THE INTERNATIONAL JOURNAL OF
SCIENCE & TECHNOLEDGE

Experimental Study for Heat Transfer Enhancement under Turbulent Flow Conditions by Increasing the Surface Area of Engine Cylinder Fins

Sivashankar M.
Assistant Professor, Department of Mechanical Engineering, SRM University, Chennai, Tamil Nadu, India
Aditya Pratap Manker
B.Tech Student, Department of Mechanical Engineering, SRM University, Chennai, Tamil Nadu, India
Raju Shriram
B.Tech. Student, Department of Mechanical Engineering, SRM University, Chennai, Tamil Nadu, India

Abstract:
Enhancement of fin efficiency of engine cylinder fins in air cooled engines under forced convection and turbulent flow was investigated by three different types of proposed fins and one conventional fin the material of all the fin is aluminium. The experiments were carried out by increasing the surface area of all proposed fins(13.86%,13.05%,32.59% respectively) compared to conventional fin.All the fins are placed on the heater which acts as a heat source and keeping air flow rate constant. The results showed that the fin efficiency for the proposed fin-3 increased by 12.39% compared to conventional fin.

Keywords: *Forced convection, Engine cylinder fins, Turbulent flow, Surface area, Heat transfer.*

1. Introduction

The advancements in the automotive sector, the size of engines is decreasing and the power output is increasing, a need arises for faster and efficient dissipation of heat from the engine. To improve heat transfer from extended surfaces for multiple applications like heat exchangers, condensers, IC engines; significance is given to maintain the appropriate dimensions of the extended surface with less effect on its manufacturability.[1]Richard and Aligan conducted experiments to investigate the performance of fins by employing different materials such as copper, aluminium and brass in a pin fin apparatus under forced convection.[2] Performance analysis by Sahin and Demir reported the heat transfer enhancement on a square surface which had perforated pin fins along a rectangular cross section, whose area was 100-250 mm^2; the fin spacing ratio of 1.208, 1.524, 1.944 and 3.417, with a Reynolds number ranging from 13,500-42,000. The results enlightened that use of square pin fins lead to enhanced heat transfer and improved efficiencies which varied between 1.1 and 1.9 depending on the clearance ratio and inter-fin spacing ratio. [3] Kukulka and Fuller conducted an experiment on heat exchangers under turbulent flow conditions by using rigidised surfaces and understanding the material composition including surface roughness, louvering, and effect of Reynolds number on the heat transfer; enhancement of heat transfer was less significant for laminar flow conditions and concluded the heat transfer increases with velocity and flow distribution.[4] Yet another experiment conducted by Hung-Yi-Li, Shung- Ming Chao, Go-Long Tsai illustrated the effects of impinging Reynolds number, the height and width of the fins on the thermal resistance has been investigated by infrared thermography. The results of which suggested that thermal resistance decreases gradually with increase in Reynolds number and also in comparison to increasing the height and width with appropriate Reynolds number also decreases the thermal resistance.[5] A numerical analysis done by Seyf and Layeghi on an elliptical pin fin heat sink by forced convection and employing metal inserts on a conjugate heat transfer model suggests the effects of Reynolds number and metal frame porosity on the overall Nusselts number and efficiency of heat sink. The results illustrate that Nusselts number increases up to 400% with decrease in porosity and increase in Reynolds number.[6] While another set of experimental investigation performed by Molki and Esfahanian to determine the convective heat transfer of a perforated baffle blockage which is located on the lower principal wall of a rectangular duct with the Reynolds number lying in between 5000 and 30000. The results indicated increased heat transfer coefficient for the perforated baffle plate. In this present study we made conventional prototype fin of TVS Apache RTR 180 engine, to fix the prototype fin in the heat source unit.

