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Effect of Load on Wear and Friction of ALSi/MWCNT Functionally Graded Material Via Powder Metallurgy with Hot Extrusion Technique

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Abstract

Due to the superior mechanical and thermal properties of nanomaterials like multi-walled carbon nanotubes, aluminum alloys containing them play a significant role in the aerospace and automotive industries. By incorporating multi-walled carbon nanotubes by weight percentage of (0, 0.25, 0.50, and 0.75) in Aluminum silicon alloy. proper dispersion is done using ball milling equipment to get the proper bonding between Aluminium silicon alloy with MWCNT then subsequently powder metallurgy followed by extrusion technique. Wear study is carried out by varying load by 20N to 40N by maintaining sliding distance constant at 1000m and speed at 3.14m/sec. Wear test indicates for 20N load that wear rate is reduced by 46% for 2-layer FGM compared to AlSi-0.5WT% MWCNT, AlSi-0.25WT% MWCNT and 10% reduction in wear rate compared to AlSi-0.75WT% MWCNT. In case of 40N, wear rate is decreased by 162% for 2-layer when compared with AlSi-0.25WT% MWCNT and by 91% when compared to AlSi-0.5WT% MWCNT. As the percentage of MWCNT increases leads to decrease in wear rate in case of 20N & 40N load for 2-layer FGM compared to nanocomposites. Optical microscopy is done to reveal the proper bonding of AlSi with MWCNT. SEM analysis is carried out to determine wear mechanism.

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Keywords
AlSi; Automobile; Aerospace; FGM; MWCNT.

Introduction

Aluminum alloys are used in several applications ranges from Automotive to Aerospace applications due to its tremendous light weightiness.[1-2] Various types of reinforcements can be added such as Silicon carbide,[3] Alumina,[4] aluminium nitride,[5] and granite[6] to Aluminum alloys to impart wear resistance properties. The novel invention of nano-

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materials such as CNT's revolution the materials research industry.[7] CNT addition to aluminum alloys leads to increase in wear resistant property of the materials.[8-11] The nano-composites produced by powder metallurgy route followed by extrusion technique leads to immense potential applications in Automobile sector. Since engine components produced by casting route has some disadvantages that will be corrected by powder metallurgy route with the invention of ball milling to get uniform distribution of constituents in composites to avoid agglomeration problem.[12] Ball milling is carried out by considering various ball milling parameters such as ball milling speed, Process control agent (PCA), ball milling time to achieve uniform distribution between the constituents.[13] In powder metallurgy route sintering plays an important role for diffusion of particles to get strengthens materials to avoid voids. Sintering of materials such as Fe-1.5 wt % Cu alloys followed. Functionally graded materials are the novel advanced materials, where in properties can be controlled with respect to the dimension of the material by controlling the constituents of the material. Tailor made properties of the material can be produced by functionally graded materials. Functionally graded materials help in enhancing the properties of the material by providing the opposite properties such as strength and ductility, hardness and toughness in the same material.

Thermal delamination problem of chromium coated cast iron piston rings occurs due to difference in co-efficient of thermal expansion of cast iron and chromium. Delamination problem can overcome by producing with the same AlSi material with controlled MWCNT weight percentage as layer to produce functionally graded material.

In this paper functionally graded material with two-layer is fabricated by powder metallurgy route with hot extrusion technique for *wear* application of piston rings. FGM fabricated to replace conventional chromium coated cast iron piston rings. Produced functionally graded material shows light weight and enhanced strength. If weight is reduced, then it reduces the weight of the engine finally it enhances the overall efficiency of the engine.

Materials & Methods

Structural integrity of multi wall carbon nanotubes helps in improving the mechanical properties and melting temperature of 3000^{o}C helps the composite material to sustain at extreme temperatures. Multi wall carbon nanotubes with purity> 99% used as reinforcement. Aluminum silicon alloy powder with average particle size of 50-60μm used as matrix. composition of Aluminum silicon alloy shown in Table.1.

