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Design and Static Analysis of Piston Housing used in Hydraulic Oil Filter Pump

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Abstract:

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 and/or connecting rod. As an important part in an engine, 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/crown cracks and so on. The investigations indicate that the greatest stress appears on the upper end of the piston and stress concentration is one of the mainly reason for fatigue failure.

In this paper describes the stress distribution of the seizure on piston four stroke engines by using FEA. The finite element analysis is performed by using computer aided design (CAD) software. The main objectives are to investigate and analyze the thermal stress distribution of piston at the real engine condition during combustion process. The paper describes the mesh optimization with using finite element analysis technique to predict the higher stress and critical region on the component. The optimization is carried out to reduce the stress concentration on the upper end of the piston i.e. (piston head/crown and piston skirt and sleeve). With using computer aided design (CAD), Creo software the structural model of a Carbon piston will be developed. Furthermore, the finite element analysis performed with using software ANSYS.

Key Words: ***IC Engines, material properties, Alloys, Ansys, Fem***

1. INTRODUCTION

An internal combustion engine (ICE) is an engine where the combustion of a fuel occurs with an oxidizer (usually air) in a combustion chamber that is an integral part of the working fluid flow circuit. In an internal combustion engine the expansion of the high-temperature and high-pressure gases produced by combustion apply direct force to some component of the engine. The force is applied typically to pistons, turbine blades, or a nozzle. This force moves the component over a distance, transforming chemical energy into useful mechanical energy. The first commercially successful internal combustion engine was created by Étienne Lenoir around 1859.

The term internal combustion engine usually refers to an engine in which combustion is intermittent, such as the more familiar four-stroke and two-stroke piston engines, along with variants, such as the six-stroke piston engine and the Wankel rotary engine. A second class of internal combustion engines use continuous combustion: gas turbines, jet engines and most rocket engines, each of which are internal combustion engines on the same principle as previously described. Firearms are also a form of internal combustion engine.

Internal combustion engines are quite different from external combustion engines, such as steam or Sterling engines, in which the energy is delivered to a working fluid not consisting of, mixed with, or contaminated by combustion products. Working fluids can be air, hot water, pressurized water or even liquid sodium, heated in a boiler. ICEs are usually powered by energy-dense fuels such as gasoline or diesel, liquids derived from fossil fuels. While there are many stationary applications, most ICEs are used in mobile applications and are the dominant power supply for cars, aircraft, and boats.

Typically an ICE is fed with fossil fuels like natural gas or petroleum products such as gasoline, diesel fuel or fuel oil. There's a growing usage of renewable fuels like biodiesel for compression ignition engines and bioethanol for spark ignition engines. Hydrogen is sometimes used, and can be made from either fossil fuels or renewable energy.

Applications

Reciprocating engine as found inside a car,

Reciprocating piston engines are by far the most common power source for land vehicles including automobiles, motorcycles, locomotives and ships. Wankel engines are found on some automobiles and motorcycles.

Where very high power-to-weight ratios are required, internal combustion engines appear in the form of combustion turbines. Powered aircraft typically use an ICE which may be a reciprocating engine. Airplanes can also use jet engines and helicopters can also employ turbo shafts; both of these are types of turbines. In addition to providing propulsion, airliners employ a separate ICE as an auxiliary power unit. Big Diesel generator used for backup power

Combined cycle power plant:

ICEs also have a role in large scale electric power generation where they're found in the form of combustion turbines in combined cycle power plants with typical electrical output in the range of 100 MW to 1 GW. The high temperature exhaust is used to boil and superheat water to run a steam turbine. Thus, more energy is extracted from the fuel that could be extracted by the combustion turbine alone. In combined cycle power plants efficiencies in the range of 50 % to 60 % are typical. In a smaller scale Diesel generators are used for backup power and for providing electrical power to areas not connected to an electric grid.

