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Design and Analysis of Four Stroke Engine Fins and compared with Modified Design

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Abstract

The Engine cylinder is the heart of the 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 executing the thermal analysis of the engine fins, it is helpful to know the heat dissipation rate and temperature distribution inside the cylinder. The main aim of the present project is to analyze the thermal properties like Directional Heat Flux, Total Heat Flux and Temperature Distribution of a modified conical design along with the existing model with three different materials (structural steel, Aluminium alloy and Magnesium alloy). The design for the fins model will be prepared in CATIA V5R20 and analyzed using ANSYS WORKBENCH with an Average Internal Temperature and Stagnant Air-Simplified case as Cooling medium on Outer surface with reasonable Film Transfer Coefficient as Boundary Conditions.

Keywords: Engine cylinder, Thermal Analysis.

1. Introduction

We know that in case of Internal Combustion engines, combustion of air and fuel takes place inside the engine cylinder and hot gases are generated. The temperature of gases will be around

2300-2500°C. This is a very high temperature and may result into burning of oil film between the moving parts and may result in seizing or welding of same that is chances of piston seizure, chances of piston ring, compression ring, oil ring etc. can be affected. Excess temperature can also damage the cylinder material. So this temperature must be reduced to about 150- 200°C at which the engine will work most efficiently. Too much cooling is also not desirable since it reduces the thermal efficiency. So, the object of 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. 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 as a temperature regulation system. It should be remembered that abstraction of heat from the working medium by way of cooling the engine components is a direct thermodynamic loss.

The rate of heat transfer depends upon the wind velocity, geometry of engine surface, external surface area and the ambient temperature. In this work analysis is done on engine block fins considering temperature inside by means of conduction and convection, air velocity is not consider in this work. Motorbikes engines are normally designed for operating at a particular atmosphere temperature, however cooling beyond optimum limit is also not considered because it can reduce overall efficiency. Thus it may be observed that only sufficient cooling is desirable.

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 the twin engine while adapting to water-cooling.

2. Existing System

In existing engine fin we are having a cylindrical like structure for temperature reduction. This may results in increase in weight as well as occupying a higher space.

3. Proposed System

In this current project we are going to modify the current design by converting cylindrical into square structure and the fin plates are designed with sharp edges. This may results in higher weight reduction which results in increased fuel efficiency and also reduction in temperature distribution, total heat flux and directional heat flux.

4. Engine Fin

An Internal Combustion Engine (ICE) is a heat engine where the combustion of a fuel occurs with an oxidizer (usually air) in a combustion chamber that is an integral part of the working fluid flow circuit. In an internal combustion engine the expansion of the high temperature and high pressure gases produced by combustion apply direct force to some component of the engine. This force moves the component over a distance, transforming chemical energy into useful mechanical energy. A cylinder is the central working part of a reciprocating engine or pump, the space in which a piston travels. Multiple cylinders are commonly arranged side by side in a bank, or engine block, which is typically cast from aluminum or cast iron before receiving precision machine work.

Heat losses are a major limiting factor for the efficiency of internal combustion engines. Furthermore, heat transfer phenomena cause thermally induced mechanical stresses compromising the reliability of engine components. The ability to predict heat transfer in engines 2 plays an important role in engine development. Today, predictions are increasingly being done with numerical simulations at an ever earlier stage of engine development. These methods must be based on the understanding of the principles of heat transfer.

5. Principles of Heat Transfer

Heat is the transfer of thermal energy. Heat is always transferred from an object of higher heat to one with lower heat. Exchange of heat occurs till body and the surroundings reach at the same temperature. The high-temperature body passes energy to the low- temperature one, eventually achieving thermal equilibrium. The tendency to thermal equilibrium, or even distribution of kinetic energy, is an expression of the second law of thermodynamics, the driving force of heat transfer. According to the second law of thermodynamics, 'Where there is a temperature difference between objects in proximity, heat transfer between them can never be stopped'; it can only be slowed down. Heat is the energy in transit between systems which occurs by virtue of their temperature difference when they communicate. Heat transfer generally occurs by following three ways:

5.1. Conduction

Thermal conduction is a process of heat transmission from a section of higher temperature to a section of low temperature with a medium (solid, liquid, or gases) or between several mediums in direct physical contact. Conduction does not include any transfer of macroscopic portions of matter relative to one another. The thermal energy may be transmitted by means of electrons which are free to move by the lattice structure of the material.

Movement of heat through materials; Fourier's law: $Q = -KA\ dT\ dt$

5.2. Convection

The thermal convection is a process of energy, transference affected from the motion or mixing of a fluid medium. Convection is performing only in a fluid medium and is at once linked to the motion of medium itself. Macroscopic particles of a fluid movement in space cause the heat exchange, and for this reason convection constitutes the macroform of the heat transfer. The effectiveness of heat transfer through convection based largely upon the mixing movement of the fluid. With respect to the origin, types of convection are distinguished; forced and natural convection.

