Design and Analysis of Aluminium Alloy -Tib2 and Silicon Carbide Composite Piston

Manikandan.R[1], Gunasekaran D[2], Naveenkumar.M[3], and Dr.Murali Manohar.R[4]
[1]Student – M.E.Engineering Design, Maharaja Engineering College, Avinashi.
[2,3,4]Assistant Professors –Maharaja Engineering College, Avinashi

***ABSTRACT* – In our present stage, metal matrix composite is more acceptable because they are suitable for applications requiring combined strength and thermal conductivity, damping properties, lower density. The properties of MMCs enhance their usage in automotive and many applications. In the field of automobile, MMCs are used for pistons, brake drum, cylinder block because of better corrosion resistance and wear resistance.TiB2 and silicon carbide is used as the reinforcement to produce the composite by stir casting. TiB2 is chosen because of it is least expensive and low density reinforcement available in large quantities. Wear rate, and coefficient of friction decreases on addition of SiC and TiB2 to the matrix material and also increasing hardness. Thus our project deals with the of a piston made of composite material comprising Al 6061 + TIB2 5%+ SiC 10%.**

- ***Keywords:*Composite materials,Aluminum,Sic,Tib2**

1.1 INTRODUCTION

1.1 COMPOSITE MATERIALS

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 crank shaft 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.

Pistons are cast from aluminium alloys. For better strength and fatigue life, some racing pistons may be forged instead. Early pistons were of cast iron, but there were obvious benefits for engine balancing if a lighter alloy could be used. To produce pistons that could survive engine combustion temperatures, it was necessary to develop new alloys such as Y alloy and aluminum, specifically for use as pistons. Metal composite materials have found application in many areas of day to day life for quite some time. In traffic engineering, especially in the automotive industry, MMCs have been used commercially in fiber reinforced pistons and aluminum crank cases with strengthened cylinder surfaces as well as particle strengthened brake disks. Aluminium is a chemical element in the boron group with symbol Al and atomic number is 13. It is silvery white, and it is insoluble in water under normal circumstances. Aluminium alloys are alloys in which aluminium (Al) is the strongest metal. The typical alloying elements are silicon and zinc. There are two divisions, namely casting alloys and wrought alloys. Silicon carbide (SiC), is a compound of silicon and carbon with chemical formula SiC. It occurs in nature as the extremely rare mineral moissanite. Silicon carbide powder has been mass-produced since 1893 for use as an abrasive. Grains of silicon carbide can be bonded together by sintering to form very hard ceramics that are widely used in applications requiring high endurance, such as car brakes, car clutches and ceramic plates in bulletproof vests. Electronic applications of silicon carbide such as light-emitting diodes (LEDs) and detectors in early radios were first demonstrated around 1907. SiC is used in semiconductor electronics devices that operate at high temperatures or high voltages, or both. Large single crystals of silicon carbide can be grown by the Lely method; they can be cut into gems known as synthetic moissanite. Silicon carbide with high surface area can be produced from SiO_2 contained in plant material.

1.2 METAL MATRIX COMPOSITE

A metal matrix composite (MMC) is composite material with at least two constituent parts, one being a metal. The other material may be a different metal or another material, such as a ceramic or organic compound. When at least three materials are present, it is called a hybrid composite. An MMC is complementary to a cermet.

1.2.1 Composition

MMCs are made by dispersing a reinforcing material into a metal matrix. The reinforcement surface can be coated to prevent a chemical reaction with the matrix. For example, carbon fibres are commonly used in aluminium matrix to synthesize composites showing low density and high strength. However, carbon reacts with aluminium to generate a brittle and water-soluble compound Al_4C_3 on the surface of the fibre. To prevent this reaction, the carbon fibres are coated with nickel or titanium boride.

1.2.2 Matrix

The matrix is the monolithic material into which the reinforcement is embedded, and is completely continuous. This means that there is a path through the matrix to any point in the material, unlike two materials sandwiched together. In structural applications, the matrix is usually a lighter metal such as aluminium, magnesium, or titanium, and provides a compliant support for the reinforcement. In high temperature applications, cobalt and cobalt-nickel alloy matrices are common.