Two-stroke engines are widely used in snowmobiles, lawnmowers, string trimmers, chain saws, jet skis, mopeds, outboard motors, and many motorcycles. Two stroke gasoline small engines are a common power source for chainsaws, leaf blowers and lawnmowers

2. DESIGN

PRO-E INTRODUCTION:

3D CAD

Three-dimensional (3D) CAD programs come in a wide variety of types, intended for different applications and levels of detail. Overall, 3D CAD programs create a realistic model of what the design object will look like, allowing designers to solve potential problems earlier and with lower production costs. Some 3D CAD programs include Autodesk Inventor, Co-Create Solid Designer, Pro/Engineer Solid Edge, SolidWorks, Unigraphics NX and VX CAD, CATIA V5.

Pro/ENGINEER Wildfire is the standard in 3D product design, featuring industry-leading productivity tools that promote best practices in design while ensuring compliance with your industry and company standards. Integrated Pro/ENGINEER CAD/CAM/CAE solutions allow you to design faster than ever, while maximizing innovation and quality to ultimately create exceptional products.

Customer requirements may change and time pressures may continue to mount, but your product design needs remain the same - regardless of your project's scope, you need the powerful, easy-to-use, affordable solution that Pro/ENGINEER provides.

Pro/ENGINEER Wildfire Benefits:

- Unsurpassed geometry creation capabilities allow superior product differentiation and manufacturability
- Fully integrated applications allow you to develop everything from concept to manufacturing within one application

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- Automatic propagation of design changes to all downstream deliverables allows you to design with confidence
- Complete virtual simulation capabilities enable you to improve product performance and exceed product quality goals
- Automated generation of associative tooling design, assembly instructions, and machine code allow for maximum production efficiency
- Pro ENGINEER can be packaged in different versions to suit your needs, from Pro/ENGINEER Foundation XE, to Advanced XE Package and Enterprise XE Package, Pro/ENGINEER Foundation XE Package brings together a broad base of functionality. From robust part modelling to advanced surfacing, powerful assembly modelling and simulation, your needs will be met with this scalable solution. Flex3C and Flex Advantage Build on this base offering extended functionality of you're choosing.

The main modules are:

- Sketcher
- Part Design
- Assembly

Pro-E features:

All relevant:
Pro / ENGINEER for all the modules are all related. This means that the product development process in particular modifications, can be extended to the whole design, the same time, automatically update all the project documentation, including assembly, design drawings, Yi Ji manufacturing data. Encourage all relevant at any point in the development cycle to modify, without any loss, making it possible for concurrent engineering, it can make some of the features developed later to play its role in advance.

Feature-Based Parametric Modeling:

Pro/ENGINEER user familiar with the characteristics of the structure as a geometric model of product elements. These features are common mechanical objects, and can be easily pre-set to be modified. For example: design features with arc, fillet, chamfer, etc., their engineering staff is very familiar, and it is easy to use. Assembly, processing, manufacturing and other disciplines are using the unique characteristics of these areas. To these features by setting parameters (including not only geometry, but also non-geometric properties), and then modify the parameters are easy to design iterations many times, to achieve product development.

Data management:

Accelerating market need in a short period of time to develop more products. To achieve such efficiency, multi-disciplinary engineers must be allowed the same time develop the same product. The developed data management module is designed to manage concurrent tasks.

Assembly Management:

Pro / ENGINEER allows the basic structure of your use of some intuitive commands such as "engagement", "insert", "align" and so very easy to assemble parts together, while maintaining the design intent. Advanced features to support the construction of large and complex assembly and management of these assembly unlimited number of parts. Easy to use: Menu is designed for the joint level appears to provide a logical option and pre-selected the most common option, but also provides a brief description and a complete menu of online help, this form allows easy to learn and use.

3. ANALYSIS

Introduction to Finite Element Analysis

The basic concept in fem is that the body or structure may be divided into smaller elements of finite dimensions called “Finite Elements”. The original body or the structure is then considered as an assemblage of these elements connected at a finite number of joints called “nodes” or “nodal points”. Simple functions are chosen to approximate the displacements over each finite element. Such assumed functions are called "shape functions". This will represent the displacement with in the element in terms of the displacement at the nodes of the elements.

