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Optimization of Cooling Fin Efficiency in IC Engine Using Heat Transfer Analysis

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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. In order to cool the cylinder, fins are provided on the surface of 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, so designing such a large complex engine is very difficult. 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. This project is to analyze the thermal heat dissipation of fins by varying its geometry. Parametric models of fins have been developed to predict the transient thermal behavior. There after models are created by varying the geometry such as rectangular, circular, wavy with extension. The modelling software used is CREO Parametric 3.0. The analysis is done using ANSYS workbench. Presently Material used for manufacturing fin body is generally Aluminium Alloy 204 which has thermal conductivity of 110-150W/m-ºC. We are analyzing the fins using material Aluminium Alloy 6061 which has higher thermal conductivity of about 160-180W/m-ºC. After determining the material, the third step is to increase the heat transfer rate of the system by varying geometrical parameters such as cross-sectional area, parameter, length, thickness, etc. which ultimately leads us to fins of varying shape and geometries.**

***Keywords*: rectangular block, circular block, wavy fins block, temperature reduction, heat flux, temperature drop, temperature distribution, thermal analysis, IC engine block, fins.**

1. Introduction

Convection may be defined as a mode of heat transfer which occurs generally between a heated plate and a fluid stream. If this heat transfer takes place naturally, this phenomenon is known as free convection. On the other hand, if heat transfer takes place on the account of some external media like fan or blower, then it is termed as forced convection. The heat transfer rate can be increased by employing extended surfaces on the region where the heat transfer rate is intended to be increased. These extended surfaces are termed as fins. The main objective of using fins is to facilitate heat transfer and get improved values of convicted heat. Fins are used in different places, particularly in automobiles and bikes, in engines for increasing the heat transfer rate.

The main use of fins is to increase convective heat transfer and to achieve an increased heat transfer area without using excessive primary surface area. They are basically used in Internal Combustion engine cooling such as fins in a Cylinder block. It is of utmost importance to predict the distribution of temperature within the fins so as to choose a configuration that is most effective. Out of the total energy liberated, only a part of it is used to run the automobile, the remaining energy is wasted in form of heat and exhaust gases. In case this excess heat is not dissipated from the engine, it results into overheating of the engine. This is accomplished with the help of cooling system. About 34% of the energy generated by the engine during combustion is lost in heat.

2. Numerical Calculations

A. Method 1 (Based on HMT Design data – Page No. 59)

1) Heat transfer

$$Q = \eta Ash(Tb - T\infty)$$

B. Method 2 (Based on HMT Design data – Page No. 58)

1) Heat transfer (Short fin end not insulated)

$$(Tb - T\infty)\frac{\tanh(mL) + \left(\frac{h}{mk}\right)}{1 + \left(\frac{h}{mk}\right)\tanh(mL)}(hPkA)\text{^}0.5$$

C. Method 3

1) Heat Loss by Fin

$$Q = KAm\theta\,\frac{hcosh(ml) + kmsinh(ml)}{mkcosh(ml) + hsinh(ml)}$$

2) Lumped Heat analysis
Instantaneous heat flow up to time:

$$q = hA(T - T\infty)$$

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Total heat flow:

$$qt = \rho c V(T - T\infty)$$

Biot Number:

$$M = \frac{\frac{hL}{K}}{\sqrt{\frac{hP}{kA}}}$$

D. Calculation and Result

Table 1
Heat flux

Fin Type	Material	Thickness	Method 1	Method 2	Method 3	Lumped heat analysis
			Heat transfer (watts)			
RECTANGULAR	Al 204	3	184.5	302.1	212.8	75.4
		2.5	180	303.5	207.4	73.5
	Al 6061	3	209.4	254.2	226.6	80.2
		2.5	204.3	255.4	220.8	78.3
WAVY	Al 204	3	166.8	297	191.9	68.2
		2.5	162.4	298.4	186.6	66.4
	Al 6061	3	189.3	249.1	204.3	72.5
		2.5	184.3	251.1	198.7	70.6
CURVED	Al 204	3	140.5	255.2	184.2	64.6
		2.5	140.5	255	184.2	64.6
	Al 6061	3	149.5	214.5	196.0	68.7
		2.5	145.3	212.5	196.1	68.7

E. Modeling

The following are the three different shapes of Cylinder block,

- Rectangular Shape
- Wavy Shape
- Circular Shape

Which are drawn using CREO 3.0.

