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Study on Wear Property of MWCNT's reinforced with Aluminium 2024 Metal Matrix Composites with Nickel Coating

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ABSTRACT

Various metal matrix composites (MMCs) are widely used in the automotive, aerospace and electrical industries due to their capability and flexibility in improving the mechanical, thermal and electrical properties of a component. However, current manufacturing technologies may suffer from insufficient process stability, reliability and inadequate economic efficiency and may not be able to satisfy the increasing demands placed on MMCs. So CNT based Aluminium based metal matrix composites (MMCs) has been a better choice for the industrial applications due to their Inherent properties like ductile, highly conductive, lightweight and have a high strength to weight ratio. In this study, Multiwall carbon nanotube(MWCNT) which is emerged as an excellent reinforcement material and 2024 aluminium alloy being a matrix material were selected for the development of MMC's. Stir casting process being a low cost casting technology which has potential to produce MMCs having agility to large scale production with great manufacturing flexibility, quality and high efficiency. In this work, The experimental investigation of CNT reinforced 2024 Aluminium MMCs under Stir casting technique were explored. Casted samples were prepared with different wt. % of reinforcements(i.e. 0.5 %, 1.0%, 1.5% & 2 % CNT's with 40micron nickel coating on the surface using electro-less plating process) and compared with unreinforced aluminium specimens for the investigation of Wear properties has been evaluated as per ASTM standard.

Keywords : Stir casting process, Al 2024, Multiwall carbon nanotube (MWCNT), nickel coating, Wear Test.

I. INTRODUCTION

The current investigation is carried out on MWCNT reinforced with Aluminium 2024 MMCs under Stir casting technique.

Aluminium matrix composites (AMCs) with their enhanced strength, improved stiffness, reduced density, improved abrasion and wear resistance offer better alternative to existing materials used for structural, non-structural and functional applications [3]. Commonly used reinforcement in AMCs are of micro level, however technological advancement in nano sciences makes it possible to use nano sized reinforcement in metal matrix composites and these are termed as Metal Matrix Nano Composites (MMNCs). "Nano composites" were proposed by Choi and Awaji [4], a new material design concept where in second phase nano particles dispersed in matrix to enhance various properties of composite materials. In MMNCs, the reinforcement is in the nanometer range (109 m) i.e. less than 100 nm which has interaction at Interface due to its increased surface area, this leads to superior material properties. Nano sized reinforcements can significantly improve mechanical strength, creep resistance at elevated temperature, better machinability and higher fatigue life without affecting ductility. Improvement in the properties of MMCs is attributed to the hardening mechanism, fine particle size, and uniform distribution, inter particle spacing and thermal stability at high temperature. Hybrid composites can have engineering combination of two or more forms of reinforcement like fibers, short fibers, particulates, whiskers and nanotubes. It can have different materials as reinforcement like (SiC, Al2O3), (Graphite, SiC) and (Graphite, Al2O3), etc. e.g. Car engine block in which graphite and alumina are used in the form of particulates [8– 10]. Hybrid metal matrix composites shows improved mechanical properties due to reduction in meniscus penetration defect and reduced formation of inter-metallic component at interfaces because of increased interfacial area.

Aluminium 2024 is a precipitation hardening aluminium alloy, containing magnesium and silicon as its major alloying elements. Al2024 alloys have been widely used as structural materials in aeronautical industries due to their attractive comprehensive properties, such as low density, high strength, ductility, toughness and resistance to fatigue. Chunfeng Deng has found that carbon nanotube offers a kind of Nano size reinforcement that is light weight, a hollow core, has immense aspect ratio and has remarkable mechanical electrical and thermal properties. The investigators have used 2024Al matrix composites reinforced with 1 wt% CNT's which was fabricated by cold isotactic pressing followed by hot extrusion techniques.

The MWCNTs were Ni plated in some cases for better wettability with the matrix which resulted in mechanical property enhancement with only 0.67 wt-%CNT addition. The study showed that the number of cycles to failure under fatigue decreases with increasing CNT content; the reason being the presence of voids at the CNT matrix interface, making the reinforcement weaker. The main issue for better performance of the composite is the dispersion and reinforcement of the MWCNTs. In this present investigation the effect of Nickel coating with Aluminium will be studied & evaluated the Wear properties as per ASTM standard.

