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Development of a Novel Al6061-MWCNTs Nano Composites using Multi Directional Forging Studies

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Abstract: Fabrication and Characterization of Al6061 Multi Walled Carbon Nanotube Metal Matrix Composite by Multi-Directional Forging. The development of newer alloys and Al6061 alloys' MMCs was necessitated by the mechanical properties of the Al6061 alloy. The high stiffness and density of MMCs make them ideal for engineering applications. Carbon nanotubes with multi-walled carbon could be a great reinforcement material for metal matrix composites based mainly on Al6061 alloys, using stir casting techniques, this work attempts to fabricate MMC's based on Al6061 alloy by utilizing MWCNTs for reinforcement and are subjected to multidirectional forging to check if any enhancement in mechanical properties. For MMCs in various compositions, the microstructure, SEM images, as well as tribological properties such as density, wear, and hardness, are shown. It has been determined from the composites' microstructure and SEM image that CNTs are distributed uniformly, and the metal matrix and multi-walled carbon nanotubes are smartly bonded. A metal matrix composite consisting of Al6061 alloy and MWCNT metal matrix is manufactured using stir casting technology.

Keywords: Metal Matrix Composite (MMC), Multi-walled Carbon Nano Tube (MWCNT), Al6061 alloy, stir casting, Multi Directional Forging (MDF)

1. Overview

Aluminum based particulate metal matrix composites (MMC's) provide widespread overall performances benefits compared to metals and metal alloys. A few potential applications can be achieved with these substances, such as in the sporting goods, aerospace, and automobile sectors. Metal matrix composite, ceramic matrix composite, and polymer matrix composite are the three basic categories into which composite materials can be grouped. Among the MMC's Al6061 alloy matrix composites have become increasingly vital because of their applications as light weight structural materials in various industries. The properties of Al6061 MMCs make them highly durable, strong, and stiff. This makes them ideal for industrial applications. Mul- tiple carbon nanotubes of single-walled are nestled within of one another to form a special type of carbon nanotube called a multi-walled carbon nanotube (MWCNT). Chiral carbon nano tubes, armchair carbon nanotubes, and zigzag carbon nanotubes are the three main types. MCNT's have young's modulus up to 0.85Gpa which will enhance the properties of matrix material. [13]A paper by P. C. Sharath discusses how multidimensional forging affects the mechanical and microstructure characteristics of zinc-24 weight percent aluminum-2 weight percent copper alloy. [1] Anjan B.N has researched about ZA27-based Silicon carbide rein- forced composites analyzed through multidirectional forging to determine their mechanical and Microstructure properties. ZA27-Based Composite Reinforced with Silicon carbide Particles of 5 weight percent and Treated by Multi-Directional Forging was the subject of an examination of wear behaviour by B. N. Ajani[2]. An investigation of the mechanical characteristics and microstructure of solution-heated and multidirectional forgings has been carried out by B Kumara [6]. A forging die of multi-directional had been designed and manufactured by the aluminum materials' processing by Madhu G [9]. [15] Satyam Suwas revolves around the application of severe plastic deformation to ultra-fine grain materials, such as steels. [7] L. Leclercqa focused on Magnesium's twin growth mechanism at an atomic scale. [5] Sheik Hassan has Re- viewed of Severe Plastic Deformation [4] Estrin, performed study on Extreme grain refinement by severe plastic deformation. Also, many researchers have carried out studies on Al-MMCs using various reinforcements such as SiC, Al_20_3, Graphene etc. [3, 8, 10–12, 14, 16]

2. Problems Formulation

Based on the literature review the following research gap has been found, upon expanding the in-depth knowledge of the MMC for Al6061 alloy from research and articles, the following opportunity path were identified: Major chunk of research studies is vital for the further advancement of Al6061 properties by enhancing its mechanical property by the addition of further foreign elements and heat treating. The humungous benefits of Multi Directional Forging process play a vital role in the preparation of Al6061 alloys and further improvisation can be achieved by altering the characteristics with MDF. Enormous benefits of CNT can be mined out, by utilizing it as the re-enforcement material along with other metal alloys in MMCs.

