Design and Analysis of Piston by amc225xe Alloy

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Abstract

In an engine the piston converts thermal energy (force produced by thermal energy) into mechanical energy. It is important to select a proper material for piston. Continuous exposure to high pressure, high temperature and vibration could damage and reduce the life of the piston. Usually pistons are made of aluminium which is light in weight and good thermal conductivity. But it has poor hot strength and high coefficient of expansion make it unsuitable for this application, so in this study a suitable material for piston is found that can withstand the stated constraints and also provides a lesser weight to the engine. The piston was modelled using Solidworks 14 and Ansys 15 software was used for studying the thermal flux, static structural and temperature properties of the material amc225xe and was compared with the conventional aluminium material. amc225xe had better result compared to aluminium. Finally, as based on the analysed characteristics material amc225xe was selected as a suitable material for piston material.

Keywords: Aluminium, amc225xe, Piston, Structural Analysis, Thermal Analysis

I. INTRODUCTION

Aluminium alloys are the preferred material for pistons both in gasoline and diesel engines due to their specific characteristics: low density, high thermal conductivity, simple net-shape fabrication techniques (casting and forging), easy machinability, high reliability and very good recycling characteristics.

amc225xe is a high quality aerospace grade aluminium alloy (AA2124) reinforced with 25% by volume of ultrafine particles of silicon carbide. It is manufactured by a special powder metallurgy route using a proprietary high-energy mixing process which ensures excellent particle distribution and enhances mechanical properties.

The key benefits of amc225xe for structural applications include:

- Weight saving
- Increased component stiffness
- High fatigue resistance.

In this project, amc225xe, an Aluminium matrix alloy is used as an alternative for Aluminium. A 3D model was made using Solidworks 14 and Structural and thermal analysis was done on ANSYS 15. Compared to Aluminium, amc225xe has better thermal properties, strength -to-weight ratios and better high temperature performance.

II. ANALYTICAL METHOD

A. Design of the Body

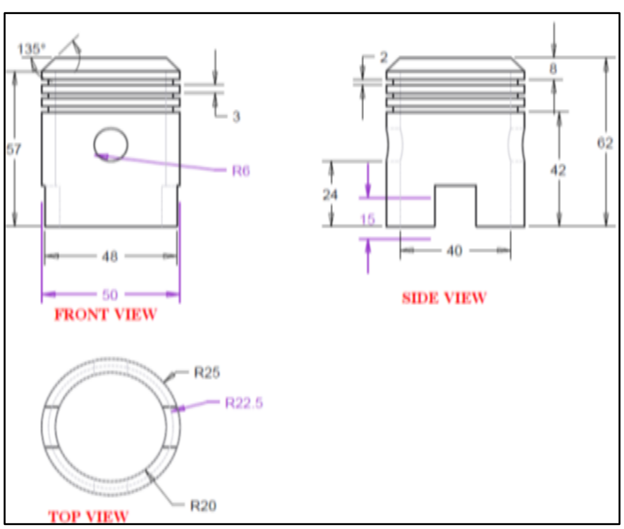

Fig. 1: Engineering drawing of a piston

Solidworks offers a range of tools to enable the generation of a complete digital representation of the product being designed. SolidWorks is a solid modelling software and utilizes a parametric feature-based approach to create models and assemblies. 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. A number of concept design tools that provide up-front Industrial Design concepts can then be used in the downstream process of engineering the product. These range from conceptual Industrial design sketches, reverse engineering with point cloud data and comprehensive free-form surface tools. We created model Piston using solid works software.

