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S & T Review

An International Journal of Science & Technology

TeerthankerMahaveer University

TeerthankerMahaveer University has been established by an 'Act' (No. 30) of 2008of the Government of Uttar Pradesh and is approved by the University GrantsCommission (UGC) vide letter No. F. 9-31/2008(CPP-1) dated October, 2008. TheUniversity is located on National Highway-24, barely 144 Km from New Delhi.

The University stands committed to the ideals of Lord Mahaveer – Right Philosophy,Right Knowledge, and Right Conduct – in all the spheres of activity and aspire to berecognized as the ultimate destination for world class education.

The multi-disciplinary University offers career oriented courses at all levels, i.e., UG,PG and Doctoral degrees across diverse streams, namely, Medical, Dental, Pharmacy,Nursing, Paramedical Sciences, Physiotherapy, Hospital Administration, Education,Physical Education, Engineering, Architecture, Polytechnic, Management, Law,Journalism, Fine Arts, Jain Studies, and Agriculture Science to meet rising aspirationsof the youth.

College of Engineering

The College of Engineering has emerged as a hub for academic excellence inengineering training. The college contributes to quality education in all majordisciplines of engineering and technical education and helps to meet the needs of industryfor trained technical manpower with practical experience and sound theoreticalknowledge.

The college was established by the university with the aim of providing relevant,essential, upgraded education to the young aspirants in the field of computer scienceand engineering, including computer applications. In recent times and the years to comethere will beincreasing demand of skilled manpower in the domain of ComputerScience and Engineering because of the 'Digital India' mission projected around theglobe by Government of India.

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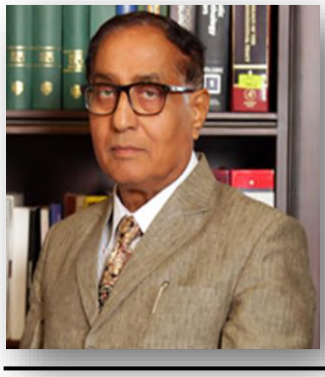

CHIEF PATRON

Shri Suresh Jain

Hon'ble Chancellor

Teerthanker Mahaveer University, Moradabad

I am extremely glad and in a state of inner happiness on the arrival of Vol-9, Issue 2of S &T Review, an International Journal of Science and Technology. Faculty of Engineering and Computing Sciences deserves great applause for this. Since the world is growing very rapidly and no doubt creative research have changed the entire technology in the domain of Engineering, Medical Sciences, Computing Sciences and variety of industrial products. Certainly, research in any discipline is not a one-day task as consistence and continuous efforts are required to put in for the sake of making it constructive for the betterment of entire mankind. Gone are the days when things used to seem impossible. The contemporary time witnesses the era wherein technology is creating wonders. In a world heralded by technology, research in academic institutes lays the foundation of a nation's growth and well-being. The University, since inception, is a research-driven university which, on one hand, strives to educate the students and on the other, endeavours to discover new knowledge frontiers through research. This is heart pleasing to notice that College of Engineering remains in sync with expanding frontiers of academics and industrial practices through various on-going research projects and collaborations with many national and international organizations. The college works diligently to realize its mission of providing the best learning, teaching and research opportunities to students and academicians alike, it continues to supply students with the basics of modern knowledge and high values. I would like to put into records sincerest appreciation and heartiest felicitations to Prof (Dr) R. K. Dwivedi, Dean, College of Engineering, and Editor- in- Chief S&T Review, Associate Editors, Advisory Committee for bringing out the journal successfully up to the extreme satisfaction of research students, researchers, and scientists on regular interval.

I believe that the college will continue to mark revolution through quality research work to bring laurels to Teerthanker Mahaveer University in India and abroad.

Institution is doing surprisingly great in all directions. Wishing a bright future to all stakeholders!

CHIEF PATRON

Shri Manish Jain

Hon'ble Group Vice Chairman,

Teerthanker Mahaveer University, Moradabad

Stellar accomplishments broaden the frontiers of knowledge and scholarship with each passing day. In this eon of Globalization of education, the apparent emphasis is on the quality of education. Since there is nothing which stands as a single yardstick of quality, a good educational institution, therefore, strives unceasingly for sustenance and enhancement of quality in every field of its activity whether it is academics, research or extra-curricular.

Education defines the path of progress and prosperity for which Faculty of Engineering & Computing Sciences is very much committed as it is evident from the various activities carried out throughout the year under the vigilant supervision of Professor R.K. Dwivedi, Dean, College of Engineering. Great Satisfaction & immense pleasure comes to the heart on witnessing that College of Engineering is publishingVol-9, Issue 2 of S&T Review in the Month of June 2025as one more step in the direction of boosting the research environment in the college. The research activities College of Engineering lead to an amazing enhancement of the experience within the students since the research training has been provided to the students to create the next generation of well-prepared scholars with advance knowledge and emerging trends of technology. The college holds firm conviction that extension of research opportunities to an ever-increasing group of undergraduate students adds a dimension of experience to the undergraduate education that, for sure, cannot be duplicated in the classroom.

S&T Review, an International Journal of Science and Technology stands as a witness to the monumental efforts taken by the college under the worthy guidance of Prof.R. K. Dwivedi, Dean, College of Engineering, to make the college as a centre of excellence in education and research.

I extend my greetings and bests wishes to the team College of Engineering and wish their endeavours for future prospects.

CHIEF PATRON

Shri Akshat Jain

Executive Director

Teerthanker Mahaveer University, Moradabad

It is with great pleasure that I present the upcoming "S&T Review, Volume 9, Issue 02" of the College of Engineering. This journal captures the vibrant spirit, remarkable achievements, and ambitious aspirations of our talented college community.

It is with immense pride that I commend the College of Engineering for its outstanding contributions to research and innovation. In today's rapidly evolving world, groundbreaking research has revolutionized fields such as Engineering, Medical Sciences, Computing Sciences, and industrial advancements. Such progress demands unwavering dedication, as meaningful research requires persistent effort to drive transformative change for society.

At the College of Engineering, research is not just an academic pursuit—it is a transformative experience for students. By equipping them with cutting-edge training, we nurture the next generation of scholars who are well-versed in emerging technologies. We firmly believe that integrating research opportunities into undergraduate education enriches learning in ways that traditional classroom settings cannot replicate.

This commitment to excellence ensures that our students are not just learners but pioneers, ready to shape the future. I take immense pride in the collaborative efforts behind this publication. Our dedicated faculty members have worked diligently to provide students with the latest knowledge and skills, preparing them to excel in a highly competitive environment.

A special acknowledgment goes to Prof. Rakesh Dwivedi, Dean, College of Engineering, whose steadfast commitment to excellence is clearly reflected in this journal.

I extend my sincere gratitude and congratulations to all contributors for their outstanding work on "S&T Review, Volume 9, Issue 02".

PATRON

Prof.V K Jain

Hon'ble Vice Chancellor,

Teerthanker Mahaveer University, Moradabad

The contemporary time witnesses an era which is truly defined as a fast-changing world, a changing society which has been progressing at a galloping speed and there is no exaggeration in saying that impact of science, scientific research, technological development, and globalization in our daily life is vibrant and inescapable. Consequently, the requirement to be geared up for tomorrow is surely greater than ever since the advent of life on earth. With this mind, the university continues to march progressively towards its aim to provide responsible citizens who will record their valuable contribution in nation building. Known to all, the progress of nation depends upon the quality of teaching-learning process along with research activities. Keeping the same in mind, together with providing responsible citizens, effectiveness, and efficiency of aforesaid is the goal of the university.College of Engineering is simply unstoppable in its progress as it has been actively involved in countless activities that have brought to light the hidden talents of the college students and staff. The highly qualified and dedicated members of the college, since inception, have always been standing shoulder to shoulder with the management and have been carrying out their duties with a level of commitment.

University education system, particularly technical education, requires a platform to encourage budding researchers for publishing their research output in the form of journal articles.Heart receives enormous pleasure to notice thepublication ofSpecial issue of S & T Review, an International Journal of Science, and Technology which is serving as a platform for publishing the research works covering all branches of Engineering and allied fields. These scholarly publications will be a medium for academic and scientific discussions and enrichment of research areas which will finally lead to the overall development of the community and society at large.

Congratulations to Prof. R.K. Dwivedi, Dean, College of Engineering, Editor-in- Chief, Associate Editors, Section Editors and Advisory committee to motivate for creating a positive environment of research in the college.

Editor in Chief

Prof. (Dr.) R. K. Dwivedi

Dean,College of Engineering

Teerthanker Mahaveer University, Moradabad

Faculty of Engineering & Computing Sciences is well known for the way it is moving ahead on the road of academic excellence in conjunction with dedication towards dissemination of knowledge in the academic world. The College strongly advocates the role of research in education, hence is committed to ripen an inclination on the way to research in both faculty and students. In this quest, the College has taken the initiative to unveil anotherissue of the journal named S &T Review, an International Journal of Science and Technology to embolden researchers and academicians to pursue research.

My heart brims with great joy and happiness by seeing the efforts of publishing team of S&T Review. With an aim to uphold high academic standards in line with academic ethics and academic integrity, a rigorous process of blind review of research papers is embraced accompanied by screening of plagiarism of each manuscript received by team S&T Review for publication. The research work published in the journal, beyond the shadow of doubt, is original which is neither in print nor presented at any other public forum.

A deep sense of satisfaction surge through my heart in acclaiming that College of Engineering has been progressing by leaps and bounds and has grown in stature and strength as it has emerged as one of the finest educational institutes dedicated to the pursuit of knowledge and experience. I believe that the current issue of Vol-9, Issue 2, alike preceding issues, will add lustre to college's prestige.

In the words of great visionary Hon'ble former president Dr APJ Abdul Kalam:

"Learning gives creativity, Creativity leads to thinking,
Thinking leads to knowledge, Knowledge makes you great."

May the quality educationCollege of Engineering has been imparting to the students enlighten their minds and ignite the spark of aiming high in their hearts.

S & T Review

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DEVELOPMENT OF PIEZO-RESISTIVE MEMS PRESSURE SENSOR DIAPHRAGM: A REVIEW

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Abstract

Pressure is one of the critical physical parameters that is required to measure for various applications from industrial to medical field. Most of the pressure sensors available in the market are fabricated using Micro-Electro-Mechanical Systems (MEMS) technology. As technology advances the concentration of the research community tends to low-pressure sensing (< 10 kPa) which is required in various fields like biomedical. The main challenge for the development of low-pressure sensing devices is the need for higher sensitivity. The main purpose of this paper is to discuss the role of diaphragm structure in enhancing sensitivity and to summarize challenges to developing high-sensitivity piezo-resistive MEMS pressure sensors so that conclusive points can be made to evaluate the need for current low-pressure sensing scenarios.

Keywords: MEMS; pressure sensor; piezoresistive; low pressure; diaphragm structure.

1. Introduction

The history of pressure sensing begins with Galileo Galilei when he patented a suction water pump developed for irrigation purposes in the 16th century. Although Galileo could not explain the core concept behind his discovery, this triggered a new area of research. In the same century, another Italian physicist Evangelista Torricelli invented a device to measure atmospheric pressure and named it “Barometer”. From here the era of revolution in pressure measurement started. In 1647 with the help of this Barometer, a French physicist Blaise Pascal, discovered the relation between height and atmospheric pressure. Simultaneously, Robert Boyle successfully conducted various experiments on compression and decompression of air. By taking these experiments into account a German physicist Otto Von Guericke developed the first air pump. However, the most remarkable invention of the pressure sensing technique was discovered after 200 years by the scientist named Eugène Bourdon, who patented a tube that can measure relative

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pressure in 1849 and called it "Bourdon Tube" after his name. As technology advances, day by day scientists and researchers explore various methods for pressure sensing. To date, scientists/researchers have achieved a maximum pressure of up to 770 GigaPascals (GPa) in the lab [1], which is more than twice the pressure in the core of the earth. The current sensing technique is based on microsystem as compared to the strain gauge technique which is primitively used. The evolution of Micro-Electro-Mechanical-System (MEMS) based pressure sensing begins with the outcome of the piezo-resistance effect in germanium and silicon [2]. In the current scenario, MEMS finds its applications in various fields like RF applications [3], physical parameters sensing [4], biosensors [5] etc. and trending towards Nano-Electro-Mechanical-System (NEMS) [6].

In almost all types of MEMS-based pressure sensors, the basic sensing element is the diaphragm, which deflects in response to the pressure. The pressure is measured across the diaphragm. If one side of the diaphragm is vented to the atmospheric pressure and another side is used to measure pressure at a point, the sensor is Gauge Type. However such measurement varies with time, temperature, altitude, and latitude due to the variability of air pressure. However, if a vacuum is used as a reference it can measure absolute pressure directly.

$$p_{absoulte} = p_{gauge} + p_{ambient} \tag{1}$$

In general Intra-Cranial Pressure (ICP), gas cylinder pressure, Blood Pressure (BP), and pressure measured on earth surface are gauge-type pressure sensors. If the pressure is measured on both sides of the diaphragm and the difference is taken as a result (with $\Delta P << P1$ or P2), the sensor is called a differential pressure sensor. We can easily find its application for accurate pressure measurement in warfare aircraft & to detect small differential pressures superimposed on large static pressures. Table 1. Gives an idea of the type and range of pressure sensors required for specific applications.

Table 1 Type and range of pressure sensor general use

S. No.	Measurement	Type of Sensor	Range
1.	Manifold Pressure in vehicles (MAP)	Absolute	Up to 100 kPa
2.	Atmospheric pressure	Absolute	Up to 101.3 kPa

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3.	In/Ex vivo blood pressure	Absolute	Up to 80/120-mm (300 mmHg max)
4.	Intraocular pressure	Gauge	Up to 15 mmHg
5.	Tire Pressure (commonly used)	Gauge	Up to 35 psi (242 kPa)
6.	Vacuum Cleaner	Gauge	100 Pa to 3 kPa
7.	Ventilators	Differential	25 cm H2O

This mechanical deflection or stress of the diaphragm is converted to an electrical signal with the help of transduction mechanisms called the piezo effect. The word Piezo is derived from the Greek word piezein, which means to squeeze or press, so in a certain type of materials when we apply mechanical stress they show some special electrical properties such as generating electric charge (piezo-electric), opposing electric current (piezo-resistive) or electrostatic transduction mechanism (piezo-capacitive). Piezo-resistive and piezo-capacitive are the most commonly used transduction mechanisms in MEMS pressure measurement and have their advantages. The piezoresistive pressure sensor is appropriate for wide pressure range applications as it is temperature independent and linear while the piezo capacitive pressure sensor provides temperature independence with high sensitivity for a part of the pressure range. In the piezo-resistive pressure sensor, the pressure is directly applied to the diaphragm while in the piezo-capacitive pressure sensor pressure is applied on the electrodes. The paper is organized into four sections, The first three sections discuss the basic development of the piezo-resistive sensor, the characteristics of the diaphragm, and the development in the design of the diaphragm. The last section concludes the paper and discusses the outcome.

2. The Evolution of Piezo-Resistance-Based Pressure Sensor

The evolution of piezo-resistance-based pressure sensors begins in the year 1961 when Pfann and Thurston [7] presented their work as stress and strain transducers. This transducer consisted of two longitudinal and two transverse diffused piezo resistors with a Wheatstone bridge to improve sensitivity. Another breakthrough of this mechanism came as a discovery of piezo-resistive properties in Polycrystalline Silicon by Onuma and Sekiya in 1970 [8] and graphical representation of piezo-resistance coefficients in silicon by [9] in 1982. The discovery of the piezo-restive nature in poly-silicon boosted the development of a piezo-resistive pressure sensor,

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as there is no issue of isolation compared to the p-n junction, and compatible with a higher temperature. Most of the current phenomena used for processing and optimization of device performance were developed from the 1980s to 1990s [10–13]. However, there is no standard classification of piezo-resistive based sensors except gauge, absolute, and differential but broad classification based on the material and technology areas below in Table 2.

Table 2 Classification of piezo-restive pressure sensor:

S.No	Classified based on	Type
1.	Piezo-resistors Materials	Poly-Silicon
		Silicon
		Silicon Carbide
		Carbon Fiber
		Carbon Nanotubes
		Silicon Nano-Wires
		Diamond
2.	Diaphragm Material	Silicon
		Poly-Silicon
		Nitride
3.	Wafer	Single Crystal Silicon
		Silicon-on-Insulator (SoI)
		Double SoI
4.	Diaphragm release technology	Bulk Micromachining
		Surface Micromachining
		Electrochemical Etch Stop

3. Characteristics of Diaphragm

The diaphragm is a part of a pressure sensor that directly interacts with subjected pressure. Hence its performance plays an important role in measuring the pressure. A diaphragm must be

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stiff enough to detect the change in the subjected pressure rather than other fluctuations. The deformation of the diaphragm is one of the performing parameters of the pressure sensor as it is correlated to the output of the sensor. The displacement of the diaphragm is measured at the center of the diaphragm due to the highest deformation as compared to the area near the fixed section. The quantity of the displacement is given by:

$$X = \frac{0.00126\ P\ L^4}{D} \tag{2}$$

Where P is defined as applied Pressure on the diaphragm, L is the length of the diaphragm, and D is the bending rigidity of the diaphragm material. Bending rigidity directly depends on the physical parameter of the diaphragm material such as Young's modulus (E), thickness (t), and Poisson's ratio (v) as:

$$D = \frac{E\ t^3}{12(1-v^2)} \tag{3}$$

Some commonly used diaphragm materials with their physical characteristics are listed in Table 3.

Table 3 Diaphragm materials with their physical characteristics

S.No	Materials	Density	Young's Modulus	Poisson's ratio
1.	SiO_2	2270	70	0.17
2.	Poly Silicon	2320	169	0.22
3.	Steel AISI 4340	7850	205	0.28
4.	Al203	3970	393	0.27
5.	Si3N4	3310	317	0.23
6.	Ge	5323	103	0.26
7.	Al	2700	70	0.25
8.	Cu	8960	120	0.34

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From the above two equations, it is concluded that the stress at the midpoint of the diaphragm increases by increasing the applied pressure. However, the shear stress at the midpoint and the maximum deflection depends on the shape of the diaphragm. For example, for the square and rectangular-shaped diaphragm, the shear stress and the maximum deflection are given as follows.

$$\text{For Square Diaphragm} \begin{cases} Maximum\ Sress\ (\sigma_{max}) = \frac{0.308\ p\ a^2}{h^2} \\ Maximum\ Deflection\ (W_{max}) = -\frac{0.0138\ p\ a^4}{E\ h^3} \end{cases} \quad (4)$$

$$\text{For Rectangular Diaphragm} \begin{cases} Maximum\ Sress\ (\sigma_{max}) = \frac{0.308\ p\ a^2}{h^2} \\ Maximum\ Deflection\ (W_{max}) = -\frac{0.0138\ p\ a^4}{E\ h^3} \end{cases} \quad (5)$$

Figure 1(a) shows a rectangular diaphragm of a piezo-resistive model pointing to the shear stress on the membrane as a color gradient. The dark red color at the center region pointed to the maximum deflection, while dark blue at the corner region (fixed section) shows zero deflection. Similarly, Figure 1(b) pointed out the linear voltage distribution for the applied pressure. The change in the resistance of the piezo-resistive material due to the applied pressure makes a change in the output voltage of the Wheatstone bridge, which impacts the sensitivity (S) of the sensor as follows.

$$S = \frac{1}{V_{in}} \frac{\Delta V}{\Delta P} \quad (6)$$

Where V_{in} is the applied voltage to the Wheatstone bridge, $\Delta V/\Delta P$ is the change in the output voltage concerning the applied pressure.

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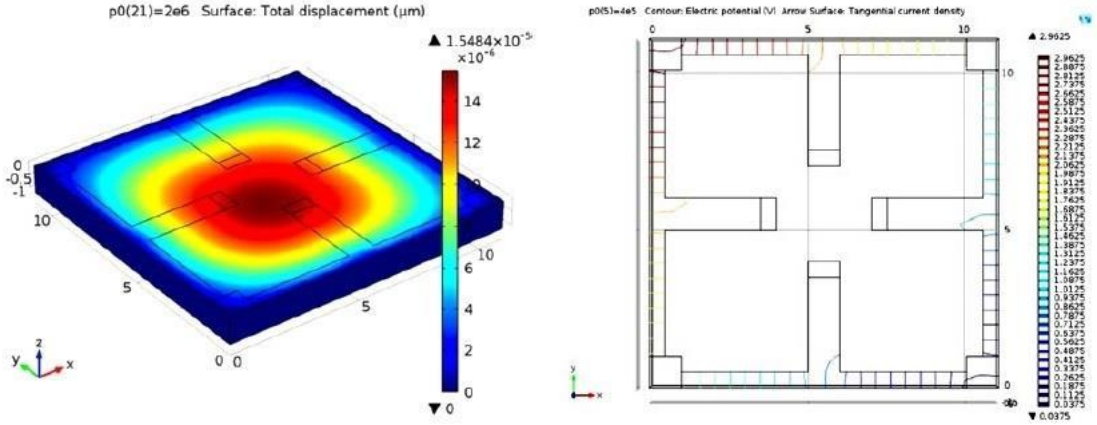

Figure 1 (a) Maximum deflection at Mid-point (b) Voltage distribution as per applied pressure.

Hence it is concluded that the shape of the diaphragm plays an important role in the detection of the pressure in piezo material-based pressure sensors.

4. Development of Diaphragm Structure

As technology enhances, the researchers find out that square shape diaphragms generate more stress than ordinary circular shape diaphragms [14] which changed the focus of the researchers towards non-conventional designs for the diaphragms such as bossed, modified square, arrow, beamed structure, etc. From equations (1) to (6) it can be seen that the sensitivity of the pressure sensor depends on the midpoint thickness level of the diaphragm. However, the thickness is limited by the rigidity as a decrement in thickness increases the sensor's non-linearity. To overcome this problem Hong et al. [15] proposed a design in which the thickness of the center of the square diaphragm is half as compared to the outer region as shown in Figure 2. The researcher claimed the improvement in the stress variation which of course increases the sensitivity of the sensor. The suggested method is not very successful for high sensitivity requirements due to the limitation of the realization and processing of very thin films in practice. To address this problem Rajavelu et al. [16] suggested a thicker diaphragm for the square structure. In this model, the diaphragm is perforated to reduce the rigidity as shown in Figure 3, and acclaimed larger deflection sensitivity (90μV/V/kPa) to sense the small pressure range below 5kPa.

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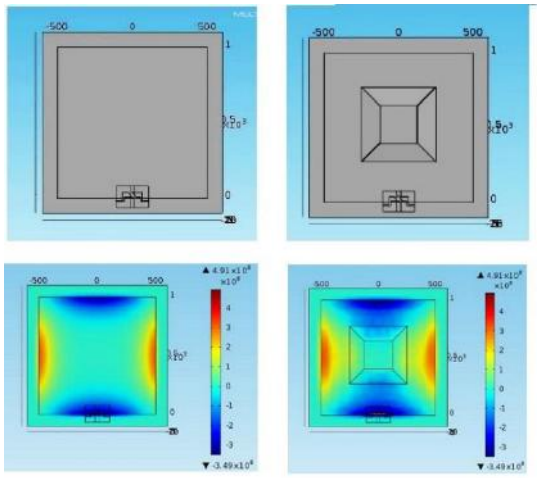

Figure 2 Increment in the stress level due to inner diaphragm structure as compare to Simple square diaphragm [15].

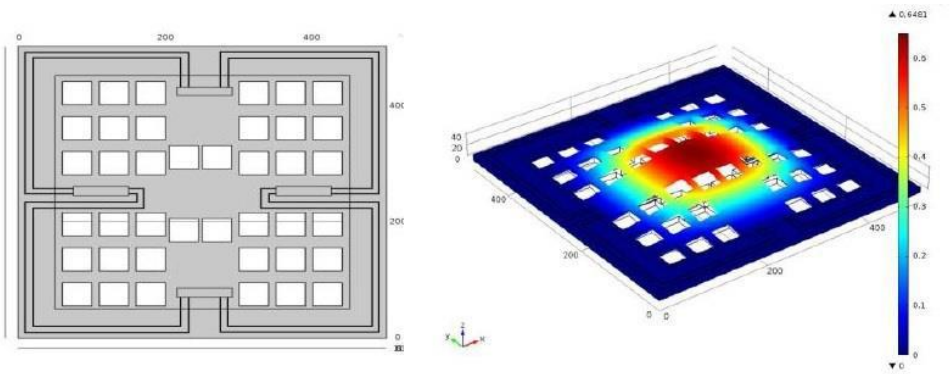

Figure 3 Perforated diaphragm design and stress level [17].

