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# Design and Simulation of Al-SIC Graphite Piston and Comparison with Alluminium Alloy, Gray-Cast Iron Pistons

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#### **ABSTRACT:**

Engines are power source to the automobiles. Engine that converts combustion of fuel gas energy in to some mechanical power. The main components of engines are piston, cylinder block, cylinder head, crank shaft, connecting rod, cam shaft, and there are other components. In this project we are studying about the structural analysis on piston .Piston that transfer the combustive gases power to the connecting rod. To improve the efficiency of the engine there is a need to study about the piston. Pistons that are usually made up with alloy steels that shows the grate resistant against thermal loads and structural loads. Alloy steel pistons are light weight in nature and they can with stand against the high compressive and tensile loads. In the project we design a piston by using ANSYS software 2016 and we did the structural and thermal load analysis on piston by using solid works

#### **Key Words:**

ANSYS SOFTWARE, Alloy Material of Al, Sic, Gray-Cast.

#### I. INTRODUCTION:

A history of development to know about. The compact, well-toned, powerful and surprisingly quiet engine that seems to be purr under your vehicle's hood just wasn't the tame beast it seems to be now. It was loud, it used to roar and it used to be rather bulky. In fact, one of the very first engines that had been conceived wasn't even like the engine we know so well of today.

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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 development of many successful 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.

Internal combustion engines can deliver power in the range from 0.01 kW to 20x103 kW, depending on their displacement. The complete in the market place with electric motors, gas turbines and steam engines. A piston is a component of reciprocating engines, reciprocating pumps, gas compressors and 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. In a pump, the function is reversed and force is transferred from the crankshaft to the piston for the purpose of compressing or ejecting the fluid in the cylinder. In some engines, the piston also acts as a valve by covering and uncovering ports in the cylinder wall.



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#### II. LITERATURE SURVEY

The cast iron pistons were superseded by aluminum alloy piston around the year 1920 (Sarkar 1975). Cole G.S. and Sherman A.M.(1995) explained that a considerable interest had been grown in replacing cast iron and steel in automotive component like piston with light weight aluminum alloy casting to improve the performance and efficiency. Haque M.M and Young J.M. (2001) referred the low expansion group of aluminum–silicon alloy as piston alloy, since this group of alloy provides the best overall balance of properties. Near eutectic aluminum silicon piston alloy exhibit complex fatigue behavior due to their multi component microstructure.

#### **TYPES OF ENGINES**

Since the invention of the internal combustion engine many pistons-cylinder geometries have been designed. The choice of given arrangement depends on a number of factors and constraints, such as engine balancing and available volume:

- In line
- horizontally opposed
- radial
- V

#### III. PISTON:

Piston is one of the main parts in the engine. Its purpose is to transfer force from expanding gas in the cylinder to the crankshaft via a connecting rod. Since the piston is the main reciprocating part of an engine, its movement creates an imbalance. This imbalance generally manifests itself as a vibration, which causes the engine to be perceivably harsh. The friction between the walls of the cylinder and the piston rings eventually results in wear, reducing the effective life of the mechanism. The sound generated by a reciprocating engine can be intolerable and as a result, many reciprocating engines rely on heavy noise suppression equipment to diminish droning and loudness. To transmit the energy of the piston to the crank, the piston is connected to a connecting rod which is in turn connected to the crank.

Because the linear movement of the piston must be converted to a rotational movement of the crank, mechanical loss is experienced as a consequence.



Fig. 1: Piston

#### **PISTON RINGS**

A ring groove is a recessed area located around the perimeter of the piston that isused to retain a piston ring. Ring lands are the two parallel surfaces of the ringgroove which function as the sealing surface for the piston ring. A piston ring is an expandable split ring used to provide a seal between the piston an the cylinder wall.Piston rings are commonly made from cast iron. Cast iron retains the integrity of its original shape under heat, load, and other dynamic forces. Piston rings seal the combustion chamber, conduct heat from the piston to the cylinder wall, and return oil to the crankcase. Piston ring size and configuration vary depending on engine design and cylinder material.



**Fig.2 : Piston Rings** 

A piston pin bore is a through hole in the side of the piston perpendicular to piston travel that receives the piston pin. A piston pin is a hollow shaft that connects the small end of the connecting rod to the piston.



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The skirt of a piston is the portion of the piston closest to the crankshaft that helps align the piston as it moves in the cylinder bore. Some skirts have profiles cut into them to reduce piston mass and to provide clearance for the rotating crankshaft counterweights.

