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Influence of nano particles reinforcement on the thermal and electrical properties of aluminium alloy matrix composites

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Abstract: An attempt is being made to develop nano particles reinforced metal matrix composites using powder metallurgy process. Uniform distribution of particles was achieved by sonication of reinforcement for distribution of Carbon nano tube (CNT). FESEM has shown the distribution with particle size conforming nano size and uniformity of distribution. Mechanical properties like radial compressive strength, microhardness, thermal and electrical conductivity were evaluated. Radial compression testing was carried out to see the influence of CNT on aluminium alloy and also evaluate the bonding phenomena. Electrical conductivity of these composites were also evaluated and presented. The findings results in guiding to select the reinforcement to achieve the desired properties.
Key words: Nano composites, radial crushing strength, electrical conductivity, sonication.

Introduction

Metal matrix composites are widely used in industrial process owing to their feasibility of tailoring the properties to specific applications like lower thermal expansion, higher thermal conductivity and higher stiffness. Fraunhofer Institute [1] have reported an increase of 20% in electrical conductivity and enhancement of electronic properties. Cu-AL_2O_3 composites improved the microhardness than pure aluminium /aluminium alloys due to its nodular structure .Bakshi et al [2] have reviewed CNT incorporated nano composites and detailed the applications in engineering industries. According to El sayed et al., [3 the exfoliated graphite nano composites increased the strength and microhardness of aluminium composites and the process is followed for preparation of CNT reinforced aluminium composites in the present work . Yufeng and Gap [4] and Choi et al.,[5] have adopted ball milling and high speed ratio rolling to develop CNT reinforced aluminium composites but stated that ball milling damages the CNT. Chunfeng et al., [6] have adopted cold iso static pressing and reported an enhancement of tensile strength to an extent of 30.8% with AA2024. The sonication ensures highly ordered dispersion of nano particle reinforcement and prevents their agglomeration without disrupting the size of the particles. Das [7] has stated that CNT reinforcements will be improving electrical properties. Jinzh et al., [8] have concluded that 0.5% CNT addition to aluminium matrix has improved tensile strength and hardness. The present paper reports the preparation of CNT incorporated aluminium composites employing sonication method as first time for achieving the desirable mechanical properties such as radial crushing strength, thermal expansion and electrical conductivity of nano composites.

Experimental details:

Preparation of Nano composite mixture using the process of Sonication

The Aluminium alloy AA6061 powder from AMPAL has been used to prepare the Nano composite and Exfoliated Graphite sheets and MWCNT sourced from ARCI Hyderabad and has been used to prepare the nano composite. Exfoliate graphene sheets are dissolved in acetone and the solution is sonicated for one hour till the uniform dispersion is achieved. Acetone is used as the solvent for dispersing the CNT and graphite Nano particles. Care must be taken with the amount of solvent used in the process. As the variation of the solvent in the process varies the dispersion achieved also varies. The frequency of agitation and the amplitude of the tip should be constant in all the processes to prevent the variation in dispersion in the mixture. Sonicated uniform solution is added with aluminium alloy powder and sonication continued for one more hour until a good dispersion is achieved in the mixture. The mixture is then heated in a hot air oven at 80^0C for 12 hours so that the solvent evaporates and a uniform mixture is achieved. This is then used for preparing the green compact. Similar process is adopted for preparing the CNT with aluminium mixture also. The mixer after drying overnight is again crushed in the ball mill to get uniform powder with tungsten carbide balls. The objective of milling is to ensure no aggregated mass is present in the powder. Sonication was performed at an amplitude of 70 µm, timer and pulser values are set to 10 mts and 6 seconds respectively.

