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Thermal Analysis of Piston

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ABSTRACT: Increasing the efficiency of an internal combustion engine is very important in the present market by improving the combustion rate and 100% utilization of heat energy produced in the engine. It is very essential for us to utilize the conventional fuels very economically and reducing the portion of unburned carbon simultaneously to reduce the emissions to avoid pollution. The engine life and performance are mainly depending on the design and the materials used for their manufacturing. Piston plays a vital role in improving the performance of an engine. The use of advance coating materials in the automobile industry giving significant results in improving engine performance. In this present work a piston is designed using CATIA V5R20 software. Complete design is imported to ANSYS 14.5 software then analysis is performed. Thermal analysis of piston has been done by selecting **316 Stainless Steel, ALUMINUM ALLOY NL, TITANIUM ALLOY, TI-6AL-4V, AL 7075-T6**, as piston material by applying. An analysis of thermal stress and damages due to application of pressure is presented and analyzed in this work. The maximum and minimum heat flux distribution with different combination of piston and its coating materials was observed. Results are shown graphically and a comparison is made to find the most suited design.

KEY WORDS: Heat flux, heat transfer, temperature field of piston.

I. INTRODUCTION

Automobile components are in great demand these days because of increased use of automobiles. The increased demand is due to improved performance and reduced cost of these components. R&D and testing engineers should develop critical components in shortest possible time to minimize launch time for new products. This necessitates understanding of new technologies and quick absorption in the development of new products. A piston is a moving component that is contained by a cylinder and is made gas-tight by piston rings. In an engine its purpose is to transfer from expanding gas in the cylinder to the crank shaft via piston rod and or connecting rod. As an important part in an engine piston endures the cyclic gas pressure and inertia forces at work and this working condition may cause the fatigue damage of the piston. The investigations indicate that greatest stress appears on the upper end of the piston and stress concentration is one of the mainly reason for fatigue failure. "Machine design" by Author by **R.S.KHURMI, J.K.GUPTA**, pp1132-1144, 2004[2] the inaugural issue of Machine Design coincided almost exactly with the 1929 stock-market crash and the beginning of the Great Depression. Although the nation was in the economic doldrums, there was significant design development taking place in almost all industrial segments including automotive, aircraft, farm equipment, home appliances, and industrial machinery.

"Mechanics and Materials in Design" Author by **P.CARVALHEIRAL**, vol 9 pp271 [3], The International Journal of Mechanics and Materials in Design features recent advances and original works in mechanics and materials engineering and their impact on the design process. The journal enables mechanical, aeronautical, civil, automotive, biomedical, chemical, and nuclear engineers as well as other researchers and scientists to stay abreast of the latest developments. Moreover, it enables them to exchange ideas concerning the use of mechanics and materials in design. Among the topics readers will discover are intelligent design, advanced materials in design, design analysis and optimization, experimental mechanics in design, and designcase studies. These topics and more are explored in an integrated, highly focused and coherent format.

II.METHODOLOGY OF PISTON

2.1 PISTON DESIGN

The piston is designed according to the procedure and specification which are given in machine design and data hand books. The dimensions are calculated in terms of SI Units. The pressure applied on piston head, temperatures of various areas of the piston, heat flow, stresses, strains, length, diameter of piston and hole, thicknesses, etc.,

2.2 Introduction to CATIA V5R20

Welcome to **CATIA (Computer Aided Three Dimensional Interactive Application)**. As a new user of this software package, you will join hands with thousands of users of this high-end CAD/CAM/CAE tool worldwide. If you are already familiar with the previous releases, you can upgrade your designing skills with the tremendous improvement in this latest release. CATIA V5, developed by Dassault Systems, France, is a completely re-engineered, Next-generation family of CAD/CAM/CAE software solutions for Product Lifecycle Management. Through its exceptionally easy-to-use and state-of-the-art user interface, CATIA V5 delivers innovative technologies for maximum productivity and creativity, from the inception concept to the final product. CATIA V5 reduces the learning curve, as it allows the flexibility of using feature-based and parametric designs. CATIA V5 provides three basic platforms: P1, P2, and P3. P1 is for small and medium-sized process-oriented companies that wish to grow toward the large scale digitized product definition.