#### IV. TYPES AND MATERIAL FOR PISTONS

The pistons are classified in to two types they are 2 stroke pistons and 4 stroke pistons. The most commonly used materials for pistons of I.C. engines are cast iron, aluminum alloy (cast aluminum, forged aluminum), cast steel and forged steel.



Fig.3:TWO stroke piston



Fig.4: FOUR stroke piston

a)For a cast iron piston, the temperature at the centre of the piston head (TC) is about 425°C to 450°C under full load conditions and the temperature at the edges of the piston head (TE) is about 200°C to 225°C. b)For aluminum alloy pistons, TC is about 260°C to 290°C and TE is about 185°C to 215°C. Coatings for rings are widely used. One example of such a coating is chromium, which is used in abrasive and corrosive conditions were running conditions are severe. Hard chrome plating is particularly relevant for the compression ring.

#### **Preparation of Al-Sicgraphite's Specimen**

Stir Casting technique is a method of producing composite materials, in which a scattered stage (fired particles, short filaments) is blended with a liquid metal by method for mechanical mixing with the help of stirrer. The liquid state composite material is cast by permanent die casting method. In this Stir casting technique has been used to prepare the work-piece samples of Al-Sic-Graphite hybrid metal matrix Composite material and accomplish the required properties of that composite material.



Fig.5:Preparation of Al-Sic graphite Specimen

#### V. THEORETICAL ANALYSIS

The function of the piston is to absorb the energy released after the Air/Fuel mixture is ignited by the high temperature .The piston then accelerates producing useful mechanical energy. To accomplish this, the piston must be sealed so that it can compress the mixture of air and fuel and does not allow gases out of the combustion chamber. This can be accomplished by the piston rings which also help to prevent oil from entering the combustion chamber from underneath the piston from contacting the cylinder wall. Less contact area between the cylinder and piston reduces friction, thereby increasing efficiency. In the previous works a paper analyzed thermally pistons made from cast iron and aluminum alloy.



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Their results are indicated that the thermal flux is very high in the center of piston crown and it is low at the piston skirt. The temperature of the cast iron piston is higher than the temperatures of aluminum alloy piston by a value about to 40-80 °C.

#### **Calculations of Heat Transfer Coefficients**

Stress calculation

1. Stress on Piston Crown

- $6b = \frac{3pD^2}{16tH^2}$
- 2. Thermal Stress

6t= E\* Coefficient of thermal Expansion\*Temp. Difference 3. Thermo-mechanical Stress, 6tm= 6b+6t

#### VI. SOLID WORKS

Solid works mechanical design automation software is a feature-based, parametric solid modeling design tool which advantage of the easy to learn windows <sup>TM</sup> graphical user interface. We can create fully associate 3-D solid models with or without while utilizing automatic or user defined relations to capture design intent. Parameters refer to constraints whose values determine the shape or geometry of the model or assembly. Parameters can be either numeric parameters, such as line lengths or circle diameters, or geometric parameters, such as tangent, parallel, concentric, horizontal or vertical, etc. Numeric parameters can be associated with each other through the use of relations, which allow them to capture design intent.

#### VII. MODELING OF PISTON



Fig.6: Sketch with dimensions of a piston

#### **STEP BY STEP PROCEDURE**

1. Open the solid works and design the piston as per given dimensions

Take a new file and select front plane and draw sketch as follows







3. Now go to features and select reference geometry for selecting a plane which is parallel to the face (as it is not planar we cannot draw the following sketch without selecting the reference plane)





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4. Four views of piston:



#### FINITE ELEMENT ANALYSIS

Finite Element Analysis (FEA) is a computer-based numerical technique for calculating the strength and behavior of engineering structures. It can be used to calculate deflection, stress, vibration, buckling behavior and many other phenomena. It also can be used to analyze either small or largescale deflection under loading or applied displacement. It uses a numerical technique called the finite element method (FEM).

### BASIC CONCEPTS OF ANALYSIS

#### Meshing

The software uses the Finite Element Method (FEM). FEM is a numerical technique for analyzing engineering designs. FEM is accepted as the standard analysis method due to its generality and suitability for computer implementation. FEM divides the model into many small pieces of simple shapes called elements effectively replacing a complex problem by many simple problems that need to be solved simultaneously.



