang and Yusuf Leblebici, CMOS Digital Integrated Circuits: Analysis and Design , Tata McGraw-Hill, 2003

7. PrasadaRao, R. Vara, N. Anjaneya Varaprasad, G.

8. Sudhakar Babu, and C. Murali Mohan. "Power Optimization of Linear Feedback Shift Register (LFSR) for Low Power

9. BIST implemented in HDL." International Journal of Modern Engineering Research (IJMER) 3, no. 3 (2013): 1523-1528.

10. A.Kavitha,G.Seetharaman, and T.N.Prabhakar,Shrinithi Design of Low Power TPG using LP/LFSR", 3rd IEEE Conference on international conference on intelligent systems modeling and simulation,2012

TRENDS OF SURFACE URBAN HEAT ISLAND IN PAST FEW YEARS IN THE CITY OF AHMEDABAD

Akanksha Singh, Shivangi Surati

Department of Computer Engineering, LDRP-ITR, Gandhinagar, Gujarat, India

ABSTRACT:

An urban heat island (UHI) effect is observed in metropolitan areas which are significantly warmer than its surroundings suburban or rural areas. Its major impact is observed during night time after three to five hours of sunset in urban areas. Hence, earlier prediction of UHI effect is required in order to mitigate its hazardous effect. At present, the existing prediction methods are based on numerical estimations. In this paper, we have used satellite data, concerning the surroundings of Ahmedabad City in Gujarat, India. Land Surface Temperature, Normalized Difference Vegetation Index (NDVI) and Top of Atmospheric (TOA) are calculated using this data and with the help of suitable digital image processing software.

Keywords: *UHI effect, LST, NDVI, TOA*

1. INTRODUCTION

An urban heat island (UHI) effect is observed in metropolitan areas which are significantly warmer than suburban or rural areas. Its major impact is observed during night time after three to five hours of sunset in urban areas. The UHI effect has been extensively studied for several cities of India in order to mitigate its harmful effect. India, being a growing economy, has undergone rapid urbanization in the last few decades. The phenomenon of UHI which is associated with urbanization has not drawn much attention from the scientific fraternity within the Indian subcontinent. Only a few studies have come up over a large span of time [1].

Hence, earlier prediction of UHI effect is required in order to mitigate its hazardous effect. At present, the existing prediction methods are based on numerical estimations. It is required to predict UHI effect area-wise. So that it possesses a synergistic effect in the speed of reducing UHI effect [2].

Satellite data is extensively used for study and analysis of UHI effect and LST derived from satellite imageries is used for the same. UHI effect, when studied using LST, is referred to as the surface urban heat island (SUHI) effect [3]. LST is one of the key parameters controlling the physical, chemical and biological processes of the Earth and is an important factor for study of urban climate [4]. LST has been utilized in numerous heat-balance, climate modeling and global-change monitoring studies [1, 3, 4].

Land cover information can be acquired effectively by visual image interpretation of satellite imagery or after applying enhancement routines and also by imagery classification. While elevation of any part of a city usually gives land use land cover patterns, the natural landscape consisting of bare ground or vegetation cover is converted into any one of the urban surfaces or even into change in vegetation cover. The objective of the

present study is to develop a linear model to predict the LST of any area on the basis of historical temperatures and parameters representing vegetation, RD and elevation of that area.

In this paper, we have used Landsat-8 multispectral data, concerning the surroundings of Ahmedabad City in Gujarat, India. Land cover information is extracted, using suitable digital image processing tools.

Landsat-8 is required to return 400 scenes per day to the USGS data archive. Landsat 8 has been regularly acquiring 550 scenes per day. This increases the probability of capturing cloud-free scenes for the global landmass. The Landsat 8 scene size is 185-km-cross-track-by-180-km-along-track. The nominal spacecraft altitude is 705 km. Cartographic accuracy of 12 m or better (including compensation for terrain effects) is required of Landsat 8 data products. In Table-1, Landsat-8 bands are summarized with its application.

Table 1: Landsat-8 Bands

Landsat-8 Operational Imager (OLI) and Thermal Infrared Sensor (TIRS) (Launched February 11, 2013)	Bands	Wavelength (micrometers)	Resolution (meters)	Applications
	Band 1 - Coastal Aerosol	0.43 - 0.45	30	whale population, bathymetry, aerosols(cloud detection)
	Band 2 – Blue	0.45 - 0.51	30	deep water imaging, smoke plumes, atmospheric haze and clouds, clouds, snow and rock
	Band 3 – Green	0.53 - 0.59	30	plant vigor and vegetation, algal and cyanobacterial blooms, urban recreation
	Band 4 – Red	0.64 - 0.67	30	soil types and geologic features, built and natural environment, chlorophyll absorption
	Band 5 - Near Infrared (NIR)	0.85 - 0.88	30	biomass content, archaeological sites, normalized difference vegetation index (ndvi)
	Band 6 - SWIR 1	1.57 - 1.65	30	moisture content, cloud/smoke penetration, mineral exploration
	Band 7 - SWIR 2	2.11 - 2.29	30	water properties, irrigation practices, mineral mapping
	Band 8 – Panchromatic	0.50 - 0.68	15	Pansharpening
	Band 9 – Cirrus	1.36 - 1.38	30	cirrus clouds
	Band 10 - Thermal Infrared (TIRS) 1	10.60 - 11.19	100	volcano activity, urban heat, weather prediction
	Band 11 - Thermal Infrared (TIRS) 2	11.50 - 12.51	100	

source: - Landsat 8 band designations. (2019). Usgs.gov. Retrieved 3 April 2019, from https://www.usgs.gov/media/images/landsat-8-band-designations

2. RELATED WORK

Due to hazardous results of the UHI effect, it is necessary to predict it with long-term and short-term implications. There are various models, methods and tools used to predict UHI intensity in urban areas are given below and discussed in detail.

2.1 Methods used to predict UHI intensity

In this section, the prediction methods for UHI are discussed on the basis of their application and input parameters. Once the UHI intensity in a specific area is predicted, the corresponding mitigation strategy can be identified and applied in advance in order to prevent or reduce the UHI intensity.

2.1.1 Local Climate Zone classification

Kotharkar & Bagade used Local Climate Zone (LCZ) method to evaluate urban climatic zones in the Nagpur city [5]. In this, remote sensing data is used to calculate NDVI, LST and LULC. They have taken meteorological data from the regional meteorological department of Nagpur city. They have used HOBO data logger for stationary data. This paper uses temperature buffer analysis, sensor lag determination, forecasting, outlier analysis and Pearson-correlation technique. They estimated CLHI (Canopy Layer Heat Island) through a traverse survey in the range between 1.76 – 4.09 °C within the built class. However, they admitted the need of more parameters to predict UHI more precisely.

2.1.2 Observational method using Automobile Devices

In this method, data is collected using different sensors mounted on devices. Mutani et al. had analyzed the UHI effect in the city of Turin [6]. He used multiple regression models and established correlation between air temperature and urban parameters like urban morphology, solar radiance, albedo coefficient etc. These devices are placed on various urban structures or urban areas having high elevation or urban morphology. The result shows 1-1.5 °C with the average air temperatures respectively in summer-time and winter-time. However, for future research they want to improve prediction models by using hourly weather data.

Amirtham analyzed the impact of urbanization on UHI intensity in the city of Chennai [7]. He used HOBO data logger for collecting temperature data to analyze UHI intensity and took reference data from Numgambakkam Meteorological station as a data source. In his studies, he revealed the presence of a cool valley effect in the city of Chennai at the time of winter with a temperature difference of 10.4oC in summer and 3.7 °C in winter.

2.1.3 Linear Time Series (LTS) Model with least-square method

Mathew et al. used this model to predict UHI intensity in Ahmedabad [8]. They developed a linear model for prediction of LST in any area based on historical temperatures and parameters representing vegetation, road density and elevation of that area. They used the last 10 years of MODIS and ASTER. LST can be predicted from previous year LST images with good accuracy and will be helpful to monitor SUHI effect which is helpful in planned development city. They discovered high correlation between the prediction model and observed LST

with an average regression coefficient (R2) value of 0.96 (of LST). However, LST models are sensitive to outliers and they have a tendency to over-fit data.

2.1.4 GIS Method

Nakata-Osaki et al. developed THIS tool based on GIS technique [9]. They calculated UHI maximum intensity along with height-width ratio. They concluded that the UHI maximum intensity increases when the height-width ratio goes up, but the urban canyons with greater roughness result in UHI maximum intensity values of around two times smaller than canyons with less roughness for the same value as the height-width ratio. They analyzed the geographical measurements in the city of f São José do Rio Preto with the altitude above sea level, census and distance in kilometer from town to center. In their work, all the linear regression models had a relative error lower than 10 %. The results show 1-1.5 °C UHI intensity with the average air temperatures respectively in summer-time and winter-time; and of 2.6-2.46 °C with the minimum air temperatures respectively in summer-time and winter-time. However, THIS tool considered temperature data as the main affecting factor.

2.1.5 Ant Colony

Diamond et al. analyzed the UHI effect of three cities using an ant colony algorithm [10]. They used data from Dryad Digital Repository. They collected acorn ants from urban and rural populations across three cities in the eastern USA viz. Cleveland, Ohio, Cincinnati, Ohio, Knoxville and Tennessee. They predicted an increase in heat tolerance of the urban population across each urbanization gradient. The results of this study suggested that the phenotypic changes in thermal tolerance that they observed in acorn ants from urban populations are adaptive. They linked phenotypic shifts in temperature tolerance with environmental changes in temperature. Among three selected cities, two cities produce the same result as their urban morphology is quite similar. However, Temnothorax is a very heat-tolerant species as compared with other ants; it is possible that low-latitude populations are beginning to push the evolutionary limits of heat tolerance, leading to reduced evolved response with increased warming in cities.

2.1.6 Artificial Neural Network (ANN)

Ashtiani et al. utilized the Artificial Neural Network (ANN) algorithm to predict the indoor air temperature and relative humidity in a house where indoor and outdoor temperature and relative humidity were measured every 15 min for 30 days [11]. They performed cross-comparison of a traditional and an advanced heat warning model with the help of the regression and ANN models respectively. The developed regression and ANN models were used to predict the hourly indoor dry-bulb temperatures of units located in downtown Montreal and the heat wave in July 2010. It is well established that outdoor dry-bulb temperature has significant influence on the indoor environment thermal condition. The variation of predicted results of ANN model about maximum and minimum indoor dry-bulb temperatures are 2.64ºC and 1.99ºC, respectively. However, they assumed many variables in their study; for example, total building volume is assumed to be proportional with building thermal mass. Apart from this, the value of emittance, ε, is assumed to be one.

Moustris developed the ANN model for complex human thermal comfort index associated with urban heat and cool island patterns [12]. This model has Penteli and Ilioupolis as study areas. The values of Physiologically Equivalent Temperature (PET) index for a number of different locations with different urban environment configurations were predicted applying the developed ANN models for the warm period of the year 2007. The

multi-layer perceptron ANN models were developed using the back-propagation training algorithm to predict PET hourly values.

2.1.7 Maximum Likelihood, Physical Scaling (using downscaling model) and other methods

Geoffrey and John analyzed UHI intensity in Manchester city by developing their own method [13]. The parameters used in this work were wind speed, the cloud cover, and the solar radiation. It is used to predict the hourly values of UHI intensity all over the year. They collected weather data from the British Atmospheric Data Centre. However, they had not included temperature as a factor in their work.

Gaur analyzed the Surface Urban Heat Island (SUHI) of 20 Canadian cities [14]. They collected MODIS data for their work. They analyzed data from 2002 to 2012. Results of UHI effect are encouraging in these regions, that is, 16 out of 20 cities were facing positive impact while the other 4 cities were experiencing negative impact of SUHI phenomena. They selected a Physical Scaling downscaling model for this work. Various parameters viz. size, elevation, and surrounding land cover of the city are considered in the study to predict UHI intensity. In addition, they estimated future predictions for the same study area. However, as the nature of UHI varies and it is based on anthropogenic activities of humans, it is possible that the estimation may differ.

Khandar and Garg used maximum likelihood method to analyze the Nagpur area and its surrounding [15]. They utilized Landsat ETM+ data of Nagpur and its surrounding area. They selected a mono window algorithm to retrieve Land Surface Temperature (LST). They also analyzed the correlation between NDVI and LST and observed that LST is weakening where NDVI is high. The result shows that UHI intensity is high in the center of Nagpur city.
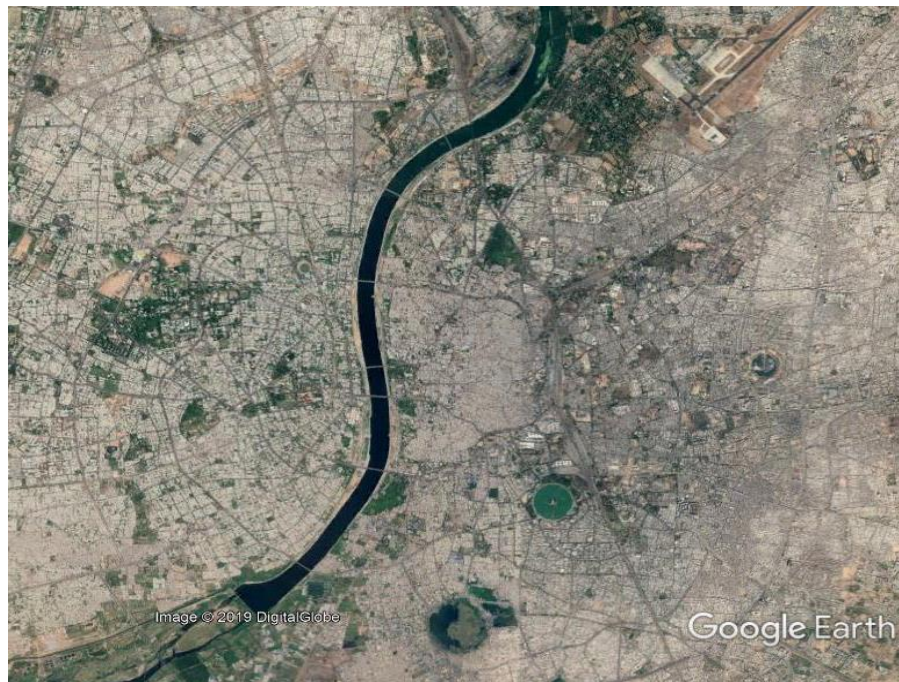
3. STUDY AREA

Figure 1: Google Earth Image of Ahmedabad City

Ahmedabad, located on the bank of river Sabarmati between 22º 56' and 23º 06' North Latitudeand 72º 37' and 72º 41' East Longitude, is the largest city in the Gujarat state of India. It is the seventh largest metropolitan area of India, with a total population of 7,208,200 (Census of India 2011), while the population in 2001 was 5,893,164. The Ahmedabad study area and its geographic location is shown in fig. 1. Climatic condition of Ahmedabad is semi-arid and hot. Climate here is extremely dry during the summer season from March to mid-June. The average annual rainfall over the area is 782 mm, although it varies considerably every year. It occurs generally during the months of June to September. The average relative humidity is 60% with a maximum of 80% to 90% during the rainy season. Ahmedabad accommodates about 11% of the state population but accounts for about 21% of the vehicles registered in the State. The number of motor vehicles registered in Ahmedabad was 1.49 million (73% were two wheelers) in the year 2004. The vehicular population of the city has increased to 3.15 million now. This rapid growth of vehicles has worsened the transport situation to a significant extent and has resulted in an increase in air pollution. Within the boundaries of Ahmedabad Municipal Corporation (AMC), the land use for residential and commercial categories, which was 35%and 2.5%, respectively in 1997 has been proposed to be increased to 44% and 3.4%, respectively in the Master Plan of 2011 [32].

As the UHI phenomenon indicates a warmer thermal climate of urban land, compared to non-urbanized areas, the study area must include sufficient non-urbanized/sub-urban areas outside the urban area for UHI studies. The urban area boundary of Ahmedabad city has been derived by extracting urban area polygon from the QGIS. The study area covers approximately 305 km². The LST image of the study area has (30, -30) pixel size. Figure 1 shows the Google Earth© image of the study area and urban area of Ahmedabad city.

4. METHODOLOGY

To extract Land Surface Temperature from Landsat image certain procedures are to be followed. The procedure to calculate LST from Landsat-8 image is discussed here. The multispectral data is preprocessed and various calculations are carried out to check the presence of UHI effect. As shown in table 5.1, multispectral data of these datasets are taken from the USGS website.

In step-1 Top of Atmospheric (TOA) spectral radiance is calculated. The TOA signifies spectral irradiance and the solar zenith angle useful in measurement of incident solar radiance.

In step-2 TOA is converted into At-Satellite Brightness Temperature. The equation is applied in step-2.

In step-3 Normalized Difference Vegetation Index (NDVI) is computed. It will show the ratio of land and vegetation with concentrated density of land.

In step-4, the proportion of vegetation Pv is calculated using obtained NDVI. This Pv is partially proportional to NDVI and UHI effect.

In step-5, The Emissivity ε is calculated using Pv and constant. In step-6, the Land Surface Temperature is calculated using previously obtained parameters.

In table 1, Calculated UHI parameters are given with periods. As it is analyzed from the given table, the UHI effect is present in the city of Ahmedabad. It can be reduced by using and implementing various vegetation strategies.
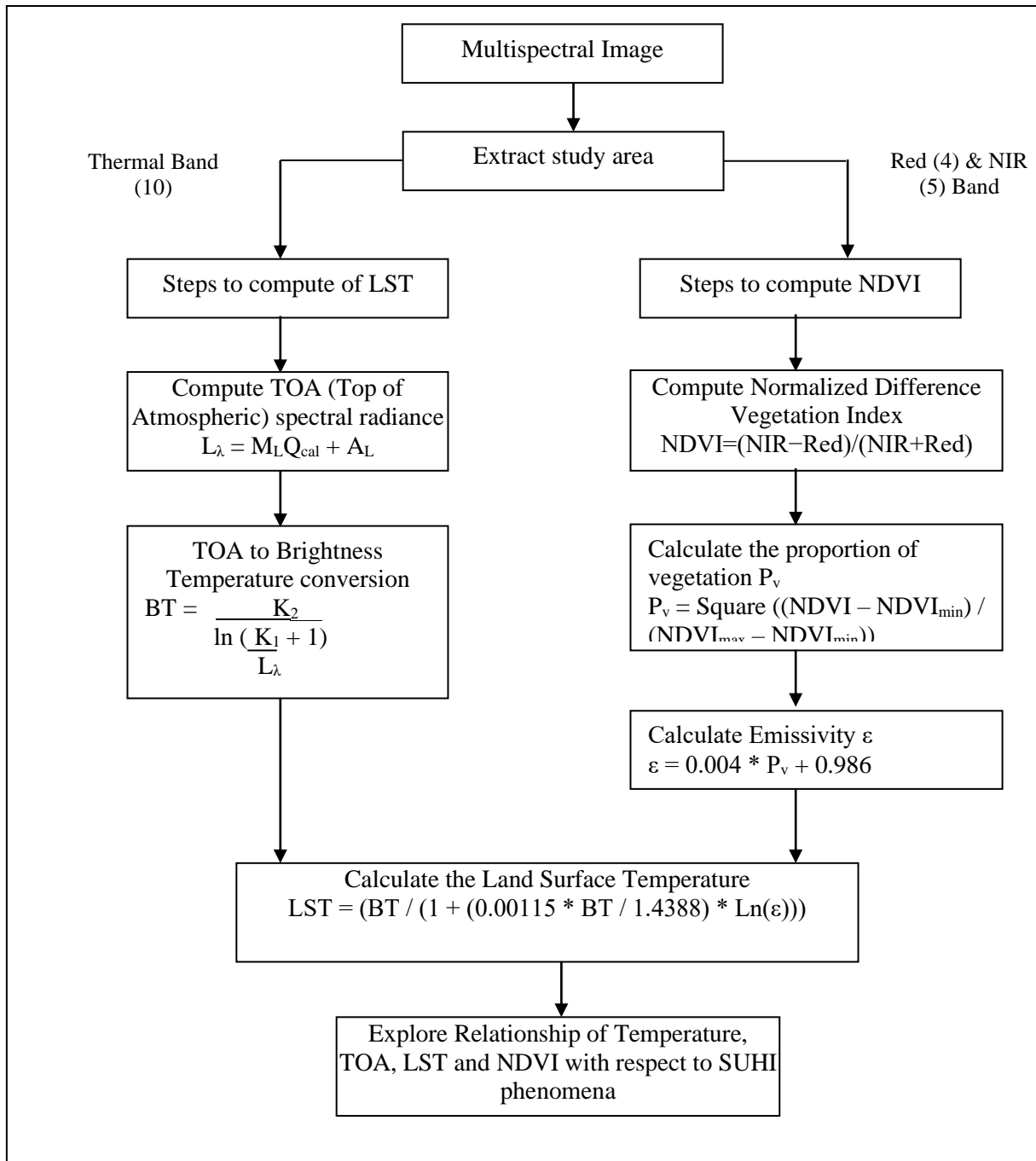
Figure 2: Applied Methodology for LST Calculation

To extract Land Surface Temperature from Landsat image certain procedures are to be followed. The procedure to calculate LST from Landsat-8 image is discussed here. The multispectral data is preprocessed and various calculations are carried out to check the presence of UHI effect. As shown in table 5.1, multispectral data of these datasets are taken from the USGS website.

In step-1 Top of Atmospheric (TOA) spectral radiance is calculated. The TOA signifies spectral irradiance and the solar zenith angle useful in measurement of incident solar radiance.

In step-2 TOA is converted into At-Satellite Brightness Temperature. The equation is applied in step-2.
In step-3 Normalized Difference Vegetation Index (NDVI) is computed. It will show the ratio of land and vegetation with concentrated density of land.
In step-4, the proportion of vegetation Pv is calculated using obtained NDVI. This Pv is partially proportional to NDVI and UHI effect.
In step-5, The Emissivity ε is calculated using Pv and constant. In step-6, the Land Surface Temperature is calculating using previously obtained parameters.

In table 1, Calculated UHI parameters are given with periods. As it is analyzed from the given table, the UHI effect is present in the city of Ahmedabad. It can be reduced by using and implementing various vegetation strategies.