3. Objective

This research study carries forward its act by asserting its objective, which were retrieved by investigating and scrutinizing the research journals and objectives. The following set of objectives are laid out, as primary focus: Procure Al 6061 composite with MWCNT as re-enforcement phase and Al as the matrix phase. Determine the behavioral changes when utilizing MDF process in the manufacturing of the samples. Understand the behavior changes like microstructure, mechanical property etc. on the Al60061 composite.

4. Materials and Methodology

In the context of this research work, the following steps were initiated, while abiding the procedures. This flowchart represents how the research work needed to be carried out, from initiation to conclusion. Conduct appropriate research study. Set the objectives and problem identification. Collect relevant materials and data. Sample preparation. Post cleaning the samples. Perform various tests and sample. Obtain the results and tabulate with figures and graphs. Compare the post analysis data and discuss. Conclusion and justification of the results.

Sample Preparation

About this research work a series of samples were developed by varying the weight percentage (wt%) of Multi-walled Carbon Nano Tubes. A total of 6 samples were generated by altering the proportion of MCNT i.e., 0%,1% & 2% volumes are tried before and after multi directional forging [MDF]. Stir casting is used to develop the samples. The dimension of the ingot is length (30 mm) x breadth (30 mm) x height (25 mm) Conducting MDF process: The ingot sample of prepared dimension is kept inside the casting case which encloses the sample. An induction coil heater is

imbibed along the casing to elevate the temperature. The variation of the temperature changes is appropriately monitored and controlled by a knobbed regulator. The temperature set is 130 to 150^0 C, which is optimum for sample to deform at precalculated observation. Molybdenum-Disulphide grease lubrication was extensively used to lubricate between the ingot sample and inner periphery of the casting. After MDF the samples were cut into smaller pieces though EDM (electrical discharge machining) cutting for future test samples.

Fig. 1 developed samples of as-cast Al6061 alloy, Al6061 with 1% MWCNT Al6061 with 2% MWCNT

Fig. 2 developed samples of as-cast Al6061 alloy, Al6061 with 1% MWCNT Al6061 with 2% MWCNT for corrosion study, hardness test and wear analysis

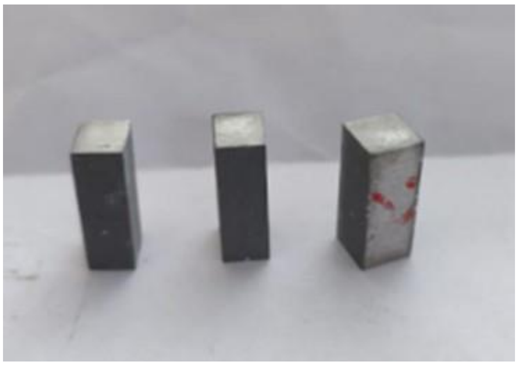
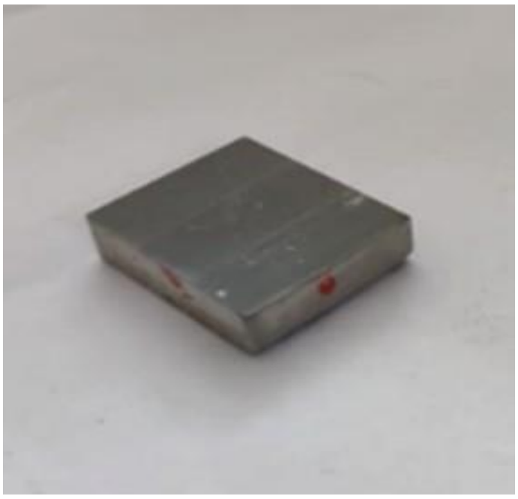


Fig. 3 developed samples for SEM analysis.



5. Results and Discussions

This chapter explains the results and discussions of Al6061 alloy reinforced with Multiwalled CNTs.

