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A Review on Various Manufacturing Techniques of Composite of Al and CNT

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***Abstract*—The improvement in properties of base material with addition of some reinforcement material. In this if this two material are get homogenous mixture then properties of composite get improved. In current paper an attempt was made to describe various mixing techniques by varying some parameter and result shows improvement in mechanical properties.**

Keywords— Aluminum, CNT.

1. INTRODUCTION

1.1 A composite material is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components. It is manufactured to increase the properties of based material by adding another material as reinforcement. Composite of copper and tungsten serve the purpose of contact breaker in electrical circuit. Copper having the property of electrical conductor and tungsten is high wear resistance property. As contact breaker must possess the property of electrical conductivity and wear resistance. Aluminum is abundantly available material in earth. It is lightweight, corrosion resistance properties which are suitable in automobile application, aerospace. As the strength and stiffness of a material increases, the dimensions, and consequently, the mass, of material required for a certain load bearing application is reduced. This leads to several advantages in the case of aircraft and automobile such as increase in payload and improvement of the fuel efficiency. A carbon nanotube is a hexagonal network of carbon atoms rolled up into a seamless, hollow cylinder, with each end capped with half of a fullerene molecule.There are two types of CNT available one is SWCNT and MWCNT. CNT used in composite manufacturing as a reinforcement.There are several methods of manufacturing composite such as thermal spraying, powder metallurgy, mechanical alloying (MA), semi-solid powder processing, spark plasma sintering, friction stir processing, flake powder metallurgy, spark plasma extrusion and nanoscale dispersion.Figure given below shows one example of manufacturing of composite.

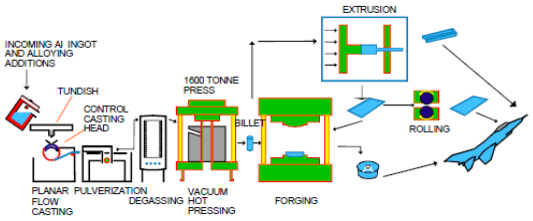

Figure: Example of manufacturing of composite.

2. LITERATURE REVIEW

The first attempt was done and published by Kuzumaki *et al*, 1998. He was using CNTs which were synthesized using arc discharge. The purity of CNT used was about 60% by volume. He mixed 5 and 10% volume of CNT with pure Al and stirred the mix in ethanol for half an hour in order to disperse CNT. The mix was then dried and packed in an Al case. The case was preheated and compressed in a steel die, and then hot extrusion was performed at 773 K. Several characterization techniques were performed, but the significant results came from the tensile strength and elongation percentage tests versus annealing time. Result show that 5 and 10 % vol. CNT prohibits the deterioration in the tensile strength as the annealing time increases; also it prevents the percentage elongation from increasing as annealing time increases [1].

Another important conclusion from George's *et al*, 2005 work was the positive effect of adding K2ZrF6 as a wetting agent. The ultimate tensile strength was noticeably increased especially when K2ZrF6 was added to the SWCNT composite. The author claims that the increase in UTS came from the effect of K2ZrF6 which from the author's point of view partially wetted the surface of the CNT. In addition, young's modulus increased with increasing the CNT content but wasn't affected by the existence of a wetting agent. These results comply with the values calculated by the shear lag method with a small error. Yield strength increased with the addition of wetting agent and with increasing the CNT content as well, which emphasizes the applicability of the shear lag model concerning the interaction between CNT and matrix [2].

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A paper published by Esawi and Morsi *et al*, 2006 investigated the morphological changes occurring when ball milling Al powder with 2wt% CNT and focused on the effect of milling on the dispersion of the CNTs. A comparison was made when Al-CNT powders were mixed using dry mixing techniques and when using high energy ball milling. Images taken by FESEM showed that CNT agglomerates still existed after 8 hours of dry mixing whereas after only 0.5 hours showed that CNT were dispersed on the surface of the Al particles. After 48 hours of milling, individual CNTs were still observed at high magnifications embedded inside the large Al particles. The large particles obtained from milling the 2% wt CNT for prolonged times were a result of the high ductility of Al which promotes the cold welding of Al flakes. The most useful conclusion from this experiment is that it proved the CNT could survive the severe conditions of ball milling for long times by being embedded inside the soft Al matrix. Additional experiments by Esawi and Morsi with 5wt% MWCNT showed that Al particle size is influenced by the CNT content of the composite [3].

R.Perez –Bustamante *et al* (2007) Al powder (99.9 % pure, 325 mesh in size) & MWCNT were used to produce Al based nano composite with three different weight percent samples (0.25, 0.50, &0.75%) were prepared. Each mixture is blended in an ultrasonic bath for 5 min and mechanically milled in a high energy shaker using different milling time (1 & 2hr).This powder is then pressed in die at 950 Mpa compacted samples were pressure less sintered during 3h at 823 K under vacuum. Yield strength increases as milling time & MWCNT weight percent increases. For 2 hours of milling time phase formation is better than 1 hr [4].