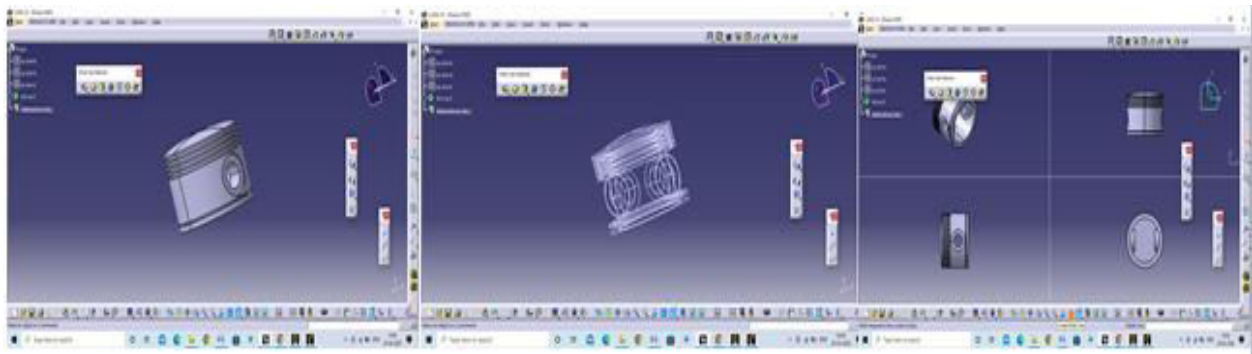


Fig.1 Design piston in CATIA

2.3 Introduction to ANSYS Workbench

2.3.1 Nodes and Elements

- Red dots represent the element's nodes.
- Elements can have straight or curved edges.
- Each node has three unknowns, namely, the translations in the three global directions.
- The process of subdividing the part into small pieces (elements) is called meshing. In general, smaller elements give more accurate results but require more computer resources and time.
- Ansys suggests a global element size and tolerance for meshing.
- The size is only an average value, actual element sizes may vary from one location to another depending on geometry.
- It is recommended to use the default settings of meshing for the initial run. For a more accurate solution, use a smaller element size.

2.3.2 Analyzing the bearing – step by step procedure

The 3D model of the Piston is designed by using pro-e software and it is converted as IGES format.

The IGES (Initial Graphic Exchange Specification) format is suitable to import in the ANSYS Workbench for analyzing; Open the ANSYS workbench; Choose static structural; Go to engineering data; Provide the required materials; Go to geometry; File – import external geometry file – generate; Close the window; Go to model; Click mesh.

