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STRUCTURAL ANALYSIS OF HYBRID COMPOSITE PISTON FOR IC ENGINE

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ABSTRACT

The main aim of this research was to analyze the performance of hybrid composite piston. The development of materiasl provided numerous possibilities for weight reduction and observed significant improvement in properties. The hybrid composite was made of Al2024, Silicon Carbide and Fly ash. The piston model was created in SOLISWORKS and thermal analysis was done on ANSYS 14.5. Al2024, Sic and Fly ash hybrid composite material showed better wear resistance, Corrossion resistance, High tensile strength, Impact strength, Hardness and low density compared to Aluminium alloys.

KEYWORDS: *Ansys14.5, Al2024, Fly Ash, Hybrid Composite, Silicon Carbide, Solid Works*

INTRODUCTION

A piston is a heart which plays a major role of working of an engine. The thermal and mechanical loading acts on the piston during its operation. The main parts of the piston are crown, piston rings, hubs and skirt. The crown, is very important in the design of a piston, supports mechanical as well as thermal loads and affects hardest deformation. The selection of piston material has an important role in its operation and performance. Aluminium alloys are commonly used piston material, but it has problems like abrasion and scratching. General trends in piston design includes minimizing of piston weight and cooperating components, increase engine mechanical efficiency, piston reliability and durability. These things are achieved by introducing new material, change geometry. The change of monolithic material structure caused by introduction to matrix material reinforcing phase result in improvement in the relation to monolithic material [1]. Analysis of the piston would help to get the idea whether the design is safe or not and what further changes can be made in the design considering in mind the reduction of the weight of the piston i.e. works towards the weight minimization. The analysis can be done to change in material of the piston can be changed for better strength and light weight

A composite piston is made of metal matrix offers high strength retention on ageing even in severe environments. AL, silicon carbide and Tib2 are found have lesser deformation, lesser stress, and good temperature distribution [2]. Stress distribution of the piston mainly depends on the deformation of piston. [3]. the weight reduction has been achieved by both design and material optimization. The weight reduction that is being achieved by 23.09 %. From their analysis, the optimized design silumin piston has low deformation and equivalent strain values compared to Existing design aluminium alloy piston deformation and equivalent strain values. So, the optimized design silumin piston can be used to reduce the cost of the material and the weight of the engine can be minimized to improve the efficiency, sic produces less stress concentration and higher reliability as compared to Aluminum 6061.The composite a piston is capable of withstanding heavy loads under very severe environments [4].

Aluminum matrix composite was successfully obtained using the self- propagating high temperature SiC particulates as a reinforcement material. The composite was found to be superior in mechanical performances to those of the composite reinforced with the conventional abrasive grade Sic particulates. High interfacial bond strength was observed between SiC and aluminum matrix [5]. Aluminum based metal matrix composite containing up to 15wt.% of SiC particles are synthesized using stir-cast method. Macrostructural studies have shown near uniform distribution of SiC particulates in the longitudinal direction. Microstructural so showed the uniform distribution along the cross section of the specimen. Friction and wear behavior is studied by using the computerized pin on disc wear testing machine. Resistance to wear has increased with increase in silicon carbide particles. But wear has increased with a normal load and sliding velocity. Hardness has increased with increase in silicon carbide particles [6].

A hardness of aluminum (Al6061) is increased from 50BHN to 88BHN with an addition of fly ash and magnesium. Fly ash up-to 15% by weight can be successfully added aluminum 6061 alloy by stir casting route to produce composites. The Ultimate tensile strength has improved with increase in fly ash content. Whereas ductility has decreased with increase in fly ash content. Compressive strength increases with the increase in reinforcement wt%[7]. Al- fly composite can be used for automotive and other applications and show details on environmental and energy benefits. The potential cost, energy, and pollution savings as a result of incorporation of fly ash are aluminum is huge. The potential reduction in cost and energy content of individual auto parts, energy consumption, and emissions due to the replacement of 20% aluminum by fly ash show the substantial benefit of using ALFA composites [8].

The coefficient of thermal expansion of pure Al containing 65 volume % of hollow fly ash particles and suggested that Composites with a lower coefficient of thermal expansion can be made by incorporating cenospheres under controlling the processing parameter for a given volume fraction of reinforcement. Composite synthesized at different pressure for different infiltration time (min) and came to conclude that increase in the infiltration pressure and temperature improves the infiltration and decreases the entrapped air voids, as a result of which lower the coefficient of thermal expansion[9].

