STRESS ANALYSIS OF 4STROKE DIESEL ENGINE PISTON

Lanka Tata Rao* [1] , Katakam Satyanarayana[1] , M.S.S.Srinivasa Rao[1,] T.V. Hanumanta Rao[1], S.V.UmamaheswaraRao[2]
[1]. Dept. of Mechanical Engg. , ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY AND SCIENCES,
Sangivalasa, Visakhapatnam-531162 Andhrapradesh ,India.
[2]. Department of Marine Engineering, Andhra University, Visakhapatnam-531006 , INDIA.
Email: [1]tatarao.lanka@gmail.com , [2]snarayanak@gmail.com , [3]msrao.me@anits.edu.in , [4]tvhanumantharao@yahoo.com, [5]svumrao@yahoo.co.in .

Abstract— piston made of Al Alloy, acts as heart of the I.C. engine and is a crucial part of internal combustion engines. When the combustion of fuel takes place inside engine cylinder; high temperature and pressure are developed due to combustion of the fuel. Because of high speed and at high loads, the piston is subjected to high thermal and structural stresses. If these stresses exceed the designed values, failure of piston may take place. The stresses due to combustion are considered to avoid the failure of the piston. Intensity of thermal and structural stresses should be reduced to have safe allowable limits. In the present work the piston model is developed using SOLID WORKS software. The analysis part was carried out using ANSYS Workbench software. The stress analysis of these piston made of Aluminium alloy was performed. Appropriate average thermal boundary conditions such as heat transfer coefficient and heat fluxes were set on different surfaces of the FE model. Two different types of loads namely Thermal load and Static load were imposed on the piston. Ten nodded tetrahedral elements (solid-87) are used to discretize the solid piston model. A surface contact element (surf-152) was also used for applying the heat transfer boundary conditions. The analysis is based on the experimental values obtained a VCR Kirloskar diesel engine at compression ratio of 16.5.

Index Terms— piston, Heat transfer coefficient, heat flux, Structural and thermal analysis.

1 INTRODUCTION

Engine pistons are one of the most complex components among all automotive and other industry field components. The engine can be called the heart of a vehicle and the piston may be considered the most important part of an engine. There are lots of research works proposing, new geometries, materials and manufacturing techniques, and this with the piston has undergone a continuous improvement over the last decades. Notwithstanding all these studies, there are a huge number of damaged pistons. Damage mechanisms have different origins and are mainly wear, temperature, and fatigue related. The fatigue related piston damages play a dominant role mainly due to thermal and mechanical fatigue, either at room or at high temperature.

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 engines. Good sealing of the piston with the cylinder is the basic criteria in 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 a 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.

1.1. MATERIAL PROPERTIES Aluminum alloys are widely used in engineering structures and components where light weight or corrosion resistance is required.

Table1.1Cast Aluminum Alloy

Physical Properties	**Metric**
Density	**2800 kg/m^3**
Mechanical Properties	**Metric**
Tensile strength, Ultimate	**900 MPa**
Tensile Strength, Yield	**600 MPa**
CTE, linear	**16.5µm/m-°C**
Specific Heat Capacity	**0.461kJ/kg-°C**
Thermal Conductivity	**228 W/m-K**
Melting Point	**1370-1430°C**

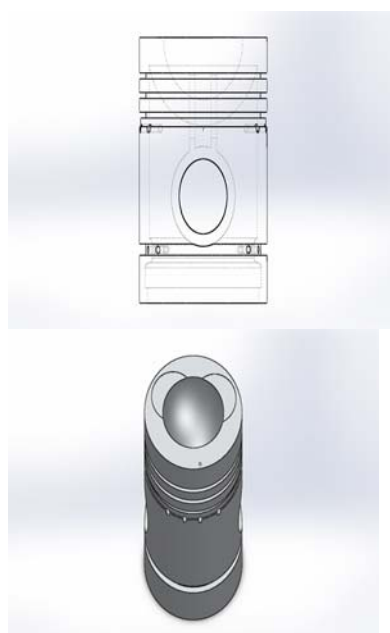
2. LITERATURE REVIEW:

The design and analysis of engine components has become more complex. One of these components is the engine piston. The piston of a diesel engine is usually subjected to periodically changing thermal and mechanical loads. Piston simulation and strength analysis has been an important area of research which has attracted great research interests .

