Optimization of the Heat Structure of the Internal Components the Engine Component

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ABSTRACT

This work's main goal is to examine how the thicknesses of the piston boss and piston crown affect the stresses placed on the piston. In the current study, a 150-cc piston of the "Hero" type, constructed of A4031 aluminum, was taken into consideration. Heats from the combustion process and gas pressure were applied to the piston head in a double-action. It was thought that the piston pin bore served as a cylindrical support. The simulation process utilizing the thermal structural coupling technique was conducted using ANSYS 15. A range of piston boss and piston crown thicknesses were chosen and examined. The piston's Von-Mises stress, mass, and temperature distribution all influenced the comparison and optimization procedures. The results unequivocally demonstrated that the ideal piston design was 3 mm piston crown and 2 mm piston boss thicknesses, based on the stress levels measured for various piston diameters. The ideal piston design raised the piston's internal temperature while decreasing overall stress and mass.

1. INTRODUCTION

Engine performance improvement has been the focus of a large number of automobile engineering research projects over the past few decades. Furthermore, scientists and engineers are being challenged to create a new class of lightweight engines that are more efficient and less polluting due to the evident link between carbon dioxide emissions from engines and global warming, which is having a significant impact on the entire planet. Numerous strategies could be used to accomplish this goal, but optimization is seen to be the most effective. This approach provides a comprehensive overview of the issue and aids in selecting the best option from the available options. Several optimization procedures are used to each engine component separately in order to improve engine performance. The piston is one of the most important components that directly affects engine efficiency. However, optimization is typically a costly procedure that necessitates a lot of material and multiple experimental investigations. Thankfully, non-destructive methods were created to satisfy the demands of research such as these.

2. LITERATURE REVIEW

A careful review of the literature reveals a large number of research that concentrate on internal combustion engines (IC engines) and piston simulations. A finite element analysis (FEA) of two engine pistons composed of ductile iron 64-44-11 and aluminum cast alloy A390 was presented by P. Carvalheira1 and P. Gonçalves [1] in 2006. This work was done as part of a project to develop an IC engine that uses less fuel in the new XC20i car. Its primary goal was to recommend two different materials for the piston and determine which was superior. To increase the design's dependability and safety, a thorough examination of the initial design parameters was carried out following the material selection [1]. Using PROE and ANSYS, M. SreeDivya and K. Raja Gopal [2] worked on the piston's design and material optimization. Their primary goal was to increase efficiency while reducing bulk. By decreasing its weight, they came to the conclusion that "a silumin piston's optimized design can be used to reduce the material cost and to optimize the engine efficiency." Because of its superior physical qualities, Silumin (AL-Si alloy) was chosen as the optimum material for the piston based on the earlier conclusion [2]. Ajay Raj Singh and Pushpendra Sharma carried out a thermal stress analysis in addition to the earlier work, examining three different aluminum alloys for a piston used in a hero motorcycle's four-stroke single-cylinder engine [3]. By lowering the piston mass, which minimizes its inertia forces, the Hero piston analysis discovered a novel way to improve engine performance. The thickness of the piston head, piston barrel, and skirt length were all taken into account when examining the piston shape's dimensions.Another investigation of the distribution of thermal stress on the piston during combustion was carried out by A. R. Bhagat, Y. M. Jibhakate, and Kedar Chimote [4]. To reduce the concentration of stress in the top piston, they provided a detailed optimization for the piston head and the piston skirt sleeve. The findings demonstrated that a stress concentration in the piston crown causes a deformation in the piston skirt, which in turn causes a crack on the upper end of the piston crown because of its reduced rigidity. We suggest a modified piston design in this study that uses the aluminum alloy A4032 for the hero 150 cc engine. Hardness, yield strength, and elongation to failure were all satisfactory with this design [5]. Thus, the goal of this study is to use thermal structural analysis to analyze the design and determine the ideal piston boss and piston crown thickness dimensions that can provide superior resistance to stresses and temperature.

