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Processing and Property Evaluation of Nano Al_2O_3 Reinforced Copper- 5% Tin Composites for Bearing Applications

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Abstract— ***Nano technology has fascinated the attention of numerous material scientists and design engineers. The nano scaled particulates incorporation exhibit many attractive and special properties. The inclusion of nano particulates into the copper matrix might augments the hardness, ultimate tensile strength and yield strength significantly increases, maintaining the ductility. In this paper, the nano Al_2O_3 reinforced copper - 5%tin- metal matrix composites were manufactured by stir casting technique and reinforcement is varied from 0wt. % to 9wt. % in ventures of 3wt. %. The nano composites are characterized in terms of their mechanical and wear properties. Results revealed that, the distribution of nano Al_2O_3 particulates is fairly uniform in copper - 5%tin metal matrix. As the level of reinforcement increases, hardness, yield strength, ultimate tensile strength, and wear resistance of the copper - 5%tin – nano Al_2O_3 metal matrix composites increases. The developed nano metal matrix composites may be an alternative material for bearing applications.***

Index Terms— ***Sliding wear, Metal matrix composites, Nano composites, and copper tin metal matrix***

I. INTRODUCTION

The incarnation of two or more substances together is called a composite material system. The composite material system consists of matrix segment and reinforcement segment. The matrix segment is material system binds the reinforcement phase. The matrix may be polymer resins, metals or alloys. The reinforcement phase consists of particulates, fibers, flakes and whisker. The composites are generally classified based on the form of reinforcement and types of matrix used in the manufacturing of the composites. The metal matrix composites are attractive extensively in the Automobile, Aerospace, sports and wind energy segments [1]. The metal matrix composite materials are adopted in these applications because of their advantages like improved tensile strength, stiffness, impact strength, bending strength and endurance strength as compared conventional materials. The belongings of the composites are obtained by inducing the specific reinforcement in the base matrix metal. The belongings can be varied by selecting proper matrix and reinforcement for the development of the novel composite material. Thus the composite materials are having more demand in the industry. The metal matrix composites are developed by reinforcing the particulates, short fibers or flakes in the metals or alloys. The metal matrix composites are employed in many applications since for their flexibility in obtaining the specific properties. The belongings of the metal matrix composites depends on many parameters for example variety of reinforcement, magnitude and profile of reinforcement, density, aspect ratio, wet ability of the reinforcement and the manufacturing method adopted for the fabrication. The scientists and research scholars were developed the metal matrix composites and characterized in terms of mechanical and wear properties [2-3].

The metal matrix composites reinforced with nano-particles are also called Metal Matrix Nano Composites (MMNCs) and these MMNCs are being explored worldwide in current year for their mechanical properties[4]. The nano particulate reinforced composites have been widely engaged in the automotive industry for their capacity to endure high temperature and pressure conditions. The metal matrix nano composite materials have appeared as a feasible substitute to conquer the restrictions of metal matrix composites; however metal matrix nano composite materials are demanding to manufacture as structural components due to difficulties in reaching a uniform allocation of the nano scaled particles. [5]. There are several methods for manufacturing of metal matrix nano composite; all the methods available are not suitable for all type of reinforcement materials. The selection of particular method is depends on the part design, type of materials selected and product application. Some of the manufacturing methods used are Powder metallurgy, Stir casting method, Spray deposition process, Compo-casting, In situ Synthesis, Squeeze casting process, [6-7]. Mechanical properties are the most significant properties and they are the fundamental motivation for the nano composite materials at which the components manufactured gets failure. The aluminium metal matrix composites were developed by inducing the micro sized and nano sized particles in the aluminium alloy. The nano particles reinforced nano composites exhibits much higher dimensional stability than micro sized particles reinforced aluminium composites [8].

Wear may be defined as the progressive loss of material from the working surface happening as a result of relative movement of the surface with respect to another body. The wear is classified as 5 different types they are abrasive wear, adhesive wear, erosive wear, surface fatigue wear and corrosive wear [9].

