

A  
**MAJOR PROJECT REPORT**  
ON  
**PNEUMATIC SHEET METAL CUTTING MACHINE**

*A Dissertation work submitted to JNTUH in partial fulfilment of the requirement for the  
award of the degree of*

**BACHELOR OF TECHNOLOGY**

*in*

**MECHANICAL ENGINEERING**

*by*

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*Under the esteemed guidance of*

**N. RAJKUMAR**

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**2022-2023**

  
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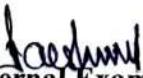
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## ABSTRACT

The objective of the project is to prepare a machine which cuts sheet metal without human efforts but operates pneumatically. Compressed air is used as working media. The compressed air moves the blades of machine to cut the sheet of metal.

The idea of the project generated due to a manual sheet metal sheering machine in workshop of our college. In that machine sheet metal is placed in between the two sheering blades of machine and the lever is pulled down to move the upper movable blade and cut the work-piece.

But in that machine large force is required which can make tire to a worker who continuously works on it for mass production in large scale industry; so to reduce the human efforts pneumatic machine should chose. Hence for some development of machine, we have chosen this subject for our project. We hope that a good idea will develop and we can use it in many industries in surrounding and our practical knowledge, team-working skill, leadership skills will be improved



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## CHAPTER-4

# RESULTS

### 4.1 Result:

The project **Pneumatic sheet metal cutting machine** was designed such that it can cut the metal using pneumatics

### 4.2 Conclusion:

Now we know that Pneumatic cutting and bending machine is very cheap as compared to hydraulic cutting and bending machine. The range of the cutting and bending thickness can be increased by arranging a high pressure compressor and installing more hardened blades. This machine is advantageous to small sheet metal cutting and bending industries as they cannot afford the expensive hydraulic cutting and bending machine.

### 4.3 Future Scope:

Since old age man is always trying to gain more and more luxurious. Man is always trying to develop more and more modified technique with increasing the aesthetic look and economic consideration. Hence there is always more and more scope. But due to some time constraints, and also due to lack of funds, we only have thought and put in the report the following future modifications. 1. It can be made rack and pinion operated or spring and lever operated, by replacing the pneumatic circuit by rack and the pinion arrangement by the square threaded screw and nut arrangement. 2. The place where there is scarcity of the electricity the electric motor operate compressor is replaced by an I.C. Engine installed compressor. 3. In this machine, compressed air is used to move the cutting tool for carrying out cutting operation. After the completion of the cycle the air moves out through the out port of Solenoid valve. This air is released to the atmosphere. In future the mechanism can be developed to use this air again for the working of cylinder. Thus in future there are so many modifications, which we can make to survive the huge global world of competition.

A  
**MAJOR PROJECT REPORT**  
ON  
**MATERIAL HANDLING MACHINE**

*A Dissertation work submitted to JNTUH in partial fulfilment of the requirement for the  
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*in*

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## ABSTRACT

Material handling machines play a crucial role in various industries, facilitating the movement, storage, control, and protection of goods and materials throughout the supply chain. Over the years, significant advancements in technology have revolutionized the field of material handling, leading to the development of more efficient and productive machines. This abstract provides an overview of the recent advancements in material handling machines, highlighting their key features and benefits.

The abstract begins by discussing the evolution of material handling machines, starting from traditional manual methods to the modern automated systems. It emphasizes the need for improved efficiency, safety, and cost-effectiveness, which have been driving the development of new technologies.

Next, the abstract explores the key advancements in material handling machines, including robotics, artificial intelligence, Internet of Things (IoT), and autonomous systems. These technologies have enabled the creation of intelligent machines capable of performing complex tasks, such as automated sorting, picking, and packaging of goods. Moreover, the integration of sensors, data analytics, and connectivity features has facilitated real-time monitoring and optimization of material handling processes, leading to enhanced operational efficiency.

Furthermore, the abstract discusses the benefits associated with advanced material handling machines. These include increased productivity, reduced labor costs, improved accuracy and precision, minimized damage to goods, enhanced worker safety, and streamlined supply chain operations. The abstract also highlights the positive impact of these advancements on sustainability, as efficient material handling can result in reduced energy consumption and waste generation.