2. Experimental Setup

The experimental setup consists of a domestic heater (Hot Plate) of capacity 1500W which has an attachment plate placed over it. An Aluminium base plate of 2.5mm thickness will be housed on top of the attachment plate having grooved slots of 2.5 mm wide and 70mm in length, such that fins fix in the slots. The fins of the same dimension 70x25x2.5 mm are used with a varying surface texture and pattern. A blower of 500W capacity is placed adjacent to the hot plate such that the flow is directed towards the fin and the nature of the flow being turbulent in order to recreate the environment which engine runs under normal operating conditions. A LM35 thermocouple with temperature range of -55°C to 250°C is used as a temperature sensor which is interfaced to an Arduino UNO such that the ambient air temperature is measured and also a thermocouple with accuracy of ± 5°C and temperature range of -25°C to 150°C with an integrated display is used in order to measure the temperature variation along the length of the fin at a distances of 8mm, 16 mm and 24 mm from the base respectively. Till the fin attains a steady state condition the values of the temperatures variation along the length as well as of the ambient air is noted for periodic intervals of time. The pre-determined air flow from the blower is used and the efficiencies and effectiveness of the fins are calculated and compared to that of the conventional fin.

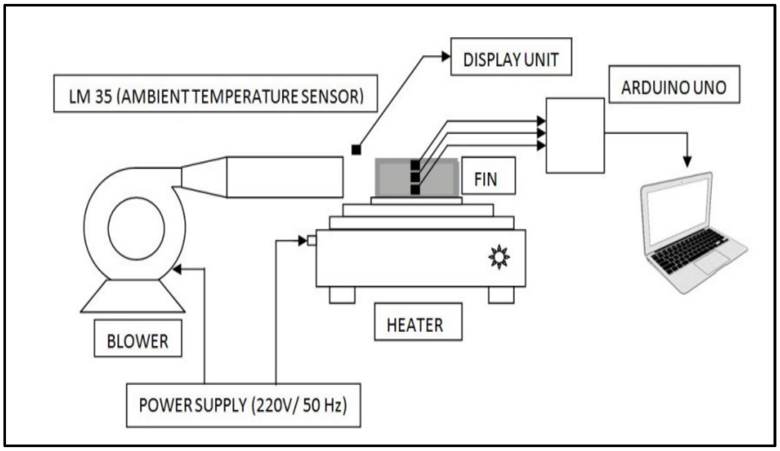

Figure 1: Block diagram of experimental setup

3. Details of Conventional and Proposed Fin

All the fins made up of aluminium and length and breadth are 25mm, 70mm respectively.

