Journal of Manufacturing Engineering, June, 2017, Vol. 12, Issue. 2, pp 77-81

EFFECT OF DIFFERENT PROPORTIONS OF SILICON CARBIDE REINFORCED MAGNESIUM ALLOY COMPOSITES FOR CONNECTING ROD APPLICATIONS

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ABSTRACT

The more self weight of connecting rod is the main cause of problem to affect the engine performance. Due to its high density characteristics which has to overcome the inertia force during the engine operation and also the fuel consumption got increased by 0.5%. Then, reducing peak engine speed and reducing bearing and crankshaft durability. Lighter connecting rod helps to decrease forces of inertia in engine as it does not require big balancing weight on crankshaft. In this study, micron-sized SiC particles were used as reinforcement to fabricate the Magnesium alloy - SiC composites at two casting temperatures (650 and 830 °C) and stirring periods (3 and 6 min). In this regard, connecting rod is replaced by Magnesium based composite material reinforced with silicon carbide and it also describes the modeling and analysis of connecting rod. The mechanical properties of Mg. alloy showed good results with addition of SiC. Finite element analysis of connecting rod is done by considering Magnesium Reinforced with Silicon Carbide. The parameters like von mises stress, von mises strain and displacement were obtained from ANSYS software. The obtained results lead to improve the engine performance & fuel economy due to the weight reduction in the Mg-SiC composites made of' connecting rod.

Keywords: *Connecting rod; ANSYS; Composites; Magnesium; Silicon carbide; analysis.*

1.Introduction

The connecting rod is the intermediate member between the piston and the crankshaft and its primary function is to transmit the gas force from the piston to the crankshaft, thus converting the reciprocating motion of the piston into rotary motion of the crankshaft. Generally connecting rods are manufactured using carbon steel and in recent days numerous studies are carried out with regard to various composite materials [1]. A connecting rod in a high performance engine is subjected to inertia forces and bearing loads and can be able to withstand these forces for a large number of cycles [2]. In order to reduce the forces exerted during engine operation, the connecting rod weigh as little as possible and have very high fatigue strength [3]. The connecting rod undergoes cyclic loads like tension, compression and bending and then it is subjected to a combination of axial and bending stresses [4]. Connecting rod should involves the overall weight of the vehicle and so that it posses lighter in weight, but unfortunately existing one leads to increase the weight of the vehicle [5]. Lighter connecting rods help to decrease lead caused by inertia forces and then it led the invention and implementation of new materials which are meets design requirements [6]. Application of metal matrix composite of connecting rod leads to effective use of fuel and to obtain high engine power [7]. Engine elements have increase of durability of particular part will result in effective reduction of weight [8]. The modeling and analysis of connecting rod made by carbon steel replaced by aluminum boron carbide fairly good [9]. The aluminum boron carbide is found to have working factory of safety is nearer to theoretical factory of safety [10]. The stress analysis of connecting rod by finite element method and it concluded that the stress induced in the small end of connecting rod are greater than the stresses induced at the bigger end, therefore the chances of failure of the connecting rod may be at the fillet section of both end [11] . The performance of the static FEA of the connecting rod using the software which gives a view of stress distribution in the whole connecting rod and also gives the information about hardened during manufacturing stage [12]. A dynamic simulation was conducted on a connecting rod made of aluminum alloy using FEA and through this analysis

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performance carried out under dynamic load for stress analysis and optimization [13]. Recently, automotive lightening has led to an increase in the demand for magnesium (Mg) alloys, which are lightweight substitutes for aluminum. If Mg alloys begin to be used for connecting rod of engines, the demand will increase [14]. In the past, various studies have been carried out on metal matrix composites SiC, TiC and B4C are the most commonly used particulates to reinforce metal or alloy matrix or aluminum or iron, while the study of SiC in Mg. alloy is still rare. However, very limited studies have been carried out and so the information and the data available on the mechanical properties are scarce and hence make this study a significant one. Moreover no research have been done on SiC reinforced Mg. alloy composites. Hence, this research work focuses on synthesis and dynamic load analysis of connecting rod made of novel composite material of magnesium alloy reinforced silicon carbide.