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II. EXPERIMENTAL DETAILS

The objectives of the current work is first to prepare the copper - 5% tin – nano Al2O3 metal matrix composite by varying the percentage of reinforcement in steps of 3, 6 and 9wt% through stir casting method and confirm the uniform distribution of reinforcement by examining SEM images. Second is to evaluate the mechanical properties like hardness, ultimate tensile strength and compression strength of copper - 5% tin – nano Al2O3 metal matrix composite and to study the wear characteristics of copper - 5% tin – nano Al2O3 metal matrix composite by varying the load, sliding distance and sliding speeds.

A. Fabrication of nano MMCs

The copper is heated to 10830 C in electrical resistance furnace to the molten state, 5% tin billet is slowly immersed into molten matrix the resulting copper alloy is stirred continuously by using mechanical stirrer which is attached to the electrical resistance furnace. Once the Vortex is created, preheated (350^0C) nano Al2O3 particulates were added slowly. The melt blend was transferred into the mould at a temperature of 950^oC and was permitted to cool at atmospheric conditions. Then the castings were cut to required shape and size as per ASTM G99-95 standard for conducting wear test on nano composite. Figure 4.4 shows the resistance furnace. The figure2 shows the castings obtained by stir casting technique.

Fig 1: Resistance furnace

Pouring of molten melt into the die

Metallic dies

As-cast Nano MMCs

Fig 2: As-cast copper + 5%tin + nano Al2O3 metal matrix composites

B. Specimen Preparation

The specimens were prepared from the copper - 5% tin matrix material and the developed copper - 5% tin-nano Al2O3metal matrix composite materials. Ultimate surface finish was obtained by mechanically buffing the sample by excellent grid size emery paper. The figure 4.6 shows the hardness, tensile and compression test specimens according to ASTM standards.

a.

b.

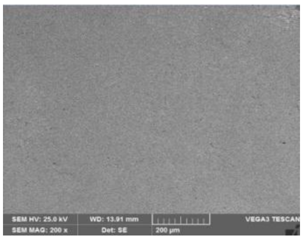
c.

Fig 3: a. Hardness test specimen, b. Sliding wear test specimen, c. Tensile test specimen

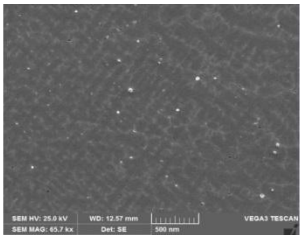
III. RESULTS AND DISCUSSIONS

A. Scanning electron micrographs studies

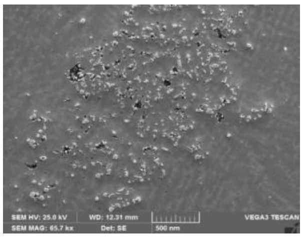
The figure 4 shows the SEM micrographs of as - cast – 5% tin matrix material and copper – 5% tin - nano Al2O3 MMCs. The SEM micrograph indicates that the MMNCs exhibit uniform distribution of reinforcements in the matrix material. The nano Al2O3 reinforcement particles are uniformly allocated in the matrix which directly influences to enhance the belongings of the copper – 5% tin – nano Al2O3 MMCs.



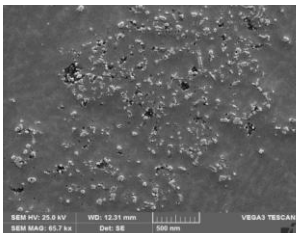
Copper - 5% Tin



CU - 5% Tin - 3 wt.% of Nano Al2O3



CU - 5% Tin - 6 wt.% of Nano Al2O3



CU-5% Tin - 9 wt.% of Nano Al2O3

Fig 4: SEM micrographs of as - cast copper - 5% Tin and copper -5% Tin - Nano Al2O3 MMCs