3.1. Conventional fin: It is a Prototype fin of TVS Apache RTR 180 engine

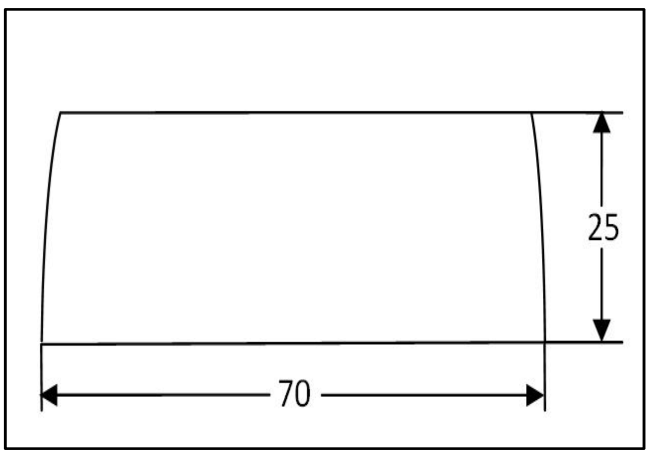

Figure 2: Details of conventional fin

3.2. Proposed fin-1: Increased surface area by hemisphere diameter 2mm on the fin.

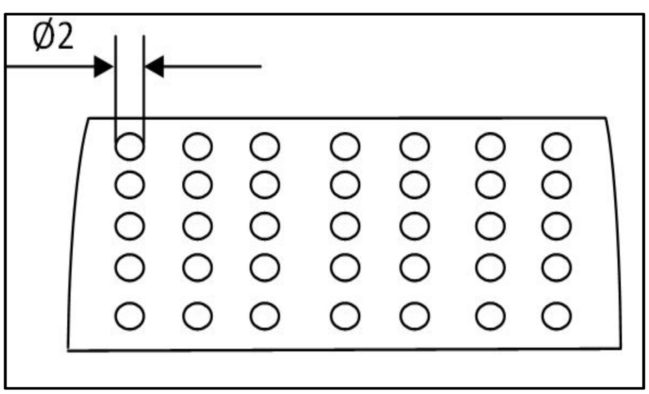

Figure 3: Details of proposed fin-1

3.3. Proposed fin-2: Increased surface area by making slots on the fin vertically.

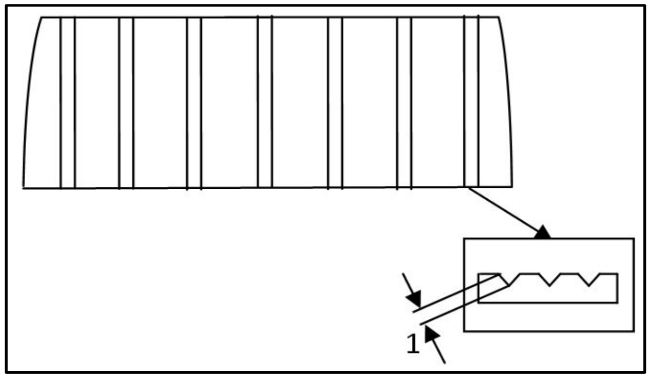

Figure 4: Details of proposed fin-2

3.4. Proposed fin-3: Increased surface area by making slots equally on the fin vertically and horizontally.

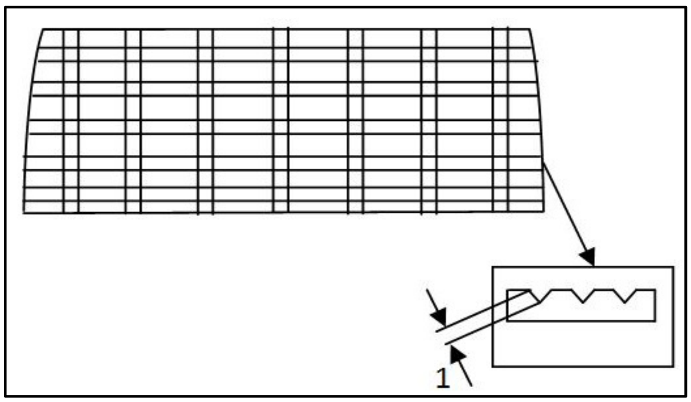

Figure 4: Details of proposed fin-3

4. Experimental Procedure

First the temperature sensor is calibrated and scrutinised for accurate values. The jumper wire connections are checked and the program is evaluated, the connections with the bread board and the Arduino are verified, also the port COM4 is specified in Arduino. Now the power is supplied to the blower and the heater. After 5 minutes the temperature at three intervals of 8 mm from the base are noted with the help of temperature sensor. A different thermocouple with an integrated display is used to measure the ambient air temperature. The heater is notched up to achieve the steady state temperature. Above steps are repeated at an interval of 5 minutes. This cycle is repeated until the steady state is achieved. After obtaining the temperature values the power supply to the heater and blower are switched off and the fin is allowed to cool to room temperature. After which the fin is replaced with other and the procedure is repeated to achieve the steady state temperature values.

5. Calculations

Surface temperature $T_S = (T_1 + T_2 + T_3)/3$
Mean film Temperature $T_F = (T_S + T_A)/2$
Velocity of air u = Flow rate, Q/ (Duct Area, A_D x Duct dia., D)
Reynolds Number Re = (u x D)/ ν
Nusselts Number Nu = $0.683 \times Re^{0.466} \times Pr^{0.333}$
Heat transfer coefficient h = (Nu x k)/ l
Perimeter of fin P= 2(l + b)
Base area of fin A = l x b
$m = (h P/k A)^{0.5}$
Fin efficiency $\eta_f = [\tanh (m l)]/ (ml)$
Heat transfer with fin $Q_F = \Delta T \times \tanh (ml) \times (h P k_a A)^{0.5}$
Heat transfer with fin $Q = h \times A \times \Delta T$
Fin Effectiveness $\varepsilon_F = Q_F/Q$