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## CHAPTER-9

### CONCLUSION

The material handling machine project has been a significant endeavor with numerous benefits for various industries. By incorporating advanced technologies and innovative design principles, we successfully developed a robust and efficient machine that improves productivity, safety, and operational efficiency. It can handle diverse materials, automate processes, and minimize human error. The project's key benefits include increased productivity, enhanced safety, cost savings through reduced labor requirements, flexibility and adaptability to different scenarios, improved inventory management, and environmental sustainability by minimizing energy consumption and carbon emissions. Overall, the material handling machine project has revolutionized material handling, delivering tangible benefits such as increased productivity, safety, cost savings, and environmental sustainability. Further advancements can optimize its performance and expand its applications in an ever-evolving industrial landscape.



A  
MAJOR PROJECT REPORT  
On  
**FABRICATION OF AIR PURIFIER**

*Submitted in partial fulfillment of the requirements*

*for the award of degree of*

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*in*

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## ABSTRACT

We tend to think of air pollution and something that happens outside but that's not always the case. Even inside your home, there are things like dust mites and dirt trodden in from outdoors to worry about. Indoor air pollution from sources like this can irritate your lungs and contribute to allergies and asthma. The trouble is, if you use an ordinary vacuum cleaner, you might simply be rearranging the dirt your cleaner will trap some of the dirt but the rest passes straight back into the room. If you suffer from asthma or another breathing difficulty you may find purification of air through Activated Charcoal following by disinfection method called Ultraviolet Germicidal Irradiation will be a well worth investment. This air purifier works efficiently as other filters (Hepa filter, Ionizer filters) and low cost as compared. This air purifier is easily maintained and affordable.

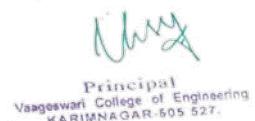
Air contributes a prime role in recycling earth's most essential substances like carbon, since carbon sources encompass fossil fuel combustion and decayed matter of dead animals. Due to urbanization, population has been increased in cities inevitably which cause dreadful air pollution and pose a profound menace to public health and the environment. Outdoor air pollution has become panic in India, because Indian cities are some of the highest polluted cities in the world. Particulate pollution has significant worsen effects on human health. Diseases like asthma, chronic obstructive pulmonary disease (COPD), allergies and insomnia are caused or triggered by rising levels of air pollution. Sometimes the poor air quality leads to long-term health effects. Air purifiers occupy as prime factor to clean the air. It promotes our health against allergies, obnoxious odor and snoring. This review article discuss the causes of air pollution, need for air purifier and mechanism of working of air purifie

## CONCLUSION

During the completion of Major Project, I was able to understand the Design and fabrication of Air purifier. Amongst these parts, a detailed knowledge on Purification of air.

The main function of our filter is to remove contaminated viruses from the air and provide clean and pure air. Thus, Air Filter is a crucial purchase element for the one suffering from dust or pollen allergy. This Filter is able to remove 99.97% particles being small as 0.03 microns.

So buy only a quality product from reliable sources and avoid buying low grade charcoal power and UVC lamp filters, as these filters will not provide you the best result as mentioned.



A  
**MAJOR PROJECT REPORT**  
ON  
**SAND FILTER MACHINE**

*A Dissertation work submitted to JNTUH in partial fulfilment of the requirement for  
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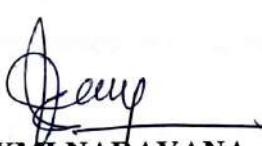


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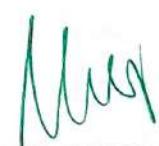
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## ABSTRACT

In recent years, the use of sand filter machine has gradually increased. But, most of them are quite large and difficult to be move. Besides that, the price to own it is quite expensive. With that, there are a large number of construction workers who have to exert their energy to making sand filters by themselves in the traditional way. However, there are some problems that come with using the traditional sand filter. Among these are, the construction workers have to exert their energy to build the sand filter. In addition, refined sand will mix with foreign matter when refined sand falls to the ground. Therefore, we have created a product that can facilitate the construction work of the construction site. Our main goal of creating sand filter machines is to reduce the workload of construction workers when they want to filter or use sand filters. It runs using an electric motor that will shake the filter. We just need to put the sand on the filter and the sand will be filtered with the shake that is produced. The sand filter machine is equipped with a funnel as a way for fine sand to fall. All we have to do is put the wheelbarrow next to the sand filter and the sand will drop into the wheelbarrow. It is different with the traditional sand filter where the refined sand falls, we have to put it in the wheelbarrow. It will use more of construction workers energy. Most important is that the filter machine is easy to move around in construction as it is equipped with two suitable wheels. It will make it easier for construction workers to filter sand in one place or another place.