Hybrid Composites

Hybrid materials are materials made by combining two or more different types of fibers in a common matrix. They offer a wide range of properties which cannot be obtained with a single matrix reinforcement.it possess low density, high strength, superior creep resistance, high damping resistance and good dimensional stability.

Material Used

Aluminium Alloy 2024

2024 aluminium alloy is an aluminium alloy, with copper as the major alloying element.it is used in applications requiring high strength, weight ratio, as well as good fatigue resistance.it has a density of 2.78g/cm^3.

Silicon Carbide

Silicon carbide is the only chemical compound of carbon and silicon.it is an excellent abrasive.it is having low density, high strength, high elastic modulus, high thermal conductivity, excellent thermal shock resistance. Elevated temperature performance and the fact that they reported only a 35% loss of strength at 1350□C and its melting point is 2700□C.

Fly Ash

Fly ash is one of the most inexpensive and low-density reinforcement available in large quantities as solid waste by-product during combustion of coal in thermal power plants. They constitute mostly of silicon dioxide, aluminum oxide/alumina, and iron oxide. Fly ash particles are mostly in shape and range from less than 1μm to 100μm.it is having high electrical resistivity, low thermal conductivity. The density of composite (Al2024, Sic and Fly ash) decreased by increasing the content of Silicon carbide and fly ash.

Properties of Hybrid composite (Al2024, Sic &Fly ash)

Table 1: Mechanical Properties

Density	2060 Kg/m³
Ultimate tensile strength	293MPa
Youngs modulus	99GPa
Poissons ratio	0.29
Hardness	95.7BHN
Thermal Conductivity	188.9 W/mk

Piston Manufacturing -Stir Casing Method

The Stir casting method (also called liquid state method) is used for the hybrid composite materials fabrication, in which a dispersed phase is mixed with a molten matrix metal by means of mechanical stirring. The liquid composite material is then cast by conventional casting methods and may also be processed by conventional metal forming technologies. In this study, the aluminium-Sic, aluminum- fly ash, aluminum-Sic-fly ash and aluminum-fly ash-Sic metal matrix hybrid composite was prepared by stir casting route. For this required amount of aluminum has been chosen and Sic, fly ash, Sic-fly ash mixtures in powder form. The fly ash and Sic and their mixture were preheated to 300°C for three hours to remove moisture. Pure aluminum was melted in a resistance furnace. The melt temperature was raised up to 720°C and then the melt was stirred with the help of a mild steel turbine stirrer. The stirring was maintained between 5 to 7 min at an impeller speed of 200 rpm. To increase the wettability, 1.5% of pure Mg was added with all composites. The melt temperature was maintained 700°C during the addition of Mg, SiC, fly ash, SiC-fly ash mixture particles. The dispersion of flash and other particles were achieved by the vortex method. The melt with reinforced particulates was poured into the preheated permanent metallic mold. The pouring temperature was maintained at 680ºC. The melt was then allowed to solidify in the mold. The metal matrix hybrid composites that we obtained.

DESIGN AND ANALYSIS OF PISTON

The Hybrid composite piston is designed with the help of machine design text book and data book. Piston dimensions are calculated and solid model is created in SOLIDWORKS 2013.Designed model of the piston is imported to

ANSYS 14.5 For analysis. The structural analysis is performed on ANSYS 14.5 WORKBENCH. Principle views of the piston are shown in figure 1 an isometric view in figure 2.