A.M.K Esawi *et al*. (2009) have done experiment with 30 gm of Al powder and 2% CNT were placed in jar with steel balls and rotate about 3 and 6h and ethanol added as a PCA. Then 26gm powder pressed in compaction die (20 mm diameter and 475 Mpa).Then hot extrusion is carried out at 500 ° C and sample is prepared. It is proved that ball milling is a promising technique for dispersing CNTs in the Al matrix. In this tensile strength improved by addition of 2% CNT. Extrusion was also found to promote alignment of CNT in the extrusion direction [5].

A paper published by Poirier *et al*. 2009 was also pretty much concerned with the analysis of the Al-CNT composite processed by high energy ball milling. 10 vol. % MWCNT with a diameter of 60-80 nm was added to pure Al and the mix was milled with tungsten carbide balls and stearic acid as a control agent in a SPEX mill at 1200 rpm for 5 hours. In addition, CNT alone was milled for 5 hours with the same milling conditions for comparison purposes. Comparing the two specimens after milling it was concluded from SEM images and x-rays that the amount of damage done to CNT if milled alone is very small compared to the amount of damage done to it if milled in the presence of a matrix even if it was a ductile metal like Al Also, the author showed that there is a big jump in hardness values from 168 to 329 VHN if the milled sample was heat treated at 635 degrees Celsius. He argues that this jump could be due to the formation of aluminium carbide that emerged from the reaction of Al with the free carbon atoms from the amorphized nanotubes. [6]

Sridhar *et al*. 2009 Prepare a sample of aluminium (99.6 % pure) and multi-wall carbon nanotubes (MWCNTs) as reinforcements are fabricated using cold uniaxial compaction followed by sintering and cold extrusion as secondary processes. The MWCNTs are pre-treated with sodium dodecyl sulfate (SDS) for improved adhesion with aluminium powder. The effect of sintering temperature on the microstructure is explored using differential scanning calorimetric (DSC) spectrum. Density is measure by Archimedes principle. The extruded samples density was increasing with increasing MWCNTs weight percentage. Hardness values of Al- MWCNTs increases as MWCNTs weight percentage increases. The micro-hardness and uniaxial tensile tests have revealed enhanced mechanical properties of Al-MWCNT composites indicating that the proposed manufacturing route is a viable cost-effective one [7].

K. Morsi *et al*. (2010) in this pure Al & MWCNT used for experiment. Two samples were prepared pure Al & Al+MWCNT .This two samples were ball milled in SPEX. These samples then compacted to a 19 mm diameter. This samples are then processed using the spark plasma extrusion with temp 433° C. Micro hardness checked under 5 kg indentation load. Pure AL shows somewhat higher pressure than Al+MWCNT. Due to their small diameter & the absence of clear contrast between the nano tubes & Al matrix. Nanotubes were only possible to detect during field emission scanning microscopy .Hardness & compressive strength increases by adding the CNTs. Milled AL (1h) & Al+CNT (1.5h) powders were successfully spark plasma extruded for the first time. Al+CNT composite displayed higher hardness (33 %) & compressive strength (10%) than the pure Al. It was concluded that ball milling was an effective means of distributing carbon nanotubes, and at longer milling times, CNTs are assumed to reside between cold welded aluminium powder particles [8].

Kwon *et al*. 2010 used a similar process; in their study they processed their material by SPS followed by extrusion. They reported that their product exhibited tensile strength that is much higher than pure Al. They prepared the powder mixture using nanoscale dispersion (NSD) method .In this process natural rubber (NR) is used as a mixing medium for the dispersion of CNT with metal powder. The author used 99.8% pure gas atomized Al powder, 5 vol. % MWCNT with an average diameter of 20nm, and natural rubber in the process. In order to disperse the CNT in Al, the mixture is put in a furnace under argon at a temperature of 500 C for 2 hours to evaporate the NR. The obtained powder is then put in a carbon mould and sintered at 600 C for 20 min under 50MPa of pressure. Finally, the sintered billet (15mm diameter, 30mm length) is extruded at 400 C with an extrusion ratio ok 20:1. The increase in the mechanical properties was attributed to particular strengthening by the CNTs, Which strongly bonded with the matrix through the generated aluminium carbide phase [9].

Sophia Rani Inbaraj *et al* (2012) By studying various AL+CNTs manufacturing techniques author select Sol gel .In this method during powder preparation CNTs were first coated with boehmite sol to avoid CNT to CNT contact & improve the matrix network .MWCNT were first dispersed in

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boehmite sol by ultra sonication in combination with magnetic stirring followed by high speed mechanical stirring for effective dispersion of CNTs. Alumina seeds in the form of slurry were added to the sol at this stage followed by gelation ,drying & calcinations. The calcined powders were compacted; sintered hot isostatically pressed & characterized for their physical & mechanical properties was attributed to particular strengthening by CNTs, Which strongly bonded with the matrix through the generated alumina carbide phase [10].

