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FABRICATION OF ALUMINIUM REINFORCED WITH CARBON NANO TUBES

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Abstract - This paper highlights the manufacturing methods used in the manufacturing of Aluminium reinforced with carbon nano tubes. The existing methods like spraying techniques, hot extrusion processes and mechanical milling with the manufacturing parameters are discussed along with the difficulties faced in those processes. New method of using ball milling followed by annealing and slow cooling which enhances its properties is discussed.

I. INTRODUCTION

Aluminium is the third most abundant element (after oxygen and silicon), and the most abundant metal in the Earth's crust. It makes up about 8% by weight of the Earth's solid surface. Aluminium metal is so chemically reactive that native specimens are rare and limited to extreme reducing environments. Instead, it is found combined in over 270 different minerals. The chief ore of aluminium is bauxite.

Aluminium is remarkable for the metal's low density and for its ability to resist corrosion due to the phenomenon of passivation. Structural components made from aluminium and its alloys are vital to the aerospace industry and are important in other areas of transportation and structural materials. The most useful compounds of aluminium, at least on a weight basis, are the oxides and sulfates.

II. NEED FOR COMPOSITES

With increase in demand for materials with improved strength and stiffness, metals are not able to provide both. So there is lot of research work going on in Metal Matrix Composites, and also extended work in MMC filled with nano fillers. In these materials, the strength and ductility are provided by the metals and the stiffness is provided the reinforcements.

III. EXISTING METHODS OF PREPARATION WITH THEIR DRAWBACKS

Powder Metallurgy route is most widely used method for manufacture of Aluminium reinforced with Carbon Nanotubes. The basic process steps consist of mixing CNTs with metal powder by grinding or mechanical alloying, followed by consolidation by compaction and sintering, cold isostatic pressing, hot isostatic pressing, or spark plasma sintering.

Plasma spraying and high velocity oxy-fuel (HVOF) spraying

Bakshi et al have carried out research on Thermal spraying where molten or semi-molten particles are sprayed onto a substrate to form a coating/deposit by way of impact and Solidification.

Laha et al. have studied the feasibility of spraying CNTs with Al powders to form composite coatings. Successful retention of undamaged CNTs in plasma sprayed aluminium coatings was reported. Laha et al. have also fabricated bulk free standing cylindrical structures of CNT-reinforced Al–23 wt.-%Si alloy using plasma spray forming (PSF) and HVOF. These cylinders were prepared by spraying on a rotating 6061 aluminium mandrel. The thickness of the PSF and HVOF cylinders were 0.64 and 1.24 mm respectively.

The thickness of the cylinders was limited due to the fact that the flowability for blended (AlCNT) powders was not good and lead to clogging of powder feed pipes. High velocity oxy-fuel resulted in a higher density coating (2.54 g/cm^3) compared to PSF (2.45 g/cm^3) because the higher velocities of the particles during HVOF lead to better compaction.

Elastic modulus and hardness were found to be higher for the HVOF coating compared to that of the PSF which was attributed to the lower degree of porosity and higher dislocation density in HVOF coatings.

Cold Spraying

Cold spraying is a relatively new process in which particles are accelerated to very high velocities at low temperature (200–500ºC) and made to impact on a substrate. The particles undergo severe plastic deformation on impact and form splats that stick to each other. Three types of deformation phenomena for cold sprayed CNTs were observed which kink formation, necking fracture and peeling of graphite layer are due to shear.

Hot Extrusion of Ball milled powders

Using hot extrusion of ball-milled powders, Choi et al fabricated Al matrix composite rods in which tightly bonded multi-walled CNTs were separately dispersed and uniaxially aligned. They showed that the reinforcing efficiency of CNTs in the composites followed the volume fraction rule of discontinuous fibers in the grain size range down to 70 nm.

Mechanical milling followed by pressure less sintering

Pérez-Bustamante et al produced Al-based Nanocomposites reinforced with multi-walled CNTs using - mechanical milling followed by pressure less sintering at 823 K under vacuum. The yield stress and the maximum strength obtained were considerably higher than those reported in the literature for pure Al prepared by the same route.

The values for yield stress and ultimate strength increased about 100% as the volume fraction of multi-walled CNTs increased from 0 to 0.75 wt.%, for 2h of milling time. They concluded that the milling time and the concentration of CNTs had an important effect on the mechanical properties of the Nanocomposites.

