# Design Analysis of Piston using Finite Element Analysis – A Review

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*Abstract*— Piston in the internal combustion (IC) engine is robust in construction that reciprocates continuously at varying temperature. Study has been made by various researchers on piston design, structural, dynamics, fatigue and wears at the interface with other element in contact along with their effects on IC engines. It was found that the friction coefficient increases with increasing surface roughness of liner surface and thermal performance of the piston increases with increased coating thickness. The free material liberated due to deep scoring between the piston and liner snowballs, leads to seizure failure.

***Key words:*** Creo/ Pro 5.0, ANSYS Workbench

## I. INTRODUCTION

Piston is one of the most important components in internal combustion engine which reciprocates within the cylinder. The main function of the piston is to transfer force from gas in the cylinder to the crank shaft through connecting rod.

It is very important to calculate temperature distribution on the piston in order to control thermal stresses and deformation in working condition, Piston produces stresses and deformation due to periodic load effects which produces from high gas pressure, high speed reciprocating motion of inertia force. Lateral force by the chemical reaction of burning the gas high pressure generates which make the piston expand which generates thermal stresses and thermal deformation. The thermal and mechanical deformation causes piston cracks. Therefore it is very essential to analyze the stress distribution, temperature distribution, heat transfer, mechanical load in order to minimize the stress at different load on piston.

### *A. Piston*

Piston is one of the most important components in I.C. engine which reciprocates within the cylinder. The main function of the piston of an internal combustion engine is to transfer force from expanding gas in the cylinder to the crank shaft through connecting rod.

Following are the main parts of piston:

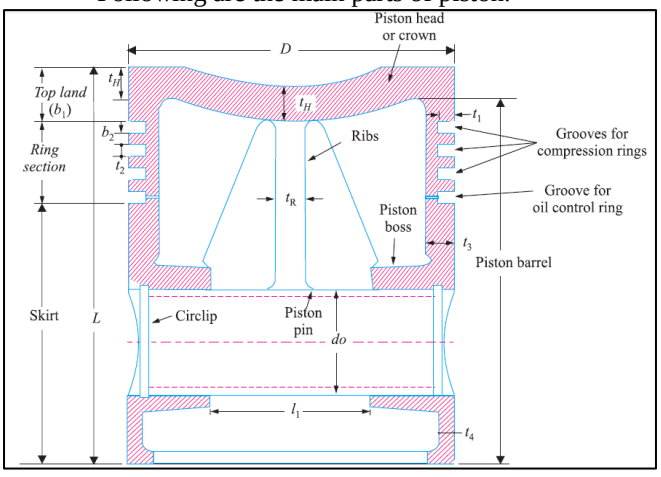


Fig. 1: Piston Components for I.C. engine

1) Piston Head or crown: It is flat, convex or concave depending on design of combustion chamber. It withstands pressure of gas in the cylinder.
2) Piston rings: It is used to seal the cylinder in order to prevent leakage of gas past the piston.
3) Skirt: It act as bearing for the side thrust of connecting rod on the walls of cylinder.
4) Piston pin: It is also called gudgeon pin or wrist pin. It is used to connect the piston to the connecting rod.

## II. LITERATURE REVIEW

Jan Filipczyk et.al.[1] had done case studies of piston damages and possibilities of early detection. Damages of car engine pistons are one of the most expensive failures which causes the possibilities of engine repair. This work is concerned with causes of piston damages and possibilities of early detections. Damaged piston of petrol and diesel engines in passenger and light duty cars have been analyzed. The causes of engine faults with piston damages can be classified as follows: those ones due to normal wear during operation, maintenance errors, damages of lubrication and cooling systems, faults of injection and timing systems, manufacturing defects. A high percentage of faulty engines with low mileage shows that early diagnosis of damages is extremely important. The faults of electronic control system, ignition timing and engine management malfunction may be the reason of a complete destruction of the engine. The commonly used methods of diagnosis may not be sufficient to detect certain types of failures. It is important to kip in mind that a lot of piston damages can be caused by many different types of faults. Therefore, finding the cause of piston damages can be sometimes extremely difficult. For example, the piston with a damage caused by improper quality of fuel might look like the piston in the engine, which was working at incorrect injection timing. The development of diagnostic methods of engines is much slower than the progress in the area of new engine construction.

Gantla Shashidhar Reddy et.al.[2] had done Modeling and analysis of diesel engine piston. In this Paper, it has been decided to study a particular piston design and its capability for various above said loads. In this work, initially planning to make a piston model using solid modeling software Pro-E. It has been decided to mesh the geometry and analyze using commercially available software tool ANSYS. For the analysis input conditions and process of analysis, lot of literature survey has been done. Initially, thermal analysis of the piston will be carried out to predict the temperature distribution of the piston. For thermal analysis of piston, basic necessary thermal boundary conditions like bulk gas temperatures and heat transfer coefficients have been obtained from literature survey. Temperature of the piston due to its working in high combustion environment will itself act as thermal load causing stress to the component. High combustion gas

 

pressures will act as a mechanical loads and cause major stresses in the critical features of the piston. Once after thermal analysis of the piston, for judging the critical features of the piston geometry, a detailed structural analysis will be carried out for various loading conditions like thermal load and mechanical load. After assessing the piston for various loads, it has been decided to calculate the factor of safety for the piston using Soderberg's criterion.