Table. 1: Constituents of Aluminum silicon alloy powder

Element	Composition (%)
Aluminum (Al)	85
Silicon (Si)	12.20
Magnesium (Mg)	1.0
Copper (Cu)	0.90
Nickel (Ni)	0.9

Multi wall carbon nanotubes uniformly dispersed in aluminium silicon alloy powder using Planetary ball milling equipment with operating parameters such as milling speed of 250rpm, time 5h, Process control agent (PCA) acetone used as 10ml after each 1h to avoid cold welding of AlSi particles. Zirconia balls are used with diameter 8mm and ball to powder weight ratio of 10:1 is used. Powder mixture of Aluminium silicon alloy and multi wall carbon nanotube cold compacted to produce specimen of dimension of 20mm×20mm using Universal testing machine with load of 100KN. Hot extrusion carried out with temperature of 600oC with extrusion ratio of 2.5:1 and gradual load of 2.5MPa is applied to produce extruded specimen of diameter 8mm and length 60mm. specimens are cut and machined for the *wear* test.[14-16]

Two Types of Samples Produced

1. Nanocomposite

2. Two-Layer Functionally Graded Materials

Nanocomposites produced with AlSi as matrix and MWCNTs as reinforcements with varying weight percentage of (0.25,0.50 & 0.75).

Step-by-step procedure followed in fabrication of two-layer FGM is powder metallurgy with hot extrusion shown in Figure.1.

Two-layer functionally graded materials fabricated in 2-layers, as one layer is base AlSi and substrate layer is AlSi-0.75wt% MWCNT can be seen in Figure. 2.

Wear test is carried out on pin on disc equipment with G99 ASTM standard. *Wear* study is carried out to determine effect of load with 20N and 40N on *wear* rate and coefficient of friction of composite and functionally graded materials.

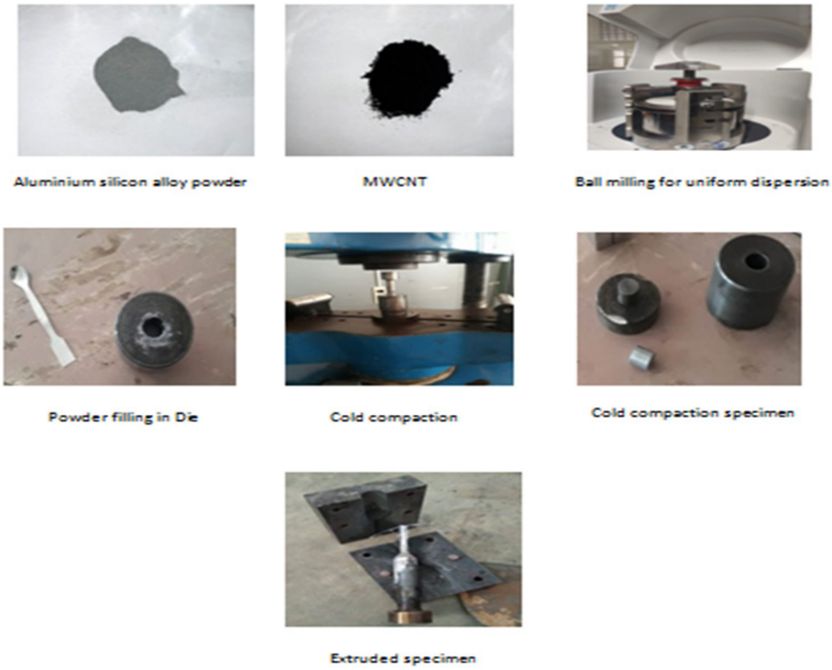

Fig.1: Flow chart for fabrication of Two-layer FGM

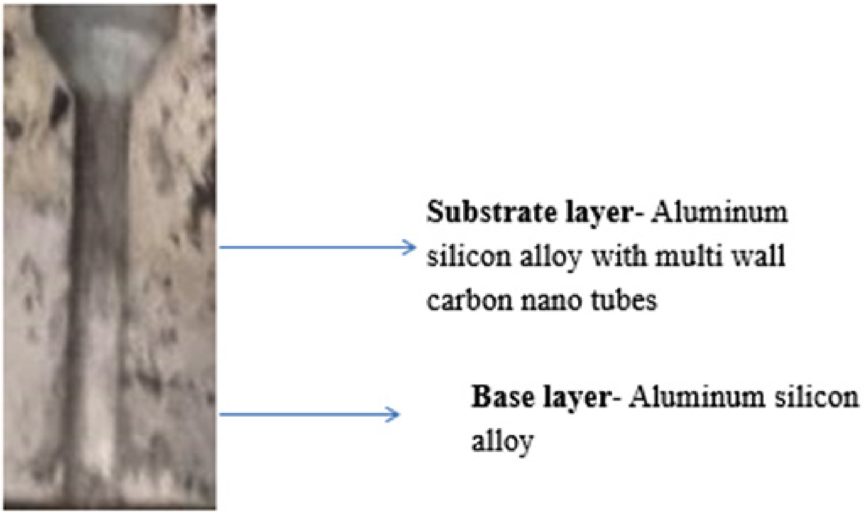

Fig .2: Shows Two-layer FGM specimen

Results & Discussion

Wear test is carried out on pin on disc machine to determine the effect of varying load by keeping sliding distance constant at 1000m and speed at 3.14m/sec. The load varied from 20N and 40N to determine its effect on *wear* and frictional force on nanocomposites and functionally graded material. SEM analysis is carried out to determine the *wear* mechanism occurring in the composites and functionally graded material.