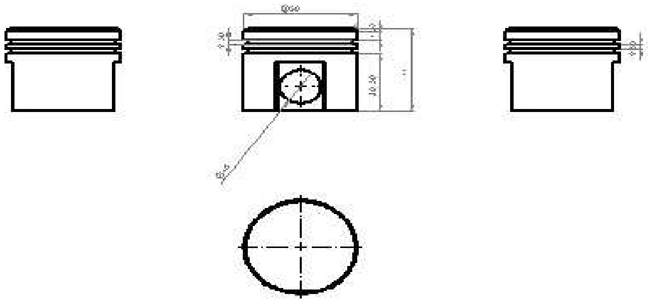

Figure 1: Orthographic Projection of Piston

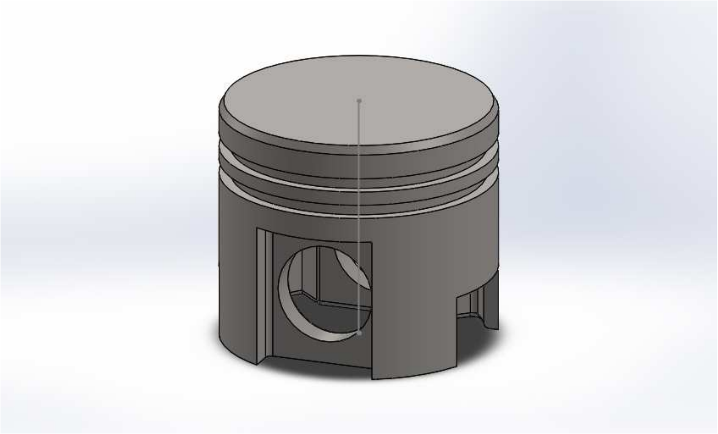

Figure 2: Isometric View of Piston

The pressure is taken as a boundary condition for structural analysis due to combustion pressure acts on the piston head during the power stroke. The piston is connected to connecting rod at small end bearing with the help of gudgeon pin which works as a fixes support. Because fixed support is given at surface of pinhole. Frictionless support has given on skirt and land. The pressure acting on the piston=5N/mm²

