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Review of Design, Thermal & Structural Analysis of Piston Using Finite Element Analysis Method

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ABSTRACT

This research discusses the findings of a prior literature review that revealed information about the inner combustion engine's parts, such as pistons. The piston converts mechanical energy into the energy of the burnt gases. Inside the cylinder liner or sleeve, the piston moves. The current project is to investigate the design of a piston petrol engine. Engineers can use computer-aided engineering software to develop products and simulate designs for residual stress, structural response, thermal impacts, pre-processing, and post-processing fatigue in the automotive industry.We can determine whether or not our intended piston is secure under actual load conditions by looking at the analysis results. Reviewing many writers in the field of thermal evaluation, the thermal flux and thermal temperature distribution are analyzed.

Keywords:heat transfer, internal combustion (IC) engines, performance, temperature field of the piston.

1.Introduction:

Cylinders, cylinders and other similar machines use pistons as a translation engine component. Piston rings keep the shifting mechanism fuel-tight even though it is housed inside a cylinder. The burned gases' energy is transported by the piston using mechanical power. Cylinder liners or sleeves are used to guide the movement of the piston. Aluminum and forged iron are the most common materials used for pistons. The purpose of this study is to examine the design of a motorcycle's piston petrol engine. Equipment for computer-aided engineering (CAD) allows engineers to create and test products, as well as evaluate the effects of fatigue on a vehicle component's structure and thermal response. Various authors in the field of thermal assessment have reviewed the thermal flux and temperature distribution in order to better understand it. This look at can be beneficial to those working in the area of steady state thermal evaluation of pistons.

FUNDAMENTAL OF PISTON

Cylindrical piece of metal, the piston, moves up and down inside the cylinder, exerting a force on the fluid inside. The rings on pistons keep the oil out of the combustion chamber and the fuel and air in the oil, respectively. Earrings can be found on most cylinder-fitting pistons. As a seal between the piston and cylinder wall, spring compression rings are commonly used, as well as one or more oil-managing rings beneath them. Piston heads are available in a variety of shapes and sizes. Cast or cast pistons are available. Although the piston's shape is typically spherical, as seen in Figure 1, it might be one of a kind. The hypereutectic piston is a unique type of solid piston. In a piston engine and in hydraulic and pneumatic systems, the piston is an essential component.

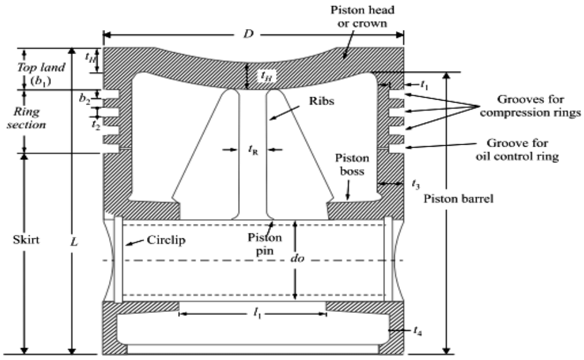

Fig. 1 Schematic diagram of piston.

2.LiteratureReview

In this section research papers are discussed relatedtothepresentwork.Publishedpapersarehighlightinthissection.

Krishnan et al. [1] Lightweight materials, such as ultra-high tensile steels, aluminium and magnesium alloys, polymers and carbon-fiber reinforced composite materials, have been investigated in detail. Aluminum with particles of silicon carbide are used to create a novel composite matrix, Al 6061 alloy in reinforcement with silicon carbide, which improves the piston's life and has the same general performance as Al 6061 alloy in reinforcement with silicon carbide. Aluminum and silicon carbide are used in a 2:3 ratio to design and analyse the piston. Autodesk Inventor is used to create a parametric version of a piston in 3-D.

S N Kurbet's [2] According to engine-parts research, the piston is the primary cause of engine-parts vibration and noise. To better understand the primary and secondary motions of engine parts and how they cause mechanical noise, the focus is on piston vibration. If a structural part is strained, it could have an impact on the engine's ability to perform. It is possible to optimise the weight of a piston so that it can perform at its best. With this review, we hope to better understand how pistons can sustain severe thermal and structural loads while also reducing stress concentrations at the piston's top end. The FEA of a standard four-stroke engine piston is proposed, and the results of the analysis are compared in order to determine the component's maximum stress. FEA is used to measure the stiffness at operating temperatures and stresses of various aluminium alloys.

F.S. Silva [3]One important conclusion that can be derived from this work is that while fatigue isn't responsible for the vast majority of broken pistons, it's still an issue with engine pistons and a solution for piston makers remains a top priority. And it's going to be a problem for a long time because of efforts to reduce fuel usage and improve power, which will lead to thinner walls and higher stress levels. It is possible to meet all of the requirements for effective piston application, including mechanical and high-temperature mechanical fatigue and thermal/thermal-mechanical fatigue, by using various concepts, such as design, materials, and manufacturing technologies.