Effect of Load on Weight Loss of Composite and Functionally Graded Materials

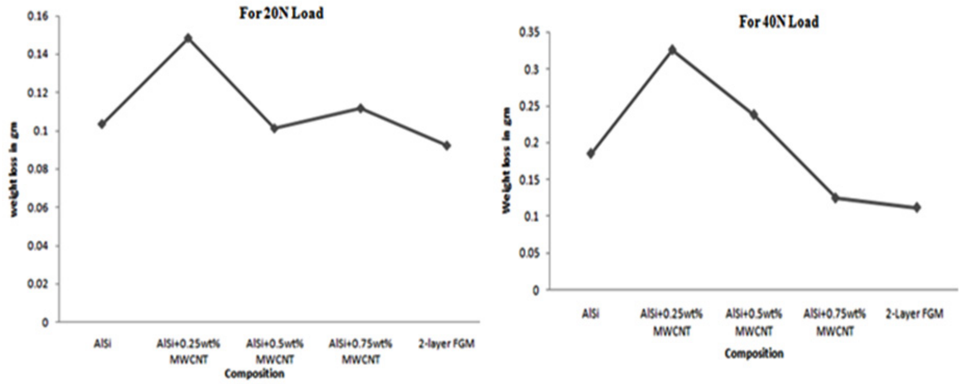

Fig. 3: Effect of load on weight loss of Composite and functionally graded materials

Figure. 3 shows Effect of load on weight loss of the composite and functionally graded materials, for both 20N & 40N load, the material loss in terms of gram for functionally graded material is less compared to nanocomposites.

Effect of Load on Wear Rate and Frictional Force

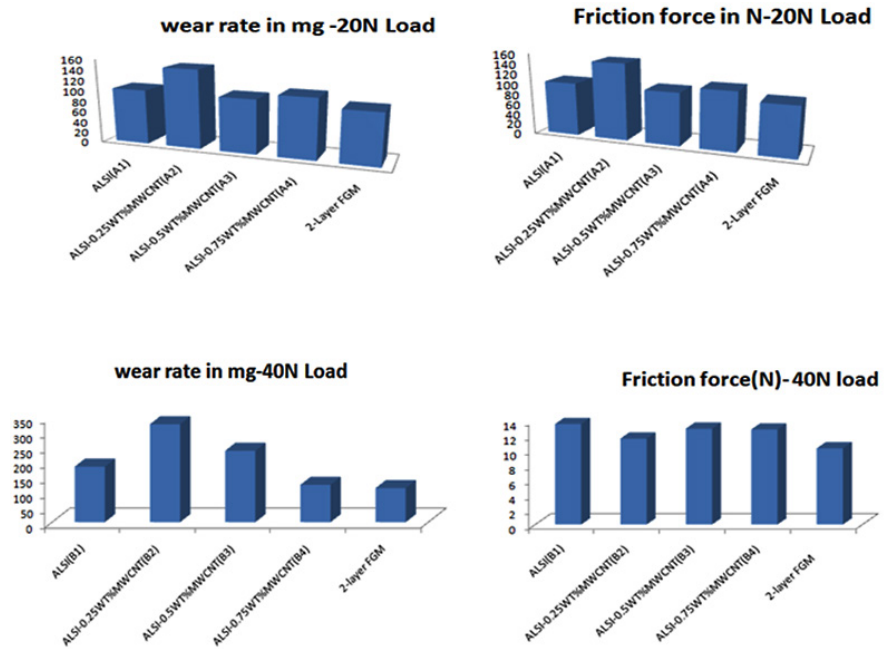

Fig. 4: Effect of Load on wear rate and frictional force on base AlSi, nanocomposite and 2-layer FGM

Wear rate and frictional force reduced immensely for functionally graded materials compared to nanocomposites with MWCNT variation in AlSi matrix. Reduction in *wear* rate and friction force is due to the proper bonding and uniform dispersion of multi wall carbon nanotubes in the AlSi matrix. *Wear* rate is very less for 40N load when compared to 20N load for functionally graded material.

