Investigation of Two Engine Pistons by FEA

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Abstract:

The aim of this work is to compare two different materials for the engine piston: Aluminum alloy A390-T5 and Ductile Iron 65-45-12 using a Finite Element Analysis (FEA) and thus choose the best suited material. Despite low thermal expansion, thermal conductivity and high mechanical strength of Ductile Iron 65-45-12, its high density causes high inertial forces on the engine. Although the Aluminums Alloy A390-T5 has a larger thermal expansion, a larger thermal conductivity and a lower mechanical strength at high temperature than ductile iron, due to its lower density it was possible to design a piston meeting all the design requirements and weighting about 66 % less than Ductile Iron piston design.

Keywords: Pistons; Aluminium Cast Alloy; Aluminium Cast Alloy

I INTRODUCTION

A piston is a component of reciprocating engines, pumps and gas compressors. It is located in a cylinder and is made gas-tight by piston rings. In an engine, its purpose is to transfer force from expanding gas in the cylinder to the crankshaft via a piston rod and/or connecting rod. The alloy from which a piston is made not only determines its strength and wears characteristics, but also its thermal expansion characteristics. Hotter engines require more stable alloys to maintain close tolerances without scuffing.

The normal temperature of gasoline engine exhaust is approximately 650ºC (923ºK). This is also approximately the melting point of most aluminum alloys and it is only the constant influx of ambient air that prevents the piston from deforming and failing. For this purpose testing different types of materials such as aluminum alloys and cast iron piston. Thermal analysis is a branch of materials science where the properties of materials are studied as they change with temperature. In an Internal combustion engine the power is developed inside the engine cylinder by burning the fuel in the cylinder itself. The heat energy produced during the combustion of fuel is converted into mechanical energy by the expansion of gases against the piston.

In recent years, more and more efforts are made to increase horse power to weight ratio of internal combustion engines. In order to achieve the increased power to weight ratio, the necessity of design optimization of various internal combustion engine components is felt very seriously. It is important to calculate the piston temperature distribution in order to reduce the thermal stresses and deformations within acceptable levels.

The investigations indicate that the greatest stress appears on the upper end of the piston and stress concentration is one of the main reasons for fatigue failure. On the other hand piston overheating-seizure can only occur when something burns or scrapes away the oil film that exists between the piston and the cylinder wall. Damaged or broken parts are generally too expensive to replace and generally are not easily available. So to avoid this problem it needs design of a new part the main requirement of a piston is a good sealing of the cylinder. The Second is that the weight of the piston and the entire crank mechanism is a minimum, particularly for high speed machines, in order to reduce the inertia force and to improve thermal efficiency.

II. LITERATURE REVIEW

The finite element analysis is performed using CAD software to investigate and analyze thermal stress distribution at the real engine condition during combustion process. Piston skirt may appear deformation usually causes crack on the upper end of the piston head. Due to deformation, stress concentration is caused on the upper end of the piston and, the stress distribution on the piston mainly depends on the deformation of piston. Therefore piston crown should have enough stiffness to reduce the deformation.[1] The preliminary analyses presented in the paper was to compare the behavior of the combustion engine piston made of different type of materials under thermal load[2] Finite element analysis is used to analyze stresses in a piston of an internal combustion engine. The stresses due to combustion gas load only are considered so as to reduce the weight and hence to increase the Power output of engine.[3]

III.CHARACTERIZATION OF MATERIALS

The materials chosen for our study are two metallic alloys usually used as substrate material
For internal combustion engine pistons.

ALUMINIUM A390-T5

A unique combination of properties makes aluminium one of our most versatile engineering
And construction materials. Besides its lower density, it has high resistance to corrosion under the majority of service conditions. A wide range of mechanical characteristics, or tempers, are available in aluminium alloys through various combinations of cold work and heat treatments.Aluminium and its alloys lose part of their strength at elevated temperatures The composition of aluminium alloy is given as:

Table 1. Composition of Aluminium A390-T5 [8].

Component	Percent of weight
Al	74.4-79.6
Cu	4-5
Fe	Max 1.3
Mg	0.45-0.65
Mn	Max 0.1
Si	16-18
Others	--

DUCTILE IRON 65-45-12

Ductile iron 65-45-12 is a high silicon ductile iron intended for use at high temperatures or
when a part is subjected to thermal cycling.