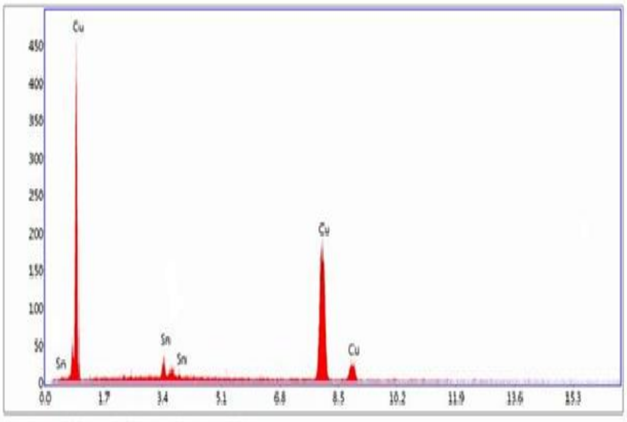


Fig 5: Energy dispersive spectrograph of copper - 5% Tin matrix material

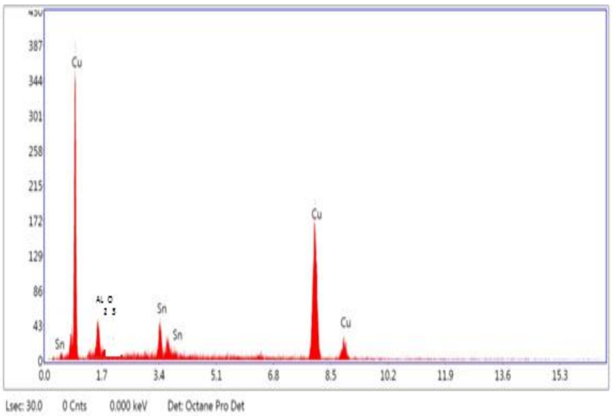


Fig 6: Energy dispersive spectrograph of copper - 5% Tin- Nano Al2O3 MMCs

Figure 5 shows the EDAX pattern of copper - 5% tin used for the development of the copper - 5% tin-nano Al2O3 metal matrix composites. The EDAX pattern shows the presence of the copper - 5% tin elements in the copper - 5% tin matrix material.

Figure 6 The EDAX pattern shows the presence of the nano Al2O3 particle elements in the copper -5% tin - nano Al2O3 metal matrix composites. The EDAX pattern confirms presence of the nano Al2O3 particles in the copper -5% tin - nano Al2O3 metal matrix composites.

B. Brinell hardness test

The variations of brinell hardness of the copper - 5% tin –nano Al2O3 composite materials are shown in the figure 7. The graph clarifies the consequences of the nano Al2O3 reinforcement on the brinell hardness of the copper - 5% tin –nano Al2O3 composites. The hardness amplifies by 18.57% by the addition of 3 wt. % of nano Al2O3 particulates in the copper - 5% tin matrix material. The copper - 5% tin –nano Al2O3 a composite reveals the superior hardness with that of the matrix material. The 9 wt.% of Al2O3 particulates reinforced copper - 5% tin - nano Al2O3 composites shows 57.14% boost in the hardness as compared to the hardness of the copper - 5% tin matrix material and 32.53% increase in the hardness with that of 6wt.% of nano Al2O3 particulates reinforced copper - 5% tin – nano Al2O3 composites. The hardness of the nano metal matrix composites enhances as the nano reinforcement content boosts in the matrix material. The increase in the hardness in the copper - 5% tin – nano Al2O3 composites is the indication of the good union among the matrix and the reinforcement material.

