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Design And Thermal Analysis of Engine Cylinder Fins of different Geometry and Material

Dinesh Mahajan[a], *Kishor Mahajan*[b], *Tushar Koli*[c],*Mayur Thakur*[d]

[a]Student,Department Of Mechanical Engineering Godavari College Of Engineering, Jalgaon
[b]Professor,Department Of Mechanical Engineering Godavari College Of Engineering, Jalgaon
[c]Professor,Department Of Mechanical Engineering Godavari College Of Engineering, Jalgaon
[d]Professor,Department Of Mechanical Engineering Godavari College Of Engineering, Jalgaon

ABSTRACT :

Extended surfaces (fins) are Generally used in heat exchanging devices for the purpose of increasing the heat exchange rate from a primary surface to the surrounding fluid. Various types of heat exchanger fins, ranging from the simple shapes, such as rectangular, cylindrical, annular, tapered or pin fins, to a mix of different geometry, have been used. These fins may protrude from either a rectangular or cylindrical base. The objective of this paper is to present an efficient heat sink model for better cooling of electronic devices. The optimum heat transfer through the fins depends on the fin height, fin thickness, fin length, base plate thickness, number of fins and fin shape or profile. In the present study, cooling is analysed by varying number of fins and fin profile. Five different types of fin profiles have been selected and the conjugate heat transfer analysis has been carried out.

Heat sinks are devices that enhance heat dissipation from a hot surface, usually the case of a heat generating component, to a cooler ambient, usually air. For the following discussions, air is assumed to be the cooling fluid. Heat sink is a passive heat exchanger that cools a device by dissipating heat into the surrounding medium. The heat sink is a very important component in cooling design. It increases the component surface area significantly while usually increasing the heat transfer coefficient as well. Thus, the total resistance from the component junction to the surroundings is reduced significantly, which in turn reduces the junction temperature within a device

Keywords: CFD, Fins, ANSYS ICEM, ANSYS FLUENT, Heat Transfer Coefficient, CFD Post etc.

1. General Introduction :

The Engine cylinder is one of the major automobile components, which is subjected to high temperature variations and thermal stresses. In order to cool the cylinder, fins are provided on the surface of the cylinder to increase the rate of heat transfer. By doing thermal analysis on the engine cylinder fins, it is helpful to know the heat dissipation inside the cylinder. We know that, by increasing the surface area we can increase the heat dissipation rate, so designing such a large complex engine is very difficult. The main aim of the present paper is to analyze the thermal properties by varying geometry, material and thickness of cylinder fins using ansys work bench. Transient thermal analysis determines temperatures and other thermal quantities that vary over time. The variation of temperature distribution over time is of interest in many applications such as in cooling. The accurate thermal simulation could permit critical design parameters to be identified for improved life. Presently Material used for manufacturing cylinder fin body is Aluminium Alloy which has thermal conductivity of 110-150W/mk. Presently analysis is carried out for cylinder fins using this material and also using Aluminium alloy 6061 which have higher thermal conductivities.

1.1. Classification Of Enhancement Techniques

- Passive Techniques
- Active Techniques
- Compound Techniques

These techniques are more complex from the application and design point of view as the method requires some external power input to cause the desired flow modification and to improve heat transfer rate. It have limited application as it require external power as it is difficult to provide external power input in many cases.

1.2. Commonly Used to Achieve High Cooling Capacity

- **Finned Tubes**

A finned tube heat exchanger consists of a tube with fins on the outer side of the tube. Finned tube heat exchangers are used in many applications such as industrial boilers, commercial air furnaces and water heaters. Because of the various industrial applications for finned tubes, there are many different fields of research.

- **Offset Strip Fins**

Offset strip fins heat exchangers are used as evaporators in the refrigeration and air-conditioning industry. The fins cause a recirculating flow between two successive fins. Enhanced heat transfer is obtained due to the fins preventing the flow from becoming fully developed and the restarting of the boundary layer produces higher heat transfer.

- **Micro Fins**

A typical micro fin tube has tiny fins of triangular cross-section at a helix angle of between 8°- 30°. The diameters of the tube varied between 6.35- and 15.9-mm. Micro fin heat exchangers are used in the refrigeration, automotive and process industries because it enhances heat transfer by two to three times that of a plain tube. Micro fin tubes are popular because a large heat transfer enhancement can be achieved relative to the increase in pressure drop. Mainly evaporation and condensation are investigated by researchers to find an optimal design for a specific application.

