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DESIGN AND ANALYSIS OF THE PISTON BY USING FIVE DIFFERENT MATERIALS

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Abstract:- In the present work describes the stress distribution and thermal stresses of Five different materials for piston by using finite element method (FEM), testing of mechanical properties. The parameters used for the simulation are operating gas pressure, temperature and material properties of piston. The specifications used for this study of these pistons belong to four stroke single cylinder engine of Pulsar 220cc motorcycle. The results predict the maximum stress and critical region on the different materials piston using FEA.Design by using catia v5 software and analysis by using Ansys software in Ansys 16.0 Static and thermal analysis is performed. The suitable material is selected based on results of structural and thermal analysis on these Al-sic graphite, A7075, A6082, A4032, AL-ghy 1250 materials

Keywords: *FEA, Piston, Stress.etc,.*

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I INTRODUCTION

Introduction An internal combustion engine is defined as an engine in which the chemical energy of the fuel is released inside the engine and used directly for mechanical work, as opposed to an external combustion engine in which a separate combustor is used to burn the fuel. The internal combustion engine was conceived and developed in the late 1800s. It has had a significant impact on society, and is considered one of the most significant inventions of the last century. The internal combustion engine has been the foundation for the successful development of many commercial technologies. For example, consider how this type of engine has transformed the transportation industry, allowing the invention and improvement of automobiles, trucks, airplanes and trains. A piston is a component of reciprocating engines, reciprocating pumps, gas compressorsand pneumatic cylinders, among other similar mechanisms. 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. Automobile components are in great demand these days because of increased use of automobiles. The increased demand is due to improved performance and reduced cost of these components. R&D and testing engineers should develop critical components in shortest possible time to minimize launch time for new products. This necessitates understanding of new technologies and quick absorption in the development of new products .A piston is a moving component that is contained by a cylinder and is made gas-tight by piston rings.

In an engine its purpose is to transfer from expanding gas in the cylinder to the crank shaft via piston rod and or connecting rod. As an important part in an engine piston endures the cyclic gas pressure and inertia forces at work and this working condition may cause the fatigue damage of the piston.

A piston is a component of reciprocating IC engines. It is the moving component with in a cylinder and is made of gas-tight by piston rings. In an engine, piston is used 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 the 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 various temperatures at the top of the piston in various strokes. This analysis could be useful for design engineers for modification of piston at the time of design.

There are significant research works proposing, for engine pistons designs, new geometries, materials and manufacturing techniques, and this evolution has undergone with a continuous improvement over the last decades and required thorough examination of the smallest details. Engine pistons are one of the complex components and its damage mechanisms have different origins and are mainly wear, temperature, and fatigue related. Among the fatigue damages, thermal fatigue and mechanical fatigue, either at room or at high temperature, play a prominent role. For mechanical fatigue analysis we have considered vibration analysis of the piston and used finite element method ANSYS 15.0.

1.2WORKING CONDITIONS OF PISTON:

Moment of explosion in combustion chamber of engine, the gas temperature can reach around 2000oC–2200oC,the temperature of the piston head is generally not less than 200oC. Top of the gas under pressure, the pressure for the maximum power stroke, in gasoline engine pressure is up to 3 ~ 5 Mpa and in diesel engine pressure is up to 6 ~ 9 Mpa (standard atmospheric pressure is 0.1 Mpa). High speed of reciprocating motion is about (8 ~ 12 m/s) and the speed is constantly changing.

PISTON FUNCTION:

The piston is an element of power transmission in engine cylinder, the energy bounded up in fuel is rapidly converted into heat and pressure during combustion process. In short period of time heat and pressure valve increase greatly, the piston has a task of converting released energy in to mechanical work. The usual structure of the piston is a hallow cylinder and closed on one side with the segment piston head with ring belt, pin bas and skirt. The piston head transfers the gas forces (fuel air mixture) from combustion chamber resulting pin boss, piston pin, and connecting rod to crankshaft [9].

