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DESIGN AND ANALYSIS OF A PISTON BY MATERIAL OPTIMIZATION

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ABSTRACT: The main objective of this study is to explore the analysis of a piston with design change to attain less volume and better efficiency. This has entailed performing a detailed thermal analysis. The study deals with dynamic, modal and transient thermal analysis. A proper Finite Element Model is developed using Cad software Solid works. In this project we are doing the material optimization in the piston. This project we are designed the 3D model of the axle by using pro-e software and the analysis taken by different materials of the bearing and the analysis taken by the ansys software. This project we are analyzing the pressure acting on the piston by the two materials. Presently the piston are made by the material of AL-Mg-Si, this project we are testing the same load under SILUMIN. Then the thermal analysis is done to determine the total heat flux in the existing piston for the given temperature conditions. The temperature acting on the surface of the piston is applied. The results were also used to determine the total heat flux for a particular material.

Key Words: [Cad software, pro-e software, ansys software, material of AL-Mg-Si, SILUMIN.]

1. INTRODUCTION

The top of the piston is called head or crown. Generally low cost low performance engines have flat head as shown. In some such pistons which come quite close to the valves, the head is provided valve relief. Pistons used in some high powered engines have a raised dome which is used to increase the compression ratio as well as to control combustion.

In some other engines the piston may be dished to form a desired shape of combustion chamber, jointly with cylinder head. In case of piston containing part of the combustion in its crown, compression ratio can be controlled very accurately but the disadvantage is that in this case much larger amount of heat has to be dissipated through the pistons and rings.

Towards the top of the piston of a few grooves are cut to house the piston rings. The bands left between the grooves are known as lands. These lands support the rings against the gas pressure and guide them so that they may flux freely in the radial direction. The supporting webs transmit the force of explosion directly from the crown to the piston pin bosses thereby relieving the groove portion of the large load and thus by preventing the deformation of the ring grooves.

The part of the piston below the rings is called skirt. Its function is to form a guide suitable

for absorbing side thrust due to gas pressure. The side thrust is produced on account of the inclination of the connecting rod with the cylinder axes. The skirt is provided with the bosses on the inside of the piston pin.

It must be of sufficient length to resist tilting of the piston under load. It is kept quite close fitting in the cylinder but even then it is separated from the cylinder walls by means of lubricating oil film for smooth running. The combustion pressure from the piston crown is transmitted to the connecting rod through webs inside the piston. The bosses form a bearing surface for the rocking motion of the connecting rod. The thick-sectioned webs also form heat paths from the piston crown to the pin bosses and the skirt and thus have to be designed so as to avoid expansion problems.

The distance between the axis of the piston pin and the top of the piston crown is called compression height and determines the compression ratio for a given engine. Thus the same engine a piston with lesser compression height would give lesser compression ratio and vice versa.

The material used for pistons at one time was cast iron which has good wearing qualities. As the technology developed Aluminium alloy containing silicon replaced cast iron as piston material, because of two distinct advantages. Firstly it is as much as three times lighter than the cast iron which makes it is desirable from inertia point of view.

Secondly it possesses a higher thermal conductivity which causes it to run cool. But the aluminium alloy has its own advantages. It is not as a stronger as cast iron and hence thicker sections have to be used. As a result of which the weight of piston is increased. It is seen that an aluminium alloy piston in actual practice is only about 50 percent in weight as compared to its cast iron counterpart. Further aluminium alloy is relatively soft as a result of which fine particles in the lubricating oil become embedded it. Aluminium alloy piston with fine particles embedded in it causes a sort of grinding or abrasion of the cylinder walls.

Another important drawback of using aluminium alloy pistons for cast iron cylinders is their unequal co efficient of expansion which causes engine slaps. Because if the cold clearance is kept just sufficient there is danger of seizure at operating temperatures and if cold clearance is kept large the engine knocks or slaps when cold.

2. PROPOSED MEHODOLOGY
2.1 Modelling Commands used in Solid works
Create the Working Directory-First create the working directory to save the all model in one folde. File – set working directory – select the required folder – ok.

SKETCH- This command is used to create the new sketch like circle, line, rectangle, ellipse, etc, In window select the sketch icon and select the plane or surface want to sketch.