5.1 Microstructure Analysis

5.1.1 Microstructural characterization of results of Al6061-MWCNTs using Scanning Electron Microscope.

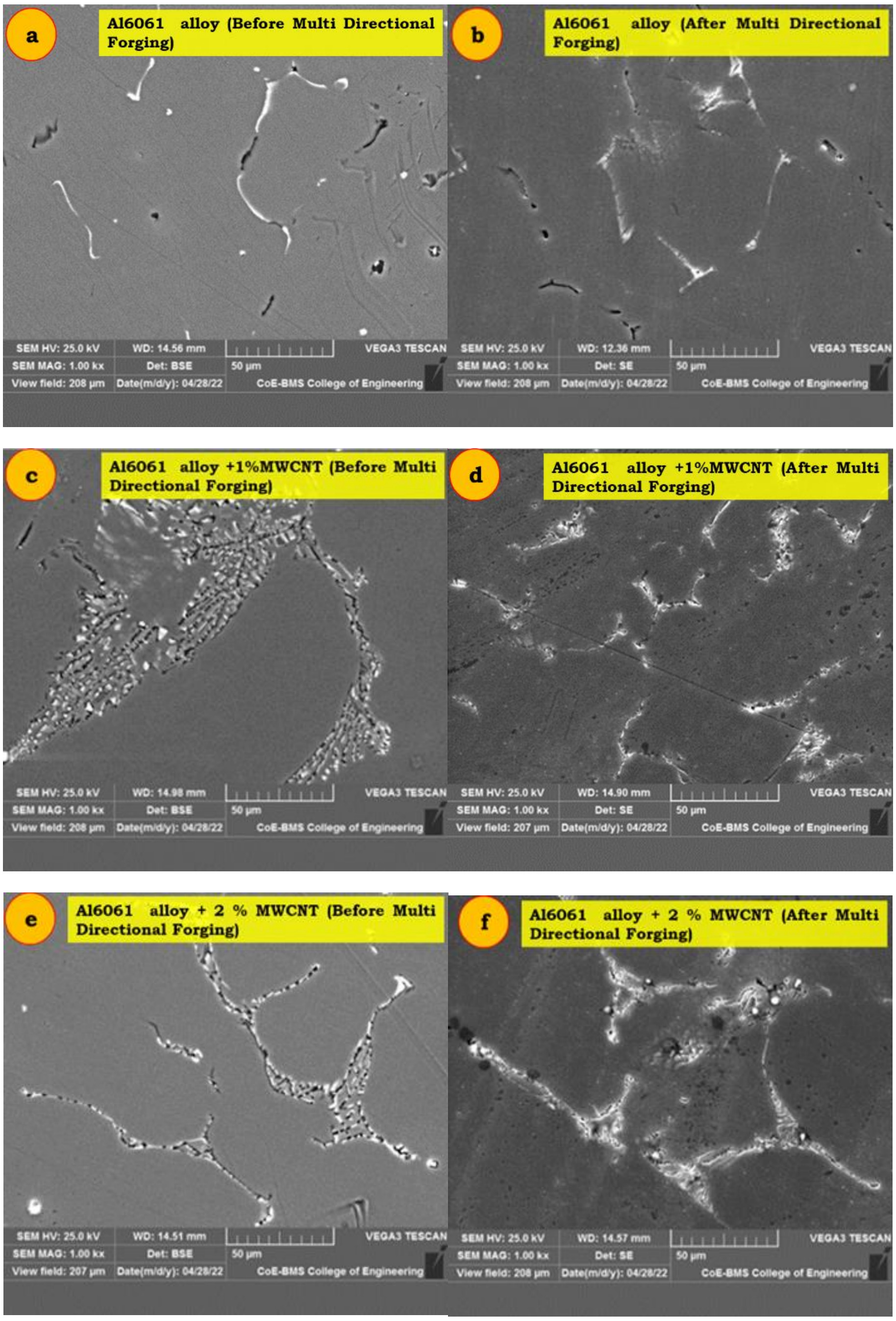


Fig. 4 SEM Morphology of (a-b) as-cast Al6061 alloy (before and after Multi directional forging), (c-d) Al6061 with 1% MWCNT Al6061 (before and after Multi directional forging), (e-f) Al6061 with 2% MWCNT Al6061 (before and after Multi directional forging)

