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DESIGN AND THERMAL ANALYSIS OF COMPOSITE PISTON

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ABSTRACT

An Internal Combustion Engine is a kind of prime mover that converts chemical energy into mechanical energy. In this paper the piston of internal combustion engine is designed and thermally analyzed between Aluminium Alloy and Aluminium-SiC composite. The 3D model of composite piston was made using Creo 1.0 and Structural and thermal analysis were done using ANSYS R14. Compared to Aluminium, Aluminium-Silicon Carbide has lesser deformation, lesser stress and good temperature distribution.

KEYWORDS

Piston, Aluminium-Silicon Carbide, ANSYS, Deformation and Temperature distribution.

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INTRODUCTION[1-6]

Piston

A piston is an important component of an internal combustion engine. It is the moving component that is contained by a cylinder and is made gas-tight by piston rings. In an engine, the purpose of the piston is to convert the expanding gas in the cylinder and transfer that force to the crankshaft via piston rod 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 like two stroke engines, the piston acts as a valve by covering and uncovering ports present in the cylinder wall.

ALUMINIUM GENERAL INFORMATION

Chemical definition

Aluminium: a chemical element (symbol Al) with an atomic number of 13, an atomic weight of 26.98, and a single stable isotope: 27. Aluminium is a soft, silvery metal. Relative density: 2.70 kg/dm3. Melting point: 660°C. When aluminium oxide made contact with the air, a thin layer is formed to protect the metal from the oxidation. Aluminium is an important metal because it combines readily with other substances, for the creation of aluminum compounds. Aluminium forms several alloys, including copper, magnesium and silicon.

ALUMINIUM SILICON CARBIDE ALLOY

The tensile and fatigue strength of the Aluminium alloys are not suitable for high temperature when it is ranging from 500F to 700F. So we are reinforcing silicon carbide in aluminium alloy to make the pistons to withstand high temperatures which has high melting temperature when compared with aluminium alloy. Aluminium silicon carbide alloy shows good enhancement of the mechanical properties like ultimate tensile strength, yield strength, hardness and ductility at elevated temperatures.

MODELING

Model is a Representation of an object, a system, or an idea in some form other than that of the entity itself. Some of the modelling softwares are,

- Solid works
- Creo
- CATIA
- Unigraphics, etc

We created model Piston using CREO software. The Creo software is used by discrete manufacturers for mechanical engineering, designing and in the manufacturing field. The parametric modelling approach uses parameters, dimensions, features, and relationships to capture intended product behaviour and create a recipe which enables design automation and the optimization of design and product development processes. Creo Elements/Pro offers a wide range of tools in the designing field to enable the digital representation of the product that have to be designed. In addition to the general geometry tools there is also the ability to generate geometry of other integrated design disciplines such as industrial and standard pipe work and complete wiring definitions. The models are shown below…

FINITE ELEMENT METHOD

The Finite Element Method (FEM) is a reliable numerical technique for analyzing engineering designs. FEM replaces a complex problem with many simple problems. It divides the model into many small pieces of simple shapes called elements. Elements share common points called nodes. The behaviour of these elements is well-known under all possible support and load scenarios. The motion of each node is fully described by translations in the X, Y, and Z directions. These are called degrees of freedom (DOFs). Analysis using FEM is called Finite Element Analysis (FEA).

Basic components of fea

- Pre-processor
- Solution
- Post processor
- General post processor

Advantages of fea

- Applicable to any field problem such as heal transfer stress analysis, magnetic field etc.
- There is no matrix restriction.
- Approximately it is easily improved by grading the mesh so that more elements appear where field gradients are high and more resolution is required.
- Compounds that have different behaviour and different mathematical description can be solved.
- FEA structure closely resembles closely the actual body or region to be analyzed.

Uses of fea

- Structural analysis
- Heat transfer analysis
- Fluid flow analysis
- Mass transport

Ansys

ANSYS is a complete FEA simulation software package developed by ANSYS Inc - USA. It is used by engineers worldwide in virtually all fields of engineering.

- Structural
- Thermal
- Fluid (CFD, Acoustics, and other fluid analyses)
- Low and High-Frequency Electromagnetic.