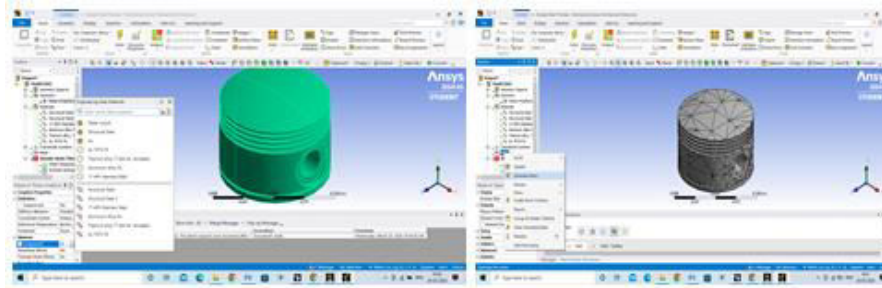


Fig.2 3D model of the Piston

2.4 Analysis of Steel Piston

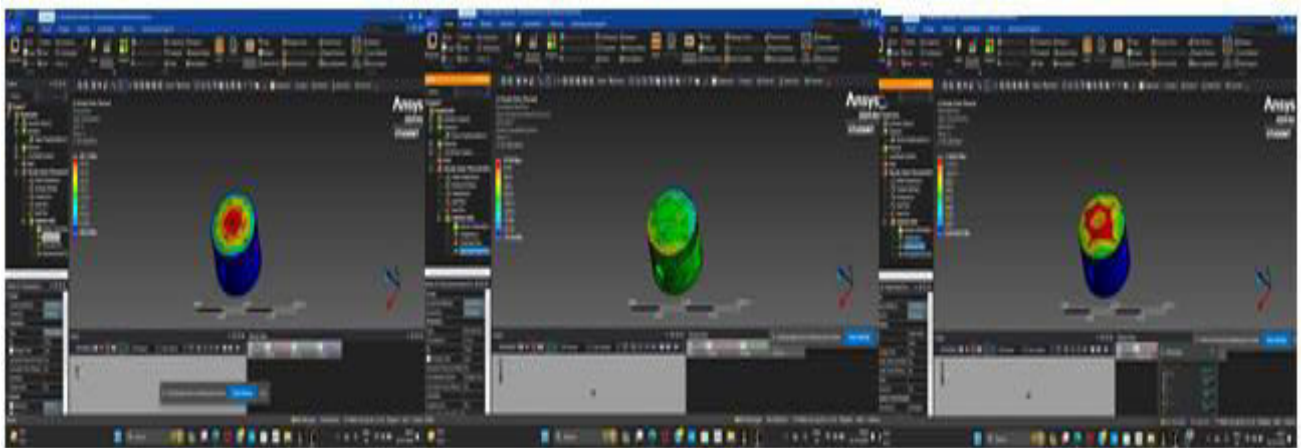


Fig.4 Thermal analysis Temperature; Heat flow rate; Heat Flux

2.5 ALUMINUM ALLOY NL

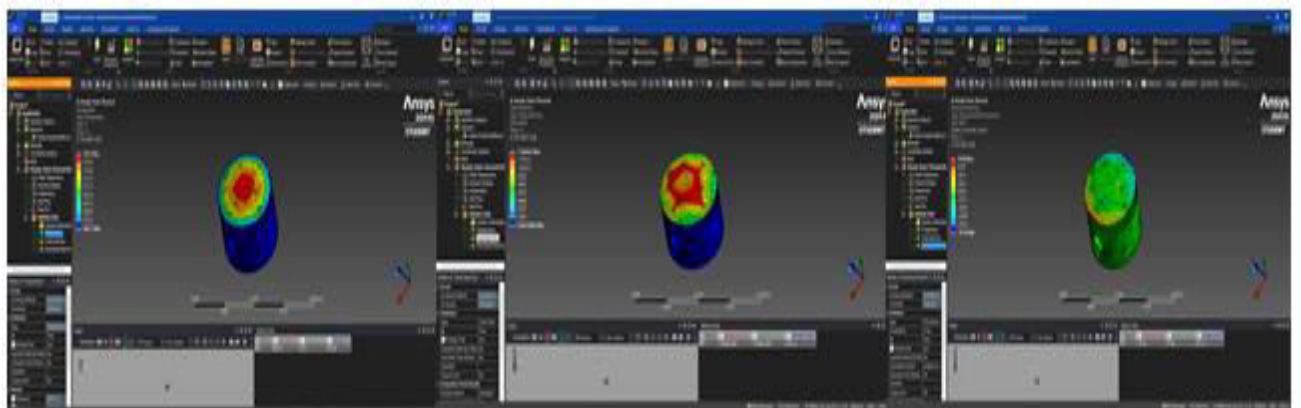


Fig.5 Thermal analysis Temperature; Heat flow rate; Heat Flux

2.6 TITANIUM ALLOY, TI-6AL-4V

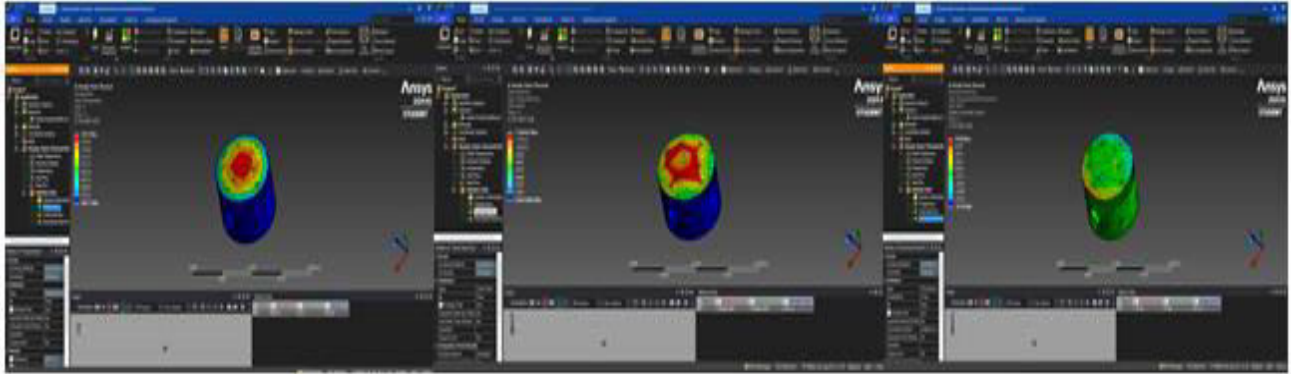
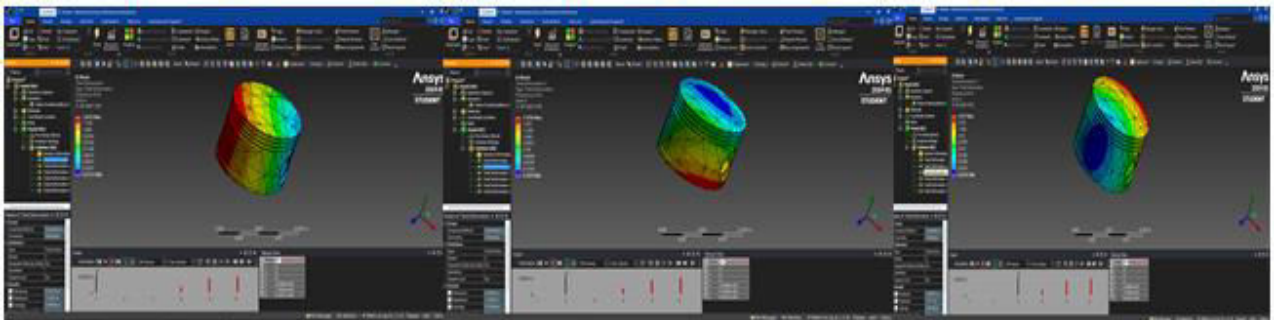


Fig.6 Thermal analysis Temperature; Heat flow rate; Heat Flux

MODEL_ANALYSIS

2.8 316 Stainless Steel



III. RESULTS AND DISCUSSION

THERMAL_ANSYS

316 Stainless Steel

Results		
Minimum	469.94 °C	1.6692e-004 W/m ²
Maximum	487.53 °C	1.3404e+005 W/m ²
Average	470.21 °C	7547.5 W/m ²
Minimum Occurs On	Piston-FreeParts Mirror3	
Maximum Occurs On	Piston-FreeParts Mirror3	

