FINITE ELEMENT ANALYSIS OF PISTON HEAD USING CAD

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Abstract

The motive of undertaking this project of structural analysis of piston head is to study and evaluate the performance in real working conditions of the piston in internal combustion engine. In this paper, the work is carried out to measure the stress distribution on the top surface of the piston made up of aluminium alloy. In IC engine piston experiences uneven temperature distribution and from piston head to skirt. The analysis predicts that due to stress generated the top surface of the piston may be damage or break during the operating conditions, since the damaged or broken parts are so expensive to replace and generally are not easily available, the 3D model of piston is created using Creo. 3D model is imported to the Abaqus and FEA is performed. By identifying the true design features, the extended service life and long term stability is assured.

Keywords: Structural analysis, piston head, FEM, CAD

1 Introduction

Engine pistons are one of the most complex components of an automobile system. The engine can be called the heart of a vehicle and the piston may be considered the most important part of an engine. Damage mechanisms of the piston have different origins and are mainly wear, temperature, and fatigue related. The fatigue related piston damages play a dominant role mainly due to thermal and mechanical fatigue, either at room or at high temperature. This paper describes the stress distribution and deformation on piston of internal combustion engine by using FEA. The paper describes the FEA technique to predict the higher stress and critical region on the component. With using Creo software the structural model of a piston will be developed. Furthermore, the FEA is performed with using software Abaqus. By applying boundary conditions stress distribution and deformation in piston is calculated. The objectives of the research are :

1. To develop 3-dimentional using finite element model of piston.
2. To investigate and analyze the stress distribution and deformation of upper piston.
3. To study the mechanical impact loading on the piston for deformation.
4. The thermal and mechanical stresses distribution in piston ring is studied.

2 Literatur Review

2.1 Engine Parts

The essential parts of automobile engine are as follows: cylinder block, cylinder head, crankcase, piston, piston rings, piston pin, connecting rod, crank shaft, fly wheel, valves and mechanism.

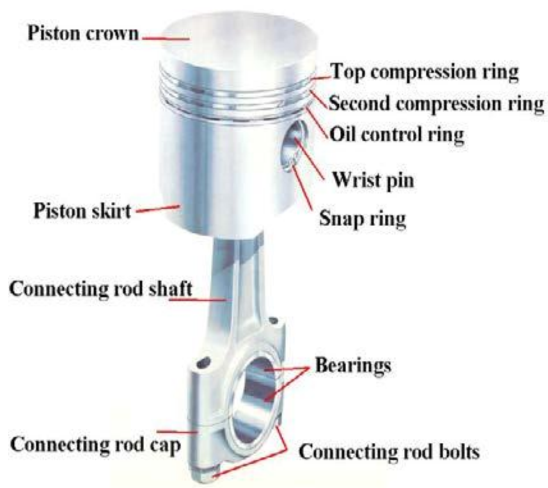

Figure 1 part of piston

2.2 Piston

Piston is considered to be one of the most important parts in a reciprocating engine in which it helps to convert the chemical energy obtained by the combustion of fuel into useful mechanical power. The purpose of the piston is to provide a means of conveying the expansion of the gasses to the crankshaft, via the connecting rod, without loss of gas from above or oil from below. Piston is essentially cylindrical plug that moves up and down in the cylinder. It is equipped with piston rings to provide a good seal between the cylindrical wall and piston. Although the piston appears to be a simple part, it is actually quite complex from the design point of view. The efficiency and economy of the engine primarily depends on the working of piston. It must operate in the cylinder with minimum of friction and should be able to withstand the high explosive force and temperature developed in the cylinder. The piston should be as strong as possible, however its weight should be minimized as for as possible in order to reduce the inertia due to its reciprocating mass.

The top of the piston is called head ring, grooves are located at the top circumference portion of the piston. Portion below the ring grooves is called skirt. The portion of the piston that separates the grooves is called the lands. Some pistons have a groove in the top land called a heat dam which reduces heat transferred to the rings. The piston bosses are those reinforced section of the piston designed to hold the piston pin.

2.3 Functions of Piston

To receive the thrust force generated by explosion of the gas in the cylinder and transmits it to the connecting rod. To reciprocate in the cylinder as a gas tight plug causing suction, compression, expansion and exhaust stroke. To form a guide and bearing to the small end of the connecting rod and to take the side thrust due to the obliquity of the rod.

2.4 Design Considerations for a Piston

In designing a piston for an engine, the following points should be taken into consideration :

1. It should have enormous strength to withstand the high pressure.
2. It should have minimum weight to withstand the inertia forces.
3. It should provide sufficient bearing area to prevent undue wear.
4. It should have high speed reciprocation without noise.

5. It should be of sufficient rigid construction to withstand thermal and mechanical distortions.
6. It should have sufficient support for the piston pin.

