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Modeling and Simulation of Fins for 150cc Engine

KEYWORDS: Fins, Total heat flux, Heat dissipation rate, Finite Element Analysis, Extended surfaces.

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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. The main purpose of fins or extended surfaces is to cool the engine cylinder by contacting it with air. In order to cool the cylinder, fins are provided on 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, but it increases weight and size. Designing such a large complex engine is very difficult. The main objective of the work is to increase the heat dissipation rate and reducing weight of engine cylinder by doing thermal analysis on fins of different materials. In this work a parametric model of the cylinder fin body is created. Transient thermal analysis is done on the fin body using different materials to reduce weight and to increase heat dissipation rate.

I. INTRODUCTION

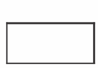
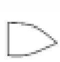
THE heat conducted through solids, walls or boundaries has to be continuously dissipated to the surroundings or to environment to maintain the system in steady state condition. In many engineering applications large quantities of heat have to be dissipated from small areas. Heat Transfer by convection between the surface and the fluid surrounding can be increased by attaching to the surface thin strips of metals called fins. Whenever available surface is found inadequate to transfer the required quantity of heat with available temperature drop and convective heat transfer coefficient, extended surfaces or fins are used. The fins increase effective area of surface thereby increasing the heat transfer by convection. The fins are also referred as extended surfaces. Fins are manufactured in different geometries depending upon practical applications.

Fins may be of uniform or variable cross section. Fins are used for cooling of

1. Electrical components.
2. Cooling of motor cycles.
3. Compressors.
4. Electrical motors.
5. Refrigerators.
6. Radiators for automobiles.

1) Types of fins used based on their shape are:
Straight fins, annular fins, longitudinal fins, rectangular fins, conical fins, Trapezoidal fins, parabolic fins, cylindrical fins, truncated conical fins, and triangular fins.

TABLE I.
FIN PROFILES

Types of radial fin profiles	Rectangle	Elliptical	Trapezoidal	Triangle
Diagram				

Three dimensional view of different types of fins is given below

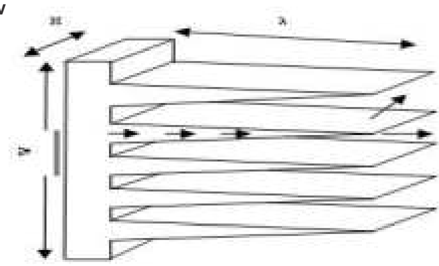


Fig.1. Triangular Fin Array

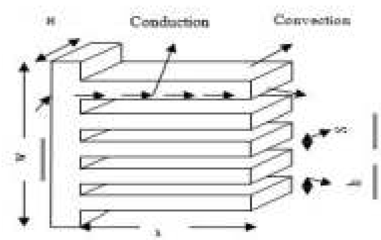


Fig.2. Rectangular Fin Array

2) Cooling systems for I.C. engines
Internal combustion engines can transform 25 to 35 percentage of the chemical energy in the fuel into mechanical energy. About 35 percentage of the heat generated is lost to the surroundings of combustion space, remainder being dissipated through exhaust and radiation from the engine. The temperature of the burning gases in the engine cylinder is about 2000 to 2500°C.

II. LITERATURE REVIEW

Magarajan U., Thundil karrupa Raj R., and Elango T [1] have carried out numerical study on heat transfer I C Engine cooling by extended fins using CFD. In this study, heat release of an IC engine cylinder cooling fins (six numbers of fins used) having pitch of 10 mm and 20 mm are calculated numerically using commercially available CFD tool Ansys Fluent. The IC engine is initially at 150 and the

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heat release from the cylinder is analyzed at a wind velocity of 10 km/h. It is observed from the CFD result that it takes 174.08 seconds (pitch=10mm) and 163.17 secs (pitch =20mm) for ethylene glycol domain to reach temperature of 423 K to 393 K for initially. The experiment results shows that the value of heat releases by the ethylene glycol through cylinder fins of pitch 10mm and 20mm are about 28.5W and 33.90W.

Pulkit Agarwal et.al [2] simulated the heat transfer in motorcycle engine fins using CFD analysis. It is observed that when the ambient temperature reduces to a very low value, it results in overcooling and poor efficiency of the engine. They have concluded that overcooling also affects the engine efficiency because of overcooling excess fuel consumption occurs.