For ultra-low pressure measurement, the need for higher sensitivity increases so that less error occurs in signal processing. To further increase the stiffness of the diaphragm, center bosses are often added which also reduces the nonlinearity error. These center bosses, however, affect the sensitivity and size of the sensor. To compensate for this problem Nambisan et al. [18] proposed two piezo resistors at the junction of the boss and the diaphragm because it is observed that maxima/minima for change in resistance ($\Delta R/R$) are formed near these regions. Although given piezo-resistor arrangement (straight) experienced lower minima than the conventional arrangement (transverse) but highly sensitive because the piezo-resistor is placed over a larger stress region. This design also suppresses the misalignment problem of the conventional arrangement. Based on their analysis non-linearity percentage and sensitivity can be calculated as follows.

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$$NL = -0.136 + D \times 1.497 \times 10^{-4} \quad (8)$$

$$S = -5.917 + D \times 0.0065 \quad (9)$$

Where NL is nonlinearity in %/full scale, D is diaphragm edge length & S is sensitivity.

Another solution to improve the sensitivity of the bossed diaphragm structure is suggested by Pramanik and Saha [19] is a complementary bossed structure, which is also suitable for biomedical applications. In this design, the thinner diaphragms are fabricated at the maximum stress regions so that maximum pressure can be applied to the piezo resistors. These bossed-like centers stiffen concepts however increase the sensitivity but with a tradeoff to linearity. They also affect other device parameters such as die size and increase the acceleration sensitivity due to the additional mass created by a boss. In the case of the higher-sensitivity pressure sensor, acceleration sensitivity is a crucial parameter because it significantly impacts the pressure sensor output. To avoid such problems Kinnell et al. [20] proposed a hollow boss structure. This hollow boss structure provides considerable stiffness without adding much mass to the diaphragm hence avoiding inertial sensitivity and reducing the die size. The design is produced by the electrochemical etch-stop technique and can create controllable etching for <10μm thick diaphragm.

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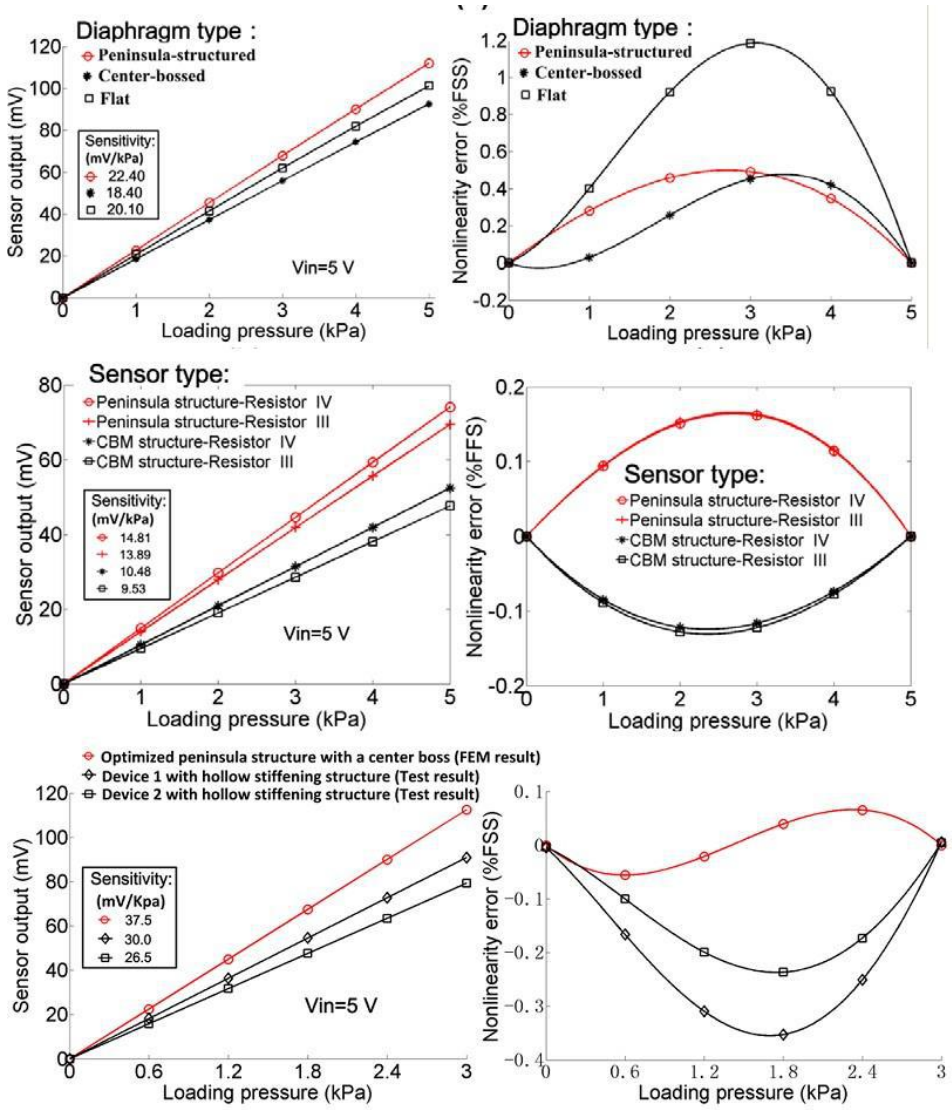

Figure 4 Comparison between center-bossed, CBM, hollow stiffening, and flat diaphragm structure [22].

However, the electrochemical etch-stop and fusion bonding process requires special production facilities that are not widely available at foundries. These structures are also not suitable where larger membrane size is required because due to inertial loads, they become more vibration sensitive. To overcome this trade-off between stability, linearity, and sensitivity. Mackowiak et al. [21] presented a partly-structure thicker membrane by optimization of the peninsula structure so that maximum stress occurs on the piezo-resistor. The core concept of this solution is to avoid stress peaks by the mean of the homogeneous distribution of the stress. The piezo-resistors are placed in the high-stress peninsula using DRIE (Deep Reactive Ion Etching)

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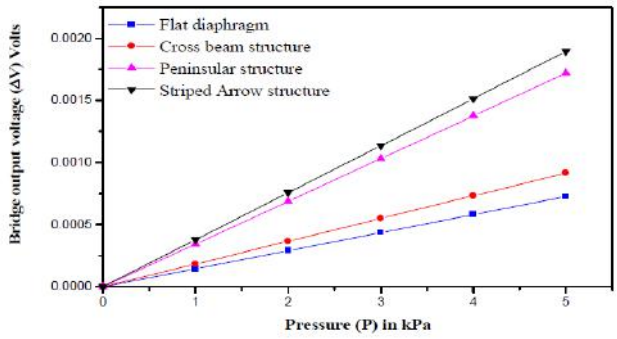
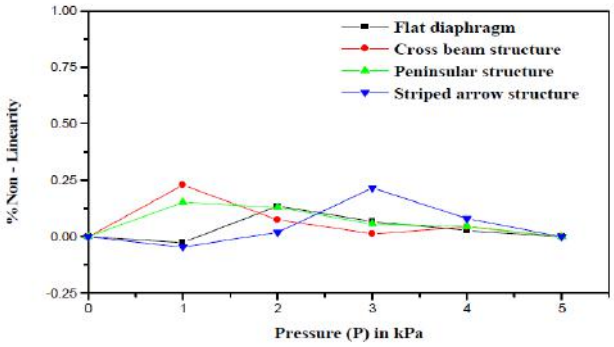
method. Another advancement of the partly-structure peninsula design is presented by Huang and Zhang [22] as a complete peninsula-structure diaphragm by utilizing more mature technology of Potassium Hydroxide (KOH) and Advanced Silicon Etching (ASE). The use of silicon wafers for production makes it low cost and with proper geometrical optimization, it provides the best performance as compared to center-bossed, CBM, hollow stiffening as well as flat diaphragm structure as illustrated in Figure 4.

Another highly sensitive, considerable linear, and low-cost stripped arrow structure is proposed by Angel and Daniel [23]. In this design authors used a burst pressure signal as input to the diaphragm in order to generate huge stresses, which increase its sensitivity three times for the pressure measurement less than 5kPa than the flat diaphragm structure, and nonlinearity less than 0.5%, a graphical comparison among flat, cross beam, peninsula structure shown in Figure 5.



(a)



(b)

Figure 5 Comparison of striped arrow structure vs. flat, cross beam, and peninsular.

As a supporting element, beam structure is also being investigated by the researchers to increase the stiffness of the diaphragm which allows measuring low pressure with high

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sensitivity. A four-diaphragm structure separated by two crossed thick beams as depicted in Figure 10 to measure the pressure range between 400Pa-40kPa is presented by Yu et al. [24]. In this design, the beams are made up of four layers of Si, SiO_2, Si_3N_4, and Al. The thin layers of Si_3N_4 and SiO_2 are used as insulators between the silicon and aluminum layers. The aluminum layer serves as a mask layer for silicon grooving and also improves the stress concentration. At the end of the beams, vertically to the membrane, two piezo-resistors are placed while the other two piezo-resistors are placed outside the membrane area. The advantages of Cross Beam Membrane Structures (CBM) over Conventional Flat Membrane (CFM) structures are i) Both longitudinal stress and transverse stress values are higher ii) The ratio of longitudinal stress to pressure is much larger as compared to CFM. The main drawback of this design is negative output voltage which is generated due to residual stress in the aluminum beam layer. However, this CBM design provides almost four times higher sensitivity (32.9μV/hPa) than the CFM structure.

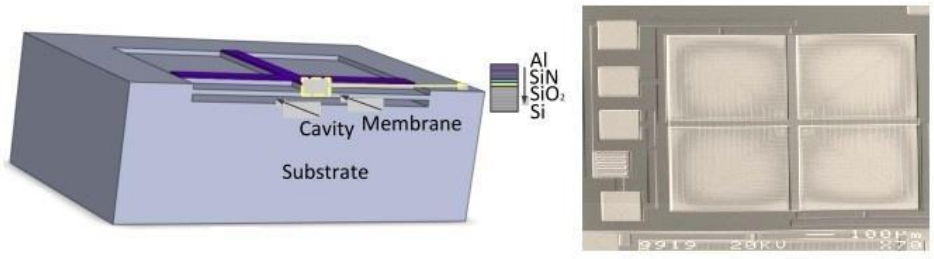

Figure 6 Four membranes crossed the beam structure.

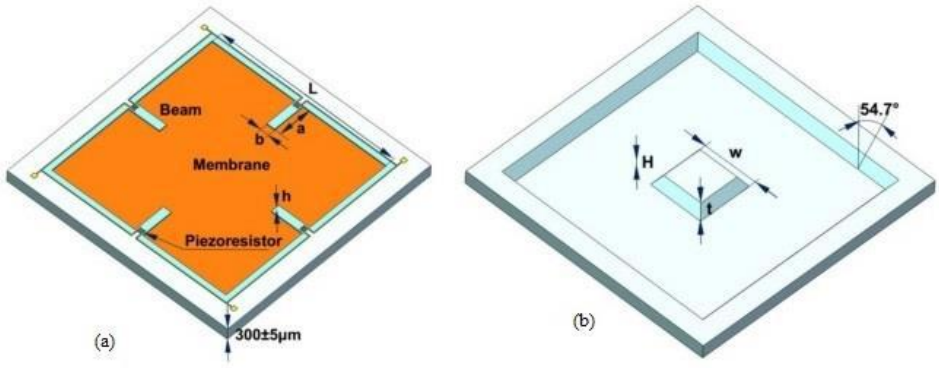

Figure 7 Four Beams Bossed Membrane (FBBM) structure.

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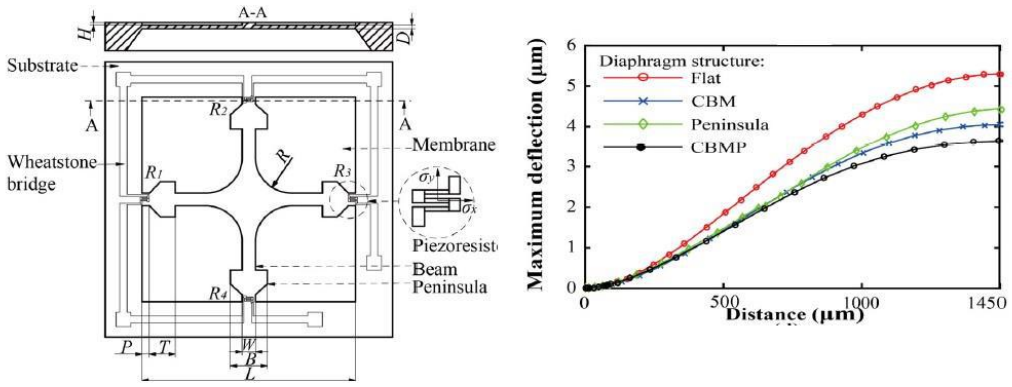

Figure 8 Crossed Beam Membrane Peninsula structure and comparison graph for membrane deflection.

In the recent development of membrane structure for low-pressure measurement, Li et al. [25] clubbed the concepts of the beam and bossed structure based on the studies done by [18] & [24]. The structure consisted of four beams and a square boss on the membrane hence called Four Beams Bossed Membrane (FBBM) structure and can measure pressure up to 5kPa. The fabrication of this sensor is done by MEMS bulk-micromachining and anodic bonding technology. The sensor is made up of an N-type silicon wafer and a dorsal cavity is created for the movement of the membrane using wet etching. Due to the anisotropy of single-crystal silicon, the wall of the sensor is inclined to 54.7° as shown in Figure 7. This design achieved a high sensitivity of 4.71 mV/V/kPa and a nonlinearity of 0.75% FSS. For micro pressure measurement, Tran et al. [26] modified the cross-beam structure by adding a peninsula for the membrane and called it the Cross-Beam Membrane Peninsula (CBMP) structure Figure 8. The stress distribution and deflection in the membrane is calculated using the Finite Element Method (FEM). These (CBMP) structures are also helpful to increase sensor sensitivity, and the stiffness of the diaphragm and to maintain high first natural frequency. Some designs presented by the researcher are listed in Table 4. However, they are also optimized for the specific applications for which they are developed.

Table 4. Comparison of Different diaphragms structures.

Diaphragm type	Sensitivity (mV/kPa)	Nonlinearity (%FSS)	Pressure Range
Inner Square	6.02	1.0	0-

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Diaphragm [15]			1000kPa
Broken Arrow [23]	3.78	0.5	0-5kPa
FBBM [25]	4.71	0.75	0-5 kPa
CBMP[26]	25.7	0.28	0-5 kPa

5. Conclusion

Our study finds that in the current scenario, researchers are concentrated only on application-specific characteristics of the pressure sensor rather than working on each parameter thus sensor designs are now trending towards the development of the new structures, optimized as per the requirement of the application. For example, in the case of a control switch application, where the sensor needs to sense only the threshold level of pressure, linearity is not a crucial parameter. While in a contrary application like altitude sensing a high degree of linearity is needed. Similarly, sensitivity is not a crucial parameter where pressure changes drastically, but for micro pressure sensing it becomes a critical parameter. Our study also suggested that the low-pressure regime piezo-resistive is more preferable transduction mechanism due to its high sensitivity that enables more linear operation. However, this transduction mechanism is not suitable for applications that lie in high-temperature regions. It is also been suggested that one should follow some common steps for better diaphragm results as per the requirement of the application. First, a proper material should be selected for the diaphragm design. For example in general, the polyimide material is more suitable for low pressure compared to silicon and PDMS for the transparent diaphragm. Secondly, if cost is not an issue one should use compensation methods to avoid environmental effects for accurate measurements. Such as the development of circuits to suppress or cancelation of offset effect. Lastly one should use proper analytical modeling for placing the resistor and optimization of the structure to avoid additional cost. For example by proper optimization of the diaphragm dimension and location of the resistor, one can not only reduce the cost but also enhance the reliability of the sensor. It is also noted that the sensor industry needs a cost-effective way for batch processing rather than a standalone method, however, some researchers developed technologies to fabricate sensors via screen printing and lithography but still, there is a need for a more simple and cost-effective way for the batch fabrication process. Another point that can be considered for further research is the development of an absolute pressure sensor which is suffering for residual stress in case of precise pressure

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sensing. Physical aging and hygroscopic swelling are also a major cause of mechanical stresses which are still desirable to entertain.

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FABRICATION OF MINI ABRASIVE VERTICAL BELT GRINDING MACHINE

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Abstract

Grinding involves the removal of metal through the use of a rotating abrasive wheel. Abrasives are materials with extremely hard particles capable of machining various materials like hardened steel, glass, carbide, and wood. It's a method often employed to eliminate thick layers (around 0.5mm) of material across different types of work. A popular finishing process in metal and wood industries is abrasive belt grinding. This technique allows for both coarse and fine grinding. The main components of this setup include the main body, motor with pulleys, and the abrasive belt conveyor. This machine aids in shaping materials effortlessly, offering a superior surface finish and a larger grinding area compared to other methods. Moreover, the maintenance cost for belt grinding is lower, it takes up less floor space, and it ensures consistent surface finishes. For our mini project, we'll fabricate a compact vertical belt grinding machine, simplifying material shaping while maintaining high-quality surface finishes.

Keywords: Abrasive belt, wheel grinding, aluminium oxide, Pulley

1. Introduction

Belt grinding machines are widely used in various industries for grinding and polishing surfaces. However, traditional belt grinding machines are often large, expensive, and require significant space and investment. This limits their accessibility to small-scale industries, hobbyists, and educational institutions. There is a growing need for a compact and efficient grinding solution that can cater to the requirements of these users.

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In recent years, there has been a trend towards miniaturization and portability in machine tool design. This has led to the development of compact and efficient machines that can perform complex tasks with precision and accuracy. In this context, the design and development of a mini belt grinding machine is a significant innovation. This machine is designed to be compact, portable, and user-friendly, making it ideal for small-scale industries, hobbyists, and educational institutions. The mini belt grinding machine is designed to provide a high-quality surface finish, precision, and accuracy, while being cost-effective and accessible. This machine has the potential to revolutionize the grinding and polishing process, making it an essential tool for a wide range of industries and users. This research aims to design and develop a mini belt grinding machine, exploring its design parameters, performance, and applications.

2. Literature Review

Shubham patil et. al.,[1]: observed abrasive belt is employed in this project to effectively grind objects of various shapes such as circular, rectangular, and polygonal. We utilize an aluminium oxide belt capable of grinding diverse materials like wood, stainless steel, cast iron, and glass. Furthermore, we have the flexibility to adjust the grinding speed according to material specifications by utilizing a variable frequency drive. Avinash parkhe et. al.[2]: Abrasive belt grinding is adept at refining surface roughness and enhancing accuracy in workpieces. Aluminium oxide belts, renowned for their high stock removal capacity, excel in cleaning and polishing tasks. Unlike wheel grinding, abrasive belt grinding offers superior efficiency and a broader parameter range for optimal results. An Jiaxiang et. al.[3]: Abrasive belt grinding technology plays a vital role in the precise shaping of intricate profile parts. By examining the strategies for mapping out grinding paths, establishing contact models, and understanding material removal processes, advancements in both domestic and international research and application of abrasive belt grinding technology are reviewed. Additionally, challenges and potential avenues for further research in the realm of abrasive belt grinding technology for complex profiles are highlighted. MR .Vigneashwara Pandiyan et. al.,[4]explained Belt grinding involves a complex interplay of factors like cutting speed, force, wheel hardness, feed rate, and grit size, influencing material removal. This study delves into how these variables impact abrasive belt grinding to create a model of material removal. Xiangyang Ren-Bernd Kuhlenkotter et. al.,[6] explores how piezoelectric materials are utilized in microfluidic drive

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technology, leveraging their exceptional dielectric, piezoelectric, and optical characteristics. Specifically, piezoelectric ceramics are selected for both theoretical analysis and experimental investigations, highlighting their rapid response and high-speed precision. M. Chandrasekhar et. al.[7] explained the abrasive belt grinding machine is primarily designed to enhance the surface finish of specimens through grinding. It utilizes an AC-powered motor as its energy source. Grinding involves the elimination of metal through the utilization of abrasive materials bonded together to create a rotating wheel. .Arwizet-karudin et. al.[8] explained the belt burrs offer advantages in various tasks, belt grinders are seldom utilized due to their perceived limited functionalities. Users often opt for alternative grinders due to the perceived inadequacies of belt grinding functions. Nonetheless, employing a belt grinder can offer significant advantages, particularly in operations where efficiency is paramount.

3. Methodology

The methodology of operating an abrasive vertical belt grinding machine. Typically employed for polishing small metallic components and refining the surface of wooden ones, this machine features abrasive belts mounted on rollers. Power is transmitted from an electric motor to the roller shafts via couplings. As the motor's initial shaft rotates, all the rollers spin at the same speed due to the abrasive belt's wrapping around them, as depicted in figure 3.1. Placing a small part on the abrasive belt and applying pressure to its surface results in the polishing of the component, the effectiveness of glassing is also achieved for aesthetically pleasing components. Abrasive belts come in different sizes on the market. Belt grinding machines come in dry, wet, or combination forms. They serve for heavy material removal or delicate polishing, depending on the grade of the belt used. This inclined grinding apparatus is utilized for grinding surfaces at angles. Grinding can be performed on stationary objects.

3.1 Design And Development

The mini belt grinding machine is designed to be compact and portable, with a footprint of 300 mm x 200 mm. The machine consists of a motor, gearbox, belt grinding mechanism, and control system. The motor is a high-speed DC motor with a maximum speed of 20,000 rpm. Enabling the machine to operate at a range of speeds. The belt grinding mechanism consists of a 20 mm

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wide belt and a tensioning system to ensure consistent grinding. The control system includes a variable speed controller and an emergency stop button.

3.2 Working Principle

The mini belt grinding machine works on the principle of abrasive machining, where a rotating abrasive belt is used to grind and polish surfaces. The machine consists of a motor, gearbox, and belt grinding mechanism. The motor drives the gearbox, which reduces the speed and increases the torque, enabling the abrasive belt to rotate at a high speed.

The abrasive belt is tensioned and guided by a system of pulleys and rollers, ensuring consistent contact with the work piece. As the work piece is fed against the rotating belt, the abrasive grains remove material, grinding and polishing the surface. The machine's compact design and precision engineering enable precise control over the grinding process, resulting in a high-quality surface finish.

The machine's working principle can be summarized as follows:1. Motor drives the gearbox2. Gearbox reduces speed and increases torque3. Abrasive belt rotates at high speed4. Workpiece is fed against the rotating belt5. Abrasive grains remove material, grinding and polishing the surface6. Precise control over the grinding process enables high-quality surface finished. The mini belt grinding machine's working principle combines the benefits of abrasive machining with compact design and precision engineering, making it an ideal tool for small-scale grinding and polishing applications.

4. Result

The mini abrasive vertical belt grinding machine has been developed for grinding the specimen to get a good surface finishing. This grinding operation may be used for removing layer up to (0.5) mm. It has maximum area of contact during removal process so that less contact pressure is developed at the surface of work piece. This vertical grinding machine has a special capacity of changing the speed of grinding wheel from 150rpm-500rpm compared to conventional grinding machine. This feature enable to get better surface finish of by changing the speed depended upon the type of material. The mini abrasive vertical belt grinding machine is prepared and operated.

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5. Conclusion

The mini belt grinding machine is a compact and efficient tool for grinding and polishing small surfaces. The machine's design and development demonstrate the potential for small-scale industries and hobbyists to access high-quality grinding and polishing capabilities. Future developments include integrating additional features, such as automated belt tensioning and coolant systems, to enhance the machine's performance and versatility.

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HISTORY OF INORGANIC – ORGANIC HYBRID MATERIALS AND THEIR FUTURE OUTLOOKS

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Abstract

The evolution of inorganic-organic hybrid materials, from ancient craftsmanship to modern scientific innovations, has played a pivotal role in the advancement of human civilization. Historical instances of these materials can be observed in various domains such as art, architecture, and medicine, with notable examples including medieval stained glass, natural resins, and Roman concrete. Over time, advancements in scientific knowledge have led to the creation of sophisticated hybrid materials that integrate organic polymers, ceramics, and nanomaterials, resulting in enhanced mechanical, optical, and functional properties. Presently, these materials find applications in fields such as biomedicine, electronics, energy storage, and sustainable technologies, paving the way for further innovations in the future. This essay delves into the scientific foundations, historical evolution, and recent advancements of organic-inorganic hybrid materials, underscoring their transformative interdisciplinary impact. The discussion concludes with insights into potential future developments in the realm of hybrid materials.