Table 1: Selected Data for Implementation from Landsat-8

No.	Image Entity ID#	Image Acquisition Date
1.	LC08_L1TP_149044_20130518_20170504_01_T1	18th May 2013
2.	LC08_L1TP_148044_20140530_20170422_01_T1	30th May 2014
3.	LC08_L1TP_149044_20150524_20170408_01_T1	24th May 2015
4.	LC08_L1TP_148044_20160519_20170324_01_T1	19th May 2016
5.	LC08_L1TP_148044_20170522_20170526_01_T1	22nd May 2017
6.	LC08_L1TP_149044_20180516_20180604_01_T1	16thMay 2018

1) Compute Top of Atmospheric (TOA) spectral radiance

$$L_\lambda = M_L Q_{cal} + A_L \qquad\qquad \dots (1)$$

Where,
L_λ = TOA spectral radiance (Watts/(m2 * srad * μm)),
M_L = Band-specific multiplicative rescaling factor from the image header (Radiance Multiplicative Band_x, where x is the band number to be corrected),
A_L = Band-specific additive rescaling factor from the image header (Radiance Additive_Band_x, where x is the band number to be corrected),
Q_{cal} = Digital Number of the band to be corrected

2) Conversion to At-Satellite Brightness Temperature

TIRS band data can be converted from spectral radiance to brightness temperature using the thermal constants provided in the metadata file:

$$BT = \frac{K2}{\ln\left(\frac{K1}{L_\lambda} + 1\right)} \qquad \text{.... (2)}$$

Where,

BT = At-satellite brightness temperature (K)

L_λ = TOA spectral radiance (Watts/(m2 * srad * μm))

K1 = Band-specific thermal conversion constant from the metadata (K1_CONSTANT_BAND_x, where x is the band number, 10 or 11)

K2 = Band-specific thermal conversion constant from the metadata (K2_CONSTANT_BAND_x, where x is the band number, 10 or 11)

3) Compute Normalized Difference Vegetation Index (NDVI)

$$NDVI = (NIR - Red) / (NIR + Red) \qquad \text{.... (3)}$$

Where,

NIR = Near Infrared Band-5 of Landsat-8 image data

Red = Band-4 in Landsat-8 image data

The computation of the NDVI is important because, subsequently, the proportion of vegetation (Pv), which is highly related to the NDVI, and emissivity (ε), which is related to the Pv, must be calculated.

4) Calculate the proportion of vegetation P_v

$$P_v = \text{square} ((NDVI - NDVImin) / (NDVImax - NDVImin)) \qquad \text{.... (4)}$$

Usually the minimum and maximum values of the NDVI image can be displayed directly in the image.

5) Calculate Emissivity ε

$$\varepsilon = 0.004 * P_v + 0.986 \qquad \text{.... (5)}$$

Simply apply the formula in the raster calculator, the value of 0.986 corresponds to a correction value of the equation.

6) Calculate the Land Surface Temperature

$$LST = (BT / (1 + (0.00115 * BT / 1.4388) * Ln(\varepsilon))) \qquad \text{.... (6)}$$

This is the final equation of the process of deriving Land Surface Temperature (LST). The final product is shown below in the image.

5. RESULTS AND DISCUSSION

By doing the analysis, we observed that in the city of Ahmedabad loud cover is reducing in the month of May. As compared with 2018 data, 2013 possesses more cloud cover (Landsat-8 band 1). Also, the city area in Ahmedabad which is included in the east zone and south zone are SUHI prone areas. New west zone is less prone to SUHI effect.
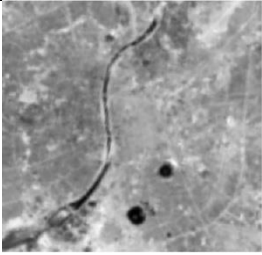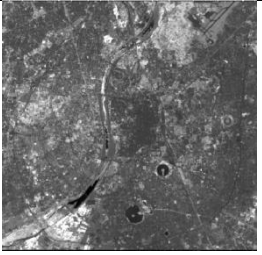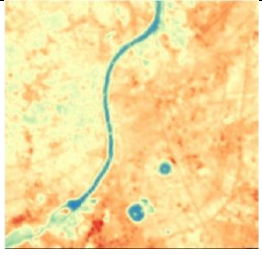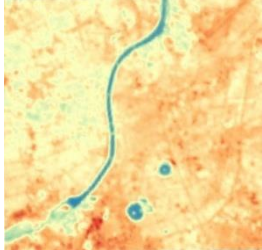
As per observation in table 2, UHI effect is expected maximum at the midnight period in the month May and June. Climate change also affects UHI, so clouds are observed in some multispectral images.
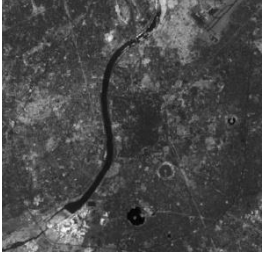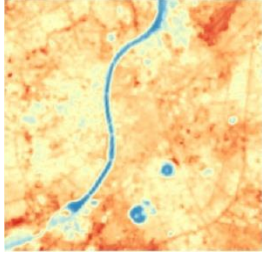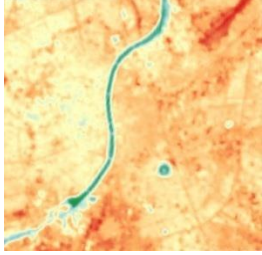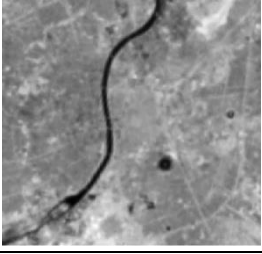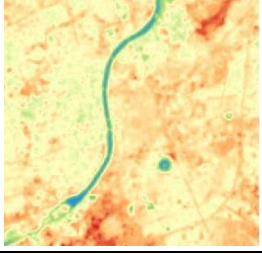
In table 3, data results are given with remote sensing images. The software tools are used to calculate LST of Ahmedabad. The results are highly hopeful. It means that Ahmedabad is able to mitigate UHI effect.

Table 2: Calculated UHI parameters

Parameter		2013	2014	2015	2016	2017	2018
NDVI	Min	-0.0683	-0.0784	-0.0335	-0.0927	-0.0322	-0.027
	Max	0.401	0.53	0.513	0.48	0.468	0.361
Top of Atmospheric (TOA) (Kelvin)	Min	304.845	302.331	301.896	304.484	301.197	302.662
	Max	322.341	318.6	314.638	323.06	315.274	318.452
LST (Kelvin)	Min	106.52	106.51	106.45	106.771	106.36	106.54
	Max	108.47	108.47	108	108.968	108.063	108.43
Brightness Temperature conversion (degree Celsius)	Min	31.695°C	29.181°C	28.746°C	31.334°C	28.047°C	29.512°C
	Max	49.191°C	45.45°C	41.488°C	49.91°C	42.124°C	45.302°C

Table 3: Calculated UHI parameters with period and images

Period	TOA (10)	NDVI (4-5)	LST	Min-Max Temperature (6 pm - 12pm)	Average Temperature (May)
2013-05-18				44-32°C	35 °C
2014-05-30				43-33°C	35 °C

2015-05-24				39-34°C	36 °C
2016-05-19				49-35°C	36 °C
2017-05-22				40-32°C	35 °C
2018-05-16				45-35°C	37 °C

REFERENCES

[1]Deosthali, V. (2000). Impact of rapid urban growth on heat and moisture islands in Pune City, India. Atmospheric Environment, 34, 2745–2754.

[2] Jawaharlal Nehru National Urban Renewal Mission Technical Report, City Development Plan Ahmedabad 2006-2012, Prepared by Ahmedabad Municipal Corporation and Ahmedabad Urban Development Authority with Technical Support from: CEPT University, Ahmedabad.

[3] Mathew, A., Sreekumar, S., Khandelwal, S., Kaul, N., & Kumar, R. (2016). Prediction of surface temperatures for the assessment of urban heat island effect over Ahmedabad city using linear time series model. Energy And Buildings, 128, 605-616.doi:10.1016/j.enbuild.2016.07.004

[4] R. Pu, P. Gong, R. Michishita, T. Sasagawa, Assessment of multi-resolution and multisensor data for urban surface temperature retrieval, Remote Sensing of Environment 104(2006) 211-225

[5] Kotharkar, R., &Bagade, A. (2017). Local Climate Zone classification for Indian cities: A case study of Nagpur. Urban Climate, 24, 369-392. doi:10.1016/j.uclim.2017.03.003

[6] Mutani, G.; Cristino, V.; Bullita, M..The urban heat island of the Metropolitan City of Turin.Strategies for a

sustainable urban planning - (In corso di stampa). ((Interventopresentato al convegno XXIII A.I.P.T. Conference (AssociazioneItalianaProprietàTermofisiche) tenutosi a Turin nel September 21st-22nd, 2017

[7] Amirtham, L. (2016). Urbanization and its impact on Urban Heat Island Intensity in Chennai Metropolitan Area, India. Indian Journal Of Science And Technology, 9(5). Retrieved from http://indjst.org/index.php/indjst/article/view

[8] Mathew, A., Sreekumar, S., Khandelwal, S., Kaul, N., & Kumar, R. (2016). Prediction of surface temperatures for the assessment of urban heat island effect over Ahmedabad city using linear time series model. Energy And Buildings, 128, 605-616. doi:10.1016/j.enbuild.2016.07.004

[9] Nakata-Osaki, C., Souza, L., & Rodrigues, D. (2018). THIS – Tool for Heat Island Simulation: A GIS extension model to calculate urban heat island intensity based on urban geometry. Computers, Environment And Urban Systems, 67, 157-168. doi:10.1016/j.compenvurbsys.2017.09.007

[10] Diamond, S., Chick, L., Perez, A., Strickler, S., & Martin, R. (2018). Evolution of thermal tolerance and its fitness consequences: parallel and non-parallel responses to urban heat islands across three cities. Proceedings Of The Royal Society B: Biological Sciences, 285(1882), 20180036. doi:10.1098/rspb.2018.0036

[11] Ashtiani, A., Mirzaei, P., &Haghighat, F. (2014). Indoor thermal condition in urban heat island: Comparison of the artificial neural network and regression methods prediction. Energy And Buildings, 76, 597-604. doi:10.1016/j.enbuild.2014.03.018

[12] Moustris K, e. (2018). Development and application of artificial neural network models to estimate values of a complex human thermal comfort index associated with urban h... - PubMed - NCBI. Ncbi.nlm.nih.gov. Retrieved 30 September 2018, from https://www.ncbi.nlm.nih.gov/pubmed/29644432

[13] Geoffrey J Levermore, John B Parkinson, (2018). An empirical model for the urban heat island intensity for a site in Manchester. Building Services Engineering Research And Technology. Retrieved from http://journals.sagepub.com/doi/abs/10.1

[14] Gaur A, e. (2018). Analysis and modelling of surface Urban Heat Island in 20 Canadian cities under climate and land-cover change. - PubMed - NCBI. Ncbi.nlm.nih.gov. Retrieved 30 September 2018, from https://www.ncbi.nlm.nih.gov/pubmed/29

[15] Khandar Vijay M., R.D. Garg (2014). Heat Island Analysis of Nagpur and Surrounding Area using Geomatics Techniques. International Journal of Engineering Research & Technology (IJERT) Vol. 3 Issue 6

[16] Weather in May 2018 in Ahmedabad, Gujarat, India. (2019). Timeanddate.com. Retrieved from https://www.timeanddate.com/weather/india/ahmadabad/historic?month=5&year=2018

[17] Dewa, R., &Danoedoro, P. (2017). The effect of image radiometric correction on the accuracy of vegetation canopy density estimate using several Landsat-8 OLI's vegetation indices: A case study of Wonosari area, Indonesia. IOP Conference Series: Earth And Environmental Science, 54, 012046. doi:10.1088/1755-1315/54/1/012046

[18] Sumit Kumar and ManojPanwar(2019).Urban Heat Island Footprint Mapping of Delhi Using Remote Sensing. Researchtrend.net. Retrieved 29 April 2019, from https://www.researchtrend.net/ijet/pdf/16-%20135.pdf

OPERATION OF REGENERATIVE BRAKING IN ELECTRICAL VEHICLES AND COMPARISON WITH CONVENTIONAL BRAKING

Mihir Barpande

G H Patel College of Engineering & Technology

ABSTRACT

Braking is the primary and fundamental feature of a vehicle. It can be regarded as one of the important and primary things, and so it's important to have efficient braking system. The mechanical braking system which is the most used braking system is sometimes inefficient and its one of the limitations is that the kinetic energy of the vehicle that is produced after braking is wasted as heat and thus this phenomenon leads to reducing the efficiency by majorly affecting the fuel and the optimization of fuel.

In, the city areas and the areas having dense population it's necessary to apply brake every time and thus decreasing the efficiency of motor. This makes the energy loss wider and thus we need effective braking system. So, engineers have invented **"REGENERATIVE BRAKING SYSTEM"** to regain the kinetic energy that is lost as heat during the old braking method. But, by the law of physics though we can't recoup the whole energy but notable amount can be recovered and can be stored in the battery or super-capacitor.

Keywords: Regenerative braking, electric vehicles, kinetic energy, working.

1.) OBJECTIVES AND METHODOLOGY

1.1) INTRODUCTION

The notion of the regenerative braking which is enacted in day-to-day vehicles is used with the help of fly-wheels. So, basically fly-wheels are the disks that are with high inertia and it rotates at a high speed. Thus, we can say that it behaves as a device or container which can store the dissipated kinetic energy of the vehicle during the process or time of braking. The, residual energy which is stored can be used for assisting the vehicle during load or the slopes having the up-hill moment.

Fig1) Algorithm of Power flow direction during regenerative mode.
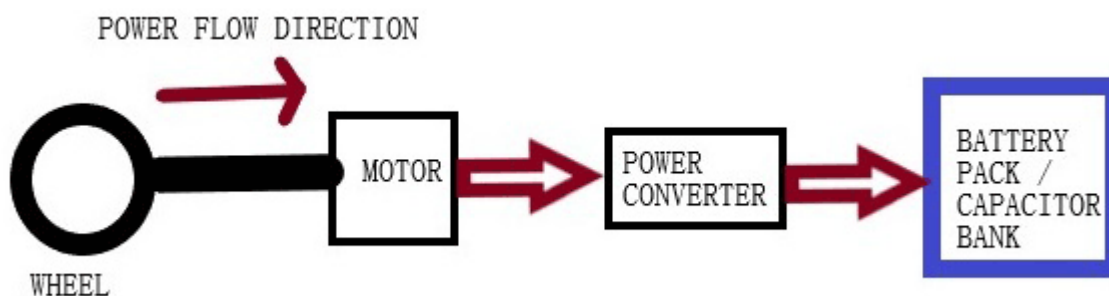
Source:- www.workingofregenerativebraking.com

The regenerative braking is the mechanism which does not get triggered on plain road surface or the area which is covered by smooth surface. It is only seen on those type of roads where we have to apply brake on speed braker or the rough surface area which contains the irregular area and some pits. This type of braking is observed when the level of battery is charged up to full extent because braking needs to be effect by energy.

In EV's (electrical vehicles) we can assimilate this braking system in more effective way with the use of electronics and thus reducing the need of heavy fly-wheels, nor it will add to the extra weight of vehicle. At the process of breaking the amount of kinetic energy that is lost can be re-converted to electrical energy and can be stored in battery or ultra -capacitor. Thus, by saving the energy we can control the energy loss and can use it whenever we want by again converting to mechanical energy at the time of load gaining or load taking by the car or any other vehicle.

1.2) FUNCTIONAL PRINCIPLE OF REGENERATIVE BRAKING

Regenerative braking method uses the mechanical energy which it gets from the motor and converts electrical energy and it flows back to the battery. There are instances when we need to stop the car or slow down the car and when we apply the force to apply brakes, the motor present there starts working in the reverse direction and thus leading to stop the car ultimately. For an instance it is very primary thing to know that when motor runs in the opposite direction of validate it acts and works as generator.

Fig2) Motoring mode

BATTERY

DIRECTION OF POWER FLOW

DIRECTION OF

MOTION

Fig3) Generating mode

BATTERY

DIRECTION OF POWER FLOW

DIRECTION OF MOTION
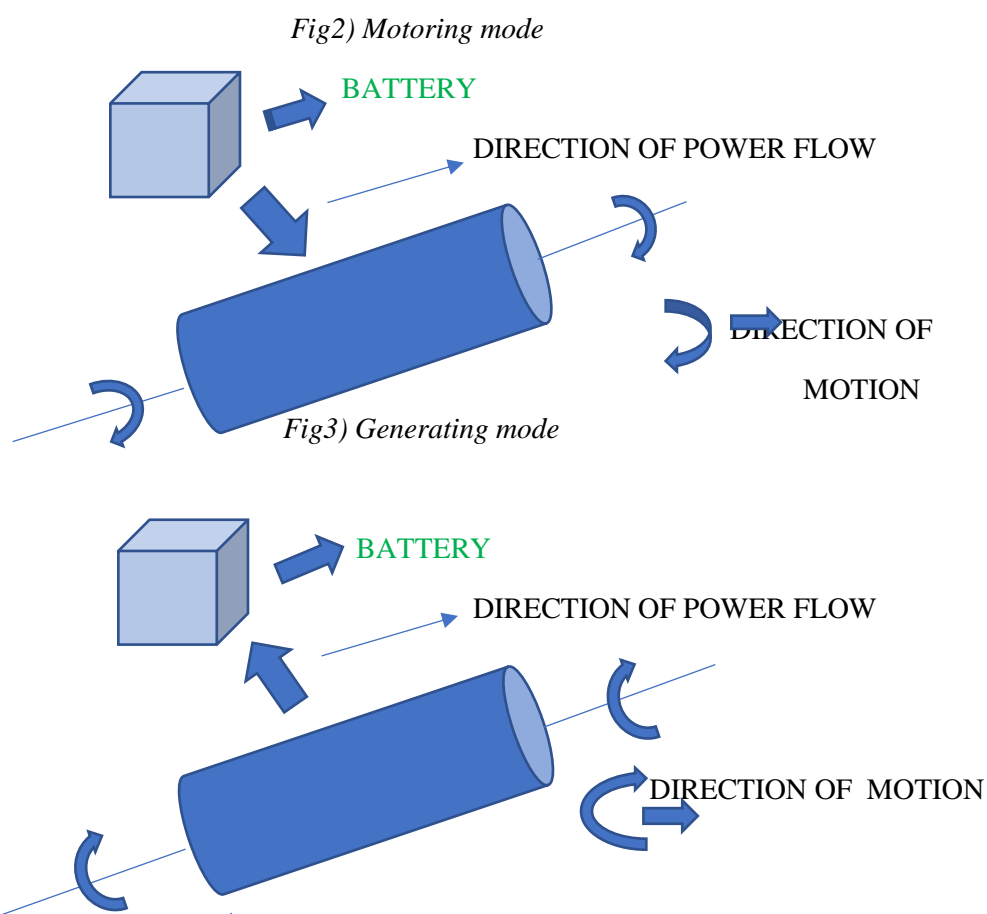
In *Fig2)* the normal running condition of motor is been shown where the motor runs in forward direction and that receives energy from battery. For an instance when we employ this type of braking system in electrical vehicles it saves the fuel, fuel economy is stabilized, emission is lowered and the energy loss is saved up to a great extent and thus we can clearly mention that this braking can eradicate traffic, also it can be seen that the energy loss is very low, almost equivalent to negligible.

In *Fig3)* the opposite condition of motor can be seen where the motor is running in the reverse direction and can be seen in the "generator mode". Thus the generating mode of the motor comes into picture and it gives energy back to the battery. In this type of mode and when the car or vehicle is to be started and it has to take off the load this energy can be used efficiently so fuel economy is increased.

Fig4) Proto-type of a car which has employed regenerative braking system.
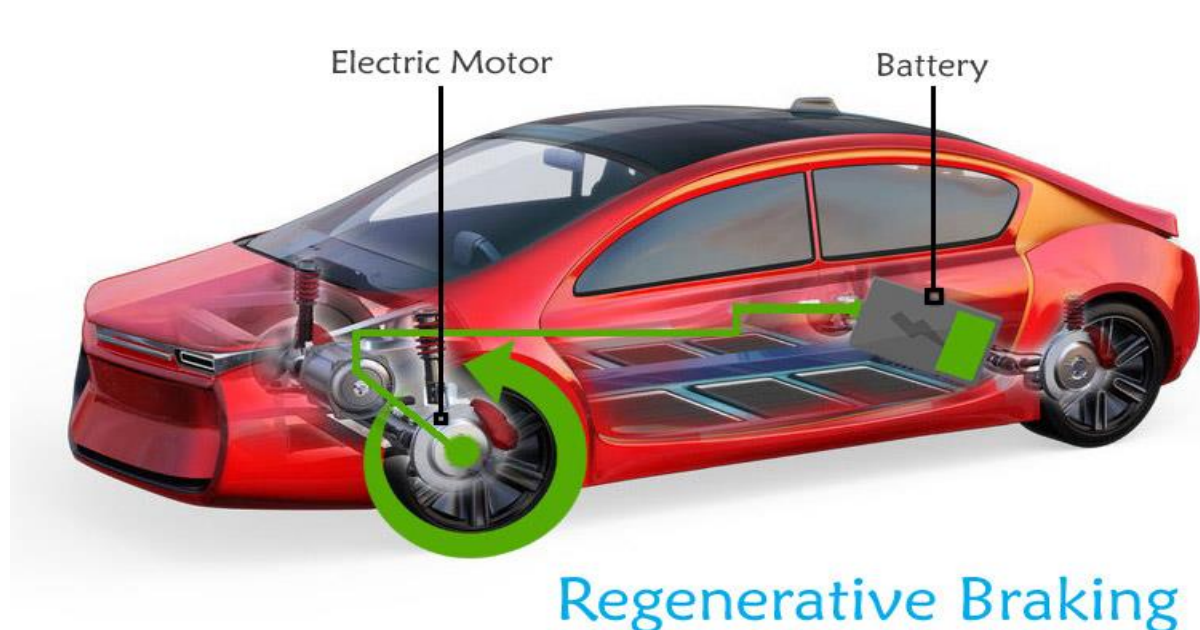
Source: - www.workingofregenerativebraking.com

The working of mechanical braking system is that, whenever we apply brakes a reverse torque is generated in the wheel(motor) and the vehicles come to halt. Likewise, in regenerative mode of braking negative torque is initiated in the motor of wheels with the help of motor controller. At, this time of running, the controller of the motor is functioned to recoup the whole kinetic energy such that it can store the regained energy in battery or the capacitor banks. Apart from saving the fuel and saving energy, regenerative braking also enhances the range by 8-15% and also, it's the most effective way of braking.

1.3) LITERATURE SURVEY

Regenerative braking system is one of the most famous and most popularly used as this method improvises the most typical problem and that is the energy conservation problem. We can save up to 25% energy and thus can give our hand to the eco-friendly system of cars. Many modules, papers and boos have been published in accordance with the regenerative braking system. Various methods and terms are used in this paper and those are derived from the researcher' knowledge.

This braking system has achieved and continued to have a good impression on automotive industry and so there are many chances that there can be very much bright future in this field. Also, there are some conditions in which this system can't be used. For e.g., high temperature of battery we cannot use that system as it tends to increase the overall temperature of the system.