II. EXPERIMENT METHODOLOGY

Al 2024: with density 2.78 g/cm3, tensile strength 483 MPa (T4 condition) and modulus of elasticity 73.1 GPa was used as a matrix material. 2024 is a precipitation hardened aluminum alloy, containing magnesium and silicon as its major alloying elements. It has significant applications in aircraft, marine and automobile industries due to its good castability and corrosion resistance.

MWCNT: The MWCNT's (Multi-walled carbon nanotubes) were used as the reinforcement material and procured from United Nanotech Innovations PVT Ltd., Bangalore, India. Nickel plating was done by electroless process over the composite surface in peenya industrial area, Bangalore.

FLY ASH: Fly ash is produced by coal-fired electric and steam generating plants. Typically, coal is pulverized and brown with air into the boiler's combustion chamber where it immediately ignites, generating heat and producing a molten mineral residue.

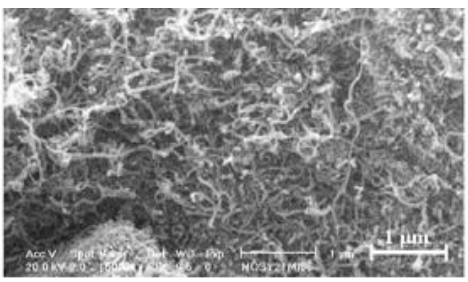

Fig 1.1: SEM Image of MWCNT

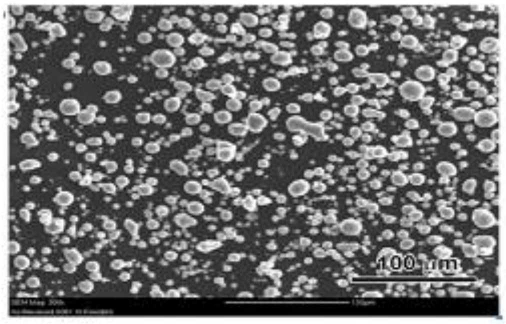

Fig 1.2: SEM Image of 2024 Aluminium Powder

Purification of MWCNTs is done using concentrated nitric acid for 0-25 hour and washing of MWCNTs with de-ionized water and drying period of 120hrs.

The Fabrication of Composite specimens using CNTs with different weight contents (0.5%, 1%, 1.5%, & 2%) reinforced with 2024 Aluminum powder is done by using Stir casting process.

Stir casting:

In a stir casting process, the reinforcing phases are distributed into molten matrix by mechanical stirring. Mechanical stirring in the furnace is a key element of this process, a major concern associated with the stir casting process is the segregation of reinforcing particles which is caused by the surfacing or settling of the reinforcement particles during the melting and casting processes.

The final distribution of the particles in the solid depends on material properties and process parameters such as the wetting condition of the particles with the melt, strength of mixing, relative density, and rate of solidification. The distribution of the particles in the molten matrix depends on the geometry of the mechanical stirrer, stirring parameters, placement of the mechanical stirrer in the melt, melting temperature, and the characteristics of the particles added. An interesting recent development in stir casting is a two-step mixing process. In this process, the matrix material is heated to above its liquids temperature so that the metal is totally melted. The melt is then cooled down to a temperature between the liquids and solidus points and kept in a semi-solid state. At this stage, the preheated particles are added and mixed. The slurry is again heated to a fully liquid state and mixed thoroughly. This twostep mixing process has been used in the fabrication of aluminium. Among all the well-established metal matrix composite fabrication methods, stir casting is the most economical.

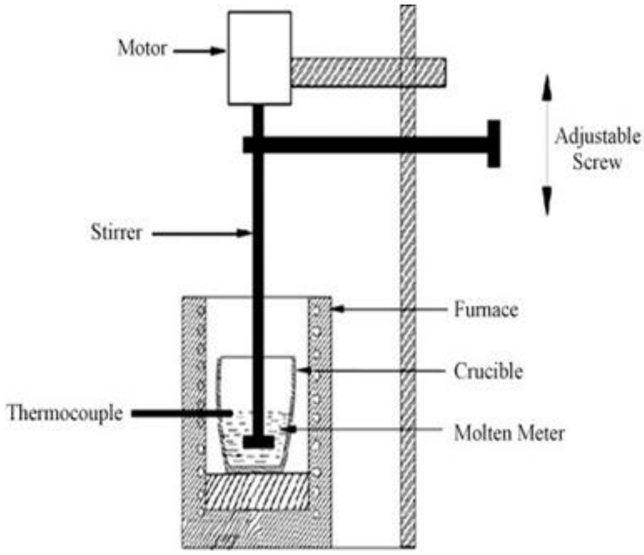

Fig. 1.3: Stir casting process

Methods:

Al 2024 and multiwall carbon nano tubes (20-30 nm) were properly mixed for composition using stir casting process with a Stirrer speed of 300rpm was used to mix the MWCNT added for casting process.

Preparation of Composite Specimens:

The CNT powder was initially purified to remove the impurities like graphite, amorphous carbon etc. by adding concentrated Nitric acid, filtering and washing with de-ionized water followed by drying at 1200 C. In stir casting process, MWNT of 0 wt%.0.5 wt. %, 1 wt. %, 1.5 wt. %, 2 wt. % was mixed with Al2024 for 20 min at 300 rpm to get uniform mixing in the crucible. The mixture of a particular weight percentage MWCNT and Al2024 was moulded in the pattern.

Fig. 1.4: CNT

Fig. 1.5: Stir casting

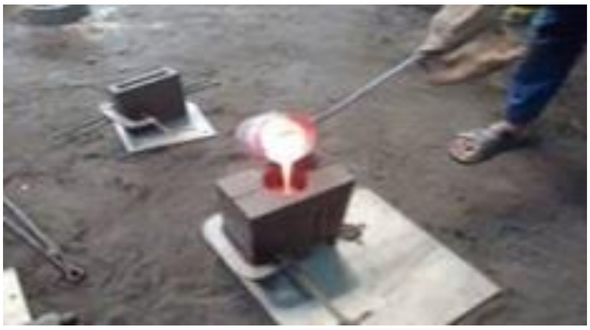

Fig. 1.6: Moulding.

Fig. 1.7: Final Castings

Fig, 1.5, 1.6 and 1.7. Liquid melt technique was used to fabricate the composite materials in which the CNT reinforcing materials were introduced into the molten metal pool through a vortex generated in the melt crucible by the use of a stainless steel stirrer which is rotating in the speed of 300rpm. The resulting mixture was tilt poured into the pre-heated permanent metallic moulds. Using CNC lathe as cast specimen are machined to required dimensions from the cylindrical bar castings as per ASTM standard. Thus about specimen undergoes the process of nickel plating which takes in different stages which involves immersion in various alkaline bath to obtain clean surface, then they are dipped in nickel salt solution for the define amount of time as calculated based on the weight of the specimen dipped in it to obtain the uniform deposition of 40micron of nickel on the surface.

III. EXPERIMENTAL PROCEDURE

1. Wear test

The wear test was conducted using a pin-on-disc computerized wear testing machine in accordance with ASTM G99 standards. The surface finish of the specimens (Ra) 2μm was rubbed against a hardened steel disc, which has a better surface finish of (Ra) 0.2μm. The test uses the specimens of diameter of 6mm and length 35mm machined from the cast specimens. The wear tests were conducted using loads of 2, 4 kg in steps of 2 kg at 300 rpm, 400 rpm and 500 rpm and 4 kg at 400 rpm and 500 rpm. The test period was taken to be 10 minutes and the track radius selected was 50mm. The apparatus consists of a steel disc of 50 mm diameter which forms the counter face on which the test specimens or the pins slide over. The wear test was also conducted for the cast specimens of Aluminium 2024 alloy with varying percentage of CNT (1 wt. %, 1.5 wt. % and 2 wt. %) and Fly ash reinforcements (4 wt. %, 6 wt. % and 8 wt. %) and were assessed for wear resistance. The wear results of as cast hybrid composites with different compositions of reinforcements at varying sliding speeds and different loads are shown in the tabulations.

Wear results are reported as volume loss in cubic millimeters for the pin and the disk separately. When two different materials are tested, it is recommended that each material be tested in both the pin and disk positions. The amount of wear is determined by measuring appropriate linear dimensions of both specimens before and after the test, or by weighing both specimens before and after the test.