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### 10.3 CONCLUSION

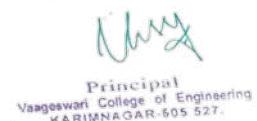
Every project that is done have their own benefits and objectives. Same like our project 'Sand Filter Machine'. There were no troubles when we do this project and the objective for this project finally can we achieve.

This project can filter the sands with the good quality of sand for the result with using the electric motor helps with 4-5 UF and the speed in about 1300 rpm that is suitable for this project. This project achieves the objective that is to get the good quality of sand without mix with foreign things compared with using the traditional sand filter.

Besides that, this project is more attractive and the size is suitable for construction surrounding. Furthermore, this project can be removing part by part, so it will more ease to bring it to everywhere. These sand filter machines also easy to handle even the users have no experience to use it.

Based on the result of research in creating and finishing this project, we found that the project's objective for this product have achieved with successfully. Besides that, it can give benefits to many party especially constructions worker and contractor where it can help to reduce the workload usage of constructions worker and got accepted from contractor for this product to be commercialized in industry sector.

Lastly, we hope this project can be fully utilized, accepted and can be applied and suitable with technological development nowadays. Besides that, we also hope that this product will give the best result to the users and it can fulfil the requirement of all users.



A  
MAJOR PROJECT REPORT  
On  
**DESIGN AND ANALYSIS OF SINGLE PLATE CLUTCH  
USING NON-FERROUS MATERIALS**

*Submitted in partial fulfillment of the requirements  
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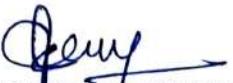
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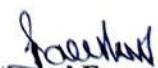
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## ABSTRACT

Clutch is one of the essential components in automobiles. It is located between the engine and the gear box. The main function of the clutch is to initiate the motion or increase the velocity of the vehicle by transferring kinetic energy from the flywheel. The present project deals with the designing and analysis of friction clutch plate. Design has done by using CATIA V5 software and static structural analysis carried by using ANSYS. The present used material for clutch disc is with different composites and aluminum alloys. In this project evaluation it is carried out by the usage of ceramic materials, E Glass Epoxy and Aluminum Alloy. One plate clutch is supposed to be modeled by the use of CATIA software. Static evaluation Dynamic analysis and Thermal Analysis is to be completed on the clutch to work out stresses and deformations using Aluminum alloy 6061/7075, Glass Epoxy and Sic. Analysis is accomplished in ANSYS15. This project presents the stresses and deformations of the assembly of the automotive single plate clutch depending on the applied materials. Structural analysis of the clutch was performed by using Ansys in results we may obtain the values of stresses and deformations that occur on the clutch during the vehicle exploitation will be obtained.



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## 6.2 CONCLUSION

Clutch is a prime component of the transmission system in automobile. The torque transmission capacity and life span of the clutch depends on the clutch plate so main focus of this work is to improve the performance of the clutch by changing the material of the clutch plate. In this work the design of the single plate clutch is done in Catia, after that the static and thermal analysis is done in Ansys by using different Non-ferrous materials. Static Analysis is done applying moment and different pressures (1,2,3,23) Mpa and transient thermal analysis is done taking a time step and max temperature as 350°C. Among those materials considering the tabulated results obtained from Ansys Aluminum Alloy 6061 has given the best results for the given conditions. At Maximum pressure of 23Mpa Total Deformation:0.014166, Vonmises Stress (Pa):28.364, Vonmises Strain (Pa): 0.00041273 and also the temperatures obtained within the given time step have a minimal increase when compared to other materials. In the absence of regular materials this Aluminum Alloy 6061 can be suggested based on the results obtained.



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A

**MAJOR PROJECT REPORT**

ON

**THERMAL ANALYSIS OF ENGINE CYLINDER FINS BY  
VARYING FIN GEOMETRY AND MATERIAL**

*A Dissertation work submitted to JNTUH in partial fulfilment of the requirement for the  
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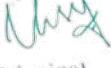


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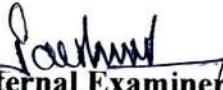
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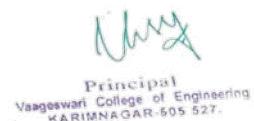
  
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## **ABSTRACT**

The Engine cylinder is one of the major automobile components, which is subjected to high temperature variations and thermal stresses. To cool the cylinder, fins are provided on the surface of the cylinder to increase the rate of Heat transfer. Thermal analysis of extended surfaces or projections of materials on the system (engine) called fins of air-cooled ICengines. The fins are used to increase the heat transfer rate from the system to the surrounding by increasing the heat transfer area. Fins are used to cool various structures via the process of convection.