2. Materials and Methods

2.1 Materials

Magnesium is the lightest commonly used structural metal. Alloy AZ91D is the most widely-used magnesium die casting alloy. It is a high-purity alloy with excellent corrosion resistance, excellent cast ability, and excellent strength. Magnesium alloys are mixtures of magnesium with other metals (called an alloy), often Aluminum, Zinc, Manganese, Silica, Copper, Ferrous. The chemical composition of Magnesium Alloy Reinforced Silicon Carbide as shown in the following table 1. Silicon Carbide is the only chemical compound of carbon and silicon. It was originally produced by a high temperature electro-chemical reaction of sand and carbon. Silicon carbide is composed of tetrahedral of carbon and silicon atoms with strong bonds in the crystal lattice. The type of the silicon carbide is F320. Density of silicon carbide is between 1.27-1.36 g/cm^3 and the mesh size is 27.2 ± 1.2 µm. The structure of the silicon carbide is hexagonal 6H with rhombohedra 15R.

Table 1.Chemical Composition of Magnesium alloy

Elements	Si	Fe	Cu	Mn	Zn	Al	Mg
Wt%	14.62	0.948	1.67	0.115	0.83	15.2	66.61

2.2 Synthesis Process

Stir casting process was used for the fabrication of the testing specimen. Stir casting is the process in which mechanical stir is used for the mixing of the particles. The speed controller maintained a constant speed of the stirrer, as the stirrer speed got reduced by 50-60 rpm due to increase in viscosity of the melt when particulates were added into the melt. After the addition of reinforcement, stirring is continued for 15 to 20 minutes for proper mixing of the prepared particles in the matrix. After this the stir is replaced by an ultrasonic probe for the proper dispersion of particulates in the matrix. Before the system the horn is preheated to higher than 5000 ^{o}C, the system frequency 20.40 KHz about. The melt was kept in the crucible for approximate half minute in static condition and then it was poured in the mould. The finger die was designed by conforming that tensile, compressive and hardness test specimen could be produced by a single casting process simultaneously. A finger die has been used for the casting of testing specimen.

2.3 Modeling

The dimensions of the selected connecting rod are calculated using Vernier calliper, Screw gauge and the same model is developed using CATIA modeling software with found out dimensions. The modeled connecting rod and it is import into design modeller of Hyperworks 11.0. The next stage of the modeling is to create meshing of the created model. For the finite element analysis 3.2 Mpa of pressure was used. The analysis was carried out using CATIA and hyper works software. The pressure is applied at the small end of connecting rod keeping big end fixed. The maximum and minimum von-misses stresses and strains were note down. The mesh model of connecting rod is as shown in Fig 1.

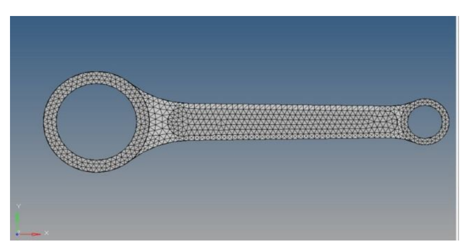

Fig .1 Mesh diagram of Mg. alloy

3 Result and Discussion

The various mechanical tests were performed such as Modulus of Elasticity, Tensile strength, Compression strength (Universal Testing Machine), and Hardness Test (Brinell Hardness Tester). Those tests are performed to investigate the mechanical properties by the effect of different weight percentage of reinforcement of SiC in Magnesium alloy composites.

Table 2. Mechanical Properties of Magnesium Alloy with SiC

Property	Mg. Alloy	Mg. alloy+1%SiC	Mg. alloy+2%SiC	Mg. alloy+3% SiC	Mg. alloy+4%SiC	Mg. alloy+5%SiC
Compression strength (Mpa)	280.4	286.3	291.4	304.6	307.5	309.9
Hardness (BHN)	78	79	80	80	81	81
Tensile Strength (Mpa)	66.9	72.3	74.26	76.26	77.46	77.85
Young's Modulus (Gpa)	64.7	72.3	77.2	78.8	79.3	80.1

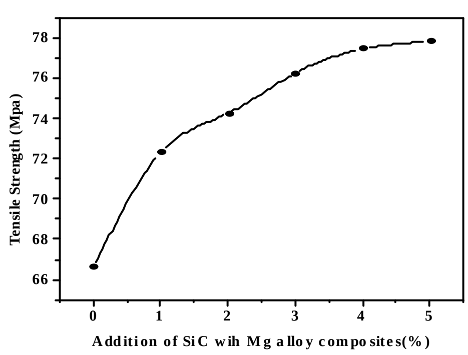

Fig. 2 Effect of tensile strength variation with SiC loading

Fig. 2 shows that, the tensile strength of Mg. alloy reinforced with SiC particles. It was observed that tensile modulus gradually increased with addition of SiC particles. It was due to the fine grain size of Magnesium and SiC, both together considered to be inhibited with improvement of the tensile property. Also, the grain size and the local strain of Mg are very small. Hence fine grain structure was formed the magnesium matrix which leads to tensile strength\increment.

