About Structural and Thermal Analysis of Diesel Engine Piston Using Ansys Software

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Abstract. The main role of the piston is to vary the dimensions of the combustion chamber in internal combustion engine. The piston is in contact with the hot gases resulting from combustion. In addition to thermal stresses, depending on the operating mode of the engine, the piston is required to alternate the inertial force. Therefore, the steel piston undergoes due to high inertial forces, and lightweight aluminium pistons cannot operate at high temperatures. In order to combine the advantages of the two types of materials it has been chosen the constructive design of the bimetal pistons. This paper aims to compare the performances of steel pistons and bimetal pistons using the Ansys software.

1. Introduction

The piston is an important component of the internal combustion engines. It has the role to shut off the combustion chamber and to convert the energy of the burned gases into mechanical work. Also, the piston creates a variable space in the combustion chamber contributing to gas exchange. Using the connecting rod - crank shaft mechanism, the translation movement of the piston is converted to rotation movement. The piston is subjected to cyclical actions of the pressure resulted from the burned gases and the inertial forces. The intensity of the cycles depends on engine parameters (rotation/min and load). The design of the piston crown depends on by the engine type (two stroke or four stroke engine) and the fuel (gas, compressed natural gas, and diesel).

The electronic computer unit of the engine can process a large number of sensors. The manufacturers of turbo-charged diesel motor started to use more sensors. These are temperature, pressure and actuator position sensors in order to obtain an accurate control of the engine. To avoid reaching a high temperature on the piston crown that causes melt or damage, engine manufacturers have installed exhaust gas temperature (EGT) sensor. When the temperature increases to the threshold of 800°C, the electronic computer unit reduces the value of the fuel injected by limiting the maxim power of the vehicle. The sensor can spot malfunction in engine operation when the injectors do not work properly and doses more fuel, preventing accidental melting of the piston.

Diesel engines working at high pressures and high exhaust gas temperatures up to 1200°C use bimetal piston. The piston crown is made of high strength forged steel, and skirt is made of aluminium alloys [1]. Thus, it can be made a piston with high temperature resistance and a less total weight than a piston made by steel or cast. Therefore, lower inertial forces allow a better operation of the engine at higher speed.
2. Materials for pistons

The most commonly used materials for manufacturing the pistons are: Aluminium alloys and Steel Cast.

The engine type and the type of fuel used allows the material to be classified according to the maximum temperature of the piston crown, such as [2]:

- Aluminium alloys for spark ignition engine with the maximum temperature of the piston crown of 280°C;
- Aluminium alloys for compression ignition engine with the maximum temperature of the piston crown of 350°C;
- Cast for compression ignition engine with the maximum temperature of the piston crown of 450°C.

3. The main size of the piston

Following the size of the piston has been released the data presented in Table 1 [2, 3, 4].

| Parameter                   | Value     |
|-----------------------------|-----------|
| $L_p$ – piston length       | 68.8 mm   |
| $L_m$ – skirt length        | 45.5 mm   |
| $H_r$ – Ring belt height    | 45.8 mm   |
| $h$ – crown piston to the top compression ring | 10 mm |
| $h_c$ – distance between the ring groove | 2.5 mm |
| $\delta$ – head rib        | 12.5 mm   |

![Figure 1. Drawing of piston.](image)

4. 3D modelling of the piston

The 3D modelling of the piston has been made using Autodesk Inventor after creating the theoretical size. In the following figure it can be seen a 3D steel piston.
The second 3D model presented in figure 3 is a bimetal piston. It is composed of two parts. The piston crown is made by steel and the skirt is made by aluminium alloy. This model has the advantage of using the steel high resistance and light weight of aluminium alloy.

The general properties of 3D models can be seen in figure 4 a) and b). It can be seen that the steel piston assembly and the wrist pin has a total weight of 1418 grams, while the bimetal piston assembly has a total weight of 1119 grams. Also, the inertial moments of bimetal piston are lower than the steel piston.
5. Structural and Thermal Analysis

5.1 Meshing
The static analysis is performed using Ansys software. For generating the mesh, it was used uniform network [5, 6] with the minimal surface of 0.02 mm. In the case of the steel piston and wrist pin, shown in figure 5, the model has been meshed in 149 180 elements by 241 492 nodes. In the second case, the assembly of the bimetal piston has been meshed in 155 048 elements by 253 912 nodes.

![Meshing of piston.](image)

**Figure 5.** Meshing of piston.

5.2 Constrain
In this study, the pressure of gases has been applied on the piston crown surface having a maximum value of 19 MPa. This value results after thermal calculation of the engine. Also, the wrist pin has been considered fixed element. The second simulation uses the same constrain.

![Constrains of piston.](image)

**Figure 6.** Constrains of piston.
5.3 Static Structural
The static structural analysis has been performed in Static Structural Module of Ansys Software. The maximum stress recorded for steel piston is 302 MPa. It can be seen the maximum stress is recorded between the head rib and the piston pin boss reinforcement area.

For bimetal piston it has been recorded a higher von-Misses stress of 358 MPa. This value is also recorded between the head rib and the piston pin boss reinforcement area.

5.4 Thermal Study
In terms of thermal study [7], it has been considered the temperature of the combustion chamber in the piston crown area of 450°C, in both situations. It can be observed the temperatures of piston skirts are different due to different materials. Since the thermal conductivities are different, the temperature of aluminium alloy skirt is 30°C higher than steel skirt temperature.
6. Conclusions
Creating a piston by two different mechanical assembled materials increases the complexity of its design as well the complexity of manufacturing. According to the static structural analysis, it is necessary to consider the design of the piston pin boss reinforcement to reduce the stress concentrators. Also, the bimetal piston weight, for the analysed piston, is lower by 299 grams, resulting lower inertial forces. Due to lower thermal conductivity coefficient of the steel, it can be used lower tolerance at the piston crown, resulting a much higher efficiency at cool start of the engine. Since the bimetal pistons have only the piston crown made of steel, it can be saved high-quality steel consumption.

References
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