3. GEOMETRY

The image below shows the geometry of the piston. The piston created by solid works is further imported to ansys software for further analysis. The following three types of boundary conditions are applied. Heat transfer co-efficient on the top and bottom surface, heat flux on lateral surfaces and pressure Forces.

3.1 Finite Element Model: The element selected for meshing the piston model's solid187 tetrahedral element. The meshing size Elements are 63,447 and no. Of nodes are 1, 15,057.



(a) 2 D model (b) 3-D Model

Fig 3.1: Kirloskar piston

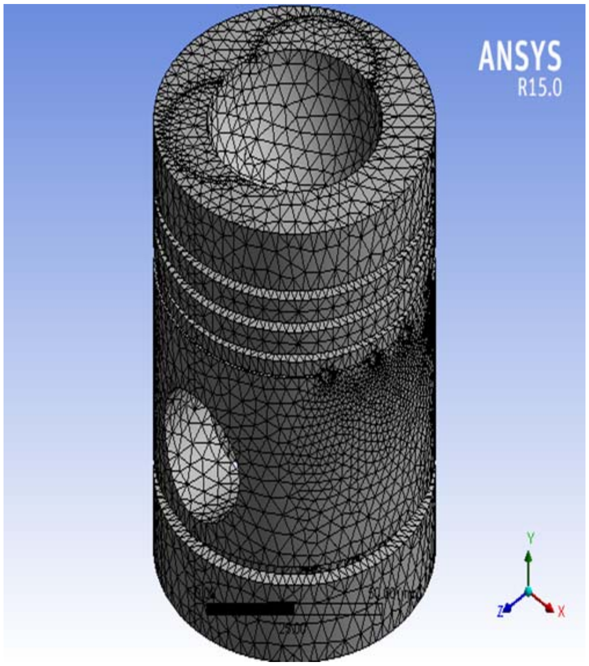


Fig :3. 2 meshing Element

4. Experimental Analysis and Calculations

4.1: Computerized VCR diesel engine specifications and Description:

4.1.1 Description:- The setup consists of single cylinder, four stroke, VCR (Variable Compression Ratio) Diesel engine connected to eddy current type dynamometer for loading. Setup is provided with necessary instruments for combustion pressure and crank-angle measurements. These signals are interfaced to computer through engine indicator for Pθ & PV diagrams. Provision is also made for interfacing airflow, fuel flow, temperatures and load measurement. The setup has stand-alone panel box consisting of air box, two fuel tanks for duel fuel test, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and engine indicator. Rota meters are provided for cooling water and calorimeter water flow measurement.

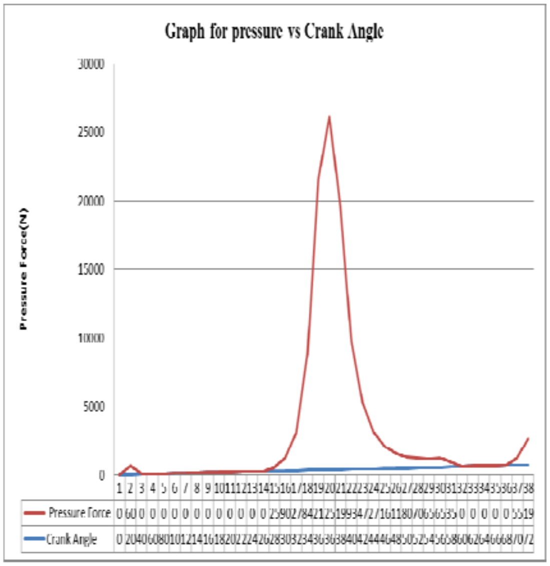
4.1.2 Engine specifications:-

Features	Specifications
Make	Kirloskar oil Engine
Type	Four stroke, Water cooled Diesel
No of cylinders	One
Combustion Principle	Compression ignition
Max speed	1500
Crank Radius	55mm
Connecting Rod length	300mm
Cylinder diameter	80mm
Compression ratio	variable
Stroke length	110mm