Fig.7: CAD model of a part

# THE SOFTWARE OFFERS THE FOLLOWING TYPES OF STUDIES

Study type	Study icon		
Static	¢*	Modal Time History	~
Frequency	۹Ÿ	Harmonic	₽
Buckling	ঝু	Random Vibration	₩
Thermal	ঝ	Response Spectrum	~
Design Study	¶.¶	Drop Test	4
Nonlinear Static	Ľ <u>I</u>	Fatigue	æ
Nonlinear Dynamic	⊭ <sub>⊉</sub>	Pressure Vessel Design	4

# TABLE 1: Types of StudiesMATERIAL PROPERTIES

#### 1. Grey Cast Iron

Density			7	7.2e-009 tonne mm^-3	
Coefficient of Thermal Expansion			1.1e-005 C^-1		
Specific Heat			4.47e+008 mJ tonne^-1 C^-1		
Thermal Conductivity			5.2e-002 W mm^-1 C^-1		
Resistivity			9.6e-005 ohm mm		
Temperature C	Young's Modulus MPa	Poisson's Ratio		Bulk Modulus MPa	Shear Modulus MPa
	1.1e+005	0.28		83333	42969

#### 2. Aluminum Alloy

Density			2.77e-009 tonne mm^-3		
Coefficient of Thermal Expansion			2.3e-005 C^-1		
Specific Heat			8.75e+008 mJ tonne^-1 C^-1		
Temperature	Young's Modulus	Poisson's	Bulk Modulus	Shear Modulus	
C	MPa	Ratio	MPa	MPa	
	71000	0.33	69608	26692	

#### 3. al-sic-graphite

Density 2.7114e-009 tonne mm^-3

Temperature C	Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa
	74000	0.34	77083	27612



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#### VIII. Ansys Analysis On Piston STATIC ANALYSIS ON PISTON

With the help of piston pin, piston and connecting rod are associated and no relative motion between piston pin and piston. Hence the piston pin holes are fully constrained for all degrees of freedom (DOF)

#### LOADING AND BOUNDARY CONDITION

In this research the effect of side thrust force is negligible but in reality it have some impact on deformation and stress on piston but pressure force and inertia force are taken in record and assumed that temperature is uniform. The pressure force 1.5 MPa is applied on piston crown.



#### **MESHING**

The piston is meshed by using the hyper mesh soft ware because of easy to mesh compared to ansys software. It comprises of 22970 nodes, 18845 elements and element size 4.



# IX. RESULTS1. MATERIAL: GREY CAST IRONA. MAXIMUM STRESS





Volume No: 3 (2016), Issue No: 10 (October) www.ijmetmr.com

October 2016



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#### C. MAXIMUM STRAIN



**D. MAXIMUM SHEAR STRESS** 



3. MATERIAL: AL-SIC

#### A. MAXIMUM STRESS



#### **B. TOTAL DEFORMATION**





#### THERMAL ANALYSIS ON PISTON

Maximum temperature given at piston crown 400deg



#### Minimum temperature given at bottom face 30deg



# MATERIAL: GREY CAST IRON

#### Temperature Distribution



#### **Heat Flux**



#### MATERIAL: ALUMINUM ALLOY Temperature Distribution



#### Volume No: 3 (2016), Issue No: 10 (October) www.ijmetmr.com

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#### **Heat Flux**



#### MATERIAL: AL-SIC

#### **Temperature Distribution**



#### **Heat Flux**



#### STATIC STRUCTURAL ANALYSIS RESULTS

Material	Maximum stress	Total	Maximum strain	Maximum shear
		deformation		stress
Grey cast iron	37.999	0.034804	0.00066503	18.363
Aluminum alloy	35.905	0.036491	0.00069221	18.476
Al-sic-graphite	35.499	0.024202	0.00046895	20.15

#### STEADY STATE THERMAL RESULTS

Material	Heat flux
Grey cast iron	0.55471
Aluminum alloy	1.8145
Al-sic graphite	1.9201

**ANALYSIS** 

#### CONCLUSION

- Modeling and analysis of piston is done
- Modeling of piston is done in solid works 2016 design software by using various commands
- The solid works part file is converted into IGS file and imported to anys workbench.
- First Static structural analysis is carried out on piston at 1.5MPa pressure with three different materials, such as grey cast iron, aluminum alloy and al-sic graphite in ansys workbench.
- Maximum stress, deformation, maximum strain and maximum shear stress are noted and tabulated
- Then steady state thermal analysis is carried out at maximum temperature 400deg and minimum temperature 30deg for the above three various materials.
- Temperature distribution and heat flux are noted for three different materials and tabulated.
- From the tables it is concluded that the aluminum silicon carbide graphite (Al-SiC Graphite) is showing efficient results
- Hence Al-SiC-Graphite is preferable among the three applied materials

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