Optical Microscopy of Alsi, Nanocomposite & Functionally Graded Material

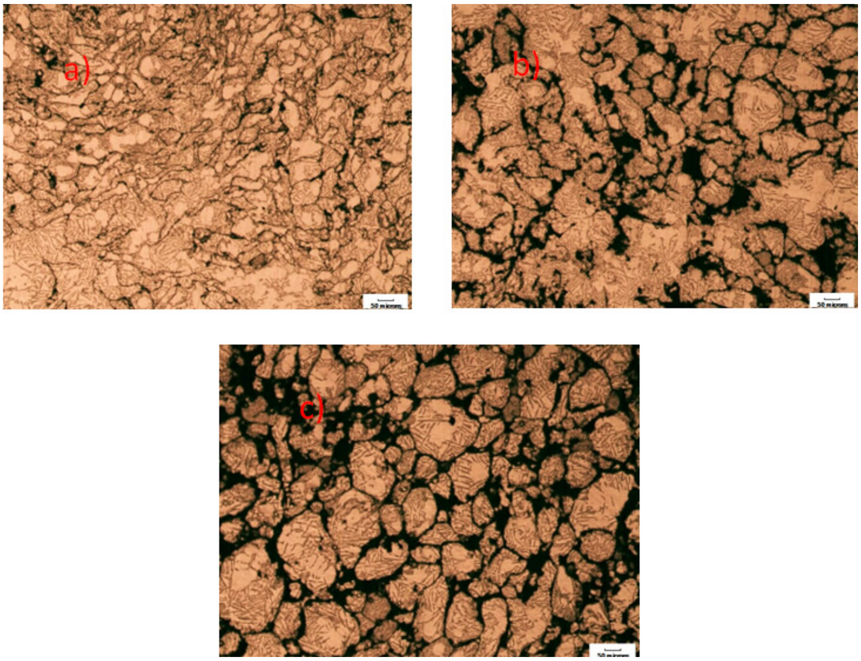

Fig. 5(a-c): Optical microscopy of a) AlSi, b) nanocomposite and c) functionally graded material

Figure.5 (a) indicates Microstructure consists of fine eutectic particles of silicon Aluminum solid solution. Figure. 5 (b-c) indicates Microstructure consists of fine eutectic particles of silicon and fine inter-metallic's such as carbon particles in Aluminum solid solution.

Dispersion of Mwcnt in Alsi Matrix Shown in Sem Analysis

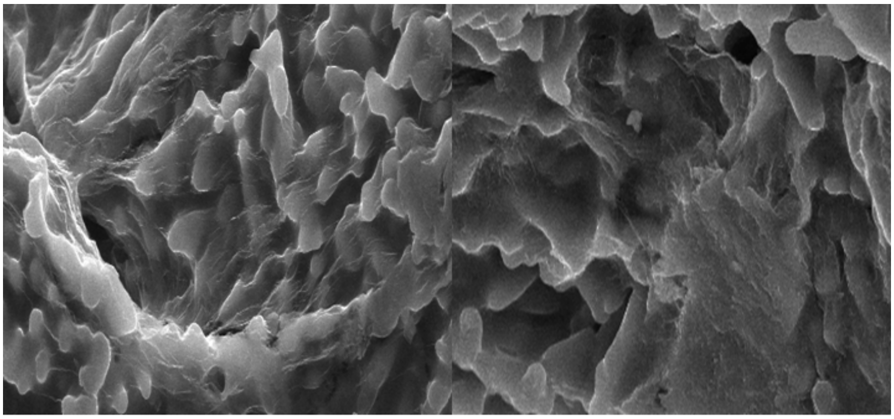

Fig. 6: SEM analysis of powder sample indicating MWCNT dispersion in AlSi material

Multi wall carbon nanotubes (MWCNT) dispersed uniformly in Aluminum silicon (AlSi) matrix as clearly seen in Figure-6. Uniform dispersion is achieved with the help of ball milling process with suitable milling parameters.

