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"A Review on Static structural behaviour of Piston"

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Abstract— Generally the piston, made of Al Alloy, is a crucial part of internal combustion engines. When the combustion of fuel takes place in heavy internal combustion engine cylinder, high temperature and pressure develops. Because of high speed and at high loads, the piston is subjected to high thermal and structural stresses. If these stresses exceed the designed values, failure of piston may take place. Various researches have been carried out to improve the working conditions of pistons inside the engine. Most of the materials have been introduced to build the piston for providing high strength in the running conditions.

Various experimental, numerical and analytical studies have been carried out to study the behavior of IC engine Piston. In this research paper various researches were studied to find the scope for the further improvement of piston.

Keywords- Piston, Carbon materials, Finite element analysis.

I. INTRODUCTION

Piston as one of the most important parts of the engine, the working conditions are harsh, because it is exposed to the influence of the thermal load in the work process. Being the most critical part of the engine, the working conditions of the piston greatly affect the life and performance of the engine, so it is particularly important to carry out the thermal and structural analysis of engine piston. In this review, it introduces the basic theory of stress and deformation analysis, by structural analysis of piston, in which the various deforming force of the piston will be calculated with the finite element analysis software. Comparing the result of analysis of the piston at several key points with calculated and repeatedly modifying the boundary condition. This analysis could be helpful for design engineer to make changes while designing the piston. This project will determines various stress calculation by using structural analysis, also finding out the various zones or region where chances of breaking of piston is possible. By performing the static structural analysis using analytical software's it has become very simple to analyze the design of piston. The major demand of piston design is to calculate the force and

pressure circulation on the piston which is used to analyze in making of piston at less cost. Mainly pistons are manufactured with aluminum alloy which has great thermal expansion coefficient, 80% larger than the cylinder bore material considered by cast iron. This leads to some differences between running and the design clearance. Therefore investigation of the piston performance is extremely essential in designing more competent compressor. Proper fitting of piston within the cylinder is primary rule in design of piston, also develops the mechanical efficiency and decreases the inertia force. In high speed machinery the weight of the piston also acts as a major role. The diameter of the piston should be less than that of cylinder diameter. The essential clearance is considered by optimized temperature variation between piston and cylinder by considering the coefficient of thermal expansion in piston. A piston is a cylindrical element of metal that reciprocates inside the cylinder which applies a force on a fluid within the cylinder. Pistons have outer rings which prevents the oil leak in to the combustion chamber and the fuel and air out of the oil. Most pistons in a cylinder have piston rings. Generally there are two spring compression rings that perform as a seal between the piston and the cylinder wall, and one or more oil control rings below the compression rings. The upper surface of the piston can be flat, bulged or other shaped. Pistons can be design by forged or cast process. The profile of the piston is normally rounded but can be different. Figure 1 shows the design of piston engine. The piston is a main element of any engine.

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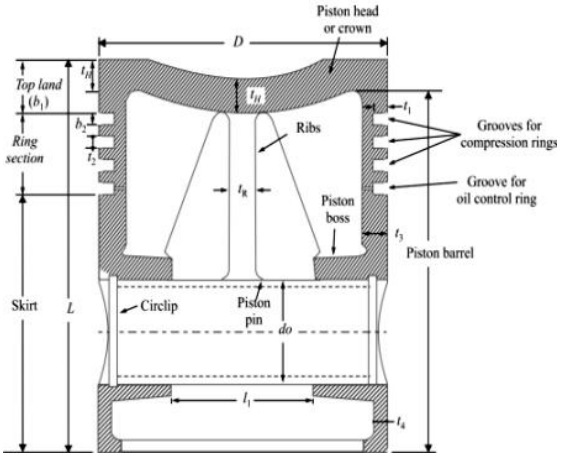

Fig 1-Piston Parts

A. Components of a Piston

The main components of the piston are as follows:

- Piston Crown- which carries gas pressure
- Skirt-which acts as a bearing against the side thrust of Connecting rod
- Piston Pin- Piston pins are used to connect the piston to the connecting rod. These pins are made from hardened steel alloy and have a finely polished surface. Most piston pins are hollow, to reduce weight
- Piston Rings- which seal the annular space between the cylinder wall and piston and scrap off the surplus oil on the cylinder.

