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A SURVEY APPROACH OF OPTIMUM DESIGN OF PISTON

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ABSTRACT

The piston is one of the main components of an internal combustion engine. The objective of this study to find suitable materials for the piston head to give more performance as compare to traditional materials. It is concluded that at some literatures the piston is required to optimum parameter like its geometric volume by regulating stresses, temperature and pressure arrived in piston and the objective of the study to apply coating of materials in piton assembly. In this study to improve the thermal performance of the piston different Thermal Barrier Coatings (TBC) have been imposed and their thermo mechanical performance have been evaluated through software tool. Many data have been generated regarding different dimensions of coatings with different material properties. These data may be used in further research to optimize material property and dimensions of Thermal Barrier Coating.

KEYWORDS: Piston, Stress, TBC, Thermo-mechanical analysis, Optimization.

I. INTRODUCTION

An engine is a device which transforms one form of energy into another form. Most of the engines convert thermal energy into mechanical work and therefore they are called Heat engines. The heat engine can be an internal or external combustion engine.

An internal combustion engine (IC engine) is an engine in which the combustion of fuel, such as petrol or diesel, takes place inside the engine cylinder. In petrol engine, air and petrol is mixed in correct proportion in the carburettor and then passed into the cylinder. The mixture is ignited by means of a spark production by the spark plug. Since the ignition is done by spark, the petrol engine is called Spark Ignition engine (SI engine). In the diesel engine, the air entrapped in the cylinder during the suction stroke is highly compressed during compression stroke. This compression increases the air temperature beyond the self-ignition temperature of diesel. The desired quantity of diesel in the form of fine spray is then admitted into the cylinder near the end of the compression stroke. The turbulent hot air ignites the diesel. Since the ignition is done by compression of air, the diesel engine is called Compression Ignition engine (CI engine).Compared with petrol engines, the diesel engines are more economical due to high thermal efficiency.[1]

In an external combustion engine, on the other hand, the fuel is burnt outside the engine For example, in a steam engine or a steam turbine, the heat generated due to the combustion of fuel is employed to generate high pressure steam which is used as the working fluid in a reciprocating engine or a turbine [2]

II. REVIEW OF PREVIOUS WORKS

A work on optimization of a piston has been done by Ch. Venkata Rajam et al in the year of 2013 [5]. They have considered a piston from a practical example which has been considered in the present work as a base model. Many work has been done on the design optimization with bare pistons as well as pistons with thermal barrier coating in recent years. Ajay Ray Singh et al. [6] described the stress distribution and thermal stresses of three different aluminium alloy pistons by using finite element method in the year of 2014.

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Shuoguo Zhao [7] presented a structural analysis of the piston in 2012. He analyzed the piston by Pro-E software to improve and optimize the structure of the piston.

Aditya Kumar Gupta et al. [8] analyzed the piston, which were consists of two steps. They were Designing and Analysis.

S. Srikanth Reddy et al. [9] in 2013 investigated the thermal analyses on a conventional (uncoated) diesel piston.

In 2012 Yaochen Xu et al. [10] analyzed a piston by ANASYS software to get the deformation, thermal and stress distribution of the piston.

S. Bhattacharya et al. [11] worked on a piston of a two-stroke spark ignition internal combustion engine which had maximum power of 6.5 kW at 5500 RPM. They were Designing and Analysis. They used Aluminium 4032 alloy as the piston material.

Dr. L.N. Wankhade et al. [12] measured the stress and temperature distribution on the top surface of a piston. The structural model of the piston would be developed using CATIA V5 software. Then they imported the CAD model into the Hyper Mesh for geometry cleaning and meshing purpose.

Amit B. Solankiet al. [13] described design analysis and optimization of hybrid Piston for 4 stroke single cylinder 10 HP (7.35 kW) diesel Engine. They used high strength cast steel for piston crown and light alloy like aluminium alloy for piston wall. Using FEM they investigated the stress distribution of piston and analyzed the actual engine condition during combustion process. To avoid the failure of the piston, the stresses due to combustion were considered.

SasiKiran Prabhala et al. [14] replaced the steel components with aluminium components to reduce the weight. The strength of aluminium components was not enough compared to steel components. Therefore, they were taking the aluminium alloy because the aluminium alloy exhibits the strength like the steel.

