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Design and analysis of hexagonal fin for air cooled engines

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ABSTRACT

Major automobile engine components are subjected to wear and thermal stress due to high temperature during combustion. Fins are used to increase the heat transfer rate of an I.C. Engine. In an internal combustion engine, the chemical energy of the fuel is converted to thermal energy to give a mechanical work as output. There is a large amount of heat is liberated to the combustion of fuel in which only a few amounts of energy is converted into useful work (60%-80% approx.) and the remaining energy is wasted. This heat is first conducted to engine cylinder and dissipated to air through extended surface called fins. In an air cooled engine, a low rate of heat transfer is the main problem. In order to avoid this, the fins of the engine are modified by changing the geometry of the cooling fins. All materials are showing the linear distribution of temperature alongside the length of fins. Also, the hexagonal shape fins increase the heat flux by converting the fin geometry from a rectangular shape to hexagonal and thus reduce the wear of engine parts and knocking of the engine.

Keywords— *Engine, Fins, Linear distribution of temperature, Hexagonal geometry, Wear and knocking*

1. INTRODUCTION

The internal combustion engine is an engine in which the combustion of a fuel occurs with an oxidizer (usually air) in a combustion chamber. In an internal combustion engine, the expansion of the high-temperature and -pressure gases produced by combustion apply direct force to some component of the engine, such as pistons, turbine blades, or a nozzle. This force moves the component over a distance, generating useful mechanical energy. Most modern internal combustion engines are cooled by a closed circuit carrying liquid coolant through channels in the engine block, where the coolant absorbs heat, to a heat exchanger or radiator where the coolant releases heat into the air. Thus, while they are ultimately cooled by air, because of the liquid-coolant circuit they are known as water-cooled. In contrast, heat generated by an air-cooled engine is released directly into the air. Typically this is facilitated with metal fins covering the outside of the cylinders which increase the surface area that air can act on. In all combustion engines, a great percentage of the heat generated (around 44%) escapes through the exhaust, not through either a liquid cooling system or through the metal fins of an air-cooled engine (12%). About 8% of the heat energy finds its way into the oil, which although primarily meant for lubrication, also plays a role in heat dissipation via a cooler.

Heat transfer is classified into three types. The first is conduction, which is defined as the transfer of heat occurring through intervening matter without the bulk motion of the matter. A solid has one surface at a high temperature and one at a lower temperature. This type of heat conduction can occur, for example, through a turbine blade in a jet engine. The outside surface, which is exposed to gases from the combustor, is at a higher temperature than the inside surface, which has cooling air next to it. The second heat transfer process is convection or heat transfer due to a flowing fluid. The fluid can be a gas or a liquid; both have applications in aerospace technology. In convection heat transfer, the heat is moved through the bulk transfer of a non-uniform temperature fluid. The third process is radiation or transmission of energy through space without the necessary presence of matter. Radiation is the only method for heat transfer in space. Radiation can be important even in situations in which there is an intervening medium; a familiar example is the heat transfer from a glowing piece of metal or from a fire. Convective heat transfer is between the surfaces and surrounding fluid can be increased by providing the thin strips of metal called fins.

The heat generated during combustion in IC Engine should be maintained at a higher level to increase thermal efficiency, but to prevent the thermal damage some heat should remove from the engine. In an air-cooled engine, extended surfaces called fins are provided at the periphery of an engine cylinder to increase the heat transfer rate. That is why the analysis of fin is important to increase the heat transfer rate. Computational Fluid Dynamic (CFD) analysis and Wind tunnel experiments have shown improvements in fin efficiency by changing fin geometry, fin pitch, a number of fins, fin material and climate condition [2].

Fins are also referred to as extended surfaces. Whenever the available surfaces are inadequate to transfer the required quantity of heat, fins will be used. Fins are manufactured with different sizes and shape depends on the type of application. Air cooling for an IC Engine is a well-known example for Air cooling system in which air acting as a medium. Heat generated in the cylinder will be dissipated into the atmosphere by conduction mode through the fins or extended surfaces are used in this system, which is incorporated around the cylinder. Fins are the extended surfaces designed to increase the heat transfer rate of the body by increasing the convective surface area. Fins find their application from the small computer chips to the huge engines. The enormous application of the fins makes it an interesting and important field. Optimizing the heat transfer rates reflects the saving in power supplied and increased efficiency in case of the automobile engines. Natural convection from cylinder block may be used to simulate a wide variety of engineering applications as well as provides better insight into more complex systems of heat transfer such as heat exchangers, refrigerators, electric conductors etc. Convection may be enhanced by using the Non-uniform fins instead of the conventional fins. An air-cooled motorbike engine dissipates waste heat from the cylinder through the cooling fins to the cooling air flow created by the relative motion of moving motorbikes. The cooling system is an important engine subsystem. The air cooling mechanism of the engine is mostly dependent on the fin design of the cylinder head and block.