Thus, it's very important to have proper blending of the torques that have been produced due to the hydraulic braking system and the regenerative braking system. If this torques are not in line then there would be a difference in braking and can make the vehicle disturbed due to the improper alignment of the braking systems.

2) RESEARCH METHODOLOGY

2.1) OPERATION OF REGENERATIVE BRAKING ELECTRIC VEHICLE

For an instance let's assume the car is been imbibed with a three phase induction motor for the purpose of propulsion .It is clear with the help of speed-motor characteristics that while induction motor runs at a speed more than synchronous speed then the slip(s) becomes negative and thus the motor works as an induction generator (alternator).The synchronous speed can be defined as the speed of rotating magnetic field of the stator which is produced due to the injection of three phase supply .

At the time of starting of motor, the EMF which is induced in the motor is at the peak level. Now when the motor starts to rotate fast the induced EMF decreases because it's a function of slip and inversely proportional and thus when the motor reaches to the synchronous speed the induced EMF becomes zero and thus vanishes in motor. Now if the rotor is rotated at the speed above than this, EMF will be induced and, in the prevailing situation, it happens oppositely that the motor gives the active power back to the source. When the brakes are applied to halt or decrease the speed of the vehicle then it is not advisable to run the motor above synchronous speed at that time so here the motor controller comes in picture.

Fig5) Torque and power flow direction when motor works as a generator.
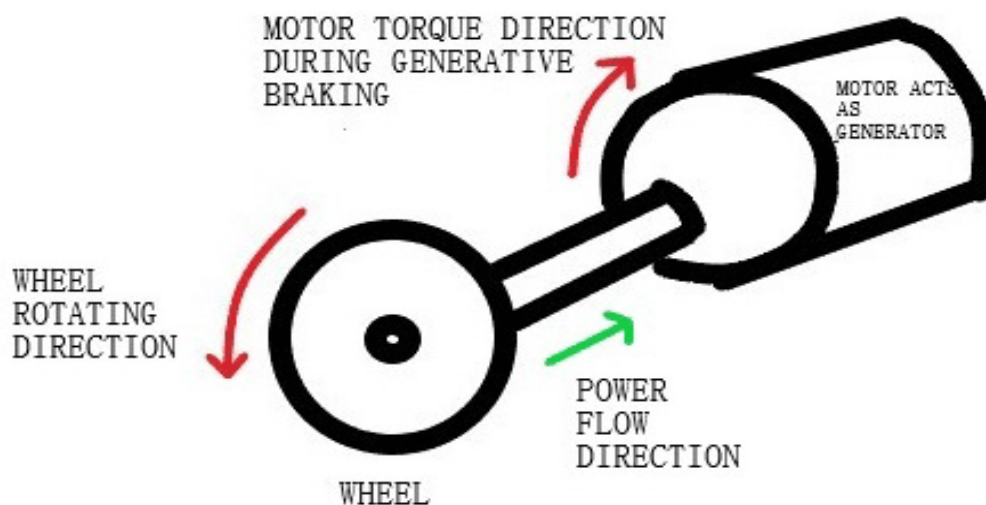
Source: - www.workingofregenerativebraking.com

Now, by assuming one situation it should be clear that how this braking works in the electrical vehicle. For an example let's take that motor is rotating at the rpm of 5000 also the fundamental frequency that is supplied be 150 Hz and at the time of braking we need to bring down or reduce the rpm to lower levels or zero. The controller coming into the picture depends upon the input that we get from the brakes and the pedal sensor and starts to carry out its functioning. When this process starts the controller automatically sets the fundamental frequency inferior than 150 Hz and will make it equal to 80 Hz and thus making the synchronous speed 2200 rpm. When we see from the reference of motor controller the speed of motor is more than its synchronous speed and as now, we are intended to reduce the speed while braking, the motor will act as a generator until 2200 rpm and in this time span, we can take out or extract power from the motor and store it in the battery or the capacitor bank.

It is here noteworthy point that the battery continues to supply the power to the three phase induction motors during the process of regenerative braking and this is because the magnetic flux of induction motor is zero when the power given(source) is 0(OFF). Also, it is known that motor enacting as generator draws the power which is reactive to produce the linkages of flux and gives active power back. The law is different for every different motor to recover or regain the kinetic energy. For instance,

1) Permanent magnet motors can act as a generator even in the absence of source power because permanent magnets are present in the rotor to generate magnetic flux.

2) Other similar types like DC shunt motor and others have residual magnetism in it which waives the need of external excitation required to produce or generate flux which is magnetic in nature.

In majority of vehicles that are running on the electrical principal, the motor is joined to the singular drive axle (mostly to the rear-wheel drive axle) and thus its necessary to use a mechanical braking or the hydraulic braking for the front wheels. And this arises the necessity that the controller should maintain coordination between both mechanical braking and the electronic braking system when we apply brakes.

3) ANALYSIS AND OBSERVATION

3.1) OPERATION OF MOTOR IN ELECTRIC VEHICLES

The figure down here shows the three-phase and no brush connected DC motor, the motor here is controlled by an inverter which is given power from supply battery. The load is connected to the end of the 3- phase bridge inverter. D1-D6 are the free-wheeling diodes and the S1-S6 are the switching devices. This inverter gives efficient way to control motor by their switching devices and thus deducting some of energy.

Fig6) Equivalent circuit of inverter driven 3phase brushless motor.
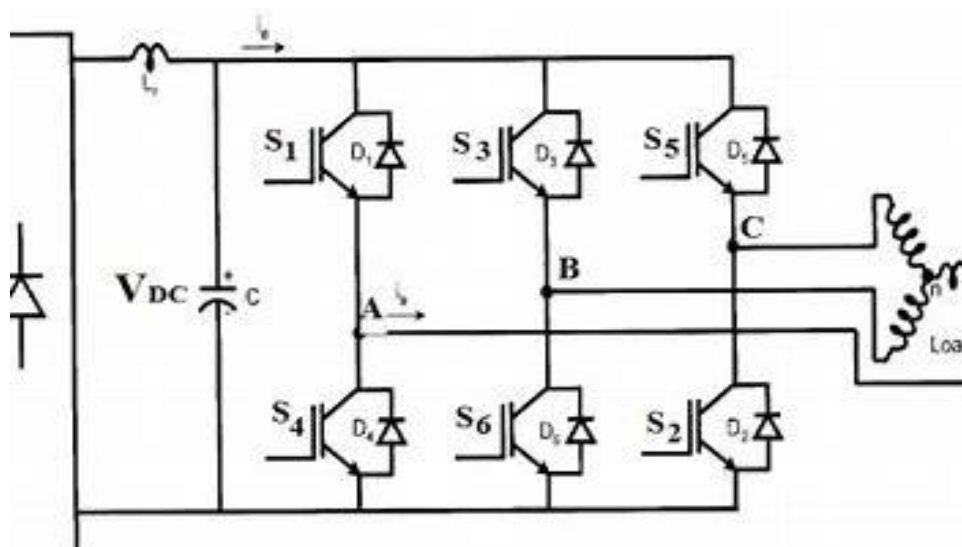
Source: - www.3-phase bridge inverter images.com

The working of this inverter driven motor is a complete commutation cycle of 360* electrical consists of 6 equal intervals. The switches are controlled in phase sequence used with control circuit based on rotor position sensors. For the effective control of torque developed by motor controlled by the inverter circuit. The operation table is for the gating scheme is given here.

Table 1: - Operation table for the gating scheme

Sr. No	Interval	Device conducting	Incoming device	Outgoing device
1	I	5,6,1	1	4
2	II	6,1,2	2	5
3	III	1,2,3	3	6
4	IV	2,3,4	4	1
5	V	3,4,5	5	2
6	VI	4,5,6	6	3

Source: - MD Singh, KB Khanchandani, Mc-Graw Hill, second edition

3.2) BALANCING OF ENERGY

We can clearly see that kinetic energy is been converted and so the fundamental problem that is need to be solved is that how much of the energy is been recovered successfully. Approximation of the recouped energy is very important to count as for design process it holds very important calculation.

- Regenerative ratio

$$\mu = \sum (V_{br} / V_{kin})$$

where,

$$V_{kin} = \sum 0.5m(V_2^2 - V_1^2)$$

$$V_{br} = \int_{t=0}^{t=end} (E_k - I(t)R(t))\, I(t)\, dt$$

E_k is the battery voltage, $I(t)$ is the battery current, $R(t)$ is the charging resistance, V_1 is the initial velocity, V_2 is the final velocity.

3.3) SUBSYSTEM FOR DRIVER

When an upward slope comes in the way the driver needs to accelerate and this acceleration produces a corresponding driver torque. The process of production of regeneration is started only after brake pedal is pressed.

The mechanical energy that is absorbed by the vehicle when driving on a specific pattern and thus it primarily depends on the three main effects:

1) aerodynamic friction loss

2) rolling friction loss

3) energy dissipated in the brakes

$$M_v \, dv(t)/dt = F_t(t) - (F_a(t) + F_r(t) + F_g(t))$$

This equation shows the longitudinal dynamics of the road vehicle.

4) THE SIGNIFICANCE OF CAPACITOR BANK OR ULTRA CAPACITORS

During the action of braking there's a sudden jerk and the speed reduces very quickly; we need to stop or reduce speed immediately. Therefore, the braking system is of very short duration, batteries have limitations and shortcomings so we cannot inject a huge amount of energy in the battery because it can cause damage to battery or severe problems can be occurred at the time of braking and it can be a risk and so to avoid this type of disadvantage, we need a capacitor bank or ultra-capacitors to the regenerative braking system. This capacitor can discharge or charge for many cycles without any harm or inefficient way, thus making capacitor bank is a prominent part of the system.

Ultra-capacitor is a device which responds quite fast as compare to other capacitors to help in capturing the energy surges effectively due to regenerative braking operation and the primary reason to choose this type of capacitors are that these are very efficient and are able to store 20 times much greater energy than that of a normal electrolytic capacitor. This kind of system gives a rise to DC-DC converter. At the time of acceleration, the "boost operation "helps the capacitor to discharge up to a finite extent maximum value. During breaking the "buck operation" helps and makes the capacitor charge up to maximum value having a good transient response and this is one of the important characteristics of the ultra-capacitor. Thus, this helps to store the energy apart from battery and giving rise to high efficiency of the vehicles and extending their range to a great extent and it can also assist to acceleration surge so that no damage is been done by the vehicle.

Fig 5) Ultra capacitor in use

Source: - www .ultra-capacitor images.com

5) PROS OF REGENERATIVE BRAKING OVER CONVENTIONAL BRAKING

5.1) ENERGY PRESERVATION:

The function of flywheel is to imbibe when braking is done with the help of a clutch system slowing down the car and making the car halt at the needed position. Now to accelerate another clutch system is advocated which connects the flywheel to the drive, thus leading to the higher speed to car and accelerating it. Energy is thus, conserved and is not wasted in the form of heat or some other dissipations which normally happens in the mechanical braking system.

Fig 6) Recent Hybrid braking complaints
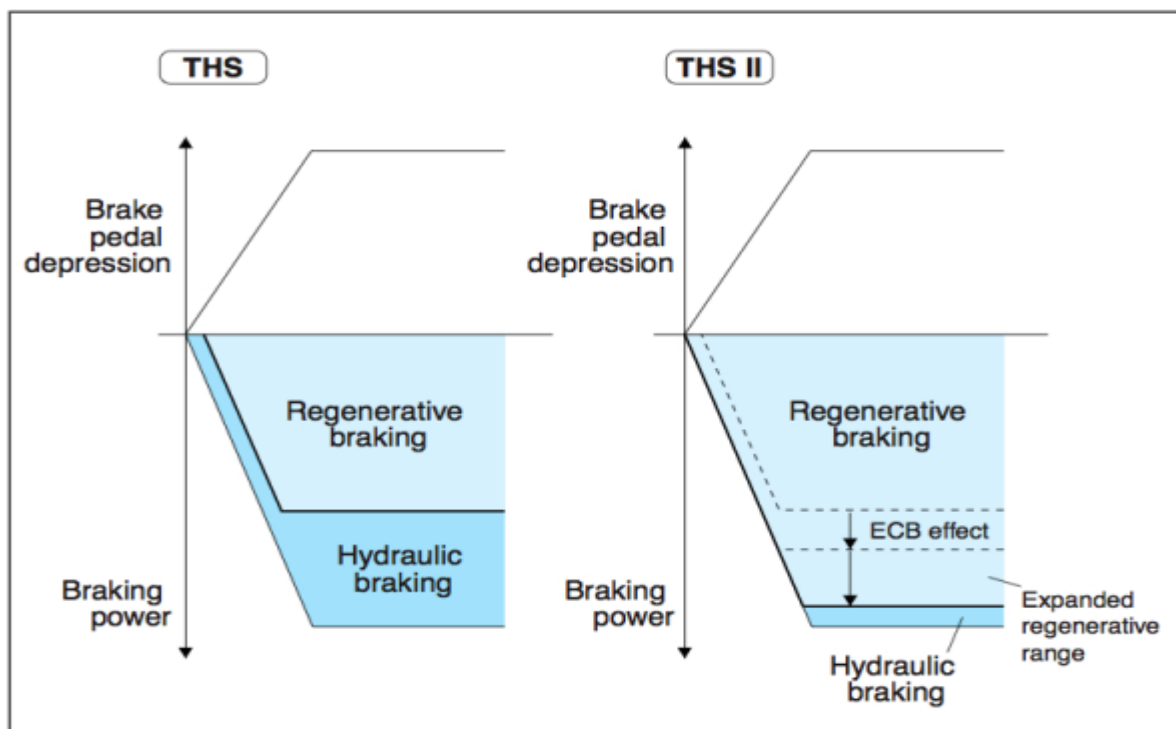
Source: - www. Images comparison of regenerative and conventional braking .com

Fig THS depicts the braking power of both the braking systems and the comparison of both braking systems and this graph clearly shows that the portion of regenerative braking is less than the hydraulic which sets a benchmark as to hydraulic braking is powerful and efficient. But there are disadvantages of both the braking systems and thus regenerative braking with proper research and proper risk should be used in vehicles.

Fig THS II shows about the ECB effect termed as eddy-current brakes shortens the stopping distance and thus the limitation of first graph is been solved and that shortcoming after getting solved helps many vehicles to help in the process of braking. Also, it has been shown in the second graph that the range of vehicle has been expanded enormously and thus can travel a longer distance and directly saving the fuel economy. The expanded regenerative range is 30-40% and so the vehicle gets boost in travelling a longer distance.

5.2) FUEL ECONOMY IS INCREASED:

 As mentioned earlier due to the effective saving of energy the fuel economy is also boosted and it gives rise to one of the most efficient cars. Thus, in conclusion it can be said that regenerative braking system is "fuel-efficient". The International Journal of vehicle design noted in 2011 that fuel consumption that was covering the NEDC (New European Driving Cycle) was improved to a great extent by 25%.

Also, another example is depicted here. The Delhi metro saved or conserved up to 90,000 tons of (CO_2) from being liberated into atmosphere by regenerating 112,400 megawatts hour of electrical energy with the proper use of regenerative braking system between 2004 – 2007. The most astonishing and mind-boggling thing about regenerative braking is that it can capture the more than half wasted energy and can put back to work in the vehicle and thus it has appreciable performance. The hydraulic braking system is much better and efficient and can produce much more effective gains and lowering the use of fuel by 30-45%.

5.3) WEAR OR TEAR AND FRICTION REDUCTION

In regenerative braking when the motor is getting or absorbing power from capacitor bank, it obstacles the alignment of wheels, which takes energy of the motion and giving that energy again to the capacitor. Thus, it reduces the wear and tear and so severe damage can be prevented and can make a smooth working cycle of the car

6) IS IT RELEVANT TO ONLY EV's (ELECTRICAL VEHICLES) OR ALL OTHER VEHICLES?

This topic also needs to be analyzed because the small cars or the cars which are for the family purposes can't be imbibed with this system so by proper analysis, we can see that the cars which can have this type of braking system should have proper alignment of vehicles, stored capacitor banks and it is present only in the electrical vehicles. The family purpose vehicles are needed to have development to install this type of braking system. The electrical vehicles are the most appropriate for having the regenerative braking system.

There is no doubt regarding the retrieving potential/energy in the concept of regenerative braking method. As stated earlier, the speed at which battery charges is much higher than at the rate at which battery discharges and thus this gives rise to the small amount of energy that the battery can store during the rapid slowing of the vehicle. And thus, the **most important thing that comes into the picture is that we should not use regenerative braking system under fully charged conditions.** It is because the overcharging can damage batteries due to severe heating of the equipment, but the electronic drive circuit prevents the damage from overcharging. In this case the storage of energy is done in the capacitor bank and it is given to the vehicle afterwards when needed and also it is used in extending the range.

The formula to find kinetic energy is $0.5*m*v^2$ and so the amount of kinetic energy that is retrieved from the vehicle is proportional to the vehicle's mass and the velocity at which the vehicle is going on. The mass is much higher in vehicles like car, trucks, JCB's, rollers and so they have more kinetic energy retrieved. In the city areas these heavy vehicles would gain a large momentum after acceleration though it has low starting speed, so during the decelerating, the kinetic energy is higher in electronic scooter which is travelling at the same speed. Thus, the efficiency of regenerative braking is much higher in electric cars, buses and vehicles. So, at last in conclusion it is to be said that this system is efficient for vehicles having high mass.

7) TYPES OF SYSTEM FOR STORING ENERGY

The storage capacity is more advanced in the new technologies mainly concentrated around ultra-capacitor, battery and converter needs to be joined to the vehicles of electric types. Various types of batteries such as nickel-zinc, lead-acid. A basic comparative study is shown of batteries.

Fig6) Life cycle, operating temp of different types of batteries

Battery type	Energy density	No. of cycles	Operating range Temp.
Ion -Li	110-160	500-1000	20^0-60^0
Ni-Zn	60-85	1000	20^0-60^0
Lead acid battery	110-160	400-1200	20^0-60^0
Ni-Cd	45-80	2000	40^0-60^0

Source: - Wikipedia.org

Thus, we can observe that there are various types of battery available to store energy and can also be used in the place of capacitor. Thus, batteries are the most basic and important element in the regenerative braking system and can be considered a necessity to the system.

The battery should be connected properly in series with the system so that it can work or function properly. Although there are many ways to connect battery in the vehicle. To choose proper battery and the proper place to install the battery is also one of the challenging tasks that needs to be performed by the engineers.

8) IMPRESSION OF REGENERATIVE BRAKING SYSTEM

Fig7) Diagram of regenerative braking system in car
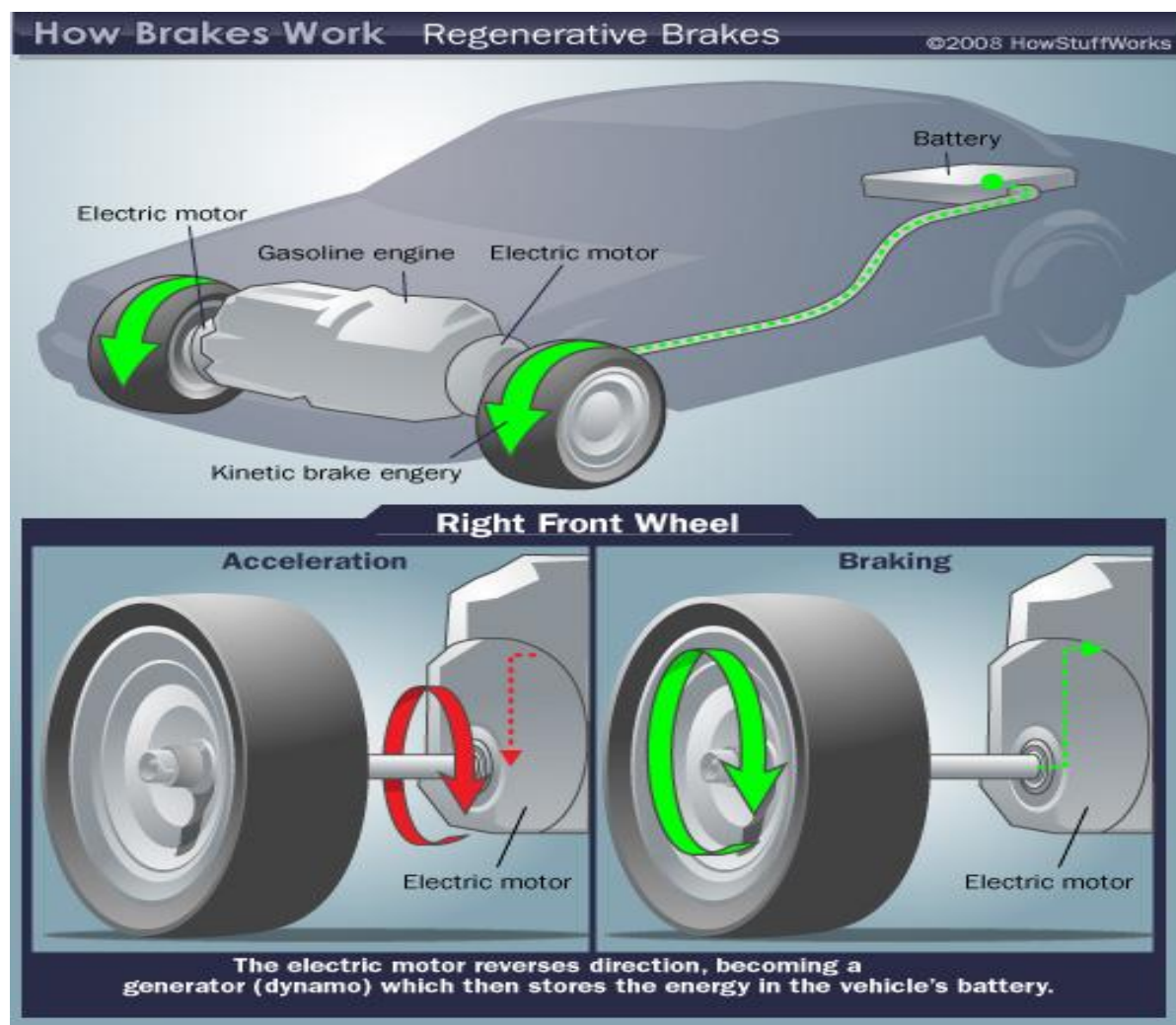
Source: - Images (how stuff works.com)

This simple diagram shows that how the regenerative braking system is able to retrieve some of the vehicle's kinetic energy and convert it to electricity or some other form of energy which can be used when needed later.