- **Other enhancement**

The above articles represent only a part of the different enhanced heat exchanger configurations. For example twisted tape inserts can be placed inside tubes to increase the heat transfer. Other types of enhanced heat exchanger are the plate- fin arrangement and the louvered fin compact heat exchanger. A popular fin pattern for heat transfer enhancement is the wavy fin configuration . In this paper, correlations for the airside performance of a wavy fin heat exchanger were derived using samples. A generalized heat transfer coefficient and friction factor were proposed that were within 15% of the sample data.

Basic Heat Transfer

- **Heat Transfer and Thermodynamics:**

The study of transfer phenomenon which includes transfer of momentum, energy, mass etc has been recognized as a unified discipline of fundamental importance on the basis of thermodynamic fluxes and forces. The transfer of such phenomena occurs due to a conjugate force of temperature gradient, velocity gradient, concentration gradient chemical affinity etc. The transfer of heat energy due to temperature difference or gradient is called heat transfer.

- **Modes Of Heat Transfer:**

The modes of heat transfer can be divided into three segments.

- **Conduction**

Conduction is one of the three main ways that heat energy moves from place to place. The other two ways heat moves around are radiation and convection. Conduction is the process by which heat energy is transmitted through collisions between neighbouring atoms or molecules. Conduction occurs more readily in solids and liquids, where the particles are closer together than in gases, where particles are further apart. The rate of energy transfer by conduction is higher when there is a large temperature difference between the substances that are in contact. Think of a frying pan set over an open camp stove. The fire's heat causes molecules in the pan to vibrate faster, making it hotter. These vibrating molecules collide with their neighbouring molecules, making them also vibrate faster. As these molecules collide, thermal energy is transferred via conduction to the rest of the pan. If you've ever touched the metal handle of a hot pan without a potholder, you have first-hand experience with heat conduction. Some solids, such as metals, are good heat conductors. Not surprisingly, many pots and pans have insulated handles. Air (a mixture of gases) and water are poor conductors of thermal energy. They are called insulators.

- **Radiation**

Before we can understand radiation heat transfer, we must first understand the concept of heat and heat transfer. Thermal energy transfer across a well-defined boundary around a thermodynamic system is characterized as heat in physics. The amount of work that a thermodynamic system can perform is defined as its thermodynamic free energy. Heat transfer, unlike state functions, is a process function (or path function); thus, the quantity of heat transferred in a thermodynamic process that changes the state of a system depends on how that process occurs, not just the net difference between the initial and final states of the process. Based on this property, we will also see the characteristics of Radiation Heat transfer. The transfer of energy via thermal radiation, i.e. electromagnetic waves, is known as radiation heat transfer. It can happen in a vacuum or transparent substance (solid, fluid, or gas). At temperatures above absolute zero, thermal radiation is emitted by all objects due to the random movement of atoms and molecules in matter. Because these atoms and molecules are made up of charged particles (protons and electrons), their movement causes electromagnetic radiation to be emitted, which transfers energy. In most engineering applications, radiation is only relevant for scorching items or objects with a huge temperature difference. Let's look at the fundamentals of radiation heat transfer and its properties.

- **Convection**

Convection is the process of heat transfer by the bulk movement of molecules within fluids such as gases and liquids. The initial heat transfer between the object and the fluid takes place through conduction, but the bulk heat transfer happens due to the motion of the fluid. Convection is the process of heat transfer in fluids by the actual motion of matter.

- It happens in liquids and gases.
- It may be natural or forced.
- It involves a bulk transfer of portions of the fluid.

1.3. Cylinder Fins

The engine cylinder is one of the major automobile components, which is subjected to high temperature variations and thermal stresses. In order to cool the cylinder, fins are provided on the surface of the cylinder to increase the rate of heat transfer. By doing thermal analysis on the engine cylinder fins, it is helpful to know the heat dissipation inside the cylinder. We know that, by increasing the surface area we can increase the heat dissipation rate, so designing such a large complex engine is very difficult. The main aim is to analyze the thermal properties by varying geometry and material of fins Presently material used for manufacturing cylinder fin body is Aluminium Alloy 204 which has thermal conductivity of 110- 150W/mk. In our project, the geometry of the fin i.e. straight fins are replaced with aero-dynamic fins and also replaced with Aluminium Alloy 7075 and Magnesium alloy. The cylinder block with fins is designed by using CATIA software. Thermal analysis is carried by using ANSYS V15.0 software. The main objective of this project is to present the Thermal analysis which is subjected to high temperature variations on Fins by varying the geometry and materials. Comparison of the temperature distribution and heat flux in both aero dynamic fins and straight fins. Finally obtained optimum temperature distribution, heat flux. We can increase the durability of the engine by increasing the rate of heat transfer.

