Thermal Study of Fins In Light Weighted Automobile Vehicles

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Abstract – *The presented paper deals with the design of fins on the cylinder of four stroke single cylinder SI engine. The main objective of design is to provide the maximum cooling which will result in producing highly efficient engine system. The significant specific data of the engine cylinder is the compression ratio of the cylinder, bore diameter, stroke length, front tyre & the rear tyre size, maximum torque, volume of the cylinder, economic speed at the highway. The analytical process is to examine the effectiveness of the fins and provides the suitable dimensions are to maximize the cooling and to maintain the engine cylinder.*

***Key Words*: Efficiency**, Effectiveness, Convection, Heat transfer, Thermal Analysis.

1. INTRODUCTION

In this era of automobile engineering our life has been very much dependent on internal combustion based vehicles. Though there are other energy sources vehicles are too present around us viz. Compressed Natural Gas (CNG), Liquid Petroleum Gas (LPG) and electrical vehicles. All these vehicles convert their respective power chemical or electrical into mechanical energy to provide mechanical torque and power. All these energy converted from one form to another one through an engine. Many scientific principles unveiled that not even a single system in this world have hundred percent efficiency.

Similarly internal combustion engine work on efficiency about 50 percent [1] even the world's largest diesel based engine has efficiency of 51.7 percent. The remaining 50 percent energy is going to convert into heat. This heat produced in engine is going to damage it. So it must be radiated out.

There are three modes of heat transfer viz. conduction, convection and radiation. Most of the engines transfer their waste heat into environment through convection by using an extended surface perpendicular to the axis of engine. This extended surface on engine is called fins, fins are of different designs and materials depending upon the amount of heat generation and heat transfer.

2. Working Principle of Fins

As fins are mainly works on principle of heat transfer through convection [2] .In convection type f heat transfer, heat is transfer from one portion of fluid to another. As fluid is heated by wasted heat energy, its heated molecule will going to rise up and the colder molecules will go down and gradually heat is distributed throughout the volume.

Mathematical equation of convection heat transfer [3],

$$\mathbf{Q_{conv} = hA_s (T_s - T_\infty)} \qquad (1)$$

Here,

h= Heat transfer coefficient in Joule/ ($^0C \times m^2$)

A_s= exposed surface area of fin (m^2)

T_s= surface temperature of engine (^0C)

T_∞= temperature of surrounding (^0C)

From equation 1, it is clear that rate of convective heat transfer is directly depend upon coefficient of convective heat transfer and surface area of engine exposed to surrounding. It is not feasible to increase surface area of engine, so we can increase coefficient of heat transfer to increase convective heat transfer.

Heat transfer coefficient is depending upon following aspects:

- Geometry of exposed surface
- Temperature difference between engine surface and surrounding
- Convective velocity of fluid
- By extending the surface area of engine, which is called fins.
- By using Al material which has high transfer coefficient.

3. Type of Fins

3.1 Pin Fins

The perpendicular surface with higher length and lesser cross sectional surface area attached to engine surface is called pin fin [4].

Fig 3.1.1 Distributed pin fins

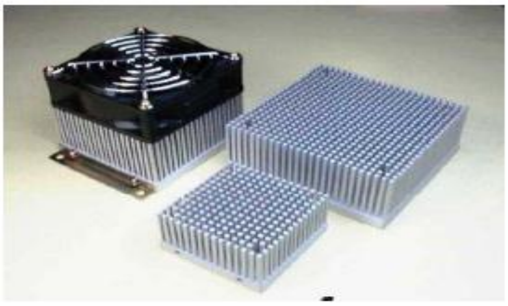
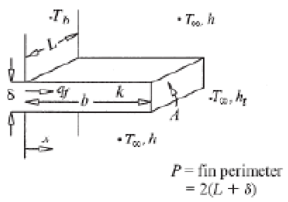


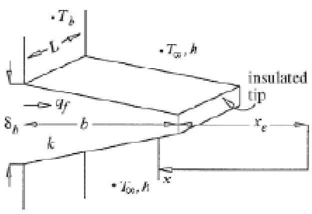
Fig 3.1.2 Pin fins used in computer CPU

3.2 Longitudinal Fins:

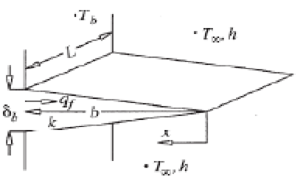
(a)Rectangular



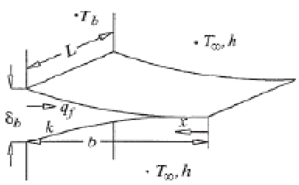
(b) Trapezoidal



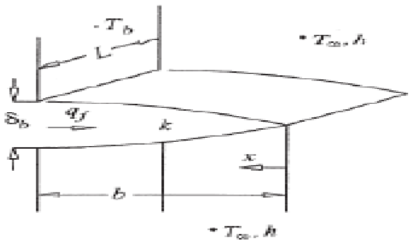
(c)Triangular



(d) Concave Parabolic

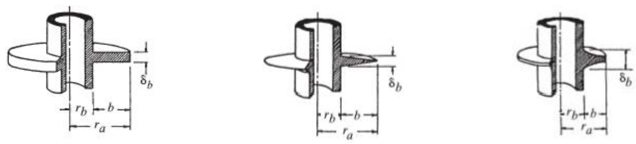


(e)Convex Parabolic



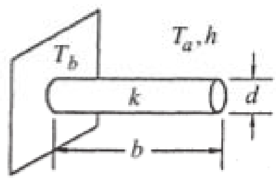
3.3 Radial Fins:

Rectangular Profile Triangular Profile Parabolic Profile

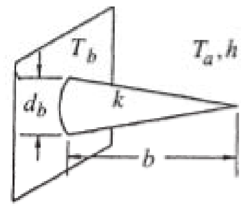


4. Type of Pins Used In Fins:

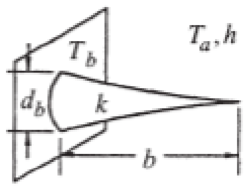
(a)Cylindrical pin



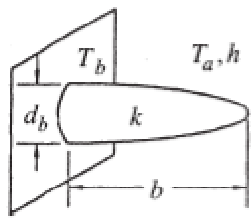
(b) Conical pin



(c) Concave parabolic



(d) Convex parabolic



5. Empirical Data of Fin Assembly

The company (Honda) introduced motorcycles that were popular in India for their fuel economy and low cost. The Honda glamour introduced the engines design specification for the markets affinities with the minimum cost and high efficiency of IC Engine of four stroke petrol engine. The leading data of the engine using for the maximum cooling to the engine under the auspices of the CFD analysis as well as analytical analysis the designing of the engine based on the specified specification of the engine i.e. suitable for the luxuries life of the human being. The leading Indian Delhi organization assimilated the specification of the engine such as the compression ratio of the cylinder, stroke length of the cylinder, bore diameter of the cylinder, front and the rear tyre size, the maximum torque for the designing of the strength of the cylinder and the swept volume of the engine. These data help us to analysis the maximum efficient designing of engine as well as the zenith life of the engine under the critical circumstances of the engine. The bike riding on the expresses way during the thermal processes produce the heat which heated to engine cylinder i.e. is affected by some parameters like temperature of the engine, mass flow rate of fuel etc. that is analysis by the CFD analysis as well as analytical analysis.

The empirical data leading from the organization are

- The compression ratio of the cylinder is 9.1:1.
- The bore diameter of the cylinder is 52.62 mm.
- The stroke length of the cylinder is 57.52 mm.
- The front tyre size is 2.75*18-42P/4PR.
- The rear tyre size is 3.00*18-52P/6PR.
- The bike is 124.69 cc.
- The maximum torque of the bike 8.1 N-m @ 3700 rpm.
- Number of fin 11.
- Diameter of the fin 30mm.
- Thickness of the fin 2.5mm.

6. Derivation of Fin Equation:

$$\dot{Q}_X = -kA_c\frac{dT}{dX}$$

$$\dot{Q}_{x+dx} = \dot{Q}_x + \frac{d\dot{Q}_x}{dx}dx$$

$$d\dot{Q}_{conv} = hdA_s(T_s - T_\infty)$$

Energy Balance Equation for fin,

$$\dot{Q}_x = \dot{Q}_{x+dx} + d\dot{Q}_{conv}$$

$$= Q_x + \frac{dQ_x}{dx}dx + hdA_s(T_s - T_\infty)$$

$$\frac{d}{dx}\left(A_c\frac{dT}{dx}\right) - \frac{h}{k}\frac{dA_s}{dx}(T_s - T_\infty) = 0$$

$$\frac{d^2T}{dx^2} + \frac{1}{A_c}\frac{dA_c}{dx}\left(\frac{dT}{dx}\right) - \left(\frac{1}{A_c}\frac{h}{k}\frac{dA_s}{dx}\right)(T_s - T_\infty) = 0$$

$$\frac{d^2T}{dx^2} + \frac{1}{A_c}\frac{dA_c}{dx}\left(\frac{dT}{dx}\right) - \left(\frac{1}{A_c}\frac{h}{k}\frac{dA_s}{dx}\right)(T_s - T_\infty) = 0$$

