Thermal Analysis of Cylinder Block with Different Number of Fins and Tilt Angles in An Air-Cooled Motor Bike Engine

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***Abstract* - The heat transfer rate in an engine is dependent on the coolant temperature and the engine size, among other variables. There are complex interactions between the various engine parameters. For example, as the temperature of the engine coolant decreases, the heat transfer to the coolant will increase, and the combustion temperature will decrease. This will cause a decrease in the combustion efficiency and an increase in the volumetric efficiency. It will also cause an increase in the thermal stresses in the cylinder sleeve, and increase the size of the radiator needed, since the coolant ambient temperature difference will decrease. The formation of nitrogen oxides will decrease, and the oxidation of hydrocarbons will decrease. The exhaust temperature will also decrease, causing a decrease in the performance of the catalytic converter and a turbocharger.**

In the present work the cooling characteristics of air-cooled cylinder blocks, with various fin pitches and number of fins, mounted at tilt angles at 0° (vertical), with the speed of motor bike varies as 20km/h (5.6m/s) to 60km/h (16.7m/s) including the value of 40km/h (11.11 m/s) . A numerical analysis has been carried out. The 3D modelling of cylinder block with different configurations keeping fin size and number of fins same designed on space claim and the analysis has been carried out using ANSYS fluent as design tool. The two variables temperature drop, and heat flux are considered as decision making criterion.

***Index Terms* - Cylinder blocks, fin, temperature drop, heat flux etc.**

I.INTRODUCTION

About 35% percent of the total chemical energy that enters an engine in the fuel is converted to useful crankshaft work, and about 30% of the fuel energy is carried away from the engine in the exhaust flow in the form of enthalpy and chemical energy. This leaves about one-third of the total energy that must be dissipated to the surroundings by some mode of heat transfer.

Two general methods are used to cool combustion chambers of engines. The engine block of a water-cooled engine is surrounded with a water jacket that contains a coolant fluid which is circulated through the engine. An air-cooled engine has a finned outer surface on the block over which a flow of air is directed.

Heat Transfer in Combustion Chambers

Depending on its size, principle of operation and combustion system, an engine converts up to 30–50% of the fuel energy supplied into effective brake work. Apart from conversion losses during combustion, the remaining percentage is released into the environment as heat, predominantly with the exhaust and by the cooling system. Only a relatively small percentage reaches the environment by convection and radiation through the surface of the engine. In addition to the component heat transferred to the coolant, the heat dissipated by a cooling system also includes the heat dissipated in the lubricating oil cooler and intercooler. Utilizing the energy loss for heating purposes and the like requires a detailed analysis of the enthalpy content of the individual kinds of heat as well as the engine's use and type. The external cooling system also has to be incorporated in the analysis. Internal engine cooling essentially covers the wall heat losses that occur when energy is converted in the combustion chamber and reaches the coolant by heat transmission. Other engine components, e.g., injection nozzles, exhaust gas turbochargers and exhaust manifolds, are often directly cooled too.

Air-Cooled Engines

The idea of air cooling – dissipating the heat of an engine's components directly to the ambient air – is as old as the internal combustion engine itself. The Frenchman de Bisschop already introduced an air-cooled internal combustion engine in 1871. Lenoir's single cylinder gas engine, which operated according to the atmospheric principle, had longitudinal fins cast on the working cylinder, which conducted the cooling energy to the environment by free convection. The meteoric development of the aviation industry after Bleriot's flight across the English Channel in 1909 also included the development of an air-cooled aircraft engine and was marked by the following milestones: The development of aluminum alloys (1915), the introduction of light alloy cylinder heads (1920) and research on the physical correlations of heat dissipated by cooling fins, their optimal design, and the influence of the cooling airflow routing. This can result in temperature differences and thermal expansion problems. When compared with liquid-cooled engines, air-cooled engines have the following advantages:

1. lighter weight,
2. less costly,
3. no coolant system failures (e.g., water pump, hoses),
4. no engine freeze-ups, and
5. faster engine warmup.

Disadvantages of air-cooled engines are that they

1. are less efficient,
2. are noisier, with greater air flow requirements and no water jacket to dampen noise, and
3. need a directed air flow and finned surfaces.

Standard heat transfer equations for finned surfaces can be used to calculate the heat transfer off of these engine surfaces.

II-LITERATURE REVIEW

Federico Brusiani et. al. 2015 present a 3D-CFD simulation methodology designed to perform a detailed evaluation of two stroke air-cooled engines. The methodology was applied on two different engines equipping handheld brush-cutter machines. The optimization of the air-cooling system of such a machine is a very challenging task because the machine design must be very compact forcing all the engine parts to remain quite close each other. The simulation results were compared to experimental evidence in order to verify the validity of the proposed approach.

