

Thermal Analysis of Engine Block

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ABSTRACT

Several automobile industries are working on it to maintain a proper temperature for increasing the efficiency and also to prevent the engine from thermal damage. So it become important to analyse fins structure for better heat transfer rate. High temperature on the surface of engine block effect the efficiency of engine. Increasing number of fins is not only the criteria to increase the heat dissipation from the surface of fins. Generally, rectangular fins are used in motor bike engine, although the temperature at the surface is in safe limit. By introducing new geometry of fin & if the minimum temperature of new geometry is less than or near about the minimum temperature of rectangular fin is not only help in increasing the efficiency of engine block but also it may help in reducing the weight of engine block. Convective heat transfer is the mechanism of heat transfer and it depends on convective heat transfer coefficient and Contact surface area with air. Fins are surfaces that extend from an object to increase the rate of heat transfer to or from the environment by increasing convection. And the analysis is done by numerical method and on Solid Works software.

KEYWORDS: Fins, heat transfer, heat convection

INTRODUCTION

Motorcycle engine are typically 2 strokes or 4 stroke internal combustion engines. Engine cooling is done by following ways- Liquid

- A. Liquid- cooled motorcycle have a radiator similar to the radiator in car. Coolant is constantly circulated between the radiator & the cylinder when the engine is running.
- B. Oil- in this cooling system, oil is circulated between engine case & a small radiator.
- C. Air- in this system moving air is used to cool the engine. The cylinder on air cooled bikes are designed with fin heat sinks to aid in this process air cooled bike are cheaper, simple and lighter than liquid & oil cooled bike.

Engine cooling in motor bike engine through fins is very important because of the following reasons:

- Combustion of fuel takes place inside engine cylinder & generates hot gases whose temperature ranges from 2300°C - 2500°C.
- It results in burning of lubricating oil film between parts, which leads towards seizing or welding moving parts.

Heat generated in internal combustion engine dissipates in the following ways:

- A. Approximately 30% of generated heat is utilizing in producing brake power.
- B. 30-35% of generated heat removed by cooling system.
- C. Exhaust gases carried away remaining heat.

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So, this high temperature of engine block needs to be lower down to the safe limit (approximately 150°C-200°C).

We must consider two parameters while designing the fins,

- A. Over heating: due to friction & combustion of fuel increases the temperature inside cylinder, if inside temperature is not reduced to safe limit then they damage different parts of engine.
- B. Under cooling-If the temperature inside the engine block is lower from the required limit then it decreases the engine efficiency & reduces the engine's service life.

So, both the condition is harmful for engine block. While designing the model we must try to lower down the temperature to the safe limit so that both the condition i.e. overheating and overcooling don't arise. We all very well known about the fins they are the extended surface which are used to cool various structure via the process of convection. Heat transfer by fins is basically limited by the design of the system but still it may be enhanced by modifying certain parameters of the fins.

LITERATURE REVIEW

[1] In this paper analysis of fin is done to increase the heat transfer rate and CFD have shown improvement in fin efficiency by changing fin geometry, fin pitch, number of fins, fin material and climate condition and the Design of different geometrical shape of Fins was in CATIA and Analysis done by the ANSYS software and generally for mashing purpose software like Hyper Mesh is used. The

analysis is done on Model of Bajaj discover. They had considered airflow velocities from 10km/hr to 40km/hr, and at air temperatures at 30°C, the temperature at the inner surface is assumed constant at 250°C to account for heat generated due to combustion inside the engine and three shapes of fins.

[2] In this paper natural convection heat transfer from solid and permeable fins are investigated by experimental analysis. Fins are formed permeable by modifying the solid rectangular fins by drilling three holes per fins in line at one half lengths of the fins of two-wheeler cylinder block. Engine cylinder blocks having fins were tested for different inputs like 75W, 60W, 45W, 30W and 15W.

