Ajay Shrivas, 11:1
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

Design Optimisation and Structural Analysis Of Piston

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Abstract- Piston upper end experiences the most stress, so stress concentration is one of the leading reasons of fatigue failure. FEA is frequently then used characterise the stress distribution on an internal combustion engine's piston. FEA is performed with the help of CAD and CAE software. Its major goals are to explore and analyse the thermal and mechanical stress distribution of the piston throughout the combustion process in such an actual engine. The paper also explains how to use FEA to estimate the component's greater stress and critical area. The structural model of a piston is created utilizing CATIA software. Simulation and stress analysis were carried out using the ANSYS V14.5 programme.

Keywords- Design, optimisation, structural analysis, piston

I. INTRODUCTION

A piston seems to be a component of an engine. It is also the moving component housed within a cylinder & sealed using piston rings. A piston rod or connecting rod transfers force from expanding gas there in cylinder towards the crankshaft inside of an engine. As either a key component in an engine, the piston was subjected to cyclic gas pressure and inertial stresses during work, which can result in fatigue damage towards the piston, including such piston skirt wear, piston head or crown fractures, and so on.

The largest stress develops on the upper end of a piston, according to the research, and stress concentration has been one of the primary causes of fatigue failure. A piston overheating seizure, on the other hand, can only happen if anything burns or scrapes off the oil coating that lies between the piston and the cylinder wall. With it in mind, it's easy see why oils with extraordinarily high film strengths are so coveted. Good grade oils can produce a film which can withstand the most extreme heat and pressure loads encountered in today's high-output engines. Thermal analysis is a discipline of materials science that studies how materials' characteristics vary when temperature changes. For thermal analysis, the finite element technique (FEM) is often utilised. On just one hand, the piston's finite element method (FEM) grew more hard due to the complex working environment; but at the other hand, the piston's finite element method (FEM) have become more difficult to such sophisticated working environment, On either hand, despite the fact that various approaches for applying optimum design have indeed been proposed, determining the ideal parameters is difficult.

Due to the general rising utilisation vehicles, automobile components seem to be in high demand these days. "The growing demand is attributable towards the components' greater performance and lower cost. To reduce the time it takes to release new goods, R&D and testing engineers must build crucial components as quickly as feasible. It needs a thorough grasp of emerging technology as well as rapid incorporation into product development. In reciprocating IC engines, a piston seems to be a component.

That's also the moving part of a cylinder that's sealed by piston rings. With such an engine, the objective of a piston rod and/or connecting rod seems to be to transfer force from the expanding pressurized gas towards the crankshaft.The piston, as both a critical component of such an engine, were exposed to cyclic gas pressure or inertial pressures whereas at operation, which could also cause piston fatigue damage such as piston side wear, piston head/crown fractures.

2.PAST STUDIES

Subbaiah(2021) investigated Internal combustion engines (IC engines) were widely used nowadays across the world. Due to stringent pollution regulations, most engineers have already been looking towards improved engine architectures that emit the least amount of pollutants. A most essential design issues for the diesel-fueled CI engine are soot and NOx emissions. A right mixing of air and fuel content improves the performance of a combustion engine.The most common method for improving air–fuel mixing within a chamber cylinder is to modify the piston bowl shape.

Subramani(2021) The pressure and knocking phenomena were investigated. The butterworth bandpass filter was utilised to obtain the pressure readings, and the potential for knocking were determined utilizing peak-to-peak pressure values as well as the species concentration. One approach utilised to reduce the incidence of knocking inside the engine is cooled exhaust gas recirculation. Furthermore, the effects of premixed methanol and engine start-up (SOI) on knocking was investigated.

Viswanathan (2021) The Hyperloop seems to be a high-speed land transportation idea that involves passengers moving in pods at transonic speeds inside a partly evacuated tube. It comprises of a low-pressure tube that travels the length with capsules moving at both low & fast speeds. When a high-speed system travels through with a low-pressure tube with such a limited diameter, like the Hyperloop does, it becomes an aerodynamically difficult challenge. The "piston effect" occurs when airflow becomes clogged in confined areas surrounding the pod, resulting in a high-pressure zone just at pod's front.

