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Enhancement of heat transfer on Engine Cylinder Block

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Abstract – *Performance of Engine depends on different parameters such as type of materials used for making engine, numbers of fins, fin thickness, and fins Shape which escort thermal effect on them. In this work, study of variation of temperature from engine cylinder through the fins is carried out .As there is more heat generated in the engine and that should be removed off .So by varying geometry of fins this work is carried out. Initially the calculations were carried out and on study of fins, we got to know that fins having triangular notch transfers more heat and has higher heat transfer coefficient of 8.2W/m²-k compared to the other notches .The theoretical rate of heat transfer is calculated for old and new design ,its value is 8700.8 watts and 8724.6 watts. The complete structure of the engine cylinder block is modeled by using the SOLID WORKS software. The analysis was carried using ANSYS Work bench software. The maximum and minimum temp was 673K and 422.2 K on the old design whereas the temp variation is found to be of maximum as 673 K and minimum as 438.7 K on modified engine block.*

Key Words: **Engine block, heat transfer rate, fins, Temperature**

1. INTRODUCTION

It has been observed that in case of IC engines, combustion of air and fuel takes place inside the engine cylinder and hot gases are being generated. The temperature of gases will be too high. At this temperature it may result into burning of oil film between the moving parts of the engine and may result it seizing or welding of same. So, this temperature must be reduced so that the engine will work much more efficiently. Too much cooling may not be desirable as it reduces the thermal efficiency of engine. So, the work of cooling system is to keep the engine running at its most efficient operating temperature. The note should be taken that the engine is quite inefficient when it is cold and hence the cooling system is to be designed in such a way that it prevents cooling when the engine is warming up and till it attains maximum efficient operating temperature and then it starts cooling.

Engines mounted on two wheelers are mostly cooled by natural air. As the heat dissipation is a function of frontal cross-sectional area of the engine, therefore there is a need to enlarge this area. An engine with enlarged area will become heavy and in turn will also minimize the power by weight ratio. Hence, as an alternative arrangement, fins are constructed to enhance the frontal cross-section area of the engine.

1.1 Objective of Study

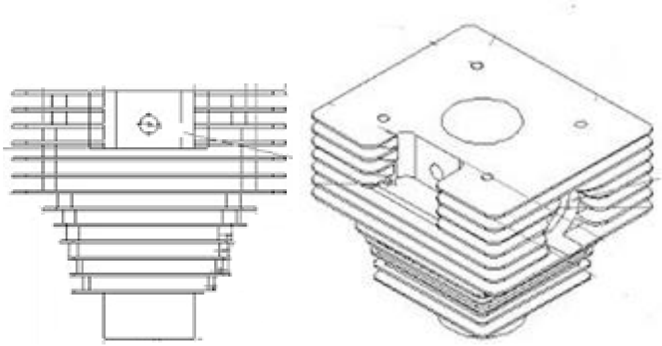
The main objective of project is to increase the rate of heat transfer through study of plate fins on the engine block having different geometrical notches. This is being done by performing experiments through analysis of plate fins and experimentation. Steps are listed below:

- To study influence of fins with and without triangular notches on engine block.
- The analytical results are carried out for heat transfer coefficient and rate of heat transfer.
- Modeling the Engine cylinder block using SOLID WORKS software.
- Carrying Model Analysis in ANSYS work bench to find out results.
- Compare the results obtained by theoretical design equations with the results of analysis.

Selection of most efficient plate fin from all other defined fins with notches

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.