9) PRACTICALS TO BE PERFORMED (ANALYSIS IN DEEP)

Fig8) MATLAB system for regenerative braking system.
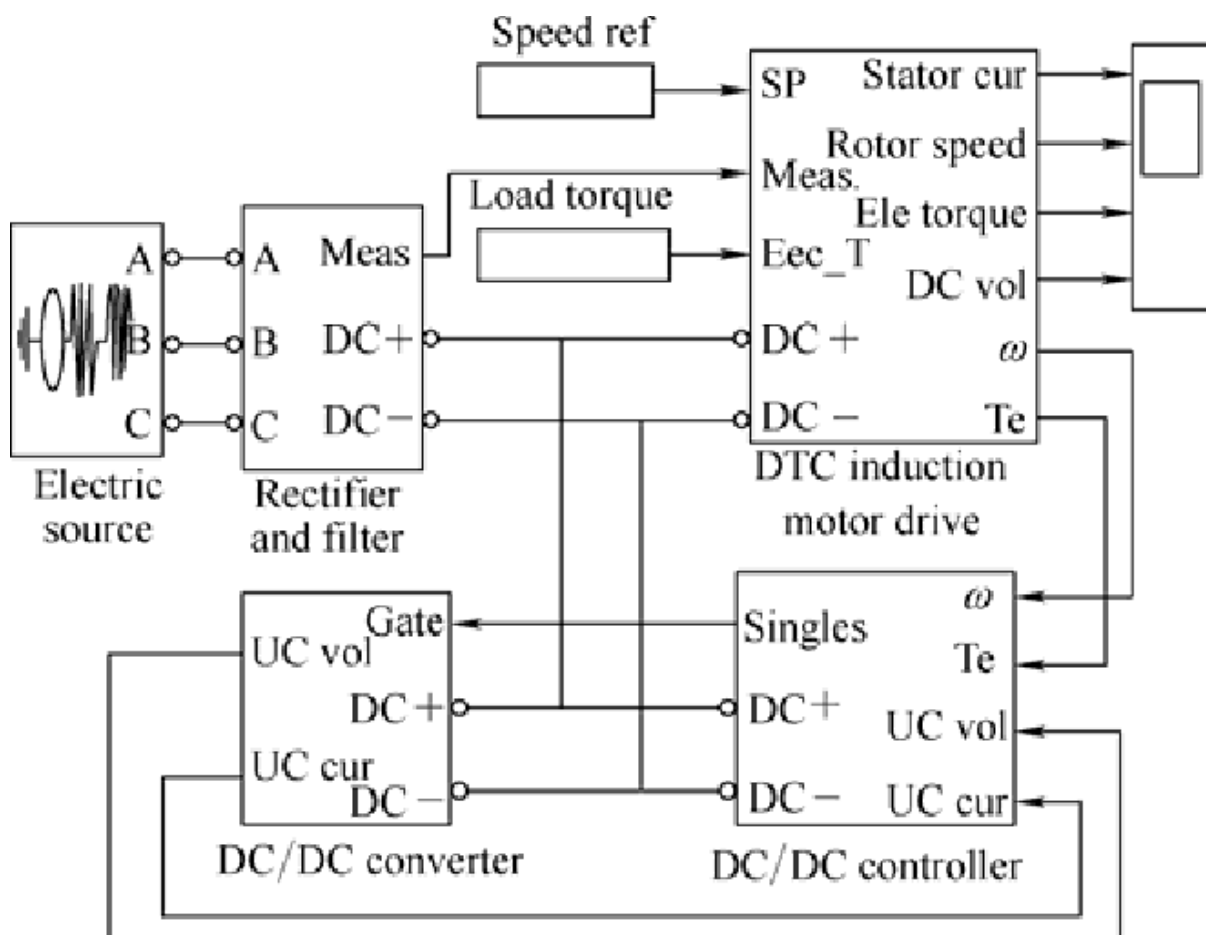
Source: - www.MATLAB simulation of braking system images.com

This is the MATLAB Simulink which is also known as the MATLAB model which is the perfect assumption that can be tested before performing on the car. This model gives us the perfect idea that how it works and can be proposed further to be more inferenced.

Here, different angles and different measures are been given to the DC controller so it can work at different stages of the braking. At the first stage where brakes are applied the energy is stored in the capacitor and after the vehicle starts to accelerate or gain load then this energy can be re-used to give and consume it to the vehicle. Thus, this model leads to the real time application of regenerative braking system.

This MATLAB model as a result generates acceleration and braking at different cases and thus can be made to be a precise consideration to install it in electrical vehicles and can be further initiated to large vehicles like car, buses and trucks.

9.1) SIMULATION OUTPUT

Fig 9) Graph of relative slip vs normal slip
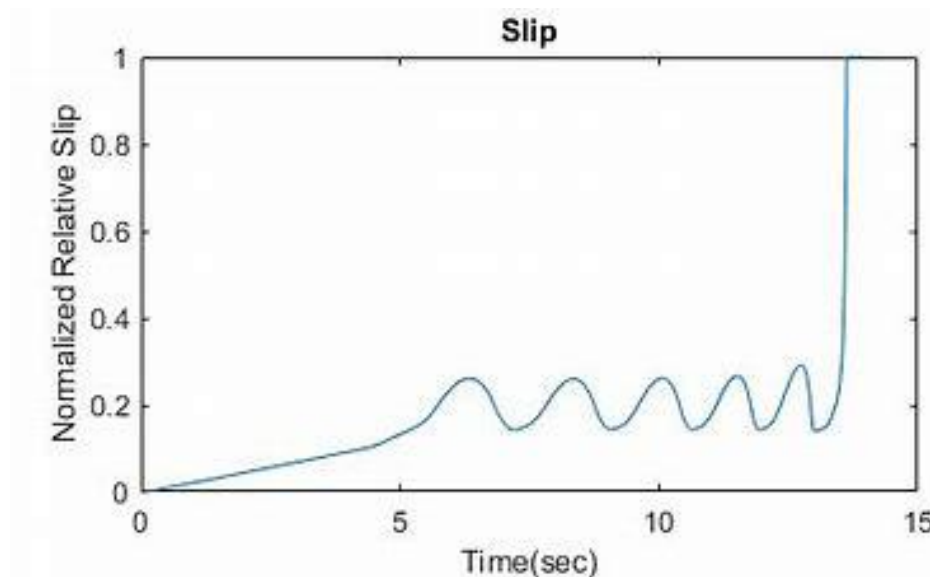
Source: - Wikepidia.org

Fig 10) Graph of force vs time period (in secs)
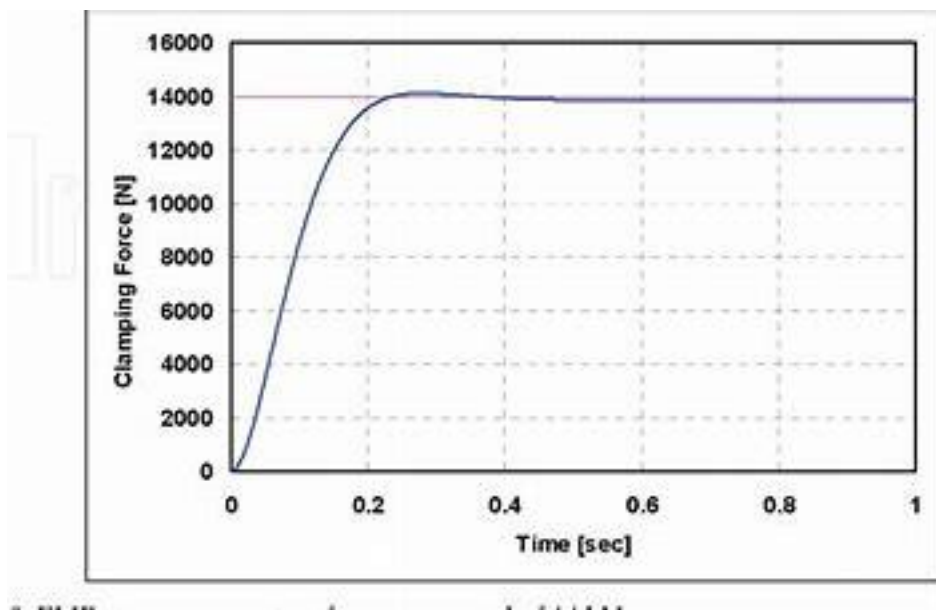
Source: - wikepidia.org

9.2) AVAILABLE ENERGY FOR BRAKING

Braking energy is the energy that is recorded when we apply brakes and so it's very important to estimate the actual braking for a braking instance which is given by the summation of rotational energy plus the translational kinetic energy from which the losses due to friction and rolling resistance are subtracted. Thus, from this formula we can find the energy that is available during the braking.

$$\Delta E_{a,\, b} = \Delta E_k + \Delta E_{rot} - V_{losses}$$

$$V_{losses} = F_{losses} * d$$

$$F_{losses} = F_d + \mu_r(mg)$$

Where,

F_d = aerodynamic drag force

μ_r = Co-efficient of rolling friction

d = Braking distance

V_{losses} = Work done

F_{losses} = Force at vehicle

10) MORE SPECIFICATIONS TO BE INCULCATED (According to Author's research)

10.1) The braking can be implemented in every vehicle to save energy and it should be connected to the rear vehicle axle and can be used effectively. For the front wheel there should be hydraulic braking.

10.2) A type of small storage battery should be connected extra to the rear vehicle so more of the dissipated energy can be stored.

10.3) The vehicle should try to avoid more braking if possible so that overheating of battery is prevented up to great extent.

10.4) An oil type cooling can be provided which can cool the overheating of battery and can prevent the harmful damage to the car.

10.5) More battery should be connected in series so it can provide effective storage to the braking system.

11) CONCLUSION

From the above research and whole analysis, we can infer and derive that the regenerative braking is one of the most effective method in the modern world. Every auto-mobile sector should include this type of braking for improving their car's quality and making them more efficient to the great extent. People should understand the importance of energy conservation and imbibe this system.

The regenerative braking system has the extra ordinary ability of saving or retrieving the waste energy to 8-15% and so improving the range of the vehicle to a greater extent. It is improved by the advanced and modern technologies and systems of power electronic components, bridge inverter, DC-DC converter and other resources. The research done above says a lot about this system and its advantages

to the world and auto-mobile industry. Also due to the sky touching petrol prices this system enables a highly efficient fuel economy and makes a vehicle better than the conventional method. The friction losses and other damages are also fully prevented and improves the fuel consumption by 33%.

The results derived above says that the power and energy is important and very useful and thus we need to use the regenerative braking system in electric vehicles.

12) REFERENCES

1) Sri Hari Karthik. "How regenerative braking works in Electric Vehicles". July 25, 2019
2) https:/HowRegenerativeBrakingWorks in Electric vehicles.html
3) Soniya.K. Malode. "Regenerative braking system in vehicles". March 2016. IRJET (Vol 3 issue 3)
4) https://www.irjet.net/archives/V3/i3/IRJET-V3I381.pdf   p-ISSN:2395-0072
5) R.H. Adware. "Regenerative braking system in vehicles". March 2016. IRJET (Vol 3 issue 3)
6) https://www.irjet.net/archives/V3/i3/IRJET-V3I381.pdf   p-ISSN:2395-0072
7) Harish Kumar "Regenerative Braking". Seminar report. June 2017
8) reference0rp/52091807-Regenerative-braking.pdf
9) Wikipedia.org
10) Amrit Mahapatra, "Regenerative Braking in Induction Motor Drives in Applications to Electric Vehicles" 2014 IEEE Students' Conference on Electrical, Electronics and Computer Science, 2014.
11) www.Howstuffworks.com
12) www.images MATLAB simulation of regenerative braking system .com
13) www. Images Comparison of regenerative braking system.com
14) www.ultra-capacitor images.com
15) www.3-phase bridge inverter images.com
16) www.workingofregenerativebraking.com
17) J Wang, Binggang Cao, "Regeneratic Strategy for Electric Vehicles" IEEE, 2009.

ANALYSIS OF THE ISSUE OF ANT BEING STUCK IN THE CYCLE BY ANT COLONY SYSTEM ALGORITHM & SOLUTION

Dhaval Varia

Gujarat Technological University, Ahmedabad

Dr. A. M. Kothari

Atmiya University, Rajkot, Gujarat. India

ABSTRACT

At the point when the size of the shortest path discovering problem increment, the intricacy of the issue increments. In such a situation, the best possibility to take care of this sort of issue is meta-heuristic methodology. Conversely, notwithstanding the way that heuristic strategies can't locate an optimum solution, they can discover a sub-ideal solution inside an acceptable time limit. Moreover, since conventional algorithms don't have a decent structure for getting away from local optima, they can't converge to a great solution. In this way, the heuristic calculations which utilize random structures for finding solutions have been proposed. Such calculations called meta-heuristic can escape from local optimum points however much as could be expected and unite to good solutions. In this study, we have proposed the procedure to identify and eliminate the cycle in the decision-making process of the ant colony system. The aim of this study is to show the number of ants stuck in the cycle of the graph if eliminated results in improvements of the computational efficiency.

Keywords: Ant colony optimization, loop design problem, shortest path finding algorithm, SUMO, Traci, Ahmedabad City, Meta-heuristic approach

1. INTRODUCTION

Smart vehicle routing problem has become popular in the past decade to solve the issues like shortest path finding problems and capacitated vehicle routing problem. The best possible methodology to take care of this type of issues is meta-heuristic approaches especially Ant colony optimization (ACO). ACO algorithms is inspired by the capability of real ants to find the shortest path from the food source to their nest. There is very little research that happened on solving the issue of ants being stuck in the cycle.

Ant algorithm (M. Dorigo & Di Caro, 1999) (Marco Dorigo & Tzle, n.d.) Is a multi-agent framework in which the conduct of simple ant called artificial ants is motivated by the genuine ants. ACO is a calculation which applied to numerous issues. Ranging from classical traveling salesman problem to routing in telecommunication.

Here the problem is to find the shortest path of graph G=(N,A). ACO algorithm exploits a set of variable T= $\tau_{i,j}(t)$ called artificial pheromone associated with arcs (I, J) of the graph. Their pheromone trail is read and written by the artificial ant. Where $\tau_{i,j} \propto utillization\ of\ the\ arcs\ by\ ants$.

At every node-local pheromone which is stored, used in the stochastic approach to choose which junction/node to pick out of the accessible junction/node. When situated at a node i an ant k uses the pheromone trails τij to process the chance that p_{ij}^k of picking j as the next junction/node:

$$p_{ij}^k = \begin{cases} \dfrac{\tau_{i,j}{}^\propto}{\sum_{j \in N_i^k} \tau_{i,j}{}^\propto} & If\ j \in N_i^k \\ \\ 0 & if\ j \notin N_i^k \end{cases}$$

Where N_i^k is the practical neighborhood of ant k when in node i. At the start of the pursuit procedure, an amount of pheromone τ0 = 1 is assigned to all the arcs of the graph G to avoid division by zero. An ant over and over jump from node to node utilizing its choice strategy until it, in the end, arrives at the goal node. While an ant comes back to the source, it adds pheromone to the edges it crosses: during its return travel the generic ant k deposits an amount $\Delta \tau^k$ of pheromone on each edge, it has visited. In particular, if ant k at time t traverse the edge (i, j), it updates the pheromone value τij as follows:

$$\tau_{i,j\ (t)} = \tau_{i,j\ (t)} + \Delta \tau^k$$

By this standard, an ant utilizing the curve associating node i and j build the likelihood that expected ants will utilize a similar edge later on.

Presently the issue is how to compute the estimation of $\Delta \tau$ for the ant k. In Simple ACO this is commonly the same consistent incentive for all the ants.in this case, the marvel works are called differential path length impact: ants which have distinguished shorter way will store the pheromone prior that the ants which find the more drawn-out way. Along these lines, the short way turns out to be more attractive snappier than longer ways and this thus decides an expansion in the likelihood that anticipated ants will pick it.

Other than this constant value for all the ants we may derive some function to deposit the pheromone by ant k on the path it found. So, we required the amount of the pheromone deposited on the path is inversely proportional to the length of the path which ant K travelled. So,

$$\Delta \tau^k = \frac{1}{L^K}\ where\ L^K\ is\ the\ length\ of\ ant\ k{'}s\ path.$$

To restrict the ant to choose a suboptimal path, the pheromone trail required to vanish. Evaporation is done by diminishing pheromone trails at exponential speed.

By and by, at every cycle of the calculation, the accompanying condition is applied to all pheromone trails:
$$\tau = (1 - \rho) * \tau\ where\ \rho\ is\ pheromone\ evaporation\ rate\ \in (0,1]$$

Following is the overview of the ACO algorithm:

Table 1 Basic Ant colony optimization algorithm suggested by the M.Dorigo & Di Caro

Algorithm 1 The Ant colony Optimization Metaheuristic (M. Dorigo & Di Caro, 1999)
Set parameters and initialize pheromone trails
while termination condition not met do
ConstructAntSolutions
ApplyLocalSearch (optional)
UpdatePheromones
end while

In this paper we have proposed the algorithm to tackle the issue of ant being stuck in the cycle and isolate the nodes which participated in the creation of the cycle.

2.   LITERATURE REVIEW

Eshghi and Kazemi (Eshghi & Kazemi, 2006) have proposed a solution for the single loop design problem. The proposed strategy is planned to locate the briefest closed loop along all divisions edges so that a closed circle is a non-crossing circle covering at any rate one edge of every office. This paper has demonstrated the examination of the proposed calculation with different procedures to tackle the single loop design problem.

Zhao & Tong (Zhao & Tong, 2009) analyzed research and discover the answer for the ant being stuck in the loop during looking for the shortest path. In this paper, the author is maintaining tabu-list if the current node is part of the tabu-list than ant will be backtrack and start searching again. This allows subsequent ants to stuck in the same loop. Our proposed solution makes the pheromone value of the specific edge of the path infinite so that the three things can be accomplished (1) Subsequent ants will avoid this path, bringing about the expulsion of the circle from search space (2) No compelling reason to maintain tabu-list (3) back-track of the ant is not required.

Elloumi et al. (Elloumi et al., 2014) have indicated improvements in the presentation for taking care of traveling salesman issues utilizing a Particle swarm optimization altered by the Ant colony technique. This paper has referenced that the ant system framework exhibited effectiveness to determine combinatorial optimization issues over PSO.

3.   RESEARCH GAP

In an ant colony algorithm, the ant isn't allowed going in reverse to expel way repeat for example one node cannot be visited more than once by a similar artificial ant. In any case, the issue is, suppose there are n no. of ants, out of which say x no. of ants follow the way 1->2->3->4->5 and stuck each time during looking through the way towards goal D since this way contains a cycle, for example, 1->2->3->4->5->1, is the misuse of the computational asset. Instead of this, if we may identify and seclude the circle going over the way then ensuing ants follow another way to look through the goal. Also, this will permit converging solutions faster. Additionally, this the calculation assets will be spared.

For the most part, in the issue, where looking through the shortest path inside the map of the city, we cannot adjust the map/Graph to expel the repeat of the path. We have to build up another system to identify the

repeat in the graph and segregate it. With the goal that ant keeps away from this way during looking for the optimal way.

In ACR Algorithm (Zhao & Tong, 2009), If ants find the way where there are no nodes, other than choosing a node which makes trap (here it can be identified using taboo list) than ants begin following to past node, ant begins looking through another way. Perception is this calculation permits all the ants to follow this way and afterward backtrack the ants. Which thus overuse the computational assets and postpones convergence of the solution. So, we find another way to build a novel system.

4. IMPLEMENTATION & EXPERIMENTS

The implementation to prove point of this paper is based on the Simulation for urban mobility (SUMO) and Traci (Python). The ant colony system (ACS) algorithm (M. Dorigo & Di Caro, 1999) implements in the Traci. Here the aim is to travel the vehicle from source to destination, using the shortest path. The shortest path finding is done using the Ant colony algorithm. The issue with the ACS is if more and more ants are stuck in the loop, it results in the deposition of pheromone on this loop. This will, in turn, become more attractive and ants would get trapped in this loop. For the purpose of experimentation, we have considered a physical map of Ahmedabad City, Gujarat-India as shown in figure 1.
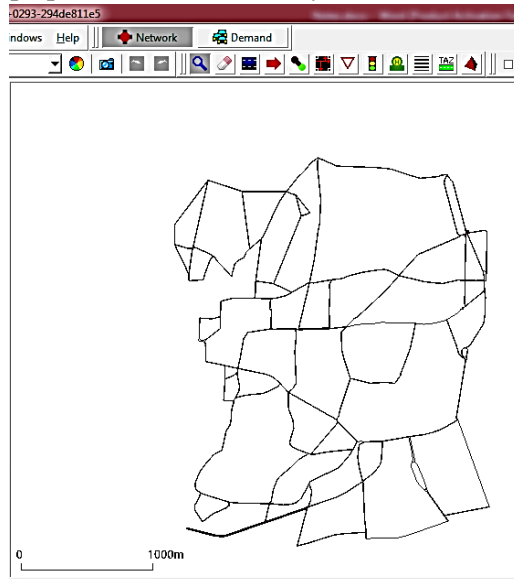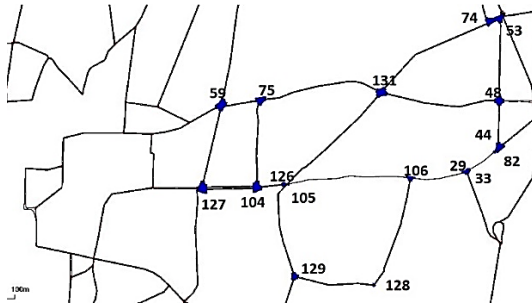
Figure 1 Considered a graph part of Ahmedabad city

Figure 2 Map to illustrate loops find by the ants during the search of the path from node 106 to 132

Figure 3 Identified Routes contains the loop

Route 1 : 106 128 **129 131** 75 104 126 105 106

Route 2 : 106 29 33 82 44 48 131 129 128 106

Route 3: 106 128 129 131 75 59 127 104 126 105 106

Route 4 : 106 29 33 82 44 48 53 74 **131 129** 128 106

Route 5 : 106 29 33 82 44 48 131 75 104 126 105 106

*Note: There is a direct path between 131 and 129

For the test-setup, we used 512 ants and the Total journey considered is 39 with 10 iterations each. For the other parameter, we choose fixed default values: $\alpha = 0.5, \beta = 0.5,$ evaporation rate = 0.75, and initially default pheromone set to all the paths are 1. The parameters are in the present model fixed; this makes it simpler to think about the outcomes. In the beginning, all the ants are assigned the source node as the start node of the journey. We have considered the following procedure to run the simulation:

Step 1: Initialize the journey by giving an array of start node and End node [Nodes are the cross-ways of the graph represented in figure 1]:

source_node = [87, 38, 88, 132, 48, 132, 145, 145, 116, 51, 81, 71, 97, 99, 99, 98, 46, 109, 101, 59, 38, 132, 36, 134, 60, 120, 97, 87, 113, 39, 39, 40, 40, 40, 47, 84, 26, 44, 41]
destination_node = [128, 27, 132, 126, 99, 106, 129, 128, 105, 48, 20, 44, 131, 83, 74, 91, 44, 128, 132, 118, 131, 75, 74, 35, 33, 44, 35, 12, 131, 129, 106, 35, 19, 56, 106, 83, 98, 51, 74]

Step 2: Start simulation of Algorithm 2 with given source and destination as (source_node[i], destination_node[i]) where i iterate from 0 to 38 to cover all the 39 journeys.