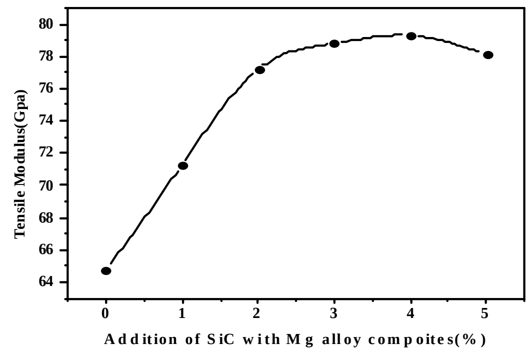

Fig. 3 Effect of tensile modulus variation with SiC loading

Fig. 3 shows that, the tensile modulus of Mg. alloy reinforced with SiC particles. It was observed that tensile modulus gradually increased with addition of SiC particles. It was due to the fine grain size of magnesium with fine powder of SiC, both together were facilitate to increase the tensile modulus.

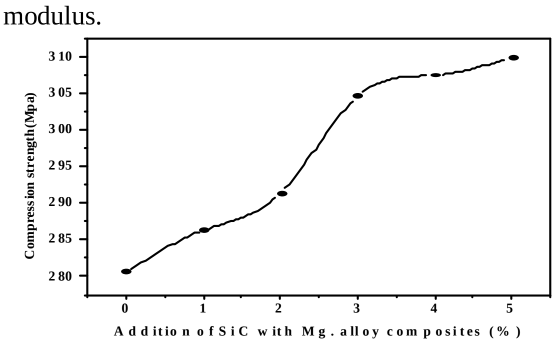

Fig. 4 Effect of compression strength variation with SiC loading

Fig. 4 shows that, the compression strength of Mg. alloy reinforced with SiC particles. It was observed that compression strength gradually increased with addition of SiC particles. It was due to SiC powder made vital role along with Al_2O_3 contents in the composition , it expressed as mass percent rather than volume percent, which leads to increase of density with magnesium alloy composites and hence compression strength increases with increment of SiC.

Fig. 5 shows that the hardness of Mg. alloy reinforced with SiC particles. It was observed that the hardness deeply increased by addition of wt. % of SiC. It was due to hardness of composite depends on reinforcement and the matrix formation. which relates to coefficient of thermal expansion of SiC (8.103µm/m ^{o}C) is less than that of aluminium alloy 5083 (24.3µm/m ^{o}C), an enormous amount of dislocations are generated at the particle- matrix interface during solidification process. It leads to further increases of the matrix hardness. Moreover, the hardness of SiC exceeded that of the representative commercial Mg alloy. Also, The contact area between the SiC powders is to increase the compacting, because the SiC powder seems like spherical in shape.

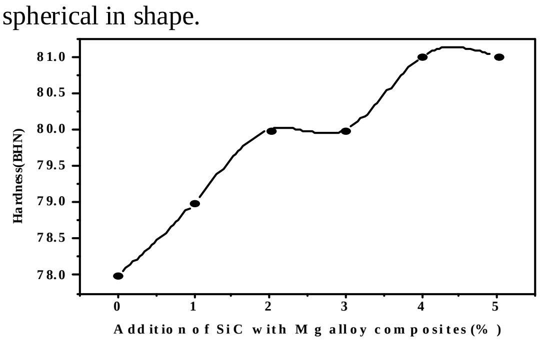

Fig. 5 Effect of hardness variation with SiC loading

4. Analysis of Connecting Rod

The von-mises stress and strain were noted for all the composites of magnesium alloy with different proportions of SiC powders are shown in the following figures 6-8.

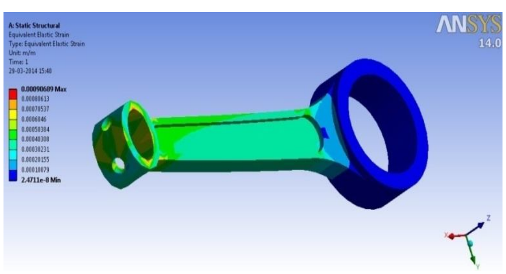

Fig. 6 Von Mises stress on connecting rod for Mg. alloy

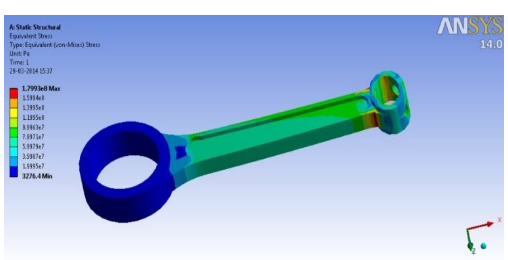

Fig. 7 Von Mises stress on connecting rod for Mg alloy with 1% SiC.