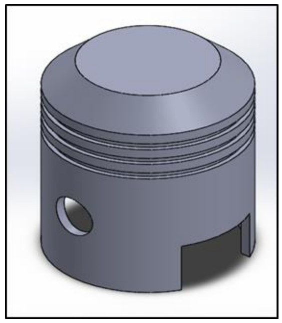

Fig. 2: 3D end model using solid works

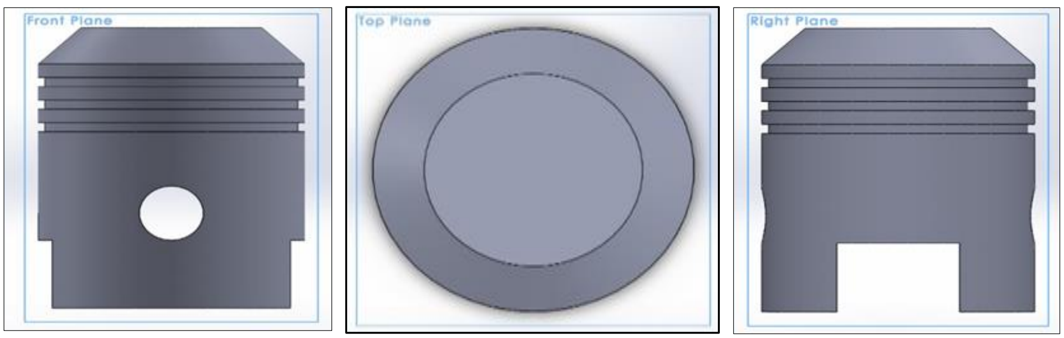

Fig. 3: Orthographic view of modelled piston

B. Material Data

- Aluminium
- amc225xe

1) Aluminium

A chemical element (symbol Al) with an atomic number of 13, atomic weight of 26.98, and a single stable isotope: 27. Aluminium is a soft, silvery metal with relative density: 2.70 kg/dm^3 and Melting point: 660°C. A thin, waterproof layer of aluminium oxide is formed on contact with the air. Aluminium is a very important construction material in combination with other metals. The major compounds of aluminium are the oxide, hydroxide, chloride, sulphate, silicate, and acetate.

Table - 1
Aluminium properties

Density	*2.7e-006 kg mm-3*
Thermal Conductivity-	*0.237 W mm-1 C-1*
Young's Modulus	*70000 MPa*
Poisson's Ratio	*0.35*
Bulk Modulus	*77778 MPa*
Shear Modulus	*25926 MPa*

2) amc225xe

amc powder metallurgy and mechanical alloying techniques are used to combine the aluminium alloy (AA2124) matrix with fine (23 micron) Silicon Carbide (SiC) particles. Process conditions are controlled to produce an even distribution of these particles, whilst maintaining the purity of the matrix alloy. Powders are compacted to fully dense billet by hot isostatic compaction. Billets are available for direct manufacture to component or for fabrication by forging, extrusion or rolling techniques. Selection of the process route depends on property requirements, component shape and the resulting process cost.

Table - 2
Properties of amc225xe

Elastic Modulus	*115 GPa*
Ultimate Tensile Strength	*650 MPa*
0.2% Yield Strength	*480 MPa*
Strain to Fail	*5%*

Poisson's Ratio	*0.3*
Vickers Hardness	*210*
Thermal Conductivity	*150 W/m/ºC*
Thermal Expansion Coefficient	*15.5 ppm/ºC*
Heat Capacity	*0.836 J/g/ºC*
Solidus	*548ºC*
Electrical Conductivity	*21 % IACS*
Density	*2.88 g/cm3*

