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Thermal Analysis of Cylinder Block with Fins for Different Materials Using Ansys

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ABSTRACT: In internal combustion engines, the cylinder block is the main part of the engine which forms walls of the combustion chamber where air–the fuel mixture burns. Due to this continuous combustion process, these cylinder walls are subjected to a combustion zone and heat transfer takes place through the cylinder walls. If the heat is not transferred properly then it causes to deformation of the cylinder block and it finally decreases the working efficiency of the engine. Heat transfer from the cylinder block plays an important role. This is done by using fins (extended surfaces) and it must have good thermal conductivity. In our project, we are going to study various materials of fins for better heat transfer from the cylinder block by performing thermal analysis in ANSYS Workbench, and results have been analyzed to find out the best material that gives a better heat transfer rate.

KEYWORDS: Thermal conductivity; composite materials; ANSYS; thermal analysis; cylinder block, fins.

I. INTRODUCTION

In the case of Internal Combustion engines, the combustion of air and fuel takes place inside the engine cylinder and hot gases are generated. The temperature of gases will be around 800°C to 1500°C. This is a very high temperature and may result in the burning of oil film between the moving parts and may result in the seizing or welding of the cylinder block. So, this temperature must be reduced to about 150°C - 200°C at which the engine will work most efficiently. Too much cooling is also not desirable since it reduces thermal efficiency. So, the object of the cooling system is to keep the engine running at its most efficient operating temperature. It is to be noted that the engine is quite inefficient when it is cold and hence the cooling system is designed in such a way that it prevents cooling when the engine is warming up and till it attains to maximum efficient operating temperature, then it starts cooling. It is also to be noted that: 20-25% of the total heat generated is used for producing brake power (useful work). The cooling system is designed to remove 30-35% of the total heat. The remaining heat is carried away by exhaust gases. This project aims to find out the effect of fin geometry and material of fin on the cooling of the engine.

II. LITERATURE REVIEW:

Obula Reddy Kummitha et. al., [1] performed thermal analysis of cylinder block with ANSYS software. In these simulations, different alloys have been considered by taking the conductivity, density, and specific heat as major material properties for thermal analysis. Materials that are used for the present analysis are aluminum, Magnesium, and cast-iron alloys. He had concluded that from all the above nodal temperature contours and from column charts, the A380 had a better heat transfer rate along with more strength as compared with other considered alloys.

G. Babu et. al., [2] explains about the internal combustion engine is an engine in which the combustion of a fuel (normally a fossil fuel) occurs with an oxidizer (usually air) in a combustion chamber. In an internal combustion engine, the expansion of the high-temperature and -pressure gases produced by combustion applies direct force to some components of the engine, such as pistons, turbine blades, or a nozzle. This force moves the component over a distance, generating useful mechanical energy.

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P. Srinivas et. al., [3] explains the extended surfaces i.e., fins of Honda Shine & Bajaj Discover two-wheeler automotives are tested to investigate the effect on heat transfer rate by Cross-section, Fin Pitch, Fin Material, and Fin Thickness. They concluded that the suitable design and material for the cylinder fins on these materials are grey cast iron, Al2014, and Al6061 materials, finally concluded that Al6061 is suitable for cylinder fins because of its better heat transfer rate.

R. Suraj et. al., [4] created models with no slot, rectangular slot, semi-circular slot, and triangular slot in catia software. Then these models are imported into the workbench and performed thermal analysis. They concluded that for rectangular fin, the heat flux increases more for rectangular slots.

Arimadla Sravan et. al., [5] says that to avoid overheating, and the consequent ill effects, the heat transferred to an engine component (after a certain level) must be removed as quickly as possible and be conveyed to the atmosphere. It will be proper to say the cooling system is a temperature regulation system. It should be remembered that the abstraction of heat from the working medium by way of cooling the engine components is a direct thermodynamic loss. Fins (or ribs) are sharp projections provided on the surfaces of the cylinder block and cylinder head. They increase the outer contact area between a cylinder and the air. Fins are, generally, cast integrally with the cylinder. They may also be mounted on the cylinder.

Prof. Rohit Soni et. al., [6] optimized the better material for the engine cylinder block for maximum heat transfer. The main focus of the study is to make as fast heat transfer from the cylinder block. He concluded that the above results it is clearly shown that the fin which is made up of Aluminium alloy 6061 attain a maximum temperature of 793.1°C at 10 seconds in comparison to others where aluminum alloy 795.71°C, Al metal matrix composition alloys (Al-MMC) 793.67°C.

Mulukuntla Vidya Sagar et. al., [7] says that air-cooled engines generally use individual cases for the cylinders to facilitate cooling. Inline motorcycle engines are an exception, having two-, three, four-or even six-cylinder air-cooled units in a common block. Water-cooled engines with only a few cylinders may also use individual cylinder cases, though this makes the cooling system more complex. The Ducati motorcycle company, which for years used air-cooled motors with individual cylinder cases, retained the basic design of their V-twin engine while adapting it to water-cooled engines.