Ashok Tukaram Pise and Umesh Vandeorao Awasarmol [3] conducted the experiment to compare the rate of heat transfer with solid and permeable fins. Permeable fins are formed by modifying the solid rectangular fins with drilling three holes per fins incline at one half lengths of the fins of two wheeler cylinder block. Solid and permeable fins block are kept in isolated chamber and effectiveness of each fin of these blocks were calculated. Engine cylinder block having solid and permeable fins were tested for different inputs (i.e.75W, 60W, 45W, 30W, 15W). It was found that permeable fins block average heat transfer rate improves by about 5.63% and average heat transfer coefficient 42.3% as compared to solid fins with reduction of cost of the material 30%.

Masao Yosidha et. al. [4] investigated effect of number of fin, fin pitch and wind velocity on air-cooling using experimental cylinders for an air-cooled engine of a motor cycle in wind tunnel. Heat release from the cylinder did not improve when the cylinder have the more fins and too narrow a fin pitch at lower wind velocities, because it is difficult for the air to flow in to the narrower space between the fins, so the temperature between them increased.

N. Nagarani and K. Mayilsamy [5] have carried out experimental heat transfer analysis on annular circular and elliptical fins. They had analyzed the heat transfer rate and efficiency for circular and elliptical annular fins for different environmental conditions. Elliptical fin efficiency is more than 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 co-efficient depends upon the space, time, flow conditions and fluid properties. If there are changes in environmental conditions, there is a change in heat transfer co-efficient and efficiency also.

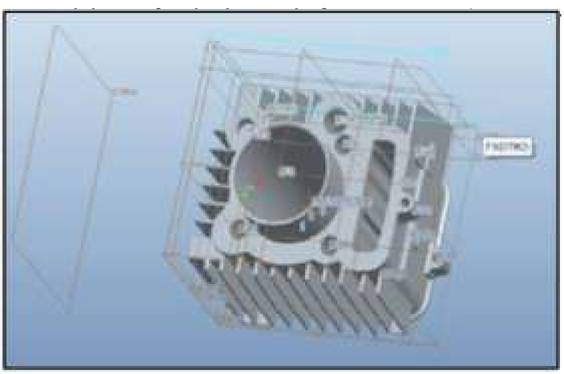

Fig.3. Modified cylinder body with fin thickness 2.5mm.

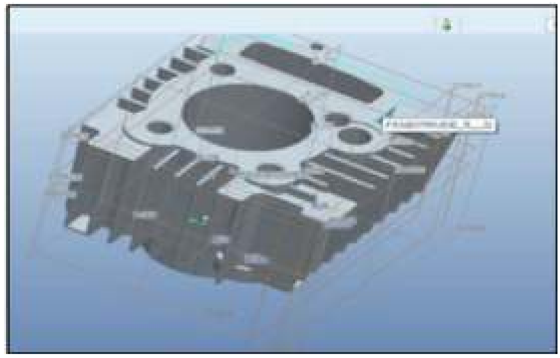

Fig. 4. Cylinder body with fin thickness 3mm

III. ANALYSIS OF VARIOUS FINS

ANSYS is general-purpose Finite Element Analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user- designated size) called elements. The software implements equations that govern the behavior of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated or graphical forms. This type of analysis is typically used for the design and optimization of a system of too complex objects.

In practice, a finite element analysis usually consists of following principal steps:

Step 1: Import the geometry file or model from the file location.
Step 2: Selection of model.
Step 3: Select the part geometry (shape: rectangular or circular or curved and thickness of fin:3mm or 2.5mm) and assign the one material as AA6061 or AA204 or CI.
Step 4: Click on 'Mesh' and select the 'relevance center' as 'medium'.
Step 5: Select 'Transient Thermal', select the inner surfaces, click on temperature and give a temperature of 12000C.
Step 6: Select all other surfaces, click on 'Convection' and give 'Film Coefficient' as 2 W/mm2 and give ambient temperature as 300C.
Step 7: Right click on 'Solution', go to 'Insert', go to 'Thermal' and add Temperature, Total Heat Flux and Directional Heat Flux one by one to get their characteristics as outputs.
Step 8: Click on 'Solve' in 'Solution'.
Step 9: Repeat from Step 1 to 8 and find the solution for different shape of fin with different thickness and different type of material.