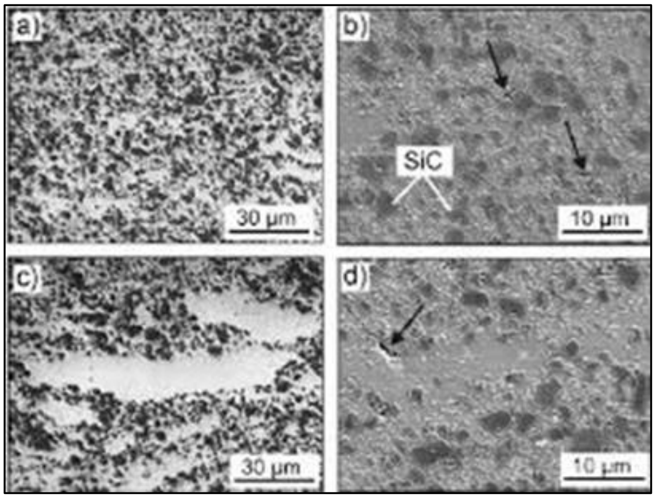

Fig. 4: Microstructure of amc225xe

III. RESULTS AND DISCUSSIONS

A. Analysis using ANSYS

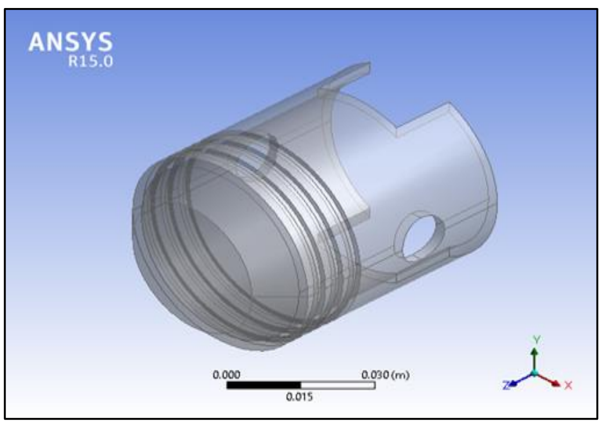

Fig. 5: Piston imported to ANSYS 15 from solid works 14

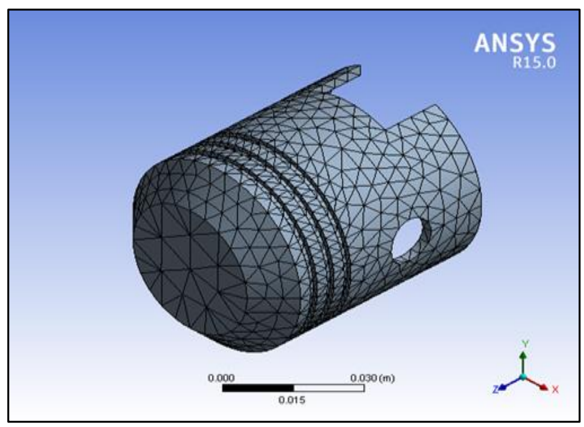

Fig. 6: Piston is auto meshed in ANSYS 15

ANSYS is an analysis software belonging to the category of finite element analysis(FEA). Hence the model is divided into number of finite elements, this is called as meshing.

1) Thermal Analysis

Thermal analysis is a group of techniques in which the variation of a physical property of a substance is measured as a function of temperature. The most commonly used techniques are those which measure changes of mass or changes in energy of a sample of a substance