2. OBJECTIVES OF THE STUDY

- To increase the heat transfer of an I.C. engine through fins.
- To minimize the knocking effect by dissipating excess heat from the engine cylinder.
- To reduce the wear and tear of the engine components (like piston, cylinder, liner and connecting rod).
- To increase the life of the lubricating oil by increasing the surface area of the fins.

3. LITERATURE REVIEW

Related work has been done on the Honda existing (150cc) bike model IC engine. There is continuous work going on for increasing the thermal efficiency and reducing the temperature of the engine. [5]

N. Nagarani and K. Mayilsamy, “Experimental heat transfer analysis on annular circular and elliptical fins.”[2] This other had analyzed the heat transfer rate and efficiency for circular and elliptical annular fins for different environmental conditions. Elliptical fin efficiency is more than a circular fin. If space restriction is there along one particular direction while the perpendicular direction is relatively unrestricted elliptical fins could be a good choice. Normally heat transfer coefficient depends upon the space, time, flow conditions and fluid properties. If there are changes in environmental conditions, there is a change in heat transfer coefficient and efficiency also.

G. Raju, Dr Bhramara Panitapu, S. C. V. Ramana Murty Naidu. [2] “Optimal Design of an IC engine cylinder fin array using a binary coded genetic algorithm”. This study also includes the effect of spacing between fins on various parameters like total surface area, the heat transfer coefficient and total heat transfer. The aspect rations of a single fin and their corresponding array of these two profiles were also determined. Finally, the heat transfer through both arrays was compared on their weight basis. Results show the advantage of triangular profile fin array.

Heat transfer through triangular fin array per unit mass is more than that of heat transfer through rectangular fin array. Therefore the triangular fins are preferred than the rectangular fins for automobiles, central processing units, aeroplanes, space vehicles etc. where weight is the main criteria. At wider spacing, shorter fins are more preferred than longer fins. The aspect ratio for an optimized fin array is more than that of a single fin for both rectangular and triangular profiles.

4. MATERIALS AND METHODS

Normally, if the metal was changed, the cost of production of the engine would go up because the production line will add one more stage of joining these fins to the engine. There may be some casting techniques by which one can cast both of them together, but even then the cost of casting would increase. If this new material is welded on to the engine, it would change some of the physical properties of the cylinder as welding creates a heat affected zone which degrades the quality of the metal. A thermal gradient may also develop between the engine and the fin, which might affect the overall heat transfer coefficient.

Materials used in fins depend on the heat transfer characteristics of the material. The materials generally used are aluminium alloy 204 which has the thermal conductivity of about 110-150w/mk, and aluminium alloy 606 which has higher thermal conductivity. Cast iron and copper alloy are also used. [5]

5. ASSUMPTIONS

The following assumptions are considered for solving the problem [4]:

(i) Fin material is assumed as homogeneous.
(ii) The thermal conductivity of the material is the same in all direction and assumed to be constant.
(iii) Ambient temperature surrounds the fin uniformly. The thickness of fin very small compared to its length and width, so temperature distribution across the fin thickness and heat transfer through the edge of fin neglected.
(iv) The temperature at the base of the cylinder is uniform.
(v) The thermal resistance between cylinder and fin contact is neglected.
(vi) Radiation heat transfer of fin neglected.

In Engine when fuel is burned heat is produced. Additional heat is also generated by friction between the moving parts. The engine has a cooling mechanism in the engine to remove this heat from the engine some heavy vehicles use the water-cooling system and almost all two-wheelers use Air-cooled engines because Air cooled engines are the only option due to some advantages like the lighter weight and lesser space requirement. The heat generated during combustion in IC engine should be maintained at a higher level to increase thermal efficiency, but to prevent the thermal damage some heat should be removed from the engine. In an air-cooled engine, extended surfaces called fins are provided at the periphery of an engine cylinder to increase the heat transfer rate.