1. Introduction

For more than 30 years, the processing of organic–inorganic hybrid materials has attracted a lot of interest from both the academic and business worlds.[1–6] Synthetic processes frequently include the "polymerization" or "insertion" of molecular, polymeric precursors or nano-objects. These reactions can occur in aqueous or organic solvents at relatively low temperatures (20–300 °C) with normal or autogenous pressure.[5,6] These extremely mild conditions are used for a variety of processes including organic and organometallic chemistry, supramolecular chemistry, intercalation chemistry, or polymer chemistry.Therefore, this kind of approach may produce

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organic and biological mechanisms and mineral components at the same time to develop unique organic–inorganic hybrid products.which frequently consist of molecular or nanoscale composites. In fact, fusing the characteristics of certain organic or biological molecules with those of inorganic substances at the molecular level in a single material has become anattainable objective.[7–9] In addition to their physical and chemical characteristics, The numerous potential that result from fusing the colloidal state with the physico-chemical properties of complicated fluids and biological systems make these multifunctional hybrid materials intriguing. Many hybrid materials may be processed easily thanks to the combination of soft chemistry and the many engineering techniques used to form soft matter, such as dip coating, spin coating, extrusion, electrospinning, microemulsion templating, aerosol processing, inkjet printing, and 3D/4D printing.In fact, hybrids may be produced into powders, foams, monoliths, intricate structures, and thick coatings and fibers in addition to thin films. These methods, which combine cleverly planned processing with molecularly constructed chemistry, enable scientists to create complex systems in a variety of shapes and sizes with flawless control at various scales of size, composition, functionality, and sound structure. The realization of intricate hybrid hierarchical structures suggests that chemistry and process are well integrated, and it clearly illustrates the crucial role that "integrative chemistry" plays in the development of innovative materials.[10,11] This is the setting in which nowadays,Hybrid systems of class I involve interactions between organic and inorganic components through weak connections, such as electrostatic, hydrogen, or van der Waals bonds. Covalent or ionocovalent chemical bonds bind the organic and inorganic components of hybrid materials, which fall under class II. Considering that many hybrid materials contain both firmly and weakly linked organomineral surfaces, this type of hybrid will also be classified as Class II because of the impact of strong chemical bonding on the characteristics of the final hybrid material.Nature used the idea of organomineral hybridization to create living materials without waiting for human recommendations. Indeed, the foundation of evolution is, broadly speaking, hybridization and cross-breeding. Nature really conceives and implements a wide range of structures, materials, systems, and functions, ranging from the most basic to the most sophisticated animals. For instance, biomineralization processes created extremely effective hybrid materials millions of years ago. In actuality, these naturally occurring hybrid materials are frequently highly integrated intelligent systems that are adept at striking a balance between a variety of properties, including density, controlled permeability, color,

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hydrophobicity, and mechanical behavior (flexibility vs. stiffnessTheir capacity to react to chemical and/or physical phenomena brought on by pressures applied at various scales seems to be the reason for these hierarchical systems' mechanical strength and dependability. Time and evolution's role in choosing the best material for a given purpose are connected to the great performance of the hybrid materials used in living things. Nature commonly optimizes its selection process by applying the hierarchical organization principle to a small number of materials.

Early in human history, man altered matter, and his earliest successes with hybrid materials are often linked to murals or artifacts that were created by accident—undoubtedly—but also because of the inventiveness of artists and craftspeople. Much later, and mostly between the 17th century and the present, is the science of materials. Figure 3 provides a historical overview of the development of hybrid materials, highlighting four key eras.Since the middle of the 20th century, hybrid material manufacturing has significantly increased in both quantity and quality, as seen in Figure 3. The earliest period, which spans from 20,000 years ago to the tenth century AD, can be illustrated by the frescoes found in prehistoric caves (Altamira, Chauvet, Lascaux, etc.), the clay-based bleaching agents used in ancient Rome or Cyprus, the hybrid clays used for the shaping and ceramization of Chinese porcelain known as "egg-shell," and the pigments known as Maya Blue or Prussian Blue. The second phase, which spans 1600–1940, saw Improvements in the chemistry of silicates, silicon and related alkoxides, and organic silicon compounds called organosilanes have led to the industrial development of silicones. The latter are glass-polymer coupling agents or hybrid glues and sealants that will gain their "letter of nobility" as a result of the Second World War's need to develop effective new materials. A variety of weakly or noninteracting scientific communities developed mixed organic-inorganic materials throughout the third phase.

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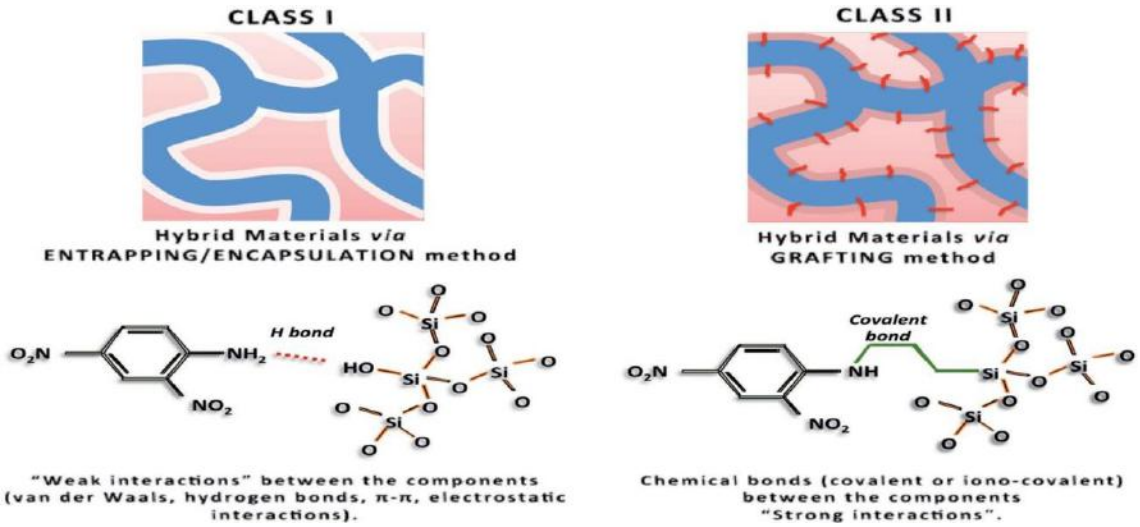

Clays, zeolites, and polymers combined their "basic compounds" with complementary components of a different kind to form unique structures and/or adjust the resulting physical properties. For example, organic cationic templates were used to produce novel zeolites, organic components (molecules, monomers, oligomers, polymers, etc.) were intercalated into clays to hybridize them, and sol-gel chemistry was used to add or manufacture inorganic nanofillers. During the fourth phase, which lasted from the early 1980s to the present, soft chemistry, or "chimiedouce," and most bottom-up techniques for the production of colloids, gels, glasses, and ceramics were developed. These techniques allowed for the general connection between the mineral content and the inorganic terms.

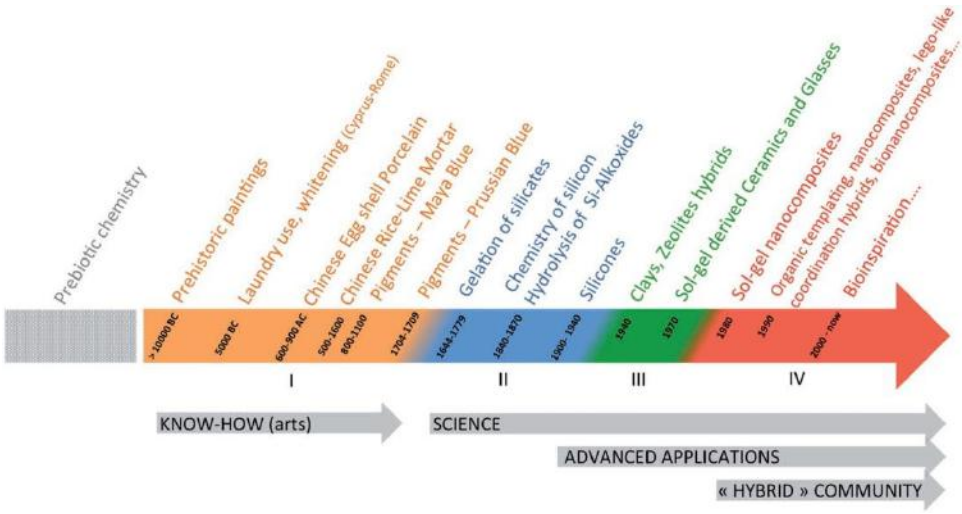

Figure 3. Timeline of the organic-inorganic hybrid materials' creation and transdisciplinary evolution.

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2. Prebiotic Hybrid Chemistry

In the past, clay-based hybrids were the first organic-inorganic materials to be made. It is generally accepted that clay minerals played a crucial which is often placed at 3.8 Ga as in Figure 4. Clay-organic compounds were presumably generated spontaneously in nature.[23] Thus, it is well known that the incorporation of swelling phyllosilicates into colloidal clay particles promotes inter-layer adsorption and organic species accommodation, resulting in the formation of organoclay complexes of varying durability.[24] Intercalation processes are caused by organic–inorganic interactions, such as van der Waals forces, hydrogen bonding and water bridges, electrostatic connections, ion–dipole and coordination, proton and electron transfers, etc.[25]One remarkable aspect of clays in this context is their surface properties, which demonstrate a replicating ability inherent in living organisms by spontaneously intercalating and catalyzing the transition of various molecular species in a repetitive manner.

Consequently, they might be regarded as templates demonstrating the ability to function as "molecular replicators." This remarkable characteristic has been put forth as an alternate explanation for the ability to selectively adsorb and concentrate prebiotic organic components from the putative primordial soup, as well as the development of complex systems with optimal self-replication characteristics in the early Earth. It is noteworthy that certain clay minerals exhibit excellent specificity and chiral stereoselectivity in the selective molecule adsorption process.[22]

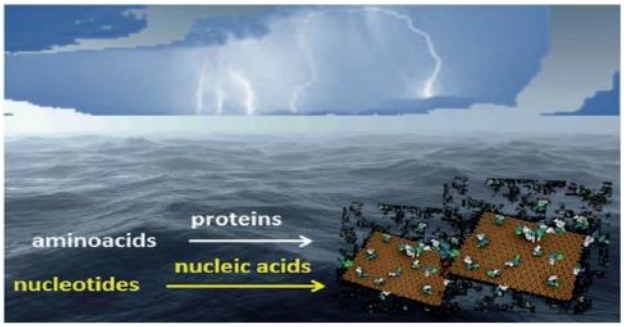

Figure 4. Ideal representation of hybrids based on clay minerals a sinter- mediates in the abiogenesis origin of life.

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Silicon Chemistry History

The silicon period, a key component in the creation of contemporary hybrid materials, began in the 17th century. While "glass technology" has been around since 3000 BC, this new silicon chemistry was created under moderate settings, which is a necessary prerequisite to get along with its organic cousin. The silicate and organosilicon chemistries, which are technically related but temporally displaced, make up the two primary branches of the domain, as shown in Figure 7.The silicate chemistry emerged early because of the natural availability of precursors. J. B. van Helmont, a Flemish chemist, physiologist, and physician, made the first contribution in 1640. He started by dissolving sand in a basic media to create a solution known as "water glass," which could be reduced in pH in an acidic medium to return to sand (silica). Van Helmont demonstrated with this straightforward experiment (backed simply by a balance) it might be imagined in a liquid media at ambient temperature.simply by adjusting the pH. More than a century later, in 1779, Swedish scientist T. Berman carried out the identical experiment under improved supervision. Crucially, he explained how the first silica "gel" was created by regulating the alkali-silicate solution's acidification process. These groundbreaking studies using silicate produced from sand were anecdotal and infrequent despite their significant significance.

Novel synthetic pathways toward novel molecular silicon and organosilicon precursors were implemented as a result of the revolutionary developments in contemporary silicon chemistry. one of the pioneers of modern chemistry, is initially credited with this invention. Although he is mostly recognized for his other significant achievements Berzelius created two groundbreaking reactions in 1824 that would advance the science. According to his 1843 chemistry textbook, the first reaction was discovered by accident when he heated potassium in an earthenware vase and saw that the interaction between metallic potassium and potassium fluorosilicate could separate elemental silicon. After first isolating silicon, he established the synthesis of silicon halides, namely SiCl4, which is an essential component of the impending inorganic polymerization.According to mining engineer J. J. Ebelmen, distillation tests and the "penetrating ethereal odor and strong peppery taste" revealed that adding soluble alcohol to silicon tetrachloride produced silicic ethers.[67] In 1846, he reported that the silicic ethers readily mixed with moisture to create a silica gel, which progressively lost volume until a clear, glass-like substance with a mechanical break was created. [68] He also conjectured about these

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materials' possible optical applications. Since he discovered these first inorganic hydrolysis and polycondensation processes, which were completely unknown at the time, J. J. Ebelmen is considered the "grandfather" of sol-gel chemistry. The concept that there may be another organic chemistry based on silicon instead of carbon was revived in 1857 when German scientist Friedrich Wöhler found silicon tetrahydride (SiH4) and described its chemical similarities to methane (CH4). In 1863, two well-known chemists, C. Friedel of France and theThe first organosilicon chemical, tetraethyl-silane, was synthesized by American J. M. Crafts (well known for their Friedel–Crafts process in organic synthesis) via a reaction between diethyl zinc and silicon tetrachloride. This was a logical step toward organic–inorganic hybridization and additional validation.[69]

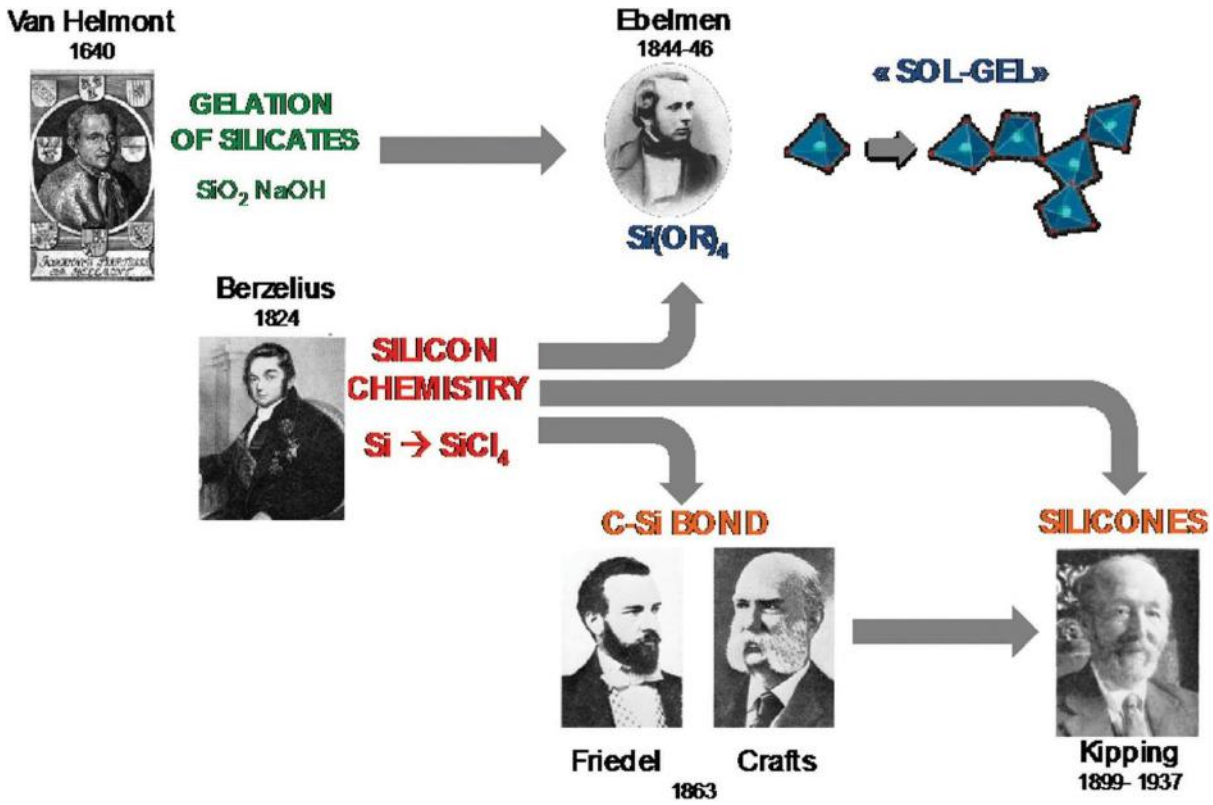

Figure 7. milestones in history pertaining to "silicon" chemistry.

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Modern Hybids

1. Clay Hybrids

As first reported by Gieseking and Hendricks in the early 1940s, the first modern preparations of organic–inorganic hybrids were likely made using layered clay minerals like smec- tites (montmorillonite and related phyllosilicates) by exchanging their interlayer organic cations by means of inorganic ones. Bradley and MacEwan subsequently demonstrated how organic–inorganic hybrids are produced by the intercalation of organic neutral molecules in this same family of clay minerals. As previously mentioned, organic compounds with a range of functions, from amines to carbonyl compounds, have been widely used as guest species because they can intercalate host layered solids like smectite clays and other phyllosilicates like kaolinite and halloysite, as well as fibrous clays like sepiolite and palygorskite. In his later research at the Universities of Granada, Complutense de Madrid, and CSIC (Spain), he employed this method to intercalate related 2D solids, such as hydroxy salts, layered hydroxides, and phitic acids, to produce more distinctive organic–inorganic hybrids.

Since, for instance, the finished products of oxidizing graphite were found within the graphene blooming and are now known as graphite oxide, this goal represented a major breakthrough in the chemistry of hybrid compounds. Importantly, the intercalation process that creates organic–clay hybrids may be seen as a model application to different 2D solids, opening the door for significant new developments in organic–inorganic hybrid materials.

LDHs, alkaline layered silicates (such as magadiite), derived layered silicic acids, transition-metal chalcogenides, hydrated vanadium pentoxide (V2O5 xerogel), titanates, niobates, molybdates, lamellar phosphates, and phosphonates, for instance, have all been used as hosts instead of clays to create a range of hybrid materials. Because of their industrial applications, clay-organic hybrids showed great relevance early on. They are used extensively as rheological agents, specific sorbents, fillers, and additives in polymers (such polymer–clay nanocomposites), and more recently as advanced materials in certain technological applications.

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2. Zeolite Based Hybrids

Though from a completely different angle, the zeolite community started hybridizing and introducing organic groups in the 1950s and 1960s, much like clays. Zeolites are alkali and alkaline earth hydrated aluminosilicates made up of linked alumina and silica tetrahedra that, by controlled condensation, produce three-dimensional crystalline forms with unique microporosity. As a consequence of their ability to sort molecules due to their regular holes and sizes, zeolites—also referred to as "molecular sieves"—have found use in ion exchange, detergents, separation, purification, and catalysis. Although natural zeolites were used to filter water in Roman aqueducts, the Swedish mineralogist A. F. Cronstedt, who is also recognized for having discovered nickel, was the first to identify this family of minerals in 1756. He created the name "zeolite" by combining the Greek words "zeo" and "lithos," which mean "to boil" and "a stone," and described the special qualities of this "unknown kind of rock."The discovery of synthetic zeolites and, by extension, the beginning of zeolite research and technology, are credited to two scientists, R. M. Barrer (England) and R. M. Milton (USA), as well as two businessmen, Union Carbide and Mobil Oil.R. M. Barrer began his ground-breaking studies on zeolite synthesis in the mid-1930s and early 1940s. These studies included the creation of a novel synthetic zeolite (later known as the KFI framework) and the synthetic equivalent of the zeolite mineral mordenite.

3. Sol-Gel Derived Glasses and Ceramics

The development of "sol-gel" science was first very progressive and, interestingly, motivated by practical, if not technical, demands; in fact, sol-gel technology preceded sol-gel research at first. Geffcken and Berger (Schott Glaswerke Company) published some ground-breaking sol-gel coating research in the 1930s.The mid-1950s saw the emergence of the "sol–gel" realm, which persisted until the 1970s. It started in the field of ceramics in 1952–1956 thanks to the efforts of Rustum Roy, an Indian-born physicist who studied ceramic materials at Pennsylvania State University. While studying the phase equilibrium of mixed oxide systems, he proposed several "sol–gel" methods for creating distinctive ceramic oxide compositions involving Al, Si, Ti, Zr, and other elements (that could not be produced using traditional ceramic powder methods) by coprecipitation of salts or hydrolysis and condensation in the presence of tetraethylorthosilicate (TEOS).[149] H. Dislich made important strides toward practical use (at Glasswek Schott, Germany, 1969). revolutionized

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the glass industry by developing sol-gel techniques that eliminate the requirement for melting and provide optical coatings of glassy, crystalline, or glassy–crystalline multicompo-nent systems.

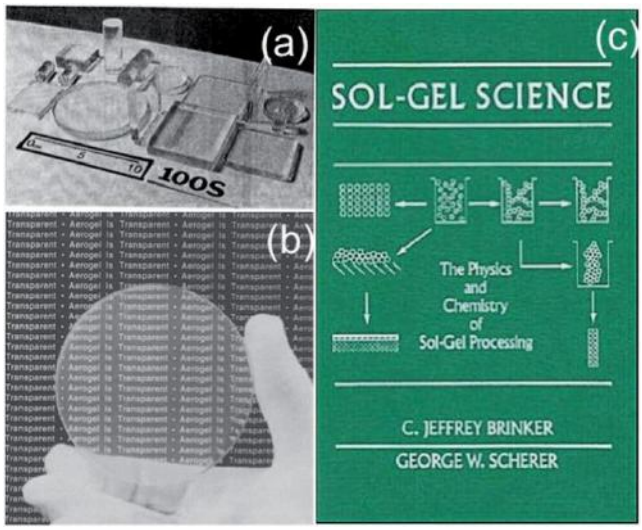

Figure – 8. a & b Illustrations of the earliest silica monoliths produced using sol-gel. c) The book cover for "Sol-Gel Science." Permitted adaptation. [159,169] Copyright Elsevier,1990.

Future Prospects of Hybrid Materials

The examination of the literature data from the perspectives of patents and publications reveals that research on hybrid materials in general is still growing. The synthetic methods described in the literature for combining mineral and organic components at the molecular or nanoscale. Several techniques can be used to create organic–inorganic hybrid compounds: (i) the introduction of organic materials into an inorganic host that has already been produced (using simple intercalation by ionic or molecular exchange, sometimes followed by chemical grafting (clays, LDHs, mesoporous oxides, etc.) in porous or lamellar hosts), (ii) the synchronous growth or dispersion of both organic and inorganic networks (kinetics can be set by experimenting with two catalysts); (iii) the inorganic component processing around the organic host; (iv) the organic component processing from the inorganic core or coupling to the inorganic core; and (v) the in situ generation of inorganic components in a polymeric network (typically nanofillers in a polymer).

Four main chemical pathways may be distinguished among the chemical techniques utilized to synthesize hybrid materials. The latter are linked to the inorganic phase's selected growth

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mode. When a metal oxide or metal oxopolymer—such as silica or silicates—makes up the mineral component, It can be formed by nonhydrolytic polycondensation processes (M—O—M bonds generated by eliminating ether, ester, RCl, etc.) or hydrolytic (hydrolysis–condensation) processes. Covalent or ionocovalent bonding can be used to organically functionalize the mineral entity in order to do the hybridization. The organic group in issue might be an organosilane, an organic complexing ligand, a polymerizable group, or anything with a simple function (hydrophobic, optical, etc.). By joining the metal centers or the oxo metallic clusters—which can be created by hydrolytic or nonhydrolytic processes—the complexing ligand can result in the creation of coordination polymers if its functionality is equal to or higher than two. Similarly, by functionalizing their surfaces with ligands, additional inorganic substances, nanometals, nanophosphides, etc., may be hybridized.

Engineering flaws, heterogeneities, or disorder in hybrid materials can result in new characteristics and structural optimization. From a historical perspective, the hybrid material's mineral component frequently outweighed its organic component, which typically served only as a sacrificial templating or guiding agent, in terms of ultimate properties, In order to boost their efficiency or integrate them into multifunctional devices, carbon-based materials with outstanding properties (fullerene, graphene, C-dot, carbon nanotubes, etc.) would need to hybridize with inorganic molecules or particles.An expanding shadow zone results from the creation of materials with increasingly intricate properties and uses while drawing inspiration from Mother Nature.