Movement of heat by fluids; Newton's law of cooling: $Q = \square CA\ T\infty - TW$

5.3. Radiation:

Radiation is the energy transfer in the form of waves through space without any medium other than conduction and convection. Conduction and convection require a medium like solid or gas but radiation only happen in space through electromagnetic waves. The black body is ideal surface for emits radiation at maximum rate, and the radiation transferred by a black body is called black body radiation. Absorptive α is another important property of a plane, is explained as the division of the radiation energy incident on a surface that is received by the surface. The entire radiation incident on it is absorbed by black body. That is, a blackbody is a perfect absorber (α=1) of radiation.

Heat movement by transfer from one body to another: $Q = \in \sigma\ T\ 4\ 1 - T\ 4\ 2$

5.4. Extended Surfaces (Fins)

In the heat transfer study, the surface that extends from an object is known as a fin. Fins are used to increase the rate of heat dissipation from or to the environment by increasing the rate of convection. The total of convection, conduction, or radiation of an object decides the amount of heat it dissipates. It increases with the difference of temperature between the environment and the object, also increasing the convection coefficient of heat transfer, or increasing the surface area. But, increase of the area also 4 causes increased resistance to the heat flow. Hence, coefficient of heat transfer is based on the total area (the base and fin surface area) which comes out to be less than that of the base. There are different types of shape and size fins used in engineering applications to increasing the heat transfer rate.

6. Introduction to CAD/CAM/CAE

The Modern world of design, development, manufacturing so on, in which we have stepped can't be imagined without interference of computer. The usage of computer is such that, they have become an integral part of these fields. In the world market now the competition in not only cost factor but also quality, consistency, availability, packing, stocking, delivery etc. So are the requirements forcing industries to adopt modern technique rather than local forcing the industries to adapt better techniques like CAD / CAM / CAE, etc. The Possible basic way to industries is to have high quality products at low costs is by using the computer Aided Engineering (CAE), Computer Aided Design (CAD) And Computer Aided Manufacturing (CAM) set up. Further many tools is been introduced to simplify & serve the requirement CATIA, PRO-E, UG are some among many.

This penetration of technique concern has helped the manufacturers to

- Increase productivity
- Shortening the lead-time
- Minimizing the prototyping expenses
- Improving Quality
- Designing better products

CAD: Computer Aided Designing (Technology to create, Modify, Analyze or Optimize the design using computer.

CAE: Computer Aided Engineering (Technology to analyze, Simulate or Study behavior of the cad model generated using computer.

CAM: Computer Aided Manufacturing (Technology to Plan, manage or control the operation in manufacturing using computer.

6.1. Need For CAD, CAE & CAM

The usage of CAD CAE & CAM have changed the over look of the industries and developed healthy & standard competition , as could achieve target in lean time and ultimately the product reaches market in estimated time with better quality and consistency . In general view, it has lead to fast approach and creative thinking.

7. Introduction to CATIA

CATIA is a robust application that enables you to create rich and complex designs. The goals of the CATIA course are to teach you how to build parts and assemblies in CATIA, and how to make simple drawings of those parts and assemblies. This course focuses on the fundamental skills and concepts that enable you to create a solid foundation for your designs.

7.1. What is CATIA?

CATIA is mechanical design software. It is a feature-based, parametric solid modeling design tool that takes advantage of the easy-to-learn Windows graphical user interface. You can create fully associative 3-D solid models with or without constraints while utilizing automatic or user-defined relations to capture design intent. To further clarify this definition, the italic terms above will be further defined:

7.2. Feature-based

Like an assembly is made up of a number of individual parts, a CATIA document is made up of individual elements. These elements are called features. When creating a document, you can add features such as pads, pockets, holes, ribs, fillets, chamfers, and drafts. As the features are created, they are applied directly to the work piece.

Features can be classified as sketched-based or dress-up

- Sketched-based features are based on a 2D sketch. Generally, the sketch is transformed into a 3D solid by extruding, rotating, sweeping, or lofting.
- Dress-up features are features that are created directly on the solid model. Fillets and chamfers are examples of this type of feature.

7.3. Solid Modeling

A solid model is the most complete type of geometric model used in CAD systems. It contains all the wireframe and surface geometry necessary to fully describe the edges and faces of the model. In addition to geometric information, solid models also convey their topology, which relates the geometry together. For example, topology might include identifying which faces (surfaces) meet at which edges (curves). This intelligence makes adding features easier. For example, if a model requires a fillet, you simply select an edge and specify a radius to create it.

Fully Associative

A CATIA model is fully associative with the drawings and parts or assemblies that reference it. Changes to the model are automatically reflected in the associated drawings, parts, and/or assemblies. Likewise, changes in the context of the drawing or assembly are reflected back in the model.