Testing of radial crushing strength

The radial crushing strength test is a destructive procedure used to determine a material strength characteristic of PM bearings and hollow cylindrical test specimens. These data can be used to grade, classify, and evaluate the materials. The radial crushing strength is evaluated as per ASTM B 939-09. This test is conducted in hollow thin walled cylindrical specimens at a rate of 1mm/min. Here controlled compressive force should be applied perpendicular to its central axis under uniformly increasing load until fracture occurs. These data can be used to grade, classify, and evaluate the materials. The specimen is prepared from 20 mm dia solid specimen of 10 mm length by wire cutting the inner dia for 10 mm. The standard of testing may be used by powder producers and parts manufacturers as a lot acceptance test for metal powders and lubricated powder mixtures intended for the production of porous parts .Companies in the PM industry use this test as a manufacturing control test because it is appropriate for production practices and Radial crushing strength is a property of the PM material but does not have a design value. However, experience has shown that the radial crushing strength of a material is approximately twice the ultimate tensile strength. Surface of the specimen and the ram flat surfaces of the universal testing machine are cleaned with acetone .Wipe the loading plates clean and lay the test specimen in the central region of the lower plate and bring the upper plate and test specimen into contact and slowly apply the load till the failure occurs by means of a crack.

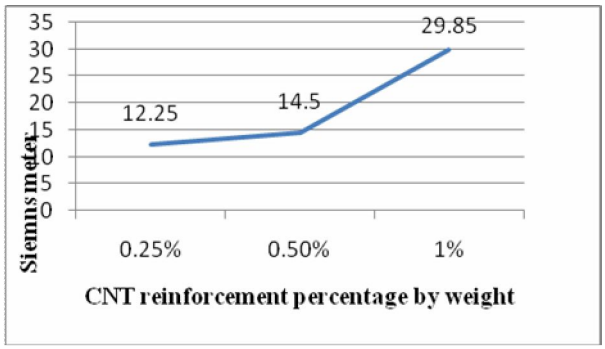

Figure 1.Electrical conductivity Vs CNT percentage.

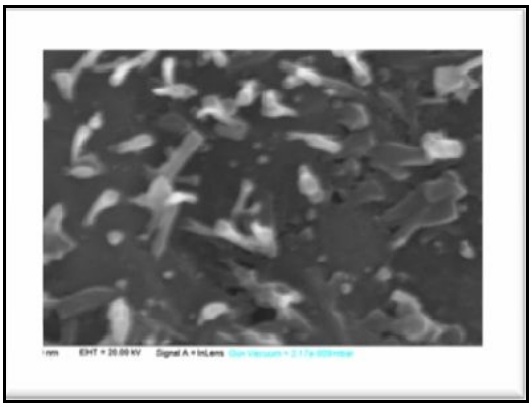

Figure 2.SEM fractograph after crushing.

Results and discussion:

Scanning electron microscope fractograph of the specimen clearly show uniform distribution of CNT in the matrix. Sonication and the subsequent process is found to be an effective method of manufacturing nano composites. Radial crushing testing has given the ultimate load for failure 471 MPa for 0.5% CNT where as it was only 35 MPa for 0.25%. This is in line with the findings of Yufeng and Gap [4] who has reported strengthening of CNT was only on account of particle rearrangement and not on plastic deformation. The failure

fractograph has evidence of uniform distribution could show effective bonding between the reinforcement and the matrix. However Yufeng and Gap who have advised higher temperatures for processing, but it is likely to facilitate formation of Aluminium carbide which is deleterious for the composite strength. Electrical conductivity was evaluated by measuring the resistance of the composite .The results are presented in figure 1.

However the strength enhancement is not appreciable with 0.25% whereas the 0.5 % reinforcement has given substantial improvement in the radial crushing strength. From our earlier studies CNT do not improve the radial crushing strength, whereas appreciable improvement in conductivity was noted. It is observed that there is an increase in conductivity by 100 % when the reinforcement percentage by weight is increased from 0.5% to 1%.Hence CNT reinforcement enhances the electrical conductivity of the matrix alloy. Lew and Luizi [9] has found that CNT reinforcement with polymer have improved the electrical conductivity which is in support of our findings.

Conclusion

Uniform distribution of CNT was achieved by sonication and powder processing.CNT reinforcement of 1% has enhanced the radial crushing strength but as that with SiC. Electrical conductivity has increased 100% while the reinforcement was increased from 0.5% to 1%.The study shows that CNT is effective in enhancing the electrical conductivity of aluminium composite. Hence the paper emphasizes judicious selection of reinforcement and processing parameters to achieve the desired property.

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