1.2.3 Reinforcement

The reinforcement material is embedded into the matrix. The reinforcement does not always serve a purely structural task (reinforcing the compound), but is also used to change physical properties such as wear resistance, friction coefficient, or thermal conductivity. The reinforcement can be either continuous, or discontinuous. Discontinuous MMCs can be isotropic, and can be worked with standard metalworking techniques, such as extrusion, forging or rolling. In addition, they may be machined using conventional techniques, but commonly would need the use of polycrystalline diamond tooling (PCD).

Continuous reinforcement uses monofilament wires or fibres such as carbon fibre or silicon carbide. Because the fibres are embedded into the matrix in a certain direction, the result is an anisotropic structure in which the alignment of the material affects its strength. One of the first MMCs used boron filament as reinforcement. Discontinuous reinforcement uses “whiskers", short fibres, or particles. The most common reinforcing materials in this category are alumina and silicon carbide.

2.PROBLEM IDENTIFICATION

2.1ABRASIVE WEAR:

Is vertical scratching or scuffing of the piston skirt. Severe peripheral ring wear and scuffing. Unusually oil consumption that mean you adding oil engine to your car. The remedies to this problem ensure air and oil filters are clean and fitted with correct filter elements. If the engine went for overhaul, must clean all engine components and oil ways. On this piston failure, new piston and new bearing should be fitted

Major Problems:

- Over heat seizure
- Ring lands
- One side skirt seizure
- Misalignment
- Insufficient clearance

Al-TiB2 composite is a metal matrix composite (MMC) that can be manufactured using the in-stir casting method. With TiB2 as the particulate addition the properties of Al 6061 alloy can be greatly improved. The addition of TiB2 to aluminum increases the strength of the aluminum. This high temperature stability is attributed to lack reactivity between TiB2 and the aluminium matrix.Wear rate and coefficient of friction decreases on addition of SiC and TiB2 to the matrix material.

AlSiC,pronounced is a metal matrix composite consisting of aluminum matrix with silicon carbide particles. It has high thermal conductivity (180–200 W/m K), and its thermal expansion can be adjusted to match other materials, e.g. silicon and gallium arsenide chips and various ceramics.Hardness, Density, yield strength, are increases with the increase reinforcement particles of silicon carbide..

3.MATERIAL SELECTION AND FABRICATION METHOD

Materials used for the pistons of automotive internal combustion engines include: aluminium alloys, – alloy steels, and – cast iron.

Materials that are most commonly used for manufacturing pistons include: cast iron, alloy steel and aluminium alloys, aluminium-silicon (Al-Si) alloys and aluminium-copper (Al-Cu) alloys. These alloys are characterized by low density, being advantageous due to the small piston mass, and a large thermal conductivity coefficient. Aluminium alloys are distinguished by good formability during casting and good machinability (machine cutting). The major drawbacks of these alloys include: a large thermal expansion coefficient, low hardness and low strength indices at elevated temperatures. Cast-iron pistons are less and less often used.

They can be found in low-speed self-ignition engines. They are characterized by good slide properties, retaining good mechanical properties at elevated temperatures, and a small thermal expansion coefficient. The main disadvantages that limit the use of cast-iron pistons in contemporary high-speed engines are: a low thermal conductivity coefficient and high density that results in a large piston mass and considerable inertia forces. Due to the high strength indices and low thermal expansion, pistons are increasingly often made of alloy steels. In spite of the high density of steel, to take advantage of the good mechanical properties of this material, designers give pistons appropriate shapes with small overall dimensions, which reduces the piston mass and makes it comparable to the mass of aluminium alloy pistons. The basic piston manufacture technology is by casting in sand or metal (aluminum alloy) moulds. For very heavily loaded engines, aluminium alloy or steel pistons are made by forging. Forging causes very favorable changes in the structure of the material, which improve its mechanical properties. The aim of this publication

is to make review different, most commonly found types of piston failures, which could be used by specialists working for the automotive industry and being concerned with diagnosing the technical condition of automotive vehicles and examining the causes of their failures. In order to be effectively performed, the diagnosis of an engine and a complete vehicle requires a comprehensive and interdisciplinary approach to the identification of their technical condition.