Procedure

Every analysis involves three main steps:

- Pre-processor
- Solver
- post processor

PERFORMING A STATIC ANALYSIS

- The procedure for a static analysis consists of these tasks:
- Build the Model
- Set Solution Controls
- Set Additional Solution Options
- Apply the Loads
- Solve the Analysis
- Review the Results

MODELING COMPOSITES

Composites are somewhat more difficult to model than an isotropic material such as iron or steel. In this case, a special care should be taken for defining the properties and orientations of the various layers because each and every layer may have different orthotropic material properties. In this section, we will concentrate on the following aspects of building a composite model:

- Choosing the proper element type
- Defining the layered configuration
- Specifying failure criteria
- Following modelling and post-processing guidelines.

ANALYSIS USING ANSYS

The following figure shows the imported model of Piston.

PISTON SPECIFICATIONS

Diameter of the piston (D)	-	50mm
Stroke length of the piston (L= 1.5D)	-	15mm
Length of the piston (l)	-	71mm

Pressure acting on the piston head (Pm) - 18 N/mm^2

MESHING USING ANSYS

In preparing the model for analysis, Ansys subdivides the model into many small tetrahedral pieces called elements that share common points called nodes.

- 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.

After meshing the model the boundary conditions are applied properly then the final results are obtained. The following figure shows the final results of structural analysis for different materials

STATIC STRUCTURAL ANALYSIS

A static structural analysis is the common application of finite element method that determines the displacements, stresses, strains, etc. in a component that is subjected to load. A Steady loading and response conditions are obtained as the load on the component vary slowly with respect to time. Here, the ANSYS software is used to perform the static structural load analysis on the component. The different types of loads that can be applied to perform a static analysis are,

- Temperatures
- Externally applied force and pressure

- Steady-state inertial forces
- Imposed or nonzero displacements.

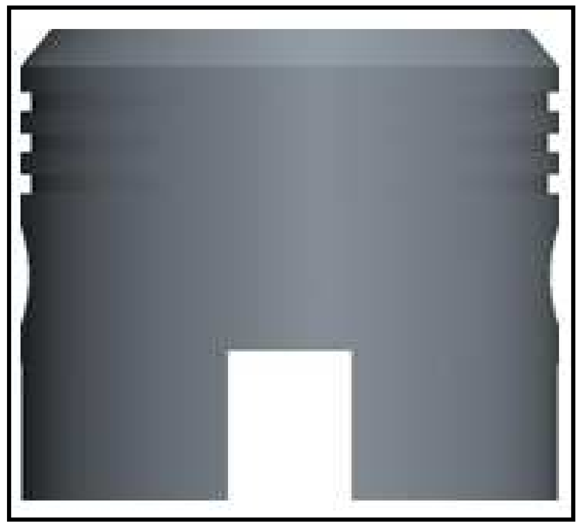
Properties of Different Material used for the Finite Element Analysis

S.No	Material	Elastic Modulus GPa	Poisson ratio (μ)	Coefficient of thermal expansion X 10-5 /°K	Thermal conductivity W /mK	Density Kg/m3
1	Al-10 wt. % SiC	77.4	0.33	2.0	173	2744.0
2	Al-20 wt. % SiC	86.0	0.32	1.75	168	2788.0
3	Al-30 wt. % SiC	92.0	0.31	1.55	164	2835.0

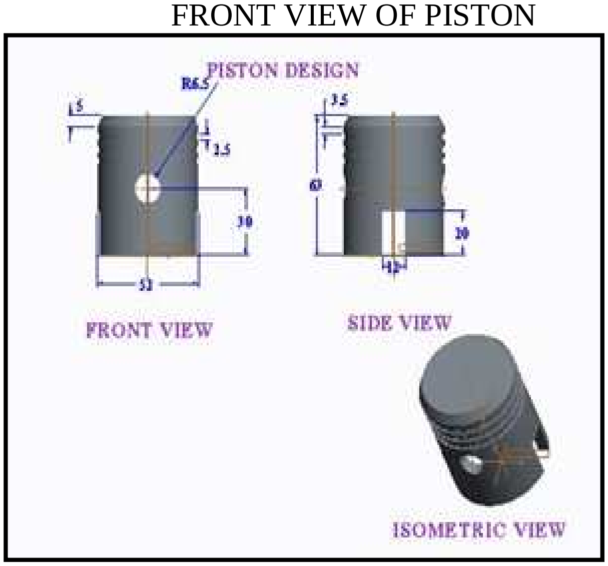
RESULTS COMPARISON

S.No	Description	Al	Al+10%Al-SiC	Al+20%Al-SiC	Al+30%Al-SiC
1	Total Deformation (mm)	0.0799	0.0799	0.06618	0.0620
2	von Mises stress	146.08	146.08	146.5	146.9
3	Elastic Strain	0.0020	0.0020	0.0017	0.015
4	Temperature Distribution	863.1	863.1	840.74	847.83