1) Rectangular block

1.1 Dimensional details:

Bore: 50mm
Stroke: 50mm
Width: 110mm
Thickness: 2.5mm
Fin pitch: 11mm
No. of fins: 7

Fig. 1. Rectangular block

2) Circular block

2.1 Dimensional details

Bore: 50mm
Stroke: 50mm
Width: 110mm
Thickness: 2.5mm
Fin pitch: 11mm
No. of fins: 7

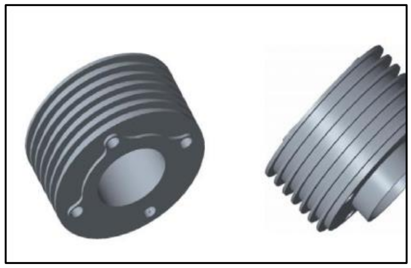

Fig. 2. Circular block

3) Wavy fins block

3.1 Dimensional details

Bore: 50mm
Stroke: 50mm
Width: 110mm
Thickness: 2.5mm
Fin pitch: 11mm
No. of fins: 7

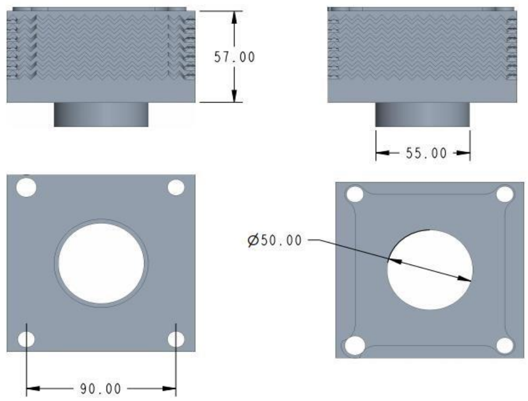

Fig. 3. Wavy fins block

3. Stimulation and Analysis

All the models were analyzed using Ansys work bench.

A. Boundary conditions

Table 2
Boundary conditions

S. No.	Property	Material: Aluminium Alloy
		Grade: 6061
1	Thermal Conductivity K	180W/mk
2	Heat transfer coefficient	25W/m^{2}k
3	Specific Heat	900 J/Kg K
4	Density	2.7g/cc
5	Ambient temperature	303K
6	Film Coefficient	25W/m^{2}k
7	Cylinder Head temperature	473K (Based on Journal for 100cc)