Generally, heat transfer by fins is basically limited by the design of the system. The heat transfer effect may be varied by changing material of different thermal conductivities, improvising engine geometry, increasing cross section area of fins, using perforations on fin and on analysis of fins. By doing thermal analysis on the engine cylinder and fins around it, it is helpful to know the heat dissipation rate and Temperature Distribution inside the cylinder. By increasing the surface area, the heat dissipation rate can be increased.

The main aim of the present project is to analyze the thermal properties like Directional Heat Flux, Total Heat Flux and Temperature Distribution by varying Geometry (Circular, square), material (Aluminum Alloy, Magnesium Alloy) and thickness of Fin (3mm, 2mm) of an approximately square cylinder model prepared for Transient Thermal analysis with an Average Internal Temperature, Stagnant Air-Simplified case as Cooling medium on Outer surface with reasonable Film Transfer Coefficient as Boundary Conditions. The Transient Heat Analysis will be performed on the fins by changing the fins thickness, materials and shapes to find out the Total Heat flux and Temperature Distribution.



## **CHAPTER-5**

### **CONCLUSION**

In present work, a cylinder fin body is modelled by using FUSION 360 and Transient thermal analysis is done by using ANSYS WORKBENCH. Design of fin plays an important role in heat transfer. There is a scope of improvement in heat transfer of air cooled engine cylinder fin if mounted fin's shape varied from conventional one. Contact time between air flow and fin (time between air inlet and outlet flow through fin) is also important factor in such heat transfer. These fins are used for air cooling systems for two wheelers. In present study, Aluminum alloy is compared with Magnesium alloy. The various parameters (i.e., geometry and thickness of the fin) are considered, by reducing the thickness and also by changing the shape of the fin to circular shape from the conventional geometry i.e. rectangular, the weight of the fin body reduces thereby increasing the heat transfer rate and efficiency of the fin. The result shows that, By using circular fin with Aluminum Alloy is better since heat transfer rate of the fin is more. By using circular fins the weight of the fin body reduces ..

  
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A  
**MAJOR PROJECT REPORT**  
ON  
**FABRICATION OF SOLAR POWERED AIR COOLER**

*A Dissertation work submitted to JNTUH in partial fulfilment of the requirement for the award of the degree of*

**BACHELOR OF TECHNOLOGY**

*in*

**MECHANICAL ENGINEERING**

*by*

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<b>G. ARAVIND</b>	<b>(20S45A0316)</b>
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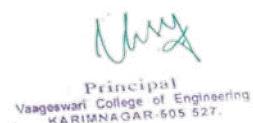
  
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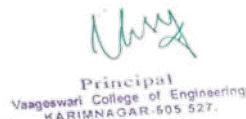
## ABSTRACT

The new developments and requirements inspired us to think of new improvements in air conditioning Engineering field. Nowadays air cooler is available in market. In our project, solar power is stored in a battery. This power is used to run the air collar whenever we required. Solar energy means all the energy that reaches the earth from the sun. It provides daylight makes the earth hot and is the source of energy for plants to grow. Solar energy is also put to two types of use to help our lives directly solar heating and solar electricity. Solar electricity is the technology of converting sunlight directly in to electricity. It is based on photo-voltaic or solar modules, which are very reliable and do not require any fuel or servicing. Solar electric systems are suitable for plenty of sun and are ideal when there is no main electricity. Our objective is to design and develop a solar system normally solar air cooler



## CONCLUSION

This project highlights the effect of dust, dirt, pollen, sea salt, and bird droppings on the PV systems' efficiency. Dust has a major impact on the efficiency and performance of the solar panels. The reduction in the peak power generation can be up to 10 to 30%. Power reduction was observed due to dust accumulation on the panels and this can be improved. CONCLUSION It reduces the cost of air conditioning compare to normal air conditioner. It is eco-friendly. It is efficient for cooling in small area. Initial cost of its installation is high but on long run it proves eco-friendly. We got lot of knowledge regarding our field which is not available in the book. We learnt how to work in team by dividing the load and work with team spirit.