Table 2. Composition of ductile iron 65-45-12 in percentage of weight of each element

Element	Percentage
Carbon	3.45 – 3.75
Silicon	3.25 – 4.00
Manganese	0.15 – 0.35
Sulphur	0.025
Phosphorus	0.05

It is important to calculate the piston temperature distribution in order to control the thermal stresses and deformations within acceptable levels. The temperature distribution enables us to optimize the thermal aspects of the piston design at lower cost, before the first prototype is constructed. As much as 60% of the total engine mechanical power lost is generated by piston ring assembly. The piston skirt surface slides on the cylinder bore. A lubricant film fills the clearance between the surfaces. The small values of the clearance increase the frictional losses and the high values increase the secondary motion of the piston. Most of the Internal Combustion (IC) engine pistons are made of an aluminum alloy which has a thermal expansion coefficient, 80% higher than the cylinder bore material made of cast iron. This leads to some differences between running and the design clearances. Therefore, analysis of the piston thermal behavior is extremely crucial in designing more efficient engine

Finite element modelling was done and the results are plotted as

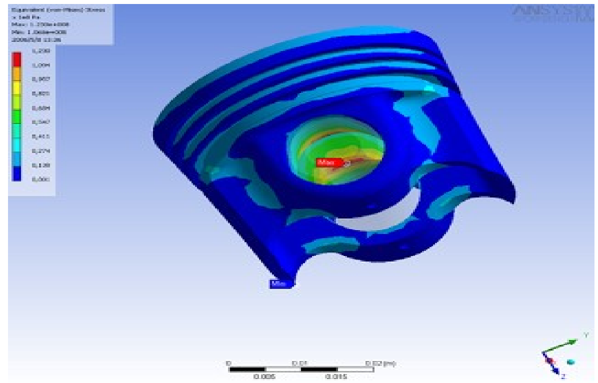

Fig 1. Stress distribution for Aluminium A390-T5 piston (hot piston condition).

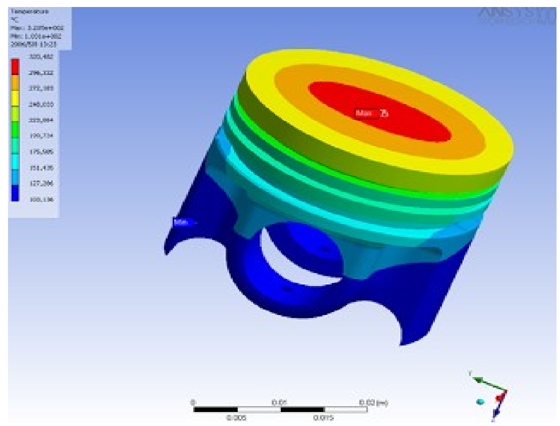

Fig 2. Temperature distribution for Ductile Iron 65-45-12 (hot piston condition).

IV.RESULTS AND DISCUSSION

COLD PISTON AND HOT PISTON CONDITIONS

The first two types of conditions considered when analyzing the piston were:

1. Mechanical load only (cold piston), i.e ., the piston is subjected to an uniform temperature distribution;
2. Thermal and mechanical loads (hot pist on), i.e., the piston is subjected to a unifor

m gas pressure and a non-uniform temperature distribution.
These two loading conditions represent two extreme engine working conditions for the piston. The cold piston represents the running condition when the engine load suddenly changes from idle condition to maximum engine rotation speed (5000 rpm) at WOT. The hot piston represents the steady-state condition when the engine isrunning at maximum engine rotation speed (5000 rpm) at WOT.

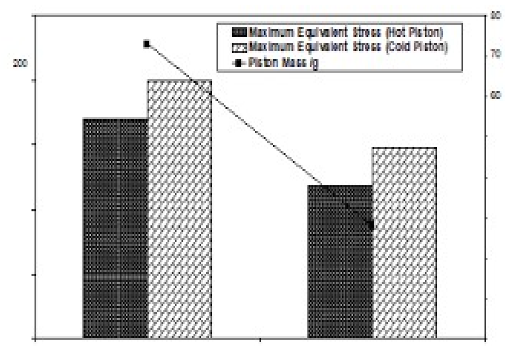

Fig.3 Comparative analysis of maximum equivalent stress (von Mises) and piston mass for Ductile Iron 65-45-12 and Aluminium A390-T5 pistons under two extreme loading conditions.

In both situations the maximum stress is located on the piston boss surface (inner side). The highest value of equivalent stress is verified for the piston made of ductile iron 65-45-12 and under application of mechanical loads only or cold piston condition. In both materials we verified a reduction of the maximum stress when we also apply thermal loads (hot piston condition). These results show the importance ofthe heating the engine before working at high loads to reduce the stress levels in the piston and improve thetribological behaviour of the piston bearings because the maximum stresses are located in a sliding region.

V.CONCLUSION

In this Paper we address is to compare two different materials for the engine piston: Aluminum alloy A390-T5 and Ductile Iron 65-45-12 using a Finite Element Analysis (FEA) and thus choose the best suited material. Despite low thermal expansion, thermal conductivity and high mechanical strength of Ductile Iron 65-45-12, its high density causes high inertial forces on the engine. Although the Aluminums Alloy A390-T5 has a larger thermal expansion, a larger thermal conductivity and a lower mechanical strength at high temperature than ductile iron, due to its lower density it was possible to design a piston meeting all the design requirements and weighting about 66 % less than Ductile Iron piston design.

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