Design Optimization Of An Air Cooled Internal Combustion Engine Fin Using CFD

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***Abstract*— Internal combustion engines, produces energy by the combustion of fuel and air, i.e. by converting the chemical energy of the fuel into mechanical energy of the reciprocating piston. During the combustion of fuel in an IC engine very high temperature of the order of 2100-2200°C is produced inside the combustion chamber, which will result into burning of lubricant oil film between the moving parts and may result into welding or seizure of the IC engine sub-parts. So, as to prevent this and to maintain the working health of an IC engine the temperature of the combustion chamber should be reduced to about 200-230°C. Too much cooling also will lead to lower thermal efficiency of the engine. Fins are provided to optimize the performance, and the efficiency of an IC engine, by providing exterior extended cooling surfaces. These fins are designed to optimize the heat loss and the temperature inside an IC engine such that the thermal efficiency is optimal and also the weight of the engine is not increased beyond optimal level. This study is an attempt to understand the effects of the number of fins, fin pitch, relative wind velocity and ambient**

temperature on air-cooling of a two- wheeler IC engine using commercially available CFD codes. Varying trends are tabulated and determined and the values which give optimized fin surface from the thermo-structural aspect at a given heat flux are determined. Further, the fin profile and fin array parameters optimized for a given heat flux using GAMBIT and FLUENT/ANSYS.

Keywords—Computational fluid dynamics, FLUENT/ANSYS, Fin profile, Fin array, GAMBIT, Internal combustion engine

I. Introduction

In an internal combustion engine, the expansion of the high-temperature and pressure gases produced by combustion applies a direct force to some component of the engine, such as pistons, turbine blades, or a nozzle. This force moves the component over a distance, generating useful mechanical energy. When the combustion of air-fuel mixture takes place in the engine cylinder, a temperature as high as 2500OC is reached. To withstand such a high temperature a very high melting point material has to be used for construction of engine [2]. Practically it is less possible because, "Platinum", which has one of the highest melting point, melts at above 1800oC.

It has been practically found that out of total heat generated by internal combustion engine due to combustion of fuel, only 30% of heat is converted in useful work, out of remaining 70% about 40% is carried by exhaust gases into the atmosphere during exhaust stroke. The rest of 30% must be passed to atmosphere by some suitable arrangement [3].

In lack of cooling system, a complete seizure of the piston, bearing and other important parts will occur. Due to this, there will be more frequent replacements of the components are required. It will also increase the repairing cost and breakdown period [1]. The engine life will be reduced considerably. Also, higher temperatures lower the volumetric efficiency of the engine; promote pre-ignition and tendency of the engine to detonate. Air-cooling is one of the very efficient and cheap method of cooling IC engines which uses the extended surfaces called 'Fins' extended from the combustion chamber to cool the engine. These fins are designed to optimize the heat loss and the temperature inside an IC engine such that the thermal efficiency is optimal and also the weight of the engine is not increased beyond optimal level [7]. However, Low rate of heat transfer through cooling fins is the main problem in this type of cooling [5]. This paper documents the effects of the number of fins, fin pitch, geometry, material, relative wind velocity and ambient temperature on air-cooling of a two- wheeler IC engine (Hero Honda Passion Plus/ Bajaj Pulsar 150cc) using analytical calculations and commercially available Computational Fluid Dynamics (CFD) codes. Varying trends of these parameters are tabulated and determined and the values which give optimized fin surface from the thermo-structural aspect for a given heat flux are determined [7]. Further, an effort is made to optimize the fin profile and fin array parameters for different materials and for a given heat flux using GAMBIT and FLUENT/ANSYS.

II. Literature review

1] Thornhill D. and May A., An Experimental Investigation into the Cooling of Finned Metal Cylinders in a free Air Stream, SAE Paper 1999-01-

3307 (1999): Effect of air velocity and environmental condition on fin performance

2] P. Agarwal, et al. (2011). Heat Transfer Simulation by CFD from Fins of an Air Cooled Motorcycle Engine under Varying Climatic Conditions. Proceedings of the World Congress on Engineering: Effect of environmental condition, material, wind velocity, ambient temperature etc. on fin performance.

3] Modelling and Simulation of engine Cylinder Fins using FEA; (IJRASET April 2014); R Arularasan, S Prathap: Effect of different fin shapes on fin efficiency using Ansys.

4] Kumbhar D.G et.al. They have concluded that the heat transfer rate increases with perforation as compared to fins of similar dimensions without perforation. The perforation of the fin enhances the heat dissipation rates at the same time decreases the expenditure for fin materials also.

5] N. Nagarani et.al.: Analyzed the heat transfer rate and efficiency for circular and elliptical annular fins for different environmental conditions.

6] Ashok Tukaram Pise and Umesh Vandeorao Awasarmol conducted the experiment to compare the rate of heat transfer with solid and permeable fins.

7] G.Raju, Dr. Bhramara Panitapu, S. C. V. Ramana Murty Naidu:This study also includes the effect of spacing between fins on various parameters like total surface area, heat transfer coefficient and total heat transfer.

8] Pulkit Agarwal et.al. Simulated the heat transfer in motor-cycle engine fins using CFD analysis. It is observed that when the ambient temperature reduces to a very low value, it results in overcooling and poor efficiency of the engine.

III. Problem formulation and modeling

A. Scheme of Implementation

Axis symmetric modeling will be used for the problem solving as modeled in fig.2. Axis-symmetric models will be made in SolidWorks and imported to Gambit for Meshing. The meshed geometries will be imported to Fluent for problem solving

After the solution of first iteration, a new model based on the case considered will be drafted and subjected to the same process.