To assure the necessary heat waste in air-cooled engines, the key point is the optimization of the air flow over the cylinder external surface. Air flow separation from cylinder external surface can result in high temperature gradients inside the cylinder volume causing destructive heat problem for the engine. It can be avoided only by a fine optimization of the cylinder fin design placed externally to the cylinder surface. To fulfil this need, the definition of specific methodology to evaluate the air-cooling effect on the engine is mandatory.

L. Álvarez, et. al. 2004, analysed how the chemical composition influences the mechanical properties of grey cast iron. The rest of the influential factors, characteristic of grey cast iron, remain constant, which means that the cooling speed does not vary in the process and is an inherent value of the moulding installation in which the work pieces will be cast. Also, the inoculation is carried out in the same way in all the samples cast, in such a way that it is not considered a variable.

Masao Yoshida, et. al. 2017, investigated the cooling characteristics of air-cooled experimental cylinders, with various fin pitches and number of fins, mounted at tilt angles between 0° (vertical) and 90° (horizontal), in a wind tunnel at air velocities of 20km/h (5.6m/s) and 60km/h (16.7m/s). Heat transfer rate from the cylinder was measured, air flow between fins was observed using the smoke wire method, and air flow over fin surfaces was observed using the oil film method. Results indicated that, except at 20km/h (5.6m/s) and a pitch of 7.5mm, cylinder cooling increased as tilt angle increased from 0° to 40°, then decreased when the cylinder tilt angle exceeded 40°. Only at 20km/h (5.6m/s) and a pitch of 7.5mm, cylinder cooling increased as tilt angle increased from 0° to 30°, then decreased when the cylinder tilt angle exceeded 30°. Cylinder cooling was maximized with 7 fins pitched at 10mm.

III-RESEARCH METHODOLOGY

CFD Analysis

Governing Equations

The conjugate heat transfer and flow using three-dimensional, steady-state, laminar flow simulations have been carried out. The simulations were conducted on the commercial Computational Fluid Dynamics (CFD) code ANSYS Fluent. The governing equations are the conservation of mass (continuity), momentum, and energy for the flow, and the heat conduction equation for the solid, which are written in Cartesian co-ordinates as follows. In the analysis, x is in the direction of the fins, y is vertical, and z is in the transverse direction normal to the fins. The continuity equation for the steady flow is

$$\frac{\partial \rho u}{\partial x}+\frac{\partial \rho v}{\partial y}+\frac{\partial \rho w}{\partial z}=0$$

where is the density, and u v, and w are the velocities in the x,y , and z directions respectively. The three momentum equations are

$$u\frac{\partial \rho u}{\partial x}+v\frac{\partial \rho u}{\partial y}+w\frac{\partial \rho u}{\partial z}=-\frac{\partial p}{\partial x}+\frac{\partial}{\partial x}(\mu\frac{\partial u}{\partial x})+\frac{\partial}{\partial y}(\mu\frac{\partial u}{\partial y})+\frac{\partial}{\partial z}(\mu\frac{\partial u}{\partial z})$$

$$u\frac{\partial \rho u}{\partial x}+v\frac{\partial \rho u}{\partial y}+w\frac{\partial \rho u}{\partial z}=-\frac{\partial p}{\partial x}+\frac{\partial}{\partial x}(\mu\frac{\partial v}{\partial x})+\frac{\partial}{\partial y}(\mu\frac{\partial v}{\partial y})+\frac{\partial}{\partial z}(\mu\frac{\partial v}{\partial z})$$

$$u\frac{\partial \rho u}{\partial x}+v\frac{\partial \rho u}{\partial y}+w\frac{\partial \rho u}{\partial z}=-\frac{\partial p}{\partial x}+\frac{\partial}{\partial x}(\mu\frac{\partial w}{\partial x})+\frac{\partial}{\partial y}(\mu\frac{\partial w}{\partial y})+\frac{\partial}{\partial z}(\mu\frac{\partial w}{\partial z})$$

where p is the pressure and is the viscosity. These equations are solved for the three velocity components and p. The single energy equation for the temperature, T, is

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}+w\frac{\partial T}{\partial z}=\frac{\partial}{\partial x}(\alpha\frac{\partial T}{\partial x})+\frac{\partial}{\partial y}(\alpha\frac{\partial T}{\partial y})+\frac{\partial}{\partial z}(\alpha\frac{\partial T}{\partial z})$$

here is the thermal diffusivity. The temperature distribution within the fins was computed by the steady state Laplacian for the temperature with constant thermal diffusivity.

3.2.2 Geometry

The aim of the study is to examine the IC engine cylinder block with different orientation angle, number of fins with different pitch. For the analysis the four different model geometry have been modelled using space claim software tool in ANSYS Fluent Workbench. The dimensions are given in figure 3.1.