CIRCLE- This command is used to create the circle. Create circle by picking the center point and a point on the circle from Right Toolchest. Pick the origin for the circle's center - pick a point on the circle's edge- click the middle mouse button – ok

ELLIPSE- This command is used to create the ellipse. Create ellipse by picking the center point and a minor radius point and major radius point, the minor and major radius of the ellipse is vertical and horizontal direction depend upon the shape of ellipse we want. Select the ellipse icon from right toolchest- Pick the center for the ellipse – pick the minor radius of ellipse point and pick the major radius of the ellipse- click the middle mouse button – ok

LINE- This command is used to create the line. Create the line by start point and end point.Select the line icon from the right Toolchest – click the start point of the line – click the end point of the circle -enter

ARC- This command is used to create the arc. Create the arc by using three points. The three points are start point, end point and center point of the arc. Select the arc icon from the right Toolchest – click the start point of the arc – click the end point of the arc and click

the middle point of the arc –enter. The dimension of the arc is modified by double click on the arc then the dimension will appear in the pop up box, then provide the value of the arc.

CREATE THE HEXAGON – The hexagon is created by insert foreign data icon in the Right Toolchest. Insert foreign data from Palette into active object - scroll down to see the hexagon - double-click hexagon- Place the hexagon on the sketch by picking a position - with the left mouse button, drag and drop the center of the hexagon at the origin - modify Scale value to the required size – click enter

RECTANGLE- This command is used to create the rectangle and square. Click the rectangle icon in the right Toolchest – click the lower left point of the rectangle and higher right corner of the rectangle we want to draw. After drawing the rectangle the dimension of the rectangle is provided by the pick the dimension command from the dimension icon in the right toolchest of the pro-e software.

DIMENSION- This command is used to provide the dimension of the sketched entities the entities may be circle, line, rectangle, ellipse, etc,..The dimension is provide to the sketch by select the dimension icon from the right tool chest then select the sketched entities and press the middle mouse button to finish the dimensioning.

To change the dimension of the sketched entities by just double click the dimension line of created sketch.

EXTRUDE – This command is used to create the material (to make 3D object from 2D sketch) from the sketched entities. The entities may be circle, line or rectangle, etc,..Select the extrude icon from the right toolchest then select the sketched part in the window, enter the extrude length and press the middle mouse button to finish the extrude command.

REVOLVE- This command is used to create the material from taking the one axis and sketched entities. The axis is the center of the revolved part. The revolve angle should between 0 degree to 360 degree. Select the revolve icon from the right toolchest then select the sketched part and axis of the object in the graphical window, enter the revolve angle and press the middle mouse button to finish the extrude command.

SWEEP FEATURES

The Sweep option extrudes a section along a defined trajectory. The order of operation is to first create a trajectory and then a section. A trajectory is a path along which a section is swept. The trajectory for a sweep feature can be sketched or selected. The Sweep option of protrusion is similar to the Extrude option. The only difference is that in the case of the Extrude option, the feature is extruded in a direction normal to the sketching plane, but in the case of the Sweep option, the section is swept along the sketched or selected trajectory. The trajectory can be open or closed. Normal sketching tools are used for sketching the trajectory.

SWEEP CUT

To create a Sweep Cut feature, the procedure to be followed is the same as that in Sweep Protrusion. The only difference is that in case of cut features, the material is removed from an existing feature. The Cut option can be invoked by choosing Insert > Sweep > Cut from the menu bar. A cut can be a solid swept cut or a thin swept cut.

2.2 ANSYS

ANSYS is an engineering simulation software provider founded by software engineer John Swanson. It develops general-purpose finite element analysis and computational fluid dynamics software. While ANSYS has developed a range of computer-aided engineering (CAE) products, it is perhaps best known for its ANSYS Mechanical and ANSYS Multiphysics products.

ANSYS Mechanical and ANSYS Multiphysics software are non-exportable analysis tools incorporating pre-processing (geometry creation, meshing), solver and post-processing modules in a graphical user interface. These are general-purpose finite

element modeling packages for numerically solving mechanical problems, including static/dynamic structural analysis (both linear and non-linear), heat transfer and fluid problems, as well as acoustic and electro-magnetic problems.

ANSYS Mechanical technology incorporates both structural and material non-linearities. ANSYS Multiphysics software includes solvers for thermal, structural, CFD, electromagnetics, and acoustics and can sometimes couple these separate physics together in order to address multidisciplinary applications. ANSYS software can also be used in civil engineering, electrical engineering, physics and chemistry.

ANSYS, Inc. acquired the CFX computational fluid dynamics code in 2003 and Fluent, Inc. in 2006. The CFD packages from ANSYS are used for engineering simulations. In 2008, ANSYS acquired Ansoft Corporation, a leading developer of high-performance electronic design automation (EDA) software, and added a suite of products designed to simulate high-performance electronics designs found in mobile communication.

And Internet devices, broadband networking components and systems, integrated circuits, printed circuit boards, and electromechanical systems. The acquisition allowed ANSYS to address the continuing convergence of the mechanical and electrical worlds across a whole range of industry sectors.

2.3 FEA

FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.