6. GEOMETRY SPECIFICATION

6.1 Existing model design specifications

Table 1: Existing model design specifications

Fin length	60mm
Fin thickness	02mm
Fin profile	Rectangular with edge fillet shape
Bore	50mm
Stroke	67mm
Volume	1.0356e-004 m^3
Total surface area	7155.23mm^3
Density	2270kg/m^3

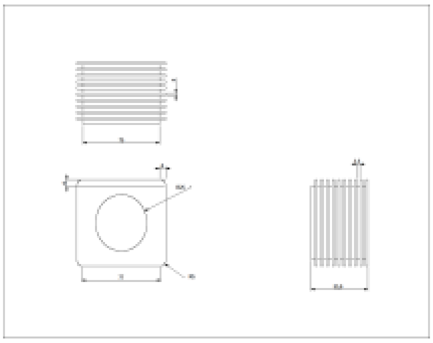

Fig. 1: Orthographic view of existing design model

6.2 New model design specifications

Table 2: New model design specifications

Fin length	60mm
Fin thickness	02mm
Fin profile	Hexagonal with edge fillet shape
Bore	50mm
Stroke	67mm
Volume	1.504e-004 m^3
Total surface area	7400mm^2
Density	2770kg/m^3

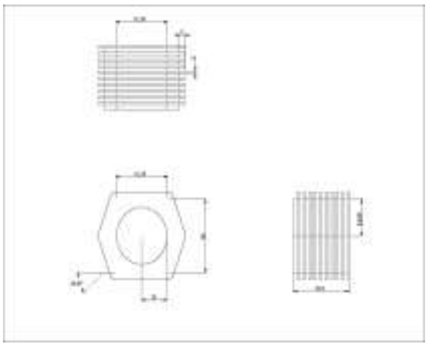

Fig. 2: Orthographic view of the new design model

7. WORKING PRINCIPLE

During the working cycle of S.I. the engine the heat is get generated, 40% of the heat is getting dissipated through cylinder and fins. The dissipated heat is extracted as by changing the fin geometry of the engine fins as rectangular shape into hexagonal shape by varying its shapes and etc.

During the combustion process, more heat energy is wasted by dissipation of heat to the surroundings. In rectangular fin area time taken to dissipate heat energy is more, therefore, heat is not properly taken from the cylinder walls to the atmosphere.

The hexagonal shape has more surface area than a rectangular shape. By increasing surface area of the fin, we can increase the heat transfer rate .heatflux also increased by changing the fin shape from rectangular cross-section to hexagonal cross section.

Forced convection is the main principle followed for this analysis because when the vehicle is in running condition, it moves against the flow of air. So it is imposed to atmospheric air flow. It is called the air-cooled engine type.

8. ANALYSIS PROCEDURE

8.1 Existing model analysis

- At first, the cad model from the creo parametric software is converted into IGES/ STEP file.

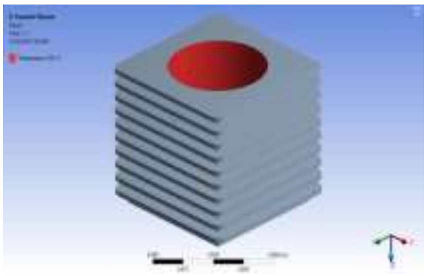

Fig. 3: Model of the cylinder without fin arrangement-temperature model

- Temperature value of 250^{0}c is given as approximate core temperature value for analysis purpose. It is set only on the circumference of the engine cylinder.
- Convection is set as forced convection method. Properties for the film coefficient, density and flow properties are taken from the simplified case convection method.

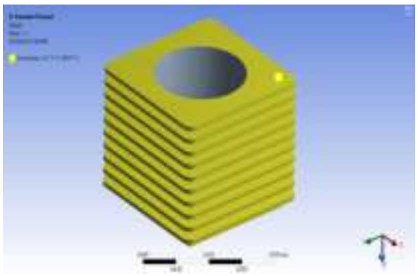

Fig. 4: Model of the cylinder without fin arrangement-convection model

- The same procedure will be followed for a new design model which is created using PTC Creo Parametric. It is converted into a neutral file format.