FRONT VIEW OF PISTON

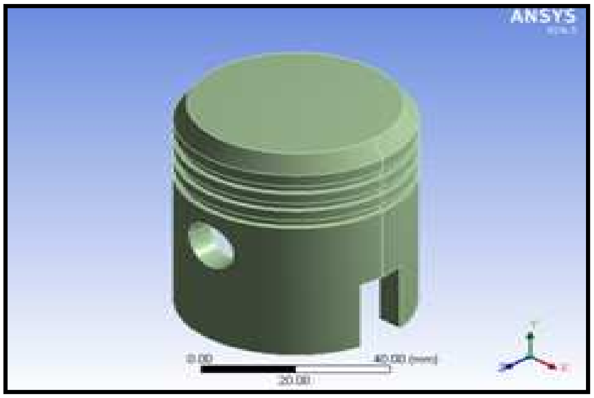


SIDE VIEW OF PISTON

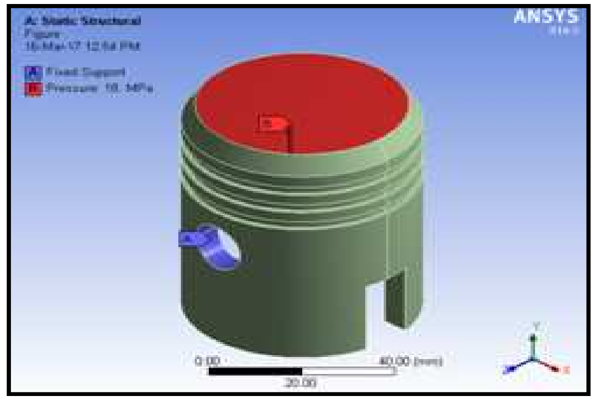


ISOMETRIC VIEW OF PISTON

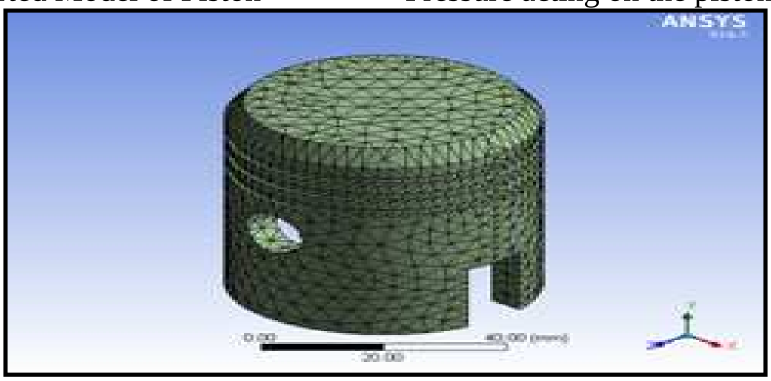
PISTON DESIGN



Imported Model of Piston



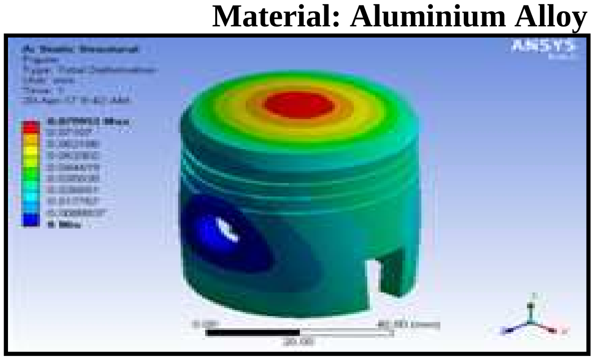
Pressure acting on the piston head



Mesh Model of Piston

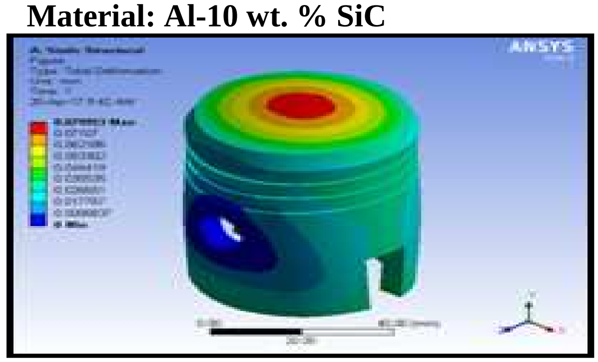
TOTAL DEFORMATION ON PISTON

Material: Aluminium Alloy



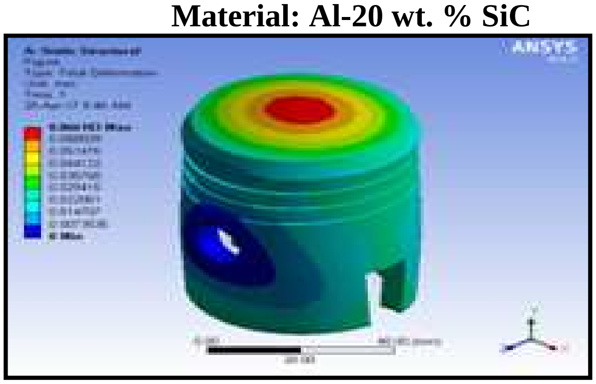
Total Deformation on Aluminium Alloy Piston