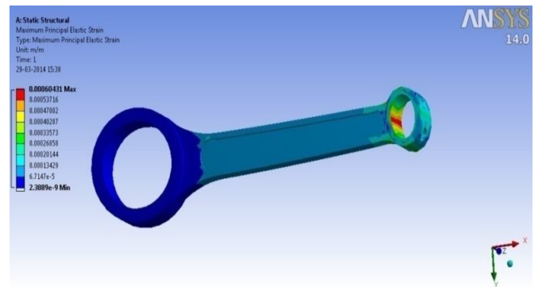

Fig. 8 Von Mises stress on connecting rod for Mg alloy with 5% SiC

Fig. 9 and 10 shows that, von mises stress and strain were observed as decreasing order as increase of SiC powders. It was due to fine form of SiC powder are uniformly distributed in the alloy matrix and good bonding with ma. Alloy which influences the mechanical properties. If addition more SiC with mg. alloy it loosens its bonding, which due to spherical shape of SiC not having good adhesion. Hence, Magnesium alloy made of connecting rod is having more weight and displacement than magnesium reinforces with SiC composites which leads magnesium alloy connecting rod show more shaky behavior.

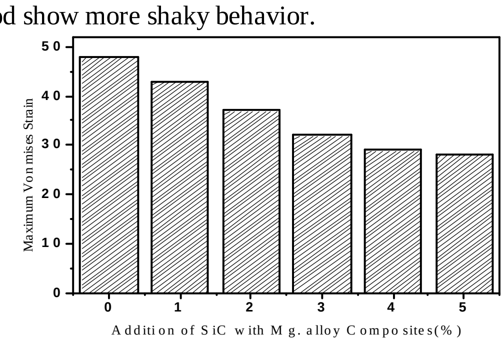

Fig. 9 Effect of Max. Von Mises Strain of Mg alloy composites with variation of SiC

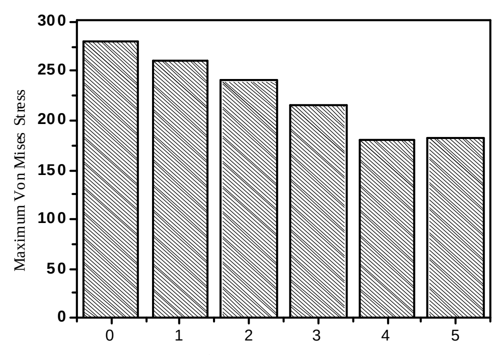

Fig. 10 Effect of Max. Von Mises Stress of Mg alloy composites with variation of SiC

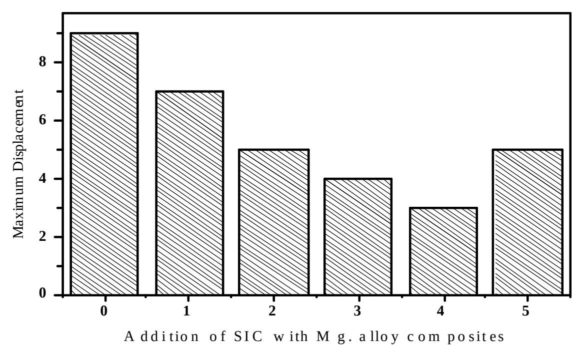

Fig. 11 Effect of maximum displacement of Mg alloy composites with variation of SiC

Maximum von mises stress, maximum von mises strain and maximum displacement are minimum in connecting rod made of magnesium alloy with 4%SiC. More than 5%SiC addition with magnesium composites appeared as von stresses higher, which leads to lesser working life/durability and hence the maximum tensile stress developed in 4% SiC in magnesium alloy composites. Also, this analysis study found that, magnesium alloys with 4%SiC is the best suitable material for connecting rod applications. It is suggested that the results obtained can be useful to bring about modification in design of connecting rod.

5 CONCLUSION

Use of Silicon carbide with Magnesium alloy composites causes enhancement in the properties. From this study, the following conclusions can be drawn:

- The tensile strength and tensile modulus gradually increased with increased 4% of SiC with Magnesium alloy composites.
- The compressive strength increased by increasing addition of SiC.
- The hardness increased deeply with addition of SiC till 4% .
- Von mises stress and von mises strain are minimum in connecting rod made of magnesium alloy with 4%SiC.
- Hence, the obtained results lead to improve the engine performance & fuel economy due to the weight reduction in the Mg-SiC composites made of' connecting rod.

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