Table 1: Hardness of copper-5%tin with different Wt. % of Nano Al2O3 Particulates

Sl. No.	Composition	Hardness (BHN)
1	Cu - 5% Sn	73.76
2	Cu - 5% Sn- 3%Nano Al2O3	82.96
3	Cu - 5% Sn- 6%Nano Al2O3	92.36
4	Cu - 5% Sn- 9%Nano Al2O3	104.1

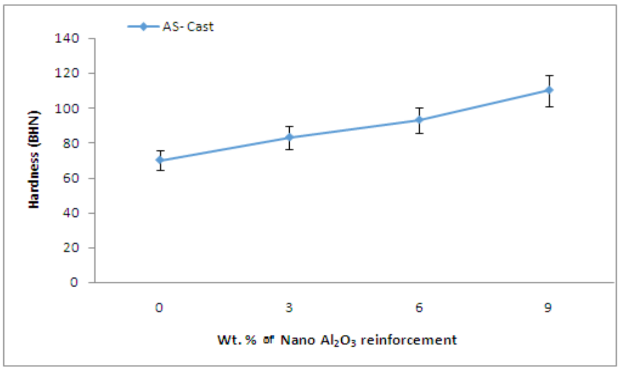


Fig 7: Effect of reinforcements on Brinell hardness of the Copper – 5% Tin - Nano Al2O3 MMCs

C. Tensile Strength

The variations of ultimate tensile strength of the copper - 5% tin – nano Al2O3 composite materials are shown in the figure 8. The graph clarifies the consequences of the nano Al2O3 reinforcement on the ultimate tensile strength of the copper - 5% tin -nano Al2O3 composites. The ultimate tensile strength amplifies by 7.14% by the addition of 3 wt.% of nano Al2O3 particulates in the copper - 5% tin matrix material. The copper - 5% tin –nano Al2O3 a composite reveals the superior ultimate tensile strength with that of matrix material. The 9 wt.% of nano Al2O3 particulates reinforced copper - 5% tin - nano Al2O3 nano composites shows 25% boost in the ultimate tensile strength as compared to the ultimate tensile strength of the copper - 5% tin matrix material and 16.67% increase in the ultimate tensile strength with that of 6wt.% of nano Al2O3 particulates reinforced copper - 5% tin –nano Al2O3 composites. The increase in the ultimate tensile strength in the copper - 5% tin – nano Al2O3 composites is the indication of the good union among the matrix and the reinforcement material.

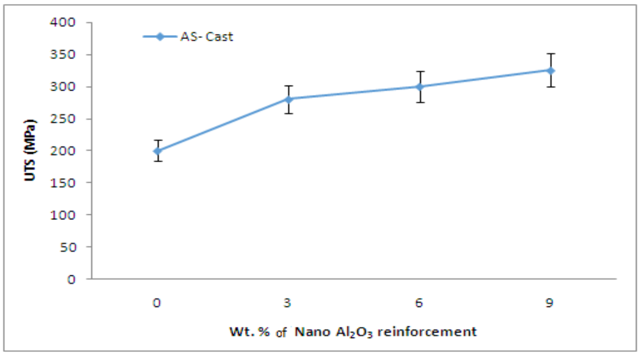


Fig 8: Effect of reinforcements on ultimate tensile strength of the Copper - 5%tin - Nano Al2O3 MMCs

D. Yield strength

The variations of yield strength of the copper - 5% tin – nano Al2O3 composite materials are shown in the figure 9. The graph clarifies the consequences of the nano Al2O3 reinforcement on the yield strength of the copper - 5% tin – nano Al2O3 composites. The yield strength amplifies by 9.1% by the addition of 3 wt.% of nano Al2O3 particulates in the copper - 5% tin matrix material. The copper - 5% tin –nano Al2O3 a composite reveals the superior yield strength as compared to the matrix material. The 9 wt.% of nano Al2O3 particulates reinforced copper - 5% tin – nano Al2O3 composites shows 22.73% boost in the yield strength as compared to the yield strength of the copper - 5% tin matrix material and 12.5% increase in the yield strength with that of 6wt.% of nano Al2O3 particulates reinforced copper - 5% tin – nano Al2O3 composites. The yield strength increases with increase in the addition of reinforcement to the matrix material, this could be due to improved in interfacial union potency between reinforcement and matrix.