A. N. Mohan Das et. al., [8] says that extended surfaces are used between two fluids for heat transfer between the hotter and colder fluid or between a solid and a fluid. There are various types of fins, viz. angular fins, circular fins, and rectangular fins. The engine piston chamber is the most precarious part of any automobile imperiled to extreme thermal shocks, hence prone to thermal stresses. Therefore, fins are introduced to cool the cylinder, which helps to improve engine performance considerably. In this study, rectangular and circular types of fins were selected, and their effect on temperature distribution and heat flux has been studied with and without the introduction of slots.

P. Sai Chaitanya et. al., [9] says that the Engine cylinder is one of the major automobile components, which is subjected to high-temperature variations and thermal stresses. In order to cool the cylinder, fins are provided on the surface of the cylinder to increase the rate of heat transfer. By doing a thermal analysis on the engine cylinder fins, it is helpful to know the heat dissipation inside the cylinder. We know that by increasing the surface area we can increase the heat dissipation rate, so designing such a large complex engine is very difficult. The main aim of the present paper is to analyze the thermal properties by varying geometry, material, and thickness of cylinder fins using an ANSYS work bench.

Masao Yoshida et. al., [10] investigated the effect of several fins, fin pitch, and wind velocity on air cooling using the experimental tunnel. Heat releases from the cylinder did not improve when the cylinder have more fins and too narrow a fin pitch at lower wind velocities because it is difficult for the air to flow into the narrower space between the fins, and the temperature between them increased.

III. METHODOLOGY:

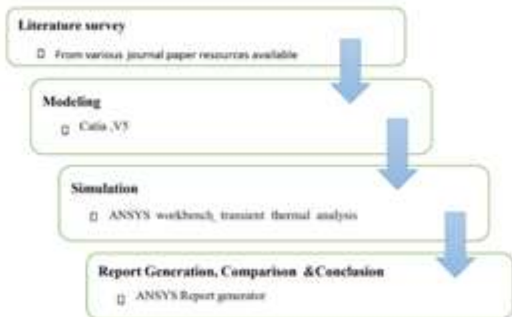

Fig-1Flow chart of methodology

The figure 1 shows the step by step procedure of modelling and analysis. By considering the BMW motorcycle we generated a model in CATIA software. The model was imported into ansys workbench to perform thermal analysis of cylinder blocks with fins for different materials. The bore of the cylinder is 44 mm, the length of the stroke is 45 mm, and the length of the fin is 60 mm. Based on the above dimensions generate three different models, after generating models they must be saved in igs format. The model which is saved in igs format that will makes easy to import the model into the workbench. So, that we perform transient thermal analysis easily.

IV. MODELLING:

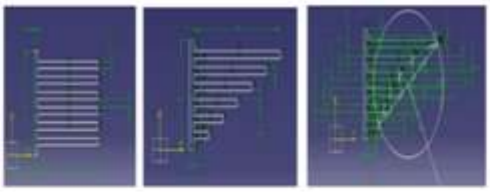

Fig-2 Models with no variation of fin, linearly variation of fin, circularly variation of fin

The figure 2 shows the Fin models with no variation of fin, linearly variation of fin, circularly variation of fin. After the models are generated we have to click on the existing workbench. Then use the shaft command to generate a 3D model and after that, the above model must be saved in .igs format for easy access to importing the geometry.

Fig-3 3D geometries of no varying fin, linearly varying fin, circular varying fin.

The figure 3 shows the 3D geometries of no varying fin, linearly varying fin, and circular varying fin. After generating a 3D model and after that the above model must be saved in .igs format for easy access to importing the geometry.

V. ANALYSIS:

Analysis of the cylinder fin for different geometries was carried out in ansys workbench. The basic model was generated using CatiaV5 and that model is imported to the ANSYS Workbench. Transient thermal analysis was carried out. Transient thermal analyses determine temperatures and other thermal quantities that vary over time. The variation of temperature distribution over time is of interest in many applications such as with the cooling of electronic packages or a quenching analysis for heat treatment. Also of interest are the temperature distribution results in thermal stresses that can cause failure. In such cases, the temperatures from a transient thermal analysis are used as inputs to a static structural analysis for thermal stress evaluations. In the present study as the fins undergo temperature variation over time so transient thermal analysis was carried out. Materials used for the present analysis are aluminum alloy 6061 and structural steel.

Load	Unit	Value
Film coefficient	W/m^2K	1073
Ambient Temperature	K	5
Material	-	Aluminium alloy 6061 Structural steel

Table- 1 Boundary condition

The boundary conditions are temperature and heat transfer coefficient. The inlet temperature is applied inside of the cylinder block and the film coefficient is applied at the outer surfaces of the cylinder block.

VI. RESULTS AND DISCUSSIONS:

Results of Al6061 material are shown in figures 5 to 7.