8.2 New design analysis procedure

- At first, the cad model from the Creo parametric software is converted into IGES/ STEP file.

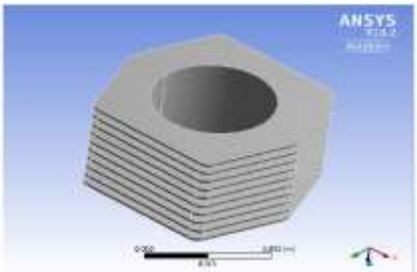

Fig. 5: Model of a hexagonal cylinder with fin arrangement

- Temperature value of 250^{0}c is given as approximate core temperature value for analysis purpose. It is set only on the circumference of the engine cylinder.

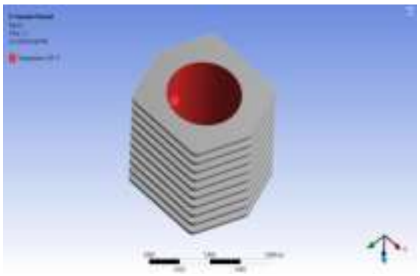

Fig. 6: Model of a hexagonal cylinder with fin arrangement-temperature model

- Convection is set as forced convection method. Properties for the film coefficient, density and flow properties are taken from the simplified case convection method from ANSYS solver.

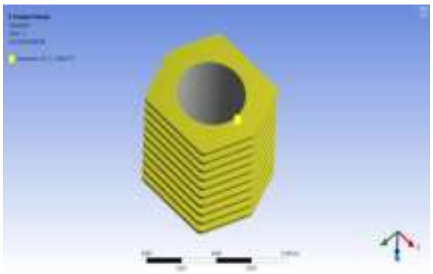

Fig. 7: Model of a hexagonal cylinder with fin arrangement-convection model

- After making all the simulation preprocessor setups, the solution is done by using ANSYS mechanical solver. 20 steps are applied for the transient thermal analysis. After the solutions, results will be taken from the post processor and contour images are taken as results.

9. SIMULATION RESULTS

After the completion of the solving process, the desired result will be get using post- processor. In the result part, both existing and new design temperature and total heat flux are to be calculated. By comparing two results we can measure the increase in heat flux using the new design with the hexagonal cross-sectional area.

9.1 Simulation results- Existing design

9.1.1 Temperature distribution

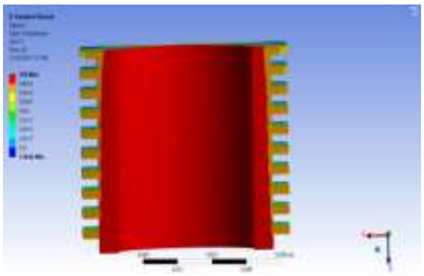

Fig. 8: Temperature model of a cylinder with a rectangular fin arrangement

9.1.2 Total heat flux distribution

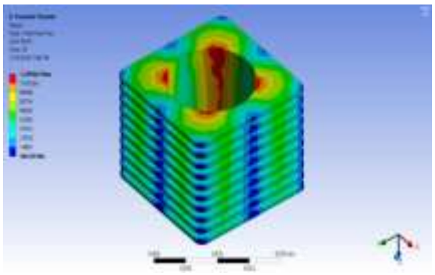

Fig. 9: Heat flux model of a cylinder with rectangular fin arrangement

9.2 simulation results- New design

9.2.1 Temperature distribution

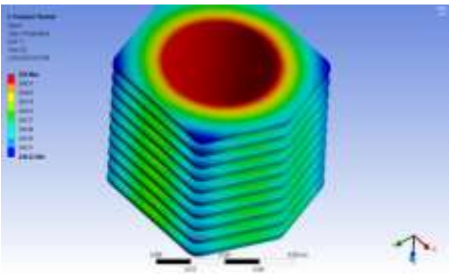

Fig. 10: Temperature model of a hexagonal cylinder with hexagonal fin arrangement

9.2.2 Total heat flux distribution

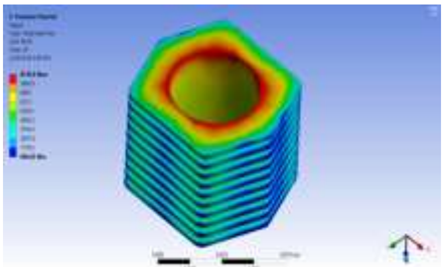

Fig. 11: Heat flux model of a hexagonal cylinder with hexagonal fin arrangement

10. COMPARISON OF RESULTS

By comparing the total heat flux distribution of new and existing models, the increased heat transfer will be measured using the graphical representations.