Material: Al-10 wt. % SiC



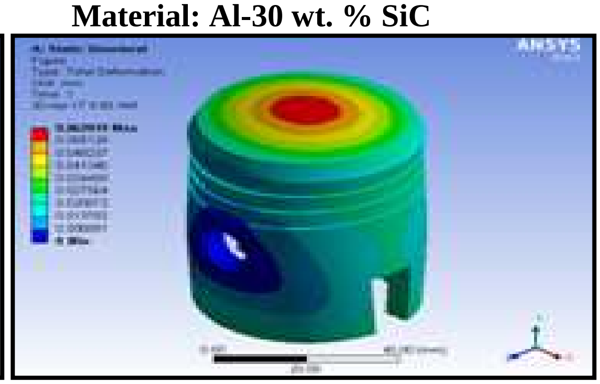
Total Deformation on Al-10 wt. % SiC Piston

Material: Al-20 wt. % SiC



Total Deformation on Al-20 wt. % SiC Piston

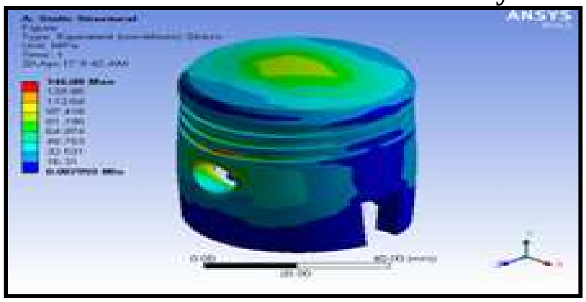
Material: Al-30 wt. % SiC

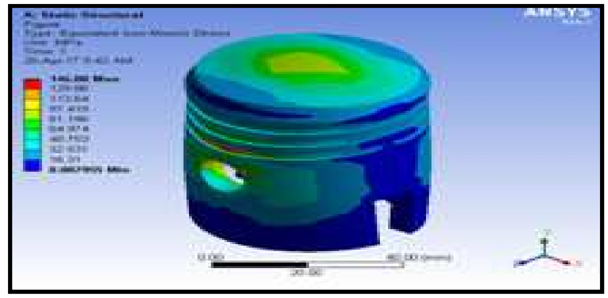


Total Deformation on Al-30 wt. % SiC Piston

RESULTANT STRESS DISTRIBUTION ON PISTON

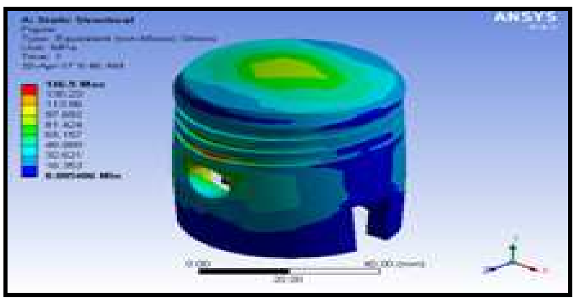
Material: Aluminium Alloy **Material: Al-10 wt. % SiC**

