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TRANSIENT THERMAL ANALYSIS AND STATIC ANALYSIS OF PISTON BY USING ANSYS WORKBENCH

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ABSTRACT - *The main objective of this work is to investigate and analyse the stress distribution of piston. In this paper transient thermal analysis and static analysis is done by using to different materials(Aluminium and Al 6061-T6). The parameter used for the analysis is operating gas pressure, temperature and material properties of piston. In I.C. Engine piston is most complex and important part therefore for smooth running of vehicle piston should be in proper working condition. Piston fails mainly due to mechanical stresses and thermal stresses. Analysis of piston is done with boundary conditions, which includes pressure on piston head during working condition and uneven temperature distribution from piston head to skirt. The analysis predicts that due to temperature whether the top surface of the piston may be damaged or broken during the operating conditions, because damaged or broken parts are so expensive to replace and generally are not easily available. The model of piston is created using CATIA V5 software. CAD model is then imported into ANSYS software for geometry and meshing purpose. The FEA performed by using ANSYS14.5(ANSYS WORK BENCH).*

Keywords: *Transient thermal, Static, Aluminium, Al 6061-T6,Piston, CATIA V5, ANSYS14.5.*

I. INTRODUCTION

A piston is a component of reciprocating IC-engines. It is the moving component that is contained by a cylinder and is made gas-tight by piston rings. In an engine, its purpose is to transfer force from expanding gas in the cylinder to the crankshaft via a piston rod. Piston endures the cyclic gas pressure and the inertial forces at work, and this working condition may cause the fatigue damage of piston, such as piston side wear, piston head cracks and so on. So there is a need to optimize the design of piston by considering various parameters in this project the parameters selected are analysis of piston by applying pressure force acting at the top of the piston and thermal analysis of piston at temperature. This analysis could be useful for design engineer for modification of piston at the time of design. In this project we determine the various stress calculation by using static analysis and transient thermal analysis form that we can find out the various zones or region where chances of damage of piston are possible. From analysis it is very easy to optimize the design of piston. The main requirement of piston design is to measure the prediction of temperature distribution on the surface of piston which enables us to optimize the thermal aspects for design of piston at lower cost. Most of the pistons are made of an aluminium alloy which has thermal expansion coefficient, 80% higher than the cylinder bore material made of cast iron. This leads to some differences between running and the design clearances. Therefore, analysis of the piston thermal behaviour is extremely crucial in designing more efficient compressor. Good sealing of the piston with the cylinder is the basic criteria to design of the piston. Also to improve the mechanical efficiency and reduce the inertia force in high speed machines the weight of the piston also plays major role. To allow for thermal expansion, the diameter of the piston must be smaller than that of the cylinder. The necessary clearance is calculated by estimating the temperature difference between piston and cylinder and considering the coefficient of thermal expansion of piston.

Introduction to piston

The piston is a vital component of a cylindrical engine. It reciprocates inside the cylinder bore. The piston acts as a moveable end of the combustion chamber. The cylinder head is the stationary end of the combustion chamber. Piston head is the top surface (closest to the cylinder head) of the piston which is subjected to pressure fluctuation, thermal stresses and mechanical load during normal engine operation. By the forces of combustion, piston reciprocates inside the cylinder bore.

In order to increase the efficiency of operation and better functionality, the piston material should satisfy the following requirements:

- Light weight
- Good wear resistance
- Good thermal conductivity
- High strength to weight ratio
- Free from rust
- Easy to cast
- Easy to machine

- Non magnetic
- Non toxic

Piston should be designed and fabricated with such features to satisfy the above requirements.

A recessed area located around the circumference of the piston is used to retain piston ring. These rings are expandable and split in type. They are used to provide a seal between piston and cylinder wall. Three such rings employed in a diesel engine are
1. Compression ring
2. Wiper or second compression ring
3. Oil ring

Compression ring is used to prevent the leakage from combustion chamber during combustion process. It is located closest to the piston head. The wiper ring is placed between compression ring and oil ring. It further seals the combustion chamber and keeps the cylinder wall clean by wiping out the excess oil. Combustion gases passed through the compression ring are stopped by the wiper ring. Oil ring is located near the crank case which is used to wipe excess oil from the cylinder wall during piston movement.

Piston ring must be provided with a radial fit between the cylinder wall and the running surface of the piston for an efficient seal. Piston ring varies depending upon the size of the engine.