Despite extensive research into the ideas of biomimicking and bioinspiration, we are still a long way from the intricacy that defines organic systems. illustrates how a material or system's performances might be theoretically mapped out in three dimensions: The axes, which are evaluated on a scale from 0 to 1, stand for the three attributes of living systems: autonomy, integration, and cognition.The living materials are at the top of the cube with 111 coordinates, and the blue sphere here stands for the "ideal" efficiency degree of living systems. When it comes to the performance of artificial (nano)materials made by humans, the green zone represents the state-of-the-art.

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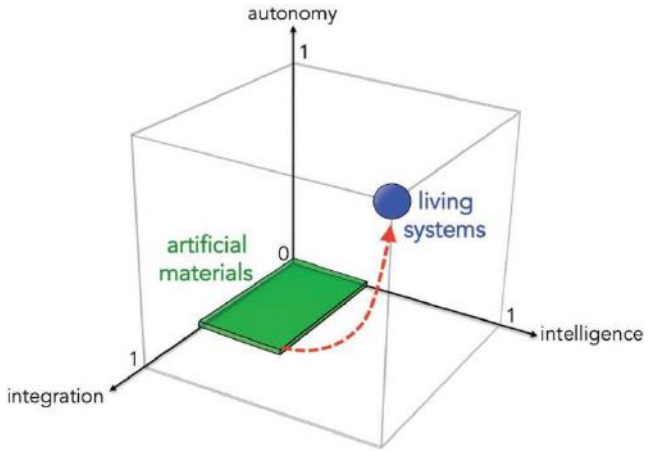

Figure 9. Material functionality in three dimensions.

Conclusion

The development of organic-inorganic hybrid materials from ancient times to contemporary inventions shows how much they have influenced human society. From traditional usage in art, architecture, and medicine to innovative applications in nanotechnology, biomedicine, and sustainable energy solutions, these materials—which blend the greatest qualities of both organic and inorganic components—have undergone significant development.The inventiveness of ancient craftspeople in utilizing natural composite systems is shown by the early usage of hybrid materials, such as Egyptian faience, Roman concrete, and medieval stained glass. Understanding hybrid structures—where inorganic phases like clays, metals, and minerals interact with organic binders like resins, waxes, and natural polymers—was made possible by these materials. These historical uses illustrate the long-standing value of hybrid materials in achieving durability, beauty, and utility.

As materials science has progressed, hybrid materials have gone from being used empirically to being logically constructed systems with exact control over their structure, content, and characteristics. Scientists are now able to create hybrids with improved mechanical, electrical, and optical performance because to advancements in sol-gel processing, self-assembled nanostructures, and functionalized surfaces. These days, organic-inorganic hybrids are essential for energy storage devices, flexible electronics, coatings, drug delivery systems, biomedical implants, and catalysis.

The future of organic-inorganic hybrid materials depends on how well they handle multifunctionality, sustainability, and biocompatibility. In order to create self-healing, eco-

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friendly, and energy-efficient materials, researchers are concentrating on bioinspired materials, which imitate natural hybrid systems like bone and nacre. Furthermore, it is anticipated that the combination of nanotechnology, AI, and quantum materials will push the limits of hybrid materials, resulting in innovations in high-performance composites, adaptable materials, and smart coatings. Scalability, recyclability, and cost-effectiveness issues still exist, nevertheless. In order to overcome these obstacles and create next-generation hybrid materials that support global sustainability goals, materials scientists, chemists, engineers, and industry specialists will need to collaborate across disciplinary boundaries.

From ancient civilizations to contemporary high-tech applications, organic-inorganic hybrid materials have proven their adaptability and revolutionary potential throughout history. These materials have the potential to completely transform a variety of industries, including electronics, energy storage, medical, and environmental technology, as long as study into their properties continues. Future hybrid materials have enormous potential to create a more efficient, technologically sophisticated, and sustainable society by fusing traditional knowledge with state-of-the-art scientific advancement.

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A REVIEW PAPER ON ECONOMIC ORDER QUANTITY MODELS TO IMPROVE MANAGEMENT EFFICIENCY

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Abstract

This paper provides a review on the basic Economic Order Quantity model, which is used to improve management efficiency in modern businesses. Inventories are company's assets, and as such, they constitute an investment. Because such investment necessitates a financial commitment, a company must keep enough inventories. If they grow too big, the company will miss out on opportunities. For businesses with complex supply networks and production processes, balancing the risks of inventory gluts and shortages is extremely tough. To attain these balances, businesses have devised inventory management techniques.

Keywords: Economic order quantity, Inventory management, demand. inventory gluts

1. Introduction

In inventory management, the choice regarding how much to order is crucial. Because the expenses of purchasing and transporting materials are quite expensive, the amount to be acquired should be neither little nor large. The EOQ is the maximum size of the property that may be acquired while being economically feasible. This is the amount of resources that can be acquired at the lowest possible cost. In general, economic order quantity is defined as the point at which inventory carrying costs equal order costs. It is one of the most ancient traditional production scheduling models. Ford W. Harris created this method in 1913, but R. H. Wilson is credited with its application and in-depth examination. The firms may minimise the cost of the ordering and inventory keeping utilising this strategy. It may be a useful tool for small company owners who need to decide how much inventory to have on hand, how many goods to order each time, and how frequently to reorder to keep prices down. Ordering costs and carrying costs are the two most essential types of inventory expenses.

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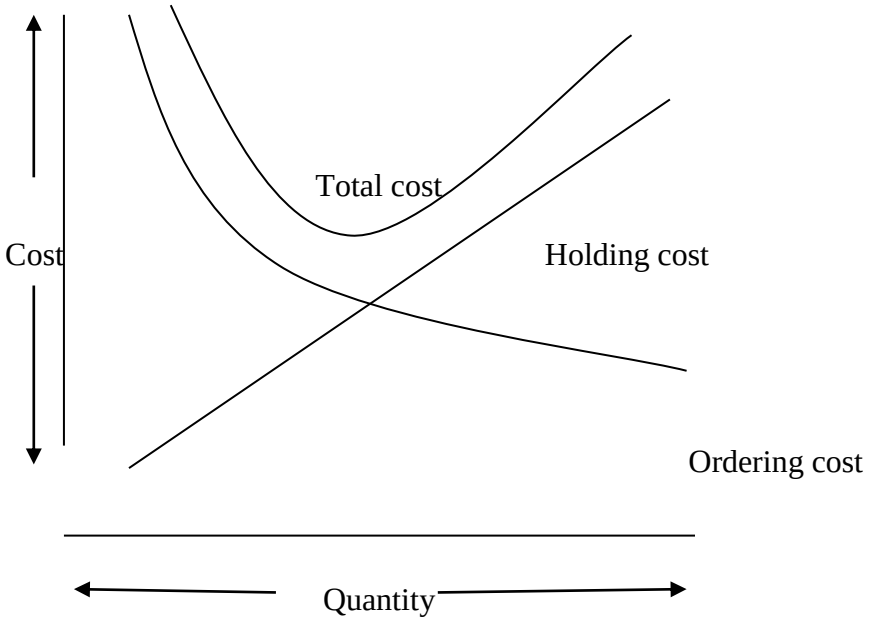

Figure – 1

Nature of Economic Order Quantity (EOQ) Costs

Ordering Costs:

These costs are incurred when supplies are purchased or ordered. These expenses include:

a) The cost of inspecting incoming supplies.

b) The cost of stationery, typing, mailing, and phone calls, among other things.

b) Costs associated with transporting purchased items.

These expenses are also known as purchasing costs, and they only appear when you make a purchase.

Carrying Costs:

These are the costs of storing inventory. If no inventories are kept, these expenses will not be incurred. Carrying cost includes:

a) The cost of capital spent in inventory. On the amount of capital held in inventory, interest will be paid.

b) The cost of storage space that could have been put to better use.

b) The price of insurance.

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d) Material handling spoilage costs.

It is obvious from the preceding explanation that ordering costs and carrying costs are diametrically opposed. If we want to keep our carrying costs low, we must place tiny orders, which raise our ordering costs. If we wish to reduce our ordering expenses, we must place fewer orders every year, which necessitates putting large orders, which raises the period's overall carrying costs. The confluence of the ordering cost curve and the carrying cost line defines EOQ since we want to maintain overall inventory costs as low as feasible. At this point, the total ordering cost equals the total carrying cost, and the sum of the two is the least.

2. Literature Review:

K. Skouri and I. Konstantaras (2009) invented an order level inventory model for seasonable products with time dependent demand. This model is very useful for the retailers or buyers in deciding the payment time and considering the profit of permissible delay in payments. The demand is assumed as linear with variable deterioration rate. The practicality of this study is increases with difference between the cost price and selling price. [2]

R. P. Tripathi (2013) also formulated an inventory model with time varying demand and different holding cost by considering two cases. In first case the demand rate is considered as constant and inn second case the holding case is considered as constant. The preliminary results of this research indicate that if we increase the holding cost and ordering cost the total inventory cost increases. [3]

N. Kumar and S. Kumar (2016) investigated a model for non-instantaneous items with considering two warehouses storage where the demand is dependent on stock with inflation affects. As result this model shows that, the total inventory cost decreases under net discount rate of inflation. [4]

D. K. Singh & S. Mahto (2018) also developed a model for optimization of ordering policies for a retailer. Two parameters weibull deterioration is also taken in consideration and assumed the demand as quadratic. This model is helpful to optimize the values of total order quantity under supplier credits. [17]

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3. EOQ Models:

There are some EOQ inventory models:

3.1 Economic Order Quantity (EOQ for purchase models) or Batch Economic Quantity model:

The following are some of the assumptions that have been made:

1. Uniform demand rate 'r'.
2. There is no lead time or replenishing time (sometimes known exactly).
3. The pace of production is limitless, i.e. it is instantaneous.
4. No shortages are permitted. (i.e. the cost of stocking up is nothing).

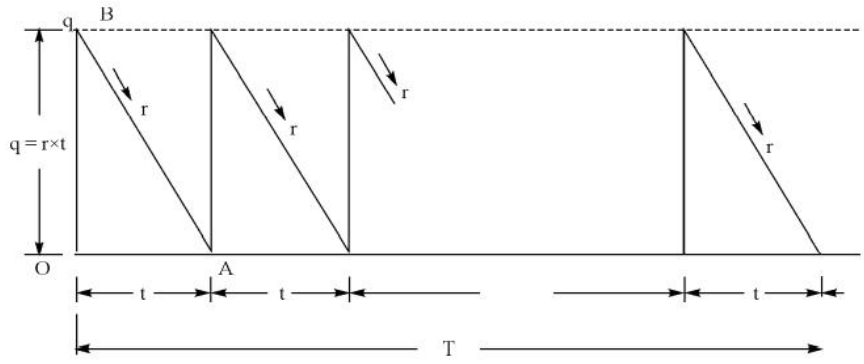

Figure – 2
Deterministic uniform demand with no shortages [1]

3.2 EOQ model of different rates of demand with different time periods:

In this model, the demand rate and the cycle period are both different.

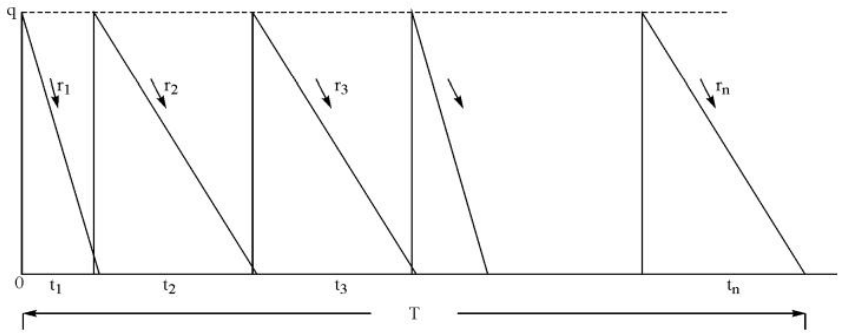

Figure – 3
EOQ model with different demand rates in different periods [1]

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3.3 **Quantity Discount Model:**

The vendor may give a discount to the buyer if he purchases a bigger quantity of products. The discount is the foundation of this concept. Discounts are divided into two categories:

(a) Discount on all units: In this case, the buyer receives a discount on all of the products he purchases, regardless of quantity.

(b) Incremental discount: In this case, the client receives a discount for each additional item purchased beyond a certain amount. [1]

3.4 Economic Lot Size: With a limited rate of replenishment and a consistent demand rate without shortages:

Assumption:

a) Manufacturing rate is greater than the demand rate.
b) Replenishment period is not zero.

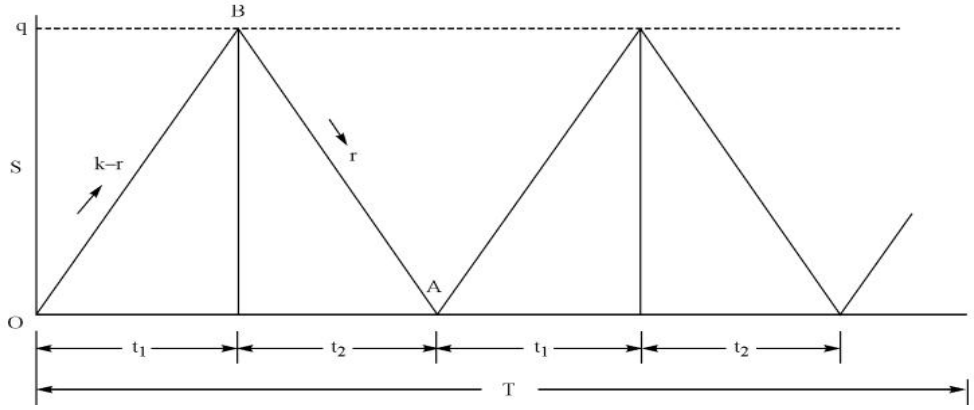

Figure –4

EOQ model for finite rate of replenishment [1]

3.5 Deterministic Models with Shortages:

When there is a demand for an item, but it is not accessible in stores, it is referred to as a shortage. As a result of this scenario, the business is unable to meet its delivery commitments. If the customer approves, the organisation will be able to fulfil his request as soon as the inventory arrives. If the consumer refuses, the company will have to cancel the order. The first is referred to as a backlog or backorder problem, whereas the second is referred to as a shortage or lost sales situation. When there is a backlog, the firm loses

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both the client and the earnings. If the stock out situation occurs frequently, the client may get unhappy with the service.

a) Instantaneous Production with back orders permitted:

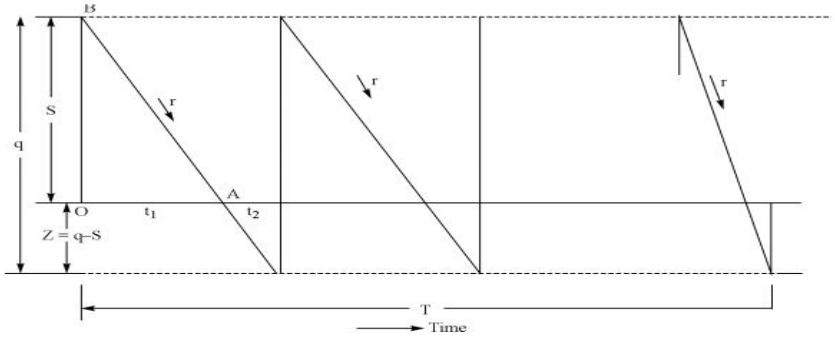

Figure – 5
EOQ mode for backorder [1]

a) Lost – Sales shortages:

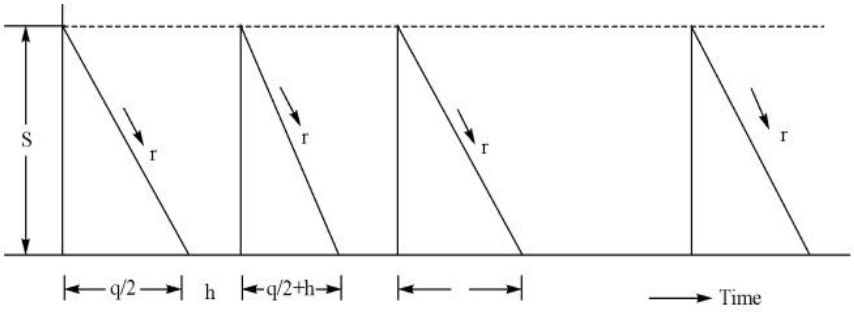

Figure- 6
EOQ model for lost sales [1]

3.6 Economic Order Quantity for Inventory Resupply at a Fixed Rate with Back Orders:

In this model the replenishment rate is finite and shortages are allowed.

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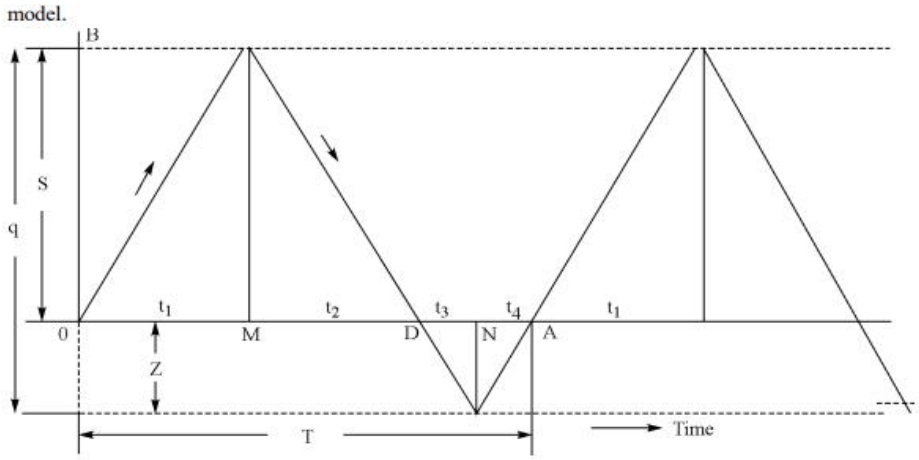

Figure – 7

EOQ model for finite replenishment with back order permitted [1]

4. Conclusion:

The EOQ is a very effective inventory control technique that may be used to manage finished items, work-in-progress, and raw material inventories. It regulates the acquisition and storage of inventory in order to ensure a steady flow of production while preventing excessive inventory investment. The goal of this study is to provide a summary of the available literature. This paper's main goal is to demonstrate the many characteristics and types of inventory control models that have been established.

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INVESTIGATION OF HEAT TRANSFER USING PERFORATED SQUARE FIN OF VARYING CROSS SECTION IN A RECTANGULAR DUCT

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Abstract

The main objective of the investigation is to quantify and compare the heat transfer rate, friction factor and enhancement efficiency at different Reynolds no, with different inter fin spacing ratio and different clearance ratio. At the time of the experiment all geometries of fin array are fixed. Air acts as working fluid with Prandlt number is 0.7. The flow regime is uniform and turbulent and the Reynolds number ranged from 7000 to 20,000 based on hydraulic diameter of the test section. The present study gives the experimental data on the heat transfer enhancement and corresponding pressure drop along the duct with the perforated fins and square uniform varying cross section. Here we analyze the square varying cross sectionals fins with cylindrical perforation. Clearance ratio and inter-fin spacing ratio are also the important parameters for the consideration. In this experiment various parameters are compared. In this investigation there are some range of important parameters like Clearance ratio defined as (C/H) is used 0, 0.33 and 1, The spacing ratio of inter-fin is (S_y/D) 1.2, and 1.8. The nusselt number and Reynolds number are considered as only performance parameters. There are three ranges of fin heights i.e. based on clearance ratio as 50 mm, 75 mm, and 100 mm. There is one circular perforation is provided to 17 mm from the base of the fin.

Keywords: Perforation, Fin spacing ratio, clearance ratio

1. Introduction

Basically, fins are extended surfaces which are used to increase the rate of heat transfer from the base which have higher temperature. This is achieved by increasing the surface area by utilizing the number of fins. The heat transfer takes place by convective heat transfer between the object and the surrounding fluid. Thus by adding the number of thin fins in a particular space is a suitable method foe convecting the maximum amount of heat from the base. Fins may be of

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different shapes such as equilateral triangle, rectangular, rod, square, tapered fins may be also used depending on the requirement. Fins are projected form and are used to generate the excessive amount of heat in a particular zone from hot surface. Fins are used effectively in that side where fluid have low heat transfer coefficient i.e. air .**Sara, O. N., Pekdemir, T., Yapici, et al. [3]**.In this paper heat transfer coefficient and the corresponding pressure drop over flat surface in a channel flow due to perforated rectangular cross sectional blocks attached on its surfaces are analyzed. **Ashok Tukaram Pise U. V. Awasarmol [9]** have claimed that Heat transfer enhancement in fins can be increased by using the porous fins. In the past experimental investigation has been conducted to analyze the natural convection heat transfer from solid and permeable fins, **B. Yazicioğlu, H. Yüncü [7].** Natural convection heat transfer from aluminum vertical rectangular fins extending perpendicularly from vertical rectangular base was investigated experimentally. Thirty different fin configurations were tested. From the investigations, it can be concluded that there are number of factors which decides the fin performance like geometric parameters of fin array, fin height, fin length and fin spacing, and base to ambient temperature **M.R. Shaeri, M. Yaghoubi [8].** Numerical investigation is made for three-dimensional fluid flow and convective heat transfer from an array of solid and perforated fins that are mounted on a flat plate. Incompressible air as working fluid is modeled. The basic idea to use perforated fins are they have higher contact area with fluid in comparison with solid fin. So the average friction drag for perforated fins is higher compared to solid fin and also it increases by adding perforations, **Kavita H. DhanawadeȦ,Vivek K. SunnapwarȦ and Hanamant S**. **[10]** This paper reports an experimental study to investigate the heat transfer enhancement over horizontal flat surface with rectangular fin arrays with lateral square and circular perforation by forced convection. The Nusselt numbers of perforated fin arrays as well as solid fin arrays increases with increase in Reynolds number. **B. A. Brigham G. J. Van Fossen[13]** Transfer from short pin fins than from longer pin fins found in tube banks and other similar configurations. Assessments of the effect of the number of pin rows and row geometry have also been made. The pin length to diameter ratio is the dominant factor in the level of array-averaged heat transfer coefficients for short pin fins, **U. V. Awasarmol and Dr. A. T. Pise[15]** Experimental studies were conducted to analyze the natural convection heat transfer from solid and permeable fins and also the effect of angle of inclination of fins on heat transfer. This paper is outcome of experimental study conducted to compare the rate of heat transfer with solid and

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permeable fins and the effect of angle of inclination of fins, **Jaber Al Hossain 1, Kazi Ehsanul Karim[14]** This paper is concerned about an experiment in which a solid annular fin was mounted on a cylinder. The cylinder was filled with water. Engines of two wheeler four stroke vehicle cannot be cooled by water cooling system due to lack of space.

1.2 Principle of Heat Transfer by Pin Fin

In thermal engineering a fin is a heat reservoir that is particularly used to transfer the heat from the base without raising the temperature of the base exceed the limit. Practically fins are used in electronic devices that have a higher temperature for a shorter period of time may cause damage of base material. Fins transfer the heat to the surroundings by different modes like as convection, radiation, and conduction. Temperature difference is the main cause of heat transfer between the fin and surrounding. Surrounding may be steam, air, oil, brine solution or water.