B. Characteristics of a Piston

- Strength to resist gas pressure.
- Must have minimum weight.
- Must be able to reciprocate with minimum noise.
- Must have sufficient bearing area to prevent wear.
- Must seal the gas from the top and oil from the bottom.
- Must disperse the heat generated during combustion.
- Must have good resistance to distortion under heavy forces and heavy temperature.

II. LITRETURE REVIEW

(Balahari Krishnan S, 2017) researched that in piston endures the cyclic gas pressure and the inertial forces at work, and this working condition may cause the fatigue damage of piston such as piston side wear, piston head cracks and so on. One of the design criteria is the endeavor to reduce the structural weight and thus to reduce fuel consumption. This has been made possible by improved engine design. These improvements include increased use of lightweight materials, such as advanced ultrahigh tensile strength steels, aluminium and magnesium alloys, polymers, and carbon-fiber reinforced composite materials. Here the life of the piston is improved by means of introducing a new composite matrix of aluminum with particulates of silicon carbide which has the maximum wear factor and which has the same performance except a little bit variation in properties called Al 6061 alloy in reinforcement with Silicon carbide. The piston is designed and analyzed through aluminum and silicon carbide in the ratio 2:3. A parametric model of a piston is done in 3D modeling software Autodesk Inventor. Further, it is analyzed for its deformation characteristics through ANSYS Workbench software.

(Jatender Datta ,. D., 2017) researched describes the stress distribution, displacement and Strain of aluminum alloy 2618, Aluminum Alloy 4032 and carbon graphite pistons by using finite element Analysis (FEA) .The parameters used for the simulation are operating gas temperature and material properties of pistons. The specifications used for the study of these pistons belong to four stroke 100cc hero bike engine. This paper illustrates the procedure for analytical design of aluminum alloy 4032, aluminum alloy 2618 and carbon graphite pistons using specifications of four stroke 100cc hero bike engine. The results predict the maximum stress and critical region on all of these pistons using FEA. It is important to locate the critical area of concentrated stress for appropriate modifications. The CAD model of the pistons was drawn by using Solidworks (Feature module) and Simulation module was used to mesh the pistons, Static analysis with temperature applied on the top of piston head.

(A. Kesavan, 2017) described engines pistons are very important parts to produce power. Piston fails mainly due to mechanical stresses and thermal stresses. An analysis of thermal stress and damages due to application of temperature is presented and analysed in this work. Aluminium alloy have been selected for thermal analysis of piston. Results are shown and a comparison is made to find the most suited design Analysis of piston crown is done with boundary conditions, which includes pressure on piston head during working condition and uneven temperature distribution from piston head to skirt. There are four types of piston crown that has been analysed in this project. The CAD model is created using CATIA software. CAD model is then imported into ANSYS software for geometry and meshing purpose. Complete design is imported to ANSYS 15 software then analysis is performed.

(Jatender Datta, 2017) showed the behavior of piston made of Carbon Graphite and Aluminum Alloy 2618 applied heat power value of 200 Watt. The result of Temperature distribution and resultant temperature gradient was found and the main motive is to find the comparison between both of materials of piston. An example of 100 cc hero bike piston was taken and drawn a 3D model in the Solidworks software after taken the dimensions using different measuring instruments and the model was meshed and analyzed using solidworks simulation software.

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(Sushanth, 2015) implement that Piston is considered as one of the most important parts in the reciprocating engines. In which, It helps to convert the indicated power gained upon burning the charge possess chemical energy into useful mechanical power. The purpose of the piston is to provide a means of conveying the expansion of the gases to the crankshaft via the connecting rod, without loss of gas. Piston is essentially a cylindrical plug that moves up and down in the cylinder. It is equipped with piston rings to provide a good seal between the cylinder wall and piston. Although the piston appears to be a simple part, it is actually quite complex from the design standpoint.

(AbhishekV.Vyawahare, 2015) implemented that the pistons are made of Al Alloy, and is a crucial part of internal combustion engines. When the combustion of fuel takes place in heavy diesel engine cylinder, high temperature and pressure develops. Because of high speed and at high loads, the piston is subjected to high thermal and structural stresses. If these stresses exceed the designed values, failure of piston may take place. The software "Pro-E Wildfire" is used to establish the three dimensional geometry model of the diesel engine piston. Then, the model is imported into ANSYS to set up a finite element model. In this work thermal stresses on piston is calculated by finite element analysis software. From results, it reveals that thermal stresses are existed on the piston and total deformation with thermal load. The conclusion of this study is that, material type of high thermal conductivity is considered better than material type of low thermal conductivity, because the maximum temperature is found in Carbon- Steel piston than Aluminum -Alloy piston. This means that the Aluminum- Alloy is considered better than the Carbon-Steel. And also due to increase in thermal Conductivity, leads to reduction in temperature at piston crown surface and increase in temperature of piston skirt

(Naik, 2012) studied that Internal combustion engine consists of many parts where Piston acts as a heart of IC engine, which works on high temperature. Beside this, it works under periodic heat load. The thermal-stress analyses are investigated on a diesel engine piston made of Aluminium-Alloy and Carbon-Steel.