They had derived following observations from their experimental works:

- Its temperature profile shows that the base temperatures of solid fins are more elevated as compared to permeable fins. Furthermore, the tip temperatures of solid fins are more in temperature as compared to permeable fins. resulting in more heat transfer rate in permeable fins as compared to the solid fins.
- The average heat transfer coefficient and the ratio of heat transfer coefficient of the cylinder with permeable fins to the cylinder with solid fins have been increased by significance value.
- There is a reduction in area resulting in less material cost of about 10-30%.

[3] In this paper analysis of heat transfer rate are done which depends upon velocity of vehicle, fin geometry and the ambient temperature. They also carried out modification of the existing shape without changing material and area of fin to increase heat transfer rate to cool the engine easily and increase the thermal efficiency because excess temperature developed in the engine causes thermal stresses on the engine parts and piston sizing. This paper discussed about the heat transfer of different fin geometry under different forced convection conditions, different fin geometries are modelled in CATIA V5 software and CFD analysis was used to simulate the heat transfer of the engine block. They had taken dimensions of the cylinders along with fins from other literature. They assumed air as incompressible fluid, ambient temperature and pressure as 298K and 101325 Pa respectively, initialization of base temperature from 373K and three shapes i.e. Wavy, Zig-Zag and Rectangular.

They had found that:

- A. At lower velocities, flat fin has higher heat transfer rate and heat transfer coefficient. And if increases, then zig zag have higher heat transfer rate followed by wavy and then flat fins.
- B. Zig zag and wavy fin preferred over conventional fins for higher speed vehicles as it induces greater turbulence and thus greater heat transfer rate.

[4] numerically investigated problem of cross flow forced convection heat transfer from a horizontal cylinder with multiple, equally spaced, high conductivity permeable fins on its outer surface. The heat transfer characteristics of cylinder with permeable and solid fins were studied with

different parameters like number of fins, and fins heights with wide range of Reynolds number (5-200). This study shows that permeable fins offered much higher Nusselt number than the solid fins under the similar operating condition. Permeable fins resulted in much larger aerodynamic and thermals wakes which significantly reduced the effectiveness of the downstream fins, especially at $\theta < 90^\circ$. A single long permeable fin tended to offer the best convection heat transfer from a cylinder. This has great practical implications in terms of weight and cost of fins needed to achieve a certain level of heat transfer enhancement.

[5] The simulation of heat transfer of motorcycle fin under varying climatic condition such as velocity of vehicle, fin geometry and the ambient temperature. Increasing the environment, increasing the convection heat transfer coefficient, or increasing the surface area of the object increases the heat transfer. CFD analysis was used to simulate the heat transfer of the engine block. CATIA and ANSYS software was used for solid modelling. Two engine block model was selected to make the comparison of heat transfer rate and it was depending on engine no. of fin, fin pitch & wind velocity.

It was found that if the cooling rate decreases, it results in overheating leading to seizure of the engine & an increase in cooling rate affects the starting of the engine and reduces efficiency. Dependence of heat transfer coefficient on wind velocity:

[6] in this paper heat transfer from cylinder to air of two stroke internal combustion finned engine has been simulated. For this purpose, a 2D model has been done. Starting from the geometry of a real engine, annular cylindrical and spherical symmetric walls to fins has been used to obtain an equivalent simplified geometry, where the heat transfer rate is the same as that in the real engine. The cylinder body, cylinder head (both provided with fins), and piston have been numerically analysed and optimized in order to minimize engine dimensions. The maximum temperature admissible at the hottest point of the engine has been adopted as the limiting condition. From the simulation they have concluded that a total reduction of 20.15% has been achieved by reducing the total engine diameter D from 90.62 mm to 75.22 mm and by increasing the total height H from 125.72 mm to 146.47 mm aspect ratio varies from 1.39 to 1.95. In parallel with the total volume reduction, a slight increase in engine efficiency has been achieved.

[7] in this paper heat transfer rate depends upon the velocity of the vehicle, fin geometry and ambient temperature. An attempt was made to simulate the heat transfer using CFD analysis. The heat transfer surface modelled in GAMBIT and simulated in FLUENT software. They considered the air flow velocities around the finned cylinder from 20 km/hr to 72km/hr and temperature ranges from -10°C to 30°C. An expression of average fin surface heat transfer coefficient in terms of wind velocity is obtained. A mathematical relation of the average surface heat transfer coefficient in terms of wind velocity was formulated by using the empirical relation: $h=5.108u^{0.683}$.