2) Analysis of Cylinder body with 2.5 mm thick fin Material: Cast Iron

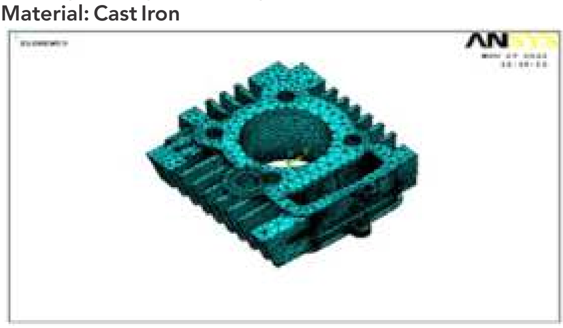

Fig.4. Meshed model of cylinder fin (2.5mm thick) body.

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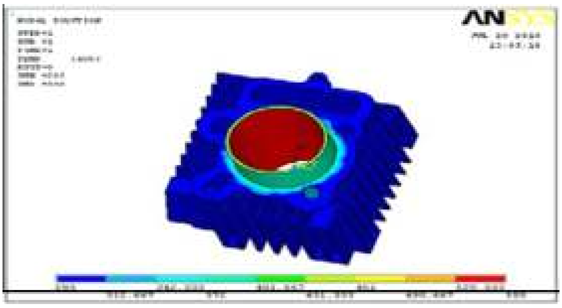

Fig.5. Nodal temperature (Material: CI)

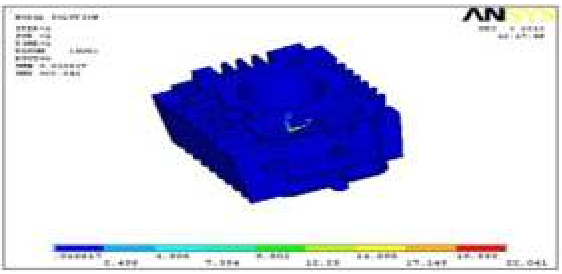

Fig.6. Thermal Gradient (Material: CI)

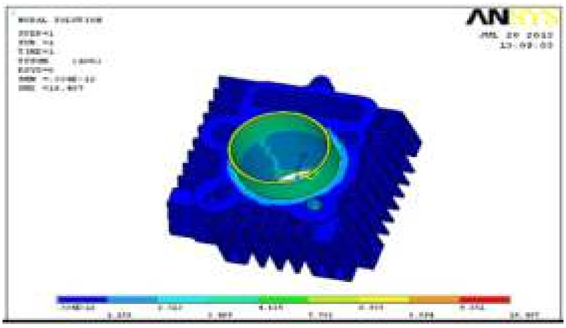

Fig.7. Thermal flux (Material: CI)

3) Analysis of Cylinder body with 2.5 mm thick fin Material: Aluminum Alloy (AA6061) material

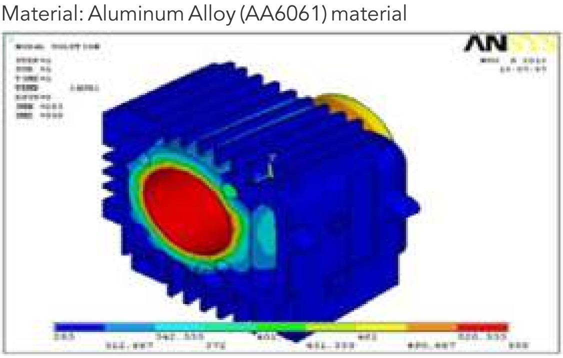

Fig. 8. Nodal temperature (Material: Aa6061)

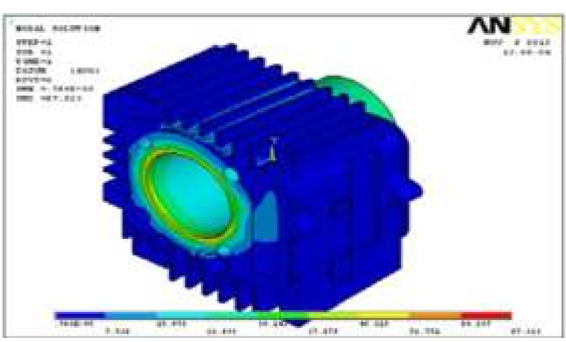

Fig. 9.Thermal gradient sum (Material: Aa6061)