There are very few papers that look at possible solutions for the piston effect. The aerodynamic performance of the a Hyperloop pod within a vacuum tube is investigated in this research utilising the Reynolds-Average Navier–Stokes (RANS) approach for three-dimensional computer analysis. Aerofoil-shaped fins also are added towards the aeroshell as both a possible technique to reduce the piston impact. These results reveal that adding fins to the pod reduces drag and eddy currents while also producing a positive lift.

Yadav(2021)done the largest stress acted here on upper region of both the piston, according to experimental research, and stress concentration also is the major cause of fatigue failure. The article explains how to increase the piston's ability to withstand significant structural and thermal loads while also reducing stress concentration in the piston's upper part.In same operating environment, an aluminium alloy piston can indeed be replaced with a carbon-carbon piston with minimal thermal stress. The thermal study of carbon-carbon composite material on a commercial vehicle diesel engine piston was investigated in this research, as well as the findings are compared to those of an aluminium alloy piston for maximum stress.

Zeng(2021) The impact of squish on the piston bowl in such a single cylinder 4 S compression ignition engine fed by jojoba biodiesel on performance, emission, and combustion parameters seems to be the subject of this study. To optimise performance, emission, or combustion characteristics, the squish area as well as its related velocity were adjusted via modifying the piston bowl cross-section without affecting the piston bowl volume. For the typical piston, CFD (Computational Fluid Dynamics) is used to investigate the velocity or squish impacts. The results were compared with those obtained with a modified piston inside the piston combustion chamber that has an octagonal bowl shape. Specific fuel consumption, brake thermal efficiency, and brake pressure vs. crank angle and heat release rate are one of the performance and emission aspects investigated.

III. RESEARCH METHODOLOGY

Since of combustion, the piston becomes subjected to high gas pressure and high temperature throughout operation. At the very same time, this is supported either by connecting rod's tiny end, which would be held in place with piston pins (Gudgeon pin). As both a result, the approach for assessing the piston was just as follows; The gas pressure of 20 MPa is delivered evenly throughout the top surface of the piston (crown), arresting all degrees of freedom for nodes inside the upper half of a piston pin boss, where the piston pin will be fixed. Only the upper part of the piston pin boss is done at this stage throughout the study since the kind of fit between piston pin & piston involves clearance fit.

It really is extremely difficult to exactly model the piston, and research is currently ongoing to determine the piston's transient thermal elastic behaviour throughout the combustion process. To represent a complicated geometry, some assumptions are always required. Those assumptions be developed with the challenges of theoretical calculation into mind, as well as the relevance of the parameters that are used and those who are neglected. They always neglect the elements and are less important but have a minor influence on the analysis while modelling. Assumptions always are made based on the level of information and precision necessary in modelling. The following are the assumptions that were used when modelling the process: -

1. The piston material is homogenous and isotropic in nature.
2. During in the analysis, both impacts of inertia and body force become minimal.
3. The piston is free of tension before the study is performed.
4. Because the analysis is focused solely on thermal loading, the stress level determined by the above is insufficient to establish the piston's life.
5. Only ambient air cooling is considered; no forced convection is used.
6. The material employed for such analysis has a consistent thermal conductivity throughout.
7. The material's specific heat remains constant throughout and therefore is unaffected by temperature.

The first stage in Taguchi optimization is to have the right objectives to optimise (minimized or maximized). A piston, and one of the most critical heated elements of an internal combustion engine, moves at quite a high speed for such a long period under significant thermal and mechanical loads. That stress created by all these loads has an impact on its service life, which would be directly tied to the internal combustion engine's dependability and durability[1–3]. The flow field, temperature field, structure, as well as other disciplines all have a role in overall design of both the piston, but each discipline seems to have a strong interaction. Currently, the approach of individually analysing the thermal stress or mechanical stress, and mastering the stresses and deflections from each, is used in the computation and analysis of both the piston, so that the entire piston's optimization & design may be completed The output parameters include piston mass, maximum temperature, maximum mechanical stress, and maximum thermo-mechanical coupling stress.