The rate at which heat is transferred by physical phenomenon, q_k, is proportional to the product of the gradient and therefore the cross-sectional area through that heat is transferred.

$$q_k = -kA\frac{dT}{dx}$$

Consider an arrangement of fin in a duct, where air smoothly flows inside the duct, as shown in Figure 2. It is assumed that the base temperature of fin blocks occupies higher temperature than the air. Applying the low of conservation of energy, for the steady-state conditions, hence by the Newton's law of cooling to the temperature nodes as shown in Figure 2 gives the following set of equations

$$\dot{Q} = \dot{m}c_{p,in}\left(T_{air,out} - T_{air,in}\right)$$

$$\dot{Q} = \frac{T_{hs} - T_{air,av}}{R_{hs}}$$

$$T_{air,av} = \frac{T_{air,in} + T_{air,out}}{2}$$

2. Experimental Investigation

An experimental investigation has been carried out to generate data on heat transfer coefficient, friction factor, pressure drop. Experimental data have been calculated on a insulated duct under similar flow and geometrical condition. In this order to have direct comparison of performance of perforated fins with varying cross section with the heating arrangement in an insulated duct

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with steady state flow characteristics. The details of experimental set-up, procedure, experimental results are described in the following section:

2.1Description of Experimental Set-Up

The schematic diagram of experimental set-up for present investigation is shown in figure 2.1. The set-up has been designed, fabricated and used for the data collection on fluid flow and heat transfer characteristics of the fin array**.** The tunnel is constructed of wood of 20mm thickness. It had an internal cross-section is 100mm width and 250 height. The total length of the channel is 1000mm. The duct will be operated in force draught mode by the help of blower of 0.5 H.P., 0 to 13000 rpm, 32W power supply, 0.02156 to 0.060971Kg/s mass flow rate, orifice manometer column of 3 to 24 cm and convergent part of the tunnel which is positioned horizontally. The tunnel has convergent and divergent part inclination of 30^{o}.The Reynolds number range is used in this experiment was 7000-20000. It is based on hydraulic diameter of the wooden rectangular channel (D_h=142.85) and the average velocity (U). Heater unit of test section has insulation of cross section of 250mm x250 mm. The heater is consists of an electrical heating arrangement placed upon the fin block array. The heater output has power of 32W and 80V and current of 0.4A. The heater unit is mounted of wooden block insulation of 270mm x 270mm. The base plate is made up of Al-1050 having the dimension 250mm x250mm and thickness of the base plate is 6 mm. The fins and base plate are made of same material due to the consideration of thermal conductivity and the cost. Total 4 base plates are made among this one is without fin, three having perforated fin height of 50mm, 75mm, 100mm and one base plate is without fin. The corresponding clearance ratio is 0, 0.33, 1,The spacing ratio in the stream wise direction (S_y/D) were 1.2mm, 1.8mm, which giving the different number of fins over the fin block. It is well known fact that the inter fin spacing in the span wise direction decreases the flow blockage is increase thus the pressure drop will increases. The inter fin spacing in the stream wise direction is not considered in this study.

The temperature of the base plate is measured by digital temperature indicator which is directly connected to the six T-type thermocouple. There are two thermocouples are attached on the inlet and outlet of the test section of the duct. Two manometers attached in the set up, one is near to the orifice meter and other is at the inlet and outlet of duct.

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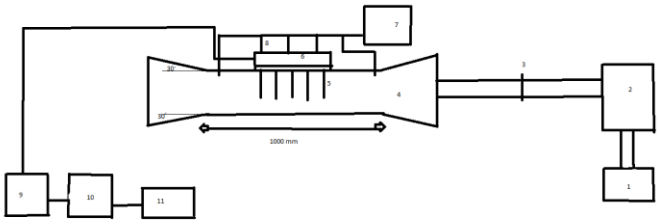

Fig1. 1-Moter, 2-Blower, 3-Orifice, 4-Duct, 5-Fins, 6-Heater, 7-Digital Temperature Indicater, 8-Thermocouples, 9-Ameter, 10-Voltmeter, 11-Power Supply

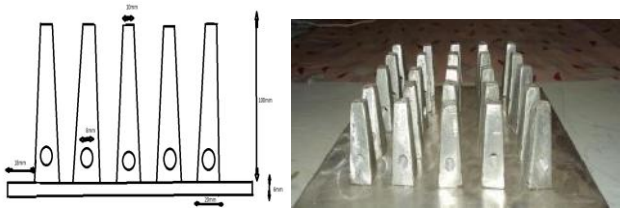

Fig.2 Fin Arrangement

Fig.3 Experimental setup

2.2 Methodology of Experimental work

The experimental data has been collected by following procedure described in the various reference papers for the testing of the fin block array operating in a steady state forced convection heat transfer. Data pertaining to a given mass flow rate was collected at the time of steady state is gained. For a particular fin array the steady state was came within 3 hours approximate. Before starting the experiment we have to be ensure for the particular power supply, insulation of the heating arrangement, and proper insulation of the duct and duct fitting

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are examined leakage was sealed by using glass putty. The blower started as per standard procedure and after attaining steady sate at particular mass flow rate the temperature readings at various points on test plate, inlet and outlet sections of the duct was recorded using digital temperature indicator . Manometer readings for pressure drop across the duct were recorded for a particular fin block. Experimental data were collected for flow rates ranging from 0.021556 to 0.060971kg/s.

2.3 Range Of Parameters

1	Reynolds No	7000-20000
2	Clearance Ratio	0,0.33,1
3	Inter Fin Spacing Ratio	1.2 & 1.8
4	Pitch	18

2.4 Validation Of Experimental Set Up

The value of Nusselt number obtained from testing of plate without fin(solid plate) is compared with relation given by Shah & Bhati for similar conditions. The deviation in the values of Nusselt number is in the range of ±10 %.

$$Nu_s = 0.07\ Re^{0.716}\ Pr^{0.33}$$ (Shah & Bhati)

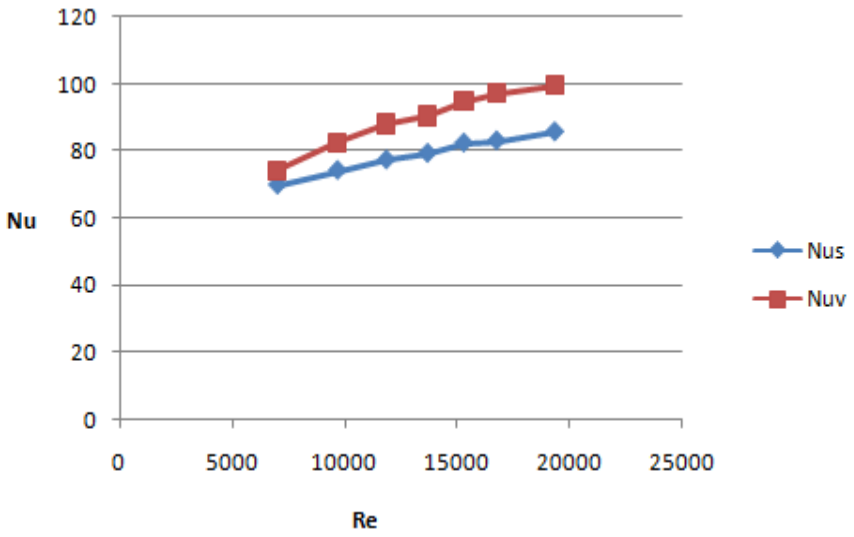

Fig.4 Validation of experimental setup

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The value of friction factor obtained from testing of plate without fin (solid plate) is compared with relation given by **Blasius** for similar conditions. The deviation in the values of friction factor is in the range of ±7 %

$$f = 0.316\ Re^{-0.25}$$

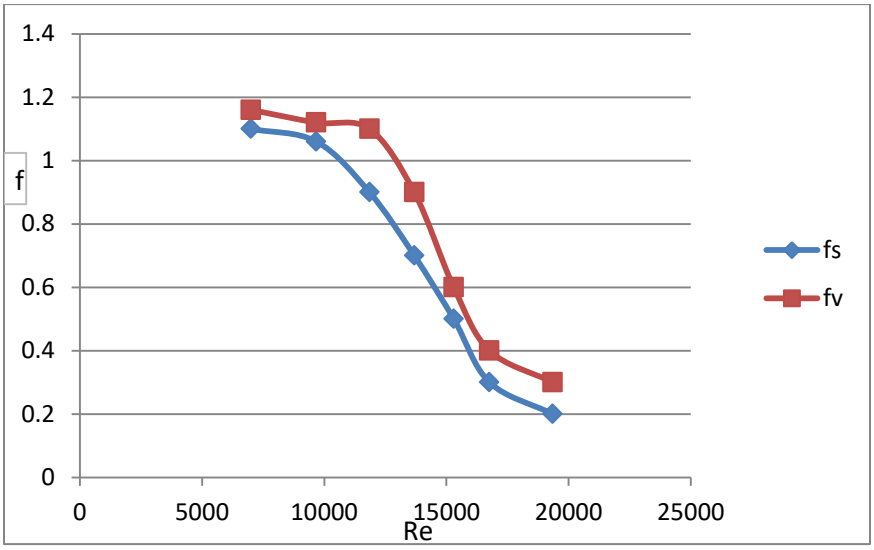

Fig.5 Validation of experimental setup

5. Result and Discussion

5.1 Heat Transfer

In order to have a basis for the evaluation of the effects of the fins, some experiments carried out with fin & without fin and compare the performance. Variation of parameters like nusselt no, heat transfer coefficient, friction factor and enhancement efficiency are analyzed with different Reynolds no. with different configuration (clearance and pitch) data has been recorded and calculated. Heat transfer coefficient, Nusselt no. increases with increase in Reynolds no. Height of fin also affects the heat transfer rate because flow field is obstructed by different height of fin. Various parameters calculated and their values are shown in the graphs given below

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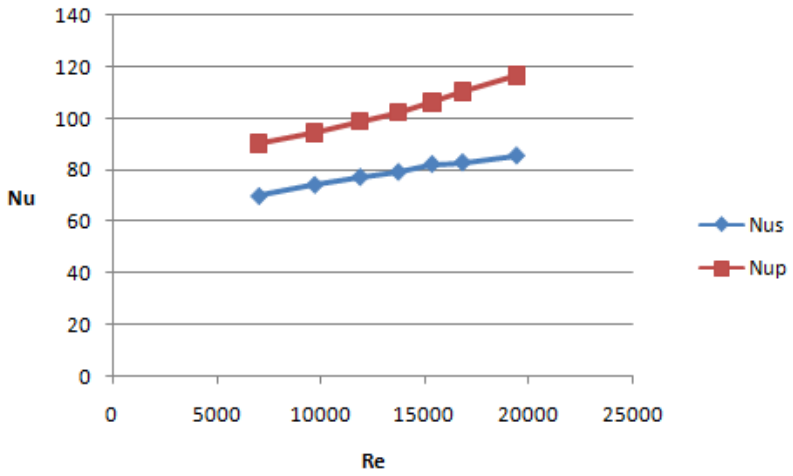

Fig.6 Comparison of Nusselt no. vs Reynolds no. for C/H =1, S_y/D=1.2

Heat transfer coefficient increases more rapidly in case of shorter fin because more fin height reduces the bypass area over the fin tips, Thus resistance against to the flow increases.

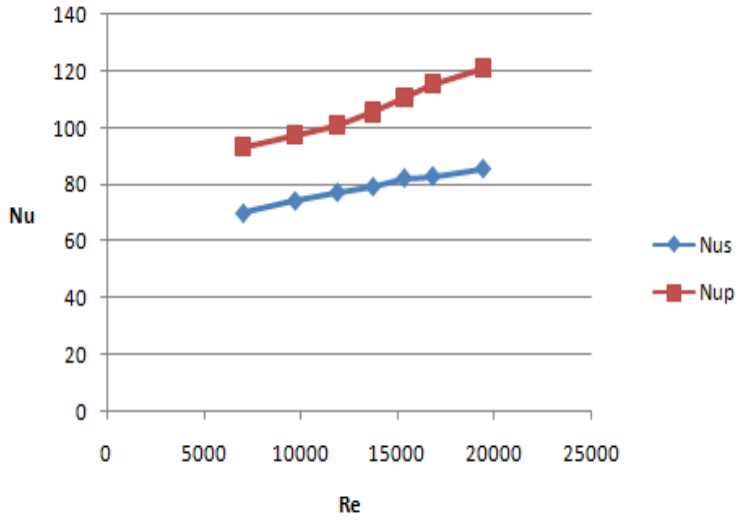

Fig.7 Comparison of Nusselt no. vs Reynolds no. for **C/H =0, S_y/D=1.2**

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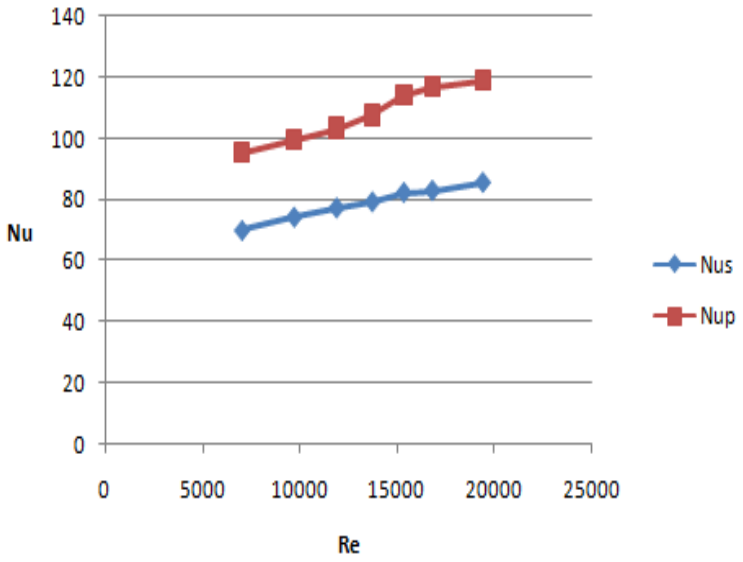

Fig.8 Comaprison of Nusselt no. vs Reynolds no. for **C/H =0.33, S_y/D=1.2**

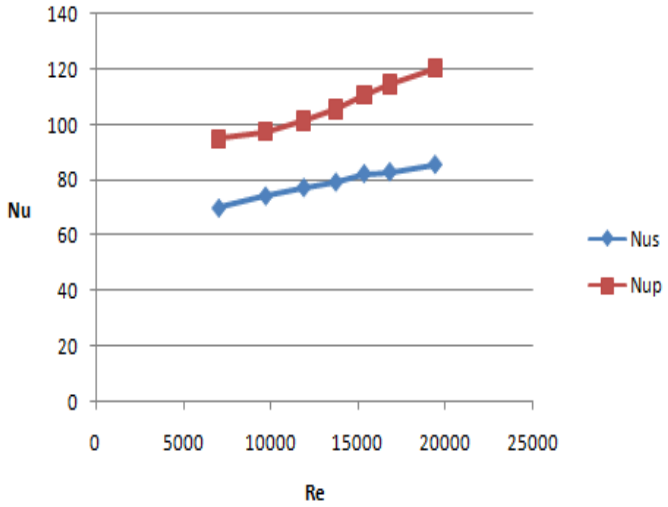

Fig.9 Comparison of Nusselt no. vs Reynolds no. **C/H =0.0, S_y/D=1.8**

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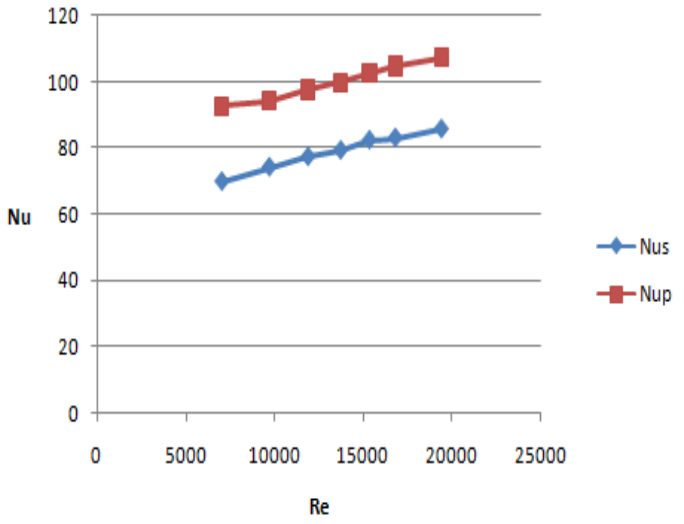

Fig.10 Comparison of Nusselt no. vs Reynolds no. **C/H =0.33, S_y/D=1.8**

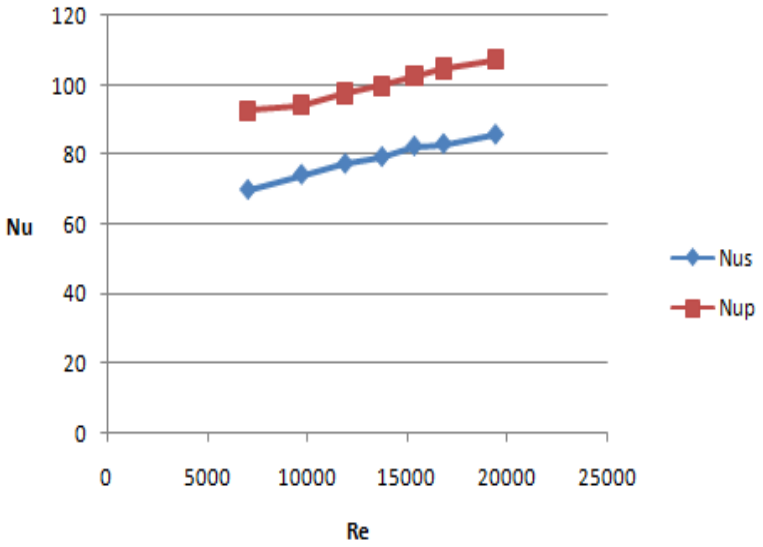

Fig. 11 Comparison of Nusselt no. vs Reynolds no. **C/H =1, S_y/D=1.8**

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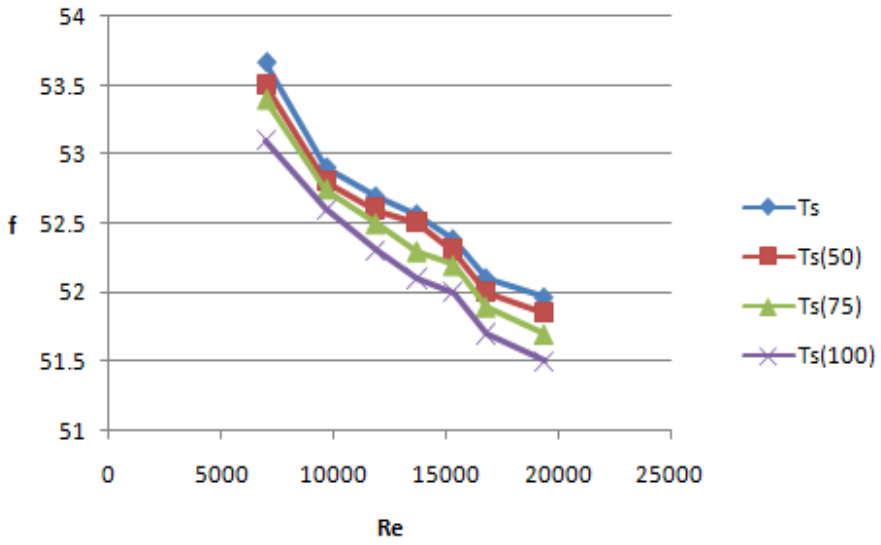

Fig.12 Variation of Friction Factor Vs Reynolds No. for different fin height and its comparison with plate without fin

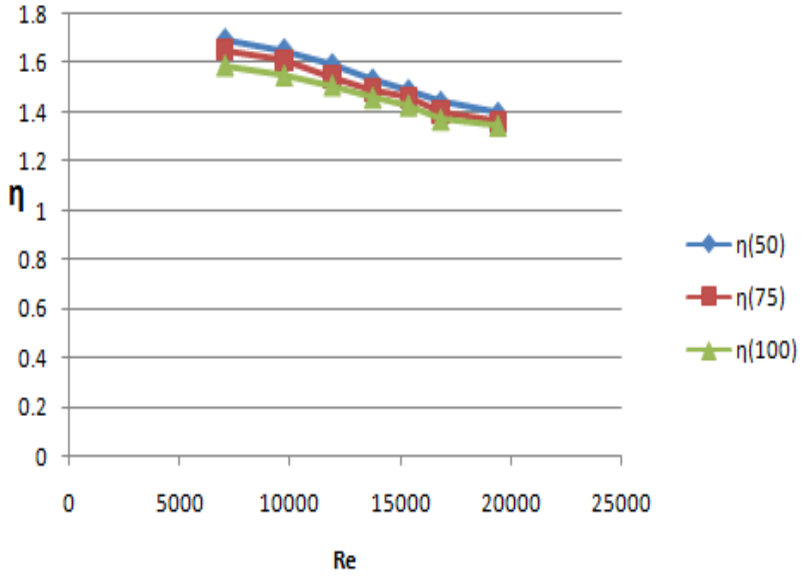

Fig.13 Variation of Enhancement efficiency(η) Vs Re & its comparison for different fin height

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5.2 Friction Factor

The pressure drop in the smooth channel is to be so small so the measurement of the pressure drop of the test section in the fin duct measured under the heated flow condition with help of manometer. Typical variation of the friction factor with Reynolds number is shown in fig11. Fricton factor decreases with increase in Reynolds numbers. Its value to be small for smooth surfaces and maximum for zero clearance ratio. Friction factor decreases with increases in Reynolds no.

5.3 Enhancement Efficiency

For a constant pumping power it is used to increase the enhancement efficiency of a heat transfer promoter in comparison with smooth surfaces. Enhancement efficiency decreases with increasing Reynolds number. This term gives the amount of heat transfer increased at the expense of pressure drop.

6. Conclusion

Present work has been done with the objective of investigation of fin performance with perforations for different clearance ratio and fin height. Various parameters like pitch, clearance, and geometry are analyzed at different Reynolds no. It has been observed that perforation enhance the performance of fin element. Range of Reynolds number (7000 -20000) investigated experimentally at constant heat supply. The results obtained from experiment show that at Reynolds no. 19655 and 75 mm fin height and fin spacing ratio of 1.2. The value of heat transfer coefficient is 19.57 W/m2-K and the enhancement efficiency is maximum with value of 1.7.

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DESIGN AND CFD SIMULATION OF SUPERSONIC NOZZLE USING K-Ω TURBULENCE MODEL ON ANSYS FLUENT

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Abstract

The nozzle contour is plotted in MATLAB. The nozzle was simulated in ANSYS Fluent 16.0 with the same assumptions and boundary conditions with K-ω Turbulence models. The convergence criteria was set to 10^{-6} .With this model the minimum pressure in the test section is found to be 1.129bar and minimum temperature 160.5K. Velocity is found to be 536 m/s and corresponding mach no 2.09 approximately and the theoretical value of mach no. was calculated 514 m/s corresponding mach no 2.02. With an approximate error of 3.47%.

Keywords: MATLAB, Turbulence models, Mach no

1. Introduction

A supersonic wind tunnel is a test bed for examining the fluid mechanics and associated fluid phenomena for air travelling faster than the speed of sound. In order for the air inside the tunnel to reach supersonic conditions, the flow must be accelerated from rest through a converging-diverging nozzle. The Mach number produced in the test section is dependent on the area ratio between the test section and the throat of the nozzle In high speed wind tunnel theory, since the air is travelling at high velocities through the nozzle and test section, it can be assumed that the air flow is adiabatic. No heat is exchanged into or out of the wind tunnel. In addition, the acceleration of the flow is caused by extremely smooth Changes of the surface contour of the nozzle. Neglecting dissipative frictional and viscous effects, it can be assumed that the flow in the wind tunnel is both reversible and adiabatic, and hence isentropic. This ideal assumption is useful in determining theoretical physical characteristics of the flow in the wind tunnel for design purposes. In reality the viscous and dissipative effects cannot be ignored. The isentropic assumption also breaks down in the vicinity of any shock waves. The supersonic nozzle design

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work presented in this paper is designed for supersonic wind tunnel by using Method of Characteristics.

2. Background Review

A number of experimental, numerical and theoretical studies have been carried out by researchers on the flow characteristic of supersonic wind tunnels. **Madhu et.al** [1] simulated supersonic flow through the rocket nozzle using numerical method. The parameters like Mach number, static pressure and shocks were observed for conical and contour nozzles using axis-symmetric model in **ANSYS Fluent 16.0**. **Katlin et.al** [2] in their project involved the design of a Dual Bell Nozzle (DBN), which was then, modeled using ANSYS Fluent. A scaled DBN was also fabricated and tested in an in draft supersonic wind tunnel. **Nazar Muneam Mahmood** [3] in this research carried out a simulation of steady flow of a gas through a convergent divergent nozzle which had a varying cross sectional area. **Md. Akhtar et.al** [4] in their paper presented a method for design of two dimensional, supersonic nozzle design based on the theory of characteristics. Numerical solution was obtained for the two dimensional, steady, inviscid, irrotational and supersonic flow. Toufik Zebbiche [5] tried to trace the profiles of the supersonic axisymmetric minimum length nozzle to have a uniform and parallel flow at the exit section. A new supersonic wind tunnel was designed and built by Wilbur Chang [6] in the University of Illinois to enhance high-speed flow testing capabilities used for studying these flow-control devices. The new wind tunnel is a rectangular testing facility with a 5×5 square inch cross-sectional area in the test section.