A

# MAJOR PROJECT REPORT

ON

## **THERMAL ANALYSIS OF ENGINE CYLINDER FINS BY VARYING FIN GEOMETRY AND MATERIAL**

*A Dissertation work submitted to JNTUH in partial fulfilment of the requirement for the  
award of the degree of*

### **BACHELOR OF TECHNOLOGY**

*in*

### **MECHANICAL ENGINEERING**

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<b>MD.SHAHNAWAZ</b>	<b>20S45A0332</b>
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**Dr. CH. SRINIVAS**  
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## **CHAPTER-5**

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A  
MAJOR PROJECT REPORT  
ON  
**COMPARATIVE ANALYSIS OF A SUPERCHARGER AND A  
TURBOCHARGER IN AN ENGINE BY CFD ANALYSIS**

*A Dissertation work submitted to JNTUH in partial fulfilment of the requirement for the  
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*in*  
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*by*

<b>E.VENU</b>	<b>20S45A0310</b>
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*Under the esteemed guidance of  
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#### CERTIFICATE

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**Dr. CH. SRINIVAS**  
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## ABSTRACT

This project aims to conduct a comprehensive comparative analysis of turbochargers and superchargers using Computational Fluid Dynamics (CFD) analysis. Both turbochargers and superchargers are widely used in internal combustion engines to enhance performance by increasing the amount of air delivered to the engine. However, the understanding of their performance characteristics and efficiency remains critical for optimizing engine designs.

This methodology involves creating detailed 3D models of a turbocharger and a supercharger. The 3D models of the supercharger and turbocharger will be created using SolidWorks software.

CFD analysis will be done by varying the mass flow rates for different speeds 80 m/s, 100 m/s, 120 m/s. The outputs of the CFD analysis will be pressure, velocity, mass flow rate and total heat transfer rates. Analysis will be done in ANSYS.

The results will aid engineers and designers in making informed decisions during the development of efficient and high-performing engines. Furthermore, the CFD analysis approach can be extended to optimize the design and performance of future forced induction systems.



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## 8.2 CONCLUSION

In this project, a comparative analysis of turbochargers and superchargers was conducted using Computational Fluid Dynamics (CFD) analysis. The analysis revealed that both turbochargers and superchargers are effective in increasing the amount of air delivered to the engine, thereby enhancing engine performance. However, important differences were observed between the two systems.

By observing CFD results, Turbochargers exhibited higher pressure ratios, mass flow rates & total heat transfer rates compared to superchargers, making them well-suited for applications where high-power output is desired. The pressure is increasing by about 50%, velocity is increasing by about 22.5%, mass flow rate is increasing by about 40.6% and heat transfer rate is increasing by about 40.45%. Additionally, turbochargers showcased better efficiency due to their ability to harness wasted exhaust energy for increased air compression, whereas superchargers require additional engine power to operate, resulting in slightly lower overall system efficiency compared to turbochargers.

CFD analysis using ANSYS can be used to optimize the design of these devices and improve performance. The outcomes of this project provide valuable insights for engineers and designers in selecting the most suitable forced induction system for specific applications.



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A  
**MAJOR PROJECT REPORT**  
ON  
**AUTOMATED DRAIN CLEANER**

*A Dissertation work submitted to JNTUH in partial fulfilment of the requirement for the  
award of the degree of*

**BACHELOR OF TECHNOLOGY**

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## ABSTRACT

Cleaning of drains has always been a problem. Cleaning drains leads to a high risk of catching infections or poisoning due to large amounts of waste and chemicals in them. Also throwing of plastic and other such objects into the drains lead to narrowing and eventually blockage in drain flow. This leads to overflow in many cases. So here we provide a fully automated drain cleaning mechanism to tackle these modern-day drain jamming issues.

Urban **drainage systems** play a vital role in managing stormwater runoff and preventing flooding in cities. However, the accumulation of debris and sediment in drainage poses a significant challenge, leading to reduced flow capacity and increased maintenance efforts. In this project, we propose an innovative solution - an automated drainage cleaner - to improve the efficiency and maintenance of urban drainage systems.

The drainage cleaner navigates along the drainage, employing its mechanical cleaning mechanism to dislodge and collect debris. The collected debris is then safely transported and deposited into a separate container for proper disposal.

The automated drainage cleaner offers several advantages over traditional manual **cleaning methods**. Firstly, it significantly reduces the need for human labour, saving time and costs associated with manual cleaning operations. Secondly, by efficiently removing debris, the system helps maintain optimal flow capacity, mitigating the risk of localized flooding. Finally, it removes plastics materials in drainage and it is used for recycling, the coagulation in drainage is prevented by removing plastic materials in drainage.