II LITERATURE REVIEW

An optimized piston which is lighter and stronger is coated with zirconium for bio-fuel.

In this paper[1], the coated piston undergone a Von misses test by using ANSYS for load applied on the top. Analysis of the stress distribution was done on various parts of the coated piston for finding the stresses due to the gas pressure and thermal variations. Vonmisses stress is increased by 16% and deflection is increased after optimization. But all the parameters are well with in design consideration.

Design, Analysis and optimization of piston [2] which is stronger, lighter with minimum cost and with less time. Since the design and weight of the piston influence the engine performance. Analysis of the stress distribution in the various parts of the piston to know the stresses due to the gas pressure and thermal variations using with Ansys.

With the definite-element analysis software, a three-dimensional definite-element analysis [3] has been carried out to the gasoline engine piston. Considering the thermal boundary condition, the stress and the deformation distribution conditions of the piston under the coupling effect of the thermal load and explosion pressure have been calculated, thus providing reference for design improvement. Results show that, the main cause of the piston safety, the piston deformation and the great stress is the temperature, so itis feasible to further decrease the piston temperature with structure optimization.

This paper [4] involves simulation of a 2-stroke 6S35ME marine diesel engine piston to determine its temperature field, thermal, mechanical and coupled thermal-mechanical stress. The distribution and magnitudes of the afore-mentioned strength parameters are useful in design, failure analysis and optimization of the engine piston. The piston model was developed in solid-works and imported into ANSYS for pre-processing, loading and post processing. Material model chosen was 10-node tetrahedral thermal solid 87. The simulation parameters used in this paper were piston material, combustion pressure, inertial effects and temperature.

This work [5] describes the stress distribution of the piston by using finite element method (FEM). FEM is performed by using computer aided engineering (CAE) software. The main objective of this project is to investigate and analyze the stress distribution of piston at the actual engine condition during combustion process.. The report describes the mesh optimization by using FEM technique to predict the higher stress and critical region on the component. The impact of crown thickness, thickness of barrel and piston top land height on stress distribution and total deformation is monitored during the study[6] of actual four stroke engine piston. The entire optimization is carried out based on statistical analysis FEA analysis is carried out using ANSYS for optimum geometry. This paper describes the stress distribution and thermal stresses of three different aluminum alloys piston by using finite element method (FEM). The parameters used for the simulation are operating gas pressure, temperature and material properties of piston. The specifications used for the study of these pistons belong to four stroke single cylinder engine. This topic shows review on design analysis of piston on the basis of improving strength according to the material properties.

Vibhandik et. al . (2014), studied that Design analysis and optimization of piston and deformation of its thermal stresses using CAE tools, he had selected I.C. engine piston from TATA motors of diesel engine vehicle. He had performed thermal analysis on conventional diesel piston and secondly on optimized piston made of aluminum alloy and titanium alloy material. Conventional diesel piston made of structural steel. The main objective of this analysis is to reduce the stress concentration on the upper end of the piston so as to increase life of piston. After the analysis he conclude that titanium has better thermal property, it also help us to improve piston qualities but it is expensive for large scale applications, due to which it can be used in some special cases.

Ch. Venkata Rajam et. al . (2013), focused on Design analysis and optimization of piston using CATIA and ANSYS. He had optimized with all parameters are within consideration. Target of optimization was to reach a mass reduction of piston. In this analysis a ceramic coating on crown is made. In an optimization of piston, the length is constant because heat flow is not affected the length, diameter is also made constant due to same reason. The volume varied after applying temperature and pressure loads over piston as volume is not only depending on length and diameter but also on thickness which is more affected. The material is removed to reduce the weight of the piston with reduced material. The results obtained by this analysis shows that, by reducing the volume of the piston, thickness of barrel and width of other ring lands, Von mises stress is increased by and Deflection is increased after optimization. But all the parameters are with in design consideration.