3. GEOMETRY AND MODELING

The piston's initial drawing [2] was intricate and necessitated much meshing research. Thus, SolidWorks created a schematic of the piston's typical shape (Figs. 1) for the purpose of simplifying analysis and meshing, and the drawing was then utilized for the Thermal-Structural analysis.

Figure 1. 3D model of Hero 150 cc used in the study

The majority of pistons are composed of cast iron, cast aluminum, and forged aluminum because of their fundamental mechanical and thermal characteristics. The basic characteristics that are typically taken into account when choosing an IC engine piston material are the coefficient of thermal expansion, thermal conductivity, mechanical strength, density, and wear resistance, as shown in Table I. Since aluminum A4032 is frequently utilized in the production of pistons, it was used in this investigation.

Table I: Properties

Parameters	**Aluminum alloy A4032**
Elastic modulus(GPa)	79
Ultimate tensile strength (MPa)	380
0.2% yield strength (MPa)	315
Poisson's ratio	0.33
Thermal conductivity (W/mK̊)	154
Coefficient of the real expansion (1/K)	79.0×10^{-6}
Density(kg/m^3)	2684

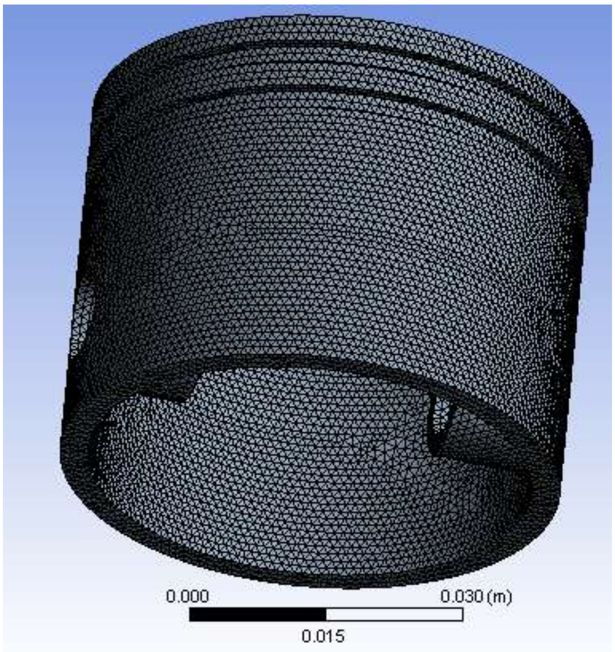

Figure 2. 3D Mesh of the model

4. RESULT

The thermal-structural analysis of the 150 cc Hero piston by ANSYS demonstrated the effect of the variation of the thicknesses of the boss and crown of the piston on stress, mass, temperature, and deformation. To begin with, a piston model with the crown thickness and boss thickness of 4 mm and 3 mm, respectively, were analyzed. By gradual thinning, it was observed that reducing the piston crown to 3 mm resulted in a stress drop of Von-Mises from 296.82 MPa to 282.87 MPa, or a 5% reduction. Continuing to reduce to a crown thickness of 2 mm resulted in an 8% reduction in stress; however, this was achieved at the expense of raised piston temperatures, increasing from 267.71°C to 303.63°C. In the same way, mass reduced by 6% and 12% for 3 mm and 2 mm crowns, respectively, while deformation was kept within tolerable limits.

For the piston boss, minimizing its thickness from 3 mm to 2 mm also resulted in a stepwise decrease in stress and mass. Von-Mises stress was decreased from 282.87 MPa to 267 MPa, while mass was minimized by about 4%. Yet, concerns over wear resistance and structural integrity ensured that the boss thickness may not be less than 2 mm. The ultimate optimized design with 3 mm crown and 2 mm boss thickness resulted in overall stress reduction of about 10% and mass reduction of 9%, though at a small increment in operating temperature by 4.4%. These findings indicate the thermal and structural optimization trade-offs and validate the proposed dimensions' feasibility for enhanced performance without compromising safety.