Fig 4 shows the SEM micrographsAl6061 alloy and its MWCNT composites before and after MDF. Fig 4 (a) exhibits as-cast Al6062 alloy with dendritic structure before MDF. Fig 4 (b) exhibits as-cast alloy refined dendritic structure is shown in as-cast state in after MDF.Al6061 alloy reinforced with 1% and 2%, MWCNTs depicted in Figs. 4 (c), (d), (e), and (f), sequentially before and after MDF Figs show a few flaws, such as blowholes and cracks spaced a short distance apart. Overall, we can see that steady MWCNTs reinforcement diffusion in the matrix enhances the composites' strength [17-19].

5.2 Hardness Test:

The results show the hardness of composite materials containing varying MWCNT percentages and matrix metal Al6061. Testing was conducted using a hardened steel or carbide ball with a diameter of 5 mm and a 50g load to determine the Micro-Vickers hardness of each sample. Typically, for 10 seconds the entire load is placed to a minimum of 15 seconds. With the help of a low-powered microscope, the indentation diameter is measured in the test material.

5.2.1 Hardness Results before MDF

Fig.4.5 shows the variation of hardness for Al-MWCNTs developed for various wt. % of MWCNT's before MDF process. Composite Al-MWCNTs exhibited a % increase in hardness of 8.9% for every 1% weight increase compared to the base alloy. MWCNTs to 16.3% for 2% wt. MWCNTs. The higher hardness of dispersed MWCNT particles may explain this increase in hardness. Numerous investigators stated similar outcomes [20-24].

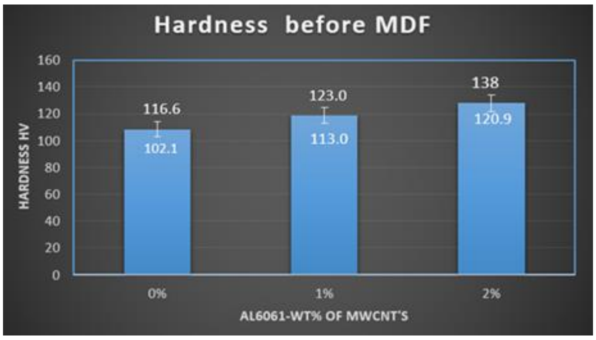


Fig. 5 Hardness test results before Multi Directional forging for varying% of MWCNT's.

5.2.2 Hardness Results after MDF

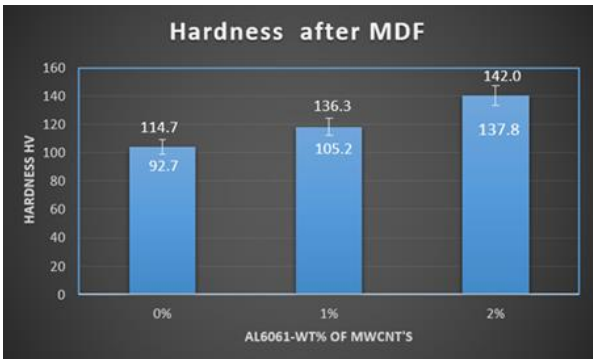


Fig. 6 Hardness test results after Multi Directional forging for varying% of MWCNT's.

Fig.6 shows the variation of hardness for Al-MWCNTs developed for various wt. % of MWCNT's after MDF process. Comparing Al-MWCNTs composite with base alloy, the hardness increase was 12.85%, which is 1 % by weight. MWCNTs to 29.85% for 2% wt. MWCNTs. The MWCNT particles dispersed in solutions have a higher hardness, thus resulting in this increase in hardness. Numerous investigators stated similar outcomes [20-24].

5.3 Wear Test:

Equipment of pin-on-disc technique was used to test dry sliding wear. They were conducted with a load range of 10N, 20N&30N at a constant speed of 300 rpm for a duration of 10 mins. The results of the wear test demonstrate that as the quantity of MWCNTs rises, so does the wear resistance of the material. Increasing the load may result in an increase in friction coefficient based on the obtained data.