1.2 Design Considerations



2. Theory of Heat Transfer through Fins

The major heat transfer takes by two modes i. e. by conduction or by convection. Heat transfer through the solid to the surface of the solid takes place through conduction where as from the surface to the surroundings takes place by convection. Further heat transfer may be by natural convection or by forced convection. The rate of heat transfer from a surface at a temperature T_s to the surrounding medium at T_0 is given by Newton's law of cooling as

$$Q = hAs(Ts - To)$$

Conduction is the mode of heat transfer in which exchange of energy takes place from the region of high temperature to the region of low temperature by the kinetic motion or direct impact of molecules, as in case of fluid at rest, and drift of electrons, as in case of metals

For heat flow in the x direction, for e.g. the Fourier law is given by

$$Q_x = -KA\frac{dT}{dX}\, watt$$

In the analysis of fins, we consider steady state operation with no heat generation in the fin; we assume the thermal conductivity 'k' of the material to remain constant. We also assume the convection heat transfer coefficient 'h' to be constant and uniform over the entire surface of fin for convenience in the analysis. We recognize that the heat transfer coefficient h in general, varies along the fin as well its circumference, and its value at a point is a strong function of the fluid motion at that point. The value of h is usually much smaller at the fin base than it is at the fin tip because fluid motion is surrounded by solid surfaces near the base, which seriously disrupt its motion to the point of "suffocating" it, while fluid near the fin tip has a little contact with a solid surface and thus encounters the little resistance flow. Therefore adding to many surfaces on a surface may actually decrease the overall heat transfer when the decrease in h offsets any gain resulting from the increase in the surface area.

The energy transfer by heat flow cannot be measured directly, but the concept has physical meaning because it is related to the measurable quantity called temperature. It has long been established by observations that when there is temperature difference in a system, heat flows from a region of high temperature to the region of low temperature.

3. THEORETICAL CALCULATIONS

3.1 Fins without notches on Engine Block

1) When motor cycle is stationary the heat transfer will be due to free convection

The calculations are carried out considering that the temp generated within the engine cylinder is around 400°c and the ambient temp is considered as 34°c.

T_s=400°c, Ta=34°c

Mean film Temp T_f=217 °c

A=0.0196m^2, L=0.126m

Properties

Density ρ =0.70kg/m^3, viscosity v=37.7×10^{-6} m^2/s

Pr=0.6785, k=0.040995W/m-k,

$\beta=(1/T)=(1/673)=1.485\times10^{-3}$

Grashoffs number

Gr=$\frac{L^3}{v^2}g\beta\Delta T$

Gr=7.5×10^6

(Gr×Pr)= 5.09×10^6

Nusselts Number

$$Nu = 0.54\frac{(GrPr)^{0.25}}{1}$$

Also, $Nu = \frac{hL}{K}$

$h=8.345 W/m^2\ {}^oc$

$Q=hA_s\Delta T$

Q=1556.6 watts

2) When the motor cycle is running the heat transfer will be due to forced convection

The velocity of air on fins is assumed as 40km/hr

Velocity

U=11.11 m/s

Reynold's Number

$$Re = \frac{LU}{v}$$

$Re=(0.126\times11.11)\div(37.7\times10^{-6})$

$Re=37.13\times10^3$

Hence the flow is turbulent

For turbulent flow for cooling

Nusselt's Number

$Nu=0.036(Re)^{0.8} (Pr)^{0.33}$

$Nu=0.036\times (37.13\times10^3)^{0.8}(0.6785)^{0.33}$

$$Nu = \frac{hL}{K}$$

$H=46.6508 W/m^2\ {}^oc$

Heat transfer from the cylinder

$Q=hA_s\Delta T$

$=46.6508\times (0.14 \times0.14\times2\times13) (400-34)$

Q=8700.8 Watts

3.2 Fins with triangular notches on Engine Block

In this the change in cross section of the engine block has been made my creating 5 triangular notches on each surface of fin.