The most commonly used materials for pistons of I.C. engines are cast iron, cast aluminium, forged aluminium, cast steel and forged steel. The cast iron pistons are used for moderately rated engines with piston speeds below 6 m/s and aluminium alloy pistons are used for highly rated engines running at higher speeds. It may be noted that

1. Since the coefficient of thermal expansion for aluminium is about 2.5 times that of cast iron, therefore, a greater clearance must be provided between the piston and the cylinder wall (than with cast iron piston) in order to prevent seizing of the piston when engine runs continuously under heavy loads. But if excessive clearance is allowed, then the piston will develop 'piston slap 'while it is cold and- this tendency increases with wear. The less clearance between the piston and the Cylinder wall will lead to seizing of piston.
2. Since the aluminium alloys used for pistons have high heat conductivity (nearly four times that of cast iron), therefore, these pistons ensure high rate of heat transfer and thus keeps down the maximum temperature difference between the centre and edges of the piston head or crown.
3. Aluminium alloys loose its mechanical properties, when it reaches the temperature around 325°C. On some unexpected conditions, like failure in cooling circuit, the engines aluminium alloy piston forms the pills, when rubbing over the cylinder wall. These pills act as an abrasive and make the alloy wearing rate higher. These phenomena are called scuffing.
4. For a cast iron piston, the temperature at the centre of the piston head (TC) is about 425°C to 450°C under full load conditions and the temperature at the edges of the piston head (TE) is about 200°C to 225°C.
5. For aluminium alloy pistons, TC is about 260°C to 290°C and TE is about 185°C to 215°C.

II. METHODOLOGY

For this study and analysis, the real time low performing IC engine is taken into an account, and the piston is designed so that it can withstand higher temperatures and stress more effectively. To check the design for transient thermal stresses evolved during operation and static stress.Initially the pistons dimensions are obtained and it is produced as a 3-D model in CATIA software, and analysed in CAE (ANSYS) software.

Properties of materials used,

Parameters	Aluminium Alloy	Al 6061-T6 alloy
Young's Modulus	71000 MPa	70MPa
Poisson's Ratio	0.33	0.33
Tensile Yield Strength	280 MPa	110MPa
Tensile Ultimate Strength	310 MPa	210MPa
Density	2.77e-006 kg/mm^3	2.703e-006 kg/mm^3
Specific Heat	8.75e+005 mJ /kg C	8.85e+005 mJ / kgC

Table 1

III. DESIGNING OF PISTON

PISTON SPECIFICATIONS

Cylinder diameter,	D	= 80 mm
Length,	L	= 56mm
Radial thickness of piston,	t1	= 2mm
Axial thickness of piston,	t2	= 2mm
Materials,		= Aluminium Alloy and Al 6061-T6

The piston is designed giving dimensions into modelling software CATIA V5 R20. The geometry of piston is designed in CATIA V5 R20 and imported to the analysis software in the IGES format. The figure of the designed piston is below,

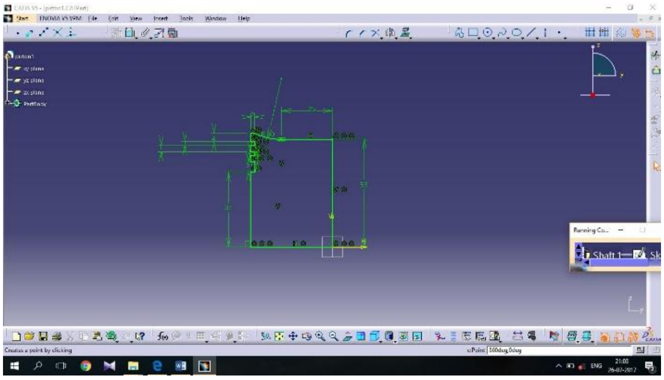


Fig 1 (a)

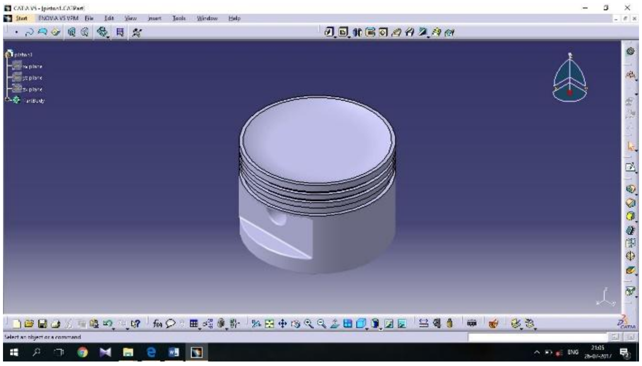


Fig 1 (b)