ALUMINUM ALLOY NL

Results			
Minimum	469.72 °C	1.6884e-004 W/m ²	-79130 W/m ²
Maximum	547.2 °C	1.3404e+005 W/m ²	79199 W/m ²
Average	470.93 °C	7547.5 W/m ²	44.101 W/m ²
Minimum Occurs On	Piston-FreeParts Mirror3		
Maximum Occurs On	Piston-FreeParts Mirror3		



TITANIUM ALLOY, TI-6AL-4V

Results			
Minimum	469.83 °C	1.6849e-004 W/m ²	-79130 W/m ²
Maximum	518.44 °C	1.3404e+005 W/m ²	79199 W/m ²
Average	470.58 °C	7547.5 W/m ²	44.101 W/m ²
Minimum Occurs On	Piston-FreeParts Mirror3		
Maximum Occurs On	Piston-FreeParts Mirror3		

AL 7075-T6

Results			
Minimum	469.98 °C	1.6345e-004 W/m ²	-79130 W/m ²
Maximum	476.83 °C	1.3404e+005 W/m ²	79199 W/m ²
Average	470.08 °C	7547.5 W/m ²	44.101 W/m ²
Minimum Occurs On	Piston-FreeParts Mirror3		
Maximum Occurs On	Piston-FreeParts Mirror3		