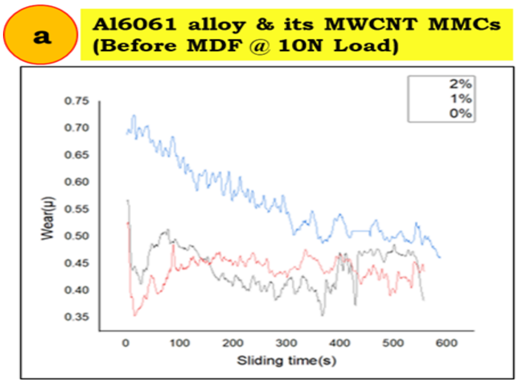


Fig. 7 (a) Wear (μ) v/s Time (Sec) of Al6061 alloy and its MWCNT MMCs (before MDF at 10N)

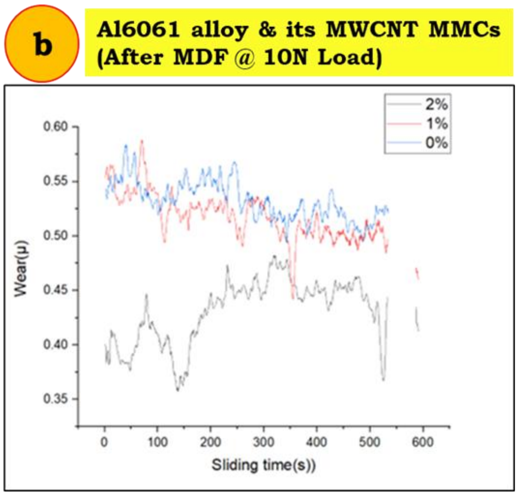


Fig. 7 (b) Wear (μ) v/s Time (Sec) of Al6061 alloy and its MWCNT MMCs (after MDF at 10 N)

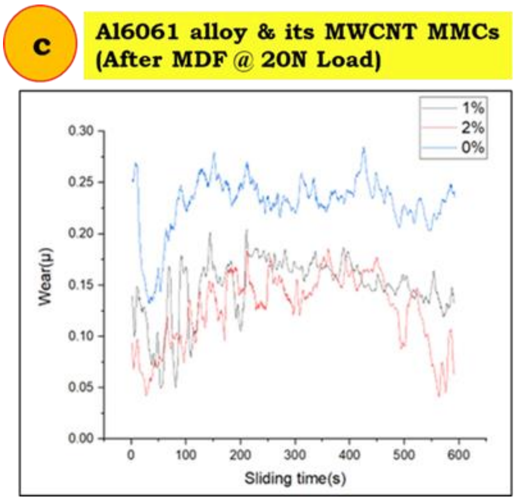


Fig. 7 (c) Wear (μ) v/s Time (Sec) of Al6061 alloy and its MWCNT MMCs (after MDF at 30 N)

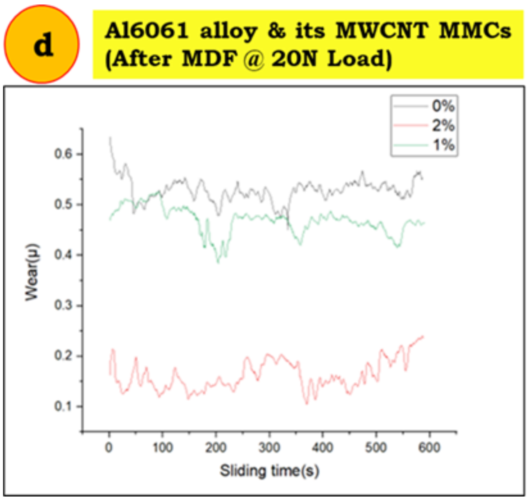


Fig. 7 (d) Wear (μ) v/s Time (Sec) of Al6061 alloy and its MWCNT MMCs (before MDF at 20 N)