Gopal et al. [4] examined a 4-wheeler petrol engine's piston, connecting rod, and crankshaft mechanisms. The components of the assembly should be rigid, and the meeting should function as a mechanism for transporting them. Static, dynamic, and thermal evaluation methods were used to replace the meeting's additives with new sets of compounds, according to the proposal. An FEA was performed in ANSYS on the engine piston, connecting rod, and crankshaft, which were modelled and constructed in accordance with the supplied design. In Hyper Mesh, the meshing was completed.

Shehanaz et al. [5]A piston constructed of cast aluminium alloy and titanium alloy is subjected to thermal studies. The most important goal is to determine the effect of the real engine state on the piston's thermal strain distribution during the combustion process. This study is being developed using finite element analysis in order to predict the higher pressure and the most critical area. ANASYS software is used to determine the piston's displacement, heat and pressure appropriation under the thermal loads and mechanical hundreds. We can deduce from these results that temperature transfer occurs at the piston's pinnacle factor while the piston is under thermal load, and quality pressure occurs at the piston's stick during this time.

Pandey et al. [6] used finite element analysis with ANSYS software to examine the design, evaluation, and optimization of a 4-stroke SI engine piston that is strong and lightweight. The response surface optimization module is used to optimise the piston. Piston mass decreased by 26.07 percent and its issue of safety increased by 3.072 percent as a result of the reduction in piston barrel thickness of 52 percent, the thickness of the piston crown head increased by 9.41 percent, the width of the top land increased by 3.81 percent, axial thickness of the hoop increased by 2.38 percent and radial thickness of the ring decreased by five, i.e., 31 percent.

K.Jagdeesh [7] the vibrating piston was subjected to finite element analysis in order to better understand the many properties of the piston. For each frequency and distance, acoustic pressure values are plotted along the axis of each of these two variables. Radiation impedance of the vibrating piston is also measured. A FE analysis is used to compare the experimental and theoretical values. His final conclusion is that a finite element analysis may be used to replicate the vibrating motion of a piston in water. Finding significant parameters, such as axial pressure and far-field pressure, as well as radiation impedance through calculations was critical in the naval application.

Rao et al. [8] Modeling the piston using Unigraphics, the results were confirmed by constructing a piston using aluminum-based mmc that contained 5, 10, 15, and 53 micrometre fly ash particles. Stir casting was utilised to achieve the desired shape and level of intricacy, and then the component underwent the necessary machining to provide the desired appearance. This strategy appears to improve the car's performance, according to the results. The redesigned piston model outperforms the original one in terms of performance. It was easier on the piston in the new type and it was more reliable because of the reduction in tensions. The issue is how the hardness, wear, and friction differ between the original and the modified versions, as determined by the different assessments that have been performed on it.

Vishal et al. [9] Materials for the piston's impacts were derived from an experimental examination of the engine's overall overall performance. The piston crown's lowest surface had the highest stress depth in all materials, as expected. The pinnacle of the pistons of 4032 and A2618 absorbed the greatest amount of displacement. Since the materials' thermal conductivity allowed for such a wide range of maximum temperatures to be determined, the whole maximum heat flow was absorbed by each of the piston materials. Alloys were found to have about the same level of performance. This means that additional research can be done using the new materials and various design optimization devices.

Venkata Reddy et al. [10] examined in order to improve the engine's performance. The piston needed to be investigated. Alloy steel is commonly used for pistons because of its high thermal and structural mass resistance. Stable works 2016 software was used to design the piston, while ANSYS workbench software was used to evaluate structural stress and temperature on the piston utilising a variety of materials, including composites.

Sundaram et al. [11] A 3-D CREO model was used to conduct CAE analysis, and ANSYS 14.5 was used to conduct thermal evaluations of 3 different piston materials (Al with 10%, 20% and 30% SiC) for the piston. For pistons, it seems that Aluminum with 10% SiC material is superior than Aluminum alloy material in terms of temperature distribution, resulting in Aluminum with 10% SiC material being preferable.

Attar et al. [12] ANSYS software may be used to study and assess thermal pressure mitigation, which is a critical component in the design of piston crowns or piston heads. Here, the focus is on reducing piston weight while still optimising the piston. There is a decrease in the piston's substance. The piston's performance was then improved. Cracks can also be seen at the upper end of the piston head when the piston skirt deforms. When the piston's stiffness fails, the situation becomes even more acute, and a crack often appears at the point A, which can spread slowly and could lead to the piston breaking vertically. This is because of the deformation, which causes the highest point of piston stress awareness. The deformation of the piston has a significant impact on stress distribution on the piston. As a result, the piston crown must be rigid enough to reduce the deformation, so as to reduce strain awareness.