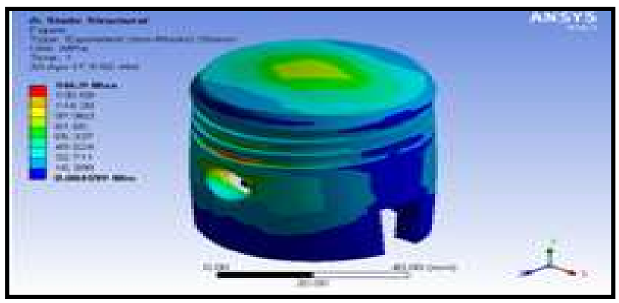




Equivalent Stress Distribution in Aluminium Alloy Piston Equivalent Stress Distribution in Al-10 wt. % SiC Piston

Material: Al-20 wt. % SiC **Material: Al-30 wt. % SiC**

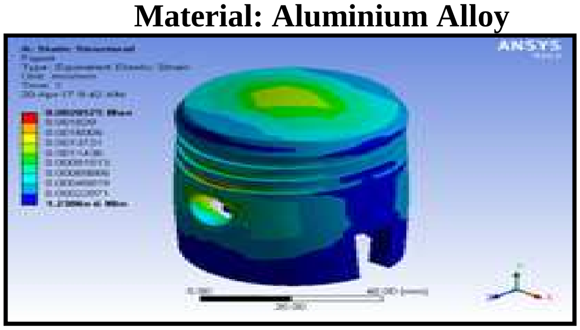


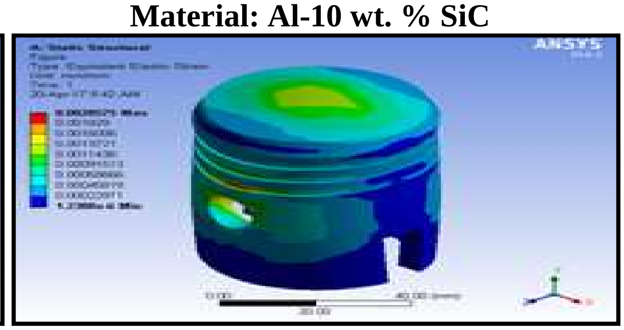


Equivalent Stress Distribution in Al-20 wt. % SiC Piston Equivalent Stress Distribution in Al-30 wt. % SiC Piston

EQUIVALENT ELASTIC STRAIN DISTRIBUTION ON PISTON

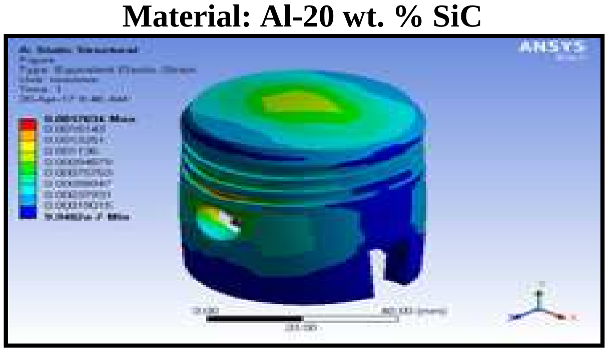
Material: Aluminium Alloy **Material: Al-10 wt. % SiC**

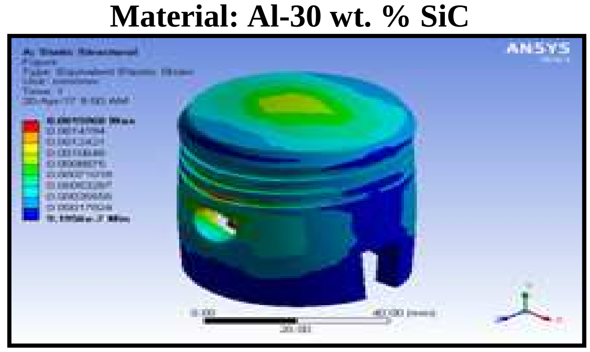




Equivalent Elastic Strain Distribution in Al-10 wt. % SiC Piston Equivalent Elastic Strain Distribution in Aluminium Alloy Piston