The Finite Element method is a mathematical tool for solving ordinary and partial differential equation because it is a numerical tool; it has the ability to solve the complex problem that can be represented in differential equation from. The application of FEM is limitless as regards the solution of practical design problems.

Due to high cost of computing power of years gone by, FEM has a history of being used to solve complex and cost critical problems.

The finite element method is a very important tool for those involved in engineering design; it is a now used routinely to solve problems in the following areas:

- Structural analysis
- Thermal analysis
- Vibrations and dynamics
- Buckling analysis
- Acoustics
- Fluid flow simulations
- Crash simulations
- Mould flow simulations

Now a days, even the most simple of products rely on the finite element method for design evaluation. This is because contemporary design problems usually cannot be solved as accurately & cheaply using any other method that is currently available. Physical testing was the norm in the years gone by, but now it is simply too expensive and time consuming also.

BASIC CONCEPTS:

The finite element method is based on the idea of building a complicated object with simple blocks or driving a complicated object into small and manageable pieces. Application of this simple idea can be found everywhere in everyday life as well as engineering. The philosophy of FEA can be explained with a small example such as measuring the area of a circle.

Area of one triangle: Si=1/2*R2*sin θI.

Area of the circle: SN=1/2*R2*N*Sin (2∏/N) →∏R2 as N→∞.

Where N= total number of triangles (elements)

If one needs to evaluate the area of the circle without using the conventional formula, one of the approaches could be to divide the above area into a number of equal segments. The area of each triangle multiplied by the number of such segments gives the total area of the circle.

BASIC STEPS IN FEA:

- Discretization of the domain.
- Application of boundary conditions.
- Assembling the system equations.
- Solution for system equations.
- Post processing the results.

ANSYS INTRODUCTION:

The ANSYS program is self-contained general purpose finite element program developed and maintained by Swason analysis systems Inc .the program contain many routines, all inter related and all for main purpose of achieving a solution to an engineering problem by finite element method.

ANSYS finite element analysis software enables engineers to perform the fallowing tasks:

- Build computer model or transfer models of structures, products, components, or system.
- Apply operating loads or other design performance conditions.
- Study physical responses, such as stress levels, temperature distributions, or electromagnetic fields.
- Optimize a design early in the development process to reduce production costs.
- Do prototype testing in environments where it otherwise would be undesirable or impossible.

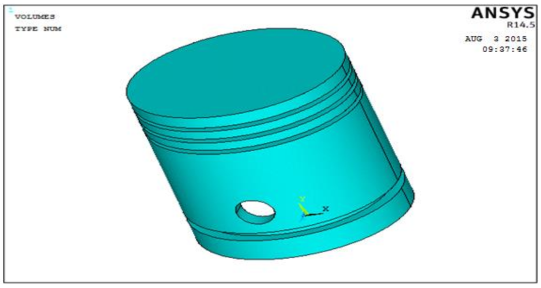
The ANSYS program has a compressive graphical user interface (GUI) that gives users easy, interactive access to program functions, commands, documentation and reference material. An intuitive menu system helps users navigate through the ANSYS program. Users can input data using a mouse, a keyboard, or a combination of both. A graphical user interface throughout the program, to guide new users through the learning process and provide more experienced users with multiple windows, pull-down menus, dialog boxes, tool bar and online documentation.

4. ANALYSIS IN ANSYS

Structural analysis of piston

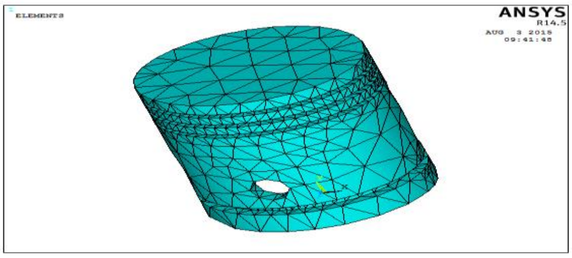
ALSI (aluminimum silicate)