Note: Number in the array represents the Junction/node of the graph shown in figure 1.

Table 2 shows the proposed algorithm for the detection of the cycle during the selection process of ACS & Table 3 shows the proposed algorithm for the removal of the cycle within the path.

Table 2 Proposed method for the detection of the cycle during the selection process of Ant colony system algorithm

Algorithm 2 Modification in the edge selection process of ACS Algorithm
Input: ants, graph

Output: Detection of the cycle and set pheromone to infinite for all/some of the edges available in the trace

For all the ants
  For all the available next_nodes for selection in the graph
   If the pheromone of the selected edge is greater than 0
    If trace of ant(i) >= 3
     If a node in trace
      print("Cycle Detected")
      Function: set_phermonone_to_inifite for all/some of the edges available in the trace

Table 3 The proposed algorithm for the removal of the cycle within the path

Algorithm 3 Process to set pheromone to infinite for all the edges available in the trace of ant, which is part of the cycle

Input: **trace, graph**
Output: **set the pheromone matrix to infinite for the edges part of the cycle**
1. *get_nodeid=0*
2. **Loop through all the nodes of trace where loop detected**
3.   *Check if any of the nodes in the trace is having more than two outgoing edge*
4.   *IF yes then get that get_nodeid*
5.   *Break*
6. *if(get_nodeId ==0)*
7. *loop through all the nodes of trace*
8.   *pheromone[x][x+1] = -1*
9. *Else*
10.   *pheromonde = default pheromone i.e. 1*
11.   *loop through all the nodes of trace*
12.   *if trce[i] == get_nodeid*
13.   *pheromonde = -1*
14.   *pheromone[x][x+1] = pheromone*

In the experiments, our graph contains 145 nodes and 300 edges in total. Decision making for each ant depends on the two matrices: 1. Distance matrix 2. Pheromone matrix. Each matrix is of size 145X145 (Where 145 is the total nodes the graph consists of.) As the ants progress the solution, ants store the node it has visited in the trace array.

Generally, the cycle consists of a minimum of three nodes. So if the trace contains nodes equal or more than three then only there is a chance of cycle. Now if the node to choose is already in the trace of ants as shown in figure 3 i.e. there is a cycle from that node to the rest of the trace. For example, if Trace = [128 **129 131** 75 104] of the ants and the next node to choose is 129, then there is a cycle detected: [128 **129 131** 75 104 129].

Now the Algorithm 3 which we have proposed is the removal of the detected cycle in Algorithm 2. Algorithm 3 has shown that, if all the nodes are having more than two outgoing edges, then there are chances

that the ant can move out of the cycle and follow the way towards the goal (refer figure 4). But if the outgoing edges are 1 or 2 then there is zero chance that cycle would bring about the ideal way for the goal.

In this way,

If *none of the nodes in the trace of ant having more than 2 outgoing edges, then set the pheromone of all the respective nodes to infinite.*

Else *Set pheromone to infinite, from the node which more than two outgoing edges.*

Figure 4 The path contains the cycle
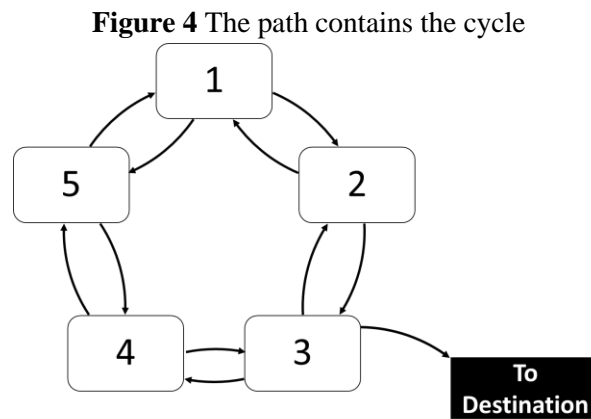
For instance, as appeared in figure 4 [Path contains the cycle] If the trace contains [1 2 3 4 5] and the following conceivable node to select is 1 then this is an event of the cycle in the graph. So if all the nodes having only two outgoing edges [i.e 2 to 3 and 2 to 1] then there is no hope to reach the destination. But here node number "3" having 3 outgoing edges [3 to 2,3 to 4, 3 to possible towards destination], so the proposed algorithm will make pheromone to interminable for edges after 3. Edges other than this [i.e. 1-2 and 2-3] will remain as it is.

5. RESULTS AND DISCUSSION

Figure 5 shows the average time t (In seconds), ants spent to find the solution in the journey Ji Where total journey in the consideration is 39 planned for the map given in figure 1. From figure 5, it is observed that the average time spent by each ant gets reduced by some amount. As per the statistics, we obtained this is 5.26% less time taken to solve the problem over the existing Ant Colony system.

Figure 5 Average time t (in Seconds) ants spent to find the solution for all the 39 journey
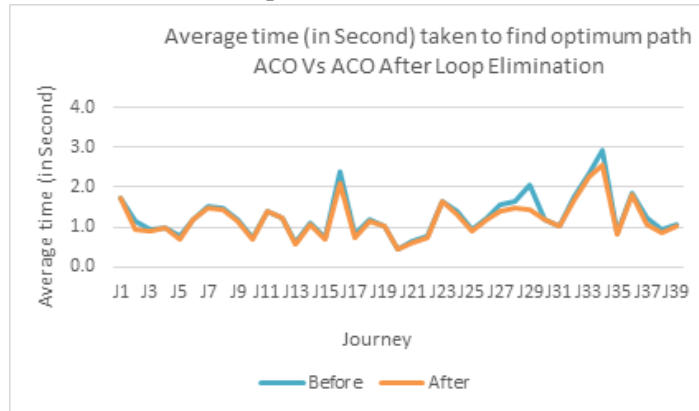
Figure 6 Some ants stuck in the cycle before and after the elimination of the cycle for all the journeys.
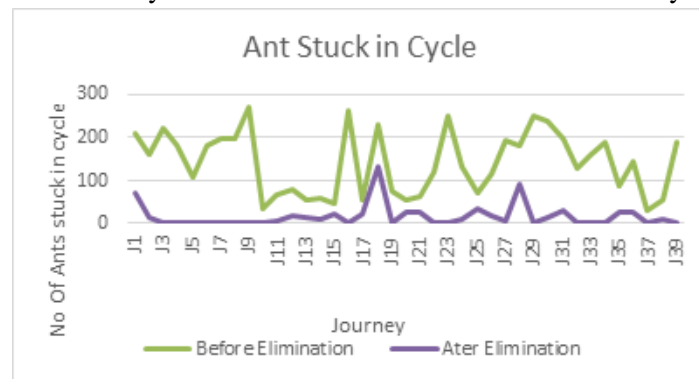
As shown in figure 6, the proposed algorithm reduces the ant to stuck in the cycle of the graph. This will let the ants contribute more to generate optimum solutions instead to get stuck in the cycle. As per the experimental statistics, the proposed algorithm reduces 85.4677% of ants to get stuck in the cycle.

Figure 7 shows no. Of cycles detected in the graph before and after the execution of the proposed algorithm. The proposed algorithm detects almost 76 % of cycles in the graph.

Figure 7 Number of Cycle detected in the graph for all the journey
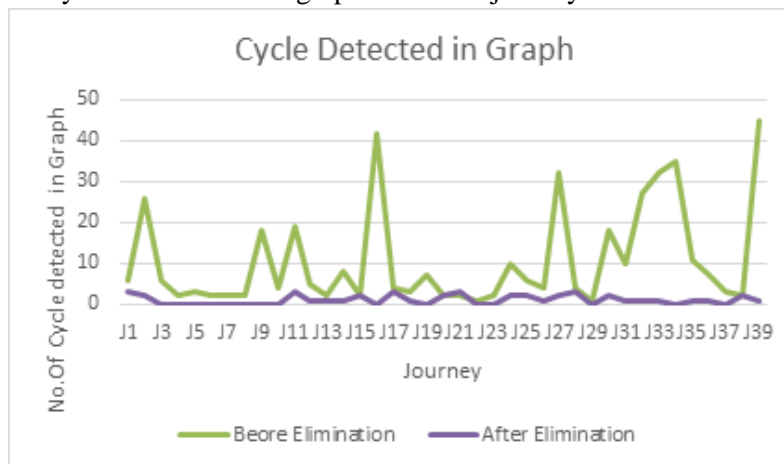
6. CONCLUSION

In this paper, the problem of ant being stuck in the cycle during the decision-making process of an ant colony system has been identified. Our proposed solution detects 76% cycles in the graph and if eliminated, will results in 5.26% less time taken to solve the problem over the existing Ant Colony system. The proposed calculation reduces the ant to stuck in the cycle of the diagram, this will let the ants contribute more to generate optimum solutions rather than stall out in the cycle. According to the exploratory insights, the proposed calculation decreases 85.4677% of ants to stuck in the cycle and improves the computational efficiency.

REFERENCES

1. Dorigo, M., & Di Caro, G. (1999). Ant colony optimization: A new meta-heuristic. *Proceedings of the 1999 Congress on Evolutionary Computation-CEC99 (Cat. No. 99TH8406)*, 1470–1477. https://doi.org/10.1109/CEC.1999.782657
2. Dorigo, Marco, & Tzle, T. S. (n.d.). *An Experimental Study of the Simple Ant Colony Optimization Algorithm*. 6.
3. Elloumi, W., El Abed, H., Abraham, A., & Alimi, A. M. (2014). A comparative study of the improvement of performance using a PSO modified by ACO applied to TSP. *Applied Soft Computing*, *25*, 234–241. https://doi.org/10.1016/j.asoc.2014.09.031
4. Eshghi, K., & Kazemi, M. (2006). Ant colony algorithm for the shortest loop design problem. *Computers & Industrial Engineering*, *50*(4), 358–366. https://doi.org/10.1016/j.cie.2005.05.003
5. Zhao, J., & Tong, W. (2009). Solution to the problem of ant being stuck by ant colony routing algorithm. *The Journal of China Universities of Posts and Telecommunications*, *16*(1), 100–110. https://doi.org/10.1016/S1005-8885(08)60187-9

CARBON NANOTUBES – A NOVEL DRUG DELIVERY SYSTEM

Shikha Singh   **Harshil Patel**

Manish Goyani   **Pinkisha Patel**

Shree Dhanvantary Pharmacy College, Kim, Surat, Gujarat

ABSTRACT

The carbon nanotubes (CNTs) are one of the unique and desirable discoveries within the field of nanotechnology. From their invention in the year 1991 by researcher Iijima, CNTs have been a great interest of area in many pharmaceutical and engineering fields because of their small size, lightweight, high tensile strength, and their good conductivity. CNTs are the hardest material invested by any human researcher till now; they are graphite in nature having sp^2 hybridization. They are having three classes: SWCNTs, DWCNTs, and MWCNTs based on their unique structure. CNTs are produced using different methods like the Arc discharge method, laser ablation method, and chemical vapor deposition. CNTs used in various applications because of their unique properties like mechanical, thermal, electrical and optical. They are used in applications like biomedicine, in the drug delivery system, like sensors, like implants, in tissue engineering, and in anticancer treatment.

Keywords: Carbon nanotube, Functionalization, Dispersion, Properties, Structure.

1. INTRODUCTION

In the current situation of novel drug delivery systems, carbon nanotube (CNTs) is one of the new and most promising approaches in pharmaceutical research and development. It was first explored in the year 1991 by a scientist named Iijima.[1] CNTs are one of the members of the fullerenes group. CNTs are large molecules of pure carbon that are long, thin, tubular and cylindrical shape and having a size range between 2-3 nm. CNTs are also defined as tubular fullerene or cylindrical graphene having sp^2 hybridization carbon atoms.[2] CNTs are having specific properties and structures and can be used in various pharmaceutical applications like cancer treatment, Drug Delivery, biosensors, biomedicine imaging as organized materials for a branch of tissue engineering. CNTs are also used in intracellular delivery of tiny drug entities, deoxyribonucleic acid, plasmids, short interfering ribonucleic acid, and proteins**.** [3] CNTs are allotropes, which is having a tubular figure and prepared from graphite. They are classified into three categories, 1. Single-walled (SWCNTs), 2. Double-walled (DWCNTs) 3. Multi-walled (MWCNTs). [1]

2. HISTORY

In the year 1952, Scientist Lukyanovich and Scientist Radushkevich bring out a research report in the "soviet scholarly diary of physical science", where he introduces carbon strands that have empty graphitic nature and having a size of around 50 nm. In the year 1979, at Pennsylvania state college, Scientist john Abrahamson offered confirmation of carbon CNT at the fourteenth biennial course of carbon. In the year 1981, a group of Soviet researchers offers the result of the synthetic and auxiliary game plan of carbon Nano extend molecule framed by a thermal catalytical lopsided of carbon monoxide (CO). At long last

during the year 1991 after all the exploration work Japanese researcher and specialist Iilima has found carbon nanotube by c*ircular segment release strategy at NEC (Nippon electric organization).[1,2,3,4]

3. ADVANTAGE OF CNTs [1,2,3]

1. High electrical along with warm conductivity

2. Very high elasticity

3. Highly adaptable and flexible (~18% lengthening before disappointment)

4. High perspective proportions

5. Good field emanation

4. DISADVANTAGE OF CNT [1,2,3,4]

1. More current innovation so not as much testing has been completed

2. Lower lifetime (1750 hours contrasted with 6000 hours for silicon tips)

Higher possibilities required for field outflow as the cylinders are not all that very much restricted so the extractor cathode must be further away.

5. CNTs CLASSIFICATION

- Single-walled CNTs
- Double-walled CNTs
- Multi-walled CNTs

5.1 Single-walled CNTs

SWCNTs are arranged from a single realistic sheet which in completely moved upon CNTs, having a circuit of 1-2 nm. The range of SWCNTs is depended upon the detailing technique. SWCNTs blend required a particular impetus for the creation of nanotubes. Mass unify is troublesome into the combination of SWCNTs in light of the fact that they required the right reform overextension and uncommon air condition. For its synthesis, it requires a catalyst. SWCNTs are poorly purified and have no complex structure. It's easy to twist. [4, 5,6]

Figure:1 Single-walled carbon nanotube
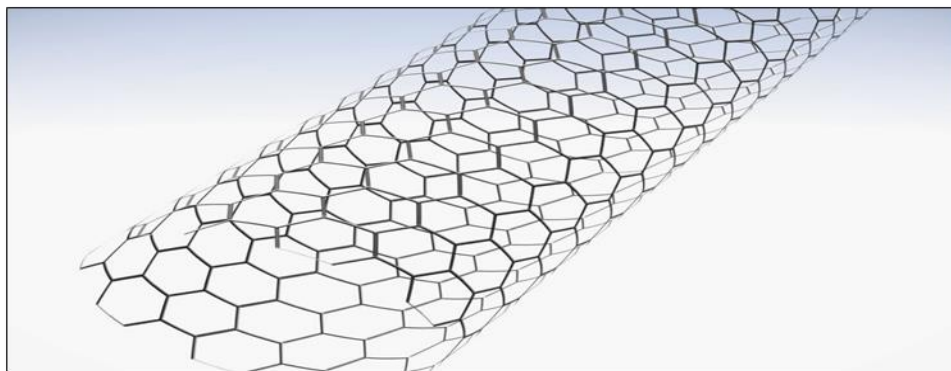
5.2 Double-walled CNTs

Since the name is given, this CNT is comprised of two concentric CNTs where an external layer of the carbon chamber is completely encased inside the internal chamber (outside cylinder is encased in inside cylinder).[7]

Figure:2 Double-walled carbon nanotube [7]
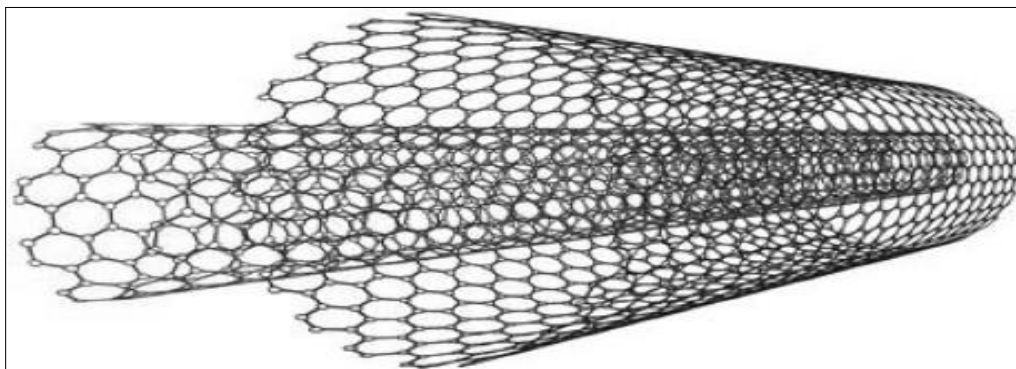
No catalyst is needed for its synthesis. MWCTs are highly pure and structurally complex. It's not easy to twist [4,5]

5.3 Multi-walled CNTs

MWCNTs have a multilayer of graphene move upon one another, having a width of 2-50 nm which depends upon the quantity of graphene cylinder present and the separation between this graphene cylinders is 0.34 nm. In the amalgamation of MWCNTs, they don't require any impetus and can be delivered by the mass union, having greater virtue then SWCNTs.[4, 5,6]

Figure: 3 Multi-walled carbon nanotube (ChemDraw)
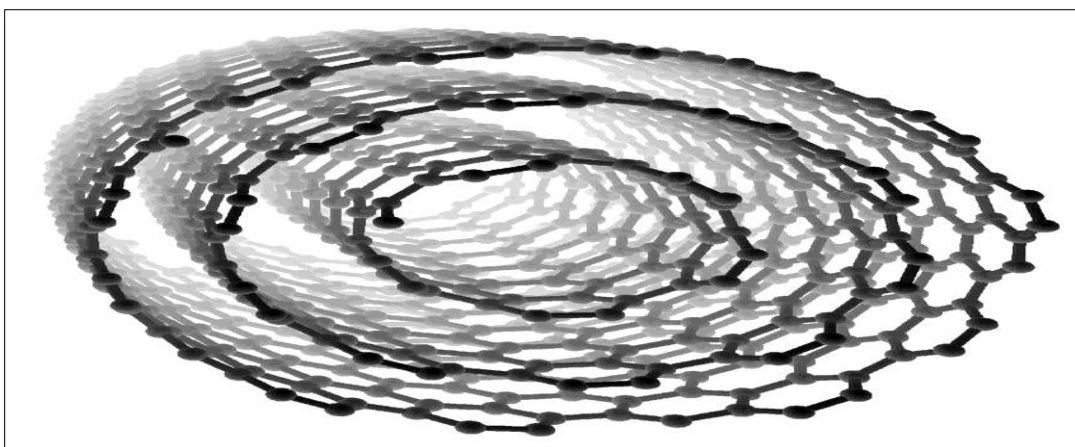
6. STRUCTURE OF CNTs

CNTs are composed entirely of carbon, and SWCNT clean structure is described as roll-up, a tubular covering, a single layer of graphene piece and developed as of benzene category of hexagonal round carbon atoms. CNTs have distance end to end ratio between 1000, having a one-dimensional structure. The graphene sheet is a specific cylinder produced from the drill pattern, which represents a solo level

of crystalline carbon. SWCNTs are consisting of two different ranges along with two different properties like physical properties and chemical properties. In which, the initial range is sidewall on the cylinder and another known as ending lid of the cylinder. The ending lid composition is the same as fullerene, they know as small molecule of fullerene (example- C_{60}). SWCNTs contain only 10 atoms, which surround the circumference, having only 1 atom thickness. MWCNTs are larger in structure along with multiple tubes arrange in one upon other, where the inside tube is completely covered with the outside tube making a multiple tube structure. MWCNTs are limited to the nanostructure with outer diameter should be less than 1nm if the diameter is more than 15 nm then it's known as carbon nanofibers. CNTs are different from carbon fibers, which are not single molecules but a strand of larger- layer graphite sheet.

Figure: 4 Eight allotropes of carbon a) diamond, b) graphite, c) lonsdaleite, d) C60 buckminsterfullerene, e) C540, Fullerite f) C70, g) amorphous carbon, and h) single-walled carbon nanotube [4]
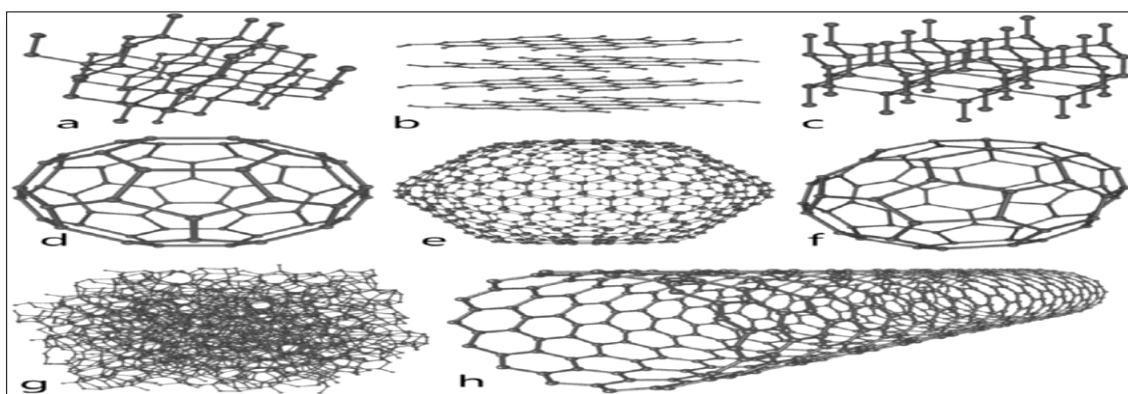
Based on the different essential structures, CNTs are divided into three different classes. The first one is a zigzag carbon nanotube, the second one is chiral carbon nanotubes and the third one is an armchair carbon nanotube. They are made up of the way graphite is roll-on throughout its formation procedure. SWCNTs type is based on the rolling alignment of the relative member to a hexagonal complex of graphene's piece along with the radius of the closed cylinder.[1 ,4]

7. PRODUCTION METHODS OF CNTs

7.1 Arc Discharge production method

7.2 Laser Ablation production Method

7.3 Chemical steam deposition or vapor deposition

7.4 Vapor – phase growth

7.5 Flame synthesis method

7.6 The recent trend in the synthesis of CNTs

7.1 Arc discharge production method

Arc evaporation production technique is known as the best technique to produce the greatest quality of CNTs, It involves the passage of the current into two separate graphite electrodes having helium

environment and the current passing between this electrode is 50 amps. Because of it, graphite will vaporization, which leads to condense of graphite on the wall of chemical reaction pan and other substances will condense on the cathode electrode.[8] This substance is accumulated on cathode known as CNTs. SWCNTs obtained after the addition of Copper (Co), Nickel (Ni) and additional metal on anode electrode.