3.1 Aluminum 6061 (a1 6061)

Aluminum is remarkable for the metal's low density and for its ability to resist corrosion due to the phenomenon of passivation. Commercially pure aluminum has a tensile strength of approximately 120 MPa and can be improved 180 MPa by cold Working. The heat treatable grades can develop a tensile strength of around 570 MPa and even higher in some alloys. The wear of MMCS depends on the particular wear conditions, but there are many circumstances where Al based composites have excellent wear resistance. The coefficient of thermal expansion of aluminum alloys is affected by the nature of their constituents: example the presence of silicon and copper reduces .expansion while magnesium Increases it. The mechanical properties of the A1 6061 is shown in the table below

Properties of Aluminium Alloy 6061

- Medium to high strength
- Good toughness
- Good surface finish
- Excellent corrosion resistance to atmospheric conditions
- Good corrosion resistance to sea water
- Can be anodized
- Good weldability and brazability
- Good workability
- Widely available

ALUMINIUM ALLOY 6061

Table 3.1 Mechanical Properties of Al6061

Density (Kg/m^3)	2710
Elastic Modulus (GPa)	70-80 GPa
Poisons Ratio	0.33
Melting Point (^{o}C)	660.3
Thermal conductivity (W/mK)	173

5.2 Silicon Carbide

It occurs in nature as the extremely rare mineral moissanite. Silicon carbide powder has been mass-produced since 1893 for use as an abrasive. Grains of silicon carbide can be bonded together by sintering to form very hard ceramics that are widely used in applications requiring high endurance, such as car brakes, car clutches and ceramic plates in bulletproof vests. Electronic applications of silicon carbide such as light-emitting diodes (LEDs) and detectors in early radios were first demonstrated around 1907. SiC is used in semiconductor electronics devices that operate at high temperatures or high voltages, or both. Large single crystals of silicon carbide can be grown by the Lely method; they can be cut into gems known as synthetic moissanite. Silicon carbide with high surface area can be produced from SiO_2 contained in plant material. . The mechanical properties of the silicon carbide is shown in the table below.

Properties of Silicon Carbide

- Low density
- High strength
- Low thermal expansion
- High thermal conductivity
- High hardness
- High elastic modulus
- Excellent thermal shock resistance
- Superior chemical inertness

SILICON CARBIDE:

Table 3.2 Mechanical Properties of Silicon Carbide

Density (Kg/m^3)	3210
Elastic Modulus (GPa)	188
Poisons Ratio	0.28
Melting Point (^oC)	2730
Thermal conductivity (W/mK)	148

3.3 Titanium Diboride

Titanium diboride (TiB_2) is an extremely hard ceramic which has excellent heat conductivity, oxidation stability and resistance to mechanical erosion. TiB_2 is also a reasonable electrical conductor so it can be used as a cathode material in aluminum smelting and can be shaped by electrical discharge machining. Exceptional hardness (25–35GPa Vickers at room temperature, more than three times harder than fully hardened structural steel), which is retained up to high temperature. High melting point (3225 °C), High thermal conductivity High electrical conductivity. The mechanical properties of the titanium diboride are shown in the table below.