3. Design Procedure

Nozzle contour is designed using “method of characteristics”. Contour is designed to expand the flow from M=1 at the throat to M=2.0 in the test section where the flow is to be uniform and parallel to the direction of flow at the throat. Method of Characteristics is numerical method of solving nonlinear differential equation of motion for inviscid flow. Since minimum length nozzle is to be designed, sharp-corner assumption has been made. For characteristics it can be proved that I) Along left running characteristics or across rightrunning characteristics, $\nu-\theta$= constant. 2) Along right running characteristics or across leftrunning characteristics, $\nu+\theta$= constant. (ν is Prandtl-Meyer function and θ is the flow turning angle) In the region to region method, the flow

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is divided into various regions by the incident and reflected characteristics (from the centerline). Now, with the help of ν and θ, Mach Numbers in the region can be calculated using the relations between ν

Table-3.1 Co-ordinate of Nozzle contour

Point	**x-coordinate**	**y-coordinate**
1	0.00	8.80
2	7.71	10.62
3	7.95	10.66
4	9.01	10.89
5	11.69	11.38
6	13.38	11.65
7	15.04	11.93
8	17.84	12.23
9	20.85	12.55
10	24.66	12.88
11	29.69	13.24
12	36.79	13.80
13	48.01	14.00
14	71. 72	14.41

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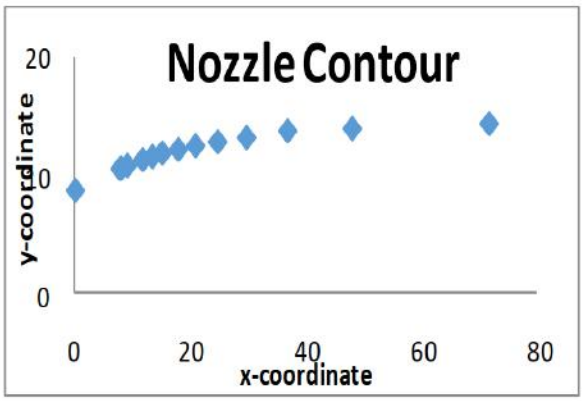

Fig.1 Divergent section of Nozzle

4. Theoretical Calculation Results

Assumption made in designing the wind tunnel

Flow is inviscid

Flow is considered to be isentropic (however at the shock plane the flow would no longer be isentropic).

The gas used is considered to behave as an ideal gas.

Properties of the gas (Nitrogen) used at room temperature. Molecular weight 28.013 Density

0.872 Dynamic viscosity 17.81micro pa-s Atomicity1.4 Gas constant 297 J/kgk Boiling point at 1bar= -195.8 degree Celsius Melting point at 1 bar= -209.2 degree Celsius Non corrosive

and fire resistance Stagnation pressure at inlet of nozzle= 792812.3017pa Stagnation temperature 300k Static pressure at inlet = 744844.327pa

Calculated pressure ratio for Mach number 2 is 7.8244

Maximum mass flow rate at this condition is 0.9602kg/s

This is the minimum mass flow rate required to get the supersonic flow

Area ratio from Mach number relationship at M=2 is 1.688

Designed area ratio 1.637

Test section velocity 524.5m/s

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Maximum achievable velocity at this energy of fluid 789.7467m/s this means that at this condition velocity in the test section reach 66.66% of the maximum velocity

5. CFD Simulation Results

Meshing of Nozzle

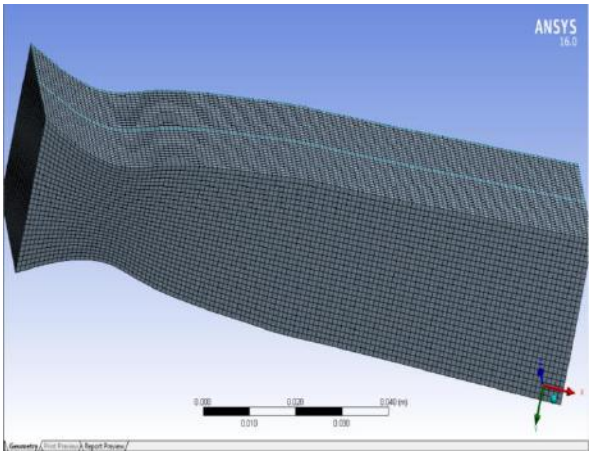

Fig.2 Grid Generation

Mesh description

Skewness	0.27176
Number of Nodes	481461
Number of Elements	450000

Table 5.1 Mesh Matrix

Mach Contour

Velocity corresponding to this Mach no. is 524.5

m/s in K-omega models expansion wave are seen which generated at the corner of the nozzle and continued in the divergent section.

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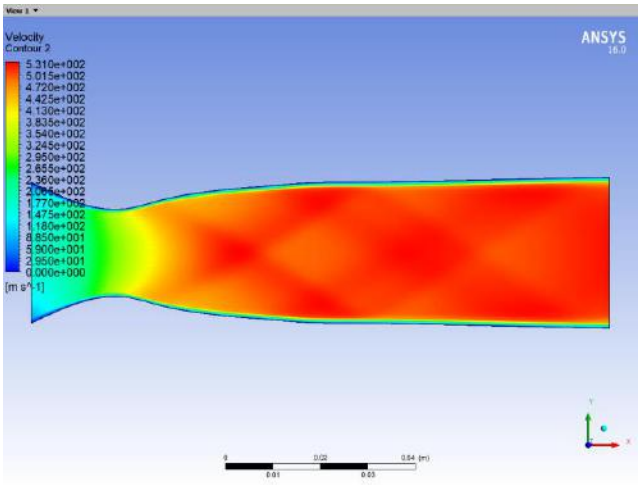

Fig.3 Velocity contour with expansion wave

Pressure contour

In this model the minimum pressure was found to be 1.129bar

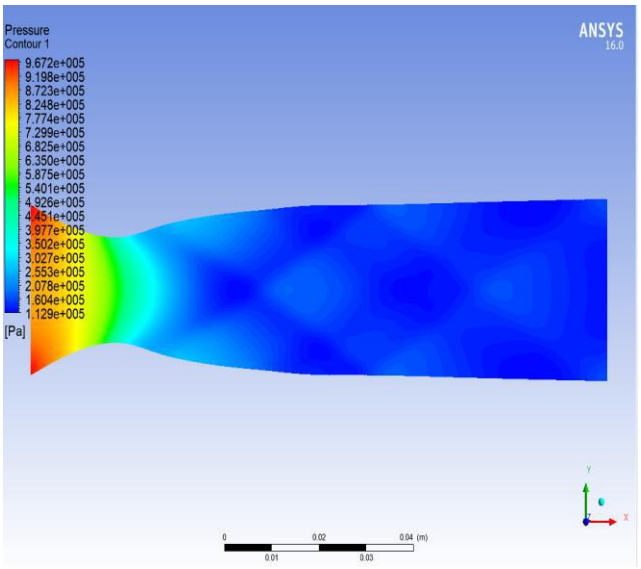

Fig.4 Pressure contour with expansion wave

Temperature contour

In this model minimum temperature was found to be 160k which in the divergent section of the nozzle

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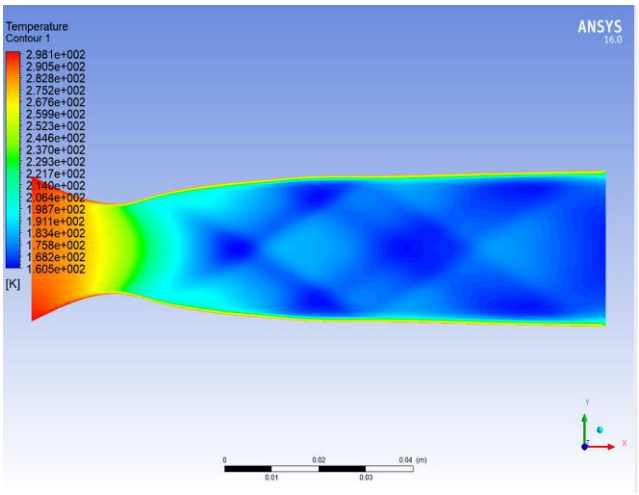

Fig 5 Temperature contour with expansion wave

Mach Curve

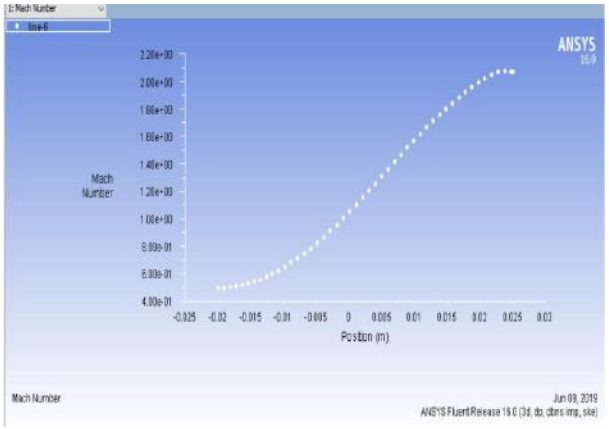

Fig.6 Variation of Mach No along the Nozzle

6. Conclusion

The supersonic nozzle is designed with the help of "Method of Characteristics" for a theoretical Mach number 2. The nozzle contour is plotted in **MATLAB**. The nozzle was simulated in **ANSYS Fluent 16.0** with the same assumptions and boundary conditions with K-**ω Turbulence** models. The convergence criteria was set to $\mathbf{10^{-6}}$ .With this model the minimum pressure in the test section is found to be 1.129bar and minimum

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temperature 160.5K. Velocity is found to be 531m/s and corresponding mach no **2.09** approximately and the theoretical value of mach no. was calculated 514 m/s corresponding mach no **2.02** with an approximate error of 3.47**%.**

Sr. No.	Properties	Theoretical Analysis	CFD Analysis (Turbulence Model)			|% Error1|	|% Error2|	|% Error3|
			Inviscid	K-Ɛ	K-ω			
1	**Velocity(m/s)**	514	524	531	536	1.94	3.30	4.30
2	**Pressure(bar)**	1.280	1.099	1.128	1.129	14.14	11.88	11.79
3	**Temperature(K)**	162.62	158.6	160.5	160.6	2.47	1.3	1.2

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FORECAST OF RELIABILITY FOR A SYSTEM HAVING REDUNDANT UNIT WITH WAITING IN REPAIR

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Abstract

In this paper the author considers a complex system with an identical unit in series and two units standby the complex system is divided into two sub systems A and B, and these having redundant units, if any subsystem fails then whole systems will be fail and repair should be provided. Using supplementary variable technique, the author has done mathematical formulation of the system.

Keywords- Complex system, Supplementary variable technique, Laplace transform, Study state behavior, Stand by redundant units, M.T.T.F.

1. Introduction

In this model, the author made his exercise to compute ability measures for a complex configuration network consists of n-identical units in series and two identical standby units. The whole system is being subdivided into two subsystems A and B which are connected in series. The subsystem B is having two identical standby redundant units B_1 and B_2. An imperfect switching device has used for change of functioning of these units. The system configuration is represented by fig1. Fig-2 shows the flow of states. The whole system may fail due to failure of its any of the subsystems. Immediate repair facilities are provided to the system for the failure of subsystem A, unit B_1 of subsystem B or both are in failed condition. The system has to wait for repair in case of repair of whole subsystem B.

2. Review & Literature:

In the previous years, no care is given for the concept of waiting in repair while in the practical situations it is not possible to arrange the repair facilities just after the failure. So, it is necessary for accurate results that waiting in repair must be taken into account while calculating the reliability parameters.

3. Material & Methods:

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Inclusion of supplementary variables technique is used for the formulation of mathematical equations for all possible flow-states. Further, Laplace transform is being used for the solution purpose of these equations. Probabilities for system being in different states have computed. Expressions for availability function, reliability and mean time to failure (M.T.T.F.) have also been computed. Time-independent transition state probabilities are driven together with a particular case, when all repairs are distributed exponentially in order to enhance practical utility of the study.

We may use the results obtained in this study to every network system of real life, with similar configurations. A numerical example and its graphical representation has also illustrated at the end to showcase important results.

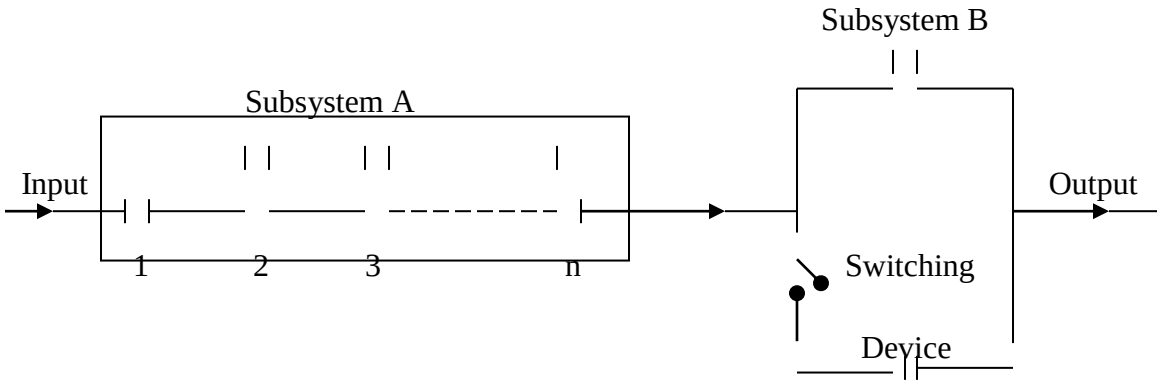
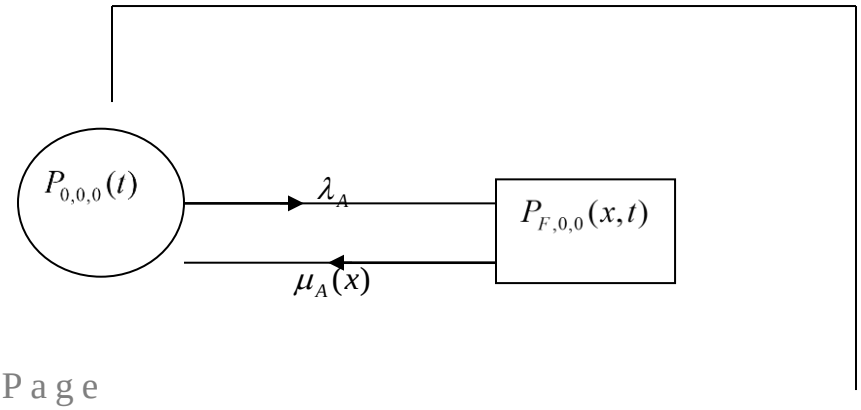


Fig-1: System configuration



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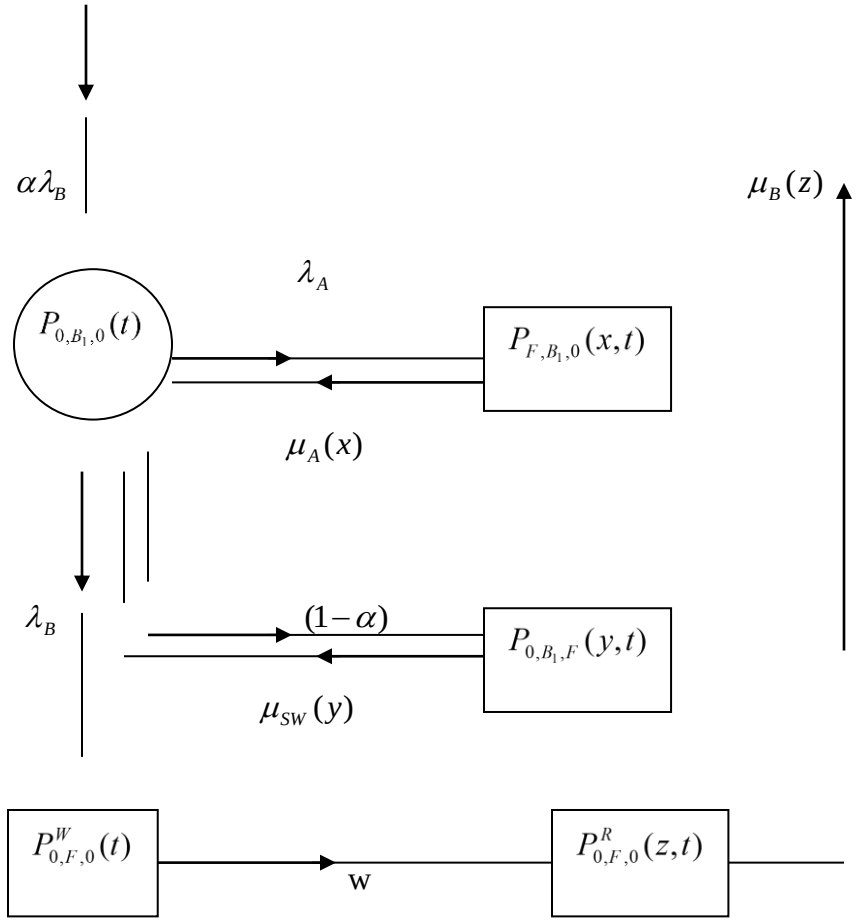

Fig-2: State-transition diagram

Assumptions associated with this research are as follows:

1. At t =0, the complete network is good and operable with full efficiency.
2. There are n units connected in series in subsystem A.
3. There is one standby unit in subsystem B and on failure of main unit, we can online standby unit through imperfect switching device.
4. All failures are distributed exponentially and are S-independent.
5. All repairs are distributed in general and are perfect.
6. System will wait for repair facilities in case of failure of both the units of subsystem B.
7. Repair to single failed unit of subsystem A will provide immediately.
8. In a failed state nothing can fail further.

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Nomenclature used for this research is described as under:

λ_A / λ_B : Failure rate of subsystem A/B.

$(1-\alpha)$: Failure rate of switching device.

W : Waiting rate for repair of whole subsystem B.

$\mu_i(j)\Delta$: First order probability that i^{th} failure can be repaired in the time interval $(j, j+\Delta)$ conditioned that it is unrepaired up to the time j.

$P_{0,0,0}(t)$: Pr {subsystem A, B and switching device is operable at time t i.e. the whole system is operable}.

$P_{0,B_1,0}(t)$: Pr {system is operable at time t while one online unit of subsystem B has failed}.

$P^{W}_{0,F,0}(t)$: Pr {system is failed at time t due to failure of subsystem B and is waiting for repair}.

$P^{R}_{0,F,0}(z,t).\Delta$: Pr (system is failed at time t due to failure of subsystem B and is ready to repair}. Elapsed repair time lies in the interval $(z, z+\Delta)$.

$P_{F,0,0}(x,t)\Delta etc.$: Pr (system is failed at time t due to failure of subsystem A}. Elapsed repair time lies in the interval $(x, x+\Delta)$.

$S_i(j)$: $\mu_i(j)\exp.\left\{-\int \mu_i(j)dj\right\}$ $\forall i$ and j.

$\overline{P}(s)$: Laplace transform (L.T.) of function P (t).

$D_i(j)$: $1-\overline{S}_i(j)/j$, $\forall i$ and j.

4. Results:

Formulation of Mathematical Equations

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Using limiting procedure and probability arguments [51], subjected to existence of limits, we obtained the set of difference-differential equations governing the behavior of system which is discrete in space and time-continuous, as follows:

$$\left[\frac{d}{dt}+\lambda_A+\alpha\lambda_B\right]P_{0,0,0}(t)=\int_0^\infty P_{F,0,0}(x,t)\mu_A(x)dx+\int_0^\infty P^R_{0,F,0}(z,t)\mu_B(z)dz \quad \ldots(1)$$

$$\left[\frac{\partial}{\partial x}+\frac{\partial}{\partial t}+\mu_A(x)\right]P_{F,0,0}(x,t)=0 \quad \ldots(2)$$

$$\left[\frac{d}{dt}+\lambda_A+(1-\alpha)+\lambda_B\right]P_{0,B_1,0}(t)=\alpha\lambda_B P_{0,0,0}(t)+\int_0^\infty P_{F,B_1,0}(x,t)\mu_A(x)dx$$

$$+\int_0^\infty P_{0,B_1,F}(y,t)\mu_{SW}(y)dy \quad \ldots(3)$$

$$\left[\frac{\partial}{\partial x}+\frac{\partial}{\partial t}+\mu_A(x)\right]P_{F,B_1,0}(x,t)=0 \quad \ldots(4)$$

$$\left[\frac{\partial}{\partial y}+\frac{\partial}{\partial t}+\mu_{SW}(y)\right]P_{0,B_1,F}(y,t)=0 \quad \ldots(5)$$

$$\left[\frac{d}{dt}+w\right]P^W_{0,F,0}(t)=\lambda_B \quad P_{0,B_1,0}(t) \quad \ldots(6)$$

$$\left[\frac{\partial}{\partial z}+\frac{\partial}{\partial t}+\mu_B(z)\right]P^R_{0,F,0}(z,t)=0 \quad \ldots(7)$$

Boundary conditions are:

$$P_{F,0,0}(0,t)=\lambda_A\ P_{0,0,0}(t) \quad \ldots(8)$$

$$P_{F,B_1,0}(0,t)=\lambda_A\ P_{0,B_1,0}(t) \quad \ldots(9)$$

$$P_{0,B_1,F}(0,t)=(1-\alpha)\ P_{0,B_1,0}(t) \quad \ldots(10)$$

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$$P^{R}_{0,F,0}(0,t) = w P^{W}_{0,F,0}(t) \quad \ldots(11)$$

Initial conditions are:

$P_{0,0,0}(0) = 1$, all other state probabilities are zero at $t = 0$. …(12)

Solution of the Model

Applying Laplace transforms to equations (1-11) with the help of I.C.'s (12), we obtain:

$$(s + \lambda_A + \alpha\lambda_B)\overline{P}_{0,0,0}(s) = 1 + \int_0^\infty \overline{P}_{F,0,0}(x,s)\mu_A(x)dx + \int_0^\infty \overline{P}^{R}_{0,F,0}(z,s)\mu_B(z)dz \quad \ldots(13)$$

$$\left[\frac{\partial}{\partial x} + s + \mu_A(x)\right]\overline{P}_{F,0,0}(x,s) = 0 \quad \ldots(14)$$

$$(s + \lambda_A + (1-\alpha) + \lambda_B)\overline{P}_{0,B_1,0}(s) = \alpha\lambda_B \overline{P}_{0,0,0}(s) + \int_0^\infty \overline{P}_{F,B_1,0}(x,s)\mu_A(x)dx$$

$$+ \int_0^\infty \overline{P}_{0,B_1,F}(y,s)\mu_{SW}(y)dy$$

…(15)

$$\left[\frac{\partial}{\partial x} + s + \mu_A(x)\right]\overline{P}_{F,B_1,0}(x,s) = 0 \quad \ldots(16)$$

$$\left[\frac{\partial}{\partial y} + s + \mu_{SW}(y)\right]\overline{P}_{0,B_1,F}(y,s) = 0 \quad \ldots(17)$$

$$[s + w]\overline{P}^{W}_{0,F,0}(s) = \lambda_B \overline{P}_{0,B_1,0}(s) \quad \ldots(18)$$

$$\left[\frac{\partial}{\partial z} + s + \mu_B(z)\right]\overline{P}^{R}_{0,F,0}(z,s) = 0 \quad \ldots(19)$$

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$$\overline{P}_{F,0,0}(0,s) = \lambda_A \overline{P}_{0,0,0}(s) \quad \ldots(20)$$

$$\overline{P}_{F,B_1,0}(0,s) = \lambda_A \overline{P}_{0,B_1,0}(s) \quad \ldots(21)$$

$$\overline{P}_{0,B_1,F}(0,s) = (1-\alpha)\overline{P}_{0,B_1,0}(s) \quad \ldots(22)$$

$$\overline{P}^R_{0,F,0}(0,s) = w\overline{P}^W_{0,F,0}(s) \quad \ldots(23)$$

Now simplifying (18), we have

$$\Rightarrow \overline{P}^W_{0,F,0}(s) = \frac{\lambda_B}{s+w}\overline{P}_{0,B_1,0}(s) \quad \ldots(24)$$

Solving (14) subjected to b.c. (20), we have

$$\overline{P}_{F,0,0}(x,s) = \lambda_A \overline{P}_{0,0,0}(s)\exp\left\{-sx - \int \mu_A(x)dx\right\}$$

integrating this w.r.t. x from 0 and ∞, we get

$$\overline{P}_{F,0,0}(s) = \lambda_A \overline{P}_{0,0,0}(s)\frac{1-\overline{S}_A(s)}{s}$$

$$\text{or, } \overline{P}_{F,0,0}(s) = \lambda_A \overline{P}_{0,0,0}(s)D_A(s) \quad \ldots(25)$$