The results of all these iterations will be tabulated and documented.

The following Scheme of Implementation followed for the work as shown in fig.1.

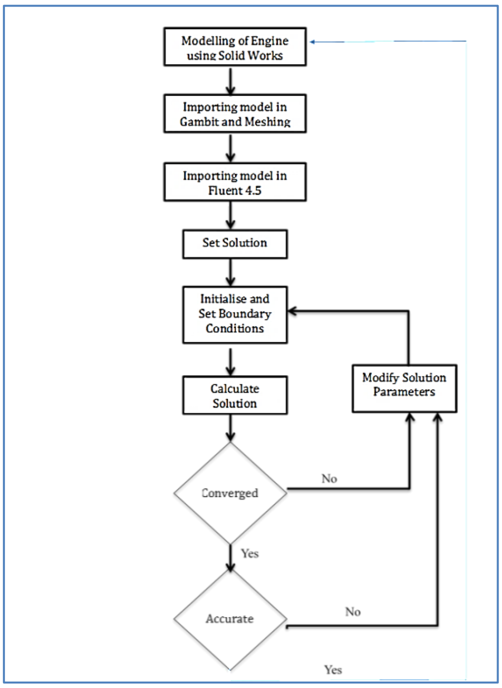

Fig.1 Schematic implementation-Flow chart

B. Modeling of an SI engine:

The Spark Ignition engine considered for this study is Bajaj Pulsar 150 cc engine. The engine and fin specifications is as follows:

Engine: 4 Stroke, Single Cylinder, Air Cooled

Displacement 149.01 cc

Bore and Stroke 57 × 56.4 mm

Compression Ratio 9.5:1

Max. Power 4.09 PS (10.35 KW) @ 8500rpm

Max. Torque 12.76 Nm @ 6500rpm

Transmission 5 Speed

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 35mm

Min. Fin Height 10mm

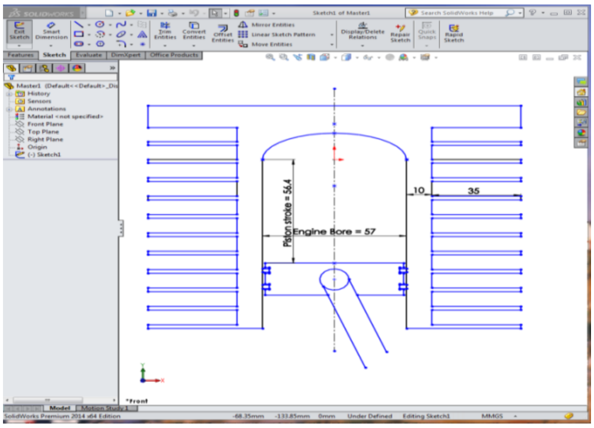

Fig.2 Symmetric modeling of Bajaj Pulsar 150 cc Engine in SolidWorks For the purpose of study, the engine is modeled as axis-symmetry with different Fin Configuration

IV. RESULTS AND DISCUSSIONS

The effectiveness of all fin configurations varies from 2.4-7.

The effectiveness of parallel fins is far lesser than other configuration fins. Hence, Parallel fins should not be chosen for designing the air-cooling systems of IC engines, until due to a configuration constraint. The weight of conical fins is 55.3% lesser than rectangular fins. However, the effectiveness is only 5.6% lower than that of rectangular fins. Hence overall, conical fins are better than rectangular fins

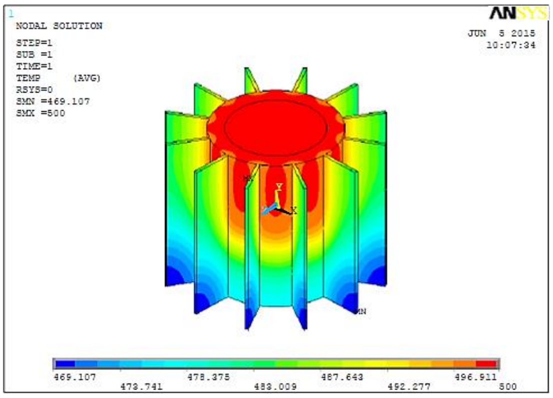

Fig.3 Temperature Profile across Parallel fin -24 No configuration

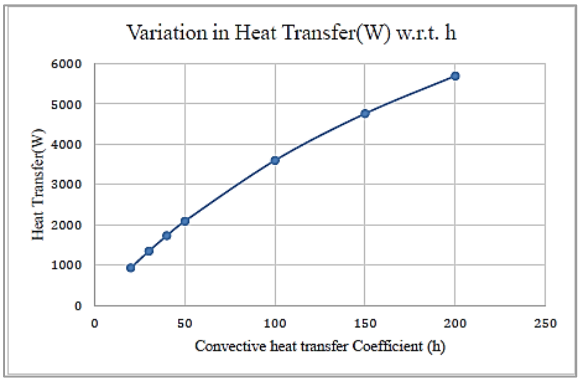

Fig.4 Effect of h on rate of heat transfer

The heat transfer rate increases with the increase in convective heat transfer coefficient, h as shown in fig.4. The rise is linear for small values of h, however for larger values of h, the increase is non-linear. The increase in h is one of the foremost way of increasing the heat transfer. Hence extra design measures should be taken in fin design to increase the turbulence and hence the convective heat transfer coefficient.

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 IC engine. 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. Aluminum is the better material for designing fins for air-cooled IC engines due to low weight, high rate of heat transfer and lower cost.

IV References

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