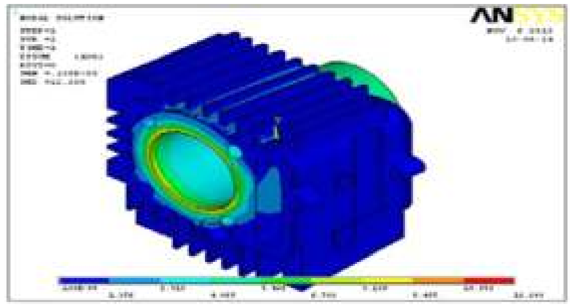

Fig.10. Thermal flux (Material: Aa6061)

TABLE II.
MATERIAL PROPERTIES

Material properties	CI	AA 6061
Thermal conductivity (w/mm K)	55	300
Specific heat (J/kg °C)	500	963
Density (g/cc)	7.1	2.7
Temperature (K)	550	550
Film coefficient (w/m2K)	39.9	39.9
Bulk temperature (K)	283	283

TABLE III.
ANALYSIS RESULTS

	CI 2.5 mm	AA6061 2.5mm
Weight (Kg)	2.53	0.8936
Nodal temperature(K)	550	550
Thermal gradient(K/mm)	22.041	67.823
Thermal flux(W/mm2)	10.407	12.208

Table 3: Experimental results
Length of fin (l) =130mm=0.13m
Width of fin (b) =130mm=0.13m
Thickness y = 2.5mm, 2y=5mm=0.005m
Perimeter of fin (p) = 0.1273m
k=conductivity of fin material =120W/Mk
h=heat transfer coefficient = 25W/m2K.
Cross sectional area of fin Ac= b × y

$$m = \sqrt{\frac{hp}{kA_c}} \quad \text{Where}$$

t=temperature of cylinder head=458K,
ta=atmospheric temperature=313K
x=distance measured from base of fin=65mm=0.065m, Θo=t-ta
Heat lost by fin

$$qfin = kA_c m\Theta o\left(\frac{h\cosh(ml)+km\sinh(ml)}{mk\cosh(ml)+h\sinh(ml)}\right)$$

Maximum heat transferable by fin when if entire fin at base temperature

qmax= h (pl) (t0-ta) = h (pl) Θo
$\eta = (q_{fin}/q_{max})$
Effectiveness of fin

$$\epsilon = \frac{\text{Heat lost with fin}}{\text{heat lost without fin}},\ \epsilon = \sqrt{\frac{pk}{hA}}$$

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Temperature on fin (θ) at distance x from base is

$$\theta = \theta o \, X \left(\frac{kmcosh\,[m\, l-x] + h[sinh\,(m\, l-x)]}{kmcosh\,(ml) + h[sinh\; ml\,]} \right)$$

Where
€ = Effectiveness of fin, A = Contact Area (m2),
q= Heat Flow (W), Q= Heat Flux (W/m2) = q/Ac,
Tg = Thermal gradient (K/m),
Θo=temperature difference between cylinder head and atmosphere.

TABLE IV.
RECTANGULAR FINS

	3 mm Thickness			2.5mm Thickness		
	AA 204	AA 6061	CI	AA 204	AA 6061	CI
Nodal Temp.(K)	558	558	558	558	558	558
Thermal Gradient (K/mm)	4.632	3.184	1.809	2.482	1.609	3.575
Thermal Flux (W/mm²)	0.5557	0.5731	0.5684	0.2876	0.2978	0.2895

TABLE V.
CIRCULAR FINS

	3 mm Thickness			2.5mm Thickness		
	AA 204	AA 6061	CI	AA 204	AA 6061	CI
Nodal Temp.(K)	558	558	558	558	558	558
Thermal Gradient (K/mm)	6.997	4.85	5.434	5.319	3.684	4.128
Thermal Flux	0.8396	0.8730	0.8639	0.6383	0.6613	0.6563

TABLE VI.
CURVED FINS

	3 mm Thickness			2.5mm Thickness		
	AA 204	AA 6061	CI	AA 204	AA 6061	CI
Nodal Temp. (K)	558	558	558	558	558	558
Thermal Gradient (K/mm)	14.608	10.612	11.736	16.117	11.744	12.165
Thermal Flux (W/mm²)	1.75	1.91	1.866	1.934	2.114	1.934

TABLE VII.
MASS OF DIFFERENT MATERIALS

Cross section	Al 204	Al 6061
Rectangular	1.0100279Kg	9.7395552 e-1Kg
Circular section	1.1846582Kg	1.1423490Kg
Curved fins	8.9376056 e-1Kg	8.6184054 e-1Kg