V. V. Mukkawar et. al . (2015), describes the stress distribution of two different Al alloys by using CAE tools. The piston used for this analysis belongs to four stroke single cylinder engine of Bajaj Pulsar 220 cc motorcycle. He had concluded that deformation is low in AL-GHY 1250 piston as compare to conventional piston. Mass reduction is possible with this alloy. Factor of safety increased up to 27% at same working condition. He used Al-GHY 1250 and conventional material Al-2618 and results were compared, he found that Al-GHY 1250 is better than conventional alloy piston.

Manjunatha T. R. et. al. (2013), underlook specification for both high pressure and low pressure stages and analysis is carried out during suction and compression stroke and identify area those are likely to fail due to maximum stress concentration. The material used foe the cylinder is cast-iron and for piston aluminum alloy for both low and high pressure. He concluded that the stress developed during suction and compression stroke is less than the allowable stress. So the design is safe. Swati S. chougule et. al. (2013), focused on the main objective of this paper is to investigate and analyze the stress distribution of piston at actual engine condition during combustion process the parameters used for simulation is operating gas pressure and material properties of piston. She concluded that there is a scope for reduction in a scope for reduction in thickness of piston and therefore 0ptimization of piston is done with mass reduction by 24.319% than non-optimized piston. The static and dynamic analysis is carried out which are well below the permissible stress value. The study of Lokesh Singh et. al . (2015) is related to the material for the piston is aluminumsilicon composites. The high temperature at piston head, due to direct contact with gas, thermal boundary conditions is applied and for maximum pressure mechanical boundary conditions are applied. After all these analysis all values obtained by the analysis is less than permissible value so the design is safe under applied loading condition. The study of R.

C. Singh et. al. (2014), discussed about failure of piston in I.C. engines, after all the review, it was found that the function coefficient increases with increasing surface roughness of liner surface and thermal performance of the piston increases. The stress values obtained from FEA during analysis is compared with material properties of the piston like aluminum alloy zirconium material. If those value obtained are less than allowable stress value of material then the design is safe.

III PROJECT OVER VIEW

3.1PISTON DESIGN FEATURES

1. Have sufficient mechanical strength and stiffness.
2. Can effectively block the heat reached the piston head.

3. High temperature corrosion resistance.

4. Dimensions as compact as possible, in order to reduce the weight of the piston.

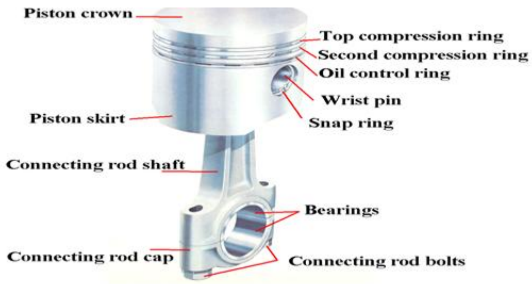

FIGURE 1: PISTON

***3.2 OBJECTIVES*:**

1. Analytical design of piston using pulsar 220cc petrol engine specifications.

2. Obtaining design of piston using catia v5 and then imported in Ansys 16.0

3. Meshing of design model using ANSYS 16.0

4. Analysis of piston by static analysis and thermal analysis method.

5. Comparing the performance of five different materials aluminum alloys piston under static and thermal analysis process.

6. Identification of the suitable aluminum alloy material for manufacturing of the piston under specified conditions.

3.2.1METHODOLOGY:

1. *Analytical design of piston, using specification of four stroke single cylinder engine of Bajaj Kawasaki motorcycle created.*

2.Creation of 3D model of piston using CATIA V5 and then imported in ANSYS 14.5.

3. Analysis of piston using FEA method.

4.Comparative performance of Al alloy piston.

5.Select the best Material for piston material

6.Based on the stresses, deformation, shear stress, Temperature distribution and Total heat flux.

3.3 DESIGN CONSIDERATIONS FOR A PISTON

In designing a piston for an engine, the following points should be taken into consideration:

- It should have enormous strength to withstand the high pressure.
- It should have minimum weight to withstand the inertia forces.
- It should form effective oil sealing in the cylinder.
- It should provide sufficient bearing area to prevent undue wear.
- It should have high speed reciprocation without noise.
- It should be of sufficient rigid construction to withstand thermal and mechanical distortions.
- It should have sufficient support for the piston pin.