3 Methodology

Finite element analysis is one of the most popular mechanical engineering applications offered by existing cad/cam systems. FEA tool is the mathematical idealization of real system. With the use of computer based technique it breaks geometry into elements and links a series of equations to each and solves the equations simultaneously to evaluate the behaviour of the entire system. It is used in situations where geometry, loading and material properties are complicated and exact analytical solution is difficult to obtain. Most often used for structural, thermal, fluid analysis, but widely applicable for other type of analysis and simulation.

3.1 Piston Materials

The material used for pistons is mainly aluminium alloy. Aluminium pistons can be either cast or forged. Cast iron is also used for pistons. In early years cast iron was almost universal material for pistons because it possesses excellent wearing qualities, coefficient of expansion and general suitability in manufacture. But due to the reduction of weight in reciprocating parts, the use of aluminium for piston was essential. To obtain equal strength a greater thickness of metal is necessary. But some of the advantage of the light metal is lost. Aluminium is inferior to cast iron in strength and wearing qualities, and its greater coefficient of expansion necessitates greater clearance in the cylinder to avoid the risk of seizure. The heat conductivity of aluminium is about thrice that of cast iron and this combined with the greater thickness necessary for strength and enables aluminium alloy piston to run at much lower temperature than a cast iron one (200 °C to 250 °C as compared with 400 °C to 450 °C) as a result carbonized oil doesn’t form on the underside of the piston, and the crank case therefore keeps cleaner. This cool running property of aluminium is now recognized as being quite as valuable as its lightness. Indeed; pistons are sometimes made thicker than necessary for strength in order to give improved cooling.

3.2 Geometric Modeling

First of all a 3D model of piston was created with the help of modeling software Creo. 3D modeling of piston can also be done on Pro-E or CATIA. After creating 3D model of piston the model is imported to Abaqus and analysis is performed.

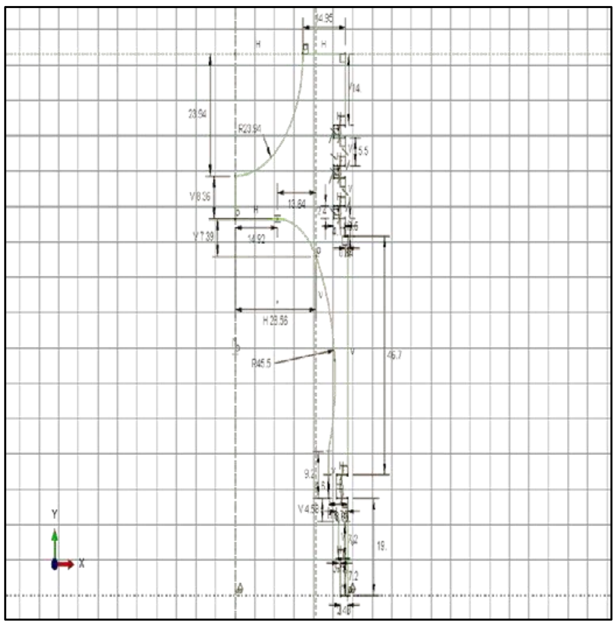

Figure 2 2-D sketch of piston

3.3 Generation of Finite Element Mesh

The finite element mesh is generated for the piston by using standard command in the three dimensional form by using hexahedral elements, tetrahedral and pentamesh and then the meshed component is tested for quality of mesh.

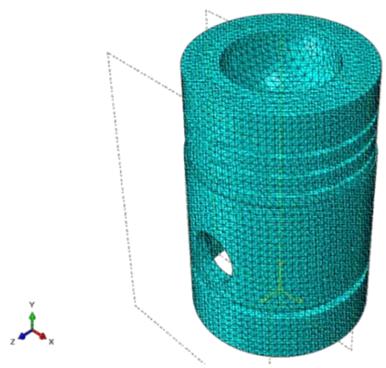

Figure 3 Piston mesh

3.4 Boundary Conditions

Figure 4 shows the loading and boundary conditions considered for the analysis. The uniform pressure of 18.00 Mpa is applied on crown.

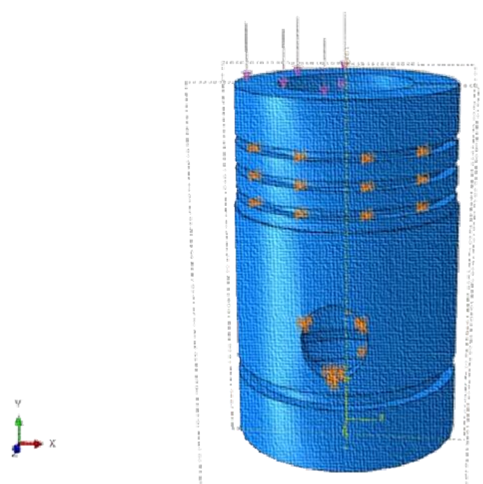

Figure 4 Boundary conditions applied on 3- D model of piston

4 Results and Discussion

From the finite element analysis, the various stress and deformation values have been found out corresponding to the gas pressure taken from the actual engine readings.