Two geometric characteristics of both the piston, namely the height of top land and crown thickness, were investigated in this study as control elements. In Table 1, the levels of every component were listed. These values are chosen consistently within the logical ranges of control parameters provided by (Zhaoju et al. 2019) and (Zhaoju et al. 2019). (Tamrakar et. al. 2014). It really should be emphasised that the Taguchi approach could only improve a piston's design parameter through discretely picking the best value for each control factor.Nevertheless, because of its cheap time cost and increased robustness, the Taguchi approach is essential & desirable for creating and optimising design parameters of pistons roughly in the first phase. The Taguchi method's discrete optimization creates the groundwork for more precise and specialised optimizations to be carried out repeatedly all around optimal values in order to enhance overall optimization outcome.

Table 1: Levels of each factor

Parameters/Factors		Level		
		1	2	3
A	Height of top land	7.2	8.0	8.8
B	Crown thickness	4	7	10

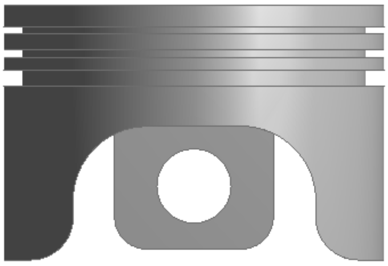

Fig. 1: Piston Model

IV. RESULTS AND DISCUSSION

With ANSYS Workbench, deformation data should be shown as total deformation or directed deformation. They're used both to calculate displacements via stresses. It offers the square root of both the sum of squared of the x, y, and z directions in complete deformation.

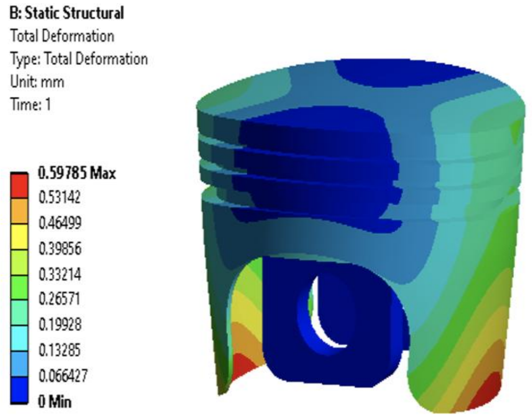

Fig.1: Field distribution of Total deformation

1.Equivalent Stress

Equivalent stress is included in the maximum equivalent stress failure hypothesis, which will be used to foresee yielding in ductile materials. The Von Mises stress seems to be a metric for determining whether a material may yield or fracture. It's most typically applied to ductile materials like as metals. A von Mises yield criteria states that such a fracture occurs when the von Mises stress under load equals equal to or greater than just the yield limit with much the same material in simple tension, which would be easy to test experimentally.

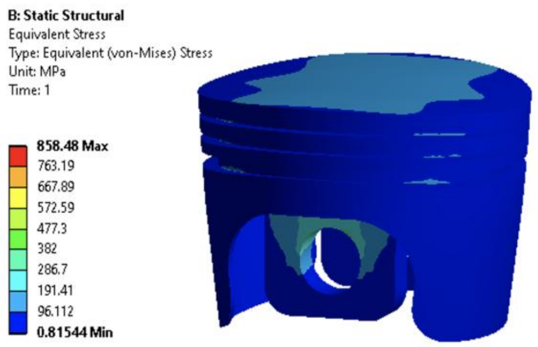

Fig. 2: Stress distribution of equivalent stress.

V. CONCLUSION

The following findings may be drawn from the current research:-

1. The optimal combination for SNR-total deformation is determined as Height of top land = 7.2 mm and Crown thickness= 7 mm.
2. The optimal combination for SNR-Equivalent stress is determined as Height of top land = 8 mm and Crown thickness= 4 mm.
3. The optimal combination for SNR-Piston mass is determined as Height of top land = 8.8 mm and Crown thickness= 10 mm.
4. The optimal combination for SNR-First ring groove temperature is determined as Height of top land = 8.8 mm and Crown thickness= 7 mm.

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