IJREAT International Journal of Research in Engineering & Advanced Technology, Volume 2, Issue 1, Feb-Mar, 2014
ISSN: 2320 - 8791
www.ijreat.org

Modeling, Analysis and Optimization of Diesel Engine Piston

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Abstract

In the now-a-days technology the diesel engines plays an important role in the transportation sector, agricultural pumping sets etc., where large amount of diesel is consumed. But according to the ministry of petroleum, this petroleum fuels will last in few years. So, one must concentrate much on the diesel engine modifications so that the amount of fuel consumption and the environmental pollutions can be reduced.

In a normally diesel engine the amount of useful energy available is less and remaining is lost to the cooling water, exhaust gases and as frictional losses. The most effective way of burning various fuels in the engine and reducing the energy losses is by using thermal barrier coatings on the various elements of the combustion chamber like cylinder head, cylinder liner, piston and valves.Among all the components in the engine, piston will play a very important role for the production of power. The amount of useful work can be increased with the modification of piston. With the various piston materials the amount of temperature available in the engine can be increased which further increases the efficiency.

The temperature distribution in the piston is a crucial parameter which influences the thermal stresses and deformations in the piston materials. This stress and deformation varies with different materials of the piston.

The present used material for Piston is Cast Aluminum. So in the present work we tried with Cast Aluminum, Aluminum MMC and Brass. For that we designed the 5 B.H.P diesel engine piston. Then the same is modeled in Pro/Engineer. Structural analysis is done on the piston by applying the pressure to verify the strength of the piston using 3 materials. Thermal analysis is done to verify the temperature distributions, heat transfer rate. Fatigue analysis is done to determine the life of the piston. The analysis is carried out in the commercially available software SolidWorks, simulation part is COSMOSWORKS.

The thickness of the piston is optimized in order to reduce the weight of the piston by design optimization in SolidWorkshe

Keywords: *Piston, Modelling, Design, Engine, Optimization.*

1. Introduction

Engine pistons serve several purposes. They transmit the force of combustion to the crankshaft through the connecting rod. They act as a guide for the upper end of the connecting rod. And they also serve as a carrier for the piston rings used to seal the compression in the cylinder.

The piston must come to a complete stop at the end of each stroke before reversing its course in the cylinder. To withstand this rugged treatment and wear, it must be made of tough material, yet be light in weight. To overcome inertia and momentum at high speed, it must be carefully balanced and weighed. All the pistons used in any one engine must be of similar weight to avoid excessive vibration. Ribs are used on the underside of the piston to reinforce the hand. The ribs also help to conduct heat from the head of the piston to the piston rings and out through the cylinder walls.

The structural components of the piston are the head, skirt, ring grooves, and land. However, all pistons do not look like the typical one. Some have differently shaped heads. Diesel engine pistons usually have more ring grooves and rings than gasoline engine pistons.

Fitting pistons properly is important. Because metal expands when heated and space must be provided for lubricants between the pistons and the cylinder walls, the pistons are fitted to the engine with a specified clearance. This clearance depends upon the size or diameter of the piston and the material form which it is made. Cast iron does not expand as fast or as much as aluminum. Aluminum pistons require more clearance to prevent binding or seizing when the engine gets hot. The skirt of bottom part of the piston runs much cooler than the top; therefore, it does not require as much clearance as the head.

The piston is kept in alignment by the skirt, which is usually cam ground (elliptical in cross section). This elliptical shape permits the piston to fit the cylinder, regardless
of whether the piston is cold or at operating temperature. The narrowest diameter of the piston is at the piston pin bosses, where the piston skirt is thickest. At the widest diameter of the piston, the piston skirt is thinnest. The piston is fitted to close limits at its widest diameter so that the piston noise (slap) i s prevented during the engine warm-up. As the piston is expanded by the heat generated during operation, it becomes round because the expansion is proportional to the temperature of the metal. The walls of the skirt are cut away as much as possible to reduce weight and to prevent excessive expansion during engine operation. Many aluminum pistons are made with split skirts so that when the pistons expand, the skirt diameter will not increase.

The two types of piston skirts found in most engines are the full trunk and the slipper. The full-trunk-type skirt, more widely used, has a full cylindrical shape with bearing surfaces parallel to those of the cylinder, giving more strength and better control of the oil film. The slipper-type (cutaway) skirt has considerable relief on the sides of the skirt, leaving less area for possible contact with the cylinder walls and thereby reducing friction.

Piston Pin - The piston is attached to the connecting rod by the piston pin (wrist pin). The pin passes through the piston pin bosses and through the upper end of the connecting rod, which rides within the piston on the middle of the pin. Piston pins are made of alloy steel with a precision finish and are case hardened and sometimes chromium plated to increase their wearing qualities. Their tubular construction gives them maximum strength with minimum weight. They are lubricated by splash from the crankcase or by pressure through passages bored in the connecting rods.