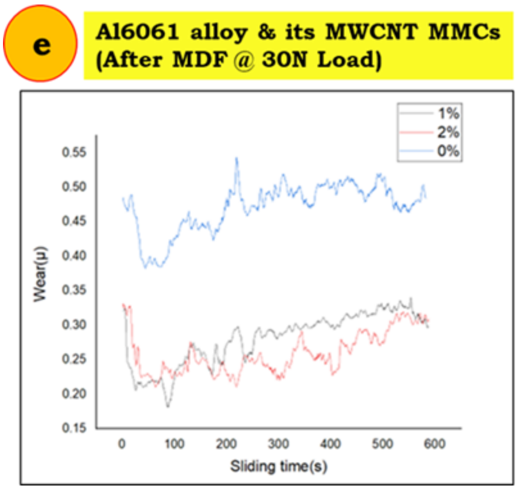


Fig. 7 (e) Wear (μ) v/s Time (Sec) of Al6061 alloy and its MWCNT MMCs (after MDF at 20 N)

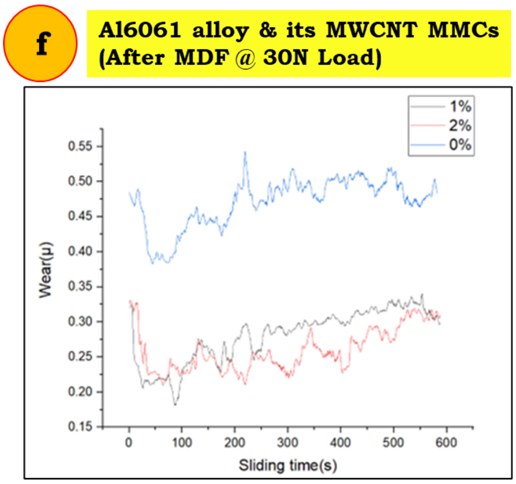


Fig. 7 (f) Wear (μ) v/s Time (Sec) of Al6061 alloy and its MWCNT MMCs (after MDF at 30 N)

The variation of Wear rate (μ) of the samples as a function of time (Sec) is shown in the graph. It could be seen from the plots, the Co efficient of friction gradually increases as the percentage of MWCNT's increased in the MMC's in both before and after MDF. Numerous investigators stated similar outcomes i.e., as time (Sec) and load (N) increases wear rate increases gradually [25-29]. It could be seen from the plots, the Co efficient of friction is more for MMC after MDF inAl6061+2%MWCNT. It shows Al6061+2%MWCNT show the maximum wear resistant than others. This is due to it being denser than other specimens also the microstructure shows Al6061+2%MWCNT have less grain boundary than other material. The above figures shows the effects of MWCNTs content on the composites' wear rate at a 0.5 m/sec sliding velocity under 10N, 20N and 30N loads. The composite's wear rate exhibits a steadily declining trend with increasing MWCNT concentration in the 0 to 2 wt. % range. In addition to the excellent mechanical properties of MWCNTs, they also exhibit a favorable effect on wear resistance. A wear rate reduction may be attributed to the harder reinforcement particles dispersed in the solution[30-34].

6. Conclusions

Al6061/MWCNTs MMC's analysis shows the following observations based on the reinforcement weight percentage:

1. Al-CNT MMCs have been revealed to be of great importance in the current study. The conclusions obtained were put forth after scrutinizing and analyzing the post data after various tests that was conducted: The SEM analysis of Al6061-wt % MWCNTs revealed no voids or discontinuities based on their image data.

2. In this study, it's been observed that carbon nanotubes with multiwall and metal matrix composites had good interfacial bonding. In terms of the microstructure, carbon nanotube reinforced composites showed good interfacial bonding between particles dispersed in the matrix and aluminum alloy 6061, as well as a reasonably uniform distribution of particles.

3. The lowest wear indicator indicates that Al6061 with CNT of 0% has high resistance. As particle volume increases, wear loss decreases, indicating that MWCNT can help reduce composite wear loss. Composites made with metal matrix materials tend to lose material less than matrix alloys composed of Al6061 in adhesive wear.

4. Al6061-wt % MWCNT composite shows good corrosion rate after MDF. From the analysis it is seen that the mechanical properties of the MMC is increased marginally, which will widen the application on the developed material in various industries.

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