***3.4 ENGINE SPECIFICATIONS*:**

The engine used for this work is a single cylinder four stroke air cooled type pulsar 220cc petrol engine. The engine specifications are given in below table Table

PARAMETERS	VALUES
Engine Type	Four stroke, Petrol engine
Induction	Air cooled type
Number of cylinders	Single cylinder
Bore	67 mm
Stroke	62.4 mm
Length of connecting rod	124.8 mm
Displacement volume	220 cm3
Compression ratio	9.5+/-0.5 : 1
Maximum power	15.510 kW at 8500 rpm
Maximum Torque	19.12 Nm at 7000 rpm
Number of revolutions/cycle	2

Table 1 ENGINE SPECIFICATIONS

***3.5 PROBLEM IDENTIFICATION*:**

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 working condition of the piston of an internal combustion engine is so worst are high chances of failure of piston due to wear and tear. So there is necessary to analyze area of maximum stress concentration, strain, deformation and temperature distribution and heat flux on piston. The objective of the present work is to design and analysis of piston madeUP of A4032, Al-GHY1250, AL6082, AL7075,ALSIC GRAPHITE.

IV INTRODUCTION TO CATIA V5R20

4.1 INTRODUCTION

Welcome to **CATIA (Computer Aided Three Dimensional Interactive Application)**. As anew user of this software package, you will join hands with thousands of users of this high-end CAD/CAM/CAE tool worldwide. If you are already familiar with the previous releases, you can upgrade your designing skills with the tremendous improvement in this latest release.

CATIA V5, developed by Dasssault Systems, France, is a completely re-engineered, Next-generation family of CAD/CAM/CAE software solutions for Product Lifecycle Management. Through its exceptionally easy-to-use and state-of-the-art user interface, CATIA V5 delivers innovative technologies for maximum productivity and creativity, from the inception concept to the final product. CATIA V5 reduces the learning curve, as it allows the flexibility of using feature-based and parametric designs.

CATIA V5 provides three basic platforms: P1, P2, and P3. P1 is for small and medium-sized process-oriented companies that wish to grow toward the large scale digitized product definition.

P2 is for the advanced design engineering companies that require product, process, and resource modeling. P3 is for the high-end design applications and is basically for Automotive and Aerospace Industry, where high quality surfacing or Class-A surfacing is used. The subject of interpretability offered by CATIA V5 includes receiving legacy data from the other CAD systems and even between its own product data management modules. The real benefit t is that the links remain associative. As a result, any change made to this external data gets notified and the model can be updated quickly.

CATIA V5 serves the basic design tasks by providing different workbenches. A workbench is defined as a specified environment consisting of a set of tools that allows the user to performspecific design tasks. The basic workbenches in CATIA V5 are **Sketcher,Part Design**, **Wireframe andSurface Design**, **Assembly Design**,**and Drafting**.

4.6 DESIGNING OF THE MODEL: DESIGN PROCEDURE IN CATIA WORK BENCH:

Create the half piston profile in sketcher workbench next go to exist work bench (part design) now go to the sketched based features and go to shaft option apply angle 360 after create the planes offset to xy planes create the circles and apply pocket around the up to surface now go to mirror option apply mirror finally as shown the figure below:

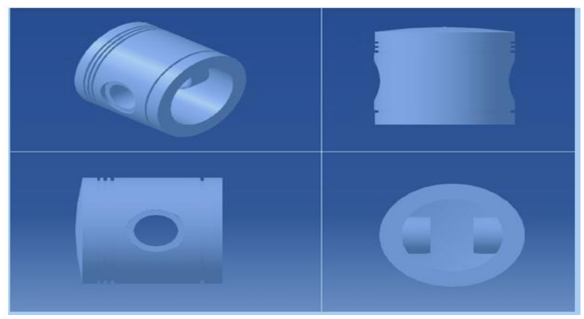

Figure 2:DIFFERENT VIEWS OF PISTON IN CATIA WORK BENCH

V INTRODUCTION TO ANSYS

ANSYS is a large-scale multipurpose finite element program developed and maintained by ANSYS Inc. to analyze a wide spectrum of problems encountered in engineering mechanics**.**