The conclusion of this study is that, material type of high thermal conductivity is considered better than material type of low thermal conductivity, because the maximum temperature is found in Carbon-Steel piston than Aluminium-Alloy piston. This means that the Aluminium-Alloy is considered better than the Carbon-Steel. And also due to increase in thermal conductivity, leads to reduction in temperature at piston crown surface and increase in temperature of piston skirt.

III. OBJECTIVE

1. Increase the performance of Piston without affecting the cost of piston.
2. Increase and enhancement of engine performance to effect the overall working of an automobile.
3. Use of an light weight high lubricating material to improve the life of piston inside the internal combustion engine. By introducing the new suitable materials for manufacturing pistons, it can give better results and performances with maintained cost.
4. Improvement in reliability, efficiency of engine and performance after changing the material of piston will be the expected outcome.

IV. EXPECTED METHODOLOGY

The technique to be applied for the design of piston is as follows:

- Data gathering of recent development in IC engine piston.
- Reverse engineering the considered piston, and calculation of dimensions for producing a 3-D model in CATIA software, and further analyzing in ANSYS Simulation environment.
- Selection of Material from Standard Parameters
- Meshing of Piston.
- Applying Boundary conditions.
- Result calculation.
- Comparing the results of structural analysis study.

A. Modeling

Modeling generally refers to a process in design which employs mathematical representation of model for 3D Surface of a model. There are various tools used for the modeling purpose in design industry, CATIA V5 R20 which is one of them is used for the modeling Pistons in this research work.

B. Finite Element Analysis

The finite element analysis is a numerical method for solving problems of engineering. It is traditionally a branch of Solid Mechanics. Most common areas of interest are Heat Transfer, Structural Analysis, and Mass Transport. For the designed Pistons it is a must to compare the performance of both pistons and for this purpose ANSYS 14.5 is used as FEA tool. ANSYS 14.5 is software used for solving a number of mathematical problems.

Finite Element method divides the structure into a number of finite elements and these elements are bridged with the help of nodes. The elements are chosen after study of the response and geometry of analyzed component. The results which are obtained by post analysis procedure depend on the mesh size. ANSYS Workbench provides potent, practical applications which simplifies the process of mesh, to Decrease the design cycle time, reduces the number of prototype production and testing, thus helps providing an optimum design.

The Process of Analysis is divided in following steps;

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1. Pre-Processing
2. Solver
3. Post-Processing

V. EXPECTED OUTCOME

1. The weight and cost optimization of internal combustion engine with respect to previously studied material.
2. This review study deals with the most efficient material in low market price. Stress analysis will be performed with the help of FEA technique on each section of the piston.
3. Selection of appropriate material for piston. Piston is very important part of engine. These are affected by overall performance of vehicle so it is very important to choose right type of material in piston.
4. Selection of most suitable material for piston which will be abundantly available in the market with the characteristics of good thermal properties.

VI. COUNCLUSION

After going through literature review of various authors it can be concluded that, Al–Si based alloys have been widely used in automotive piston and other thermal applications because of good mechanical and thermal properties, lightweight structures, environmental and other attractive properties. But to manufacturing the automotive piston the basic Al-Si alloys are unbeneficial and may not fulfill the basic requirements of piston. And produced various unwanted stresses in components during the manufacturing. By controlling the exhaust gas temperature, catalytic converter life span can be improved. The heat transfer in exhaust arrangement directly influences the functions and the discharge characteristics of the internal combustion engine. For improvement in the performance of an engine, it is necessary to control the temperature in automotive exhaust system. To calculate the force impact to the engine piston crown it is concluded that spatial and time averaged combustion in side boundary situation is a most favorable and suitable treatment technique inside engineering approximations. From the above literature it is concluded that there is a scope for the implementation of new material to improve the working of existing piston and a further study can be carried out in this direction.

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