Figure: 5 Graphic representation of arc- discharge equipment
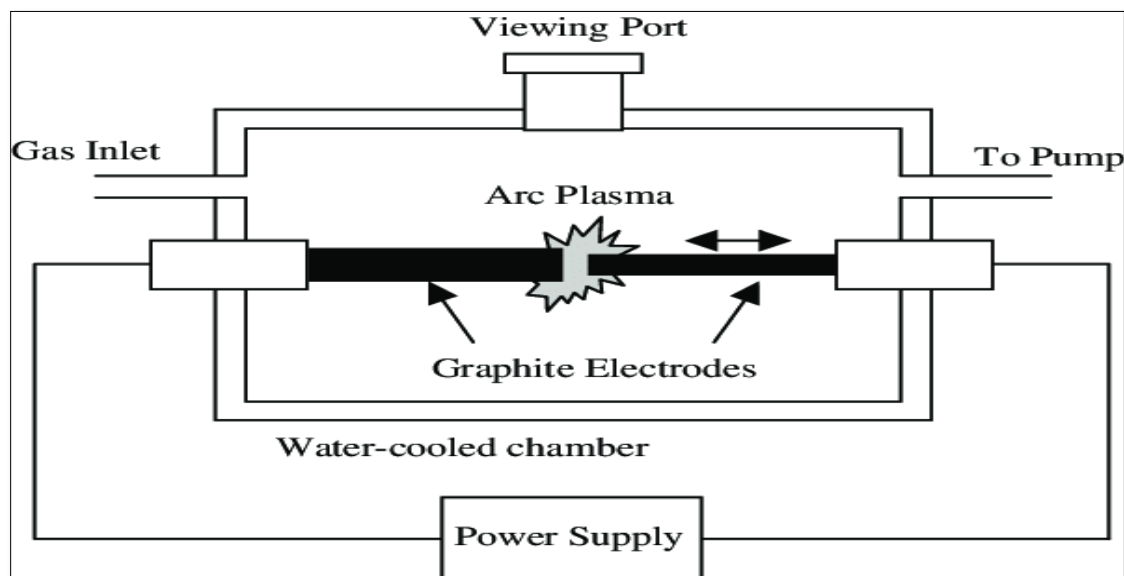
Source: Research Gate

This method is known from the year 1950, with the aim of CNTs produces through the passage of carbon holding gas, like hydrocarbon, in excess of catalyst. The catalyst made up of nano-sized atoms of metal like Ferrous, Copper or Nickel. Nanosize atom catalyzes lead to degeneration of gaseous molecule in carbon, which leads to the generation of the tube with metal nanoparticles on the tip. [9]

In the year 1991, researcher Iijima informed the production of a new kind of limited carbon structure contains needle-type cylinders. This tubes synthesis with arc discharge disappearance production method, similar to the fullerene production. These carbon needles have a diameter range between 4- 30 nm and length equal to 1 mm, produce on the negative side of the electrode in this method, where negative carbon electrode use as a direct current supplier in a container containing argon gas which leads to vaporization(arc discharge) of carbon. Arc discharge production technique used to manufacture SWCNTs on a large scale. Big -level production of MWCNT using a variation of typical arc discharge production technique informed by researcher Ebbesen and researcher Ajayan in the year 1992.[10]

Researcher (C. Somu et.al.) has worked on the Synthesis of various forms of carbon nanotubes by arc discharge methods. Where he gave a review on a detailed analysis of Carbon Nanotubes synthesis developments over the past using the Arc Discharge process. It was seen that the main synthesis method for both SWCNTs and MWCNTs emerged after the discovery of CNTs by Ijima arc discharge.

It was seen that the carbonaceous matter was deposited mostly on the electrode with the lower current density i.e. with a larger diameter during a DC arc discharge process. If we use the AC arc discharge method with two equivalent electrodes, however, we are sure to find that the soot is deposited on the wall

instead of the electrode, thereby increasing the yield of SWCNTs.In addition to the others, extremely careful conditions led to the formation of DWCNTs, so this method was a tool for the production of DWCNTs. It is also shown that the yield of the MWCNTs in the presence of liquid nitrogen increases. The yield of the SWCNTs and DWCNTs has been significantly improved by rotating the Anode i.e. Use the method of spinning plasma. It has also been found that there has been an improvement in the synthesis and purity of SWCNTs with the temperature increase up to 6000C.[11]

7.2 Laser Ablation Method

In the year 1996, researcher Smalley and coworkers produce a large number of SWCNTs using a laser ablation production technique in which graphite rod have a small quantity of Nickel and Copper at 12000C high temperature.[12] The cylinder continues to grow until a large number of catalyst atoms gather on the ending point of the nanotube. Bigger particle removes or turns into more- coated during tolerable carbon that becomes toxic to catalysis.[13] This process allows the elimination of the tube along with a fullerene-alike tip or else elimination along with a catalyst atom. Arc-discharge technique and laser-ablation technique both systems contain the benefit of large amounts of SWCNT production and having the drawback of its dependence upon vaporization of carbon particle from the solid objective at 3000.0C temperatures, and tubes are disorganized which makes defaulting in the purification process of the CNTs along with the application of CNT samples.[12]

Figure: 6 Schematic representation of laser ablation equipment [14]
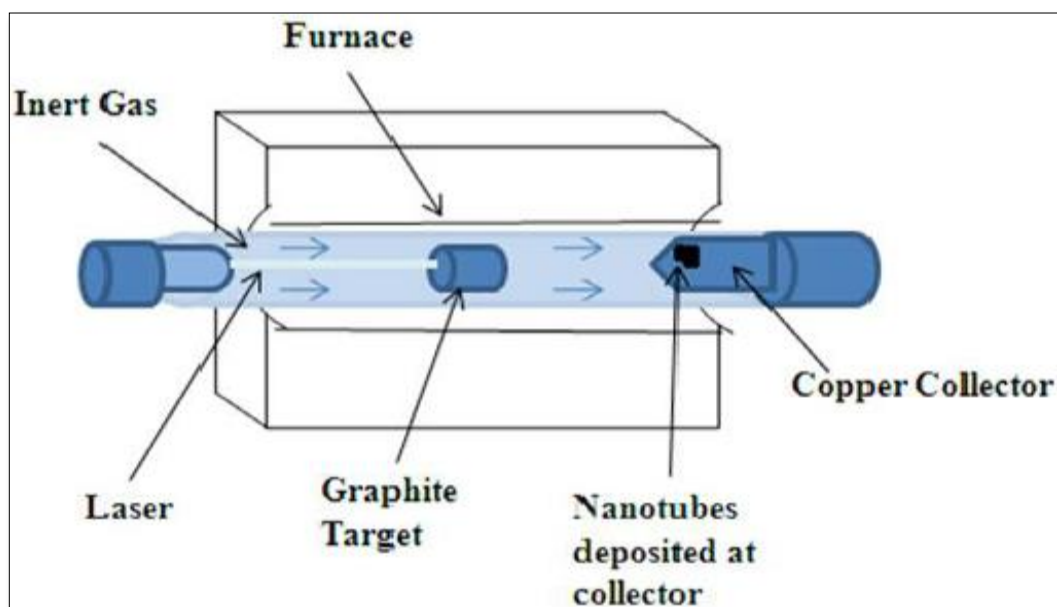
Researcher (Mitsuhiro K.*et.al.*) has worked on the production of single-wall carbon nanotubes by a XeCl excimer laser ablation. Possible mechanisms of growth were provided for pulsed and laser excitations. In order to prepare single-walled carbon nanotubes, different types of lasers are now widely used. For the synthesis of CNTs, a XeCl excimer laser with the oscillation wavelength was used in the UV field. The frequency of the oscillation and the duration of the pulse (FWHM) are 308 nm and 16 ns. The average energy is 58 mJ / pulse and the variability during the ablation is T0.5 percent. The chamber used for laser ablation is a 51 mm diameter ceramic pipe inserted in the center of an electric furnace with a maximum temperature of 1773 K available. A graphite target of 1.2%

Ni and 1.2% Co was put in the quartz tube with a diameter of 8 mm inserted in the ceramic tube mentioned above. It was found that SWNTs were formed at 1273 K, 1373 K, 1473 K and 1623 K in ablated carbonaceous soot. The 1623 K ablation recorded the highest SWNT yield. Raman spectroscopy and scanning and transmission electron microscopy estimated the diameter distribution and the length between 1.2 nm and 1.7 nm and 2 Am or above.[15]

7.3 Chemical Vapor deposition method

From the above production methods, two primary troubles are associated. The first one is the understanding of big- scale manufacturing and the second one is prearranged production. During the year 1996, CVD (chemical stem\vapor deposition) technique was invented for production nanotube. It's a technique developed to overcome the problem associated with the above two methods. It has the capability of both controlling the development path above the substrate and produced a large number of CNTs. through this method, a combination of hydrocarbon gas, CH_3, acetylene, or else combination of ethylene and N_2 is inserting into reaction slab.[16] Throughout the reaction, CNTs obtaining on the substrate through the decay of hydrocarbon at high temperatures up to 700°C to 900°C at full of atmosphere force.[17]

Figure: 7 Schematic representation of Chemical Vapor Deposition [19]
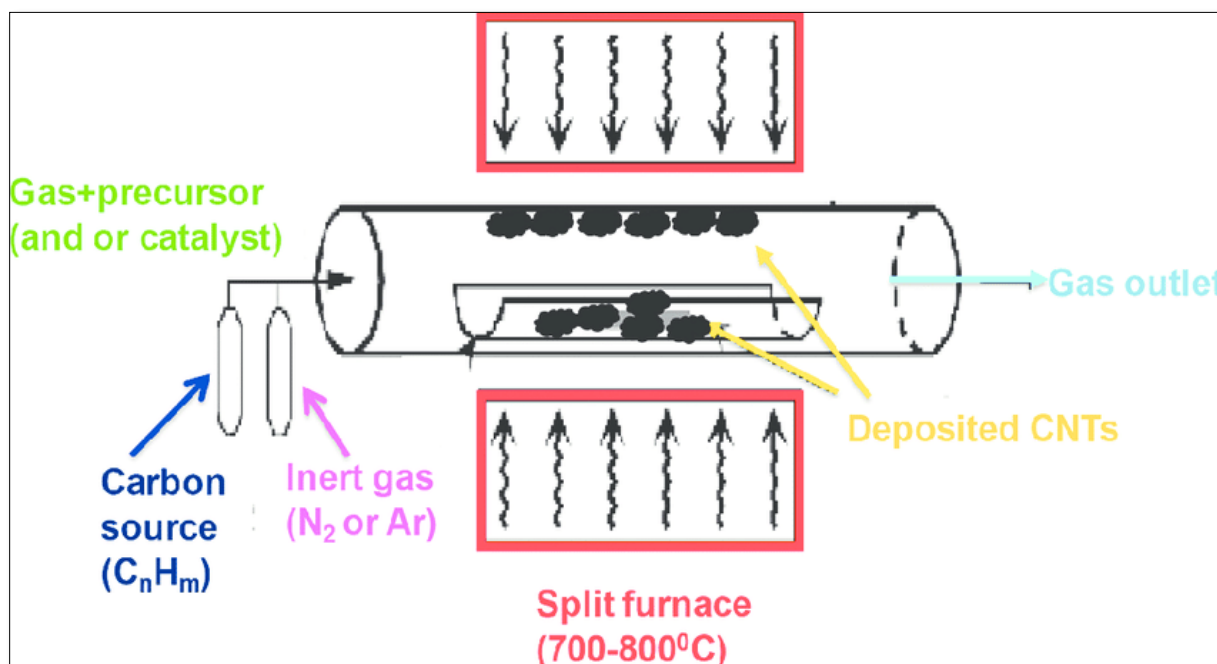
This method has two main advantages. The first one it obtain CNTs at low temperature, even though in minor quality, and the second one is withdrawn of catalyst above the substrate, which permits CNTs to implement well-planned structures. [16]

Researcher (Sunny E.I *et.al*,) has worked on Catalytic Production of Carbon Nanotubes in a Swirled Fluid Chemical Vapor Deposition Reactor. The catalytic chemical vapor deposition process, catalytic carbon graphitization was used to illustrate the synthesis of acetylene carbon nanotubes. A basic kinetic mechanism and model described the catalytic graphitization of carbon to CNTs from C2H2 and graphite using the

CCVD process. Catalytic graphitization of C2H2 to CNTs using the CCVD technique was used to synthesize CNTs and nanoparticles at various temperatures of 850–1100 C and atmospheric pressure, and the kinetic model was obtained using the Langmuir-Hinshelwood method. At 11000 C, an optimal output level of 8.2 mg / s and 4725 ppm of acetylene feed was reached. The production rate of CNTs decreased as the hydrogen flow rate increased. The equations and experiments of the computed model are in good conformity.[18]

7.4 Vapor- phase growth production method

It,s a new method also known as the converted type of CVD technique. Central dissimilarity in this technique is CNTs produced straight from reaction gas plus catalytic metal within the slab, not including any substrate. Two heating system is located within the reaction slab. Catalyst use inside this process is ferrocene. Carbon catalytic vaporization is maintaining a small temperature in the initial furnace. Fine catalytic atoms are produced now and after they arrive at the subsequent furnace, at that time fresh carbons absorbed within this medium through diffusion, where they transformed into CNTs [10,20]

7.5 The flame synthesis production method

The flame synthesis technique is another method where CNTs able to produce. During this technique, hydrocarbon blazes re-used. These blazes give out beginning growths of nanotubes. A gas such as carbon monoxide, methane, C_2H_4, ethane, and C_2H_6, they present inside the after-flame portion and have a great source for carbon. This reaction is exoergic and releases chemical power within the outline of heat which assists inside blaze which holds endothermic carbon displacement reactions. Catalysts are necessary for the supply reaction place for the deposition of rock-solid black carbon. CNTs grow in this method is a similar way as inside CVD methods. In a suitable catalyst, flame and reaction condition is supplier, a big quantity of CNTs can produce commercially.[21]

Researcher (Yuan-Yao Li*et.et.al*) has worked on the Synthesis of Carbon Nanocapsules and carbon nanotubes by an acetylene flame method where he investigated the production of Carbon Nanocapsules and carbon nanotubes (CNTs) using a system of acetylene flame. In a well-controlled combustion process, MWNTs with a diameter ranging from 20 to 30 nm were successfully synthesized with the presence of CoCl2 catalysts in the reaction. The temperature of the reaction played an important role in MWNT synthesis. Besides the MWNTs, the method is capable of producing Nanocapsules of carbon without the involvement of a catalyst. [22]

7.6 Current trend into the production of CNTs

Modern nebulizer spray pyrolysis technique has been utilizing for production for MWCNTs. Nebulizer spray is a primary factor in this technique, where it's obtained through the particular ultrasonic atomization method. MWCNTs have been produced through this technique with objectively homogeneous diameters within range bunches. (Yamaguchi T *et.al*, 2004) Utilization of ultrasonic nebulizer, where ferrocene used as catalyst, ethanol used as a solvent and carbon supply sprayed inside the tubular heating system at 800^0C set temperature underneath argon movement within 1 L/min range. Ethanol used as a solvent and carbon supplement because of its muddy characterization, less cost, nontoxic by-product, and it easily can be handle. Elevated development of MWCNTs on the surface is formed. The benefit of using nebulizer spray is, it's simple for production into industrial level manufacturing because reactants continuously fed into the furnace.[23]

8. FUNCTIONALIZATIONOF CNTs

CNTs are material virtually insoluble, or else barely dispersed, in solvents. To incorporate CNTs technology with biological background, the solubility of tubes mainly inside aqueous solutions should enhance. Numbers of dispersion and solubilization methods are examined and mainly two approaches are presented.[24] The first approach is a procedure made up of the non-covalent bond functionalization CNTs by surface-active agents, peptide, polymer, nucleic acids, and oligomers. The merit of this procedure is the protection of the electronic structure of the aromatic surface of the nanotube. Its Characterization has fundamental importance for the use of CNTs like biosensors. The second approaches are to stand on CNT's covalent bond functionalization. Initial, CNTs are cut and pass through the oxidization process to produce a number of CNTs moreover it's derivative with dissimilar kinds of molecules. Nanotubes wall-sides work straight through adding reactions. The introduction of moieties on the outer surface of CNTs leads to induce repulsion among single CNTs permit them normally disperse inside solvents.[25]

Four basic approaches have been used to obtain dispersion**;**

8.1 Non-covalent bond functionalization

Many small or large molecules of drugs are adsorbed non-covalently over the wall layer of the CNTs. Therefore, via host-guest interaction, CNTs act as nano-reservoirs to absorb the drug molecule. The adsorption is a hydrophobic type. There are π-π stacking interactions between the CNTs and the adsorbed molecules of the chain. The hydrophobic force exists for loading drug molecules onto the CNTs in the case of lipophilic drug molecules. The voltage on the surface of CNTs induces the adsorption of charged molecules by ionic interactions due to chemical treatment. [26]

8.2 Covalent bond functionalization

The mixture of drug molecules or functional groups is comparatively safer in the covalent functionalization of CNTs.Covalent functionalization of CNTs, produced by oxidation of CNTs by strong acids, induce reduction and produce groups of carboxylic acids, resulting in increased dispensability in the aqueous medium. Alternatively, they are water-soluble by adding hydrophilic groups to the external walls and tips of CNTs.Covalent functionalization of CNTs is commonly used for drugs such as methotrexate and reactions to 1,3-cycloaddition. Characterizing covalent functionalized CNTs for accurate determination of the location of functionalization and mode of addition is a difficult task. [27]

8.3 Dispersion of CNTs using surfactant

Surface active agents used for nanotubes dispersion inside polymeric resources. Main surface-active agents for example polyethylene glycol, sodium decyl-sulfate, and dodecyl-benzene sodium sulfonate mostly use to decrease lump disposition of nanotubes inside the water and similar solvents. The high dispersive efficiency of CNTs depends upon the presence of benzene rings. To increase in adsorption ratio of surfactants, P- stacking interaction of benzene ring on the surface of CNTs sidewall is required. The figure demonstrates the mechanism through which surface-active agents micelles defeat weak Van der Waal's bonds.[28]

9. PROPERTIES OF CNTs

CNTs have an extremely elevated surface region, high phase ratios, and superior mechanical resistance. CNTs tensile power is 100 times greater than that of steel, and the coppers have an approach to electrical and thermal conductivity. These specific properties make CNTs excellent candidates for registered appropriate buyer products as a cartridge in various polymers and pots. It was also anticipated that CNT-based on the field-effect transistors (FETs) will quickly be giving their analog counterparts based on silicon. Because of their special electrical, mechanical as well as thermal behavior, CNTs are also superior encapsulating agents. [29, 30]

9.1 Electrical characteristics of CNTs [29, 30]

CNTs have chiral-shaped electrical characteristics. Researchers have demonstrated that CNTs have particular conductive characteristics. These were the foremost findings to propose that the electronic characteristics of CNTs are more influenced by geometric variations such as defects, chirality, distinct size ranges, and crystalline tubular structure. SWCNTs are resistivity-type metals ranging between 0.34 $\times$ 10–4 to 1.0 $\times$ 10–4 ohm-cm from carbon atom bonding within. CNTs, prearranged in a hexagonal pattern, every carbon atom is covalently linked by sp2 molecular hybridization to three distinct neighboring carbons. Thus, in all parts, the fourth valence e- leftovers free, and these free e- are arranged in an irregular pattern across all atoms, giving the electrical behavior of CNTs. CNTs can be applied in sophisticated electronics in transistors and further switching applications. The significant aspect of CNT emitters is that at a reduced voltage the discharge can be achieved.

9.2 Mechanical characteristics of CNTs

As of now, CNTs are the most grounded issue in disposition. The audit of the writing says CNTs are well-manufactured materials, especially inside the pivotal course. The Young's modulus esteems under 270 to 950 GPA and having high pliable power in the middle of 11–63 GPA. Such a significant number of data have appeared in the spiral course that, CNTs be moldable. The underlying outspread adaptability TEM study demonstrated that two nearby nanotubes be fit for distorted by the powers of Vander Waal.[31] Later than that, independent gatherings of researchers directed Nano-cooperation through a nuclear power magnifying instrument (AFM) to quantitatively assess the spiral adaptability of MWCNTs and tapping technique, where AFM was connected to watch SWCNTs. The discoveries saw that in the outspread course, CNTs are inconceivably smooth. CNTs outspread course adaptability is required, principally for the production of CNT Nano measured material even its mechanical qualities, where coordinated funnels are acquainted with significant crossways stress when an intertwined design is pressurized. Because of one of the unbelievably solid holdings in nature is the carbon-carbon bonding found inside graphite, CNTs have amazingly brilliant power as they are the hardest game plan still delivered by any analyst.[32]

Material	Young's modulus (GPa)	Tensile Strength (GPa)	Density (g/cm3)
Single wall nanotube	1054	150	N/A
Multiwall nanotube	1200	150	2.6
Steel	208	0.4	7.8
Epoxy	3.5	0.005	1.25

| Wood | 16 | 0.008 | 0.6 |

Table -1 Comparison of Mechanical Properties of CNTs with other string materials[33]

Looking at CNTs in TEM has uncovered that they are versatile and don't break when turning. Scientist Treacy, who originally estimated the amplitudes of warm vibrations in CNTs in the TEM technique, led the Underlying exertion to build up Young's modulus for each MWCNT.