SEM Analysis of Worn Surfaces of Alsi, Nanocomposites & Functionally Graded Materials

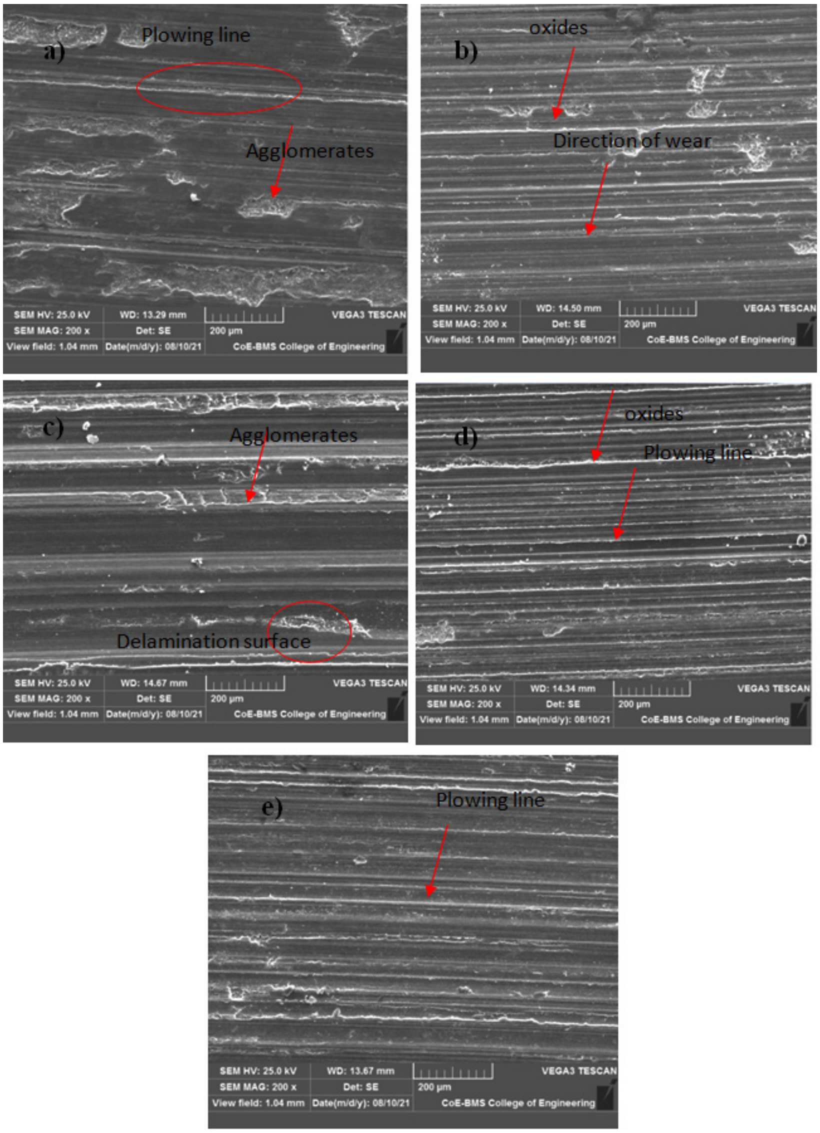

Fig. 7: Shows SEM images of worn surfaces of a) AlSi, b) AlSi-0.25wt% MWCNT, c) AlSi-0.25wt% MWCNT, d) AlSi-0.25wt% MWCNT & e) 2-layer FGM

Wear mechanism occurring in the nanocomposites and functionally graded material studied through SEM analysis of worn surfaces. Wear mechanism occurring in the nanocomposites by the combination of agglomerates, oxide formation and delamination. Plowing line and direction of wear indicates how the wear is occurring the nanocomposites. Functionally graded material shows indication of delamination and agglomerates that clearly indicates less *wear* occurring in the functionally graded materials.

Functionally graded materials demonstrate less wear compared to nanocomposites there by providing enhanced bonding and strength in the material.

Conclusion

Functionally graded materials successfully fabricated by powder metallurgy route with hot extrusion technique. Functionally graded material fabricated in axially to give the required wear strength to the exposed layer. Comparative *wear* study is carried out with AlSi, nanocomposites with varying load by 20N to 40N by maintaining sliding distance constant at 1000m and speed at 3.14m/sec. Optical microscopy is done to see the proper bonding of AlSi with MWCNTs. Uniform dispersion of MWCNT in AlSi is depicted in SEM morphology of specimen. SEM analysis is carried out to determine the *wear* mechanism occurring in the AlSi, nanocomposites and functionally graded material. Effect of load on *wear* and frictional force is determined. Functionally graded material shows less wear rate and frictional force compared to AlSi and nanocomposites, same can be seen in SEM images.

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Conflict of interest

Authors do not have any conflict of interest among themselves.

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