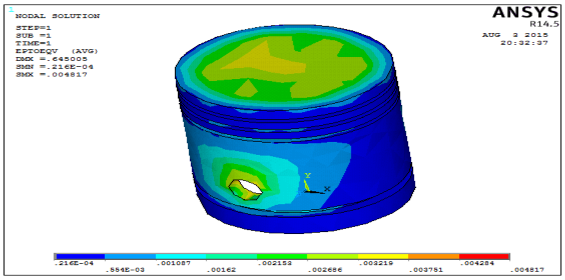
Imported Model from Pro/Engineer



Element Type: Solid 20 node 186
Material Properties:
Youngs Modulus (EX) : 90000N/mm^2
Poissons Ratio (PRXY) : 0.3
Density : 0.0000027 kg/mm^3

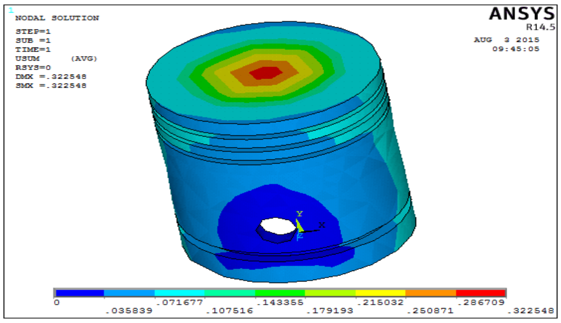
Meshed Model



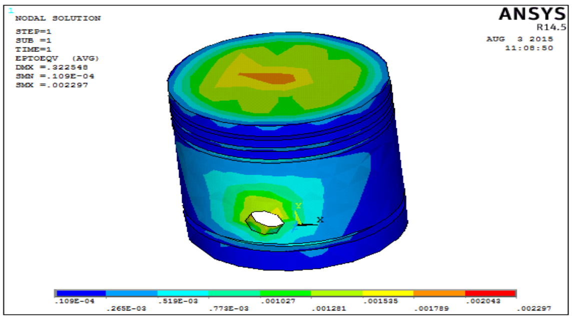


Loads: Pressurevalues –10.936N/mm2

Von Mises Stress

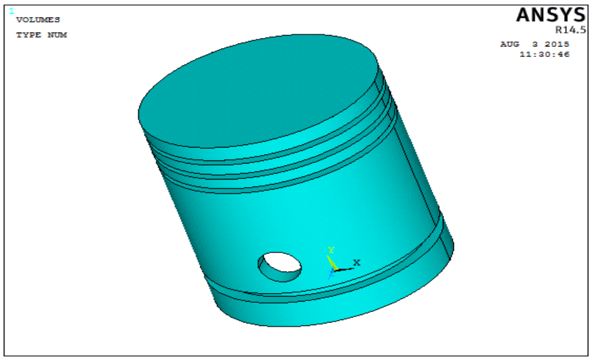


Total mechanical Strain



STRUCTURAL ANALYSIS OF PISTON

Steel alloys



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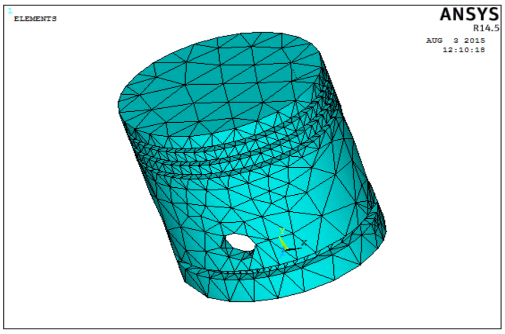
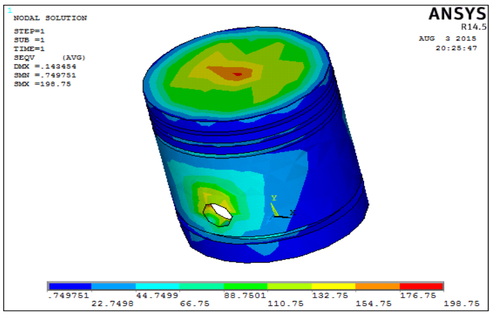
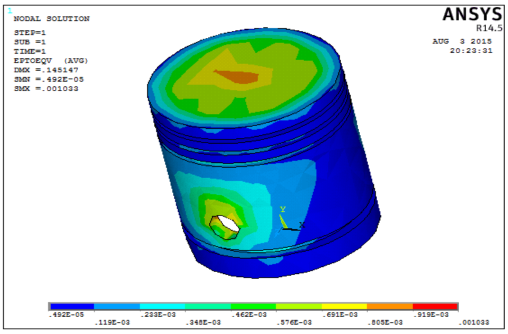
Meshed model