They demonstrated that nanotubes having Y = 1 to 1.8 TPA modulus of mean Young modulus which is outstandingly enormous contrasted with generally open carbon filaments. The twisting capability of MWCNTs was legitimately dictated by various examination associations as a reason for substitution inside an AFM. It was found that the standards go for the Young module were between 0.32 to 1.47 TPA.[34] Scientist Falvo analyzed that these MWCNTs could be twisted at pointed edges without by an AFM tip to experience some configuration move. A single perfect nanotube is about 10 to 100 times stronger than steel per unit weight. The Young's modulus of the best nanotubes can be as high as 1000 GPA which is approximately 5x higher than steel. The tensile strength or breaking strain of nanotubes can be up to 63 GPa, around 50x higher than steel.[35]

9.3 Thermal properties of CNTs

Not just due to their electronically just as mechanical attributes, however moreover because of warmth qualities, CNTs are of astounding criticalness and interest. Since their measurement is very minor, the quantum effects are basic and show straight proof of the 1-D gammadion of the phenomenon band arrangement in CNTs at abject temperature specific warmth and specific warm conductivity. The support of perfect and functionalized nanotubes in particular items that have the option to twofold the warm conductivity for a charge of only 1 percent, which demonstrates that blended nanotube segments can be useful for mechanical warm association importance.[32]

10. CELLULAR UPTAKE MECHANISM OF CNTs

It has been found that the internalized nanotubes at the cellular level are biocompatible and non-toxic. The advantages of SWCNTs and MWCNTs over other carriers are important due to their close-packed hexagonal cylindrical structure and sp2 hybridization, which makes them easy to work with the respective ligand or therapeutic mood. To conclude on the exact cellular uptake path of CNTs, it is thought that there are two different routes to cross the cell membrane. The first is the endocytosis-dependent pathway, which can be either mediated by a receptor or mediated by a non-receptor, and the second is based on an independent endocytosis pathway that includes diffusion, membrane fusion or direct transport of the extracellular material into the cell. The internalization cycle of CNTs depends on several parameters such as volume, distance, functional group nature, and hydrophobicity and CNT surface chemistry.[36] the endocytosis-dependent pathway is an energy- and temperature-dependent transport process involving the creation of a saccule or vesicle of extracellular materials within a segment of the cell membrane. In the case of receptor-mediated endocytosis legend, conjugated-drug-charged CNT binds to the complementary transmembrane receptor. Proteins and then enters the cell in clattering-coated vesicles as receptor-ligand complexes. [37] Following the development of internalization vesicles known as early endosomes and the ligand dissociates from the receptor due to a drop in pH. When the receptors are activated, the vesicles carrying the extracellular particle fuses with lysosomes and thus trigger the release of the drug particle by the action of lysozymes on the endosomes and the free receptors thus produced are recycled into the plasma membrane to combine with other ligand-conjugated CNTs.

Figure: 9 CNT Penetration pathways into the cell
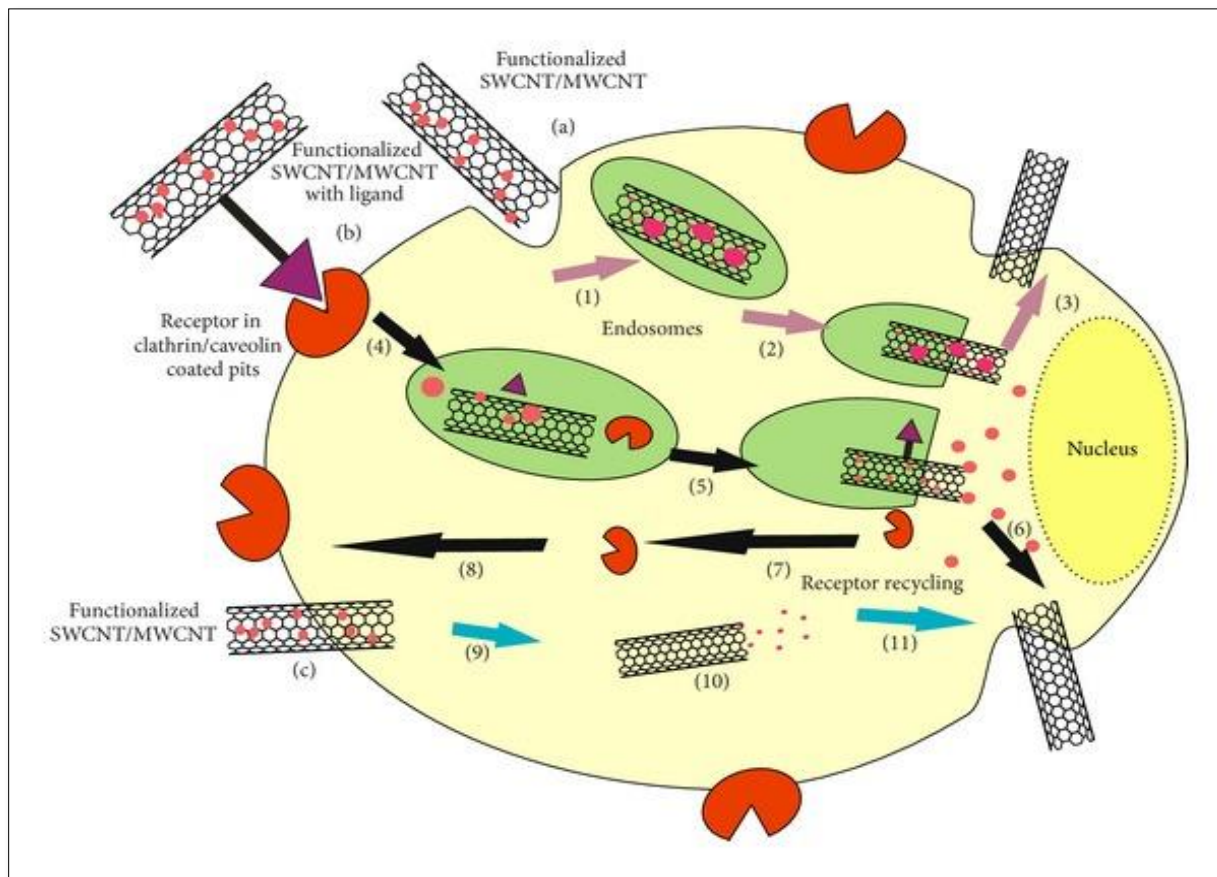
(Source: Pubmed)[38]

(A) non-receptor-mediated endocytosis: (1) the membrane surrounding the drug-loaded with functional CNTs; (2) the internalization of the drug-loaded with CNTs; and (3) the release of the drug; (b) the receptor-mediated endocytosis: (4) the membrane surrounds the CNT-receptor conjugate by forming endosomes followed by internalization; (5) the release of the drug; and (6, 7, 8) the receptor regeneration;(C) independent endocytosis pathway: (9) direct drug-loaded penetration of functionalized CNT and (10) drug release.

11. PURIFICATION OF CNTs

Aromatic SWCNTs contain many impurities of carbon species such as unstructured carbons, carbon nanoparticles, and conversion metals which have been implemented as catalysts. Graphite as wrapped sheets, amorphous carbon, metal catalyst, and the lesser fullerene is the primary residual content in the aromatic carbon structure. These residue influence the Secant's required characteristics But it is necessary to get hold of SWCNTs in investigating, as pure as possible without affecting their properties. The SWCNT samples must also be as homogeneous as probable in order to improve comprehend the characterization.[39]

11.1 Oxidation

SWCNT's oxidative treatment is one of the best approaches to remove carbonaceous impurities and clear

the metal surface. But the chief demerit of the oxidation reaction is not only the residual content is oxidized, however along with that the SWCNTs are also pass through the oxidization process. Though spoil to SWCNTs is fewer than spoil to the residue which makes this method helpful in some purification of CNTs. These impurities have an extra open constitution. One more reason why impurities oxidization is favored is that all these residues are mainly fond of metal catalysts and it acts as an oxidizing reagent. Effectiveness, as well as the yield of this method, be most reliable on factors like content of metal, time of oxidation, atmosphere as well as an oxidizing agent.[39]

11.2 Acid treatment

Basically, treatment shall acid will eliminate the catalyst of metal. In this method initially, the plane area of metal should be exposed via oxidization or sonication process. After that catalyst of metal, it comes in contact with acid even solvated too and SWCNTs remain in hang structure. While utilizing reaction in nitric acid, the acid merely has outcome over the catalyst of metal and there is no effect of NO_3 is observed. It has no consequence on SWCNTs and further particles like carbon it is one of the biggest advantages of this method.[34]

11.3 Annealing

Because of the higher temperatures range of CNTs between 873 – 1873 Kelvin, the nanotubes shall be repositioned moreover impurities will be devoured. Due to a higher temperature range, it could convert the graphite containing carbon and the tiny fullerenes with pyrolysis and in elevated temperature (1873 K) performing vacuum action may cause the metal melting and because of that, it can easily remove.[35]

11.4 Ultra sonication purification method

Within this method, particles were divided because of an ultrasonic tremble. Because of variable Agglomerate, Nano-sized particles shall force to induce vibration and because of this vibration, it will become further dispersed. The division of these Particles through its impurity is most reliant on the surface-active agent, vehicle and reagent utilized in method. The vehicle affects the steadiness of dispersing tubes within this process. Within poor vehicles, SWCNTs have high stable if they are fond of metal. When utilization of method is done; the purification of SWCNTs relies on the given time. While tubes come in contact with acid on behalf of a little time phase, after then barely solvates of metals are utilized, however, for higher contact time, tubes shall too be chemically cut and then applied.[39]

12 APPLICATION OF CNTs

Nanotechnology is the largest, latest and well-developed technology, having a lot of benefits intended for new materials among enhanced properties and be able to utilize in a number of applications in various fields like Nano-medicine, energy, chemical sensors moreover in aerospace technology.CNT is the most hopeful approach, ever since its invention in the year 1991 via researcher Iijima.[4] Several scientists moreover researchers have devoted enough attempt to the development of the new properties and to increase the numerous novel applications use in different areas like materials science even in electronics and energy storage, where the main focused is on studies of nanotechnology and utilization of CNTs as fillers.[1,2]

12.1 CNTs as gene delivery platform

Nanotubes are used as a medium of genes (gene therapy) for the treatment of cancer and genetic disorders due to their special cylindrical shape and properties. These have been confirmed by their tubular existence as a vector for gene therapy.[40] Before being killed by the cell defense system, nanotubes complexed with DNA are found to release DNA, dramatically improving transfection. In respiratory syncytial virus

(RSV), a virus with severe bronchitis and asthma, nanostructures have an antiviral effect. In general, the treatment is done by combining nanoparticles with technologies for gene slicing. Here RNA fragments capable of inhibiting a protein (needed to multiply the virus) are encapsulated in nanotubes and administered as nasal sprays or drops. The promising results have been noted inhibiting further growth of the virus. For helical crystallization of proteins and growth of embryonic rat brain neurons, nanotubes are recorded. With 1-pyrene botanic acid and succinimidyl ester, streptavidin protein is successfully immobilized on CNT. Nanotubes and Nano horns can adhere to different antigens on their surface, thus acting in vaccines as a source of antigen.[41]

12.2 CNTs as Carrier for drug delivery

CNTs are examined among Amphotericin B targeting to various cells. A drug like cisplatin encapsulated oxidized SWCNHs have reported slowing discharge of Cisplatin in an aqueous environment. Discharge of Cisplatin has been efficient in discontinuing the enlargement of human lung cancer cells, where SWCNHs has been used as a carrier system that only did not demonstrate anticancer efficiency. The drug used in cancer like Polyphosphazene platinum known by CNTs had improved permeation, distribution and maintenance of the drug in the brain tumor because of controlled lipophobicity of CNTs. An antibiotic like Doxorubicin specified with CNTs is observed for the enhancement of permeation and the intracellular component. A mixture of gelatin CNTs used as hydro-gel and has been used as an important carrier system for biomedicine. The carrier system based on CNTs may be used as a victorious administration by the oral route of Erythropoietin (EPO), and it is not feasible due to the denaturation of erythropoietin by the GIT situations moreover enzymes.[10]

Researcher (Zhuang Liu et al.,) has work Drug Delivery with Carbon Nanotubes for In vivo Cancer Treatment. In tumor-targeted accumulation in mice, chemical-functional single-walled carbon nanotubes (SWNT) have shown promise and show biocompatibility, excretion, and low toxicity. Where they used paclitaxel (PTX), a widely used cancer chemotherapy drug, is conjugated to branch polyethylene glycol chains on SWNTs to obtain a water-soluble SWNT-PTX conjugate by means of a cleavable ester bond. WNT-PTX provides higher efficacy in suppressing tumor growth than clinical Taxol in a murine 4T1 model of breast cancer as a result of prolonged blood circulation and 10-fold higher PTX tumor uptake through SWNT delivery, likely through increased permeability and retention. Pharmaceutical molecules carried into the reticuloendothelial system are released from SWNTs and excreted through the biliary Pathway without having noticeable toxic effects on healthy organs.[42]

12.3 CNTs as filler

CNTs are utilized as fillers inside different assets to shape Nano-compound are principally formed and accomplishment into nanotechnology. Researchers are chipping away at Nano-composite so they can utilize carbon nanotubes the same as filler in numerous materials. The primary reason for carbon nanotubes' embodiment inside divergent polymeric and further assets is to redesign properties of these assets. Analyst Garcia-Gutierrez has arranged Melt-prepared infused shaped in which poly-butylene terephthalate utilized as polymer moreover SWCNTs nanocomposites are utilized as embodying specialist and this procedure will impact on polymer frame of mind during shearing with the format the crystallization conduct of PBT. Specialist Soichia establishes elasticity and yield quality expanded with an expansion of SWCNT stacking inside polyimide Nano-composite.[43] With great scattering, they additionally improve the mechanical assets of polyimide. The PA66 materials were implanted onto the

outside of MWCNTs. In which the chain span of PA diminished with an expansion of MWCNTs, the warm rot temperature of PA-MWCNTs was advanced than unadulterated PA66 composite, and capacity quality was improved through expansion of MWCNTs.[39]

Researcher S. Peeterbroeck has prepared A new type of materials using direct melt mixing, based on EVA, clays and multi-walled carbon nanotubes. The presence of nanofillers has improved both the thermal and mechanical properties of the resulting modern binary and ternary nanocomposites. By incorporating organo-modified clays and carbon nanotubes together, a synergistic effect is observed: the thermal and flame retardant properties of the corresponding EVA matrices are improved.[44]

12.4 Artificial Implants

Normally the body cannot accept implants, it shows refusal response for implants during after administration ache. Because of its small diameter CNTs can attach among further proteins plus amino acids and avoid refusal of Implants. CNTs utilize like implants in the shape of synthetic joints devoid of human body refusal response. Because of high tensile power, CNTs filled easily with calcium along with easily arranged inside the organization of bone and it serves as a bone surrogate. [39]

Researcher Vohrer U. has work on a huge variety of industrial applications, low voltage artificial muscles which has great importance. Carbon nanotube sheets also are known as bucky paper with suitable electromechanical properties were described. An experimental set-up has been developed that allows the analysis of actuation forces vertically to the sheet plane for the first time. The filtration technique used single-walled carbon nanotubes (SWNT) from the arc discharge or HiPco process as well as multi-walled carbon nanotubes (MWNT) as received or after further purification steps. Many parameters affect the electromechanical properties such as the sheet size, the electrolyte used, the voltage applied, etc. However, the nanotube material itself and the procedure for the production of bucky paper must also be considered intensively to avoid large differences between different batches and to produce indiscriminate and reproducible nanotube carbon sheets. [45]

12.5 CNTs as a Catalyst

CNTs can act as a catalyst, by encapsulation of catalyst at the molecular level in a large quantity and after the administration of CNTs, it will release in the required rate and at the required time. Which leads to a reduction of frequency and quantity of catalyst.[2]

Researcher Avelino C. has worked on Catalytic activity of palladium supported on single-wall carbon nanotubes compared to palladium supported on activated carbon Study of the Heck and Suzuki couplings, aerobic alcohol oxidation and selective hydrogenation. Palladium nanoparticles (2–10 nm) were deposited on single-wall carbon nanotubes (SWNT) by spontaneous reduction of Pd(OAc)2 or oxime carbapalladacycle. For the Heck reaction of styrene and iodobenzene and for the Suzuki coupling of phenylboronic and iodobenzene, these catalysts have higher catalytic activity than palladium over activated carbon (Pd / C). This fact was attributed as reflecting the size particle's dramatic influence on the palladium catalyst activity for C-C bond forming reactions compared to other less demanding reaction types from the particle size point of view. In comparison to the reactions of Heck and Suzuki, Pd / C is more active than palladium nanoparticles deposited on SWNT for catalytic oxidation of cinnamaldehyde by molecular oxygen and 3-phenylpropionate aldehyde hydrogenation.[46]

12.6 Preservative

CNTs go about as a cancer prevention agent in nature. Therefore, they are utilized to shield drug definitions from antimicrobial development and oxidation. In view of their cell reinforcement property, they are utilized in anti-aging beauty care products and with ZnO, they are utilized like sunscreen dermatological for counteracting the oxidation of makeup definition. [1, 2, 4]

CNTs as a Diagnostic Tool

Protein-consolidated otherwise protein-compound packed CNTs, in light of the fact that their fluorescence limit in presence of bio-particles has been utilized like implantable biosensor. Indeed, even in Nano-capsules pack with attractive materials and radioisotope chemicals can be utilized as biosensors. Nano-size machines and engines with CNTs can be utilized in the investigation of cells and organic frameworks. [47]

Researcher Shun-Rong Ji has given a review on Carbon nanotubes in cancer diagnosis and therapy. Carbon nanotubes (CNTs) have become a popular tool in cancer diagnosis and therapy because of their unique physicochemical properties. These are known to be one of the most promising nanomaterials with the potential to both identify cancer cells and supply these cells with drugs or small therapeutic molecules. They are considered to be one of the most promising nanomaterials with the ability to both detect cancer cells and supply these cells with drugs or small therapeutic molecules. CNTs have been explored in almost every form of cancer treatment over the past several years, including drug delivery, lymphatic targeted chemotherapy, therapy, photodynamic therapy, and gene therapy. Surgery continues to play a major role in early cancer survival through the removal of observable tumors among all cancer treatment options such as surgery, chemotherapy, radiotherapy, thermotherapy, and immunotherapy, etc. Patients with advanced cancer, palliative surgery, chemotherapy, and radiotherapy are required. Even in patients with radical tumor resection, radiochemotherapy and other therapies are sometimes prescribed to avoid residual micrometastases relapse.[48]

12.7 CNTs in engineering

In hereditary designing, CNTs are utilized to misuse genomes and particles in the advancement of bioimaging genomes, proteomics and tissue building. As a result of their cylindrical nature, it has demonstrated that they are utilized as a vector in quality treatment. The DNA breeze around SWCNT by interfacing its particular nucleosides and change in its electrostatic properties. This nature of CNTs makes its potential application in diagnostics and therapeutics. [49]

Researcher Sheetal Gavankar has worked on The Role of Scale and Technology Maturity in Life Cycle Assessment of Emerging Technologies. Where she study the Life cycle assessment (LCA) was applied to evaluate emerging technologies, where there is usually a lack of large-scale production data. This research presents a structured scheme for preparation levels of technology and production to contextualize the development stage of technology. The carbon nanotube (CNT) LCA found that irrespective of the synthesis technique, the production of CNT would become less energy-intensive with higher readiness levels. They examine the effect of production volume on LCA results was analyzed using primary data from a commercial CNT manufacturer with a production volume of approximately 100 grams per day and the engineering design of a scaled-up process with a production capacity of 1 ton per day. This study shows that LCAs on emerging technologies based on outdated data should be viewed in accordance with their readiness levels of technology and manufacturing and highlights the need to standardize and communicate information in life cycle procurement processes on these readiness levels and scale of output. [50]

12.8 CNS as a sensor

Sensors are a distinguishing gadget that is utilized generally in various fields. CNTs are utilized to improve the effectiveness of biosensors and sub-atomic sensors by joining them. Researcher Wood and Wagner presumed that CNTs are exceptionally delicate to polymer-inserting forms, on the grounds that the CNTs somewhat disfigure within the sight of various fluid media.[1,2,4]

Researcher Giovanni N has worked on The controlled deposition of metal oxides onto carbon nanotubes by atomic layer deposition: examples and a case study on the application of V2O4 coated nanotubes in gas sensing. Where they research on the manufacture of composites of metal oxide–CNTs, a newly introduced atomic layer deposition method was used. The reaction of a metal alkoxide with acetic acid in ALD has been shown to result in a homogeneous coating of the outer and inner surface of the carbon nanotubes at a well-controlled thickness. The electrical and gas sensing properties of the nano heterostructures of V2O4–CNTs synthesized under this protocol have been investigated. Composite sensors showed better performance than uncoated CNTs-based sensors, indicating that the strict contacts between V2O4 coating and CNTs lead to improving sensing performance. The sensors ' thermal treatment plays a key role. Indeed, both the as-deposited film's basic resistance and the sensitivity to NO2 increase by adequate pretreatment of the sensors in the air at temperatures between 150 and 200 1C. This suggests that the sensor response can be further improved by optimizing the expansion of the depletion layer with respect to the thickness of the multi-walled CNTs. By a suitable in-situ thermal treatment, the electrical properties of the vanadium oxide-carbon nanotube composite can be finely tuned. [51]

12.8.1   Adsorption mechanism of CNTs as sensors

CNTs are a new type of adsorbent and for many reasons have a significant position in carbon-based sensor materials. Secondly, they have chemically inert surfaces and highly specific surfaces for physical adsorption, offering directly a variety of well-defined adsorption sites for adsorbed molecules.[52] Different load distribution resulting from the transfer of load and different adsorption energy attributed to gas morphology coexisted in the adsorption process provide a qualitative and quantitative explanation for the increased or decreased conductivity of the CNT sensor gas adsorption experiment, and it separates the particular gas from the others [53]

12.8.2   CNTs as DNA detection sensors

Researcher W. Qiu has worked on Carbon nanotube-based lateral flow biosensor for sensitive and rapid detection of DNA sequence, where he gives the principle of proof-of-concept by a target DNA and a pair of DNA samples that are identical to the target DNA in two different locations. The sample solution with target DNA has usually been added to the sample surface. The solution subsequently migrated by capillary action, then the hybridization reactions between the target DNA and the MWCNTs–DNA conjugate detection DNA sample occurred, and the shaped complexes (MWCNTs–DNA–target DNA) proceeded to migrate along the line. Upon entering the test zone, the complexes were captured in the second h by the biotinylated capture DNA sample immobilized in the test zone. Due to the accumulation of MWCNTs on the test zone, a typical black band could be observed. Once the solution passed through the control zone, the biotinylated control DNA probe collected the excess MWCNTs – DNA conjugates, thereby creating a second black band. Only the black band in the control zone is observed in the absence of target DNA. In this case, the control zone's black band (control line) shows the LFB is working properly. Simply observe the color shift of the test zone and quantitative analysis is done by analyzing the LFB picture images with Image J software. [54]