Fig.1 (a, b) Design of piston

IV. ANALYSIS OF PISTON

The piston is analysed by giving the constraints they are

1. Boundary conditions
2. Pressure or structural analysis
3. Transient thermal analysis

Structural analysis of piston

Combustion of gasses in the combustion chamber exerts pressure on the head of the piston during power stroke. The pressure force will be taken as boundary condition in structural analysis using ANSYS 14.5 Workbench. Fixed support has given at surface of pin hole, because the piston will move from Top Dead Centre (TDC) to Bottom Dead Centre (BDC) with the help of fixed support at pin hole. So whatever the load is applying on piston due to gas explosion that force causes to failure of piston pin (inducing bending stresses).

Taking the boundary conditions as,

A. Constraints the Gudgeon pin hole.
B. Pressure acting on piston equals to 1.2 MPa as shown in figure.

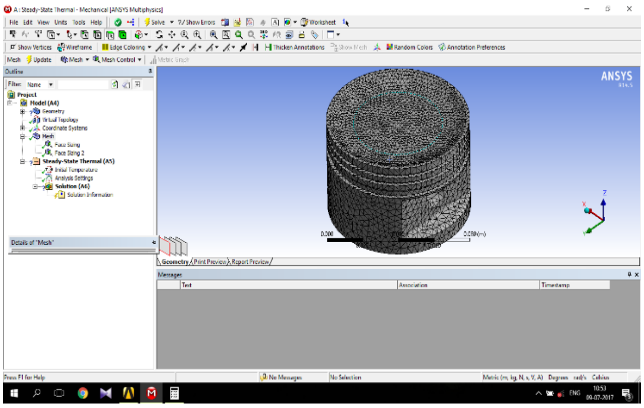
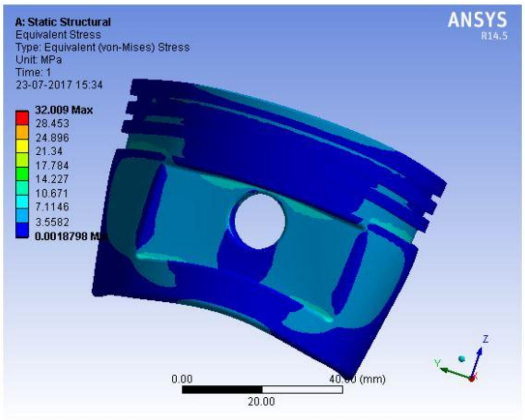


Fig.2. Meshed model of piston

RESULTS OF STRUCTURAL ANALYSIS OF PISTON



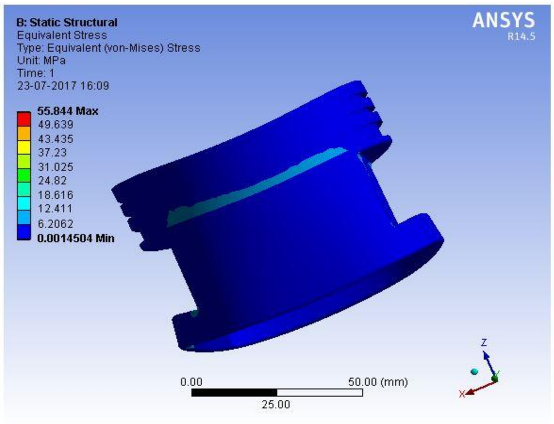


Fig 3 (a) Equivalent (Von-Mises) Stress in Al alloy Fig 3 (b) Equivalent (Von-Mises) Stress in Al 6061-T6 alloy

CONTENTS	ALUMINIUM ALLOY	AL 6061-T6 ALLOY
Pressure (MPa)	1.2	1.2
Minimum Stress (MPa)	1.8798e-003	1.4504e-003
Maximum Stress (MPa)	32.009	55.844

Table 2: Static analysis comparison

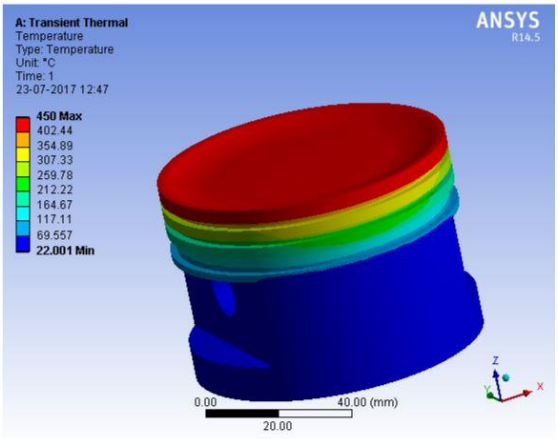
TRANSIENT THERMAL ANALYSIS

The temperature is applied at top face as the hot gasses exert temperature on top as the power stoke takes place. Taking the boundary conditions as,

