Comparative study of aluminium alloy pistons manufactured by casting and powder forging

S.Srivathsan

ABSTRACT –

Engine pistons are one of the most complex components among all automotive or other industry field components. The engine can be called the heart of a car and the piston may be considered the most important part of an engine. Damage mechanisms have different origins and are mainly wear, temperature, and fatigue. Mechanical fatigue, either at room or at high temperature, plays a prominent role. A static stress analysis is used to determine the stress distribution.

Keywords — ANSYS Workbench, Piston, Finite Element analysis, PRO/E

---------- @@@@ --------------

1 INTRODUCTION

Piston materials and designs have evolved over the years and will continue to do so until fuel cells, exotic batteries or something else makes the internal combustion engines obsolete. The piston is one of the most stressed components of an entire vehicle. Damages may have different origins: mechanical stresses; thermal stresses; wear mechanisms; temperature. In this work only mechanical damages will be assessed. Deformation occurs due to load on the piston. In this work, 1.4 litre diesel engine pistons from automotive engines will be presented. Only aluminium pistons are assessed in this work because most of the engine pistons are in aluminium.

2 Types of Pistons

The common types of pistons used in automotive industries are cast iron, aluminium alloy etc. Aluminum is the material commonly used for making pistons. It is the metal with features of excellent lightness, thermal conductivity, corrosion resistance, characteristics of casting, low temperature, machine processing and recycling, etc. Aluminium alloys will be made by casting, forging, powder metallurgy process like powder forging etc.

2.1 Material Properties

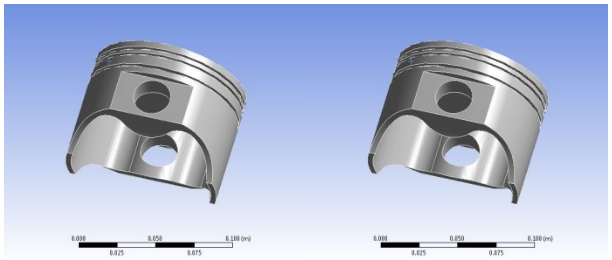
Material property	Aluminium alloy - casting	Aluminium alloy – powder forging
Poisson Ratio	0.3	0.33
Young's Modulus	71 Gpa	81 Gpa
Tensile Yield Strength	435 Mpa	580 Mpa
Tensile Ultimate Strength	485 Mpa	630 Mpa
Hardness	71 HRB	77.5 HRB

2.2 Piston proE Model

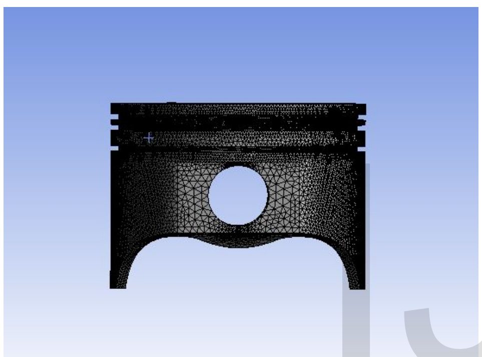
The three dimensional models of piston is created in proE and file was exported in IGES (International Graphics Exchange Specification). The three dimensional models that were developed is shown in figure below

ISSN 2229-5518

FRONT VIEW ISOMETRIC VIEW



The mesh was meshed with 10-node tetrahedral structural solid element. The wheel was meshed with an element of minimum edge length of 2.2576e-003m. Total number of nodes and elements are 21640 and 11607 respectively. The finite element realization of wheel obtained is shown in figure.



2.3 Meshing of piston

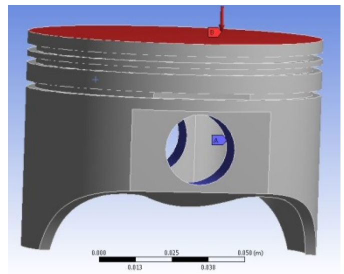
The meshing was performed by the mesh generate option in ANSYS workbench

3 Loads and boundary conditions

To ensure the accuracy and reliability of the analysis result For 4 cylinder small car engine (say 1.4 litres) the power output might be 100 kW at 3600 RPM. There are 2 firing strokes per rev so there are 7200 strokes per minute or 120/second.