If linear measures of wear are used, the length change or shape change of the pin, and the depth or shape change of the disk wear track (in millimeters) are determined by any suitable metrological technique, such as electronic distance stylus profiling. Linear measures of wear are converted to wear volume (in cubic millimeters) by using appropriate geometric relations. Linear measures of wear are used frequently in practice since mass loss is often too small to measure precisely. If loss of mass is measured, the mass loss value is converted to volume loss (in cubic millimeters) using an appropriate value for the specimen density. The photograph of the tribo-meter (pin on disk wear testing machine) used in the current work is given below in figure – 1.8 and the schematic is given in figure – 1.9.

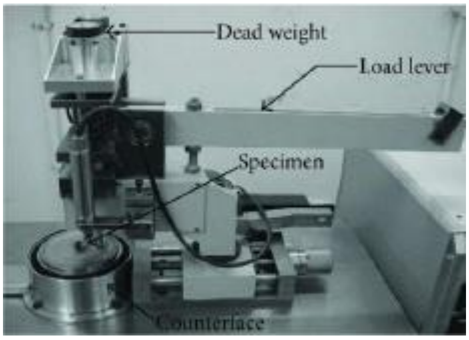

Fig 1.8 Pin-on-Disk Machine

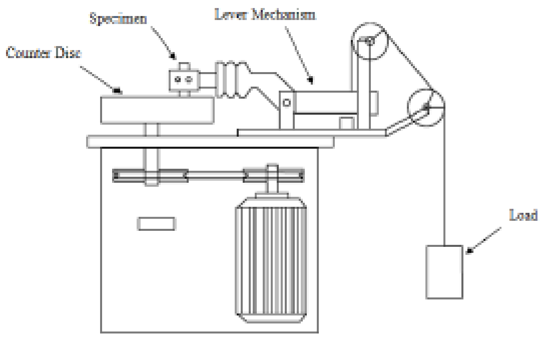

Fig 1.9 Schematic diagram of Pin on Disk apparatus

IV. RESULT

Wear Test

Wear may be defined as damage to a solid surface caused by the removal or displacement of material by the mechanical action of a contacting solid, liquid or gas. It may be significant surface damage and the damage is usually thought of as gradual deterioration. Wear rate and percentage of wear decreases greatly for specific proportion of CNT as 2 wt. % and 8 wt. % fly ash. The significant improvement in wear resistance of the composite may be due to size of reinforcement or dispersion of reinforcement used, it is generally found that the benefits of reinforcement are greater for increase in the content of reinforcement. The results of wear are tabulated in the tables. The variation of wear properties are ascertained by conducting test for different wear loads of 2 kg and 4 kg and at different speeds of 300 rpm, 400 rpm and 500 rpm. After performing Hardness and Wear test for different weight percentages of CNT and fly ash, the wear rate of the composite decreases as the percentage of CNT increases from 1 wt. % to 2 wt. %. The use of CNT and fly ash as reinforcement materials at a specified proportion increases the hardness and decreases the wear rate.

Table – 1.1 Wear Results for 20 N Load, 50 mm Wear track diameter, 500 rpm disc rotational speed and duration of wear of 8 minutes.

Sl.no	Specimen Designation	AA 2024	MWCNT	Fly Ash	Wear Rate mm^3/m
1.	AM1F4	95	1	4	14.85
2.	AM1F6	93	1	6	12.15
3.	AM1F8	91	1	8	9.90
4.	AM1.5F4	94.5	1.5	4	12.60
5.	AM1.5F6	92.5	1.5	6	9.00
6.	AM1.5F8	90.5	1.5	8	8.55
7.	AM2F4	94	2	4	10.35
8.	AM2F6	92	2	6	8.55
9.	AM2F8	90	2	8	7.65

V. DISCUSSION & CONCLUSION

The results of wear tests clearly gives an inference that the wear rate of the composites decrease with the increase in weight percentage of reinforcements in the matrix phase, owing to micro-coring and segregation that ensures better bonding between the matrix and reinforcement phase thereby increasing the strength and hardness characteristics of the composite specimens. Further, the composite specimens exhibit an increase in the strength properties when the weight percentage of MWCNT increases from 1 weight percent to 2 weight percent in intermittent steps of 0.5 weight percent.

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