A. Temperature (C) =450.
B. Convection Heat Transfer takes place at the top of the piston head.

RESULTS OF TRANSIENT THERMAL ANALYSIS OF PISTON

Material: Aluminium alloy



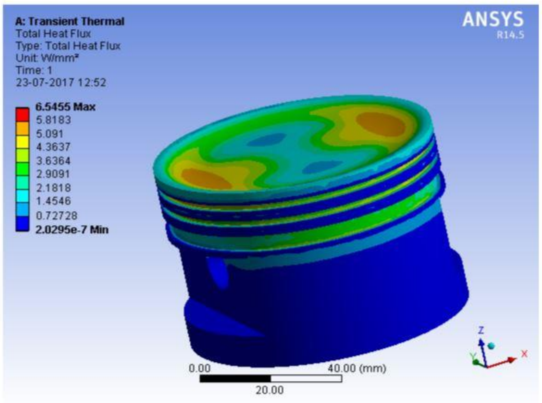
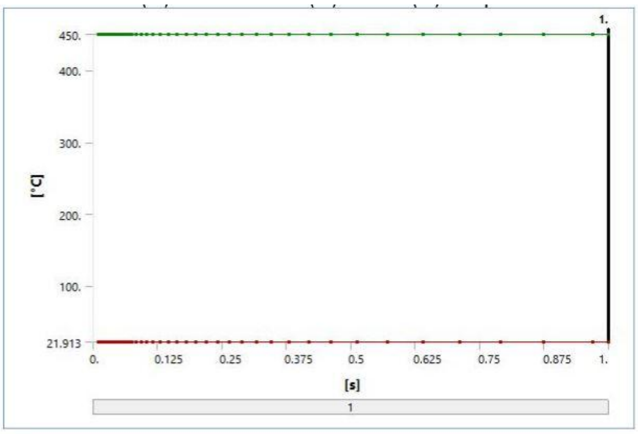
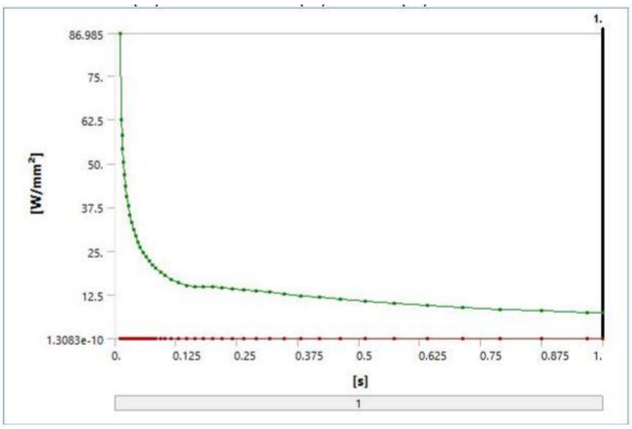


Fig 4 (a) Transient Thermal condition in Al alloy Fig 4 (b) Heat Flux condition in Al alloy



Time verses Temperature graph of Al alloy



Time vs Total heat flux graph of Al alloy

Type	Temperature	Total Heat Flux
Results		
Minimum	22.002 °C	8.0813e-008 W/mm²
Maximum	450. °C	7.3835 W/mm²
Minimum Value Over Time		
Minimum	22. °C	2.9205e-010 W/mm²
Maximum	22.001 °C	2.0295e-007 W/mm²
Maximum Value Over Time		
Minimum	450. °C	6.5455 W/mm²
Maximum	450. °C	87.912 W/mm²