They had found that:

- When the ambient temperature reduces to a very low value, it results in overcooling and poor efficiency of the engine overcooling affects the engine efficiency because of overcooling excess fuel consumption occurs. This necessitates the need for reducing air velocity striking the engine surface to reduce the fuel consumption. It can be done placing a diffuser in front of the engine which will reduce the relative velocity of the air stream thus decreasing the heat loss.
- The temperature and heat transfer coefficient values from fin base to tip are not uniform which shows the major advantage of CFD for analysis of heat transfer.

OBJECTIVE

Objective of project is to study new geometry of fins by changing different parameter like wind velocity or speed of vehicle, drilling holes, changing length, width, height and number of fins.

Generally Rectangular fins are used in motor bike engine so we try to modify it's geometry and study it by changing different parameters in such a way that it does not undergoes under cooling and overheating condition.

And also try to reduce it's weight by drilling holes which not only helps in weight reduction but also in reducing the cost of material handling and material requirement. But drilling holes in fins in such a way that it does not lower down it's strength and Factor of Safety (FOS).

METHODOLOGY

Numerical method:

From introduction and literature review after understanding the problem of project i.e. increasing heat transfer that mainly occur due to convection mechanism in bike engine follows the Newton's cooling law. According to law heat transfer depend on convective heat transfer coefficient and surface area.

$$Q = h A \Delta T = h A (T - T_s)$$

h = convective heat transfer coefficient

A = surface area available for heat transfer

T = temperature anywhere the length of fin

T_s = temperature of surroundings

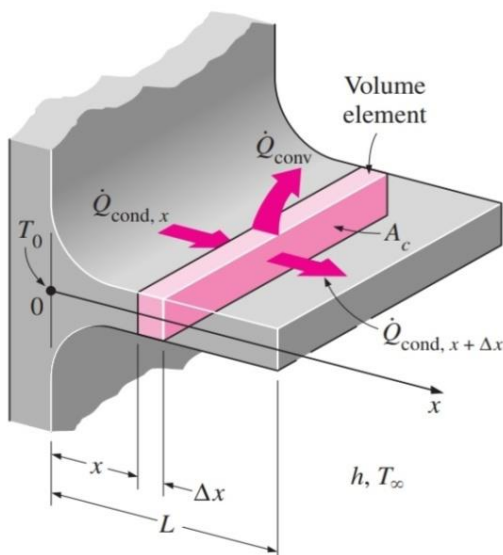


Figure 1: Rectangular fin

For our problem there were two solutions:

- increase-convective heat transfer coefficient
- increase-surface area available for heat transfer

We approached to increase the surface area for which fins are used (as it is not practical to increase the convective heat transfer coefficient. For increasing convective heat transfer coefficient we had to use fan blower that made system bulky and uneconomical)

After this we performed modelling simulation on SOLIDWORKS by varying the geometry and area of fins. We also made hole in modelling fin to increase the heat transfer.

To verify our modelling on SOLIDWORKS we approached to numerical solution of our project problem.

For Rectangular fins we solved by theoretically.

As in our problem fin thickness is very small we assumed one dimensional heat transfer.

Here L = length of fin

We take an elementary section of length dx at distance x from the base.

A_c - Cross-sectional Area

p - Perimeter

Here the energy balance on this volume element can be expressed as-

$$(\text{rate of heat conduction into element at } x) = (\text{rate of heat conduction from the element at } (x+dx)) + (\text{rate of heat convection from the element})$$

By solving the energy balance equation the heat transfers equation:

$$\frac{d^2T}{dx^2} - \frac{ph}{ak} (T - T_s) = 0$$

After solving this equation:- let it be equation (1),

$$(T - T_s) = (T_b - T_s)$$

$$\frac{*km \cosh m(L-x) + h(\sinh m(L-x))}{km \cosh(mL) + h \sinh(mL)}$$

We get above temperature distribution formula; by inputting parameter we get the temperature distribution along the length. After which we compared this value by SOLIDWORKS and C programming.