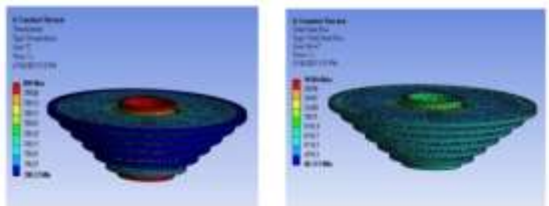

Fig-5 Temperature distribution and Heat flux of linearly varying fin

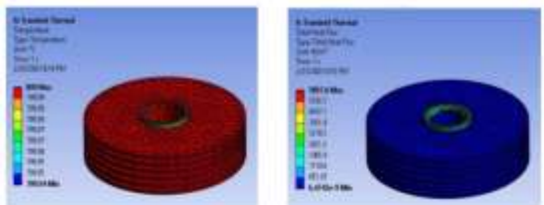

Fig-6 Temperature and Heat flux of no varying fin

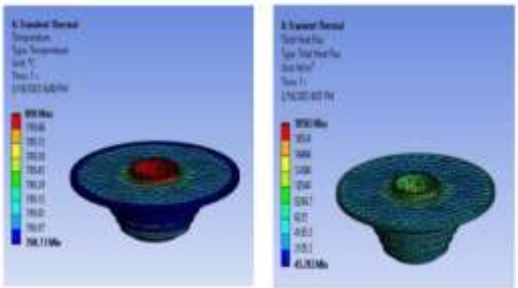

Fig-7 Temperature distribution and Heat flux of circularly varying fin

Results of Structural steel material are shown in figures 8 to 10

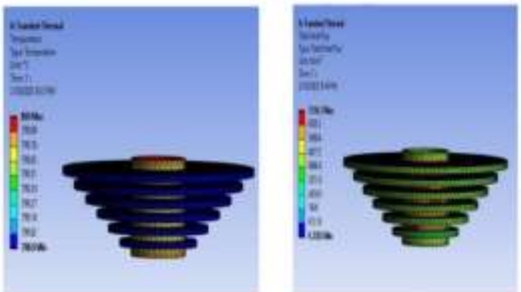

Fig-8 Temperature distribution and Heat flux of linearly varying fin

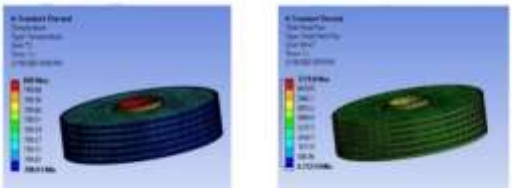

Fig-9 Temperature distribution and Heat flux of no varying fin

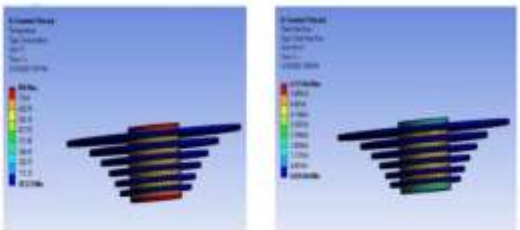

Fig-10 Temperature distribution and heat flux circularly varying fin

The figure 5 shows the temperature distribution and total heat flux of linearly varying fins. The aluminum alloy 6061 of linearly varying fins gives minimum temperature distribution of 798.72^{o}C. Maximum heat flux for aluminum alloy 6061of linearly Varying fin gives 18,384 W/m^2.

The figure 6 shows the temperature distribution and total heat flux for no varying fins. The aluminum alloy 6061 of no variation of fins gives minimum temperature distribution of 799.94^{o}C. Maximum total heat flux for aluminum alloy 6061 of no variation of fins 5897.6 W/m^2.

The figure 7 shows the temperature distribution and total heat flux for circular varying fins. The aluminum alloy 6061 of circular variation of fins gives minimum temperature distribution of 798.73^{o}C. Maximum total heat flux for aluminum alloy 6061 of no variation of fins is 18,583 w/m^2.

The figure 8 shows the temperature distribution and heat flux of linearly varying fin. The structural steel of linearly varying fin gives minimum temperature distribution of 798.9^{o}C. Maximum heat flux for structural steel of linearly varying fin gives 7316.1 w/m^2.

The figure 9 shows the temperature distribution and total heat flux for no varying fins. The structural steel of no variation of fins gives minimum temperature distribution of 798.91^{o}C. Maximum total heat flux for structural steel of no variation of fins 7279.8 w/m^2.

Thefigure 10 shows the temperature distribution and total heat flux for no varying fins. The structural steel of circular variation of fins gives minimum temperature distribution of 798.91^{o}C. Maximum total heat flux for structural steel of no variation of fins 7279.8 w/m^2.

VII. CONCLUSION:

Fins play an important role in the cooling of engine cylinders. Thermal analysis of cylinder block with fins is done with different geometry and with different materials. The fin's geometry and cross-sectional area affect the heat transfer rate. In this present work, a cylinder block created in 3D software CATIA three different designs are generated by taking specifications of a BMW motorcycle in which no variation of fins, linearly varying fins and circularly varying fins are considered for analysis. From all these cases it is concluded that the suitable design and material for the cylinder fins is no variation in fin length. If we consider the temperature distribution, Al6061 with no variation in fin length is adopted. If we consider heat flux structural steel with circularly varying fin lengths is adopted, but the structural steel has more weight compared to Al6061, and so Al6061 material is suggested for the engine design.

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