Optimization of Engine Cylinder Fin by Varying its Geometry and Material

M Syamala Devi[1], E Venkateswara Rao[2], K Sunil Ratna Kumar[3]

[1, 2, 3]Department of Mechanical Engineering, Sir CR Reddy College of Engineering, Eluru, Andhra Pradesh, India

Abstract: ***As we all know, Engine cylinder plays a crucial role in running an engine efficiently. Piston reciprocates inside the engine cylinder and the cylinder is subjected to continuous temperature variations and thermal stresses. So cooling an engine cylinder plays an important role to increase the life. Engine cylinder can be cooled by fluids like oil and air as media. To improve the efficiency of air cooling, fins will be provided as they provide the more surface area for heat dissipation. But when we keep increasing the surface area, there are other factors like weight & size will shoot up which will complicate the design of fins and engine cylinder. In order to keep the design simple, thermal analysis is done by varying the size, shape and material of fins. Good thermal conductive materials like LM13 (AL356) and Aluminum alloy, 3D modelling software – Pro/Engineer and the analysis tool ANSYS are used for this study. This study will guide us to define the optimum size and shape of the fins to have highly efficient cooling for the complicated designs***

Keywords: Cylinder Fins, Thermal analysis, Aluminum alloy, Heat Transfer

1. Introduction

Heat transfer is classified into three types. The first is conduction, which is defined as transfer of heat occurring through intervening matter without 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 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. Fins are also referred 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 well known example for Air cooling system in which air acting as a medium. Heat generated in the cylinder will be dissipated in to the atmosphere by conduction mode through the fins or extended surfaces are used in this system, which are incorporated around cylinder.

2. Why Engine Cooling is required

1) Engine valves wrap due to low heat transfer
2) Changes the material properties for critical components like Piston, Engine cylinder, etc…
3) Thermal stresses will be induced into the engine critical parts which cause distortion and cracks in the parts.
4) Pre Ignition occurs due to overheating of Spark plug
5) Overheating reduces the efficiency.

3. Application of Fins

1) Electrical components
2) Cooling of motor cycles
3) Compressors
4) Electric Motors
5) Refrigerators
6) Radiators

4. Literature Survey

Pulkit Agarwal etc. [1] simulated the heat transfer in motor cycle engine fan using CFD analysis. It is observed that ambient temperature reduces to the very low value; it results in over cooling and poor efficiency of the engine. They have concluded that over cooling also affects the engine efficiency because over cooling excess fuel consumption occurs.

Masao Yosidha etc. [2] investigated effect of number of fins, fin pitch and wind velocity on air cooling using experimental tunnel. Heat releases from cylinder did not improved 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 into the narrower space between the fins, the temperature between them increased..

5. Thermal Analyses

5.1 Equations applied in theoretical calculations

Length of fin (L) = 600 mm=0.60 m
Width of fin (b) = 450mm=0.45 m
Perimeter of fin (P) = 0.1273 m

K=conductivity of fin material = 160W/Mk
h=heat transfer coefficient = 19W/m^2K.
Cross sectional area of fin Ac = b × y
$M = \sqrt{hp/kA_c}$
T = temperature of cylinder head = 458K
Ta = atmospheric temperature = 298K
X = distance measured from base of fin=65mm=0.065m.

$\Theta = T - T_a$

$\Theta = \Theta_o \times (k m \cosh[ml-x] + h[\sinh\{ml-x\}] k m \cosh(ml) + h[\sinh ml]$

Heat lost by fin

$Q = K A_c m \Theta_o (h\cosh(ml) + km\sinh(ml) m k\cosh(ml) + h\sinh(ml))$

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

$Q_{max} = h\,(Pl)\,(t_0 - t_a) = h\,(Pl)\,\Theta_o$

$\eta = (Q_{fin}/Q_{max})$

Effectiveness of fin

∊=heat lost with fin heat lost without fin $\quad \epsilon = \sqrt{pk/hA}$.

5.2 Material Properties

Table 1: Material properties

Thermal Properties	*LM13*	*Al alloy*
Thermal conductivity	160 W/mK	170 W/mK
Specific heat	0.434J/go c	0.875J/go c
Density	2.69g/c	2.77g/c
Film coefficient	19W/mm2K	23W/mm2K
Bulk temperature	298K	298K
Temperature	500K	500K