1) When motor cycle is stationary the heat transfer will be due to free convection

New area $A_s=0.018465m^2$, L =0.09225m

Grashoffs number

$Gr=\frac{L^3}{v^2} g\beta \Delta T$

$Gr=2.945\times10^6$

$(Gr\times Pr)= =2\times10^6$

Nusselts Number

$$Nu = 0.54\frac{(GrPr)^{0.25}}{1}$$

$$Nu = \frac{hL}{K}$$

$h=9.022 W/m^2\ {}^oc$

As the heat transfer takes place from the both sides of fins (No of fins=13)

$Q=hAs\Delta T$

$=9.022\times0.018465(673-304) \times2\times13$

Q=1585.28 watts

2)When the motor cycle is running the heat transfer will be due to forced convection

U=11.11 m/s

Reynold's Number

$$Re = \frac{LU}{v}$$

$Re=27.185\times10^3$

Nusselt's Number

$Nu=0.036(Re)0^{.8} (Pr)^{0.33}$

$$Nu = \frac{hL}{K}$$

$H=49.65 W/m^2\ {}^oc$

Heat transfer from the cylinder

$Q=hAs\Delta T$

Q=8724.6 Watts

4. SOLID MODELING

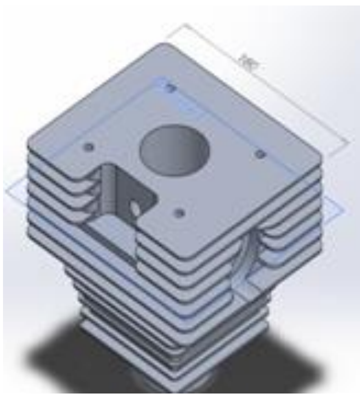


Fig4.1 Solid Model of Engine Block without notch

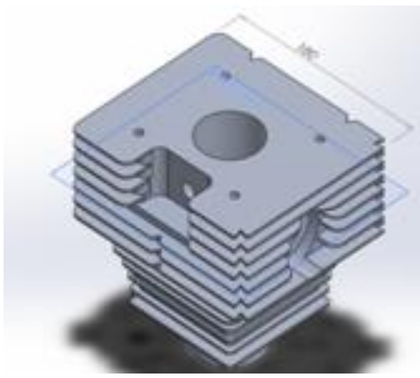


Fig4.2 Solid Model of Engine Block with notch

Table 4.1 Properties of Solid model

Without Notches	With Notches
Volume:0.0016267 m^3	Volume:0.0016272m^3
Density:2700 kg/m^3	Density:2700 kg/m^3
Weight:43.0941 N	Weight: 42.6911

Meshed model of the Cylinder Engine Block

Meshing is carried out on the entire engine block, considering each part. The fine mesh is carried out on the entire block using tetrahedron element for meshing.