Properties of Titanium Diboride

- Exceptional hardness, more than three times harder than fully hardened structural steel)
- Retained up to high temperature
- High melting point
- High thermal conductivity
- High electrical conductivity

TITANIUM DIBORIDE:

Table 3.3 Mechanical Properties of Titanium Diboride

Density (Kg/m^3)	4520
Elastic Modulus (GPa)	555
Poisons Ratio	0.110
Melting Point (^oC)	3230
Thermal conductivity (W/mK)	25

Stir Casting Method

Stir casting process is one of the least cost and common process that are used around to form or fabricate a metal matrix composite. The stir casting process is a liquid state process. This process is cheaper than compared to the other metal forming process. The steps involved are

i. The material that are of the high composition is called the base metal of the composite.

ii. The metal is first placed in a crucible and the metal is heated up to its melting point in order to melt the down the material.

iii. The reinforcement materials are blended together and they are placed in a pre-heating furnace and the materials are heated up to a critical level.

iv. The molten metal is then transferred into the stir casting furnace and kept at the same temperature.

V. The pre heated reinforcement particles are then added into the molten metal and the stirrer is used to mix the reinforcement material in the furnace.

Vi. The composite molten metal is picked up and they are poured into the die.

vii. After few minutes the metal is removed from the die and is machined to attain the desired dimension using the electric discharge machining process.

4.FABRICATION METHOD

Aluminum alloys was melted in a graphite crucible inside a high temperature furnace for a temperature for about 600 to 650°C until the aluminum is melted. The reinforcing materials such as Titanium diboride and silicon carbide are mixed and are preheated at a temperature of 450^0c in a pre-heater furnace for 15 to 20 min. then the aluminum is lifted off from the furnace and placed in the stir-casting furnace and the pre heated reinforce materials are then mixed with the aluminum alloy where the temperature of the furnace is maintained at a temperature of 760°C.The mechanical stirrer is inserted into the crucible and the composition are stirred at a rpm of 400 for 10mins until the materials are mixed the molten aluminum is poured in the die. Stir casting process is one of the least cost and common process that are used around to form or fabricate a metal matrix composite. The stir casting process is a liquid state process. This process is cheaper than compared to the other metal forming process

Al-SiC10%-$TiB_2$5%

Table 4.1 Mechanical Properties of Al-SiC10%-$TiB_2$5%

Density (Kg/m^3)	2850.5
Elastic Modulus (GPa)	106.05
Poisons Ratio	0.314
Thermal conductivity (W/mK)	217.5

HEAT TREATMENT'S

- Annealing
- Normalizing
- Quenching
- Case hardening

ANALYTICAL METHOD

CREO PARAMETRIC

PTC Creo, formerly known as Pro/ENGINEER is a parametric, integrated 3D CAD/CAM/CAE solution created by Parametric Technology Corporation (PTC).

Creo Parametric is powerful software used to create complex designs with great precision. The design intent of a three-dimensional (3D) model or an assembly is defined by its specification and its use. You can use the powerful tools of Creo Parametric to capture the design intent of a complex model by incorporating intelligence into the design. Once you understand the feature-based, associative, and parametric nature of Creo Parametric, you can appreciate its power as a solid modeler.

Modeling

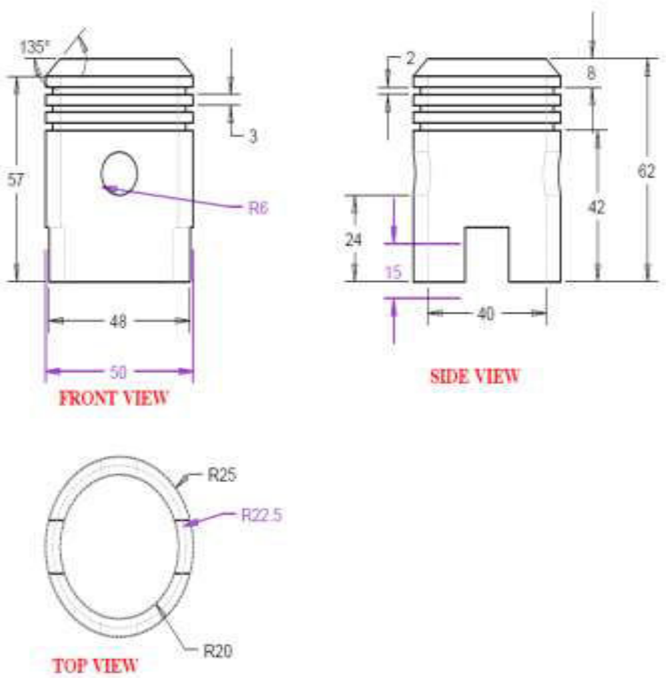

Fig. 1: Modeling of Piston

Fig. 2: Complete Assembly

RESULT AND DISCUSSIONS

FINITE ELEMENT METHOD:

The Finite Element Method (FEM) is a reliable numerical technique for analysing 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).

Ansys formulates the equations governing the behavior of each element taking into consideration its connectivity to other elements. These equations relate the displacements to known material properties, restraints, and loadsNext, the program organizes the equations into a large set of simultaneous algebraic equations. The solver finds the displacements in the X, Y, and Z directions at each node. Using the displacements, the program calculates the strains in various directions. Finally, the program uses mathematical expressions to calculate stresses.

Finite element proceeds at present very widely used in the engineering analysis. The procedures are employed extensively in the analysis of solids structure has transferred and finite element methods are useful in virtually every field at engineering analysis.

The finite element method is a numerical analysis technique for obtaining approximately solution to varieties of engineering in the finite element analysis actual continuum or body of the matter like solid, liquid or gas is represented as an assemblage of sub division called finite element. These finite elements of field variable inside the finite element can approximately by the single function.

The approximately functions are defined in terms of the values of the field variable of the nodes by solving the solid variables the total values of the field variable of the nodes by solving the solid variables the total values of the nodes by soling the solid variables the total values of the field variable can be found out.

Analysis Using Ansys :

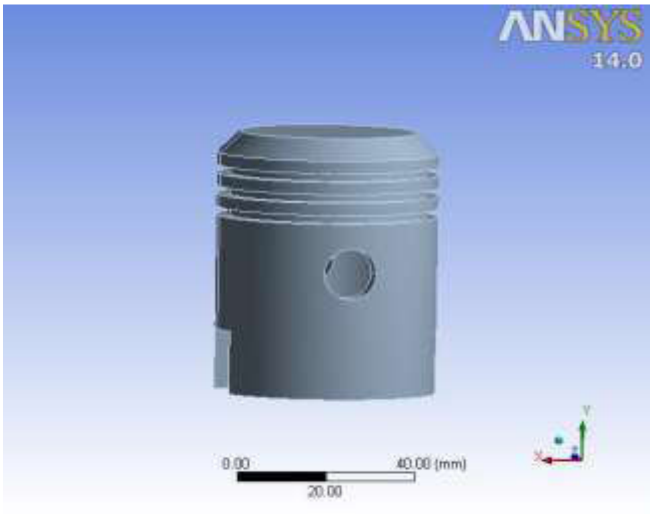

Fig. 3: Model of Piston

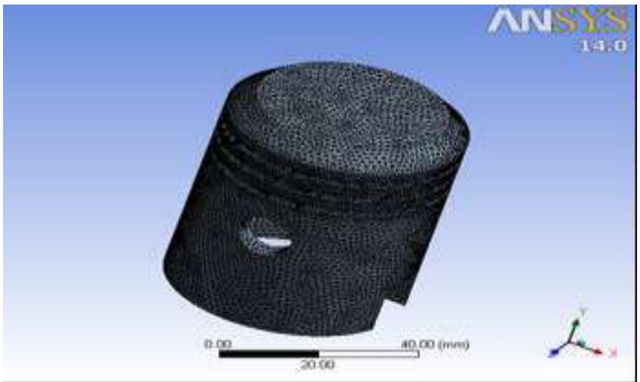

Fig. 4: Shows the Mesh Model of Piston

Thermal Analysis:

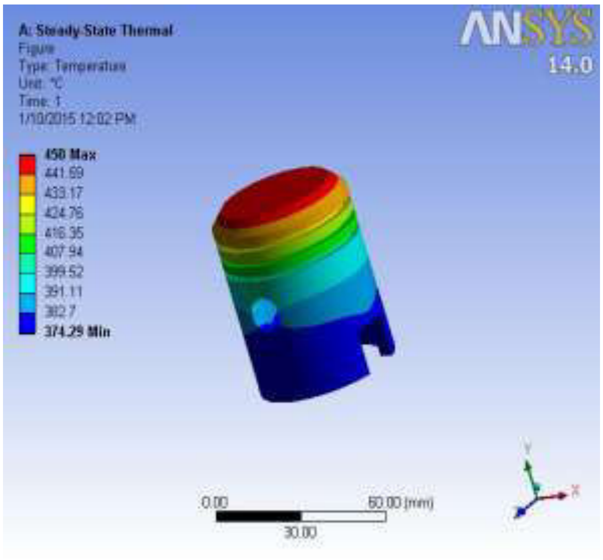

Fig. 5: Temperature Distribution in Aluminium Piston

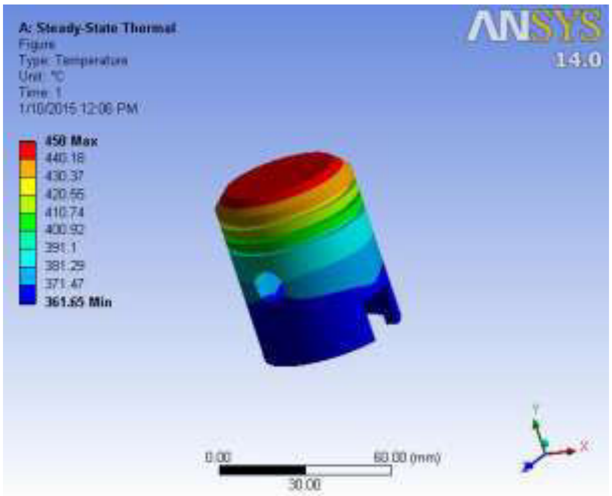

Fig. 6: Temperature Distribution Al sic tib2 Piston

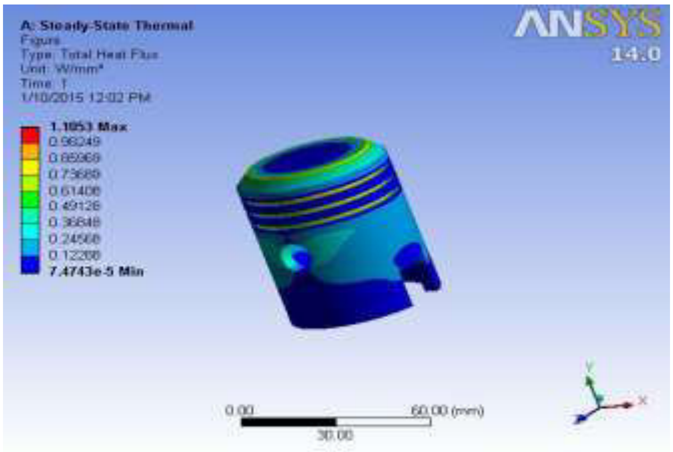

Fig. 7: Total Heat Flux InAluminium Piston

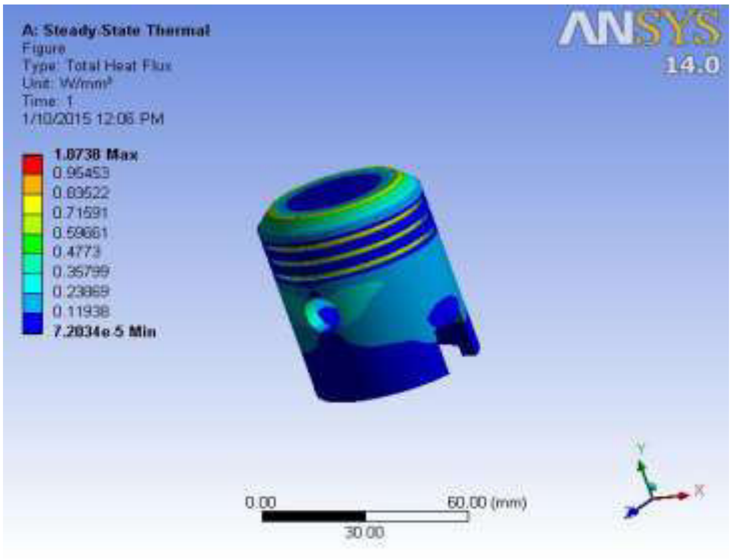