Length of piston stroke = say 0.1 meter

If the average force is F newton, work per stroke = 0.1F that gives an average force of 8300 newton or about 2000 pounds.

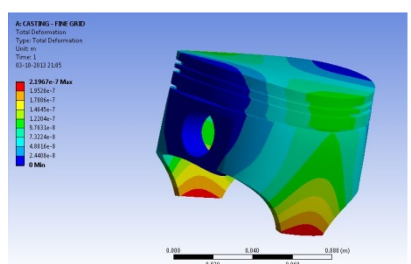


Loads and boundary conditions

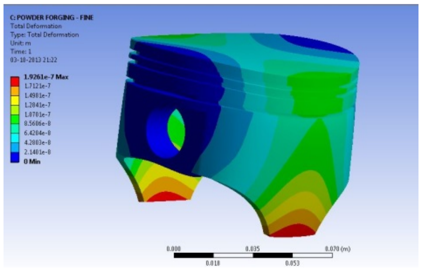
4 Results and Discussions

Following by von misses yielding principle; the results of finite elemental analysis were post-processed for visualization. Below fig shows the equivalent stress distribution of al wheel, mg wheel and the redesigned mg wheel respectively under the same working condition as illustrated in fig. the stress value is graded with colors from red to blue, reflecting the stress descending from high to low.

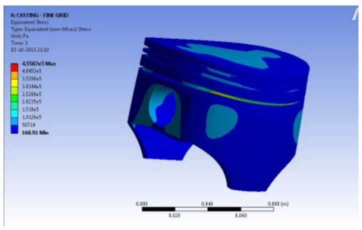
Deformation on casting



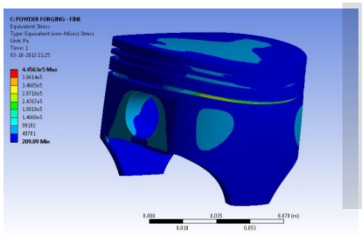
Deformation on powder forging



Stress Distribution on casting



Stress Distribution on powder forging



As the figures indicate the maximum stress acting on casting process is more when compared to powder forging.

5 Conclusion

Mechanical properties of the aluminium alloy piston is evaluated by the theoretical analysis, using simulation.

The deformation, von mises stresses, strain energy of the piston formed by powder forging technology were much excellent than casted pistons.

Tensile strength and hardness are more than casted pistons.

REFERENCES

- Cho JR, Joo YS, Jeong HS. The Al-powder forging process: its finite element analysis. J Mater Processing Technol 2001;
- 11 Nakajima K, Otaka H, Kashimura T, Sakuma S, Tanaka M. Newly developed hollow ring groove insert piston – part 2: producing technology of new piston. JSAE Rev 1996;17(4):448.1(1–3):204–9.Martin, Gary G. Failure of stationary pump engine piston. J Failure Anal Prevention 2004;4(1):37–9.
- J. H. Lee, Y. S. Lee, and H. S. Chung, "Development of Bevel Gear by Powder Forging Process," Journal of Korean Powder Metallurgy Institute, Vol. 4, No. 4, pp. 258-267, 1997.
- Y. Iwata, S. Mae, Y. Urai, and T. Tsunoda, "Aluminium Alloy having an Excellent Forgibility," United States Patent[19], P. N. 4889557, Dec. 26,
- J. J. Park, "A Yield Function for Sintered Porous Metals," The Korean Society of Mechanical Engineers, Vol. 17, No. 5, pp. 1115~1122, 1993.
- Alexandrov et al., 1998 I.V. Alexandrov, Y.T Zhu, T.C. Lowe, R.K. Islamgaliev, R.Z. Valie
- Heywood, J.B.: "Internal Combustion Engine Fundamentals,' McGraw-Hill, Inc., New York, 1987.
- Rohatgi, P.: "Cast Aluminum Matrix Composites for Automol ive Applications." Journal of Metals, pp. 10-15, April 1991.