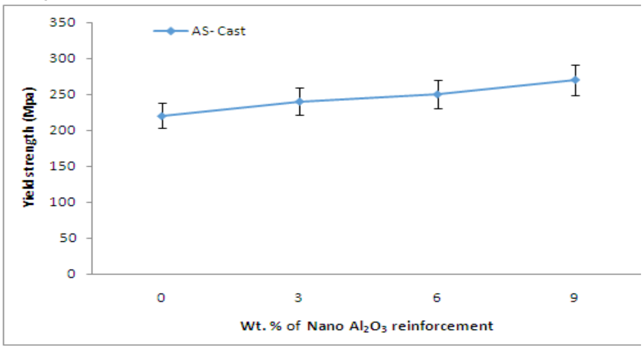


Fig 9: Effect of reinforcements on yield strength of the Copper – 5% Tin - Nano Al2O3 MMCs

E. Ductility

The variations of ductility of the copper - 5% tin – nano Al2O3 composite materials are shown in the figure 10. The graph clarifies the consequences of the nano Al2O3 reinforcement on the ductility of the copper - 5% tin – nano Al2O3 composites. The ductility declines by 7.19% by the addition of 3 wt.% of nano Al2O3 particulates in the copper - 5% tin matrix material. The 9 wt.% of nano Al2O3 particulates reinforced copper - 5% tin - nano Al2O3 composites shows 25.18% dwell in the ductility as compared to the ductility of the copper - 5% tin matrix material and 19.38% decrease in the ductility with that of 6wt.% of Al2O3 particulates reinforced copper - 5% tin –nano Al2O3 composites. The decline in the ductility in the copper - 5% tin – nano Al2O3 composites may be due to nano scale hard ceramic Al2O3 particulates reinforcement in the copper - 5% tin matrix material.

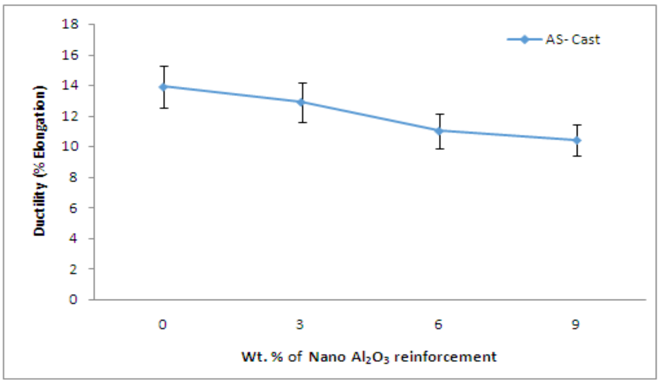


Figure 10: Effect of reinforcements on ductility of the Copper – 5% Tin - Nano Al2O3 MMCs

Table 2: UTS, YS and percentage elongation of Copper – 5% Tin with different wt. % of Nano Al2O3 Particulates

Sl. No	Composition	UTS (MPa)	YS (MPa)	Elongation (%)
1	Cu - 5% Sn	272.07	215.13	13.73
2	Cu - 5% Sn-3%Nano Al2O3	290.29	228.29	12.38
3	Cu - 5% Sn-6%Nano Al2O3	313.57	252.94	11.55
4	Cu - 5% Sn-9%Nano Al2O3	351.87	274.15	10.40

F. Compression strength

The variations of compression strength of the copper - 5% tin - nano Al2O3 composite materials are shown in the figure 11. The graph clarifies the consequences of the nano Al2O3 reinforcement on the addition of 3 wt. % of nano Al2O3 particulates in the copper - 5% tin matrix material. The 9 wt.% of nano Al2O3 particulates reinforced copper - 5% tin - nano Al2O3 composites shows 25.18% dwell in the ductility as compared to the ductility of the copper - 5% tin matrix material and 19.38% decrease in the ductility with that of 6wt.% of Al2O3 particulates reinforced copper - 5% tin –nano Al2O3 composites. The decline in the ductility in the copper - 5% tin – nano Al2O3 composites may be due to nano scale hard ceramic Al2O3 particulates reinforcement in the copper - reinforced copper - 5% tin – nano Al2O3 composites.