Fig. 8: Total Heat Flux InAluminium Silicon Carbide Piston

Total Deformation in Piston with Various Materials:

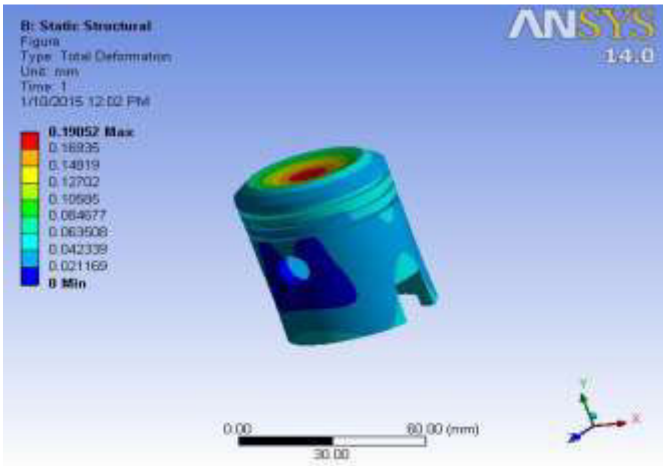

Fig. 9: Total Deformation on Aluminium Piston

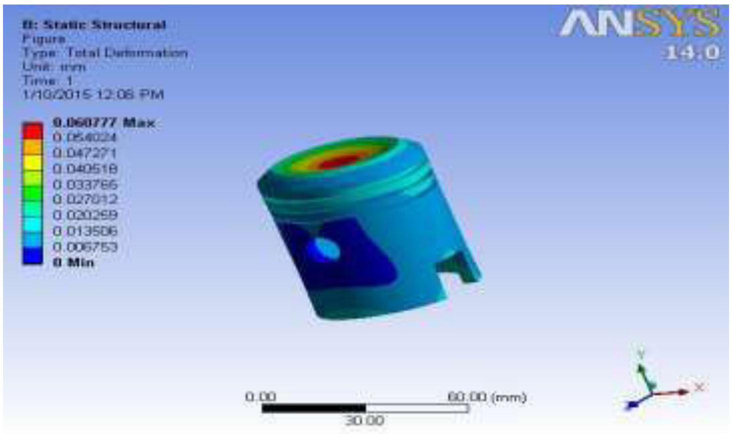

Fig. 10: Total Deformation on Al-sic-tib2 Piston

Normal Stress Distribution in Piston with Various Materials:

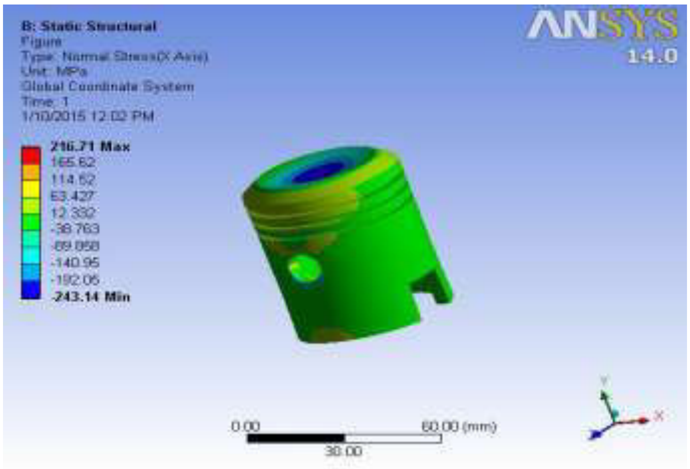

Fig. 11: Normal Stress Distribution InAluminium Piston

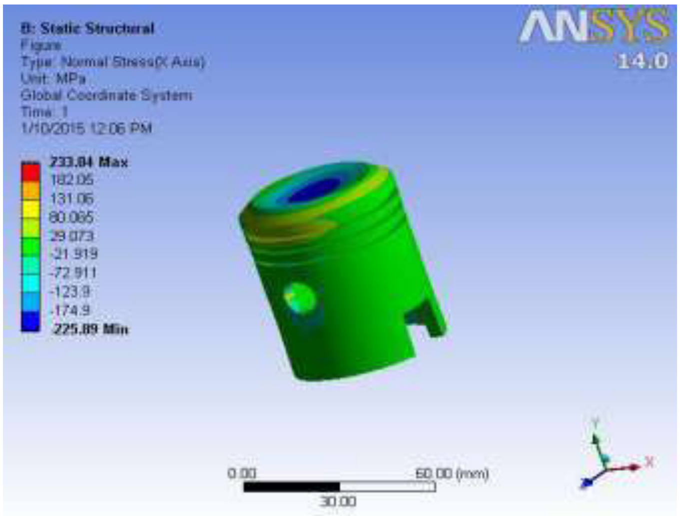

Fig. 12: Normal Stress Distribution In Al-sic-tib2 Piston

CONCLUSIONS

The composite with the composition of Al-TiB2-SiCare prepared by the stir casting process**.**A piston made of composite material (Aluminum Alloy -Tib2 and Silicon Carbide) is designed and analyzed successfully**.** Composite piston made of metal matrix offers high strength retention on ageing even at severe environments**.** Compared to Aluminum, Aluminum Alloy -Tib2 and Silicon Carbide is found to have lesser deformation, lesser stress and good temperature distribution**.** Some of the limitations faced by aluminum piston are overcame by the Aluminum Alloy -Tib2 and Silicon Carbide piston**.** From this project we get the clear knowledge about the composite material Al-Tib2-SiC and its features

REFERENCES

1. Arun Kumar M. B. and R. P.Swamy, “Evaluation of Mechanical Properties of al6061, SiC and e-glass Fibre Reinforced Hybrid Metal Matrix Composites”, ARPN, 2011, Vol.6, Issue.5.
2. B.S.Motgi, R Patil, “A Study on Mechanical Properties of SiC and Tib2 Reinforced Aluminium Alloy Composites”, IOSR,Vol. 7, Issue 6, 2013, pp.41-46.
3. H.C.Anilkumar, H.S.Hebbar and K.S.Ravishankar, “Mechanical properties Of SiC Reinforced Aluminium Alloy Composites”, IJMME, 2011, Vol.6, Issue.1, pp. 41-45.
4. J P Pathak, J K Singh, S Mohan, “Synthesis and Characterization of aluminum silicon-silicon carbide composite” Indian journal of eng. And material science Vol. 13, pp 238-246, June 2006.
5. ManojSingla, D. Deepak Dwivedi, Lakhvir Singh, VikasChawla, “Development of Aluminium Based Silicon Carbide ParticulateMetal Matrix Composite”, Journal of Minerals & Materials Characterization & Engineering, Vol. 8, No.6, pp 455-467, 2009.
6. Sandeep Kumar Ravesh, Dr. T. K. Garg, “Preparation & Analysis for Some Mechanical Property of Aluminium Based Metal Matrix Composite Reinforced with Sic”, IJERA, 2012, vol.2, issue6, pp.727-731.
7. Vivekanandan.P, Arunachalam.V.P, “The Experimental Analysis of Stir Casting Method on Aluminium-Tib2 Composites”, IJCET, 2013, Vol.3.