2. Steady State Thermal Analysis

2.1. Pre-processing

- **Construction of Model**
  Geometry was created using CATIA V5 software which is specifically designed for the creation and preparation of a geometry.
- **Grid Generation**
  Creation of an accurate computational mesh for the domain under investigation is a paramount importance in CFD simulations. The shape of control volumes should satisfy certain geometry requirements in order to eliminate irregularities in computational results
- **Create Mesh for Geometry**
  The ANSYS is used for discretization of domain. Initially a relatively coarser mesh is generated. This mesh contains tetrahedral cells having triangular faces at the boundaries. Care is taken to use tetrahedral cells as much as possible.

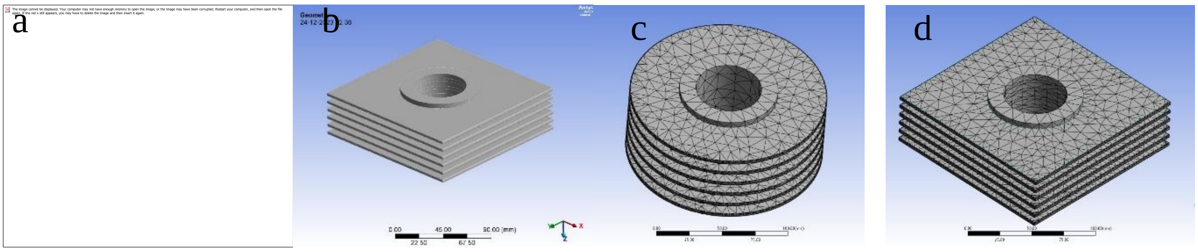

Fig.1 - (a) 3D Model of Circular Fin; (b) 3D Model of Rectangular Fin ;(c) Mesh Model of Circular Fin; (d) Mesh Model of Rectangular Fin.

Table 1 - Fin Meshing Data.

Particular	Circular	Rectangular
Nodes	40586	49659
Elements	22234	25944

Table 2 – Material Use for Analysis .

Properties	Cast Iron	AL 6061	SS 304
Density (kg/m3)	7.8	2.712	7.78
Sp. Heat (Cp) (J/kgK)	4690	9145	4870
Thermal Conductivity (W/mK)	70	237	79

- **Boundary Conditions**

All boundary conditions get implemented by the inclusion of additional source and/or sink terms in the finite volume formulation for computational cells at the boundaries. In natural convection flows there is no information regarding the velocity and temperature fields before the start of calculations. Since governing equations are invariably coupled, the temperature field causes the velocity field to develop and which in turn affects the temperature field. The base plate (wall) is assigned certain value of heat flux, This value of heat flux is decided according to the heater input to the cartridge heaters.

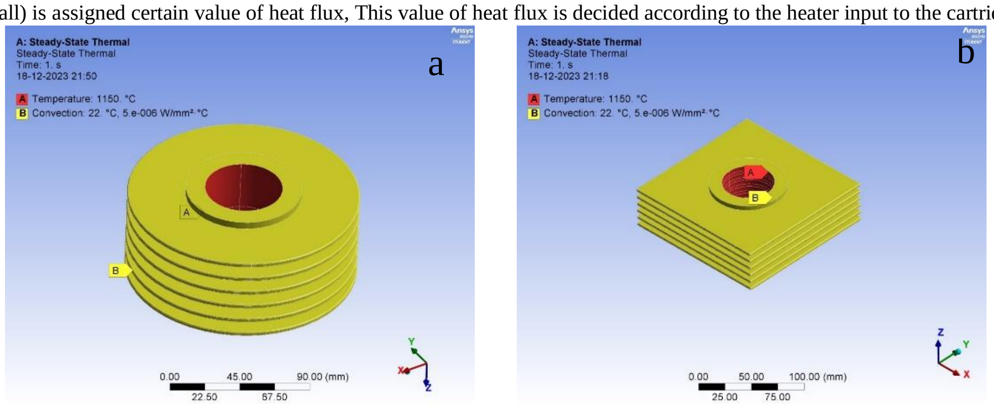

Fig. 2 - (a) Boundary Conditions for Circular Fin ; (b) Boundary Conditions for Rectangular Fin