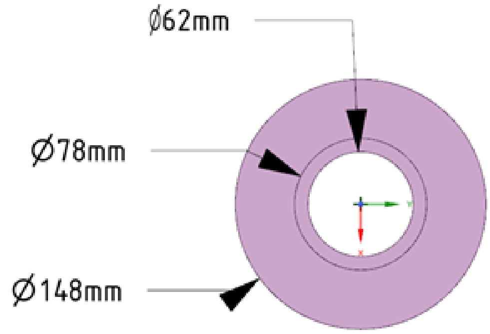
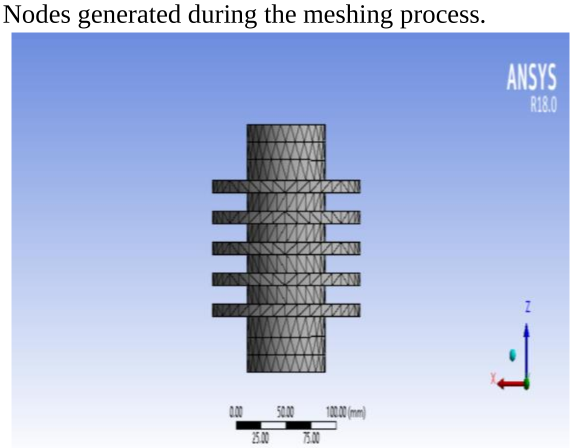


Figure 3.1 Cross Sectional Dimensions,

Discretization

The computational domain was discretized with fully structured hexahedral grids with high resolution in the near wall region to capture the effects of thermal boundary layer more accurately. A typical computational mesh used in the simulation is shown in Figure 4.2.

Figure 4.2 shows the meshed model of the cylindrical fins and Table 4.1 shows the Number of Elements and Nodes generated during the meshing process.



(a)

Figure 3.2 Discretization

IV-RESULT ANALYSIS AND DISCUSSION

4.1 General

For the analysis the tilt angle i.e. 0°, is considered. The number of fins varies as 5,6,7. The temperature-drop and heat flux has been considered as the decision criterion. The following results have been obtained:

4.2 Results for 5 Fins, 15 mm Pitch Cylindrical Block Considering 0° (Vertical) Tilt Angle

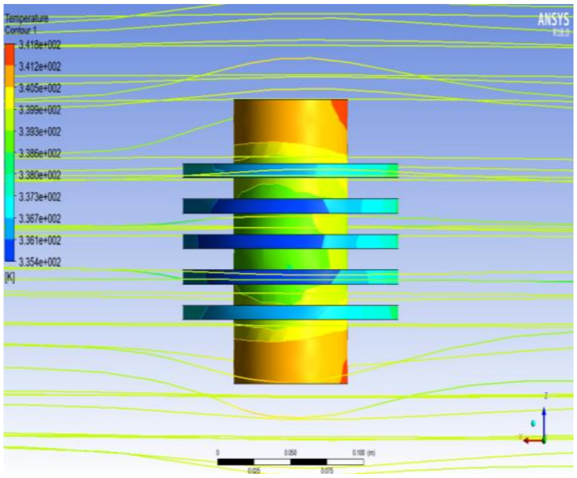


Figure 4.1 Temperature Contour for 5 Fins, 15 mm Pitch Cylindrical Block at 0° (Vertical) Tilt Angle, 20km/h motor bike speed

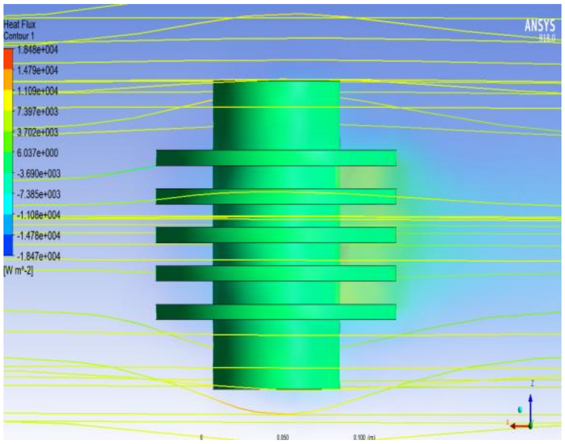


Figure 4.2 Heat Flux Contour for 5 Fins, 15 mm Pitch Cylindrical Block at 0° (Vertical) Tilt Angle, 20km/h motor bike speed