There are generally two types of analysis that are used in industry: 2-D modeling, and 3-D modeling. While 2-D modeling conserves simplicity and allows the analysis to be run on a relatively normal computer, it tends to yield less accurate results. 3-D modeling, however, produces more accurate results while sacrificing the ability to run on all but the fastest computers effectively. Within each of these modeling schemes, the programmer can insert numerous algorithms (functions) which may make the system behave linearly or non-linearly. Linear systems are far less complex and generally do not take into account plastic deformation. Non-linear systems do account for plastic deformation, and many also are capable of testing a material all the way to fracture.

FEA has been developed to an incredible precision. Present day supercomputers are now able to produce accurate results for all kinds of parameters.

2.4 Nodes and Elements
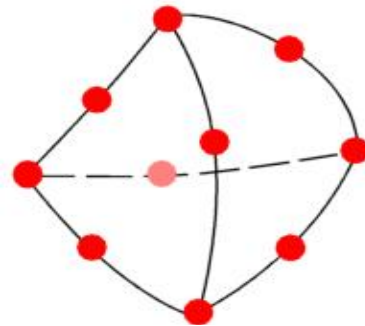
Red dots represent the element's nodes.Elements can have straight or curved edges.Each node has three unknowns, namely, the translations in the three global directions.The process of subdividing the part into small pieces (elements) is called meshing. In general, smaller elements give more accurate results 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.
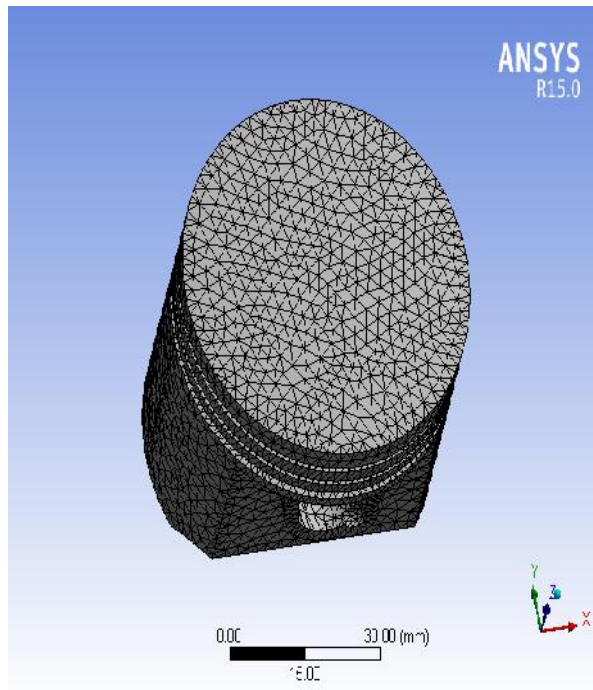
2.5 ANALYSIS: WORKBENCH

MESH OF PISTON IN ANSYS WORKBENCH
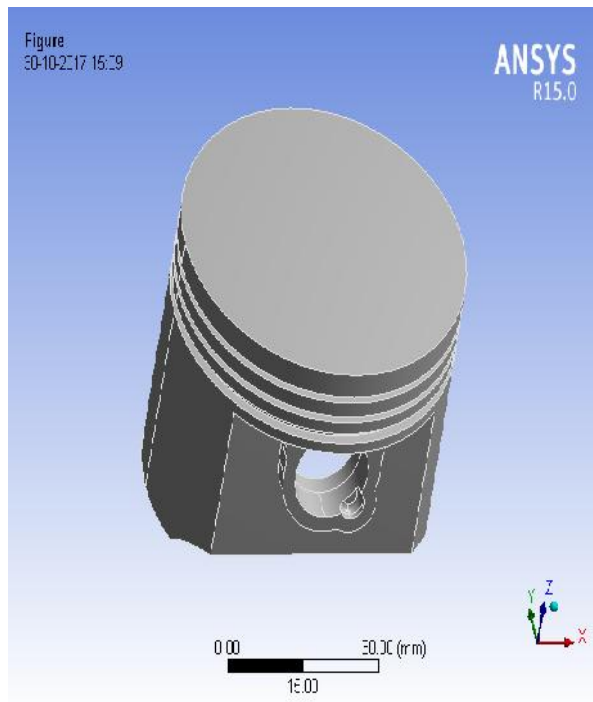
BOUNDARY CONDITIONS OF PISTON IN ANSYS WORKBENCH
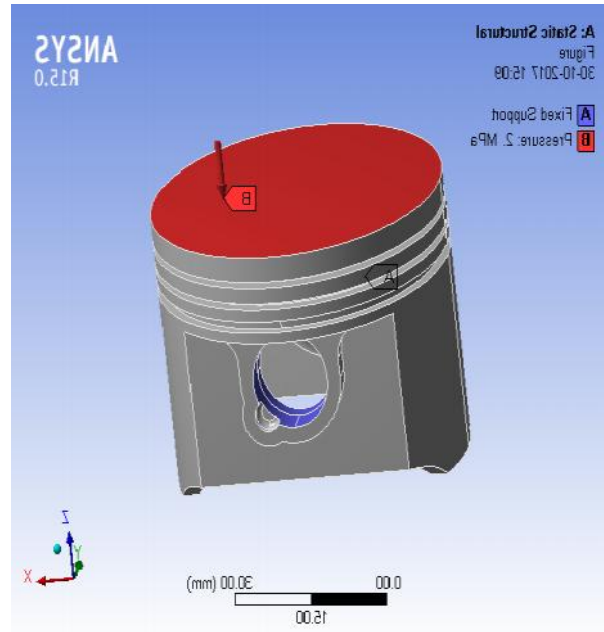
2.6 MATERIAL PROPERTIES