3. Result and Discussion

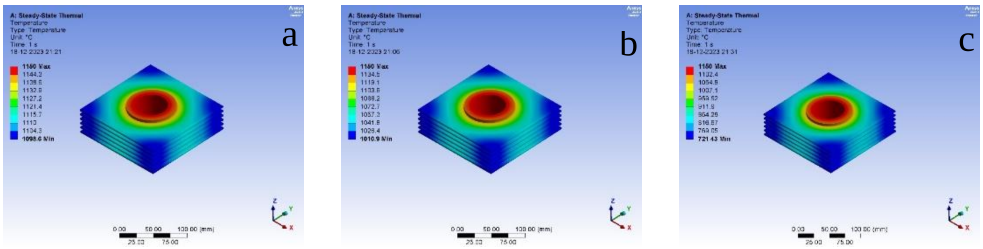

Fig. 3 - (a) Temperature Distribution in Aluminium Alloy; (b) Temperature Distribution in SS 304;(c) Temperature Distribution in Cast Iron transfer

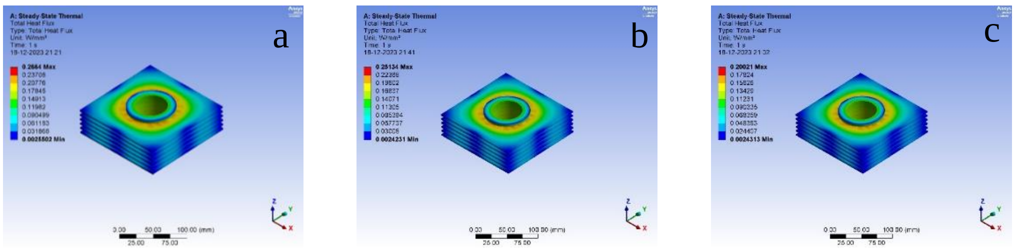

Fig. 4 - (a) Total Heat Flux for Aluminium Alloy ; (b) Total Heat Flux for SS 304 ;(c) Total Heat Flux for Cas Iron

Table 3 – For Circular Fins.

MOC	Maximum Temperature	Weight	Total Heat Flux
Cast Iron	1150 °C	3.1668 kg	0.0024231 W/mm²
Aluminum Alloy	1150 °C	1.1175 kg	0.0025502 W/mm²
SS 304	1150 °C	3.1265 kg	0.0024313 W/mm²

Table 3 – For Rectangular Fins.

MOC	Maximum Temperature	Weight	Total Heat Flux
Cast Iron	1150 °C	3.5666 kg	0.25134 W/mm²
Aluminum Alloy	1150 °C	1.2585 kg	0.2664 W/mm²
SS 304	1150 °C	3.5211 kg	0.20021 W/mm²

Conclusion

- In present work, a cylinder fin body is modelled and Steady State thermal analysis is done by using CATIA and ANSYS.
- These fins are used for air cooling systems for two wheelers. In present study, Aluminium alloy 6061, Cast Iron and SS 304 are used and compared.
- The various parameters (i.e., shape and geometry of the fin) are considered in the study, shape (Rectangular and Circular) and also by changing the shape of the fin to circular shaped, the weight of the fin body reduces thereby increasing the heat transfer rate and efficiency of the fin.
- The weight of the fin body is also reduced when is used Aluminium alloy 6061.
- The results show, by using circular fin with material Aluminium Alloy 6061 is better since heat transfer rate, Efficiency and Effectiveness of the fin is more.
- By using circular fins, the weight of the fin body reduces compare to existing engine cylinder fins.
  - It is found that natural convection heat transfer is depending on fin height and fin length as predicted.
  - For selected fin spacing, the convection heat transfer rate increases with fin height and decreases with fin length.
  - Convective heat transfer increases with aspect ratio but this behaviour is different for different angle of inclination.
  - Smaller fin length has no influence over heat dissipation through inclined base.
  - Natural convection heat transfer increases monotonously with heat input and therein with temperature difference.

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