Material: Al-20 wt. % SiC **Material: Al-30 wt. % SiC**

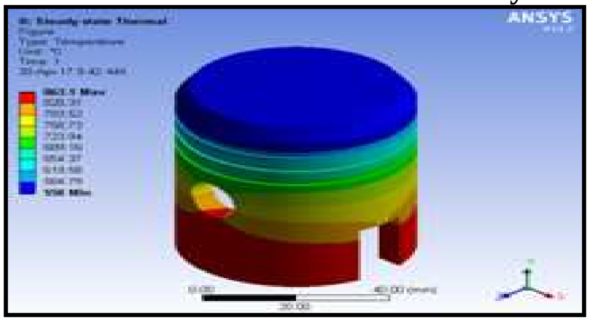




Equivalent Elastic Strain Distribution in Al-20wt. % SiC Piston Equivalent Elastic Strain Distribution in Al-30 wt. % SiC Piston

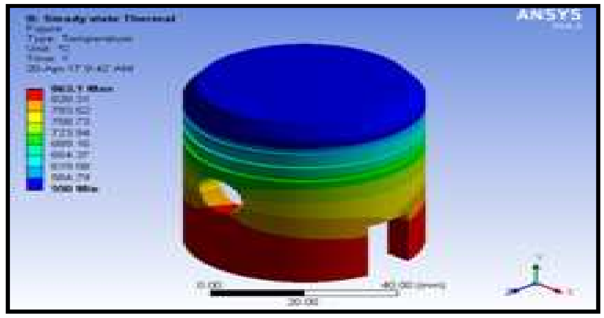
TEMPERATURE DISTRIBUTION ON PISTON

Material: Aluminium Alloy



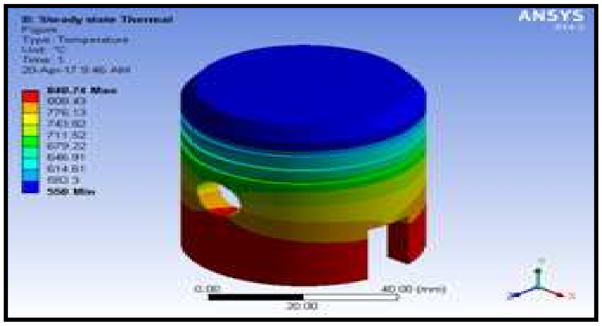
Temperature Distribution in Aluminium Alloy Piston

Material: Al-10 wt. % SiC



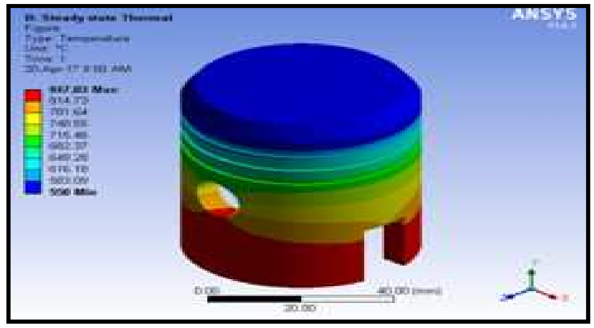
Temperature Distribution in Al-10 wt. % SiC Piston

Material: Al-20 wt. % SiC



Temperature Distribution in Al-20 wt. % SiC Piston

Material: Al-30 wt. % SiC



Temperature Distribution in Al-30 wt. % SiC Piston

CONCLUSION

Hence a piston made of composite material (aluminium silicon carbide alloy) is designed and analyzed successfully. Composite piston made of metal matrix composites has high strength retention on ageing at severe environments. Compared to aluminium alloy, the aluminium silicon carbide alloy is found to have lesser deformation, lesser stress and good temperature distribution. Instead of these some of the limitations faced by aluminium alloy piston are cured by these aluminium silicon carbide alloy piston. From this project we get the clear knowledge about the composite materials and its features.

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CONFLICT OF INTEREST

We declare that we have no conflict of interest.

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