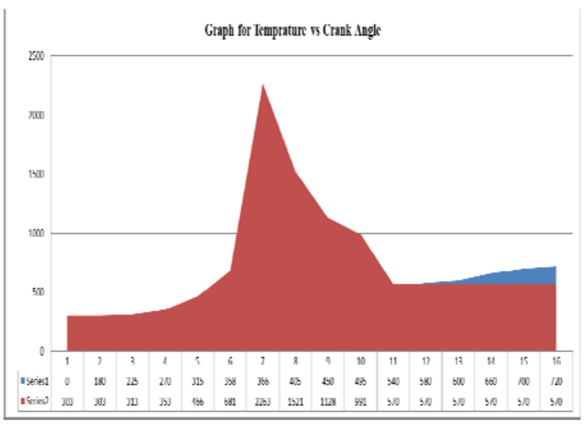
4.1.3: The following reading were taken from experimentation:-

Features	Specifications
Load	21.27 N-M
Speed	1470 rpm
Fuel rate	2.06 kg/hr
Air rate	16.20 m^3/hr
Water Flow	40.80 cc/sec
Cooling Water inlet Temp	26.70 ^{0}C
Cooling Water outlet Temp	30.80^{0}C

4.2: Variation of pressure Force with Crank Angle:-



4.3: Variation of temperature with Crank Angle:-



4.4 Calculations:

Based on these inputs following parameters for thermal analysis is calculated:

Total heat lost through water jacket = 20.59 watts

Average temperature of the piston =412 ^{0}C

Heat transfer coefficient on top surface (h) = 174.125 w/m^{2}k

Heat transfer coefficient on bottom surface (h_b) = 8.6193 w/m^{2}k

Heat flux applied on lateral surface = 780 w/m^2

5. RESULTS

By applying the boundary conditions heat transfer analysis is carried out.

5.1. Based on thermal analysis:-

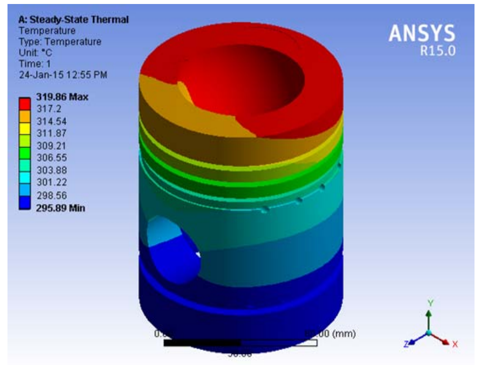


Fig 5.1.1. Temperature distribution plot:

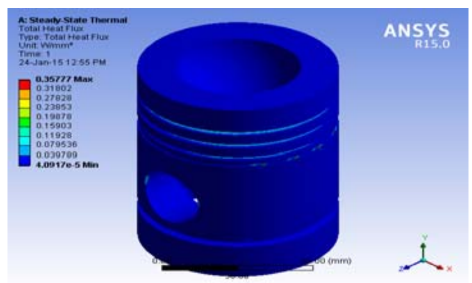


Fig 5.1.2 Total heat flux plot:

we observe from the plots maximum temperature in the piston is 319.86 ^{0}C and minimum temperature in the piston is 295.89 ^{0}C. Maximum heat flux in the piston is 0.35777 w/mm^2

5.2 Based on Static Loads:-

Structural Analysis:.