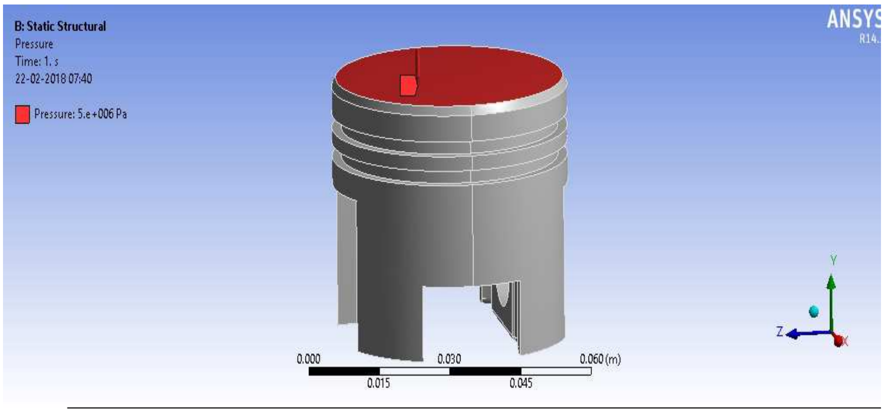

Figure 3: Boundary Condition-Pressure

RESULTS AND DISCUSSIONS

Total Deformation

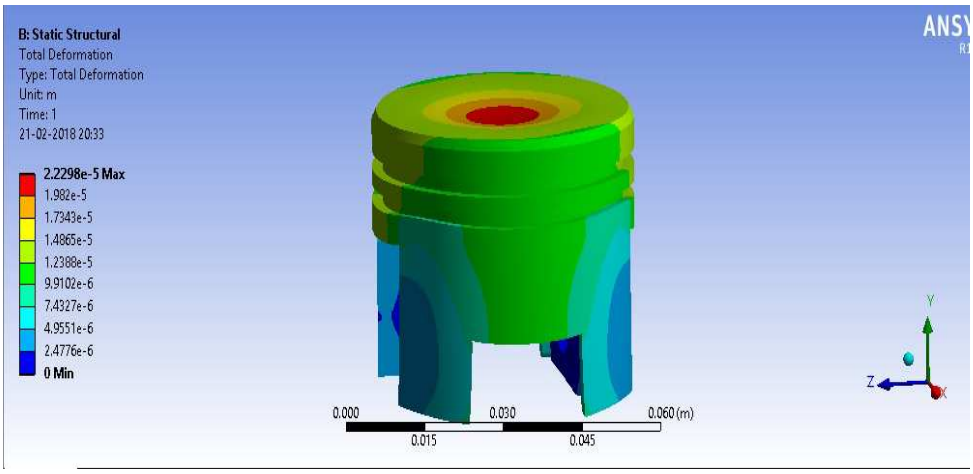

Figure 4: Total Deformation on Hybrid Composite Piston

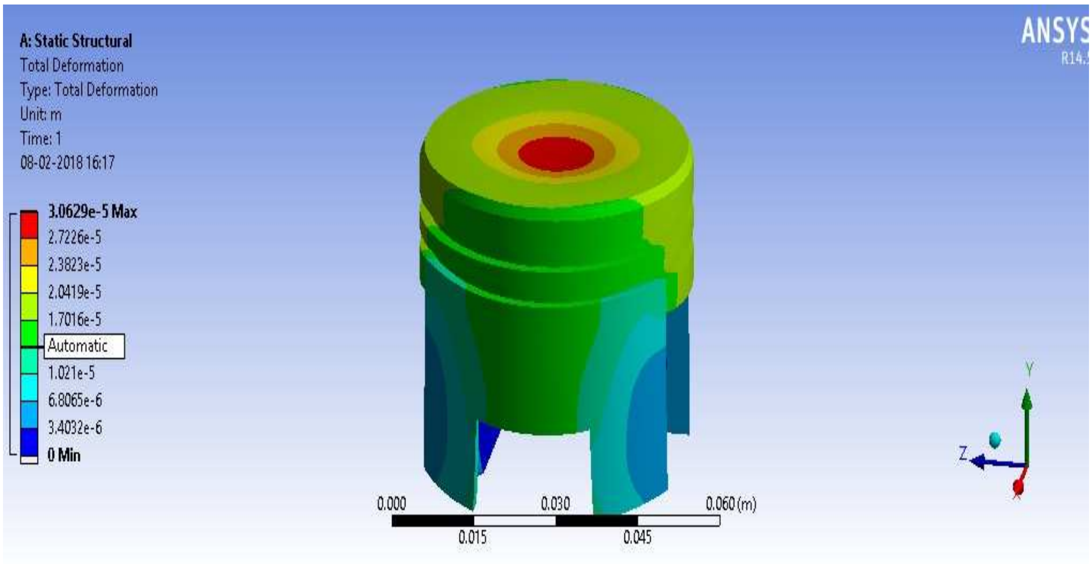

Figure 5: Total Deformation on Aluminium Alloy Piston

The figure 4 and 5 shows the total deformation of hybrid and aluminium alloy piston during application of load. From the figures, it is observed that total deformation of hybrid composite piston($2.2298x10^{-5}$ m) is less than Aluminium alloy($3.0629x10^{-5}$ m).

EQUIVALENT (VON-MISES STRESS)

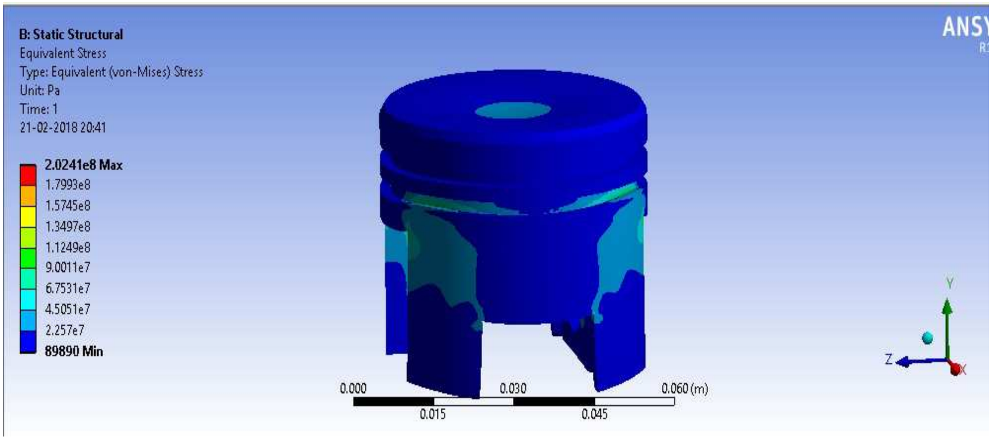

Figure 6: Von-Mises Stress on Hybrid Composite Piston

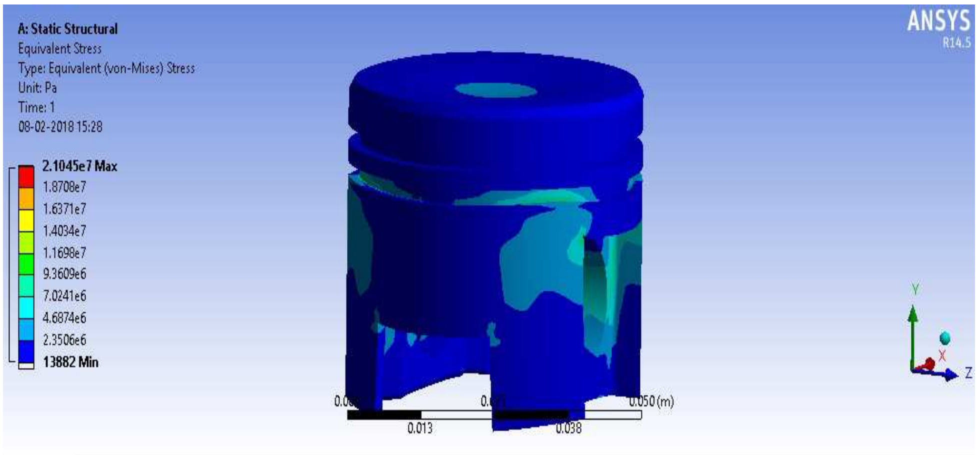

Figure 7: Von-Mises Stress on Aluminium Alloy Piston

From the above figures 6 and 7, it is evident that Stress concentration found to be less on hybrid piston compared to aluminium alloy.