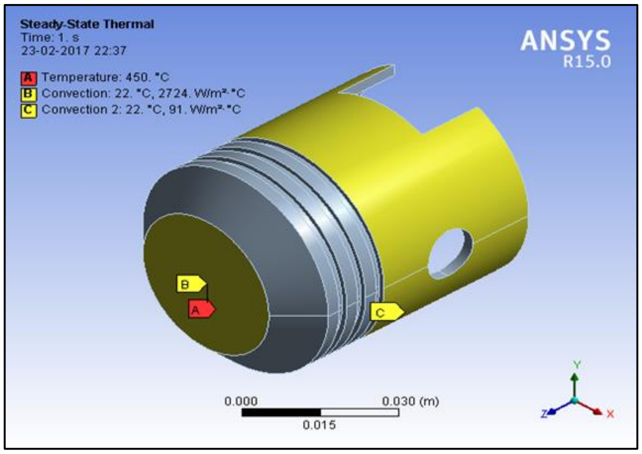

Fig. 7: Initial setup (assumptions) for thermal analysis

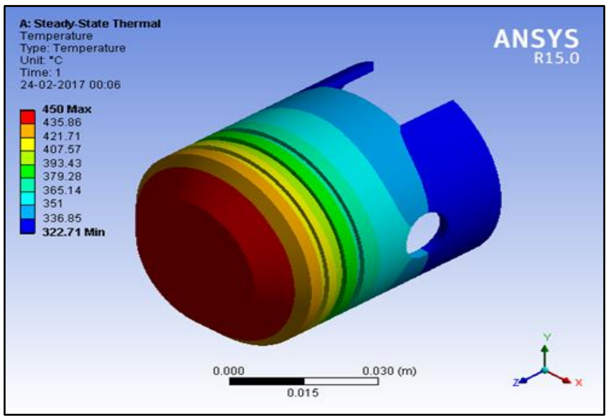

Fig. 8: Steady state thermal analysis for Aluminium piston

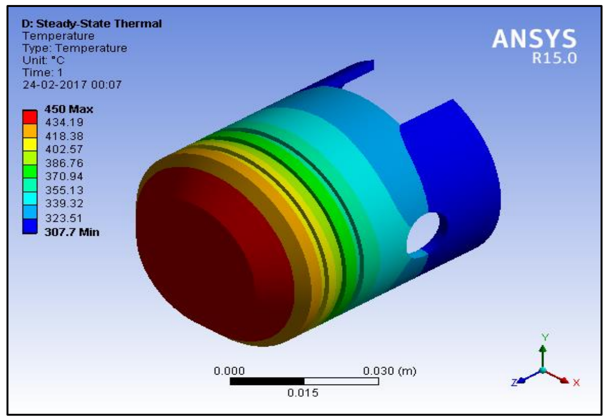

Fig. 9: Steady state thermal analysis for amc225xe piston

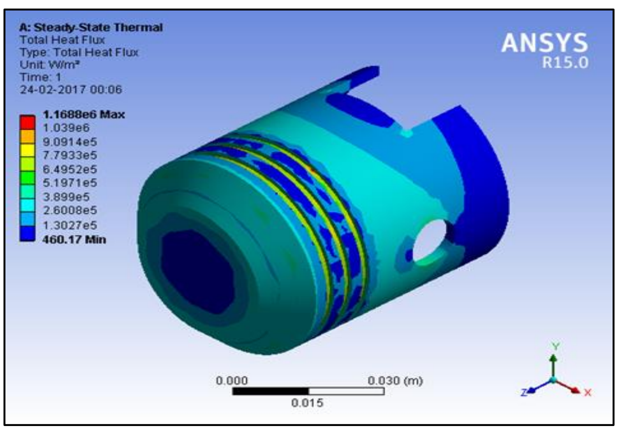

Fig. 10: Heat flux in Aluminium piston

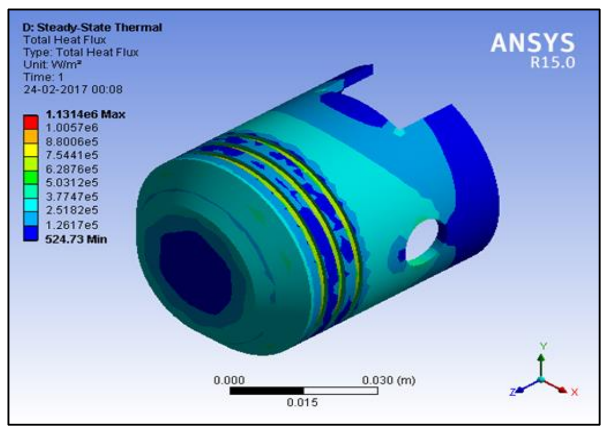

Fig. 11: Heat flux in amc225xe piston

B. Static Structural Analysis

A static structural analysis determines the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time. A static structural load can be performed using the ANSYS. The types of loading that can be applied in a static analysis include:

– Externally applied forces and pressures
– Steady-state inertial forces (such as gravity or rotational velocity)
– Imposed (nonzero) displacements
– Temperatures (for thermal strain)

