CFD ANALYSIS OF HEAT TRANSFER FOR WAVY FINS OF IC ENGINE

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ABSTRACT

This project is an attempt to study the effect of wavy (S-shaped) fins on the heat transfer rate of an existing motorcycle engine. A detailed literature survey is conducted to study the effect of fin geometry and other environmental parameters on the rate of heat transfer from IC engine. The rate of heat transfer is found for various parameters of fin geometry for wavy fins using commercially available CFD/FEA software's, Fluent and Ansys. These results are then compared with the existing designs commercially available in the markets. Further, an effort has been made to optimize the fin profile and fin array parameters for wavy fins for a given heat flux using FLUENT/ANSYS.

Solidworks and AutoCAD 2015 software's are used for designing; modeling and drafting of fin geometries and Ansys& Fluent are used for analysis.

Keywords: ANSYS15. Workbench, ALLOYSTEEL, Autocad2015, SOLIDWORK, Finite Element analysis.

I. INTRODUCTION

The internal combustion engine is an engine in which the combustion of a fuel (a fossil fuel) occurs with an oxidizer (usually air) inside a combustion chamber. In an internal combustion engine, the expansion of the high-temperature and pressure gases produced by combustion applies a direct force to the reciprocating piston thus producing the rotary motion of the crankshaft. This force moves the component over a distance, generating useful mechanical energy.

All IC engines include five general processes:

1. An intake process, during which air or a fuel–air mixture is inducted into the combustion chamber
2. A compression process, during which the air or fuel–air mixture is compressed to higher temperature, pressure, and density
3. A combustion process, during which the chemical energy of the fuel is converted to thermal energy of the products of combustion
4. An expansion process, during which a portion of the thermal energy of the working fluid is converted to mechanical energy

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5. An exhaust process, during which most of the products of combustion are expelled from the combustion chamber.

For an IC engine, the fins are designed for material, geometry (length, Distance between two fins (pitch), cross sectional area) and the heat transfer coefficient of the surrounding fluid etc.This report documents the effects of wavy (S shaped) fins on the rate of heat transfer when compared to commercially available fins (Hero Honda Passion Plus/ Bajaj Pulsar 150cc) using commercially available Computational Fluid Dynamics (CFD) codes. Varying trends of heat transfer parameters (convective heat transfer coefficient 'h', total heat transfer 'Q' etc.) are tabulated and determined and the values which give optimized fin surface from the thermal aspect for a given environmental condition are determined.Further, an effort is made to study the advantages of S shape fins on the rate of heat transfer and for a given heat flux using GAMBIT and FLUENT/ANSYS.

The literature survey, analytical calculations, the problem formulation and the preliminary results are documented in the following chapters

II. PRINCIPAL

Convection heat transfer between a surface (at TW) and the fluid surrounding it (at T∞) is given by:

$$Q = h\,A\,(TW - T\infty)$$

Where h is the heart transfer coefficient and A is the surface area of heat transfer. For gases h(= kf/δt) is low, since the thermal conductivity kfof a gas film is low. For transfer from a hot gas to a liquid through a wallhgas<<hliquid .To compensate for low heat transfer coefficient, surface area A on the gas side may be extended for a given Q. Such an extended surface is termed a 'Fin'. Thus 'Fin' is a surface that extends from an object to increase the rate of heat transfer to or from the environment by increasing convection.

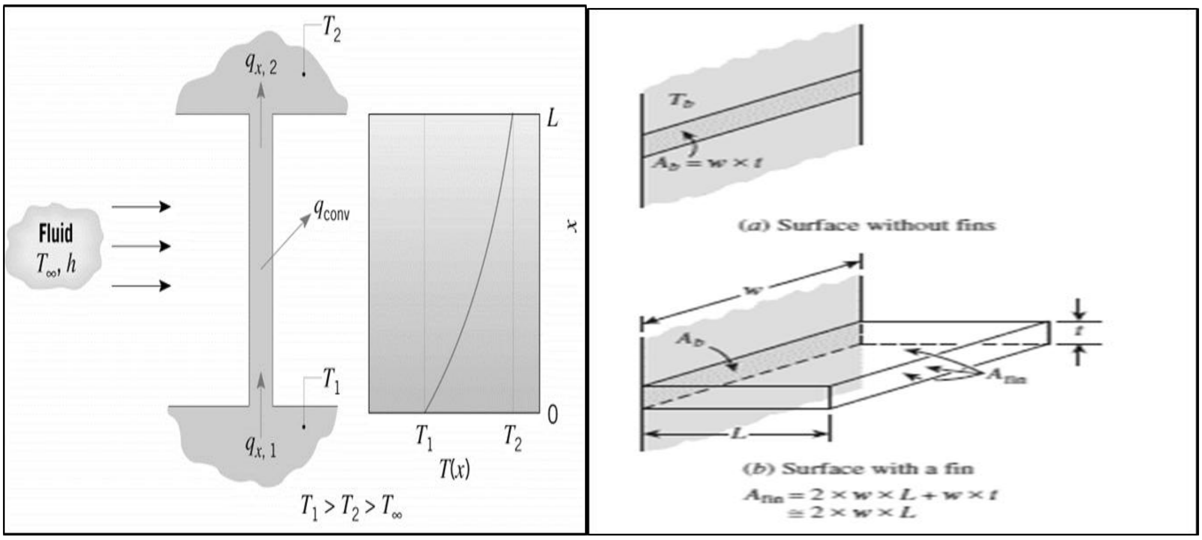

Fig. II (a) Combined Convection and Conduction in a bar And Use of Fin enhances heat transfer from a plane wall by increasing