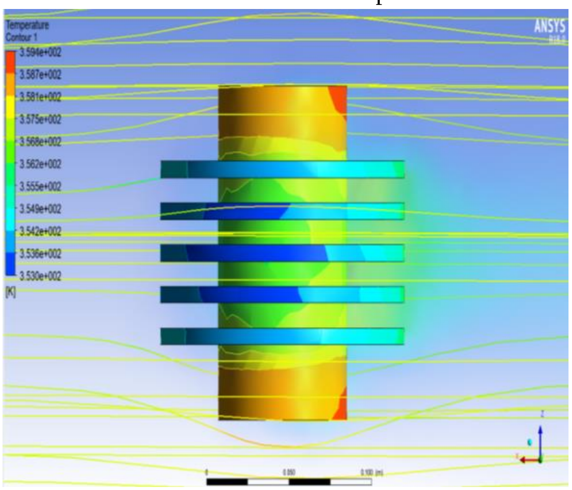


Figure 4.3 Temperature Contour for 5 Fins, 15 mm Pitch Cylindrical Block at 0° (Vertical) Tilt Angle, 40km/h motor bike speed

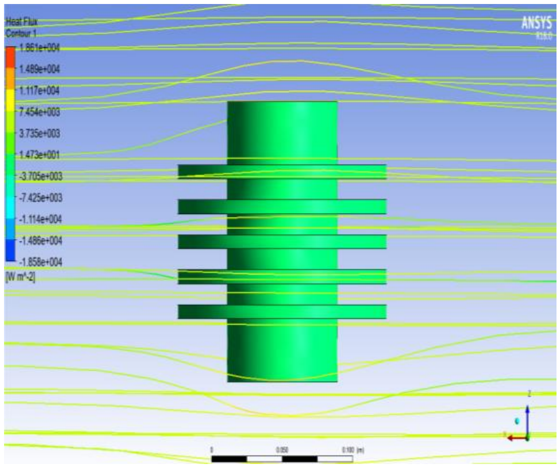


Figure 4.4 Heat Flux Contour for 5 Fins, 15 mm Pitch Cylindrical Block at 0° (Vertical) Tilt Angle, 40km/h motor bike speed

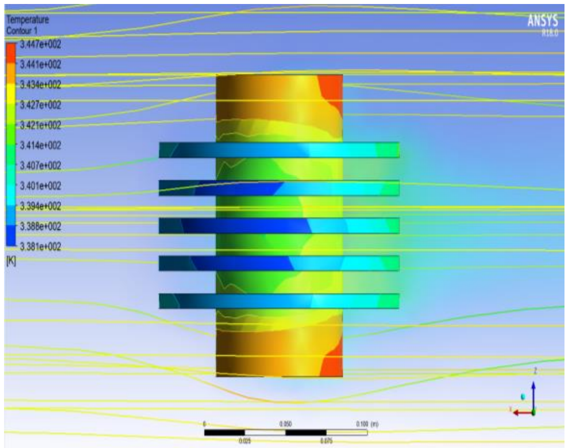


Figure 4.5 Temperature Contour for 5 Fins, 15 mm Pitch Cylindrical Block at 0° (Vertical) Tilt Angle, 60km/h motor bike speed

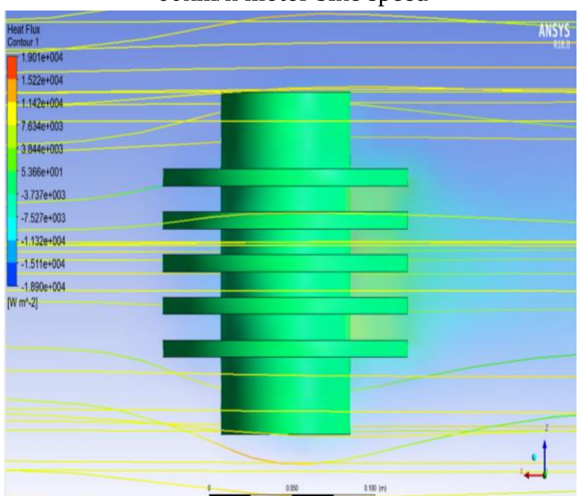


Figure 4.6 Heat Flux Contour for 5 Fins, 15 mm Pitch Cylindrical Block at 0° (Vertical) Tilt Angle, 60km/h motor bike speed

Figure 4.1 to 4.6 shows the temperature and heat flux contour for 5 fins, 15 mm pitch cylindrical block at 0° (vertical) tilt angle, for 20km/h, 40 km/h and 60km/h motor bike speed correspondingly.

V-CONCLUSION

In the present work CFD analysis of air-cooled engine cylinder block has been carried out. The constant length and diameter of cylinder block has been considered at different number of fins and it is obtained by varying the pitch of the fins. For the analysis the tilt angle i.e., 0°, is considered. The temperature-drop and heat flux are the variables considered for the study. The following calculations can be obtained:

- For different speed, the cylinder block having number of fins 5 shows the same variation of temperature drop i.e. heat transfer.
- The tilt angle shows the various heat transfer rate for all the cylinder blocks having different number of fins.
- The heat flux shows the same trends as the temperature drop.

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