Figure: 10 Schematic representation of the principle of DNA measurement on MWCNT-based lateral flow biosensor [54]
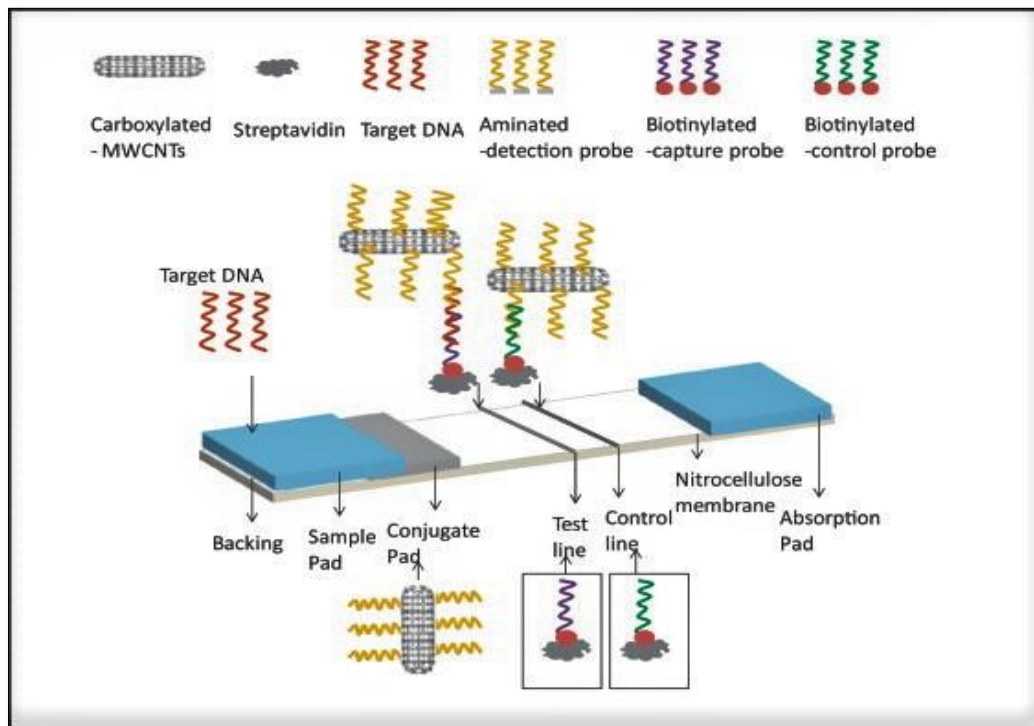
13. LIMITATION OF CNTs [55, 56]

- CNTs have an absence of dissolvability in many solvents good with the organic condition most likely watery based.
- CNTs can be created just in the event that they are basically and synthetically reproducible bunches with indistinguishable attributes.
- CNTs are trouble in keeping up high caliber and least polluting influences

14. METHODS FOR OPENING, FILLING AND CAPPING OF CNTs [57, 58]

Carbon nanotubes are capped and thus there are essentially two approaches for drug loading that include carbon nanotubes being filled during synthesis or after synthesis. Adding the contents of the in-situ nanotubes appears to be a less efficient approach, yielding about 10% while the post-synthesis process can be better controlled and yields of 50-100% can be achieved. The effective method depends on the material to be introduced into the CNT. Melting temperature, reactivity, surface tension, and product resistance are included in the parameters. Post-synthesis processing of CNTs means that the ends must be opened. This can be done by passing electrical currents through the CNT, by hitting the CNT with acid that most corrodes the twisted sections of the tube (i.e. the ends), or by oxidizing with carbon dioxide. Including foreign particles in CNTs are two forms. One classification is decoration, which is the bonding mechanism between a functional unit and CNTs.[57] This is difficult as carbon is rather inert, so a more reactive attachment surface is formed by oxidization. The functional unit is bonded either inside or outside the walls. Capillarity is the most common mechanism to fill CNTs. The capillarity limiting factor is the diameter of the CNT and the material's surface tension. In aqueous solutions, hydrophobic forces

and van-der Waals also play a role. It is possible to lower this stress for chemicals with higher surface pressures by producing an effective matrix that can be chemically reduced to the original product once the CNT has been filled. The CNTs are capped after filling by transferring a current that fuses the closed ends.[58]

14.1   Drug loading [58]

It may be internal or external to locate the drug to be delivered by the CNT. Internalization or encapsulation is focused on the incorporation of Van der Waals into the CNT and is ideally used for drugs that are responsive to external conditions and easily break down.

15. TOXICITY OF CNTs [59, 60]

Concerns have been raised over possible toxicity problems with carbon nanotubes. Data and understanding of their impact on biological systems are currently lacking. Given the likely widespread use of CNTs in the future, understanding their impact on biological systems is imperative before they can be used in the delivery of mainstream drugs. Also, the main factors of possible cytotoxicity are the most desirable properties of Nano-materials for biomedical applications, i.e. their small size, large surface area, high reactivity, and high aspect ratio.[59] The study suggests that SWCNTs can induce adverse cellular responses through molecular signaling activation associated with oxidative stress (cancer induction). Several groups have already observed that CNTs may exhibit asbestos fiber-like behavior in mice experiments. When comparing the structure of both compounds, this concern becomes understandable. Chrysotile asbestos (left) and MWCNT (right) structures are shown above. The main problem with asbestos (and the question with CNTs) is that they quickly become airborne and are carried into the lungs due to their Nano-scale and lightweight. CNTs resembling asbestos fibers contribute to this concern in terms of aspect ratio, bio-persistence, and reactivity. Whilst there is good reason to be concerned about the potential similarities to asbestos fibers, there is evidence to suggest that industrially produced MWCNTs in high doses do not result in cell death in lung epithelial in the way that asbestos fibers do. No big adverse effects are caused by long-term exposure to pure MWCNTs at low concentrations.[60]

16. FACTORS AFFECTING CNTs [60]

The following is a list of factors found to influence the degree of toxicity of CNTs;

o Concentration / dose of CNTs.

o SWCNTs or MWCNTs

o Length of the tubes

o Catalyst residues leftover during synthesis or functionalization

o Degree of aggregation

o Oxidization

o Functionalization

Two appear to yield the most concomitant results; concentration and performance. [61]

16.1.1   Concentration / dose of CNTs

Using rat erythrocytes (red blood cells) it has been shown that no adverse effects on cells were observed at MWCNT concentrations of 25 μg / mL. However, erythrocyte hemolysis (cell membrane breaking)

was increased at concentrations of 50 µg / mL. One likely explanation is that the MWCNTs agglomerate at these higher concentrations, which seems to accelerate the process of hemolysis. High dose levels and prolonged incubation times both increase toxicity and reduce the viability of cells.[62]

16.1.2 Functionalization

The focus of a large body of research has been the degree to which functionalization affects CNT toxicity. It is also likely to be one of the research areas that attract the greatest focus as active and passive targeting is directly linked to the CNT's form and degree of functionality. It has been shown that an SWCNT's degree of freedom will dramatically reduce its cytotoxicity.[63]

CONCLUSION

This review on CNTSs uncovers the diagram on grouping, structure, scattering strategies, blend, decontamination techniques, and use of CNTs alongside their properties, advantages, and restriction. CNTs have the additional favorable position of being forthcoming Nano-gadgets for controlled medication conveyance. The exceptional physical properties of CNTs make a large group of use potential outcomes, some determined as an expansion of customary carbon fiber applications, yet many are new conceivable outcomes, in view of the novel electronic and mechanical properties of CNTs. The fervor in this field emerges because of the adaptability of this material and the likelihood to foresee properties dependent on its well-characterized impeccable precious stone cross-section. The properties and attributes of CNTs are as yet being looked into and researchers have started to tap the capability of these structures. Single and various walled carbon nanotubes have officially demonstrated to fill in as more secure and progressively viable plausibility to past medication conveyance strategies. CNTs can go through films, they can convey helpful medications, immunizations, and nucleic acids profound into the cell to targets site which is already inaccessible. CNTs likewise fill in as perfect non-dangerous vehicles which, now and again, increment the solvency of the medication connected, which brings about more noteworthy viability and wellbeing of medication. By and large, late investigations with respect to CNTs have demonstrated an exceptionally encouraging event eventual fate of what lies ahead later on for drugs.

REFERENCES

1. Rajwant, K. Pooja, V. Mandeep, K. (2018). Carbon Nanotubes: A Review Article. Indian Journal of Research in Applied Sciences Engineering,6(5), pp. 5075-5079.
2. Valentin, N. P. (2004). Carbon nanotubes: properties and application. Materials Science and Engineering R.43 (2), pp. 61–102.
3. Beatriz, R.C.M. Karla, F. R. et.al. (2019). Recent advances on the use of carbon nanotubes as smart biomaterials. Journal of Materials Chemistry B. 1(2), pp. 1-20.
4.   Iijima, S. Ichihashi, T. (1993). Single-shell carbon nanotubes of 1-nm diameter. Nature. 1(4), pp. 363- 603. http://dx.doi.org/10.1038/363603a0
5. Aqel, K.M.M. Abou, El-Nour R.A.A. Ammar, A. Warthan, AL. (2012). Carbon nanotubes, science and technology part (I) structure, synthesis and characterization. Arab. J. Chem. 2(5), pp.1–23.
6. Kalpna, V.(2014). Carbon Nanotubes: A Review on Synthesis, Properties and Applications. International Journal of Engineering Research and Generic Science.2(4), pp.660-677.
7. Gul, R. Zainab, N. Asad, M. Salma, B. (2019). An Overview of the Recent Progress in the Synthesis and Applications of Carbon Nanotubes. J. carbo Res. 5(3), pp. 2-31.

8. Yamaguchi, T. Bandow, S. Iijima, S. (2004). Synthesis of carbon nanohorn particles by simple pulsed arc discharge. Chem. Phys. Lett. 389(2), 181-185.

9. Hwang, I. Mchhowalla, San, N. Jia, S. Amaratungal, G. (2004). Large scale synthesis of single walled carbon nanohorn by submerged arc. Insti Phy pub nanotech. 5(4), pp. 546-550.

10. Sinnott, S.B. Andrews, R. (2001). Carbon Nanotubes: Synthesis, properties and applications. Critical Reviews in Solid State Mat. Sci. 26(4), pp.145–249.

11. Somu, C. Karthi, A. Sanjay, S. Karthikeyan, R. (2017). Synthesis of various forms of carbon nanotubes by arc discharge methods – comprehensive review. Int. Res. J Eng Technolo. 4(1), pp. 344-354.

12. Teo, K.B.K. Singh, Ch. Chhowalla, M. Milne, W.I. (2003). Catalytic synthesis of carbon nanotubes and nanofibers. In Encyclopedia of Nanoscience and Nanotechnology, Nalwa, H.S., Ed.; American Scientific Publisher: Valencia, CA, USA (1), pp. 665–668.

13. Prasek J, Drbohlavova J, Chomoucka J. Methods for carbon nanotubes synthesis-review, journal of Material Chemistry,2011, DOI: 10.1039/c1jm12254a.

14. Choudhary V, Singh B P,Mathur R B. Carbon Tubes and Their Composites, 2013, DOI: 10.5772/52897

15. Mitsuhiro, K. Yoshiaki, T. (2006). Production of single-wall carbon nanotubes by a XeCl excimer laser ablation. Thin Solid Films. 4(5), Pp. 255 – 258.

16. Nguyen, D.V.Q , Dinh, Q. K. Tran, N.T.(2019). Carbon Nanotubes: Synthesis via Chemical Vapour Deposition without Hydrogen, Surface Modification, and Application. J. Che.5(2), pp. 1-14.

17. Abubakar, Y. Sani Garba, D. Zulkifli, A. (2019). Graphene Synthesis by Chemical Vapour Deposition (CVD): A Review on Growth Mechanism and Techniques. International Journal of Engineering Research and Technology .8(5), pp. 15-26.

18. Sunny, E.I Saka, A. A. Samuel, A. A. Christo, H.Z.P. (2007). Catalytic Production of Carbon Nanotubes in a Swirled Fluid Chemical Vapour Deposition Reactor. International Journal of Chemical Reactor Engineering. 5(5), pp. 1-9.

19. Khan W, Sharma R, Saini P, Carbon Nanotube-Based Polymer Composites: Synthesis, Properties and applications,2016, DOI: 10.5772/62497

20. Lee, CJ. Lyu, SC. Kim, HW. Park, CY. Yang, CW. (2002). Large-scale production of aligned carbon nanotubes by the vapor phase growth method. Chem Phys Lett. 5(2), pp. 359, 109.

21. Paradise, M. Goswami, T. (2007). Carbon nanotubes-production and industrial application. Mat. Design, 28, 1477– 1489.

22. Ting-C, L. Yuan-Y, L. (2006). Synthesis of carbon nanocapsules and carbon nanotubes by an acetylene   flame method. Carbon. 44(5), pp. 2045–2050.

23. Mamalis, AG. Vogtländer, L. Markopoulos, A. (2004). Nanotechnology and nanostructured materials: trends in carbon nanotubes. Precis Eng, 28(5), pp. 1-16.
       http://dx.doi.org/10.1016/j.precisioneng. 2002.11.002

24. Saeed, K. (2010). Review on the properties, dispersion and toxicology of carbon nanotubes. J Chem Soc Pak. 32(4), pp. 561-570.

25. Kim, JH. Min, BG. (2010). Functionalization of multi-walled carbon nanotube by treatment with dry ozone gas for the enhanced dispersion and adhesion in polymeric composites. Carbon Lett. 11(2), pp. 290-298.

26. Tarlton, T. Sullivan, E. Brown, J. Derosa, PA. (2017). The role of agglomeration in the

conductivity of carbon nanotube composites near percolation. Journal of Applied Physics. 2(8), pp. 121-130.

27. Ma, PC. Siddiqui, NA. Marom, G. Kim, JK. (2010). Dispersion and functionalization of carbon nanotubes for polymer-based nanocomposites: A review. Composites Part A: Applied Science and Manufacturing. 41(10), pp. 1345- 1367.

28. Vaisman, L. Wagner, HD. Marom, G. (2006). The role of surfactants in dispersion of carbon nanotubes. Adv Colloid Interface Sci. 37(2), pp.128-130.

29. Dai, H. Javey, A. Pop, E. Mann, D. and Lu, Y. (2006). Electrical transport properties and field-effect transistors of carbon nanotubes. NANO. 1(1), pp. 1–4.

30. Prabhakar, R.B. (2007). Electrical Properties and Applications of Carbon Nanotube Structures, J. Nanosci. Nanotechnol. 2(7), pp. 1–29.

31. Nardelli, M. Fattebert, J.L. Orlikowski, D. Roland, C. Zhao, Q. (2000). Mechanical properties, defects, and electronic behavior of carbon nanotubes. Carbon. 38(2), pp. 1703-1711.

32. Dresselhaus, MS. Dresselhaus, G. Charlier, JC. Hernandez, E. (2004). Electronic, Thermal and mechanical properties of carbon nanotubes. PhilosTransact A Math Phys Eng Sci. 362(2), pp. 2065-2098.

33. Yu, M.F. Files, B.S. Arepalli, S. and Ruoff, R.S. (2000). Tensile loading of ropes of single wall carbon nanotubes and their mechanical properties. Phys. Rev. Lett. 84(24), pp. 5552–5555.

34. Khurshed, A. S. Bilal, A. T. (2016). Synthesis of carbon nanotubes by catalytic chemical vapour deposition: A review on carbon sources, catalysts and substrates. Materials Science in Semiconductor Processing. 41(5), pp. 67–82.

35. Lixing, D. Jan S. (2016). Mechanical Properties of Carbon Nanotubes- Polymer composites. IntechOpen.2nd. ED

    https://www.intechopen.com/books/carbon-nanotubes-current-progress-of-their-polymer-composites/mechanical-properties-of-carbon-nanotubes-polymer-composites

36. Kostarelos, K. Bianco, A. Lacerda, L. et al. (2012) Translocation mechanisms of chemically functionalised carbon nanotubes across plasma membranes, Biomaterials. 33(11), pp. 3334–3343.

37. Mu, Q. Broughton, D.L. and Yan, B. (2009). Endosomal leakage and nuclear translocation of multiwalled carbon nanotubes: developing a model for cell uptake. Nano Letters. 9(12), pp. 4370–4375.

38. Alberts, B. Johnson, A. Lewis, L. Raff, M. Roberts, K. and Walter, P. (2002). Transport into the cell from the plasma membrane: endocytosis. in Molecular Biology of the Cell, Garland Science, New York, NY, USA, 4th edition. pp. 2245-2255.

39. Hirlekar, R. Yamagar, M. Garse, .H. Vij, M. Kadam, V. (2009). Carbon nanotubes and its applications, Asian J Pharm Clin Res. 2(l), pp. 24-26.

40. Foldvari, M. Bagonluri, .M. (2008). Carbon nanotubes as functional excipients for nanomedicines: I. Pharmaceutical properties, Nanomedicine: NBM. 4(8), pp. 173-182.

41. Pantarotto, D. Partidos, C. Hoebeke, J. Brown, F. Kramer, E. Briand, J. (2003) Immunization with peptide- functionalized carbon Nanotubes enhances virus-specific neutralizing antibody responses. Chem Biol. 10(5), pp. 961-966.

42. Zhuang, L. Kai, C. Corrine, D. Sarah, S. Qizhen, C. (2008). Drug Delivery with Carbon Nanotubes for In vivo Cancer Treatment. Cancer Res. 68(16), pp. 6652-6660.

43. Yinghuai, Z. , Peng, AT. Carpenter, K. Maguire, JA. Hosmane, NS. Takagaki, M. (2005).

Substituted carborane- appended water-soluble single wall carbon nanotubes: new approach to boron neutron capture therapy drug delivery. J Am ChemSoc. 127(2), pp. 9875-9880.

44. Peeterbroeck, S. Alexandre, M. Nagy, J.B. Pirlot, C. et. al. (2004). Polymer-layered silicate–carbon nanotube nanocomposites: unique nanofiller synergistic effect. Composites Science and Technology 64(10), pp. 2317–2323.

45. Vohrer, U. Kolaric, I. Haque, M.H. Roth, S. et.al. (2004). Carbon nanotube sheets for the use as artificial muscles. Carbon. 42(2), pp. 1159–1164.

46. Avelino, C. Hermenegildo, G. Antonio, L. (2005).Catalytic activity of palladium supported on single wall carbon nanotubes compared to palladium supported on activated carbon Study of the Heck and Suzuki couplings, aerobic alcohol oxidation and selective hydrogenation." Journal of Molecular Catalysis A: Chemical, 2(3), pp. 97–105.

47. Pantarotto, D Partidos, C. Hoebeke, J. Brown, F. Kramer, E. Briand, J. (2003) Immunization with peptide- functionalized carbon Nanotubes enhances virus-specific neutralizing antibody responses. Chem Biol. 10(5), pp. 961-966.

48. Shun-rong, J. Chen, L. Zhang, B. Feng, Y. et.al. (2010). Carbon nanotubes in cancer diagnosis and therapy. Biochimica et Biophysica Acta. 1806, pp. 29–35.

49. Hahm, M.G. Hashim, DP. Vajtai, R. Ajayan, PM. (2011). A review: controlled synthesis of vertically aligned carbon nanotubes. Carbon Lett. 12(2), pp. 185-197.

50. Sheetal, Ga.. (2014). The Role of Scale and Technology Maturity in Life Cycle Assessment of Emerging Technologies A Case Study on Carbon Nanotubes. Journal of Industrial Ecology, 19(1), pp. 51-60.

51. Marc-G, W. Giovanni, N. Anna, B. (2009). The controlled deposition of metal oxides onto carbon nanotubes by atomic layer deposition: examples and a case study on the application of V2O4 coated nanotubes in gas sensing. Phys. Chem. Chem. Phys. 11(2), pp. 3615–3622.

52. Ren, X. Chen, C. Nagatsu, M. Wang, X. (2011). Carbon nanotubes as adsorbents in environmental pollution management: a review. Chem Eng J. 170 (2–3), pp.395–410.
doi: 10.1016/j.cej.2010.08.045

53. Sun, SJ. (2008). Gas adsorption on a single walled carbon nanotube-model simulation. Phys Lett A. 372 (19), pp 3493–3495.
doi: 10.1016/j.physleta.2008.02.030.

54. Wanwei, Q. Hui, X. Sunitha, T. et.al (2015). Carbon nanotube-based lateral flow biosensor for sensitive and rapid detection of DNA sequence. Biosensors and Bioelectronics. 64 (3), pp. 367–372.

55. Mu, Q. Broughton, D.L. and Yan, B. (2009). Endosomal leakage and nuclear translocation of multiwalled carbon nanotubes: developing a model for cell uptake. Nano Letters. 9(12), pp. 4370–4375.

56. Lindberg , H.K. Falck, G.C.M. Suhonen, S. Vippola, M. (2009). Genotoxicity of nanomaterials: DNA damage and micronuclei induced by carbon nanotubes and graphite nanofibres in human bronchial epithelial cells in vitro. Toxicol. Lett. 186(3), pp. 166-173.

57. Monthioux, M. (2002). Filling single-wall carbon nanotubes. Carbon. 40(10), pp.1809-1823.

58. Tsang, S.C. Chen, Y.K. Harris, P.J.F. Green, M.L.H. (1994). A simple chemical method of opening and filling carbon nanotubes. Nature. 2(3), Pp. 159-162.

59. Lindberg, H.K. Falck, G.C.M , Suhonen, S , Vippola, M. (2009). Genotoxicity of nanomaterials:

DNA damage and micronuclei induced by carbon nanotubes and graphite nanofibres in human bronchial epithelial cells in vitro. Toxicol. Lett. 186(3), pp. 166-173.

60. Taylor, A. Turnbull, B. (2011). The potential use of carbon Nanotubes for cancer treatment. Nature, 321(2), pp. 1- 16.

61. Bottini, M. Cerignoli, F. Dawson, M.I. MagrinI, A.T. (2006). Full-length single-walled carbon nanotubes decorated with streptavidin-conjugated quantum dots as multivalent intracellular fluorescent nanoprobes. Biomacromolecules, 7(8), pp. 2259-2263.

62. Kalaugher, L. (2005). Nanotube toxicity linked to functionalization. Technology Update. 3(3), pp. 1-9.

63. Azizian, J. Tahermansouri, H. Biazar, E. (2010). Functionalization of carboxylated multiwall nanotubes with imidazole derivatives and their toxicity investigations. Int. J. Nanomedicine, 3(5), pp. 907-914

Author Guidelines

1. Every author has to register himself /herself on given website
2. After Registration, author will be allotted unique author code (e.g. AM0003) which will be author's identification number for further correspondence.
3. All fields in the registration are compulsory, and no changes in the details will be allowed once the author has registered.
4. If, there are multiple authors for a single manuscript then every author has to register separately. All the authors will be given a unique author code which they have to use for further correspondence.
5. This unique Author Id will be communicated to authors by their registered e-mail only. Hence it is mandatory to provide correct mail id.

For more information click on below link:
http://researchjournal.gtu.ac.in/ImpPdf/GuidelinestoAuthors.pdf

Disclaimer

Facts and opinions published in *Multidisciplinary International Research Journal of Gujarat Technological University* express solely the opinions of the respective authors. Authors are responsible for their citing of sources and the accuracy of their references and bibliographies. The editors cannot be held responsible for any possible violations of third parties' rights.

Contact Person

DR. PANKAJRAY PATEL
Director & Editor in Chief
Graduate School of Management Studies
Gujarat Technological University

DR. SARIKA SRIVASTAVA
Assistant Professor & Editorial Board Member
Graduate School of Management Studies
Gujarat Technological University

Correspondence Address

Gujarat Technological University