6. Results and Discussion

S. No.	Fin	Surface Area (m^2) X 10^{-3}	Nusselt Number	Heat Transfer Coefficient (W/m^2K)
1.	Conventional	3.84	698.63	821.74
2.	Proposed 1	4.38	708.49	830.51
3.	Proposed 2	4.34	703.22	819.38
4.	Proposed 3	5.09	716.97	828.86

Table 1: Results of fin and Heat transfer Parameter

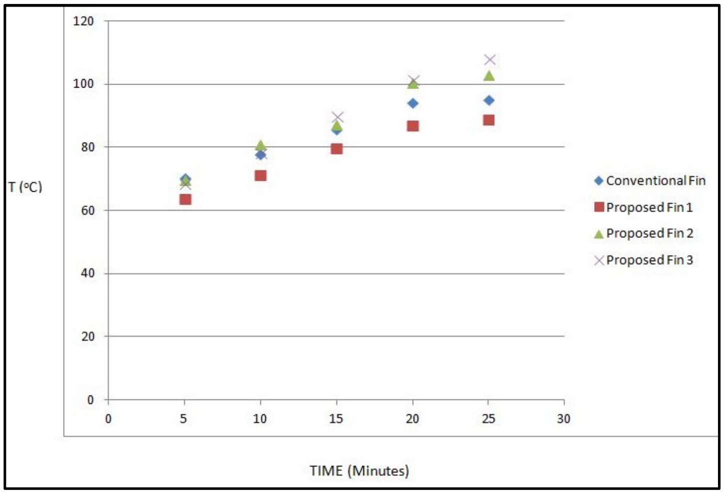

Figure 5: Temperature Vs Time

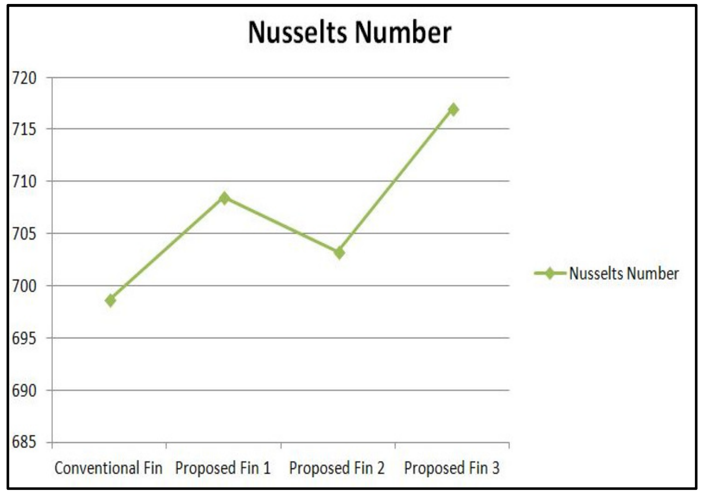

Figure 6: Nusselts number Variation along with various fins

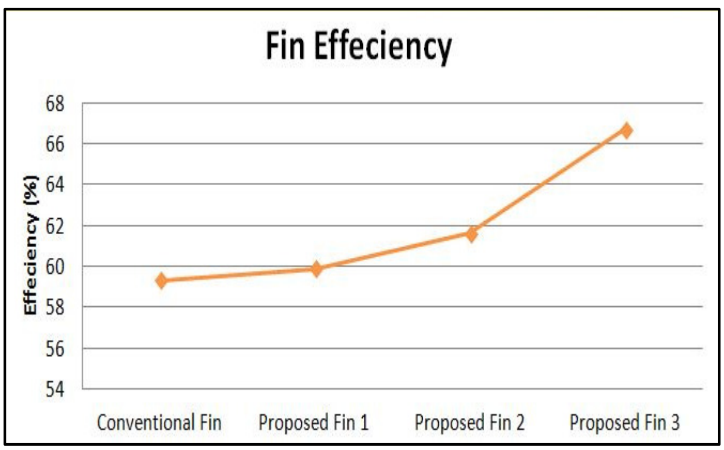

Figure 7: Fin efficiency along with various fins

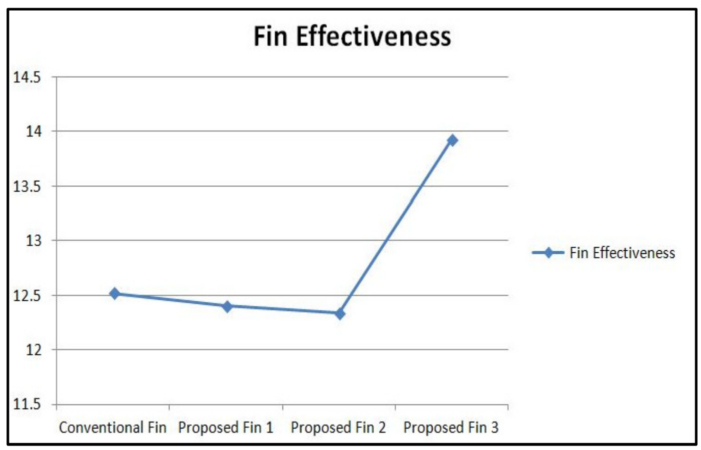

Figure 8: Fin Effectiveness along with various fins

S. No.	Fin	Fin Efficiency (%)	Fin Effectiveness	% increase in Efficiency	% increase in Effectiveness
1.	Conventional	59.31	12.51	-	-
2.	Proposed 1	59.87	12.40	1.90	-0.92
3.	Proposed 2	61.59	12.33	3.83	-1.46
4.	Proposed 3	66.66	13.92	12.39	8.88

Table 2: Details of fin efficiency and effectiveness

The experimental study reveals that the increment in surface area reflects a considerable increase in the efficiency of fin. This is accountable by the Newton's Law of cooling which suggests an increased heat transfer coefficient with the increase in surface area. Accordingly, the proposed fin 1 shows increase of 1.90% in fin efficiency when compared to the conventional fin, whereas proposed fin 2 shows increase of 3.83%. While the highest increase is viewed in proposed fin 3 at an increase of 12.39%. Also a slight decrease in the effectiveness for the proposed fin 1 and proposed fin 2 can be observed due to improper flow distribution across the fin. The effectiveness of the proposed fin 1 has a percentage decrease of 0.92 and the proposed fin 2 shows a percentage decrease of 1.46 in comparison to the