Fin Design-

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For a rectangular fin tip of the fin is adiabatic (Qfin tip =0), i.e., $\frac{d\theta}{dx} = 0 \ at \ x = L$, the temperature distribution θ along the fin length is given by:

$$\frac{\theta}{\theta_b} = \frac{T - T_\infty}{T_b - T_\infty} = \frac{\cosh m(L-x)}{\cosh mL}$$

The rate of heat transfer is given by:

$$Q = M \tanh mL$$

where,

$$m = \sqrt{\frac{hP}{kA_c}}$$

$$M = \sqrt{hPkA_c} \ \ \theta_b$$

h= convection heat transfer coefficient

P= perimeter of the pin drawn in the plane parallel to the base

k= thermal conductivity of fin material

Ac= cross sectional area of the fin (assumed to be constant for the entire fin)

Now,

Equation gives:

$$Q = \sqrt{hPkA_c}\theta_b \tanh mL$$

$$= \sqrt{hPkA_c} \tanh mL \ (T_b - T_\infty)$$

$$= \frac{(T_b - T_\infty)}{\frac{1}{\sqrt{hPkA_c} \tanh mL}}$$

$$= \frac{(T_b - T_\infty)}{R_t}$$

where, Rt = Thermal Resistance of fin = $\frac{1}{\sqrt{hPkA_c} \tanh mL}$

Now, Eqn. gives

Qα (tanh mL)

i.e. Rate of heat transfer Q is directly proportional to (tanh mL)

(mL)	tanh(mL)
0	0.197375
0.2	0.379949
0.4	0.53705
0.6	0.664037
0.8	0.761594
1	0.833655
1.2	0.885352

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1.4	0.921669
1.6	0.946806
1.8	0.964028
2	0.975743
2.2	0.983675
2.4	0.989027
2.6	0.992632
2.8	0.995055
3	0.996682
3.2	0.997775
3.4	0.998508
3.6	0.999
3.8	0.999329
4	0.99955
4.2	0.999699
4.4	0.999798
4.6	0.999865
4.8	0.999909
5	0.999939
5.2	0.999959
5.4	0.999973
5.6	0.999982
5.8	0.999988
6	0.99999

Table II (a) Variation of tanh(mL) w.r.t (mL)

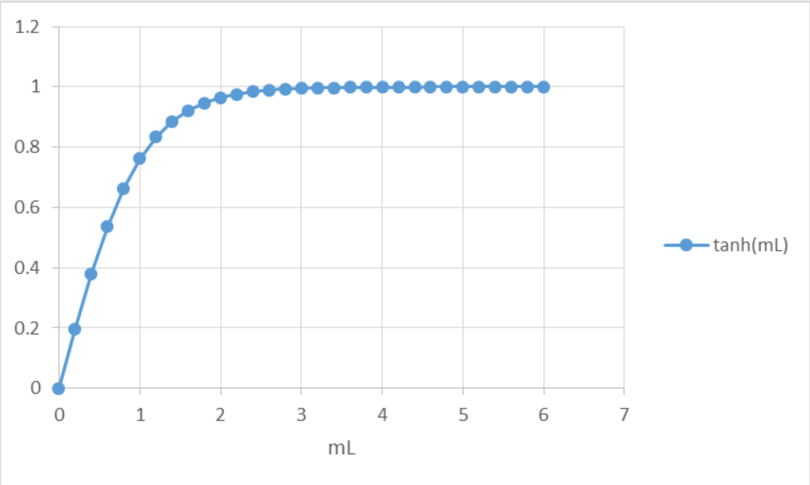

Fig 2.13: Variation in *tanh(mL)* w.r.t. *mL*

From Table 2.1 and Figure 2.10 it is seen that rate of heat transfer Q rapidly increases at first, with increase in *L(tanh(mL))*, and then slowly increases and becomes asymptotic at mL=3 which indicates that any further increase in L will not increase the rate of heat transfer.

III. ANALYSIS

Geometry

The Spark Ignition engine considered for this study is Honda Shine 125 cc engine. The engine and fin specifications is as follows:

Engine	4 Stroke, Single Cylinder, Air Cooled
Displacement	125 cc
Fin Material	Al. Alloy
No. of fins	12
Fin Pitch	10
Fin Thickness	2mm
Fin Profile	Rectangular (uniform cross section) with curved edges
Max. Fin Height	30mm
Min. Fin Height	12mm

The properties of Al alloy AA6061 and boundary conditions are given below:

Material Properties	Al. alloy AA 6061
Thermal conductivity (W/m K)	210
Specific heat (KJ/kg oC)	0.9
Density (kg/m3)	2780
ID wall Temperature (K)	473/500
Ambient Temperature (K)	300
Convective heat transfer coeff.(W/m2K)	40

Table: III (a) Material Properties of AA 6061 7 boundary conditions.