Three methods are commonly used for fastening a piston pin to the piston and the connecting rod: fixed pin, semifloating pin, and full-floating pin. The anchored, or fixed, pin attaches to the piston by a screw running through one of the bosses; the connecting rod oscillates on the pin. The semifloating pin is anchored to the connecting rod and turns in the piston pin bosses. The full-floating pin is free to rotate in the connecting rod and in the bosses, while plugs or snap-ring locks prevent it from working out against the sides of the cylinder.

Piston Rings - Piston rings are used on pistons to maintain gastight seals between the pistons and cylinders, to aid in cooling the piston, and to control cylinder-wall lubrication. About one-third of the heat absorbed by the piston passes through the rings to the cylinder wall. Piston rings are often complicated in design, are heat treated in various ways, and are plated with other metals. Piston rings are of two distinct classifications: compression rings and oil control rings.

The principal function of a compression ring is to prevent gases from leaking by the piston during the compression and power strokes. All piston rings are split to permit assembly to the piston and to allow for expansion. When the ring is in place, the ends of the split joint do not form a perfect seal; therefore, more than one ring must be used, and the joints must be staggered around the piston. If cylinders are worn, expanders are sometimes used to ensure a perfect seal. The bottom ring, usually located just above the piston pin, is an oil-regulating ring. This ring scrapes the excess oil from the cylinder walls and returns some of it, through slots, to the piston ring grooves. The ring groove under an oil ring has openings through which the oil flows back into the crankcase. In some engines, additional oil rings are used in the piston skirt below the piston pin.

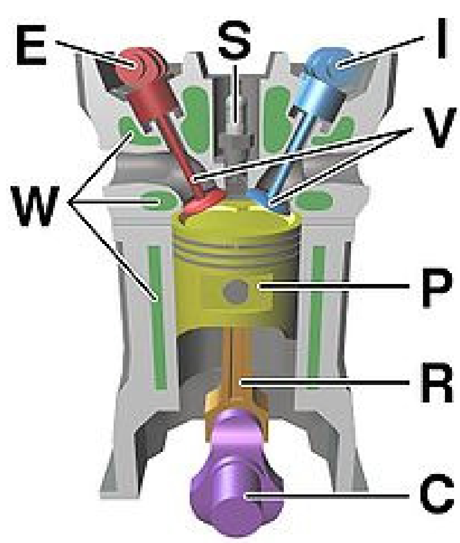

Fig 1 Engine components

2.Modelling of piston

CAD is an important industrial art extensively used in many applications, including automotive, shipbuilding, and aerospace industries, industrial and architectural design, prosthetics, and many more. CAD is also widely used to produce computer animation for special effects in movies, advertising and technical manuals. The modern ubiquity and power of computers means that even perfume bottles and shampoo dispensers are designed using techniques unheard of by engineers of the 1960s. Because of its enormous economic importance, CAD has been a major driving force for research in computational geometry, computer graphics (both hardware and software), and discrete differential geometry.

Current computer-aided design software packages range from 2D vector-based drafting systems to 3D solid and surface modellers. Modern CAD packages can also frequently allow rotations in three dimensions, allowing viewing of a designed object from any desired angle, even from the inside looking out. Some CAD software is capable of dynamic mathematic modeling, in which case it may be marketed as CADD — computer-aided design and drafting.CAD is used in the design of tools and machinery and in the drafting and design of all types of buildings, from small residential types (houses) to the largest commercial and industrial structures (hospitals and factories).CAD is mainly used for detailed engineering of 3D models and/or 2D drawings of physical components, but it is also used throughout the engineering process from conceptual design and layout of products, through strength and dynamic analysis of assemblies to definition of manufacturing methods of components. It can also be used to design objects.