conventional fin. The proposed fin 3 reflects a percentage increase of 8.88% in fin effectiveness when compared to the conventional fin. This can be accounted due to several factors such as improved flow distribution on the basis of the rigid texture while also the increase in Nusselts number and surface area of the fin. The Nusselts number increases as a result of increase in the Reynolds number. This occurs due higher convective heat transfer across the boundary layer of the fin under turbulent flow conditions. The increased average surface area depicts the effective dissipation of heat with respect to time for various fins.

7. Future Scope

- Change of material aluminium to aluminium alloy
- To vary the air flow rate from the blower
- To modify the fin shapes

8. References

i. Allan Harry Richard.T.L, Agilan.H. Experimental Analysis of Heat Transfer Enhancement using Fins in Pin Fin Apparatus. ISSN: 2348 9510, International Journal of Core Engineering & Management (IJCEM) Volume 2, Issue 1, April 2015.
ii. B. Sahin, A. Demir, 2008. Performance analysis of a heat exchanger having perforated square fins. Appl. Therm. Eng. 28, 621–632.
iii. David J. Kukulka, Kevin G. Fuller. Development of an Enhanced Heat Transfer Surface. 2010 Elsevier B.V.
iv. H.Y. Li, K.Y. Chen, 2007. Thermal performance of plate-fin heat sinks under confined impinging jet conditions. Int. J. Heat Mass Transfer 50, 1963–1970.
v. Hamid Reza Seyf and Mohammad Layeghi. Numerical Analysis of Convective Heat Transfer From an Elliptic Pin Fin Heat Sink With and Without Metal Foam Insert. J. Heat Transfer 132(7), 071401 (Apr 22, 2010).
vi. M. Molki, A. Hashemi-Esfahanian, 1992. Turbulent convective mass transfer downstream of a perforated baffle blockage. Int. J. Heat Fluid Flow 13 (2), 116–123.