Similarly, solving (16) and (17) subjected to b.c.'s (21) and (22), respectively, we obtain

$$\overline{P}_{F,B_1,0}(x,s) = \lambda_A \overline{P}_{0,B_1,0}(s)\exp\left\{-sx - \int \mu_A(x)dx\right\}$$

$$\Rightarrow \overline{P}_{F,B_1,0}(s) = \lambda_A \overline{P}_{0,B_1,0}(s)D_A(s) \quad \ldots(26)$$

$$\text{and } \overline{P}_{0,B_1,F}(y,s) = (1-\alpha)\overline{P}_{0,B_1,0}(s)\exp\left\{-sy - \int \mu_{SW}(y)dy\right\}$$

$$\Rightarrow \overline{P}_{0,B_1,F}(s) = (1-\alpha)\overline{P}_{0,B_1,0}(s)D_{SW}(s) \quad \ldots(27)$$

Again simplifying (19) subjected to (23) and (24), we get

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$$\overline{P}^{R}_{0,F,0}(z,s) = w\,\overline{P}^{W}_{0,F,0}(s)\exp\left\{-sz - \int \mu_B(z)dz\right\}$$

$$\Rightarrow \overline{P}^{R}_{0,F,0}(s) = \frac{\lambda_B w}{s+w} D_B(s)\overline{P}_{0,B_1,0}(s) \qquad \ldots(28)$$

Now simplifying (15) using relevant expressions, we have

$$[s+\lambda_A+(1-\alpha)+\lambda_B]\overline{P}_{0,B_1,0}(s) = \alpha\lambda_B\overline{P}_{0,0,0}(s) + \lambda_A\overline{S}_A(s)\overline{P}_{0,B_1,0}(s)$$

$$+(1-\alpha)\overline{S}_{SW}(s)\overline{P}_{0,B_1,0}(s)$$

$$\Rightarrow [s+\lambda_A+(1-\alpha)+\lambda_B-\lambda_A\overline{S}_A(s)-(1-\alpha)\overline{S}_{SW}(s)]\overline{P}_{0,B_1,0}(s) = \alpha\lambda_B\overline{P}_{0,0,0}(s)$$

$$\Rightarrow \overline{P}_{0,B_1,0}(s) = \frac{\alpha\lambda_B\overline{P}_{0,0,0}(s)}{s[1+\lambda_A D_A(s)+(1-\alpha)D_{SW}(s)]+\lambda_B}$$

$$\text{or, } \overline{P}_{0,B_1,0}(s) = A(s)\overline{P}_{0,0,0}(s) \qquad \ldots(29)$$

$$\text{where } A(s) = \frac{\alpha\lambda_B}{s[1+\lambda_A D_A(s)+(1-\alpha)D_{SW}(s)]+\lambda_B}$$

Finally, simplifying (13) subjected to related relations, we obtain

$$\overline{P}_{0,0,0}(s) = \frac{1}{B(s)}$$

Thus, we get the following L.T. of state probabilities in term of B(s):

$$\overline{P}_{0,0,0}(s) = \frac{1}{B(s)} \qquad \ldots(30)$$

$$\overline{P}_{F,0,0}(s) = \frac{\lambda_A D_A(s)}{B(s)} \qquad \ldots(31)$$

$$\overline{P}_{0,B_1,0}(s) = \frac{A(s)}{B(s)} \qquad \ldots(32)$$

$$\overline{P}_{F,B_1,0}(s) = \frac{\lambda_A D_A(s)\,\mathrm{A}(s)}{B(s)} \qquad \ldots(33)$$

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$$\overline{P}_{0,B_1,F}(s) = \frac{(1-\alpha)D_{SW}(s)\,\mathrm{A}(s)}{B(s)} \quad \ldots(34)$$

$$\overline{P}^{W}_{0,F,0}(s) = \frac{\lambda_B\,\mathrm{A}(s)}{B(s)(s+w)} \quad \ldots(35)$$

$$\overline{P}^{R}_{0,F,0}(s) = \frac{\lambda_B \mathrm{w}\,D_B(s)A(s)}{B(s)(s+w)} \quad \ldots(36)$$

where $A(s) = \dfrac{\alpha\lambda_B}{s\left[1+\lambda_A D_A(s)+(1-\alpha)D_{SW}(s)\right]+\lambda_B}$ …(37)

and $B(s) = s+\lambda_A+\alpha\lambda_B-\lambda_A\overline{S}_A(s)-A(s)\overline{S}_B(s)\dfrac{\lambda_B w}{s+w}$ …(38)

It is interesting to note here that Sum of equations (30) through (36) = $\dfrac{1}{s}$ ….(39)

$$P_{0,0,0} = \frac{1}{B'(0)} \quad \ldots(40)$$

$$P_{F,0,0} = \frac{\lambda_A M_A}{B'(0)} \quad \ldots(41)$$

$$P_{0,B_1,0} = \frac{\alpha}{B'(0)} \quad \ldots(42)$$

$$P_{F,B_1,0} = \frac{\lambda_A \alpha M_A}{B'(0)} \quad \ldots(43)$$

$$P_{0,B_1,F} = \frac{\alpha(1-\alpha)M_{SW}}{B'(0)} \quad \ldots(44)$$

$$P^{W}_{0,F,0} = \frac{\alpha\lambda_B}{wB'(0)} \quad \ldots(45)$$

$$P^{R}_{0,F,0} = \frac{\alpha\lambda_B M_B}{B'(0)} \quad \ldots(46)$$

where $M_i = -\overline{S}'_i(0) =$ Mean time to repair subsystem I

and $B'(0) = \left[\dfrac{d}{ds}B(s)\right]_{s=0}$

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Time-Independent States

Using final value theorem in L.T., *viz*; $\lim_{t\to\infty} P(t) = \lim_{s\to 0} s\bar{P}(s) = P(say)$, subjected to existence of limits, in equations (30-36) we compute the following time-independent state probabilities:

Particular Case

Case i: When all repairs are distributed in exponential manner

In this case, setting $\bar{S}_i(j) = \mu_i / (j + \mu_i)$, $\forall$ i and j, in equations (30-36), we obtain L.T. of probabilities of various states as under:

$$\bar{P}_{0,0,0}(s) = \frac{1}{E(s)} \quad \ldots(47)$$

$$\bar{P}_{F,0,0}(s) = \frac{\lambda_A}{E(s)(s+\mu_A)} \quad \ldots(48)$$

$$\bar{P}_{0,B_1,0}(s) = \frac{C(s)}{E(s)} \quad \ldots(49)$$

$$\bar{P}_{F,B_1,0}(s) = \frac{\lambda_A C(s)}{E(s)(s+\mu_A)} \quad \ldots(50)$$

$$\bar{P}_{0,B_1,F}(s) = \frac{(1-\alpha)C(s)}{E(s)(s+\mu_{SW})} \quad \ldots(51)$$

$$\bar{P}^{W}_{0,F,0}(s) = \frac{\lambda_B C(s)}{E(s)(s+w)} \quad \ldots(52)$$

$$\bar{P}^{R}_{0,F,0}(s) = \frac{\lambda_B w C(s)}{E(s)(s+w)(s+\mu_B)} \quad \ldots(53)$$

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$$\text{where } C(s) = \frac{\alpha\lambda_B}{s\left[1 + \frac{\lambda_A}{s+\mu_A} + \frac{(1-\alpha)}{s+\mu_{SW}}\right] + \lambda_B} \qquad \ldots(54)$$

$$\text{and } E(s) = s + \alpha\lambda_B + \frac{s\lambda_A}{s+\mu_A} - C(s)\frac{\lambda_B w\mu_B}{(s+w)(s+\mu_B)} \qquad \ldots(55)$$

Case ii: When we used the perfect switching device

In this case, putting $\alpha = 1$ in equations (30-36), we obtain the required results. Further, note that in this case, $\overline{P}_{0,B_1,F}(s) = 0$.

Reliability And M.T.T.F. Computation

Reliability of this network can be obtained as

$$\overline{R}(s) = \frac{1}{s + \lambda_A + \alpha\lambda_B}$$

or, $R(t) = L^{-1}\left\{\overline{R}(s)\right\}$

$\therefore$ $R(t) = \exp\left\{-\left(\lambda_A + \alpha\lambda_B\right)t\right\}$ …(56)

Also, $M.T.T.F. = \int_0^\infty R(t)dt$

$$= \frac{1}{\lambda_A + \alpha\lambda_B} \qquad \ldots(57)$$

AVAILABILITY OF THE SYSTEM

For the considered network

$$\overline{P}_{up}(s) = \frac{1}{s + \lambda_A + \alpha\lambda_B}\left(1 + \frac{\alpha\lambda_B}{s + \lambda_A + (1-\alpha) + \lambda_B}\right)$$

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$$\therefore P_{up}(t)=\left[1+\frac{\alpha\lambda_B}{(1-\alpha)(1+\lambda_B)}\right]e^{-(\lambda_A+\alpha\lambda_B)\,t}-\frac{\alpha\lambda_B}{(1-\alpha)(1+\lambda_B)}e^{-(\lambda_A+(1-\alpha)+\lambda_B)\,t} \quad \ldots(58)$$

Also, $P_{down}(t)=1-P_{up}(t)$

Numerical Computation

For a numerical demonstration, let us consider the following value set for parameters:

$\lambda_A = 0.45,\ \lambda_B = 0.37,\ \alpha = 0.7$ and t = 0,1,2, -----10.

t	R(t)
0	1
1	0.492136
2	0.242198
3	0.119194
4	0.05866
5	0.028869
6	0.014207
7	0.006992
8	0.003441
9	0.001693
10	0.000833

Table-1

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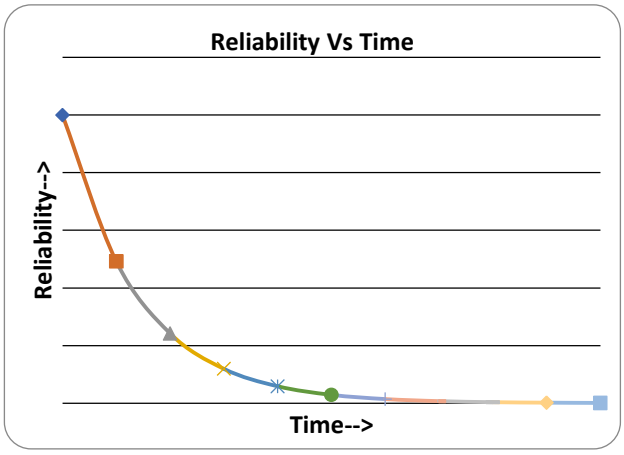

Fig-3

t	Pup(t)
0	1
1	0.596659
2	0.327741
3	0.17242
4	0.088485
5	0.044731
6	0.0224
7	0.01115
8	0.005529
9	0.002734
10	0.00135

Table-2

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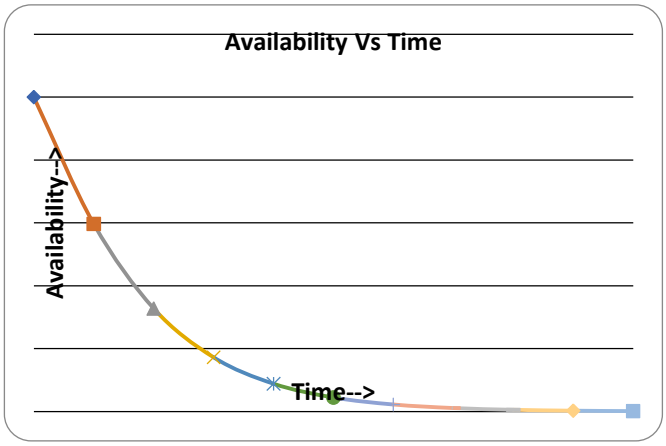

Fig-4

λ_A	**MTTF**
0	3.861004
0.01	3.717472
0.02	3.584229
0.03	3.460208
0.04	3.344482
0.05	3.236246
0.06	3.134796
0.07	3.039514
0.08	2.949853
0.09	2.86533
0.1	2.785515

Table-3

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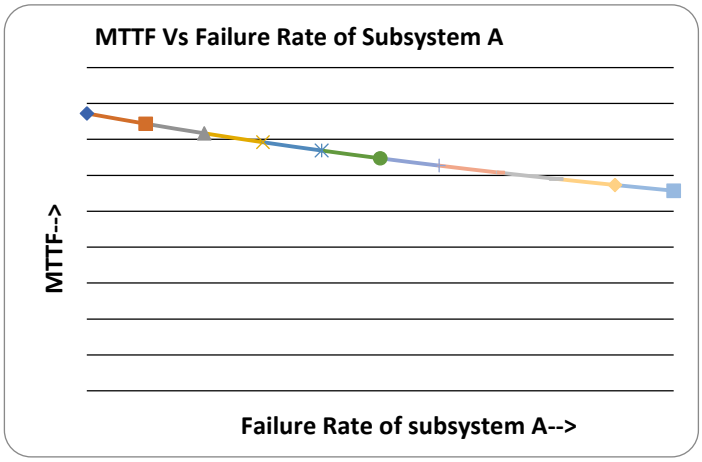

Fig-5

λ_B	**MTTF**
0	2.222222
0.001	2.218771
0.002	2.21533
0.003	2.2119
0.004	2.208481
0.005	2.205072
0.006	2.201673
0.007	2.198285
0.008	2.194908
0.009	2.191541
0.01	2.188184

Table-4

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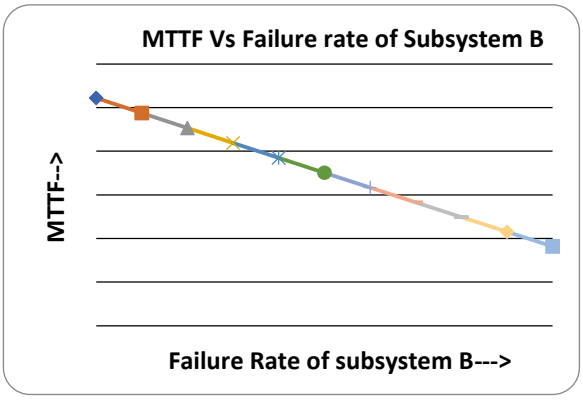

Fig-6

4. Discussion

Table-1 computes the reliability of system at different time t. Its graph has been depicted in fig-2. Analysis of these reveals that the reliability of system decreases approximately in consistent way and there are no jumps in the values of reliability.

Table-2 computes the availability. Its graphical representation is depicted in fig-3. Critical examination of these yields that value of availability decreases rapidly in the starting but after that it decreases constantly.

Table-3 computes the values of M.T.T.F. of system for different values of failure rate of subsystem B. Its graph has been sketched in fig-5. Analysis of these concludes that value of M.T.T.F. decreases.

Table-5 computes values of M.T.T.F. of system for different values of failure rate of subsystem A. Its graph has sketched in fig-6. Analysis of these predicts that value of M.T.T.F. decreases catastrophically.

5. Summary and Conclusion:

In this model, the author made his exercise to compute ability measures for a complex configuration network consists of n-identical units in series and two identical standby units. The whole system is being subdivided into two subsystems A and B which are connected in series. The subsystem B is having two identical standby redundant units B_1 and B_2. An imperfect switching device has used for change of functioning of these units. Inclusion of supplementary variables technique is used for the formulation of mathematical equations for all possible flow-states. Further, Laplace transform is being used for the solution purpose of these equations. Probabilities for system being in different states have

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computed. Expressions for availability function, reliability and mean time to failure (M.T.T.F.) have also been computed. Time-independent transition state probabilities are driven together with a particular case, when all repairs are distributed exponentially in order to enhance practical utility of the study. The results computed by this study are seems much better than in earlier study [79, 102]. We observe that the reliability, availability and MTTF remain comparatively higher than in [102].

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CREATIVITY: A SOUL OF MIND

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Abstract

This paper is a study of the digital Media and designer perspective to use media elements or artistic thoughts. The process of designing is not new since it's from the start of civilization when human used to have different form of designing. Gradually the time got changed with introduction of new technology so the art is also got changed accordingly. The main goal of this paper is establish the fact that it is very important to have a good media designer to make a good design and implementing creativity in design as much as it is necessary to give design principles and elements to. Good design varies from person to person and it is also possible that may be the design is correct according to the principles but not good in look and feel. When a designer follows the principles and proper use of element of designs he/she needs to have same amount of the artistic thought process to make a good design and to define the performance of his/her art with his thinking matching with the output. Sometimes a good design needs a little punch of artistic thought rather than a correct principle used in designing with long designing hours. In this, it is being told that how creativity is promoting digital media, somewhere creativity is contributing a lot. And in this paper have shown from analysis that it has worked.

Keywords- Digital Media, Artistic thought Elements, Principles, and Creativity

1. Introduction

The mentality or thinking of some people is that the creativity is a gift of God, yes we can say but if it is not a gift from God then it can be developed easily, only the thing required is a keen interest and also good observation. Creativity requires patience also.

Some people believe that the field of designing is not right for us because our or our child's creative thinking is not there but it is a wrong opinion because it is not necessary that every person is born before being creative. Creativity can also be created. And similarly some people think that designing can be improved only by the elements and principles of design, but we have been successful in proving that apart from that a good designer also requires a good designer. In this, we will solve this

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problem by an example. Just as in correcting a patient, it is not necessary to have the right doctor or medicine, in which the patient or the nurse who gives the medicine reaches the patient at the right time. Those who will be masters of this creative field will agree that we understand our children through the same Philosophy. But if we talk about the output, then every child's performance is different. The study will be done in two different ways.

Innate Creativity (God-Given Ability) Creativity; rather than being an otherworldly capacity, a mysterious and an arbitrary Go's blessing power under the syndication of set number talented individuals in the public eye, is a psychological and socio-social climate related aptitude found in all people at any age.

Learned Creativity (Acquired Artistic Thinking) In the field of graphic design, creativity refers to the problem solving abilities of students. The issues in design are often regarded as creative problems. A supernatural is the gift power of God which is bestowed on some people in the society which is affected by a cognitive and socio-cultural environment. As far as we have heard, creativity is a psychological effect that happens in any person from childhood, it is right from childhood. Also, elements to make good design works when there is an art called creativity in us. A design is said to be a good design not because of only elements but also because of good imagination and observations. Also, an individual need to keep in mind that the arrangement or plotting of the elements should be done carefully so that the design looks attractive and eye- catching. Design means we have to create a harmony and tone between different elements.

Design elements provide guidelines that assist graphic designers in their creative process:

Line – A fundamental design element that connects two points. In artistic terms, a line can be a random stroke or a deliberate visual component.

Color – Plays a significant role in conveying emotions and personality.

Shape – Created when an area is enclosed by a line, representing different objects.

Texture – Differentiates objects and adds depth to designs.

Scale & Size – Defines proportions and contrast within a composition.

The Design Process

Graphic design involves more than just arranging text and images. It follows a structured process:

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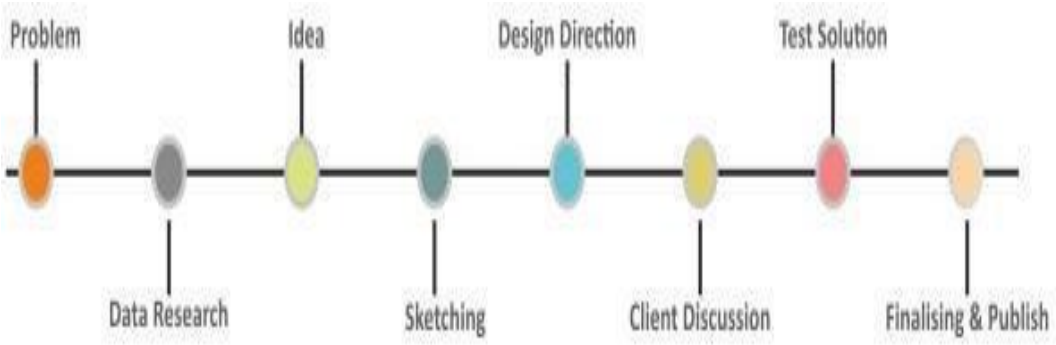

Designning Process

To bring their ideas to life, designers use various graphic design software, including Adobe Illustrator, Adobe Photoshop, Adobe In Design, and CorelDRAW.

Just it is mentioned that in which way a designer performs his art, similarly he/she needs a software to give a new look to his art. Our various types of graphics software are used such as Adobe Ilustrator, Adobe Photoshop, Adobe Indesign, & Corel Draw etc. That is one of the software I used to create a logo.

2. Survey and Competitive Analysis

A survey was conducted to analyze the importance of graphic design in different regions. The study covered metro cities, major cities, towns, and villages.

Table No. 1 A survey has been done to test different fields and to check their importance in the metro cities, major cities, towns and villages.

Source	Design element	Innovative	Illustration	Principal of design	Attractive
Metro City	80%	90%	70%	85%	95%
major city	90%	80%	90%	80%	95%
small city like village	75%	80%	80%	80%	95%
Town	80%	75%	80%	80%	95%

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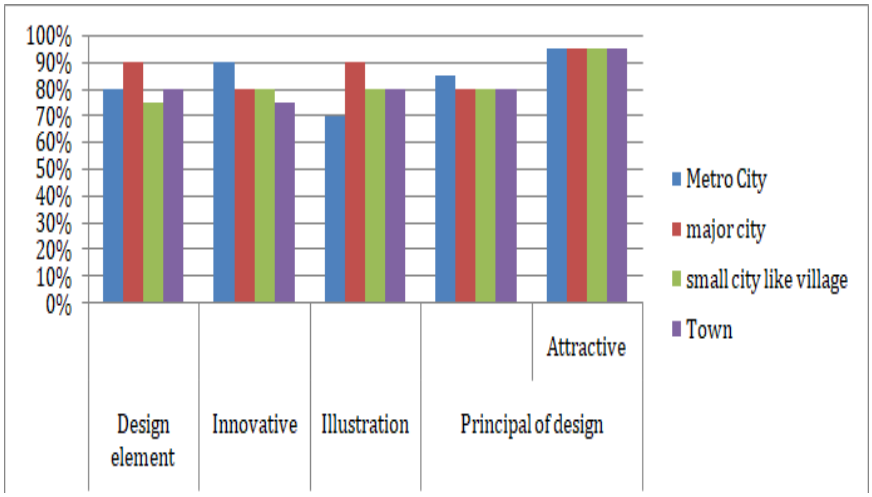
Table No. 2 Competitive analysis of a design in various city categories by class



2.1 Metro Cities

The table shows that the competitive analysis done by the class is very effective as compared to the previous ones. The total growth taken place in metro cities for Design element is upto 80% as more as compared to responsible for the proportions and contrast in the scene last one. Also, 90% took place in innovation field. Also, illustration a major factor for designing has increased upto 70%. The elements of design has taken place more effectively i.e upto 85%. Moreover the attractive field has also developed much i.e upto 95%.

2.2 Major Cities

The table shows that the competitive analysis done by the class is very effective as compared to the previous ones. The total growth taken place in major cities for Design element is upto 90% as more as compared to last one. Also, 80% took place in innovation field. Also, illustration a major factor for designing ha s increased upto 90%. The elements of design has taken place more effectively i.e upto 80%. Moreover the attractive field has also developed much i.e upto 95%.

2.3 Village and Towns

The table shows that the competitive analysis done by the class is very effective as compared to the previous ones. The total growth taken place in villages and towns for Design element is upto 75% as more as compared to last one. Also, 80% took place in innovation field. Also, illustration a major factor for designing has increased upto 80%. The elements of design has taken place more effectively i.e upto 80%. Moreover the attractive field has also developed much

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i.e upto 95%. The conclusion is that the progress took place in many years is good as compared to the previous ones.

Creativity thinking process is based on the creative process. It encourages children towards the growing phase of the creative process, both academic and professional, immersed in the arts and in addition to artistic skills, personal voice and the interaction of the unexpected. The way students are stimulated to imagine, examine, construct and reflect. That is why we need our children to learn art. So we must know how important it is to have creativity in any of our arts, then the question arises as to how we can increase our creativity, So here we have given you some tips with which you can dramatically improve your creativity.

Listening to music - Music is the type of hobby that most of the people have to have a resourceful piece of their mind. As according to many researches, music helps a person to divert their thinking and concentrate on whatever creative work they are trying to do. Calm state of mind brings the most creative thoughts and ideas in a person's brain, that's what music helps us for. The most generally a painter might work for hours if there is a good melody buzzing in his ears, his creativity and capability can be shown right through his work.