Comparison of heat flux distribution will be shown below:

10.1 Total heat flux distribution- Existing design

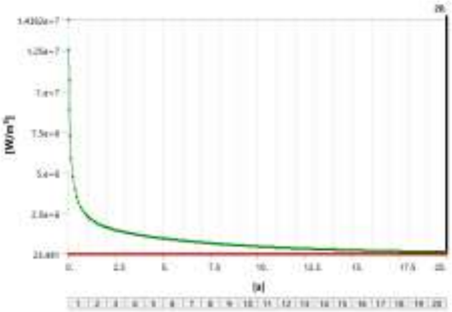

Fig. 12: Total heat flux distribution for existing model

From the above graph, the heat flux distribution is plotted. The maximum heat flux value is $1.25e^{+7}$w/m^2. The minimum heat flux value is 23.491w/m^2. In order to increase the heat dissipation, the heat flux is to be increased so that the design parameter is changed based on the desired output.

The expected heat transfer rate will be calculated by modifying the existing design with the new design of hexagonal cross-section.

10.2 Total heat flux distribution- New design

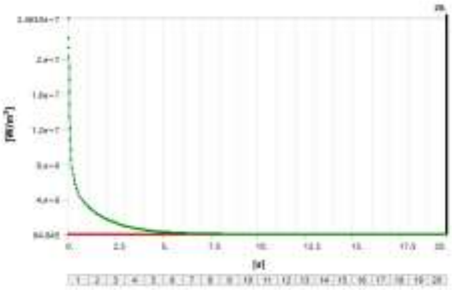

Fig. 13: Total heat flux distribution for the new model

From the above graph, the total heat flux distribution for the new design is calculated. From this, the maximum heat flux value is $2e^{+7}$w/m^2. The minimum heat flux value is 64.845w/m^2.

By comparing the two results we can measure the increase in heat flux by modifying the shape of the fin from rectangular cross-section to hexagonal cross section.

Table 3: Comparison of results

Maximum heat flux for existing design	**$1.25e^{+7}$w/m^2**
Maximum heat flux for new design	**is $2e^{+7}$w/m^2**
Increase in heat flux by changing the design	**$7.5e^{+6}$ w/m^2**
Minimum heat flux for existing design	**23.491w/m^2**
Minimum heat flux for new design	**64.845w/m^2**

11. MERITS

- Knocking will be reducing by dissipating the excess heat from the core of the engine cylinder
- Wear out of engine components is reduced
- Increased heat transfer for high heat dissipation by changing the fin geometry.
- Increased lubrication oil life by increasing the heat flux through fins.

12. CONCLUSION

From the comparison of two total heat flux distribution, the increased maximum heat flux value is $7.5e^{+6}$w/m$^{2.}$

From the above comparisons, the increased minimum heat flux value is 41.354w/m^2

Table 4: Comparison of heat flux

Maximum heat flux for existing design	**$1.25e^{+7}$w/m^2**
Maximum heat flux for new design	**is $2e^{+7}$w/m^2**
Increase in heat flux by changing the design	**$7.5e^{+6}$ w/m^2**
Minimum heat flux for existing design	**23.491w/m^2**
Minimum heat flux for new design	**64.845w/m^2**
Increase in heat flux by changing the design	**41.354w/m^2**

From the two analyses, the increase in temperature dissipations will be calculated by comparing two temperature distributions contours of the existing and new design.

Table 5: Comparison of temperature distribution

Temperature distribution	Maximum	Minimum
For existing model	**250° C**	**219.62° C**
Temperature distribution	Maximum	Minimum
For the new model	**250° C**	**249.32° C**

Rise in temperature by changing the design **249.32°C – 219.62°C = 29.7°C**

From the above data, it is to be concluded that the rise in temperature by changing the design cross section from a rectangular cross-section to hexagonal cross section is 29.7^{0}C. Heat dissipation is increased by 29.7^{0}C by the implementation of this concept.

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