Following are geometry's configuration are studied for the rate of heat transfer-

A) Circular Rectangular fin
B) Circular Rectangular fin –Tapered Configuration
C) Circular Rectangular fin
D) S shape Wavy fin
E) S shape Wavy fin – Tapered Configuration

Boundary Conditions -

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Ambient Temperature (K)	300
Convective heat transfer coeff.(W/m2K)	40

Table:III (b) Material Properties of AA 6061 boundary conditions

The following assumptions are made in all analysis:

- The heat flow through the fin is considered as in steady state, so that the temperature of the fin does not vary with time.
- The temperature of the inner cylinder is constant.
- The thermal conductivity of the fin material is uniform and constant.
- The radiation heat transfer of the fin is neglected.
- Uniform ambient temperature of 300 K is considered.

The different configurations are analyzed for Al. alloy AA6061, having coefficient of thermal conductivity is 210 W/mK. The convective heat transfer coefficient is 40W/mK. The combustion chamber ID temperature is 500K and the ambient temperature is 300K.After the application of boundary conditions, the problem is solved in Ansys14.0. The solution after convergence, the temperature distribution, the thermal flux and the temperature gradient are plotted.

The convective heat transfer coefficients are documented by the below mentioned references:

	Thornhill et al. [1]	Gibson [2]
Cylinder Diameter[mm]	100	32-95
Fin Pitch [mm]	8-14	4-19
Fin Length mm]	10-50	16-41
Material	Aluminium Alloy	Copper, Steel, Aluminium
Wind Velocity [km/hr]	7.2-72	32-97

Table III (c): Boundary conditions for finding h for Thornhill et al. [1] & Gibson [2]

Thornhill[1] gives the heat transfer coefficient(α) as α= 2.11u0.71 x s0.44 x h-0.14

Gibson[2] gives the heat transfer coefficient(α) as

α= 241.7{0.0247-0.00148(h0.8/p0.4)} u0.73

where:

α: Fin surface heat transfer coefficient (W/m2K)

h: Fin length [mm],

u: Wind velocity[km/hr],

s: fin pitch length[mm]

The methodology used for solving the problem statement is:

Step A: Modelling of 2-D fin geometries in Solid Works.

Step B: Importing file in ANSYS 14.0 and meshing using triangular element (Triangle 6 node 35)

Step C: Application of Boundary conditions on the model.

Step D: Solving and Analysis.

Step E : Post-processing and Data generation.

IV. RESULT

Fin Configuration	Heat transfer (W)	Fin Weight (kg)	Effectiveness
Circular Rectangular	1972.2	0.750	6.73
Circular Rectangular Tapered	1829.3	0.600	5.96
Circular Conical	1841.2	0.350	6.65
Circular Shaped Fin	2040.0	0.792	7.23
Circular Shaped Tapered Fin	1827.3	0.630	6.24
Cylinder without fin	295.3	0	1

OBSERVATION-

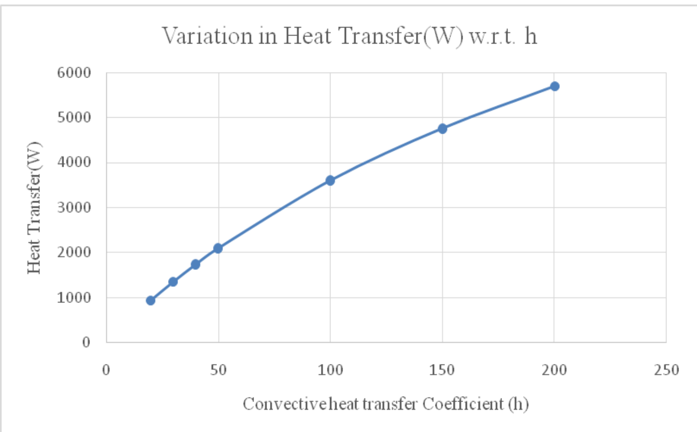

Fig IV (a) Effect of h on rate of heat transfer.

V. CONCLUSION

The effect of fin geometries, coefficient of heat transfer coefficient (h) and material (K) is studied for the heat loss for air cooling of an existing 125 cc IC engine. The temperature profile, thermal gradient and thermal flux is plotted and studied for all configurations.

It is found that providing an arch shape to fin, instead of rectangular cross section Increases the heat transfer. The provision of arching will also increase the turbulence, increasing the h and hence the heat transfer. Also heat transfer per unit weight of fin is larger for conical fin than rectangular fins, hence conical fins are preferred over rectangular cross section fins.

The rate of heat transfer increases with increase in h, linearly, for small values of h. Aluminium is the better material for designing fins for air-cooled IC engines due to low weight, high rate of heat transfer and lower cost. There is further scope to do a 3-D analysis of the configurations to accurately account for the convective heat transfer coefficient. Also the effect of introducing radial holes in fins can be studied for the rate of heat transfer.

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