Cold isostatic press and subsequent hot extrusion

Deng et al carried research on using cold isostatic press and subsequent hot extrusion techniques. They found that the tensile strength and the Young's modulus of the composite were enhanced markedly, and the elongation didn’t decrease when compared with the matrix material fabricated under the same process.

Powder rolling technique

In the research carried by Esawi and El Borady, a powder rolling technique is used to fabricate CNT-reinforced Al strips. The Al-CNT mixtures were blended in either a mixer-shaker at a rotary speed of 46 rpm, or under argon in a planetary mill at a rotary speed of 300 rpm, prior to rolling. Ball-milled and extruded (un-annealed) samples of Al-2 wt.% CNT demonstrated high notch - sensitivity and consistently fractured outside the gauge length during tensile testing.

In contrast, extruded samples annealed at 400 and at 500 °C for 10 h prior to testing, exhibited more ductile behavior and no notch sensitivity. Ball milling for 3 h followed by hot extrusion and annealing at 500 °C resulted in enhancements of around 21% in tensile strength Cold compaction and hot extrusion were used to consolidate the ball-milled Al–CNT mixtures. In comparison with pure Al, 50% increase in tensile strength and 23% increase in stiffness was obtained.

IV. SUGGESTED PROCESS

Use of ball milling process

Ball milling can be carried out with 99.7% pure aluminium with CNT (purity > 95%). CNT with l/d ratio approximately equal to 375 can be used which is expected to increase the mechanical properties. Ball milling is done by using 80-100 SS balls in argon filled environment. Ball milling when done shorter time (<1 hour) will not be much efficient as the tensile strength will be considerably low. When worked for longer time (around 2-3 hours), there will be good improvement in tensile strength values.

The values for yield stress and ultimate strength increased about 100% as the volume fraction of multi-walled CNTs increased from 0 to 0.75 wt.%, for 2h of milling time. These are due to fine grain structures Suitable milling speed will be around 350-400 rpm. The suitable grain size ranges from 40nm and 140nm diameters.

The strength and wear resistance were significantly enhanced and the coefficient of friction was extremely reduced, for grain size decrease. The ultrafine-grained composite containing 4.5 vol. % of CNTs exhibited more than 600 MPa in yield stress and less than 0.1 in the coefficient of friction.

Use of Cold Extrusion Process

The main disadvantages with hot extrusion process is that the formation of voids. In different studies involving hot extrusion processes, voids were found to be formed in the material when viewed under Scanning Electron Microscope (with 150-200nm grain size). This also forms layers of discontinuous fibers. These voids have affected the value of yield strength. The yield strengths were observed to be increased by only 33% which is comparatively very less than that would be obtainable from cold extrusion process.

Use of Cold Extrusion process decreases the wear rate and lower the friction co-efficient. It was also observed in a study by Umma A et al that, the main wear mechanism was the delamination wear on the worn surface for 2.0% CNTs. So Cold rolling reduces the surface problems. Also no voids were found to be formed when viewed under SEM. This is expected to increase the yield strength to 96%.

Heat Treatment Processes

It is been observed that the tensile strength and the Young's modulus of the composite were enhanced markedly, and the elongation didn't decrease. It also results in high notch - sensitivity and consistently fractured outside the gauge length during tensile testing. In order to overcome this defect heat treatment becomes necessary.

Annealing is found to be more suitable for Aluminium reinforced CNT. After manufacturing of the composite, elongation in fibers were found. In order to obtain fibers of required length and even dispersion & orientation, annealing is carried out. The working temperature is around 650-700ºC. It is allowed to stabilize in that temperature for 24 hours. These parameters may slightly change depending upon the composition of materials used. Cooling is carried out slowly and evenly.

The damping capacity of the composite with a frequency of 0.5 Hz reached 975×10^{-3}, and the storage modulus is 82.3 GPa when the temperature was 650 °. Improved damping properties are achieved at elevated temperature without sacrificing their mechanical strength and stiffness. This also leads to much enhanced creep resistance.

V. CONCLUSION

Thus it is found that from study that by the implementation of the suggested process the disadvantages of the existing process will be overcome. By the implantation of the process it is found that the tensile strength and stiffness will be improved at a higher rate. It is also found that strength and wear resistance will be increased. It is also found that co-efficient of friction will be decreased. It is also found that damping property and creep resistance will be increased.

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