$$\frac{dA_c}{dx} = 0$$

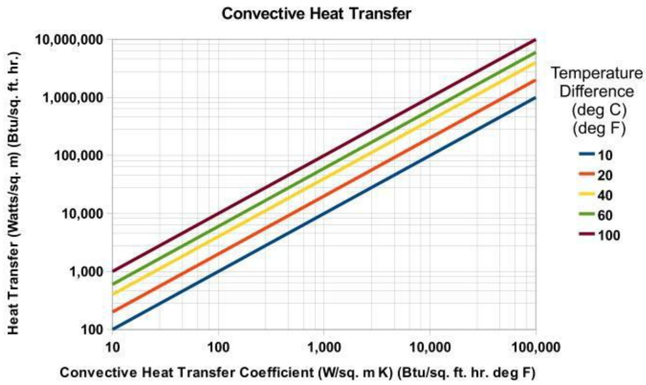
$A_S = P_x$ $\quad \frac{dA_c}{dx} = P$

$$\frac{d^2T}{dx^2} - \left(\frac{hP}{kA_c}\right)(T_s - T_\infty) = 0$$

Solution of differential equation,

$$\Theta(x) = T(x) - T_\infty$$

$$\frac{d^2\theta}{d^2x} - m^2\theta = 0$$



7. Mechanism of Convective Heat Transfer

Convection is the mechanism of heat transfer through a fluid in the presence of bulk fluid motion. Convection is classified as natural (or free) and forced convection depending on how the fluid motion is initiated. In natural convection, any fluid motion is caused by natural means such as the buoyancy effect, i.e. the rise of warmer fluid and fall the cooler fluid. Whereas in forced convection, the fluid is forced to flow over a surface or in a tube by external means such as a pump or fan.

The rate of convection heat transfer is expressed by Newton's law of cooling,

$$Q_A = hA(T_s - T_\infty)$$

The convective heat transfer coefficient *h* strongly depends on the fluid properties and Velocity of the fluid flow over the solid surface, and the type of the fluid flow (laminar or turbulent). [5]

8. Analytical Calculation and Result

Equations	Evaluated parameter	value
$\eta = 1 - \frac{1}{r^{\Upsilon-1}}$ (Υ=1.165)	Efficiency (η)	30.67%
$V_1 = r * V_2$	Total Value (V_1)	0.000140095 m³
Calorific Value of fuel	C.V	44400 KJ/kg
Initial temperature	T_1	300 k
$\frac{T_2}{T_1} = \left[\frac{V_1}{V_2}\right]^{\Upsilon-1}$	T_2	432.71 k
Mep (kPa)= $6.28 n_r T(N.m) / V_d(dm^3)$	mep (kPa)	816.416 kPa
Mep= $\frac{P_1 r(r_p-1)(r^{\Upsilon-1}-1)}{(\Upsilon-1)(r-1)}$	Pressure ratio (r_p)	3.716
$\frac{P_3}{P_2} = \frac{T_3}{T_2}$	Maximum pressure of cycle	1608 K
$W_{net} = \frac{P_1 V_1}{\Upsilon-1}(r_p r^{\Upsilon-1} - r_p - r^{\Upsilon-1} + 1)$	Net work done of the cycle (W_{net})	332.7695 kW/cycle
$\eta = \frac{W_{net}}{Q_s}$	Heat supplied per cycle	1085 kJ/cycle
t = 0.045 D + 1.6 mm + C	Thickness of the cylinder (t)	5 mm
$h = (10.45 - v + 12.7 V^{1/2})X$	Convective heat transfer coefficient	42.5 W/m²K
$q = \frac{2\pi KL(T_{s,1}-T_{s,2})}{ln\left(\frac{r_2}{r_1}\right)+\frac{1}{h}}$	Total heat transfer by conduction with film thickness	511.43 kW
$q = \frac{2\pi KL(T_{s,1}-T_{s,2})}{ln\left(\frac{r_2}{r_1}\right)}$	Temperature of the outer surface of the cylinder	677 K
$q_f = (2\pi k r_1 t \Delta_b m)\frac{k_1(mr_1)I_1(mr_2) - I_1(mr_1)k_1(mr_2)}{k_0(mr_1)I_1(mr_2) + I_0(mr_1)k_1(mr_2)}$	Heat transfer by a fin	22.220 kW
Efficiency of the fin	η_f	0.91
Effectiveness of the fin	ε	1.4
$\eta_0 = \left[1 - \frac{NA_f}{A_t}(1-\eta_f)\right]$	Overall efficiency of the fins	0.98

9. Conclusion

The thermal analysis of the fins exactly goes for the evaluation of the heat transfer through the fin for the maximum cooling to the engine. The specifications of the engine demonstrates in the annular design of the fins with the heat dissipated to ambient at the maximum temperature occurs inside the cylinder with including the conductive heat transfer as well as convective heat transfer, and with few variable parameters of heat transfer or the cylindrical material. The heat transfer rate with the variation of convective heat transfer rate, thermal conductivity of aluminium with the temperature, the minimum thickness of the fins and the velocity of air flowing etc.

9.1 Future scope:

- The similar studies can be made for other types of fins heat dissipation like rectangular shape, triangular shape and trapezoidal shape etc.
- The heat dissipation study goes for the different heat transfer coefficient which is strongly depends upon the velocity of air.
- The material properties affected due to temperature variation of the cylinder and the fins.

10. References

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