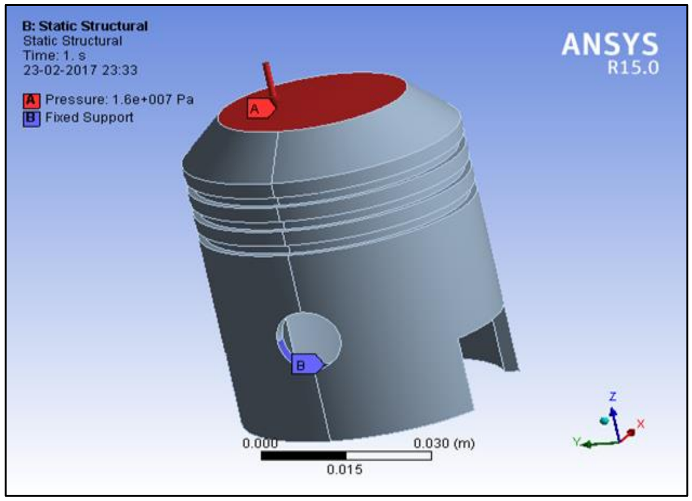

Fig. 12: Initial condition (assumption) for static structural analysis

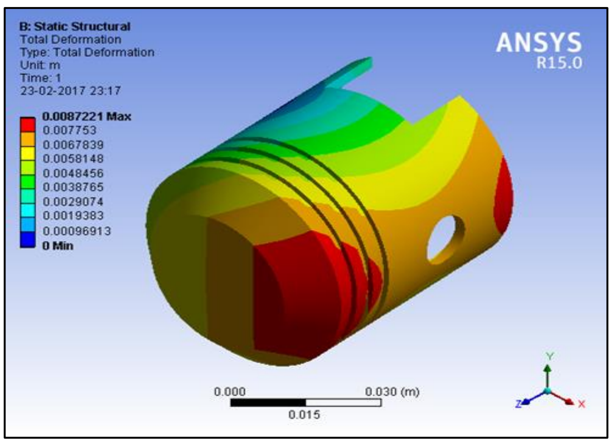

Fig. 13: Total deformation of amc225xe piston

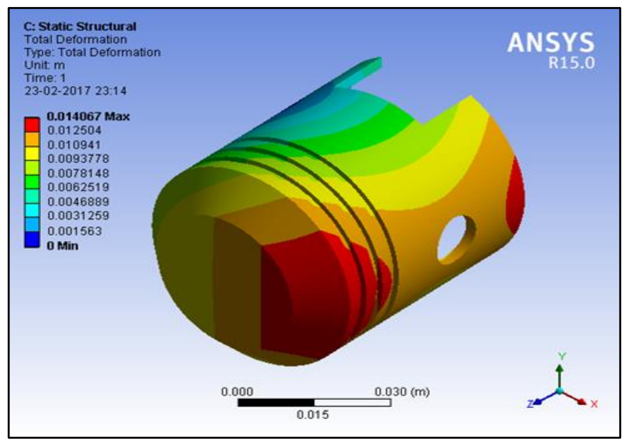

Fig 14: Total deformation of aluminium piston

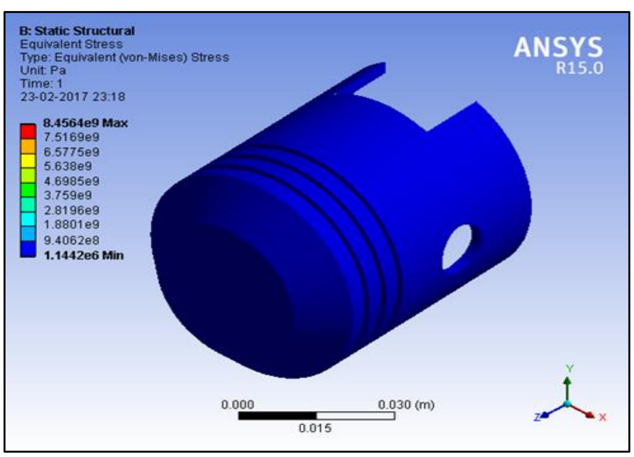

Fig. 15: Equivalent stress of aluminium piston

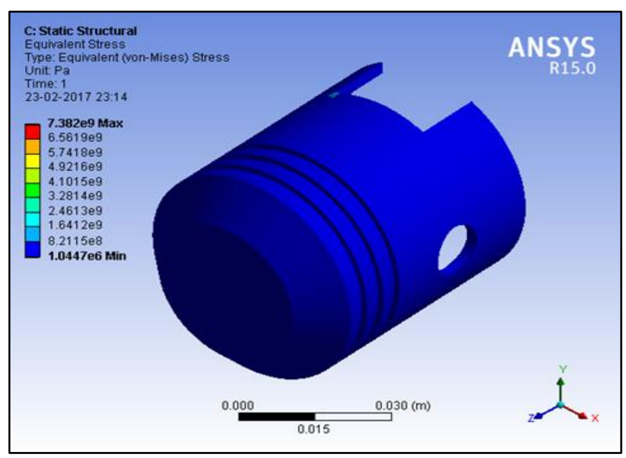

Fig. 16: Equivalent stress of amc225xe piston

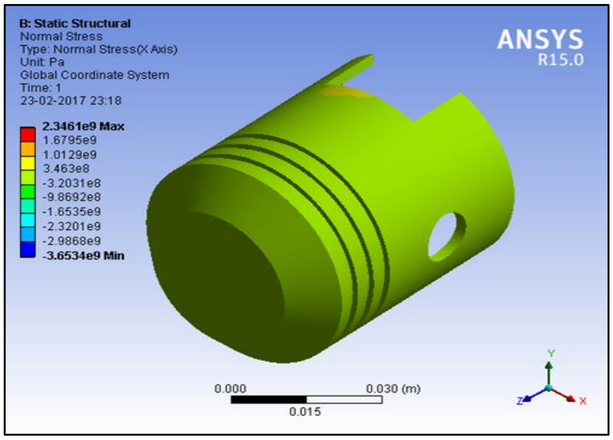

Fig. 17: Normal stress of aluminium piston

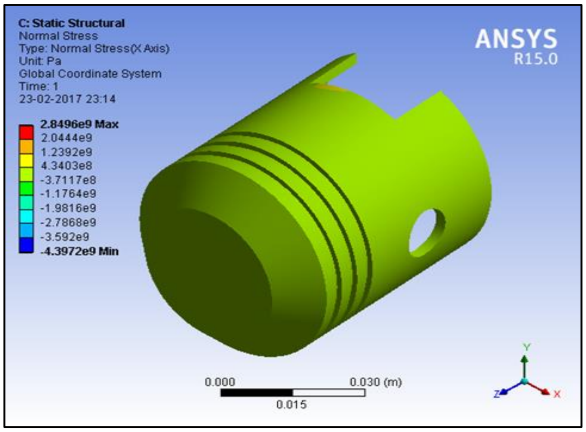

Fig. 18: Normal stress of amc225xe piston

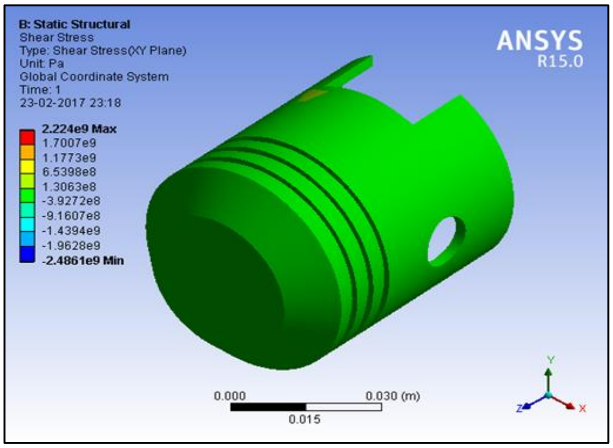

Fig. 19: Shear stress of aluminium piston

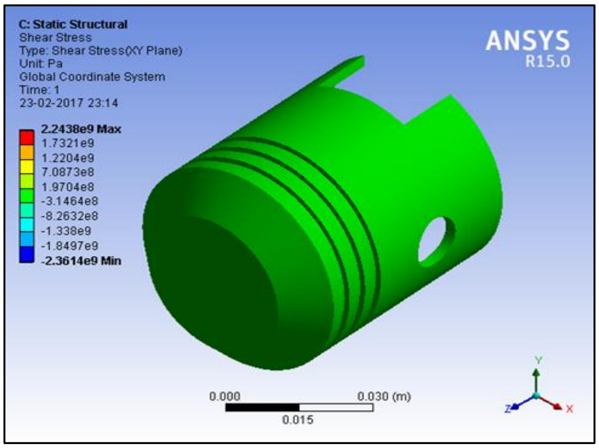

Fig. 20: Shear stress of amc225xe piston

IV. Comparison

Table - 3
Comparison of Thermal properties

Material	*Temperature (·c)*		*Total Heat flux(w/m²)*
	Maximum	*Minimum*	
Aluminium	*450*	*322.71*	*1.1688*10⁶*
Amc225xe	*450*	*307.7*	*1.1314*10⁶*

Table - 4
Comparison of Structural properties

Material	Total deformation(m)	Equivalent stress(Pa)
Aluminium	0.014067	$8.4564*10^9$
Amc225xe	0.0087221	$7.382*10^9$

V. Conclusion

A piston made of amc225xe is designed and analysed successfully. Composite piston made of metal matrix offers high strength retention on ageing even at severe environments. Compared to aluminium, the aluminium silicon carbide is found to have lesser stress and good temperature distribution. Some of the limitations faced by aluminium piston are overcame by the aluminium silicon carbide piston. From this project we get the clear knowledge about the composite material amc225xe and its features

Acknowledgement

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