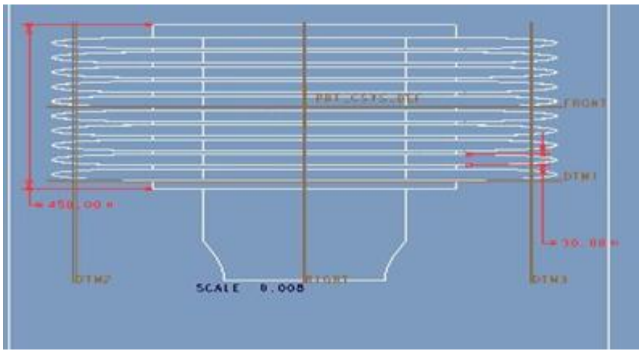


Figure 1: Elliptical Fin in 2D

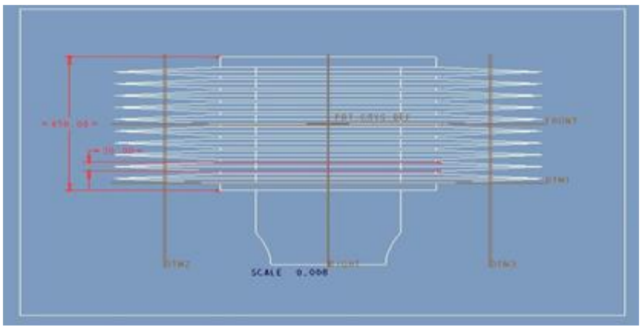


Figure 2: Triangular Fin in 2D

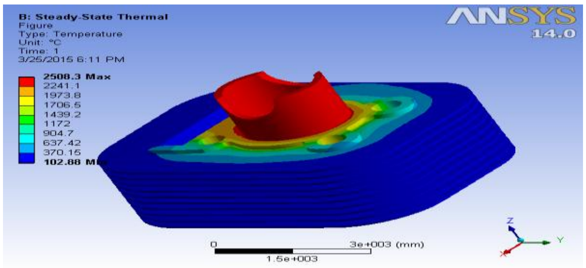


Figure 3: Nodal temperature (material LM13)

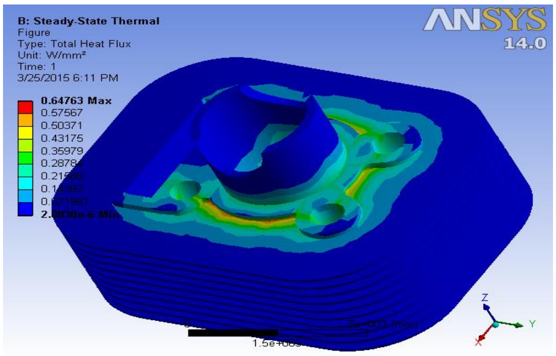


Figure 4: Heat Flux (material LM13)

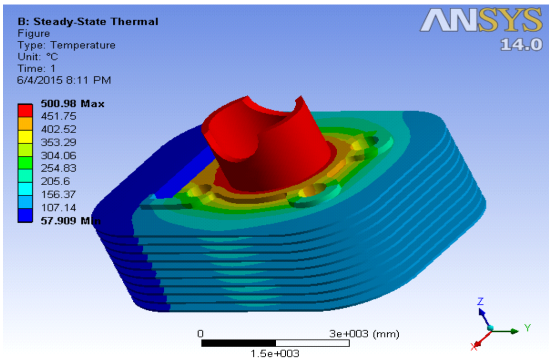


Figure 5: Nodal temperature (material Al alloy)

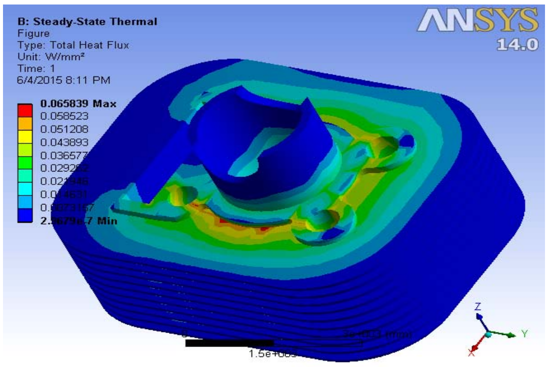


Figure 6: Heat Flux (material Al alloy)

5.3 Mass of Fins

Table 2: Mass at 3 mm thickness

Shapes of Fin	*Al 204*	*LM13 (Al 356)*	*Al alloy*
Rectangular	1.0100	1.2654	1.3031
Elliptical	1.1847	1.2466	1.2837
Triangular	0.8376	1.0704	1.1022

Table 3: Mass at 2.5 mm thickness

Shapes of Fin	*Al 204*	*LM13 (Al 356)*	*Al alloy*
Rectangular	0.9710	1.0265	1.0543
Elliptical	1.2047	0.8735	0.8990
Triangular	0.9254	0.9253	0.8574

Table 4: Mass at 2.0 mm thickness

Shapes of Fin	*Al 204*	*LM13 (Al 356)*	*Al alloy*
Rectangular	0.9710	0.9170	0.9443
Elliptical	1.2047	0.8485	0.8590
Triangular	0.9538	1.0137	1.0438

5.4 Analysis Results

Table 5: Results for rectangular fins

Material Name	*Thickness of the fin*	*Nodal Temperature (K)*	*Total Heat Flux (w/mm2)*
Al alloy 204	3	500.26	0.5299
	2.5	500.54	0.6383
	2	501.18	0.8396
LM 13 (Al 356)	3	500.98	0.6692
	2.5	500.51	0.7183
	2	500	0.8658
Al alloy	3	500.96	0.6935
	2.5	500.52	0.7416
	2	500	0.8839