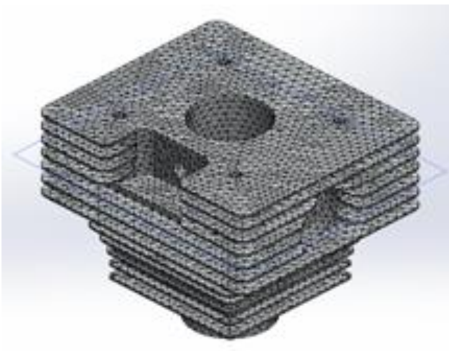


Fig4.3 Meshed model without notch

Table4.2Nodes and elements of old model

Total Nodes	154720
Total Elements	96866

Meshed model with notch

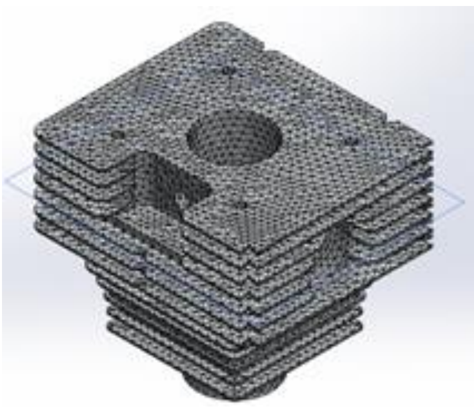


Fig4.4 Meshed model with notch

Table4.3Nodes and elements of old model

Total Nodes	154530
Total Elements	96780

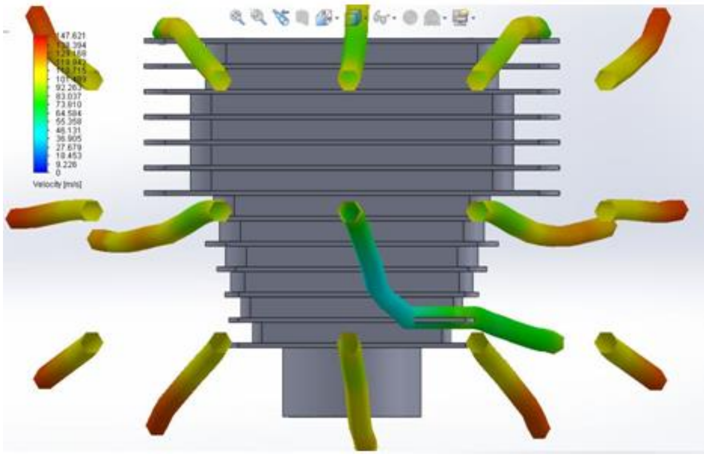


Fig4.5 Flow express of air over engine block

5. RESULTS AND DICUSSIONS

A three dimensional steady state conjugate heat transfer analysis has been done by assuming a constant temperature on the inner surface of the cylinder wall and evaluating the quantity of heat lost from the engine surface which is modeled as a finned cylinder. The temperature at the inner wall of cylinder surface is assumed constant at 400^{0}C to account for heat generated due to combustion inside the engine.

For obtaining the relation between heat transfer coefficient and velocity, the temperature was maintained constant and the simulation were carried out at a velocity of 40km/hr. The values of heat transfer coefficient were directly proportional to wind velocity specified for the simulation.

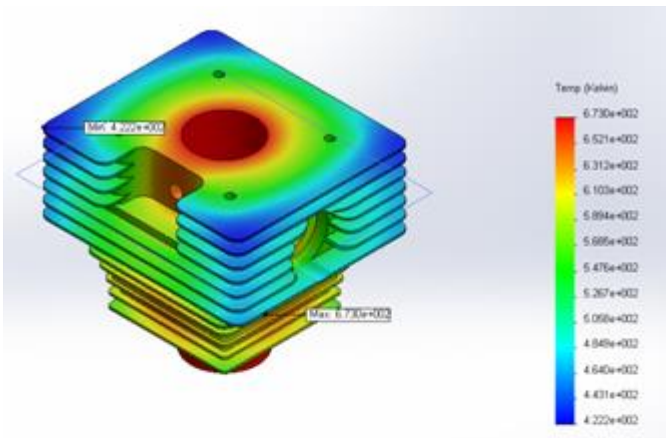


Fig5.1 Analysis of the model without notches

The thermal analysis is carried out on the engine cylinder block on applying the temperature at the inner portion of the block. The fig the above shows the temp variation from engine cylinder to the ends of fins.