ALUMINIUM

DENSITY	2.77e-006 kg mm^-3
YOUNG'S MODULOUS	71000 MPa
POISSION'S RATIO	0.33
THERMAL CONDUCTIVITY	0.175 W mm^-1C^-1

SILUMIN

DENSITY	2.659e-006 kg mm^-3
YOUNG'S MODULOUS	317000 MPa
POISSION'S RATIO	0.27
THERMAL CONDUCTIVITY	0.134 W mm^-1 C^-1

CONCLUSION

From the above analysis, the weight reduction have be achieved by both design and material optimization.

Strength is been retained by replacing the optimized piston with silumin which is a best material for piston.

From this analysis, we conclude that the best material for piston is silumin as it has low values of deformation.
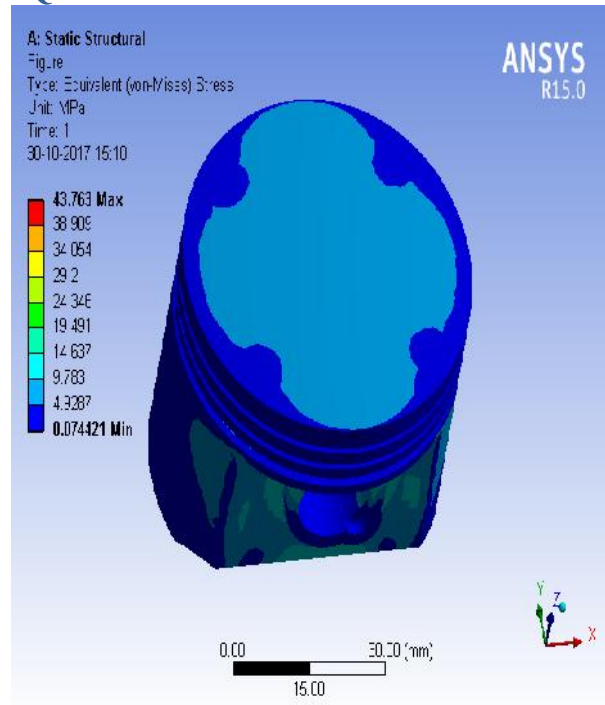
3. EXPERIMENTAL RESULTS
3.1 RESULTS FOR ALUMINIUM ALLOY

TOTAL DEFORMATION
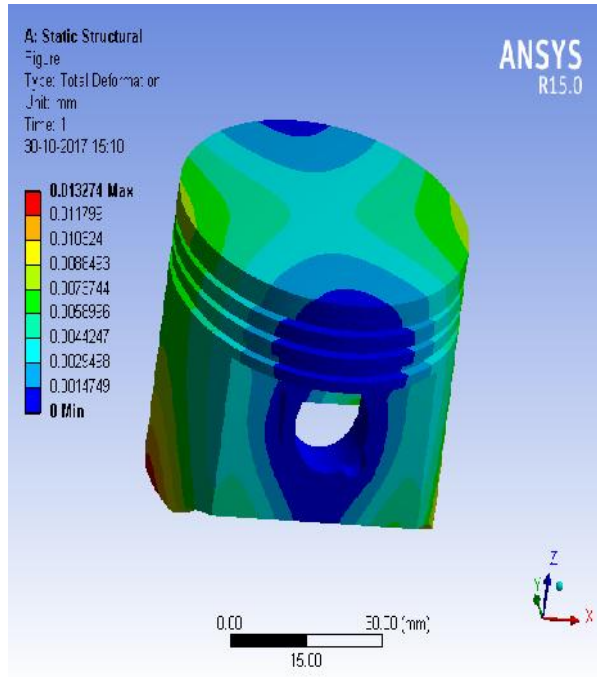
EQUIVALENT ELASTIC STRAIN

EQUIVALENT STRESS