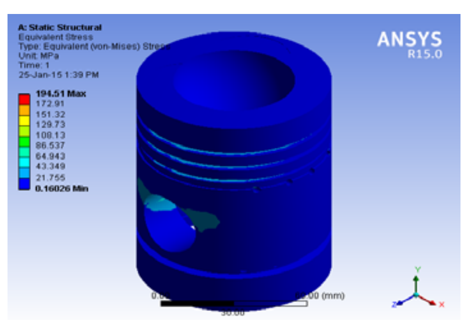


Fig 5.2.1 Von-mises stresses plot:

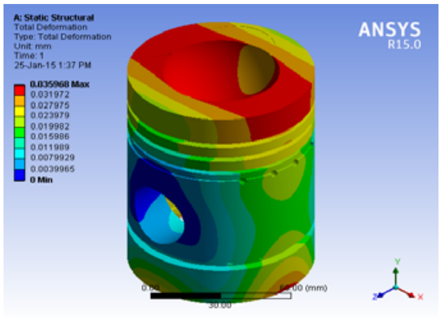


Fig 5.2.2 Total deformation plot:

For structural analysis ,the piston pressure of 53 bar is applied on the piston and FEM analysis carried out. we observe from the plots maximum are 194.51 Mpa and minimum is 0.160 Mpa. von-mises stresses in the piston located. Maximum total deformation in piston is 0.035968 mm.

6. CONCLUSION:

Experimental investigation carried out on computerized VCR diesel test rig to determine the variation of pressure with crank angle in the cylinder at particular compression ratio. The temperature variation of gases was further evaluated using the results obtained from the experimentation.

Using this experimental observations and they actual dimension of piston, stress analysis was carried out with the aid of the modern software like solid works and Ansys.

The stress induced in piston and deformations were found to be with in allowable limits. The factor of safety is found to be around 3. Further investigation is to be carried out at higher compression ratio.

7. ACKNOWLEDGEMENT

We express our sincere thanks to Anil Neerukonda Institute of Technology and sciences for providing experimental test rig Computerized VCR diesel engine,

8. REFERENCES

.

[1] Hongyuan Zhang, zhaoxun Lin, Dawei Xu, in: An Analysis to Thermal Load and Mechanical Load Coupling of a Gasoline Engine Piston. *Journal of Theoretical and Applied Information Technology, Vol. 48(2)*, 2013, pp. 911-917

[2] Dr. Ahmed A, Dr. Basim., "*Thermal effects on diesel engine piston and piston compression ring*", Engineering and technology Journal, Vol. 27, No. 8, 2009.

[3] Piotr szurgott, Tadeusz Niezgoda "Thermo Mechanical FE Analysis Of The Engine Piston Made Of Composite Material With Low Hysteresis", Journal of KONESpower trains and transport, Vol 18, No 1, 2011.

[4] Dr. S.N.Kurbet and R.Krishnakumar ., "*A Finite Element study of Piston Tilt effects on Piston Ring Dynamics in IC Engines*", Proc Instn Mech Engrs (IMECHE) Part K.2004, pp 107-117.

[5] Mahdi Hamzwhei and Manochehr Rashidi., *"Determination of Piston and Cylinder Head Temperature Distribution in a 4-Cylinder Gasoline Engine at Actual Process",* Proceedings of the 4th WSEAS Int. Conf. on heat transfer, thermal engineering and environment, Elounda, Greece, August 2006.

[6] M. M. Rahman, A. K. Ariffin, N. Jamaludin, and C. H. C. Haron "Finite Element Based Vibration Fatigue Analysis for A New Free Piston Engine Component" April2009 The Arabian Journal for Science and Engineering, Volume 3.

[7] K.S. Narayana, S. Phani Kumar, M.S.S. Srinivasa Rao **"**Thermo-Structural Finite Element Analysis of I.C. Engine Pistons "International Colloquium on Materials Manufacturing and Metrology, ICMMM 2014, *August 8-9,* IIT Madras, Chennai, India. P 882-84.