## **CHAPTER-VI**

### **CONCLUSION & FUTURE SCOPE**

#### **6.1 CONCLUSION**

In the treatment system of drainage, waste water control by the machine and the collecting bin to achieve automatic control of drain cleaner treatment. Drainage from domestic and industries is treated through this project to meet the national emission standards, with stable operation, low cost, and good effect.

The cleaner functions more effectively during the heavier rains which has more volume of running water with garbage and high velocity. Risk of Labours catching infections or poisoning due to large amounts of waste and chemicals will be reduced. Automation is a technology concerned with this application of mechanical, electronic and computer-based systems to operate and control production. This system is used to Operate Automated Drain Cleaning System.

This project may be developed with the full utilization of men, machines, and materials and money. Also, we have followed thoroughly the study of time motion and made our project economical and efficient with the available resources.

The automated drain cleaner has proven to be a valuable solution, offering several advantages over traditional manual cleaning methods. It has significantly improved cleaning efficiency, reducing the time and labour required for drain maintenance.

Furthermore, the automated cleaner has contributed to maintaining optimal flow capacity in drainages, mitigating the risk of localized flooding during heavy rainfall.

The implementation of the automatic drainage cleaner has resulted in cost savings, as it reduces reliance on manual labour and optimizes operational efficiency. By streamlining maintenance operations, municipalities and maintenance agencies can allocate their resources more effectively to other critical areas.

A  
MAJOR PROJECT REPORT  
ON  
**CFD ANALYSIS OF SHELL AND TUBE HEAT EXCHANGER  
WITH SEGMENTAL BAFFLES**

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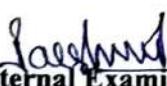
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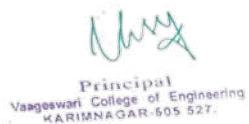
  
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## ABSTRACT

In this numerical work, CFD simulation of a Shell and Tube Heat Exchanger is performed using the commercial software ANSYS Fluent®. The CFD model is made to grab all the physical phenomena such as heat transfer rating, temperature, velocity and pressure distributions within the computational domain. A sufficiently high detailed geometry and fine mesh characteristics are adopted taking into account the computation resources and time, yet satisfactory enough to show that the numerical model can be validated using the results obtained from the calculations based on the heat transfer formulas, correlations, tables and graphs. This gives researchers working in the Heat Exchanger area the opportunity to design their systems using CFD, without depending on a prototype that needs to be tested before the actual product is marketed. Normally, a new type of heat exchanger with specific shell and tube dimensions and number of tubes has to be manufactured using general a heat exchanger calculation approach that will most of the time require the revision of the preliminary design.



## CHAPTER VI

### CONCLUSION AND FUTURE SCOPE

#### 6.1 CONCLUSION

##### 6.1.1 Effect of number of baffles on heat transfer

As the number of baffles increasing for same length of shell, then spacing between the baffles are decreasing. Since the spacing between the baffle is less so the area of recirculation is less and high turbulence is developed. In high turbulence region, heat transfer rate is also high. Another point of interest is that due to increase in number of baffles, fluid has to cover more distance in the shell so the effective heat transfer area increases which results in high heat transfer rate. Heat transfer is 35.344% more in case of 8 baffles as compared to 4 baffles.

##### 6.1.2 Effect of number of baffles on shell side pressure drop

As the number of baffles increasing, pressure drop in shell side increases. Since increasing in number of baffles means decreasing the space between baffles so the path for fluid flow becomes narrow. When fluid passes through narrow path, its pressure decrease and kinetic energy increase. So pressure drop increases with increase in number of baffles. As the pressure drop increase pumping power required to maintain the flow is also increases. Pressure drop is an adverse phenomenon which should be taken into consideration while designing the shell and tube heat exchanger. Pressure drop in shell side is 51.225% in case of 8 baffles as compared to 4 baffles.

#### 6.2 FUTURE SCOPE

- Optimization of baffle spacing, to reduce the pressure drop in shell side and increase the heat transfer rate. Optimizing baffle spacing in a shell and tube heat exchanger with segmental baffles improves heat transfer and minimizes pressure drop. Proper spacing ensures efficient fluid flow, enhancing heat exchange between the shell and tube sides. This optimization maximizes performance, enhancing overall efficiency and reducing energy consumption.
- Optimization for baffle cut. Optimization techniques are employed to enhance the baffle cut in shell and tube heat exchangers with segmental baffles, improving heat transfer efficiency. This process aims to maximize fluid flow while minimizing pressure drop, resulting in optimal performance and energy utilization.