4.1 Von Misses Stresses

Figure 5(a) and 5(b) shows the distribution of Von misses stresses induced within the piston body in the real working conditions. The maximum von misses stress acting on piston in real working condition was found to be 7.444×10^{1} N/mm^2 and 9.66110^{-1} N/mm^2 as minimum.

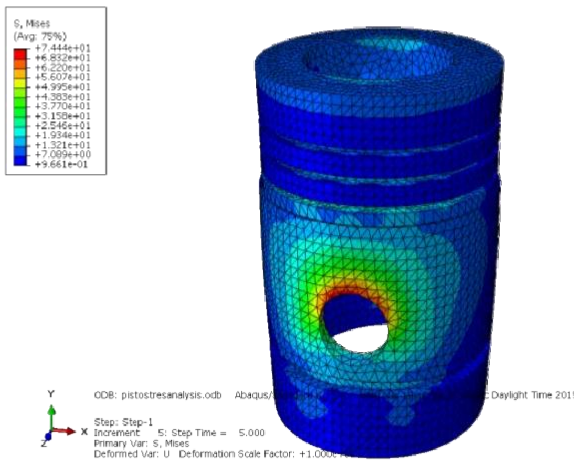

Figure 5 Von Misses Stress acting on piston

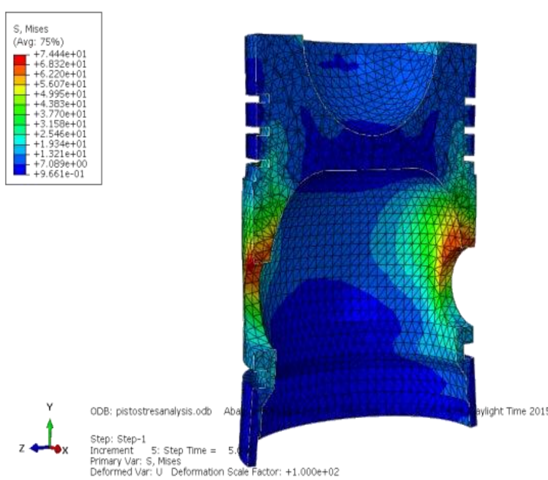

Figure 6 Cut section of piston acted upon by von-misses stress

4.2 Deformation in The Piston Body

Figure 6 shows deformation of piston body due to mechanical and thermal stress generated during real working conditions of the internal combustion engine. Maximum deformation occurs in the red coloured area. Minimum deformation occurs in the dark blue coloured area.

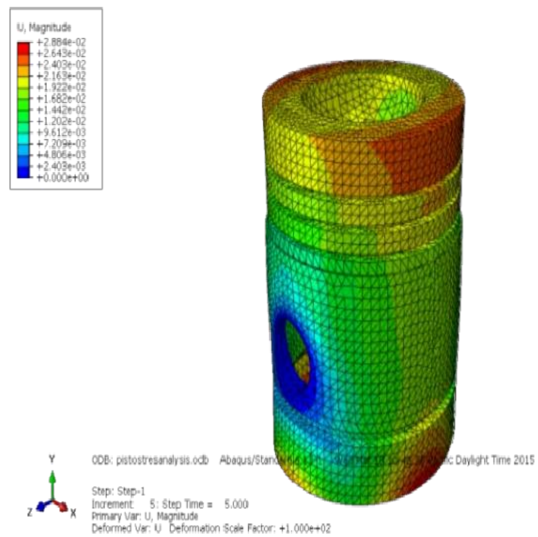

Figure 7 Deformation of piston due to stresses generated during real working condition

5 Conclusion

The structural analysis of the piston made up of aluminium alloy for the stresses and gas pressure on the piston for different position of the piston in the cylinder moving between TDC to BDC have been studied and the following conclusions are made. The piston experiences maximum stress in the region where the combustion of the fuel takes place, i.e., at the piston head and skirt. This high stress region in the piston deforms more than the other region of the piston. The deformation in the piston causes it to displace more in this region and this cycle repeats even for the reduction in combustion pressure. It is observed that although fatigue is not the responsible for biggest slice of damaged pistons, but the stresses induced are the major factor for piston failure. Also from analysis various results are obtained like the maximum values of equivalent stresses goes up to 7.444×10 N/mm^2 due to the application of 18 MPa gas pressure on crown of piston. Thus, we can coclude that piston of alumunium alloy is suitable to use and can with stand in real working conditions and can bear the thermal and mechanical stresses generated.

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