Table 6: Results for Elliptical fins

Material Name	*Thickness of the fin*	*Nodal Temperature (K)*	*Total Heat Flux (w/mm2)*
Al alloy 204	3	500.22	1.2532
	2.5	500.36	1.7534
	2	500.91	1.8432
LM 13 (Al 356)	3	500.5	1.3912
	2.5	501.26	1.831
	2	501.32	1.8791
Al alloy	3	501.32	1.496
	2.5	501.23	1.8551
	2	501.3	1.9134

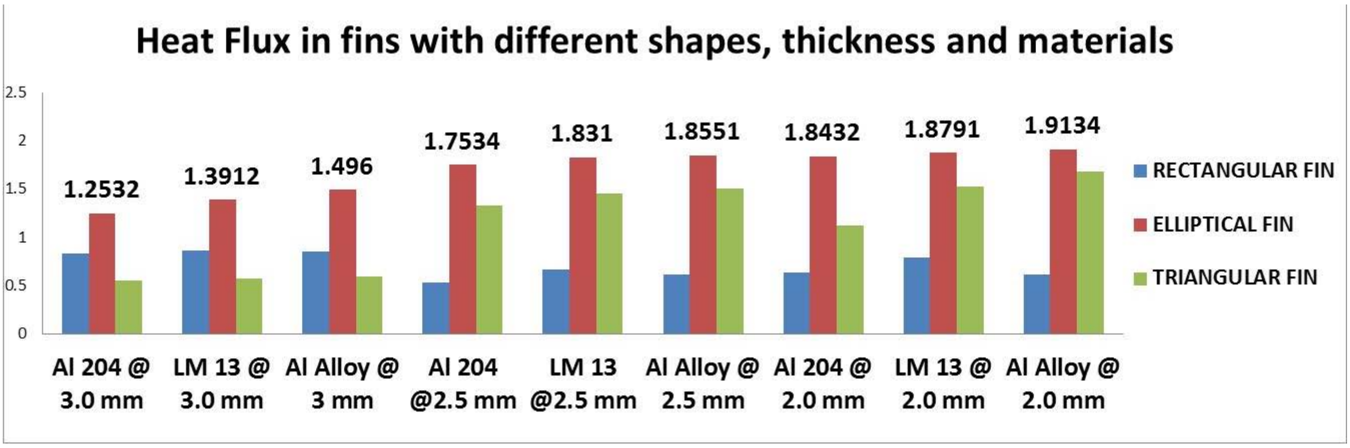
Table 7: Results for Triangular fins

Material Name	*Thickness of the fin*	*Nodal Temperature (K)*	*Total Heat Flux (w/mm2)*
Al alloy 204	3	500.64	0.5555
	2.5	500.89	1.3297
	2	501.48	1.3719
LM 13 (Al 356)	3	501.3	0.573
	2.5	502.06	1.4567
	2	502.16	1.5269
Al alloy	3	501	0.5916
	2.5	502.03	1.5061
	2	502.1	1.68923

5.5 Theoretical Results

Table 8: Results for theoretical calculations

Shape	*Material*	*Thickness*	*Heat lost (W)*	*Efficiency*
RECTANGULAR	*LM13*	3	111.26	18.37
		2.5	127	20.6
		2	136.78	23.44
	AL ALLOY	3	122.72	20.48
		2.5	128.86	21.34
		2	138.56	24.58
ELLIPTICAL	*LM13*	3	131.085	22.1
		2.5	134.46	22.6
		2	141.78	24.33
	AL ALLOY	3	139.26	23.92
		2.5	162.632	28.36
		2	179.87	27.54
TRIANGULAR	*LM13*	3	64.6403	6.08
		2.5	68.426	11.25
		2	72.736	13.52
	AL ALLOY	3	84.26	14.87
		2.5	102.22	17.34
		2	81.823	15.06



Graph 1: Heat flux in fins with different materials and thickness

From the above results, thickness and geometry plays an important role for the heat flux. Al alloy is showing better results when compared to the LM13 at the thickness 2.0 mm for the elliptical shape.

We can interpret from the graph that elliptical shaped fins are showing the better results compared to the rectangular and triangular fins. So we can conclude that elliptical fins have more heat transfer compared to other shapes for a defined material.

6. Conclusions

In this project, we have designed a cylinder fin body in 3D modelling software – Pro/Engineer and analyzed the thermal properties in ANSYS.

From the analysis, we concluded that shape and thickness along with material plays an important role in defining the amount of heat transfer from the fins. Among the 3 shapes, elliptical shape fins are giving the best results than the rectangular and triangular fins.

Also, thickness of the fins plays an important role in heat transfer. As we keep reducing the thickness, heat transfer rate is shooting up for a defined shape and material. But while reducing the thickness, we should consider the strength of the fins to understand that till which thickness fins can withstand the working temperatures. From the results, we have observed 2.0 mm thickness is giving the better results compared to 3.0 & 2.5 mm thickness.

We have analyzed the fins heat transfer rate with 2 materials, LM13 & Al Alloy. Al alloy is giving the better results compared to the LM13 as Al alloy is having the better thermal conductivity, specific heat properties.

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