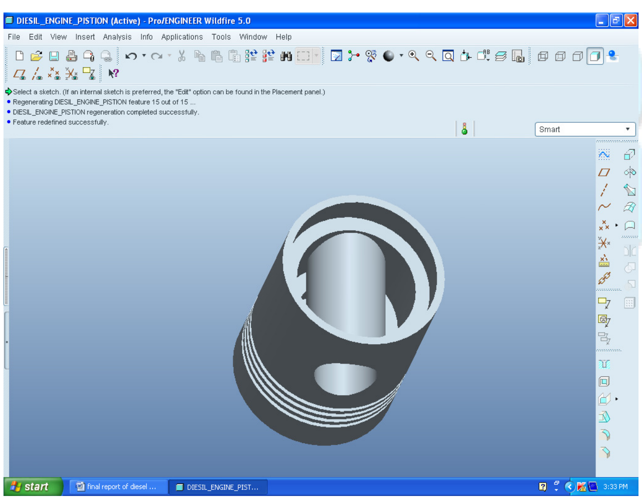

Fig 2 Design of piston

3.Analysis of piston

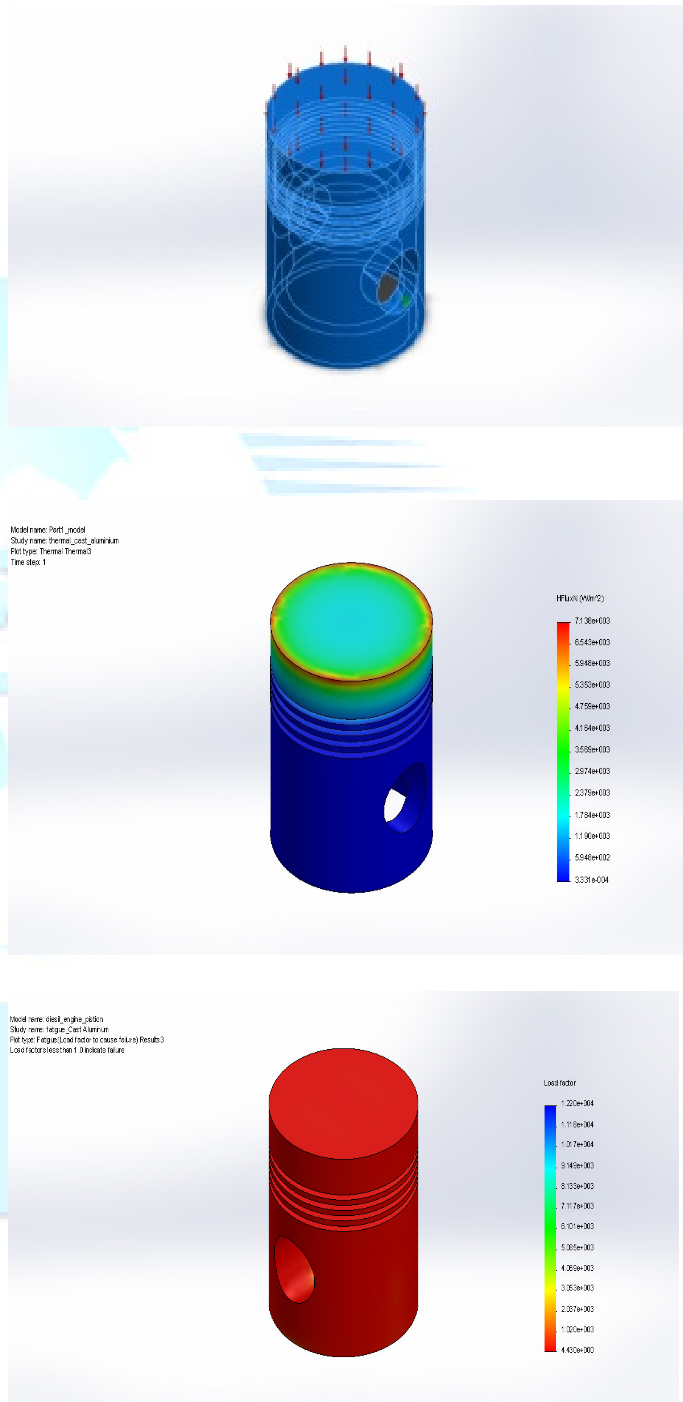

Fig 3 FEA Results

4 Conclusions

In this project, a piston is designed used in a diesel engine and modeled in 3D modeling software Pro/Engineer. Present used material for piston is Cast Aluminum. The Cast aluminum is replaced with Aluminum Metal Matrix Composite and Brass. The weight of the piston is more when Brass is used since its density is more.

Structural analysis is done on the piston by applying the pressure to verify the strength of the piston using 3 materials. Thermal analysis is done to verify the temperature distributions, heat transfer rate. Fatigue analysis is done to determine the life of the piston. The analysis is carried out in the commercially available software SolidWorks, simulation part is COSMOSWORKS.

From the structural analysis, by observing stress values for both the materials, the analyzed stress values are less than their respective yield stresses. So we can decide that our design is safe. By comparing the values of stress for Cast Aluminum, Aluminum Metal Matrix Composite and Brass, the stress values are almost same.From the thermal analysis results, the heat transfer rate is more when Brass is used.We have also done fatigue analysis on the piston to determine the life of the piston under given load conditions. We have derived damage factor, life and load factor. By observing damage factor, the damage caused by applying the load is very less for both materials. The life of piston when cast aluminum used is $4e^7$ cycles, when Aluminum MMC used is $2e^7$ cycles and when Brass used is $1e^6$ cycles. The piston will fail when the load is increased about 12197times the present load when Cast Aluminum is used. . The piston will fail when the load is increased 13424 times the present load when Aluminum MMC is used. The piston will fail when the load is increased 20851.2 times the present load when Brass is used.
Design optimization is done to reduce the weight of the piston. The present thickness of the piston is 3.2mm. The design is optimized by reducing the thickness. By observing the results, the optimal thickness value is 1.7mm.So we can conclude that by structural analysis using Aluminum MMC is better.

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