Z.Y. Liu *et al*. (2012) Pure Al powder (99.5% purity, about 13 lm in diameter) and MWNTs (about 10–20 nm in diameter and 5 lm in length), supplied by Tsinghua University, were used in the present study. To obtain a homogeneous distribution of CNT and lower damage of CNTs, 99.5 g Al and 0.5 g CNT powders were ball-milled with stainless steel balls in a stainless steel jar using a Planet-Ball- Grinding machine at 300 rpm. The milling time was set to be 2, 4, 6, 8 and 12 h, respectively. 1.8 wt.% stearic acid was added into the powders as a process control agent. The as-milled powers were could-compacted in a cylinder die, degassed and hot-pressed at 560° C into cylindrical billets with a diameter of 40 mm and a height of 30 mm. The as pressed billets were hot forged at 450° C into disk plates with a thickness of about 7.5 mm. Dog-bone tensile samples with a gauge length of 2.5 mm, a gauge width of 1.4 mm and a gauge thickness of 0.8 mm were machined perpendicular to the forging direction and then polished. It can be seen that more mixture powders became flattened as the ball-milling time increased from 2 to 8 h, which was caused by the shearing effect of the balls. Ball-milling was beneficial for the dispersion of CNTs in the Al matrix and the strengthening of the Al matrix; however, extended ball-milling time (8–12 h) caused serious damage to the CNTs [11].

A.H. Javedi *et al* 2012 in this paper Al powder (99 %, 200 mesh) irregular in shape with a flake morphology & MWCNT are 20-0 nm in diameter. Powder is intensive sonication in ethanol and then heated to 50° C and ultrasonicated until most of the ethanol evaporated .After this 2 % MWCNT and AL powder is placed in 300 ml mixing jar in which 25 stainless steel milling balls of 10 mm in diameter with orgon as a PCA. The jar is rotated at different milling time with 250 rpm/min. It is rotated up to 24 hr. After ball milling powder mixture were compacted in a cylindrical compaction die up to 375Mpa.After this samples were sintered in a tube furnace .Most of the MWCNT are very flexural .However the MWCNT were homogeneously dispersed and rarely tangled together after sonication .Improvement in the hardness after addition of MWCNT. The problem of agglomeration was solved by sonication before mechanical alloying. The MWCNT were homogeneously dispersed in the composite, and their structures were kept unchanged by the mechanical alloying. [12]

U. Abdullahi *et al*. (2013) manufactured a composite by using pure Al (99.7 %) with particle size of 78um & MWCNT (diameter 10nm, length 5-15um). The composite is made with different composition (1, 1.5, 2, and 2.5 %) using planetary ball milling (250 rpm) with 10mm ball at different milling time (1, 2 and 3hr). Samples are drawn and compacted using cold unidirectional pressing machine at the pressure of 48MPa .Sample size is 10*10*20mm.Then sintering is done with hot isostatic pressing with orgon as a PCA. Author check wear rate on pin on disc with different load (5.5, 7.2 and 10N). CNT-AL nano composite shows lower wear rate than pure AL & wear rate of all tested materials increases with increase in normal applied load wear rate & hardness decreases up to 0 to 1.5 % & increases slightly from 1.5 -2 % then increases rapidly. Hardness increases with increase in CNT content from 0-1.5 wt % and decreases gradually from 2.0 wt %. [13]

Sehyun Ko *et al*. 2013 in this experiment pure Al (99.9 wt %) atomized aluminium powder of 30um of diameter and MWCNT (1-10 um in length) were used. Al and CNT (10 and 20 wt %) are mixed in 200ml acetone ultrasonic cleaner .This powder is vacuum in at 2.7 pa and 50° C until the acetone was completely evaporated .This mixture then placed in stainless steel jar whose inside wall are coated with Al and stainless steel ball also to avoid contamination .0.4 ml of methanol is added as a PCA. Milling time is 2 to 24 hr at a speed of 87 rpm. Then powder precursor was Ni coated using electroless plating. Characterization of the milled and electroless Ni plated powder was conducted using scanning electron microscopy and XRD. By studying we come to know that as milling time increases dispersion of CNT is good. [14]

In this paper Tokutomi et al (2015) manufactured a composite with pure Al and MWCNT.I n this experiment first CNT were mixed in ethanol and ultrasonicated for 30 min and then in this solution pure Al powder mixed. And the ethnol was evaporated using an evaporator in vacuum. Secondly, the powder placed in a billet and then compressed and sintered.The electrical conductivity of sample was measured by a four terminal method at room temperature. A tensile test was carried out on the tensile testing machine. Elecrical conductivity of sample increases with compressive stresses. Electrical conductivity of sample is 5% greater than pure Al sample.The mechanical properties of this MMC specimen were slightly better than pure Al sample. [15]

3. CONCLUSION

From above literature review we can conclude that if CNT dispersion is good then there must be increase in mechanical properties of composite. For effective dispersion there is different method employed such as ball milling, ultrasonication, high energy ball milling, nanoscale dispersion. By varying CNT content and milling time there is improvement in properties. In Aluminum if CNT are homogenously mixed.

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