John et al. [13] In research on aluminium silicon carbide (AlSiC), an aluminium matrix composite is used as an option for aluminium. CATIA v6 was used to create a 3-D model, while ANSYS 14 was used for structural and thermal analysis. AlSiC provides greater abrasion resistance, creep resistance, dimensional stability, reasonable stiffness-to-weight and strength-to-weight ratios, and better performance in extreme temperatures than aluminium.. The use of AlSiC in piston manufacture is likewise more straightforward than that of aluminium.

Devan et al. [14] investigated to find out how different types of piston materials conduct heat. Keeping the piston in a correct position is critical to the proper operation of an IC engine, as it is one of the most significant and complex components. Temperature failure is a common occurrence in pistons, and this is especially true when they are used in engines. Many piston materials were examined in order to achieve the desired heat distribution. In comparison to Al-Si, Al-Mg-Si, and Alloy, the average heat flux is reduced in AlSiC composite, according to the results of testing the impacts of various materials on the piston. Carbide content in AlSiC Alloy will increase as a result of a reduction in the maximum heat flow.

Sonar et al. [15] completed a thermal analysis of the piston and discovered unique mechanisms that cause the piston to suffer The maximum amount of deformation that the piston can withstand has been determined. The most significant influences affecting the piston's performance have been identified and investigated in depth. The deformation of the piston is particularly important for determining the stress distribution at the piston. As a result, the piston crown must be strong enough to reduce deformation if the stress awareness is to be decreased. Temperature has a major impact on the piston's deformation and strain, thus it's critical to shape the piston to minimise its temperature.

Singh et al. [16] CATIA and SOLIDWORKS software are used to construct a 3-Dimensional, strong version of the piston that includes the piston pin. The distribution and deformations of thermo-mechanical stresses and stresses in mechanical-thermal couplings are computed. After that, the ANSYS workbench software was used to complete the fatigue analysis for the purpose of investigating protection and life expectancy elements in the piston assembly. As a piston material, aluminum-silicon composites are commonly employed. With the strain assessment effects at work, it is possible to improve design at an early stage while simultaneously lowering the time and cost required to build a piston element. As a further result of the calculations, the maximum thermal load is 96.014 MPa, and the maximum gaseous-fuel explosive pressure (MPa) is 210.75.

Srinadh et al. [17]powerplant with a 1300cc diesel engine and used three piston rings with excellent profile. The computations were used to produce a two-dimensional graphic. Pro/Engineer software has been used to model the piston and piston jewels. During the structural evaluation, strain was used to calculate the piston and ring stress and displacement. In the thermal evaluation, temperatures measured at the piston surface were used to estimate thermal flux and temperature dispersion. Cast iron, Aluminum Alloy A360, and Zamak were used for the structural and thermal evaluation of the piston and piston rings model. The best material for the production of pistons and piston rings has been selected after a thorough evaluation of all available materials. In addition, ANSYS software was used to perform structural and thermal evaluations.

Dilip Kumar Sonar, and et.al [18] Tell me about that! Wear, temperature, and fatigue are the most common causes of damage, although other factors also play a role. Temperature-induced thermal fatigue and mechanical fatigue are two of the most common causes of fatigue damage. CATIA V5R20 software is used to design a piston in this project. To do an analysis, the design is imported into the ANSYS 14.5 programme.

Prasanth et al. [19] a piston's thermal performance was evaluated using a Hybrid steel matrix. Specimens of Al-Sic-graphite included in particle metal matrix composites are created using the stir casting method in the triumphant artwork The expansion degree of graphite is varied between 3% and 5%, while the charge of SiC remains constant, at 5%.. The composites were put through rigorous testing to determine their brinnel hardness, tensile strength, and affect electricity in accordance with industry standards. A close examination of the network's microstructure revealed a pattern of consistent appropriation. It has been shown that the hardness of the composite increases by up to 5% with an increase in graphite. The composites' tensile energy was similarly positioned to retain the distributed graphite in Al amalgam, which helped to improve the composites' tension. CATIA was used to model the piston, and ANSYS was used to do FEA on the same model for aluminium (pure) and aluminium (Al-SiC-graphite).

JasimJaber [20] addresses the possibility of using composite materials to replace the aluminium alloy. The weight of the piston can be lowered by 20-40% while still maintaining its durability thanks to the use of composite materials. Fuel consumption was successfully reduced by lowering the weight of the piston.

Conclusion

Impacts on piston strength can be seen in piston materials, which have a significant effect in engine performance. The piston crown's bottom surface shows the greatest amount of stress in both materials, which is to be expected. The top of the piston is made of aluminium alloy and grey cast iron, which absorbs the maximum amount of displacement. Due to the thermal conductivity of the piston materials, the maximum heat flux is absorbed by both piston materials, resulting in the highest maximum temperature. As a result, new materials and a variety of design and analysis tools can be used to enhance study. Concave pistons exhibit greater stresses and overall deformations than convex pistons in the designs for which analysis are performed. Concave or cup-shaped pistons in diesel-fueled, large-sized IC engines are hence justified.

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