Vivek Zolekar et. al.[3] had done Finite Element Analysis and Optimization of I.C. Engine Piston Using RADIOSS and OptiStruct. In this paper, the wok is carried out to measure the stress and temperature distribution on the top surface of the piston. In I.C. Engine piston is most complex and important part therefore for smooth running of vehicle piston should be in proper working condition. Pistons fail mainly due to mechanical stresses and thermal stresses. Analysis of piston is done with boundary conditions, which includes pressure on piston head during working condition and uneven temperature distribution from piston head to skirt. The analysis predicts that due to temperature whether the top surface of the piston may be damaged or broken during the operating conditions, because damaged or broken parts are so expensive to replace and generally are not easily available. The CAD model is created using CATIA V5 tool. CAD model is imported into the HyperMesh for geometry cleaning and meshing purpose. The FEA is performed by using RADIOSS. The topology optimization of the model is done using OptiStruct module of HyperWorks software. He concluded that, for further development work, RADIOSS can be used efficiently to study Fluid Structure Interaction (FSI) Analysis i.e. coupled field analysis of same problem. After topology optimization of piston we are planning to do the Shape optimization for further improvement.

Ashwani Kumar et.al.[4] had performed Thermo-Mechanical and Vibration Analysis of the I.C. Engine Piston made of SiC reinforced ZrB2 composite using Finite Element Method (ANSYS). The main objective of this research work is to investigate and analyze the stress distribution of piston at actual engine condition. The parameter used for the simulation is operating gas pressure and material properties of piston. To evaluate the material properties of piston the maximum principal stress, minimum principal stress and von mises stresses were calculated. These stresses were calculated for three different materials by comparing we found out that SiC reinforced ZrB2 composite material provides less stress concentration and more stability at higher temperature. For stability checking at higher temperature thermal analysis were carried out. This research work suggests a new type of SiC reinforced ZrB2 composite material that can sustain at higher temperature (1680 K) and pressure (18 MPa). The structure of piston was modeled by using SOLIDEDGE software. Finite element modeling and analysis were performed using ANSYS 14. The natural frequency and Vibration mode of the piston were obtained and its vibration characteristics are analyzed. The free vibration analysis show that the natural frequency of vibration varies from 1.28e-5 Hz to 274.44 Hz. After the analysis, he was observed that vibration and the stresses induced are the two major factors for piston failure. The results of this study show that the stresses which are produced during the operations for SiC reinforced ZrB2 material are less than the design stress. Also the distribution of the temperature is in prescribed limit.

Lokesh Singh et.al.[5] discussed about the Finite Element Analysis of piston in ANSYS, In this paper the material for the piston is aluminum-silicon composites. The high temperature at piston head, due to direct contact with gas, thermal boundary conditions is applied and for maximum pressure mechanical boundary conditions are applied. After all these analysis all values obtained by the analysis is less than permissible value so the design is safe under applied loading condition.

Dr. B. Sudheer Prem Kumar et.al.[6]. had done Thermal analyses were investigated by S. Srikanth Reddy, they found that thermal analyses are investigated on a conventional (uncoated) diesel piston, made of aluminum silicon alloy for design 1 and design 2 parameters. Secondly, thermal analysis is performed on piston, coated with Zirconium material by means of using a commercial code, namely ANSYS. The effects of coating on the thermal behaviors of the pistons are investigated. The finite element analysis is performed by using computer aided design software. The main objective is to investigate and analyze the thermal stress distribution of piston at the real engine condition during combustion process.

## III. SUMMARY

Research is to be carried out to select material with less weight and higher strength, so as to reduce the inertia forces. The stress distribution on the piston mainly depends on the deformation of piston. Therefore, in order to reduce the stress concentration. The piston crown should have enough stiffness to reduce the deformation. Optimization technique gives flexibility to the designer to choose the concept as per requirement. Piston skirt may appear deformation at work, which usually causes crack on the upper end of the piston head. Due to the deformation, the greatest stress concentration is caused on the upper end of the piston, the situation becomes more serious when the stiffness of the piston is not enough. In all these researches structural and thermal analysis is to be carried out. In analysis of thermal stresses damages due to application of pressure is presented and analyzed in this work. In all these analysis comparative performance is made. Most of the piston made of aluminum alloy which has thermal expansion coefficient 80% higher than the cylinder bore material made of cast-iron. It is observed that vibration and the stresses induced are two major factors for piston failure.

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