Results of Al alloy

Material: Al 6061-T6 alloy

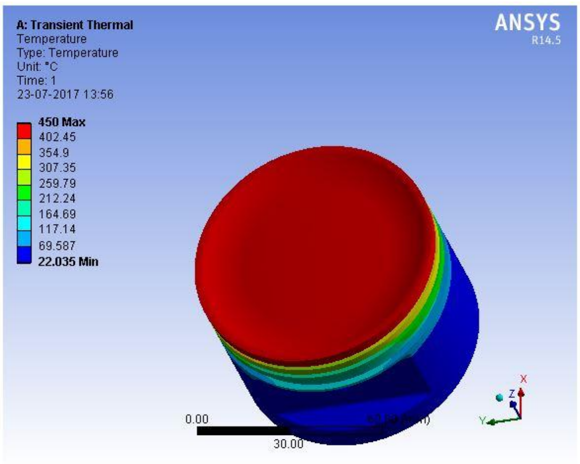


Fig 5 (a) Transient Thermal condition in Al 6061-T6 alloy

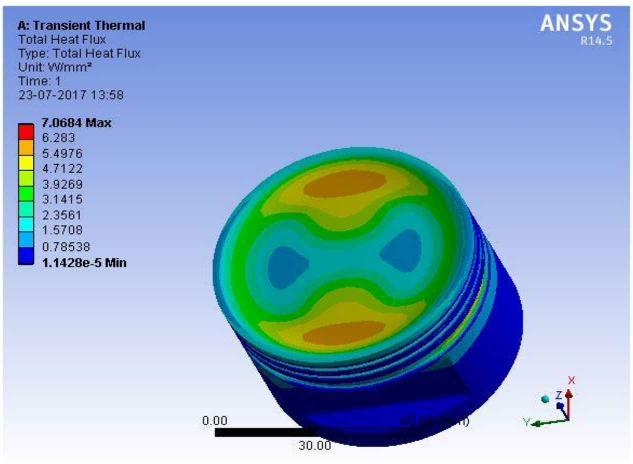
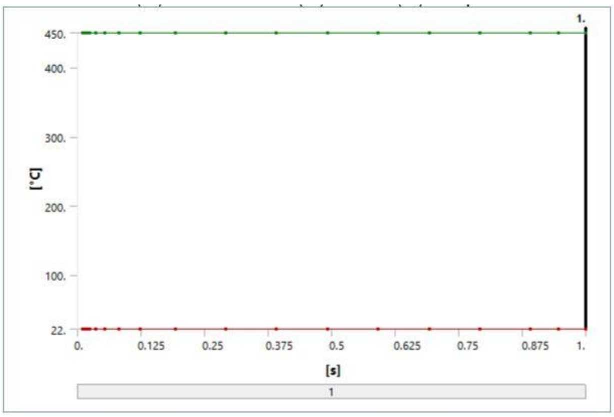
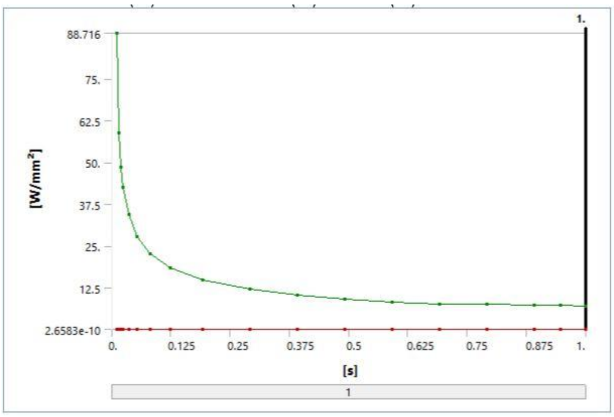


Fig 5 (b) Heat Flux in Al 6061-T6 alloy



Time verses Temperature graph of Al 6061-T6 alloy



Time vs Total heat flux graph of Al alloy

Type	**Temperature**	**Total Heat Flux**
Results		
Minimum	22.035 °C	1.1428e-005 W/mm²
Maximum	450. °C	7.0684 W/mm²
Minimum Value Over Time		
Minimum	22. °C	2.6583e-010 W/mm²
Maximum	22.035 °C	1.1428e-005 W/mm²
Maximum Value Over Time		
Minimum	450. °C	7.0684 W/mm²
Maximum	450. °C	88.716 W/mm²

Table 3. Results of Al 6061-T6 alloy

V. CONCLUSION

In present work, a piston is modeled by using CATIA V5, Then Transient thermal analysis and Static analysis is done by using ANSYS WORKBENCH. In present study, Aluminum alloy is compared with Al 6061-T6 alloy.
The various parameters (i.e., geometry) are considered, by changing the shape of the piston shape from the conventional geometry, the weight of the piston body reduces there by increasing the heat transfer rate and efficiency of the Piston.

The results shows, by piston with material Al 6061-T6 alloy is better since heat transfer rate of the piston is more.

VI. REFERENCES

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