5.1 PROGRAM ORGANIZATION:

The ANSYS program is organized into two basic levels:

- Begin level
- Processor (or Routine) level

The Begin level acts as a gateway into and out of the ANSYS program. It is also used for certain global program controls such as changing the job name, clearing (zeroing out) the database, and copying binary files. When you first enter the program, you are at the Begin level.

At the Processor level, several processors are available. Each processor is a set of functions that perform a specific analysis task. For example, the general pre-processor (PREP7) is where you build the model, the solution processor (SOLUTION) is where you apply loads and obtain the solution, and the general postprocessor (POST1) is where you evaluate the results of a solution. An

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additional postprocessor, POST26, enables you to evaluate solution results at specific points in the model as a function of time.

5.2MATERIAL MODELS:

ANSYS allows several different material models like:

- 1.Linear elastic material models (isotropic, orthotropic, and anisotropic).

2.Non-linear material models (hyper elastic, multi linear elastic, inelastic and Visco elastic)

3. Heat transfer material models (isotropic and orthotropic)

4. Temperature dependent material properties andCreep material models

5.3LOADS:

The word loads in ANSYS terminology includes boundary conditions and externally or internally applied forcing functions, as illustrated in Loads. Examples of loads in different disciplines are:

VI FINITE ELEMENT METHOD

6.1 INTRODUCTION

The Basic concept in FEA 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 element.

The Finite Element Method is a mathematical tool for solving ordinary and partial differential equations. Because it is a numerical tool, it has the ability to solve the complex problems that can be represented in differential equations form. The applications of FEM are limitless as regards the solution of practical design problems.

6.2 BASIC STEPS IN FEA

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

Discretization of the domain: The task is to divide the continuum under study into a number of subdivisions called element. Based on the continuum it can be divided into line or area or volume elements.

Application of Boundary conditions: From the physics of the problem we have to apply the field conditions i.e. loads and constraints, which will help us in solving for the unknowns.

Assembling the system equations: This involves the formulation of respective characteristic (Stiffness in case of structural) equation of matrices and assembly.

Solution for system equations: Solving for the equations to know the unknowns. This is basically the system of matrices, which are nothing, but a set of simultaneous equations is solved.

Viewing the results: After the completion of the solution we have to review the required results.

6.3 BOUDARY CONDITIONS AT STATIC & THERMAL ANALYSIS

BOUNDARY CONDITIONS AND LOADS AT STATIC ANALYSIS:

1. Maximum pressure load at the top surface of the piston crown 13.65 Mpa

2. Temperature at the top surface of the piston crown 800^0C

3. Piston pin holes are fixed DX = DY = DZ = 0

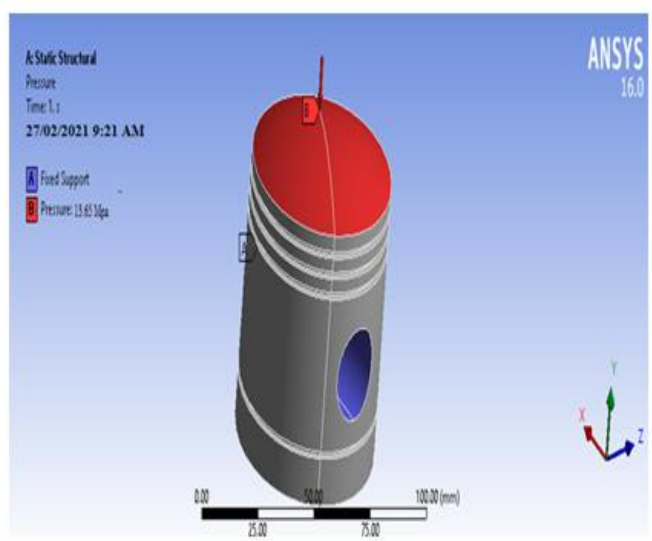

Figure 3:Boundary condition of static analysis

BOUNDARY CONDITIONS AND LOADS AT THERMAL ANALYSIS:

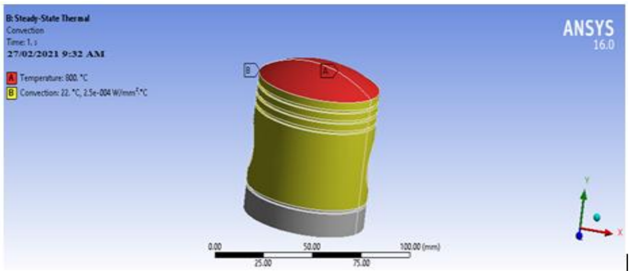

Figure 4: Boundary conditions of thermal analysis

VII RESULTS AND DISCUSSIONS

The constructed piston in catia is analyzed using ANSYS V16.0 and the results are depicted below. Combustion of gases in the combustion chamber exerts pressure on the head of the piston during power stroke. Fixed support has given at surface of pinhole. Because the piston will move from top dead center to bottom dead centre with the help of fixed support at pinhole.

STATIC & THERMAL ANALYSIS

***7.1: AL-SIC GRAPHITE*:**

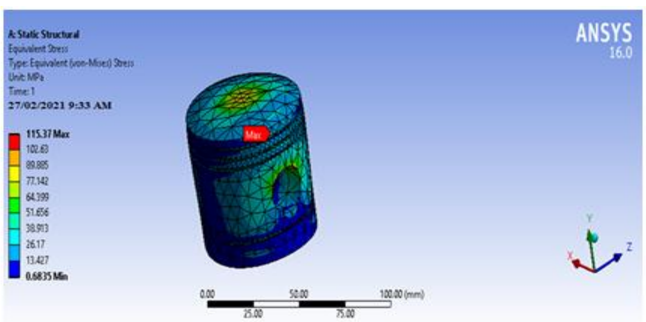

Figure5: Stress of AL-SIC graphite material

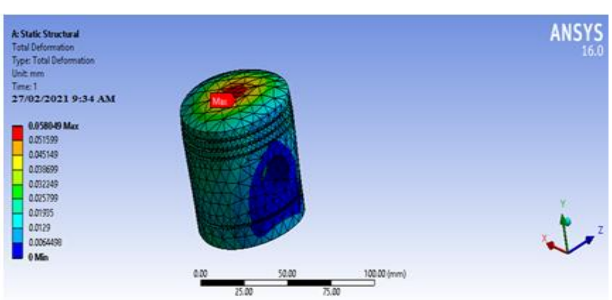

Figure 6:Total deformation of AL-SIC graphite material

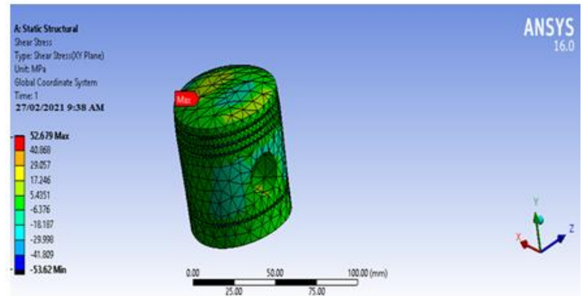

Figure 7: Shear stress of AL-SIC graphite material

7.2 AL4032 MATERIAL:

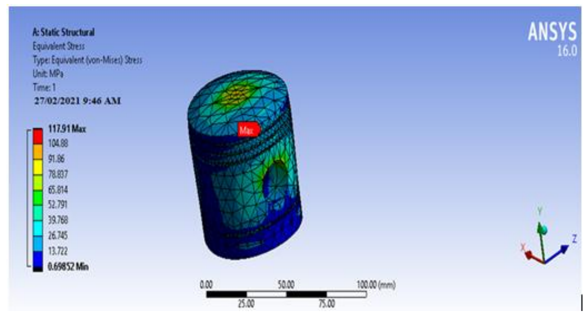

Figure 8:Vonmises stress of AL4032 Material