TABLE VIII.
THEORITICAL RESULTS

Section	Material	Thk (mm)	Heat Lost (W)	Effectiveness	Efficiency
Rectangular	Al 204	3	132.369	56.56	15.3
		2.5	140.64	61.96	11.5
	Al 6061	3	128.64	69.28	11
		2.5	135.09	75.89	8.8
	CI	3	131.21	65.11	12.4
		2.5	132.27	71.33	11.8
Circular	Al 204	3	269.9	56.6	23.33
		2.5	269	61.96	26.2
	Al 6061	3	151.04	69.28	26.99
		2.5	151	75.89	26.8
	CI	3	272.47	65.11	19.3
		2.5	272.47	71.33	19
Curved	Al 204	3	69.84	56.56	23.33
		2.5	43.32	61.96	10
	Al 6061	3	64.49	69.28	12.7
		2.5	70.48	75.89	12.2
	CI	3	62.76	65.11	13.9
		2.5	58.15	71.33	12.7

IV. RESULTS AND DISCUSSION

In this work we have designed a cylinder fin body used in a 150cc Motorcycle and modeled in parametric 3D modeling software Pro/Engineer. Three materials used for thermal analysis are Al 204, Al 6061 and Cast Iron (CI). Shapes of fins used for analysis are rectangular, circular and curved. Moreover thickness for fins used is 3.0mm and 2.5 mm. It means 3x3x2=9 types of fins are analyzed. A thermal analysis is carried out on the fin body by varying materials, geometry and thickness. Tables IV, V, VI, VII and VIII show the results. From table IV Rectangular fins AA6061 have more value of thermal flux (i.e. more transfer rate per unit area) compared to other materials AA204 and CI. AA 6061 heat flux is for rectangle fin of 3mm thick is 0.8730W/m2, whereas for AA204 it is 0.8396W/m2 and for CI it is 0.8639 W/m2. Heat flux for AA6061 rectangular fin having 2.5mm thick is also more as compared to AA204 and CI material. It is also clear from table V and VI i.e for circular fins and curved fins. From table 7, it is clear that mass of curved fins is 8.6184054e-1Kg which is less when compared to other two types of fins. Table VIII shows that AA6061, 2.5mm thick fin have more effectiveness i.e. 75.89 compared to all other types of fins. Since thickness is reduced from 3.0mm to 2.5mm, weight is further reduced. From all above the results it clear that AA6061 curved shape fin with 2.5 mm thick have more effectiveness i.e more heat transfer rate and weight is less. This is also shown in graph 1. Hence it is best suitable for cylinder fins.

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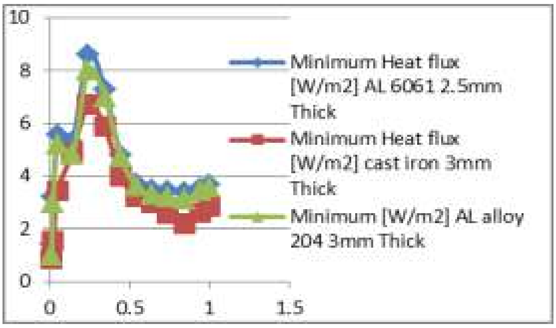

Graph1. Minimum Heat flux [W/m2] V/s Time (Sec) for 2.5mm Aluminum Alloy 6061, 3mm Cast iron, 3mm Aluminum Alloy 204 cylinder fin body.

V. CONCLUSION

The following conclusions can be drawn from the present work. In this work, a cylinder fin body for 150cc motorcycle is modeled using parametric software Pro/Engineer. The thickness of the original model is 3mm. But in this work it is reduced to 2.5mm. Present used materials for fin body are Al 204, CI and Al 6061. In this work, thermal analysis is done for all the three materials Cast Iron, Aluminum Alloy 204, and Aluminum alloy 6061. The material for the original model is changed by taking the consideration of their densities and thermal conductivity. Density is less for Aluminum alloy 6061 compared with other two materials so weight of fin body is less using Aluminum alloy 6061. By observing the thermal analysis results, thermal flux is more for Aluminum alloy 6061 than other two materials and also by using Aluminum alloy 6061, the weight is less for because thick is reduced from 3mm to 2.5 mm. So Aluminum alloy 6061 having 2.5mm and curved shape is better for fin.

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