$$m = \sqrt{\frac{ph}{ak}}$$

Heat transfer coefficient,

$$h = 5.108 * u^{0.643} = 60 W/m^2K$$

$$(u = 45 m/hr)$$

$$p = 2(w + t)$$

$$p = 0.04 m$$

$$A = w * t = 0.01 * 0.01 = 10^{-4} m^2$$

Putting all in equation (1) we get,

$$m = \sqrt{\frac{ph}{ak}}$$

$$= \sqrt{\frac{0.04 \times 60}{0.0001 \times 210}}$$

$$m = 10.69$$

Now calculating temperature difference between base and ambient temperature:

$$\theta_b = T_b - T_s$$

$$= 533 - 300$$

$$= 233K$$

$$L_c = 0.15 + \left(\frac{0.01}{2}\right) = 0.155m$$

From equation (1),

$$T = 300$$

$$T = 383K$$

| θ | X |
|----------|-----|
| 232.99 | 0 |
| 83 | 150 |
| 99.95 | 100 |
| 145.92 | 50 |

Table 1: Temperature distribution

Now finding heat dissipation from fin,

$$Q(\text{fin}) = \sqrt{hpkA} \cdot \tanh(mL_c) \theta_b$$

$$= \sqrt{60 \times 0.04 \times 210 \times 0.0001} \cdot \tanh(10.69 \times 0.155) \times 233$$

$$= 48.63J$$

ANALYSIS BY SOLIDWORKS SOFTWARE:

Analysis of rectangular, triangular and triangular with holes, models in Solid works for more precise and accurate result.

| Fins | Dimensions (in mm) |
|-----------------------|--------------------------|
| Rectangular Fins | L=150, w=150, h=10 |
| Triangular Fins | L=160, w=160, h=10 |
| Triangular with holes | L=160, w=160, h=10, D=10 |

Table 2: Dimension of different fins

INPUT PARAMETER:

Internal temperature: 260°C

Ambient temperature: 27°C

Convection coefficient: 60 W/Wm²K

ANALYSIS OF RECTANGULAR FINS:

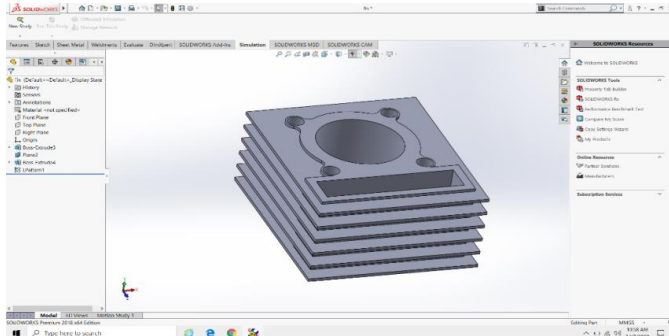


Figure 2: Design of rectangular fins

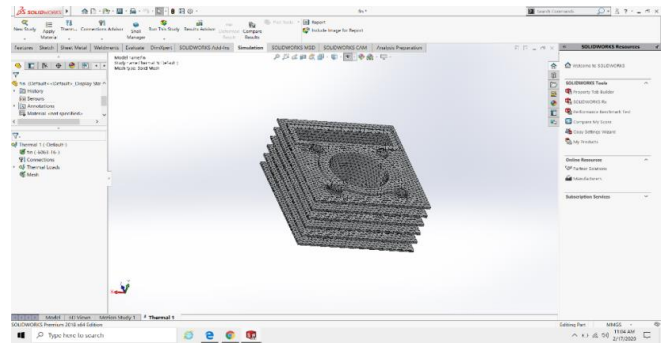


Figure 3: Meshing of model

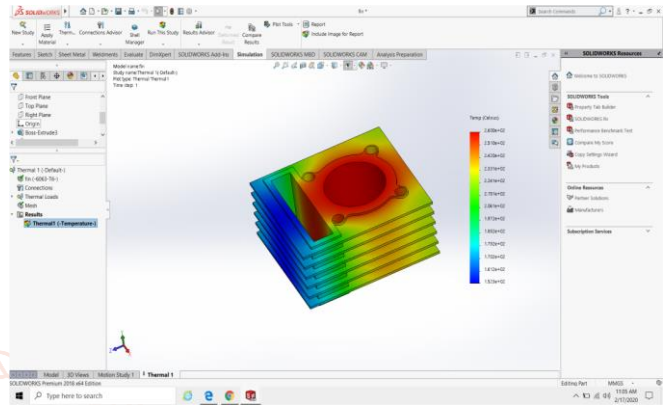


Figure 4: Temperature distribution in model

ANALYSIS OF TRIANGULAR FINS:

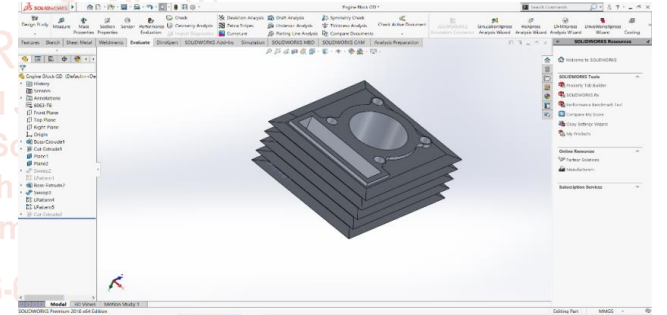


Figure 5: Model

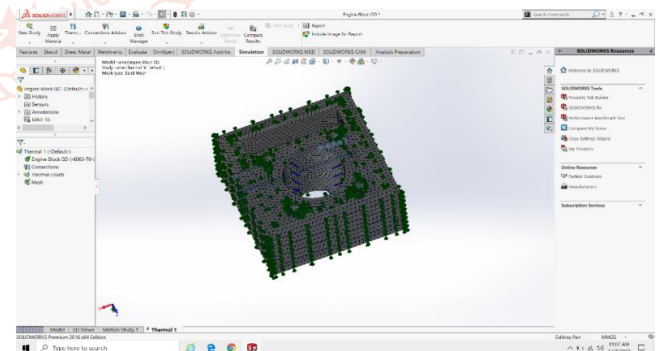


Figure 6: Meshing

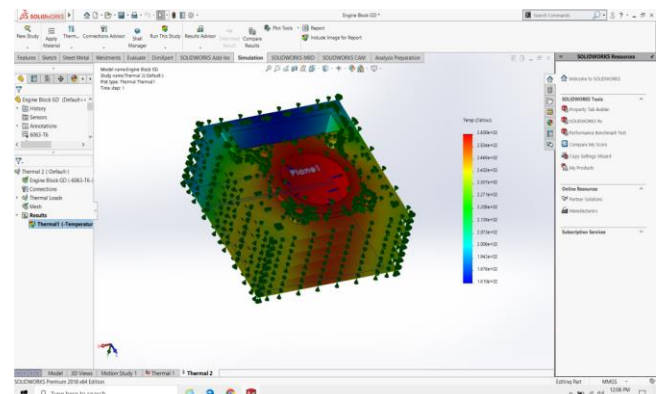
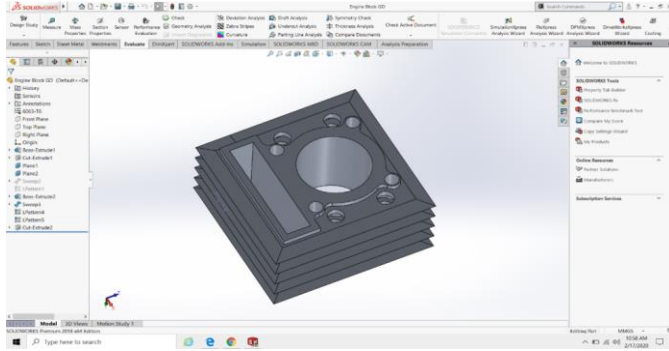
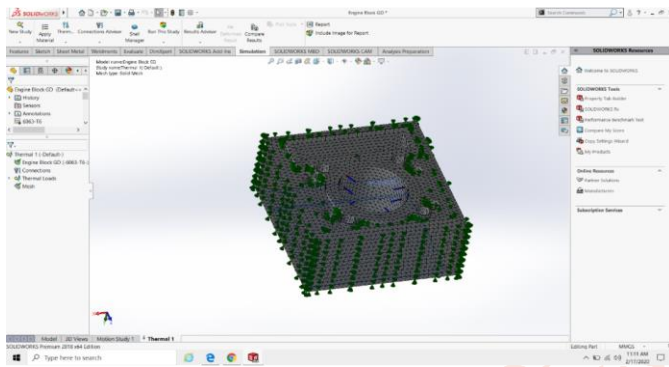
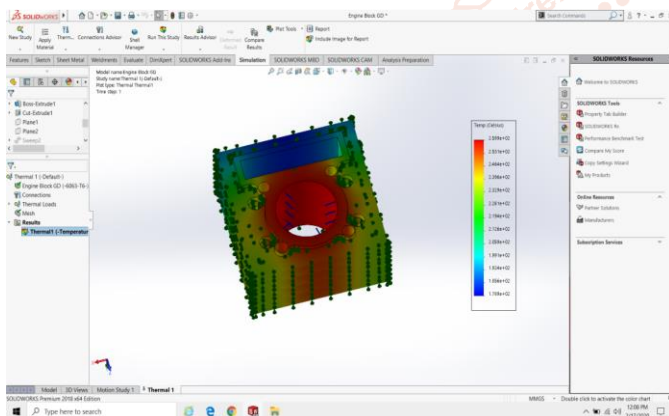