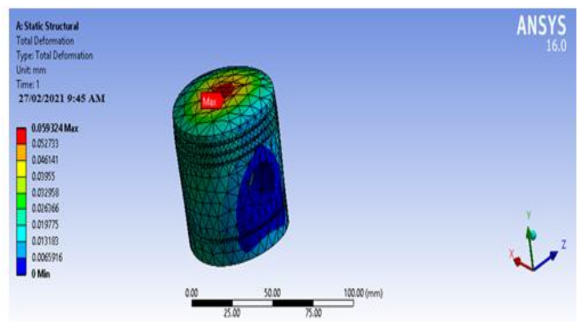

Figure 9: Total deformation of AL4032 Material

7.3 AL6082 MATERIAL:

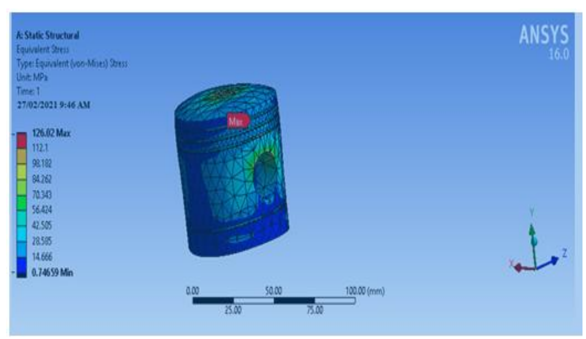

Figure 10: Von-mises stress of AL6082 Material

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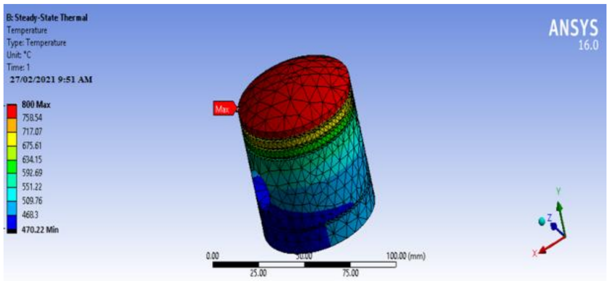

Figure 11: Temperature distribution of AL6082 Material

7.4 AL7075 MATERIAL:

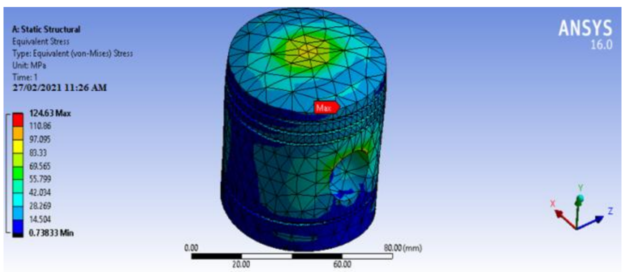

Figure 12: Von-misses stress of AL7075 Material

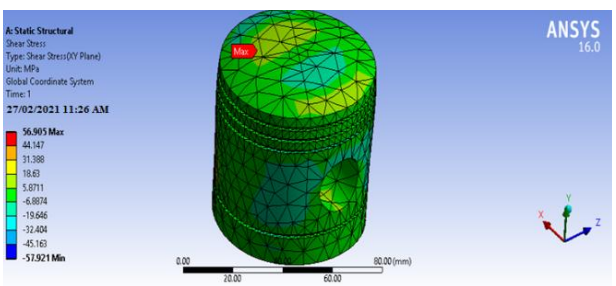

Figure 13: Shear stress of AL7075 Material

7.6 GRAPHS :

7.6.1STATIC STRUCTURAL ANALYSIS :

The static structural analysis of Al-sic graphite, A7075, A6082, A4032, AL-ghy 1250are done and results are obtained for Equivalent (Von-Mises) stress, shear stress, total deformation, heat flux, and temperature . These results are plotted graphically and a comparison is made between these results.