EQUIVALENT STRAIN (VON-MISES STRAIN)

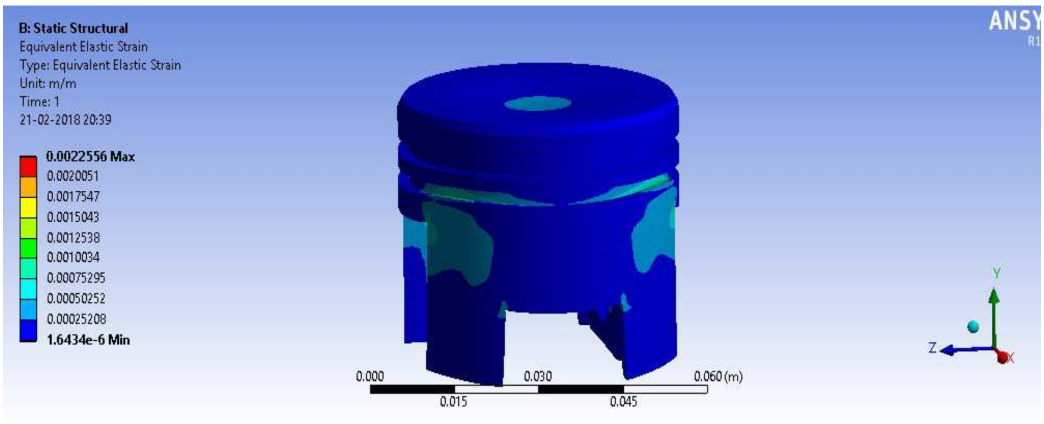

Figure 8: Von-Mises strain on Hybrid Composite Piston

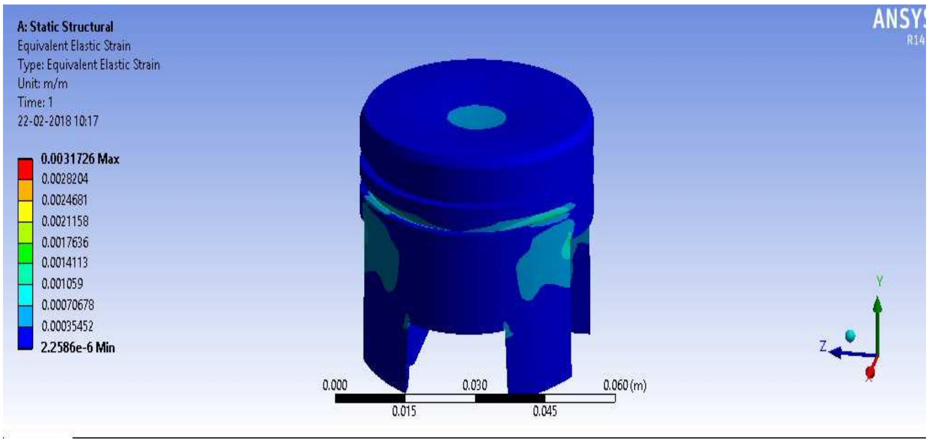

Figure 9: Von- Mises Strain on Aluminium Alloy

The maximum von-mises strain on hybrid composite piston is 0.0022556 and minimum is $1.6434x10^{6.}$ The maximum and minimum von-mises strain on aluminum alloy is 0.0031726 and $2.2586x10^{-6}$**.** The Strain found to be in a hybrid composite piston.

CONCLUSIONS

A hybrid composite piston was designed in SOLIDWORKS 2013 and structural analysis was performed successfully on ANSYS 14.5 workbench. The Hybrid composite material has better mechanical properties than aluminium alloy. From the analysis, it is concluded that hybrid composite piston found to be less deformation, less strain and reduced stress concentration on the piston head compared to aluminum alloy. The piston made of aluminum 2024,Silicon carbide and fly ash possess high wear resistance, high corrosion resistance, low density, high hardness, tensile strength and impact strength. Problems like scratching and abrasion faced by the alumini\um alloy piston can be solved by a hybrid composite piston.

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