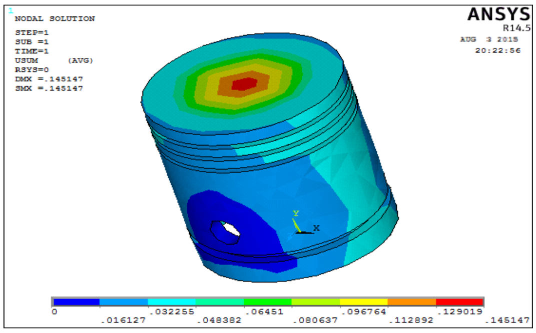
Load Pressure value -10.936N/mm2



Von Mises Stress

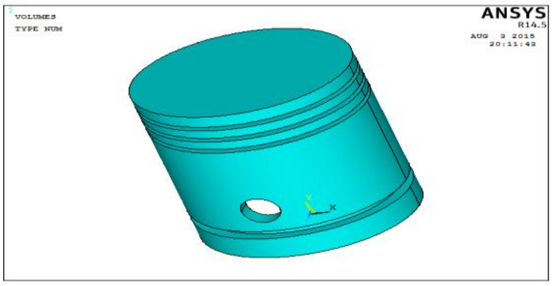


Total mechanical Strain

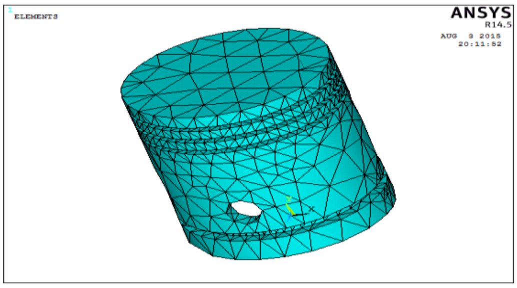


MGZRO3

Imported Model from Pro/Engineer

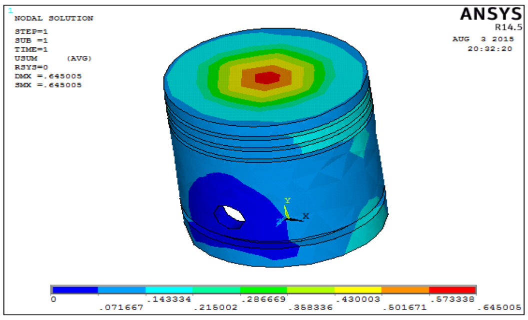


Meshed Model

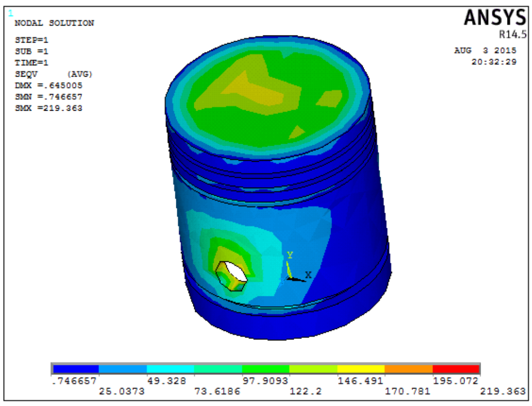


Loads:Pressurevalues–10.936N/mm2

Displacement Vector Sum



Von Mises Stress



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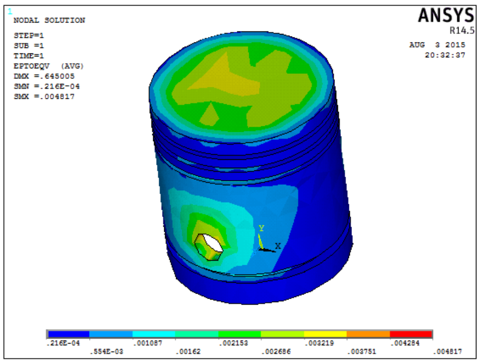
Total mechanical Strain