**MODAL ANALYSIS
316 Stainless Steel**

Definition						
Type	Total Deformation					
Mode	1.	2.	3.	4.	5.	6.
Results						
Minimum	0.27213 m	0.1829 m	0.20767 m	0.18471 m	5.6186e-002 m	0.14529 m
Maximum	1.2652 m	1.5556 m	1.4171 m	1.5709 m	1.5153 m	1.4962 m
Average	0.80946 m	0.76586 m	0.86368 m	0.75511 m	0.82912 m	0.81668 m
Minimum Occurs On	Piston-FreeParts Mirror3					
Maximum Occurs On	Piston-FreeParts Mirror3					
Information						
Frequency	0. Hz		2.8996e-003 Hz	7.9589e-003 Hz	8.9297e-003 Hz	

ALUMINUM ALLOY NL

Definition						
Type	Total Deformation					
Mode	1.	2.	3.	4.	5.	6.
Separate Data by Entity	No					
Identifier						
Suppressed	No					
Results						
Minimum	0.3171 m	1.1748 m	0.34988 m	0.24544 m	6.4175e-002 m	0.18665 m
Maximum	2.0915 m	1.423 m	2.0975 m	2.378 m	2.2989 m	2.3157 m
Average	1.2083 m	1.2715 m	1.1963 m	1.1786 m	1.2289 m	1.2549 m
Minimum Occurs On	Piston-FreeParts Mirror3					
Maximum Occurs On	Piston-FreeParts Mirror3					
Information						
Frequency	0. Hz		4.7496e-003 Hz	7.7468e-003 Hz		



TITANIUM ALLOY, TI-6AL-4V

Results						
Minimum	0.50871 m	0.22391 m	0.31443 m	0.33613 m	0.21273 m	0.12578 m
Maximum	1.5737 m	1.9001 m	2.0118 m	1.9407 m	1.9611 m	1.9741 m
Average	1.0896 m	1.1412 m	1.0055 m	0.99923 m	1.0472 m	1.0778 m
Minimum Occurs On	Piston-FreeParts Mirror3					
Maximum Occurs On	Piston-FreeParts Mirror3					
Information						
Frequency	0. Hz		4.6407e-003 Hz	7.0362e-003 Hz	8.7533e-003 Hz	

AL 7075-T6

Definition						
Type	Total Deformation					
Mode	1.	2.	3.	4.	5.	6.
Separate Data by Entity	No					
Identifier						
Suppressed	No					
Results						
Minimum	0.41968 m	0.70181 m	3.9725e-002 m	0.31256 m	0.34201 m	5.4545e-002 m
Maximum	2.198 m	2.2245 m	2.7172 m	2.5367 m	2.3496 m	2.4784 m
Average	1.3829 m	1.5056 m	1.3173 m	1.2995 m	1.4255 m	1.47 m
Minimum Occurs On	Piston-FreeParts Mirror3					
Maximum Occurs On	Piston-FreeParts Mirror3					
Information						
Frequency	0. Hz		3.9297e-003 Hz	8.6623e-003 Hz	8.9756e-003 Hz	

III.CONCLUSION

To increase the life of the piston, there has been more research going on in modifying the design of the piston, changing the material and also changing the method of the manufacturing. In this paper thermal stress distribution is shown for the simple piston and reduced skirt length piston. by changing the geometry of the piston and it is suggested that which piston is better for same thermal load. Steady state thermal analysis of the Piston has been done in ANSYS 2024. The use of advance coating materials in the automobile industry giving significant results in improving engine performance. In this present work a piston is designed using CATIA V5R20 software. Complete design is imported to ANSYS 14.5 software then analysis is performed. Thermal analysis of piston has been done by selecting **316 Stainless Steel. ALUMINUM ALLOY NL. TITANIUM ALLOY, TI-6AL-4V, AL 7075-T6**, as piston material by applying. An analysis of thermal stress and damages due to application of pressure is presented and analyzed in this work. The maximum and minimum heat flux distribution with different combination of piston and its coating materials was observed. Results are shown graphically and a comparison is made to find the most suited material **TI-6AL-4V**.

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