7.7 VON-MISES STRESS(MPA):

we can observe that in case of equivalent (von-mises) stress, piston made of Al-sic graphite is found to have least stress of 115.37 MPa in comparison with remaining materials. Highest stress of 126.02MPa is observed Al6082 Material.

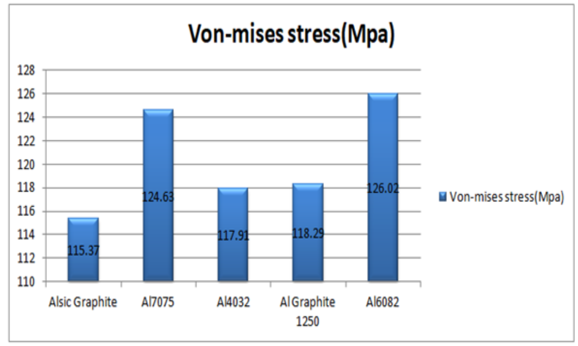

Figure 14: Von-misses stress graph

7.8 SHEAR STRESS GRAPH:

we can observe that in case of equivalent Shear stress , piston made of Al-sic graphite is found to have least shear stress of 52.679 in comparison with remaining materials including the present material. Highest shearstress of AL6082 is observed.

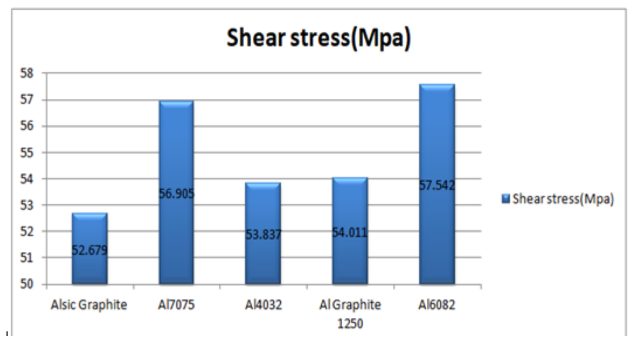

Figure 15: Equivalent Shearstress graph

7.9TOTAL DEFORMATION

we can observe that in case of total deformation , piston made of Al-sic graphite is found to have least total deformation of 0.058 in comparison with remaining materials including the present material. Highest total deformation of 0.063mmis observed.

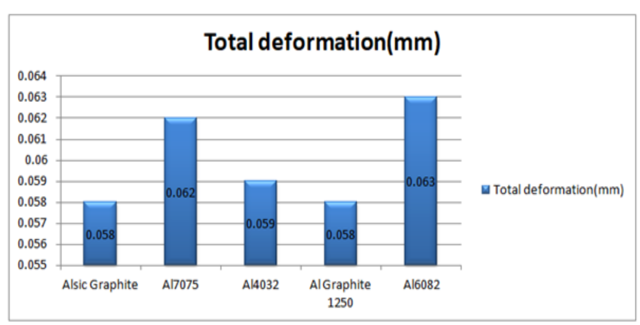

Figure 16: Total deformation graph

VIII CONCLUSION

Modeling and analysis of piston is done . Modeling of piston is done in catia 2016 design software by using various commands.The catia part file is converted into IGS file and imported to ansys workbench. First Static structural analysis is carried out on piston at 13.65MPa pressure with three different materials, such as grey cast iron, aluminum alloy and al-sic graphite in ansys workbench.Pistons made of different aluminum alloys like Al-sic graphite, A7075, A6082, A4032, AL-GHY 1250 were designed and analyzed successfully. In static analysis, and in thermal analysis the pistons were analyzed to find out the equivalent (von-mises) stress, equivalent elastic strain, total deformation heat flux and temperature distribution in all conditions ALSIC material is better compared to the remaining materials because of From above results we can conclude that ALSIC alloy piston is better than conventional alloy piston.

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