Deovrat Vibhandik et al. [15] compared the behavior of the combustion engine pistons which were made of different type of materials under thermal load. Geometrical model of the piston was developed by CAD software. The model was based on the actual engine piston of TATA MOTORS four stroke diesel engine.

Vaishali R. Nimbarteet al. [16] investigated and analyzed the stress distribution of piston at actual engine condition. In their paper, pressure analysis, thermal analysis and thermo-mechanical analysis of the piston was performed. For analyzed the piston they used operating gas pressure, temperature and material properties of piston as parameter. Piston was analyzed using boundary conditions, which includes pressure on piston head during working condition and temperature distribution from piston head to skirt. K

Venkateswara Raoet al. [17] designed a 5B.H. P diesel engine piston. They modeled the piston using Pro-E software. They used Cast Aluminum, Aluminum MMC and Brass as piston material. Structural analysis was done on the piston by applying the pressure to determine the strength of the piston using 3 materials. Thermal analysis was done to find out the temperature distributions, heat transfer rate of the piston.
Vinod Yadavet al. [18] illustrated design procedure for a piston for 4 stroke petrol engines for Hero bike. They analyzed by the comparison with original piston dimensions which was used in bike. They considered the combined effect of mechanical and thermal load while determining various dimensions of the piston.

Kethavath Vishalet al [19] worked with the design and analysis of piston. Here the piston design, analysis and the manufacturing processes were studied. Purpose of the investigation was the measurement of piston transient temperature at various points on the piston, from cold start to steady condition and comparison with the results of finite element analysis.

Dilip Kumar Sonar et al [20] designed a piston using CATIA V5R20 software. Complete design was imported to ANSYS 14.5 software and analyzed. Aluminium alloy was selected for structural and thermal analysis of piston.

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Hitesh Pandey et al [21] studied the pressure due to expanding combustion gases in the combustion chamber space at the top of the cylinder which generate thermal stresses due to presence of heat involved on the reciprocating masses. They worked with the use of different materials for IC engine piston and a comparative study was made to achieve the best possible result.

A. R. Bhagat et al. [22] described the stress distribution of piston for four stroke engines. The main objectives were to investigate and analyze the thermal stress distribution of piston at the real engine condition during combustion process. Using finite element analysis technique, they presented the mesh optimization to get the higher stress and critical region on the piston.

P. Carvalheira et al. [23] compared two different materials for the engine piston. One of the materials was Aluminium Alloy A390-T5 and another was Ductile Iron 65-45-12. They compared the two materials with the help of Finite Element Analysis (FEA) and chose the best suited material for piston. To predict the thermal and mechanical stresses on the piston, a number of FEA were done and thus they optimized the piston shape.

Muhammet Cerit [24]described temperature and stress distributions in a partial ceramic coated spark ignition (SI) engine piston. He investigated the effects of coating thickness and width on temperature and stress distribution and made a comparison with results from an uncoated piston. He observed the coating surface temperature increase with increasing the thickness in a decreasing rate. With 0.4 mm coating thickness surface temperature of the piston was increased up to 82 °C.

M. Cerit et al. [25] investigated the effect of partially thermal barrier coating on piston temperature distribution and cold start HC emissions of a spark ignition (SI) engine numerically and experimentally. They performed thermal analysis for both standard and coated pistons by using ANSYS. They used a single cylinder, water cooled SI engine for both standard and coated cases. The result of their analysis shown that the surface temperature of the coated piston part was increased up to 100◦C, which leads to an increase in air fuel mixture temperature in the crevice and wall quenching region. Thus, cold start HC emissions considerably decrease compared to the standard engine without any degradation in engine performance. Maximum decrease in HC emissions was 43.2% compared to the standard engine.

III. CONCLUSION

Study of literatures it is observed that the piston shows early indication of failure, and by checking the engine properly it can detect these types of failure. Hence the proper checking of piston of engine and piston for failure is necessary. The piston undergoes stress, temperature, pressure changes frequently and thermal and mechanical fatigue occurs. Hence the analysis and some modification are required to detect this failure and shutout the problem. It is concluded that at above mentions literatures the piston is required to optimum parameter like its geometric volume by regulating stresses, temperature and pressure arrived in piston and the objective of the study to apply coating of materials in piton assembly.

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