Live example –while walking on a park, you suddenly come across a beautiful wall painting. The creative mind of yours will be filled with the thoughts of what the painter might be conveying through it, hence your curiosity starts burning with the creativity. It is rightly said, we learn from our own surrounding. The examples present in front of us make us more willing to do something extraordinary each and every time. In this generation we are well aware of the influence of social media. But, we can easily gather lots and lots of ideas from the social media as well. Social media is one of the best platforms to show your creativity. Every time you dance, you can show it to everyone. It is just a better way to communicate with certain artists and as well as create something new and knowledgeable for the public to see.

The more you read, the more you gain. It goes like the more research you do on a topic, more creative you get. It is good if we learn a lot of new things every day, but we can't be good in each one of them. Our creativity flashes when we come across the thing that we are interested in, about which we have a wide knowledge. Quickly taking an example of a cricketer, we might say that he researches a lot about the game in his early matches and from time to time come with his own ideas of handling the bat and ball. This applies to everyone, the more you devote your time on researching, the more idealistic you become.

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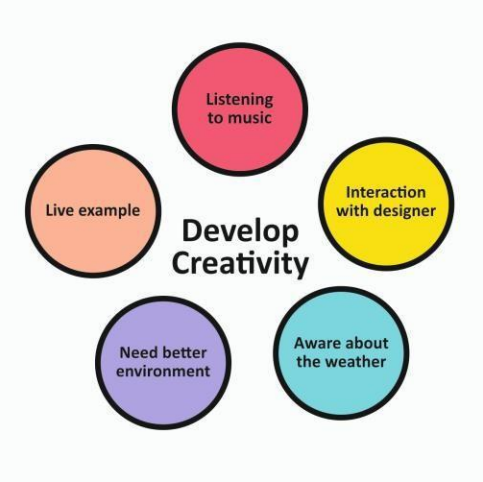
2.4 Need better environment- In an experiment it has been proven that, green and blue color in our surroundings enhance creative performance. Creativity spikes in dimly lit environment i.e., People feel more free to explore when a room is darker. Moderate and low level of ambient noise enhances your performance…



2.5 Aware about the weather- Creativity has a deep connection to the season because human also changes their mood by watching the changing season. We should also be aware of the changing weather with every season, at what time our product can be mixed with which theme. In winter season our mood is very calm and peace. Same as in rainy and in spring season but in summer season we feel so lazy and tired.

Interaction with designer- Those who are senior designers in this market or with us, we should stay in touch with them because we can become creative designers only when we know what trend is going on in the market and what kind of demand the customers are making. With the help of senior designer we learn so many things about the new design. Senior designers will tell so many things which are beneficial for us in upcoming future. Try to connect with your senior designers it will help you to find a good design or you become more creative.

3. Conclusion

We are all naturally creative and like every other skill. Some people have more natural talent than others. However, everyone increase his/her creativity. Just as everyone can increase his/her musical athletic ability with appropriate training and focused practice and these skills can be learn. Here the variety of people is there everyone is not so creative in comparison of others because everyone has their different thinking level and mind. Some of them can explore them in well creative manner but

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some can't explore them the question arises here why? Because they don't get proper training and practiced well.

Hence it is not God gifted it is created. If people have that courage and enthusiasm of learning and addiction towards learning new things makes their mind creative and gives innovative ideas. Thus, it is not genetic it is learned.

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UTILIZATION OF BRICK DUST AND FLY ASH AS A PARTIAL REPLACEMENT OF CEMENT IN CONCRETE

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Abstract

Concrete is second most used material on the earth after water and a freshly mixed material that can be moulded into any shape. The cement, aggregate and water mixed together in a particular proportion to control the properties of concrete in the wet as well as dry state.

Construction is the key for the development of any Nation. Cement is the most widely used construction material on the earth. The production of 1 ton of cement releases 0.9 ton of CO_2 in the atmosphere. This further pollutes the environment.

Some of the pozzolonic materials viz. fly–ash, brick powder, marble dust etc. are found to be possessing cementitious properties, hence the use of these waste materials can replace the cement by some percentage without compromising the strength and workability of cement. The reduction in the quantity of cement will reduce CO2 content in the atmosphere, thereby saving the environment and our mother earth.

1. Introduction

Concrete Mix Design is a procedure of determining the relative quantities and proportions of different ingredients of the concrete i.e. Cement, Water, Fine Aggregate, Coarse Aggregate, with the object of producing homogeneous fully compactable concrete having required Strength and Properties with economy.

Now days with the advancement of concrete technology, the mix design of concrete is in a boom due to the requirements of High Grades of Concretes with required amount of workability, durability and other properties. But the main factor is that these all properties are achieved by mix design and also comply with economy for producing a particular type of concrete grade. Concrete mix design should be as per IS code provisions.

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2 Materials and Methodology

2.1 Concrete

Concrete is a freshly mixed material that can be molded into any shape. The relative quantities of concrete are the cement, aggregate and water mixed together in a particular proportion to control the properties of concrete in the wet as well as dry state. The cement in concrete hydrates with water to act as a binder. The obtained result is a hardened mass with "filler" and pores.

There are various types of cement for low heat, rapid set and other properties. Other minerals or materials may be added for getting the result. The proper proportions by volume, of the mix constituents determine strength, which is related to the water to cement ratio (w/c). It also determines other properties, such as workability of fresh concrete. Vibration may also be used to get the mix to flow into forms and fill completely.

2.2 Cement

Cement in general sense are adhesive and cohesive materials which are capable of bounding particles of solid matter into a compact durable mass. For our project work, we use ordinary Portland Cement (OPC) of 43 grade.

2.3 Fly Ash and Brick dust

Fly ash, a waste generated by thermal power plants due to combustion of coal is as such a big environmental concern. Fly ash is the notorious waste product of coal based electricity generating thermal power plants, known for its ill effects on agricultural land, surface and sub-surface water pollution, soil and air pollution and diseases to mankind. Fly ash consists of finely divided particles ranging from 1 micron to 120 micron. Fly ash generally captured from the chimneys of coal-fired power plants, and is one of two types of ashes that jointly known as coal ash; other, bottom ash, is removed from the bottom of coal furnaces. Fly ash is very much similar to volcanic ashes used in production of the earliest known hydraulic cement about 2,300 years ago. For our project we bring fly ash from Dadri located thermal power plant

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Fig: 1 Fly –Ash

Brick dust is a waste product obtained from different brick kilns and tile factories. There are numerous brick kiln which have grown over the decades in an unplanned way in different part of the country. Tons of waste products like brick dust or broken pieces or flakes of bricks (brickbat) come out from these kilns and factories. So far, such materials have been used just for filling low lying areas or are dumped as waste material. Here we use brick dust by passing through 90 micron sieve

Fig: 2 **Brick dust**

2.4 Aggregate

Aggregate is a granular material, for instance, sand, rock, squashed stone, crushed pressure driven bond, or iron effect radiator slag, used with a water controlled building up medium to make either concrete or mortar.

2.4.1Coarse Aggregate

The aggregates which retained on 4.75 mm I.S. sieve are termed as coarse aggregates. Coarse aggregates provide strength to concrete. For this work, the aggregates passing through 20mm IS sieve and retained on 12mm IS sieve was used. The aggregate thus used in consists of both angular and rounded shape.

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2.4.2 Fine Aggregate

The aggregate which passes through 4.75mm IS sieve were used. Fine aggregates assist in producing workability and uniform mixture. For our work, the sand passing through 4.75mm IS sieve was used.

3.0 Methodology

In this research it was tried to replace the cement by equivalent fine BD (passing through 90 micron sieve). To achieve this we have carried out various test including workability and compressive strength.

The various combinations for replacement of cement with BD and FA were tried as under:

1.	5% BD & 5 % FA
2.	10% BD & 10% FA
3.	10% BD & 5% FA
4.	5% BD & 10% FA

In this experimental work attempt are made to replace cement with brick dust and fly ash. Both brick kiln dust and fly ash are waste materials and are dumped as waste, causing land scarcity and environmental pollution. For the comparative study of the compressive strength and workability the consistency are calculated before adding admixtures and after adding admixtures

4.0 RESULTS AND DISCUSSION

30 cubes were casted and the results thus obtained are shown in tabular form for the comparative study.

4.1 Workability Test

Comparison between workability of nominal M20 grade concrete, 5% (B.D. F.A.), 10% (B.D., F.A.), (5% B.D., 10% F.A.) and (10% B.D., 5% F.A.)

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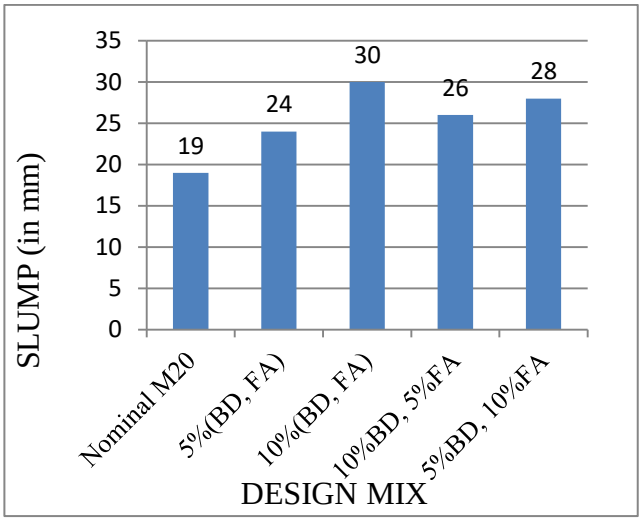

Fig: 3 Comparison b/w workability of various mix design

As far as workability of concrete is concerned it was observed that the slump was about 19mm for nominal M20 grade mix. When cement was replaced by BD & FA both 5%, the slump was increased to 24 mm i.e. an increase of about 26% in slump as compared to nominal mix & when further it was increased to 10% the slump was 30mm i.e. an increase of about 58% in slump, indicating more workable concrete.

It was also observed that when cement was replaced by 10% BD & 5% FA the slump was dropped to 25mm, but an increase of 6mm in slump as compared to nominal mix, means an increase of about 32% when compared with nominal mix. When cement was replaced by 5%BD % 10% FA the slump was again reached to 28 mm i.e. an increase of 9mm in slump as compared to nominal mix and in terms of percentage it is an increase of about 47% as compared to nominal mix.

From the above trials it was learnt that by increasing the quantity of FA the workability was increased. This shows that less w/c ratio is required after adding FA. Hence it was concluded that for more workable concrete few percent of FA can be used as a partial replacement of cement.

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4.2 **COMPRESSION TEST**

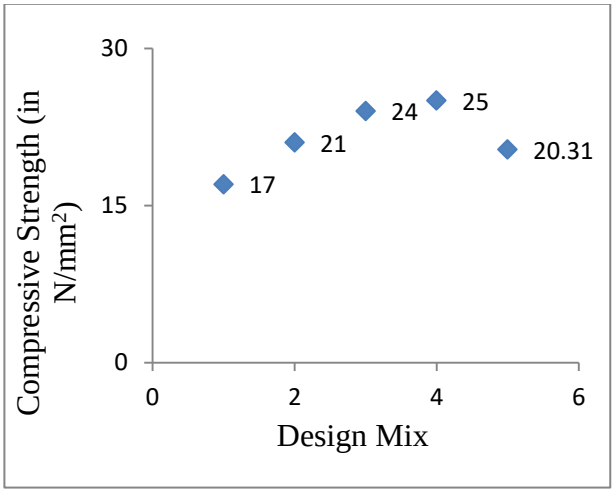

Fig: 4 Compressive strength of concrete at 14 days

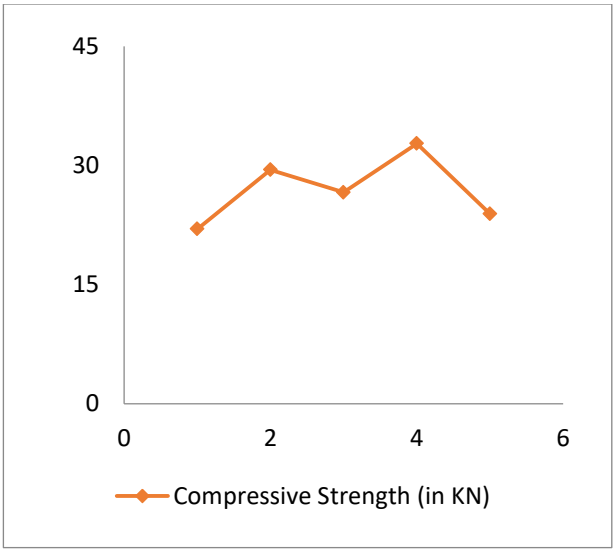

Fig: 5 Compressive strength of concrete at 28 days

When cement was replaced using 5% BD and 5% FA. The strength of cubes was 21 MPa and 29.46 MPa for 14 and 28 days respectively. When the quantity of cement with respect to nominal mix was replaced with 10% BD and 10% FA the compressive strength was 24 MPa and 26.63 MPa for 14 days and 28 days respectively. It was observed that the strength was increased by 7MPa and 4.63 MPa for 14 days and 28 days respectively as compared to nominal mix. It means there is an increase of about 41% for 14 days of compressive strength and an increase of about 21% for 28 days of compressive strength when it is compared to the nominal mix of M20 grade concrete.

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When the cement in nominal mix was replacedby 10% BD and 5% FA, the strength was 25 MPa and 32.76 MPa for 14 days and 28 days respectively. This was more by 8 MPa and 10.76 MPa for 14 days and 28 days respectively. It means there is an increase of about 47% at 14 days and an increase of about 49 % at 28 days in compressive strength as compared to nominal mix.

When the cement in nominal mix was replaced by 5% BD and 10% FA, the strength was 20.31 MPa and 23.93 MPa for 14days and 28 days respectively. This was more by 3.31 MPa and 1.93 MPa for 14 days and 28 days respectively. It means there is an increase of about 19% at 14 days and an increase of about 09 % at 28 days in compressive strength as compared to nominal mix.

5. Conclusion

From the above discussion as per the bar charts for compressive strength it was learnt that when the cement was replaced by 10% BD and 5% FA, the maximum gaining (i.e. of 25 MPa and 32.76 MPa for 14 days and 28 days respectively) was observed. The replacement of cement by BD can be a very useful concept.

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WIND POWER: A WORLD WIDE POTENTIAL SOURCE OF RENEWABLE ENERGY

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Abstract

The energy requirements of all the countries world wide are constantly increasing at a high rate on account of rise in population, fast economic growth, ramp and urbanization and industrialization. The conventional sources of energy like coal, oil and gas are non-renewable and hence depleting very fast and prove to be expensive for the governments to provide. As an alternative solution, the renewable sources of energy come into the picture including the solar, wind, hydro, geo-thermal and biomass. Solar and wind constitute the major part of renewable energy sources as they are freely available and create almost no environmental pollution. Despite the hype around solar, actually wind power has more economic, technical and environmental viability in India and it has been proved by the fact that India witnessed more added capacity of wind power as compared to solar in 2015-16. According to available reports, the wind power has much more potential in India then earlier estimated by the government. A brief about wind power, its present status in Rajasthan and India, its scope and potential in near future has been discussed in this paper.

Keywords—Wind power, Renewable energy, Wind farm, Wind turbine, Wind energy potential

1. Introduction

The requirement of energy has become one of the most important needs of the day for every human being on this earth. The population of the world is increasing by 0.9 percent per year on an average and the situation for India is especially grim because of the deficit on even existing demand levels. As such, there is a dire need for trapping and using non-conventional energy sources in India for our future needs. However, we know that grid extension in rural areas is often very costly, therefore, decent realized electricity generation with non-conventional energy sources such as solar, wind, hydro, biomass and energy from waste are most suitable to the increasing demand.

India is one of the fastest growing countries with regard to energy consumption. At present, it is the fifth largest consumer of energy in the world and it is expected to gain the third position by 2030. At the

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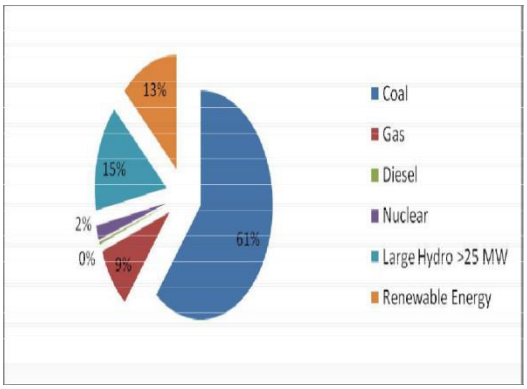
same time, the country is heavily dependent on fossil sources of energy for most of its demand; hence it is necessary to adopt alternative renewable energy sources.

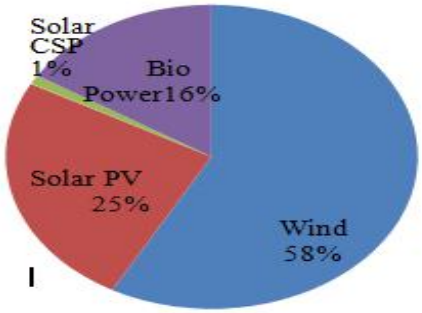
India has a large reservoir of renewable energy resources, and it has started one of the largest programs in the world for deploying renewable energy products and systems. In fact, India is the only country in the world to have an exclusive ministry for renewable energy development known as Ministry of New and Renewable Energy Sources (MNRE).

Out of the 13% share of renewable energy sources, 8.6% is wind power, 1.5% small hydropower, 1.3% solar, 1.6% biomass and others. The current global scenario of renewable energy sources is as per the following graph

1.1 Current Status of Renewable Energy



Graph1: Overall Generation Mix inIndia:284GW ason31.12.2015
(Source: Central Electricity Authority(CEA),2015)



Graph2: Global Installed Renewable Energy Capacity

Table 1:

Coal	Gas	Diesel	Nuclear	Hydro	Renewable
173	24.5	1	5.78	42.6	37.4

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Table 2: Sector-wise Potential of Renewable Energy Sources in India

Sector	Potential MW	Cumulative Achievement MW
Wind Power	1,02,772	25,088
Solar Power	7,48,990	4,879
Bio –Power	19,749	4,177
Waste to Power	22,536	4,551
Total	2,554	127
	8,96,602	38,822

(Source:MNRE,2015)

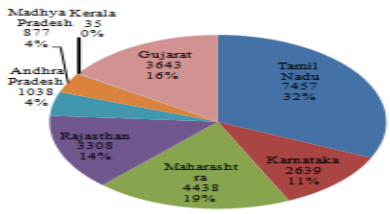
As compared to the other renewable resources, wind is one of the most cost-effective and mature renewable energy sources available commercially in India, with an installed capacity of 23 GW and yet increasing more rapidly. Also, the cost of wind power is now at par with imported coal and natural gas-based plants and wind can play a significant role in dealing with energy security and environmental concern s in an economic way.

Despite the hype around solar, India actually added more

capacity in wind than in solar in the last financial year 2015-16 Wind still remains the primary source of renewable energy, leaving behind the cumulative capacity of solar energy. However, as of 31 March 2016 the installed capacity of wind power in India has increased to 26,769 MW

.

2. **Wind Energy Technology** Wind energy or wind power explains the process by which wind is used to produce mechanical power or electricity. Wind turbines change the kinetic energy available in the wind in to mechanical power, which can be used for different tasks (such as pumping water or grin ding grains) or a generator can convert this mechanical power in to electricity. The wind turbines are machines having a rotor with three propeller blades. These blades are explicitly arranged in a horizontal way to push wind for generating electricity. Wind



Graph3: State-wise Wind Power Installed Capacity in India
(Source: MNRE, 2013)

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turbines are placed in those are as having high speeds of wind ,to spin the blades much faster for the rotor to transmit the electricity produced to a generator. Finally, the electricity produced is supplied to different stations through the grid.

The major components of a turbine are:

- Rotors which convert wind energy into mechanical energy of the shaft Wind power is an inexhaustible source of energy.
- The wind is available freely and using modern technology it can be captured efficiently.
- It does not create any type of environmental pollution.
- The wind turbines require less pace than the average power stations; there by the land around wind turbines can be used for other useful purpose like farming etc.
- When combined with solar electricity, it proves to be great for developed and developing countries to provide a stable and consistent supply of electricity.
- Wind turbines can be used to produce electricity for remote areas, where other sources of energy are not available.
- Wind energy can directly be used as mechanical energy.
- Wind power is comparatively cost-effective among the available renewable sources of energy.

DISADVANTAGES OFWINDPOWER

- The major disadvantage of wind power is the unpredictability. The winds are often uncertain and unpredictable and hence continuous supply of power cannot be obtained.
- Only those areas are suitable for wind power where strong winds are expected for most of the time during a year.
- Construction of wind farms generally requires large open spaces.
- Most of the wind farms and wind turbines are located in remote areas where transmission lines are not available. Hence, it becomes a costly affair to lay long transmission networks to make use of the generated power.
- Local wild life and birds can get damaged due to wind blades.
- Wind turbines create noise and disturbance in the nearby area.
- The average efficiency of wind turbines is less as compared to conventional fossil fuel power plants.

• The wear and tear of mechanical parts of wind turbines makes their maintenance costly

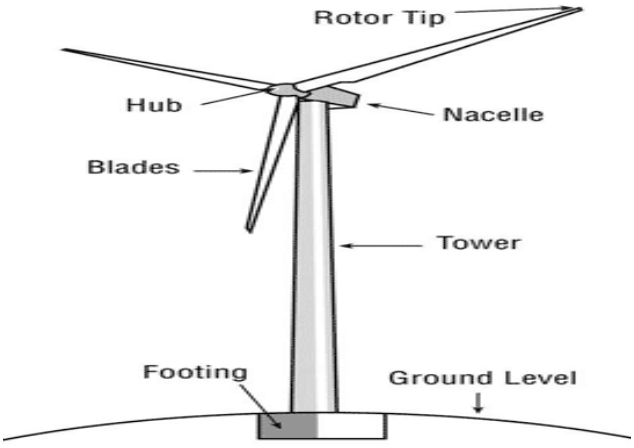
Table 3:State-wise Potential of Wind Energy in India

State	Potential MW
Andhra Pradesh	44,229
Gujarat	84,431
Karnataka	55,857
Telangana	4,244
Madhya Pradesh	10,484
Maharashtra	45,394
Rajasthan	18,770
Tamil Nadu	33,800

(Source:MNRE,2016)

Conclusion

Energy is the primary need of modern world. Wind power is the most mature form of all the renewable energy sources with regard to commercial development. It has positive aspects of renewability, availability and potentiality. Wind power is the most economic power plant technology, due to less installation costs, less construction time and no fuel costs as compared to other power plants. Therefore, to generate electricity, it is definitely preferable to generate it in such a way that it has the least possible impact on our environment. Also, from technical and economic point of view, the wind energy can prove to be the best form of renewable and clean energy to fulfill our increasing energy requirements.



It can successfully contribute to combat climate change while at the same time provide environmental, social and economic benefits. The only thing required is to minimize the demerits and negative impacts of the wind energy in near future.

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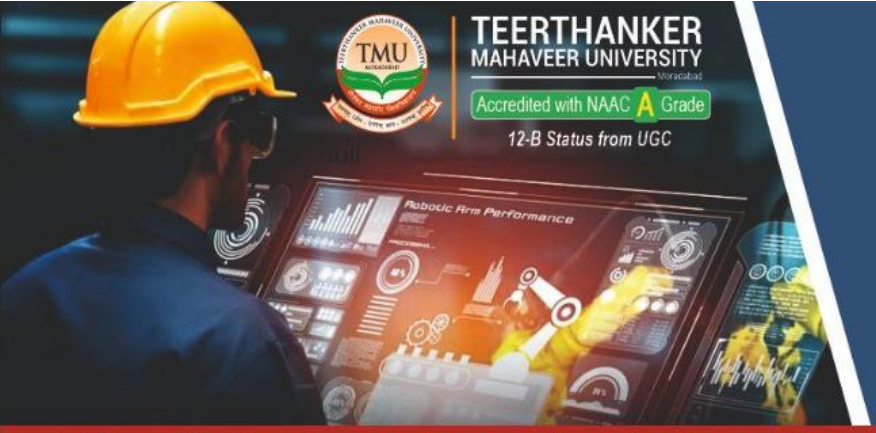

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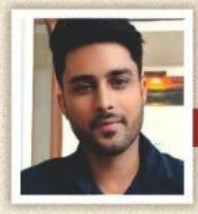

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