Constraints

Geometric constraints (such as parallel, perpendicular, horizontal, vertical, concentric, and coincident) establish relationships between features in your model by fixing their positions with respect to one another. In addition, equations can be used to establish mathematical relationships between parameters. By using constraints and equations, you can guarantee that design concepts such as through holes and equal radii are captured and maintained.

CATIA User Interface

Below is the layout of the elements of the standard CATIA application.

- Menu Commands
- Specification Tree
- Window of Active document
- Filename and extension of current document
- Icons to maximize/minimize and close window
- Icon of the active workbench Toolbars specific to the active workbench
- Standard toolbar
- Compass
- Geometry area

Different types of engineering drawings, construction of solid models, assemblies of solid parts can be done using inventor.

Different types of files used are:

- Part files: CATPart
- Assembly files: CATProduct

8. Results

S.No.	Content		Steel	Mg alloy	Al alloy
1	Temperature	Max	1500	1500	1500
		Min	1220.1	1194	918.04
2	Total heat flux	Max	8.6665e5	1.13644e6	1.16e6
		Min	6852.1	9907	110186
3	Directional heat flux	Max	7.956e5	1.0566e6	1.0826e6
		Min	-7.987e5	-1.0511e6	- 1.076e6

Table 1. Comparison Results of Normal Engine Fin

S.No.	Content		Steel	Mg alloy	Al alloy
1	Temperature	Max	1500	1500	1500
		Min	509.33	886.28	935.14
2	Total heat flux	Max	7.316e5	1.0174e6	1.0441e6
		Min	3566.4	7991.4	8622
3	Directional heat flux	Max	6.7347e5	9.1903e5	9.423e5
		Min	-6.736e5	-9.192e5	-9.426e5

Table 2. Comparison Results of Normal Engine Fin

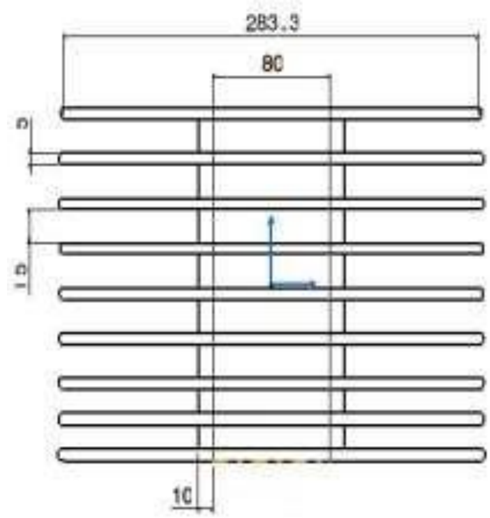

Figure 1. Design of Normal Engine Fin

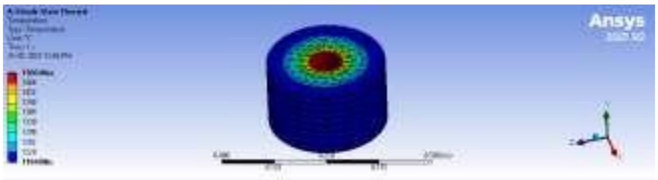

Figure 2. Results of Normal Engine Fin using Aluminium

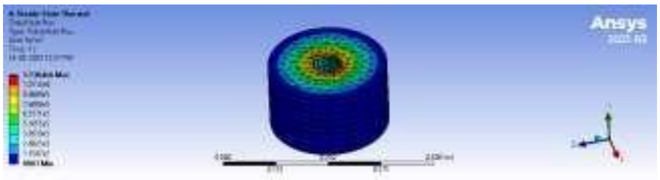

Figure 3. Total heat flux of Aluminium engine fin

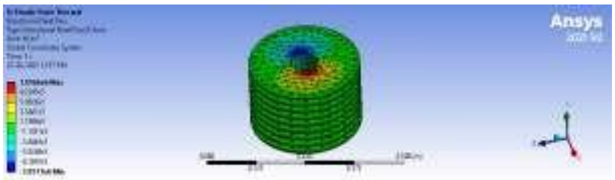

Figure 4. Directional heat flux of Aluminium engine fin

9. Conclusion

We have implemented that the minimum temperature of the engine reduces on by changing the design of the fins which is done by reducing the surface area of the fin surface. We also implemented the reduction in minimum temperature of the engine by implementing the material from AL 6063 to Aluminium alloy (Al + Silicon carbide) which is showing better and more efficient results than structural steel and magnesium alloy. It has been seen that the implementation results in increased temperature distribution, Total heat flux and Directional heat flux of the engine up to 20% in Aluminium silicon carbide. It is clear from thermal analysis that, to achieve better cooling results Aluminium silicon carbide is a better option for engine fins.

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