Figure 7: Temperature distribution

ANALYSIS OF TRIANGULAR FINS WITH HOLE:**Figure 8: Model****Figure 9: Meshing****Figure 10: Temperature distribution****RESULT AND DISCUSSION**

After analysis the models in software (SOLIDWORKS) we have found certain outcomes which are given below:

| Geometry | Rectangular fin | Triangular fin | Triangular fin with holes |
|--------------|-----------------|----------------|---------------------------|
| Minimum (°C) | 122.3 | 151.73 | 137.5 |
| Maximum (°C) | 260 | 260 | 260 |

Table 3: Temperature distribution at different geometry

| Geometry | Numerical | | Solid Works | |
|-------------|--------------|--------------|--------------|--------------|
| | Maximum (°C) | Minimum (°C) | Maximum (°C) | Minimum (°C) |
| Rectangular | 260 | 110 | 260 | 122.3 |

Table 4: Comparison of Numerical and Solid Works solution

1. Rectangular fins are used in every motor bike engine, we try to modified it is geometry & lower down it is weight by drilling holes in fins. From Table, we conclude that the minimum temperature of both fins (Rectangular and Triangular with holes) having a difference of approximately 10-15°C but on further drilling some holes in model it reduces it is Factor of Safety by 2-3 which reduces it is strength.

2. Minimum temperature of rectangular fin in both numerical & analytical approach having a difference of approximately 10-15°C.

3. Heat dissipation from fin is depend upon various factors other than geometry such as Ambient Temperature, speed of bike or air, No. of fins, length, width & height so, with the help of C-PROGRAMING we can easily calculate Temperature at surface of fin, heat dissipation from fins by simply varying these factors.

CONCLUSION

From result of Thermal Analysis of Rectangular fins, Triangular fins & Triangular fins with holes, following conclusion are made which are given below:

1. The minimum temperature of triangular fins is higher than the minimum temperature of rectangular fins, which fails our objective that the minimum temperature of triangular fins is almost or lower than the temperature of rectangular fins.
2. The minimum temperature of triangular fins with holes is near about or a difference of about approximately 10°C from the minimum temperature of rectangular fins.
3. Ascending order of heat dissipation from fins from different geometry is given as: Triangular fins < Triangular fins with holes < Rectangular fins
4. The model is not under overheating & under cooling condition i.e. it is in from result of Thermal Analysis of Rectangular fins, Triangular fins & Triangular fins with holes.

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