TEMP: Temperature
Min -422.174 Kelvin

Max --673 Kelvin

Rate of heat transfer
$Q=hAs\Delta T$
Q=7833.57 watts

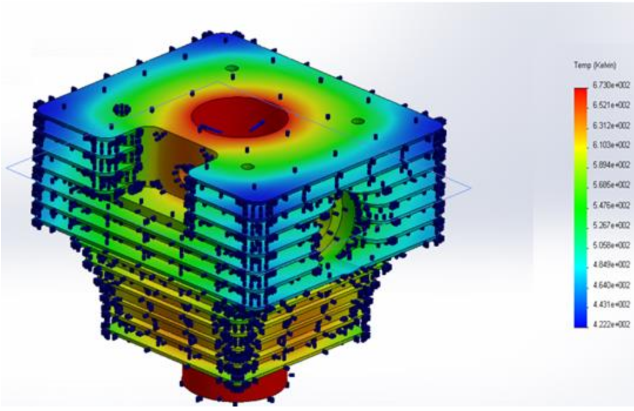


Fig5.2 Analysis of the model without notches

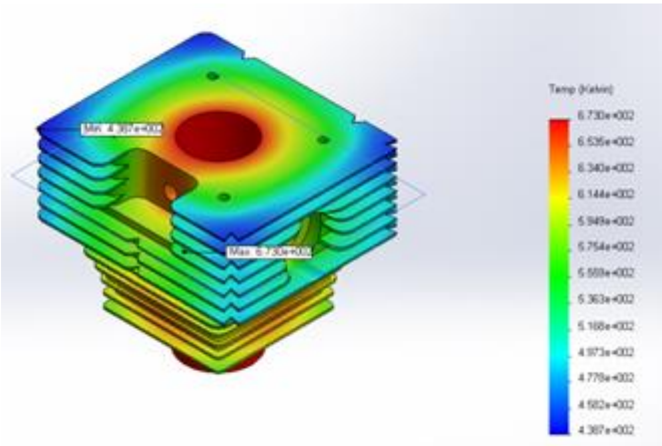


Fig5.3 Analysis of the model with notches

TEMP: Temperature
Min -438.7 Kelvin

Max –673 Kelvin

Rate of heat transfer
$Q=hA_s\Delta T$
Q=7907.08 watts

The old design was modified and new one was created by varying the geometry by creating triangular notches on the fins. The thermal analysis is carried out on the engine cylinder block on applying the temperature at the inner portion of the block. The figure the above shows the temp variation from engine cylinder to the ends of fins.

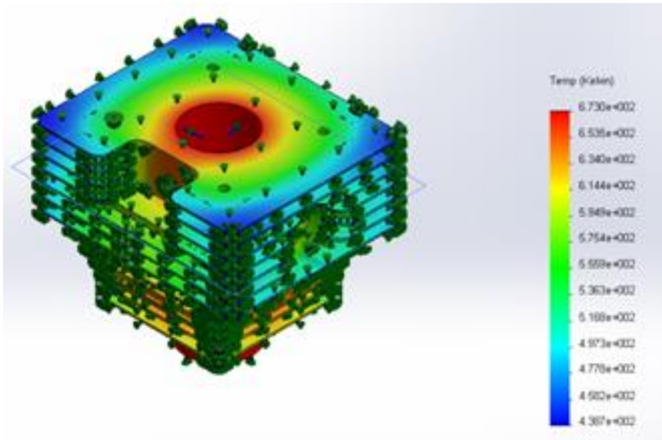


Fig5.4 Analysis of the model with notches

The distribution of heat taking place on the block where the red color shows maximum temp of 673K and blue color shows minimum temp of 438.7K

6.CONCLUSION

Design of fin plays an important role in heat transfer. There is a scope of improvement in heat transfer of air -cooled engine cylinder if mounted fin's shape varied from conventional one. Triangular notched fin shaped cylinder block can be used for increasing the heat transfer from the fins by creating turbulence for upcoming air.
A brief summary of the work completed and significant conclusions derived from this work are highlighted below.

- A model for an air cooled motorcycle engine was developed and effects of wind velocity and air temperature were investigated. The work confirms the results of the study of heat transfer dependence on different geometries. An analysis of heat transfer on the engine block with and without notches under surrounding temperatures has also been carried out.
- The temperature and heat transfer coefficient values from fin base to tip are not uniform

which shows the major advantage of analysis of heat transfer.

- The analysis of the engine cylinder block without the notches on it shows the temp variation where temp varies from 422.2 K to 673 K.
- The analysis of the engine cylinder block with the notches on it shows the temp variation where temp varies from 438.7K to 673 K.

This concludes that the modification of engine is found to be successful as the rate of heat transfer is more in the new design and hence the heat is being removed off at a faster rate on the new design of engine block which will result in improvement of heat transfer.

Table 6.1 Comparison of Theoretical and Analysis Results

Model	Max Temp	Min Temp	Heat transfer coefficient 'h' W/m²k		Q_{th} watts	Q_a watts	%error
Engine block without notch	673	422.2	46.65	43	8700.8	7833.57	11.07
Engine block with notch	673	438.7	49	45	8724.6	7907.0	10.33

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