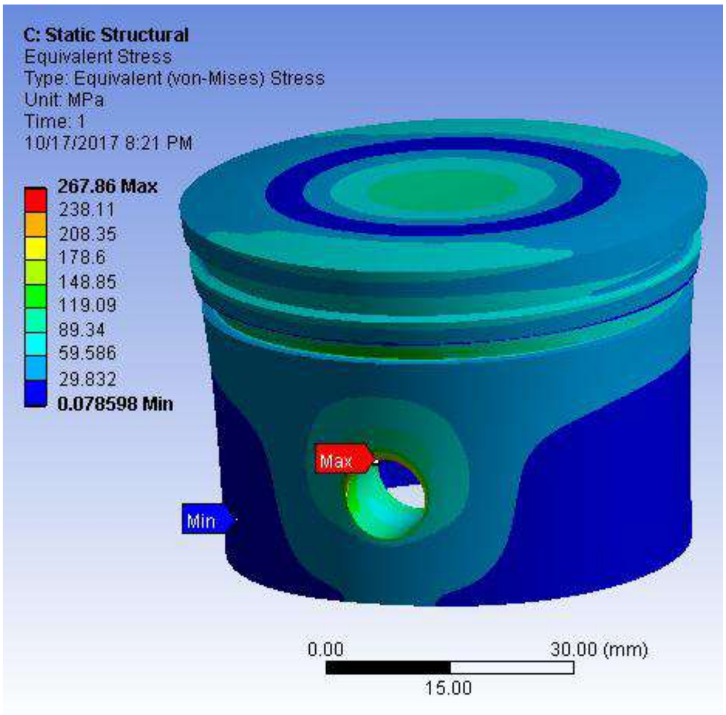

Figure 3. Von-Mises stress on the piston

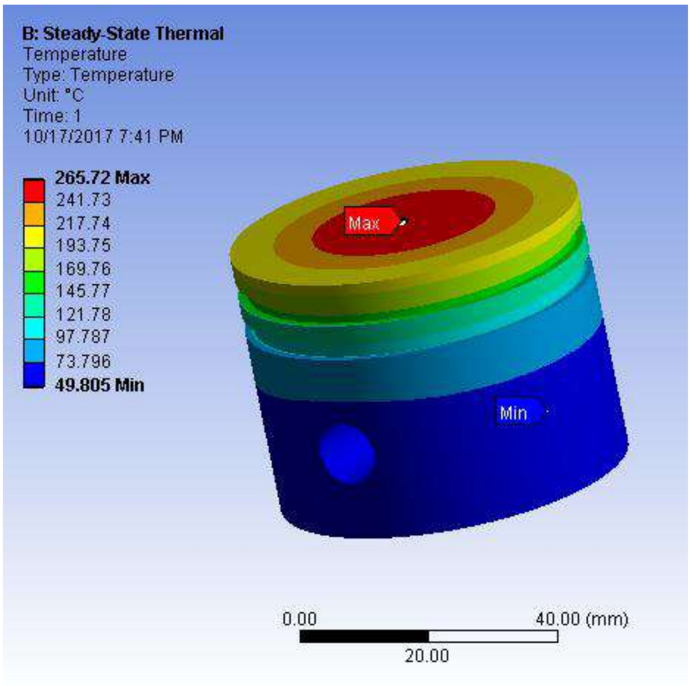

Figure 4. Temperature distribution

TABLE II. RESULTS OF DIFFERENT PISTON BOSS THICKNESS

Piston boss thickness (mm)	3	2.5	2
Von-Mises (MPa)	282.87	277.59	267
Mass(g)	74.704	73.24	71.94
Change in stress%	-	2%	6%
Change in mass%	-	2%	4%

Safety factor	1.11	1.13	1.18
Deformation(mm)	0.13564	0.13569	0.13562

5. CONCLUSION

Thinning of piston boss and piston crown thickness increases the thermal diffusivity and reduces bulk and tensions. Safety factors must be considered when designing the piston boss to avoid wear failure. It was found that the best piston design, which used a 3 mm piston crown and 2 mm piston boss thickness, reduced mass by 9% and overall stress by 10%, but increased the internal piston temperature by 4.4%. Time and funds may be preserved by optimizing processes in the right way through the use of non-destructive testing techniques, including simulation software, which will give the same outcome as destructive testing.

6. REFERENCE

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