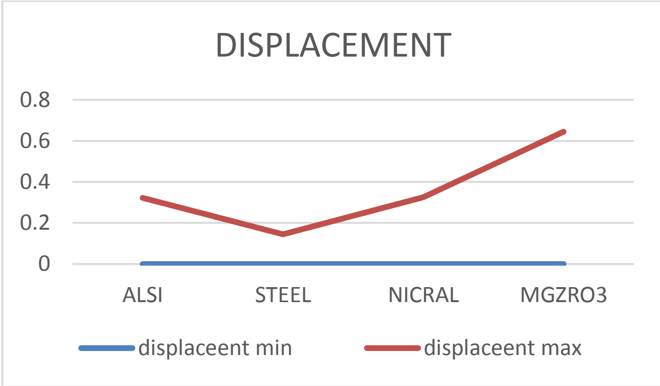


5. RESULTS & DISCUSSION

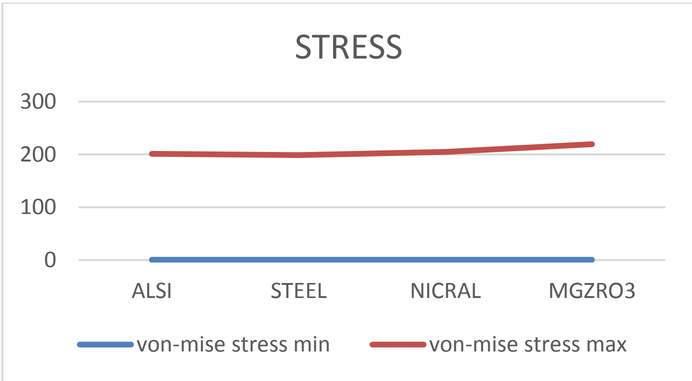
The results obtained during the analysis using Ansys software are tabulated below and they are compared graphically

Sl. No	Material	Displacement Min	Displacement Max	Stress Min	Stress Max	Strain Min	Strain Max
1	ALSI	0	0.322548	0.725857	201.397	1.09E-05	0.002297
2	STEEL	0	0.145147	0.749751	198.75	4.92E-06	0.001033
3	NICRAL	0	0.325503	0.713828	205.101	1.09E-05	0.002321
4	MGZRO3	0	0.645005	0.746657	219.363	2.16E-05	0.004817

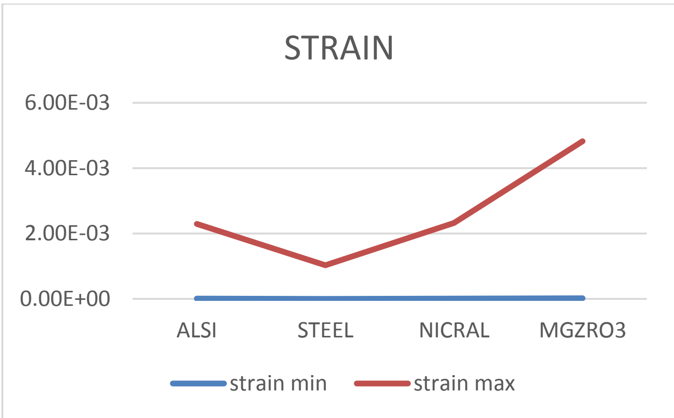
Table.1



Graph 1



Graph 2



Graph 3

From graph 1, 2, and 3 we observe that displacement, stress and strain are low in steel when compared to the remaining materials

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6. CONCLUSION

As observed in the above graphs the stress value is very much low for the steel when compared to the other materials like AL, nickel &Mg, coming to the strain also when observed in the graph steel and al got the same results, but coming to the stress the value of steel is much better than the AL when compared to all the analysis materials, by observing the stress values and results steel piston is very better than the other materials.

So finally we can conclude that steel is much better than the remaining materials.

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