B. Analysis results of the models

1) Rectangular block

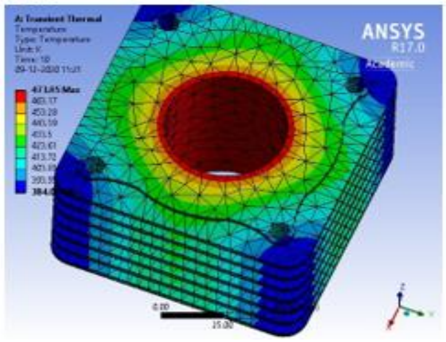

Fig. 4. Temperature reduction

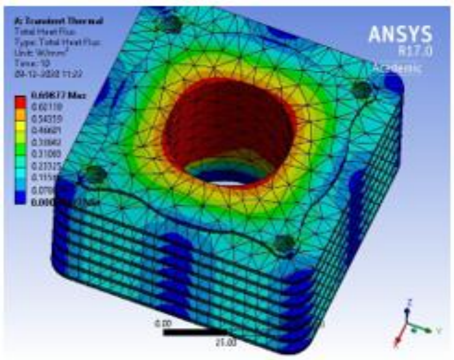

Fig. 5. Heat flux

2) Circular type

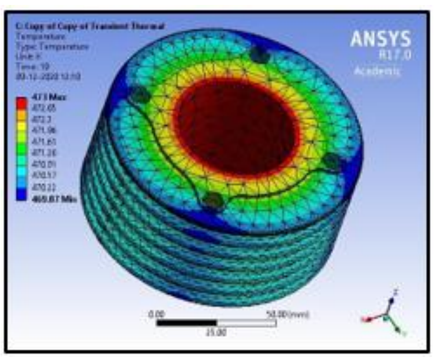

Fig. 6. Temperature reduction

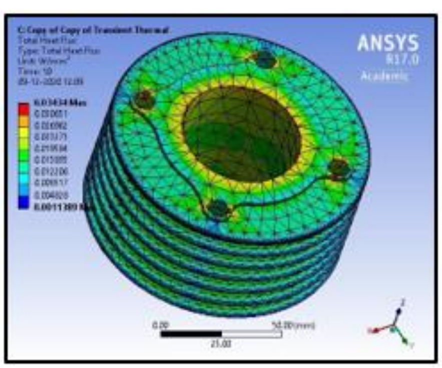

Fig. 7. Heat flux

3) Wavy block

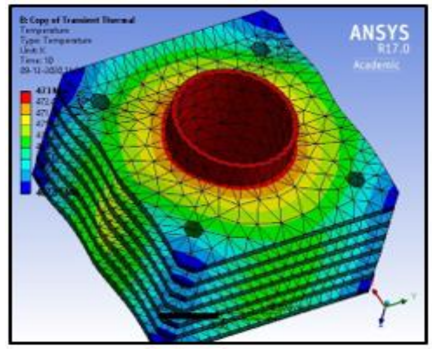

Fig. 8. Temperature reduction

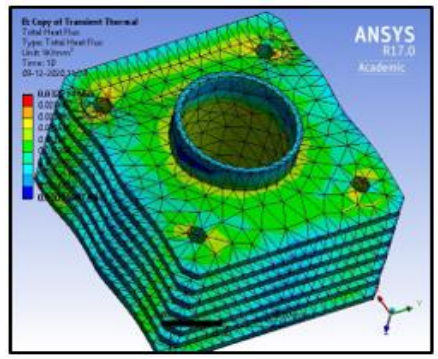

Fig. 9. Heat flux

4. Results and Discussion

A. Temperature drop

The below chart shows the Temperature variations of different kinds of fins during transient heat analysis in ANSYS.

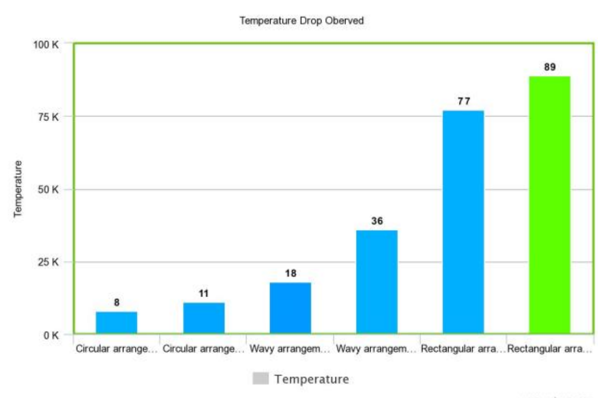

Fig. 10. Temperature drop comparison

B. Temperature distribution

Around 89 deg K Temperature drop observed with rectangular fins block when compared with other configurations.

Temperature distribution observed with rectangular fins are found better compared with other configurations.

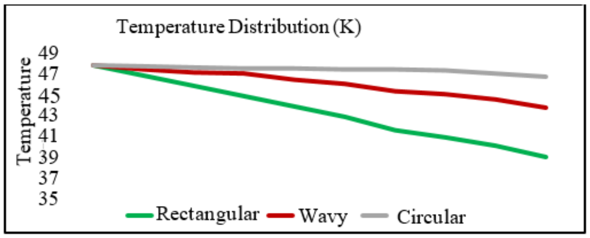

Fig. 11. Temperature distribution comparison

C. *Reason for rectangular fins with al6061 are better*

- Rectangular fins have higher perimeter area when compared to wavy and circular configuration.
- Rectangular fins with AL6061 material have better heat transfer rate due to high thermal conductivity and better heat transfer coefficient.
- Rectangular fins have a uniform distribution of temperature over the time.
- There is no restriction of Air flow.
- AL6061 material have better density. It will improve the heat transfer rate.
- Pressure reduction observed between the fins have found good in rectangular fins when compared with wavy fins and circular fins

D. *Comparison Analysis*

Table 3
Theoretical vs. Simulation

Type	Analytical Calculation		Simulation	
	Heat Transfer (watts)	Heat Flux (W/mm^2)	Temperature (K)	Heat Flux (W/mm^2)
Rectangular	226.6	0.042	89	0.06
Wavy	204.35	0.03	36	0.032
Circular	196.08	0.031	11	0.034

- Based on analytical calculations, Heat transfer rate is found better in rectangular fins block. Same phenomena have replicated in simulation method in terms of temperature drop.
- And heat flux also found no significant variations.

5. Conclusion

From the comparative analysis of engine cylinder with rectangular shape fins, Wavy Fins and Circular area shaped fins minimum temperature is found in engine cylinder with Rectangular (384 K) area shape fins when compared to wavy (437K) and circular fins(462K) So, it is concluded that engine cylinder with rectangular area shape fins is shows better Heat transfer properties in this analysis. Thus, heat transfer for engine cylinder in an experimental result show that rectangular area of fins profile having better than engine cylinder within circular area shaped fins and wavy fins.

From the above study following conclusions are made:

- By thermal analysis of fins to modifying its certain parameters such as geometry and material of engine cylinder fins with rectangular shape or Circular area shape will gives the better impact in heat transfer rate.
- By observing the analysis results, we can easily say using engine cylinder with rectangular area shape fins with material Aluminum alloy 6061 is better since the temperature drop and the heat transfer rate in an engine cylinder have much better compared to engine cylinder within Circular area fins and wavy fins.

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