Table 3: Compression strength Copper – 5% Tin with different wt. % of Nano Al2O3 Particulates

Sl No.	Composition	Compression Strength MPa
1	Cu - 5% Sn	781.50
2	Cu - 5% Sn-3%Nano Al2O3	830.58
3	Cu - 5% Sn- 6%Nano Al2O3	879.22
4	Cu - 5% Sn- 9%Nano Al2O3	919.36

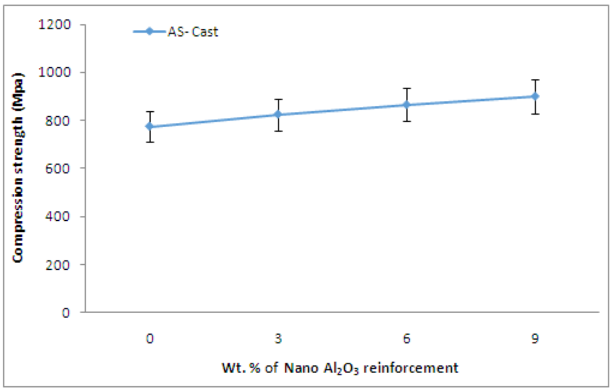


Figure 11: Effect of reinforcements on compression strength of the Copper - 5% Tin - Nano Al2O3MMCs

G. Compression strength

Effect of reinforcement on wear rate

Figure 12 illustrates the consequence of reinforcement on wear rate of copper - 5% tin matrix material and the copper - 5% tin - nano Al2O3 composites. The figure explains that as the reinforcement portion amplifies, the wear rate of copper - 5% tin - nano Al2O3 metal matrix composites enhances. The wear rate of the matrix material is higher than that of the copper - 5% tin – nano Al2O3 metal matrix composites. The wear rate decreases by 8.33% by the addition of 3 wt.% of nano Al2O3 particulates in copper alloy - 5% tin matrix material. The wear rate of copper - 5% tin -9 wt.% nano Al2O3 MMC declines by 33.33% and copper - 5% tin - 6wt.% nano Al2O3 MMC shows 19.44% decrease in the wear rate as compared to wear rate of copper - 5% tin matrix material.

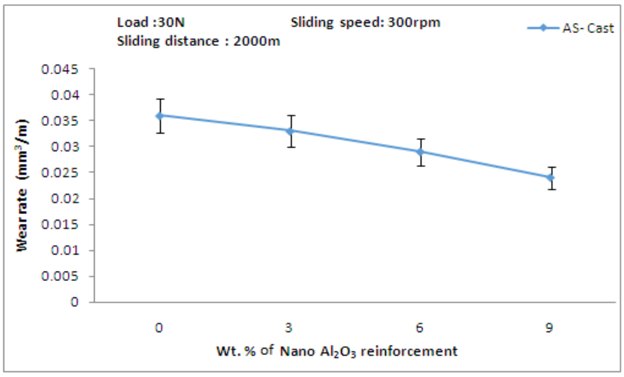


Fig 12: Effect of reinforcements on wear rate of as – cast Copper – 5% Tin Nano Al2O3 MMCs

Effect of load on wear rate

Figure 13 illustrates the consequence of load on wear rate of copper - 5% tin matrix material and the copper - 5% tin – nano Al2O3 composites. The figure indicates that as the load added further, the wear rate of both the copper - 5% tin - nano Al2O3 metal matrix composites and the matrix material amplifies. The wear rate of copper - 5% tin matrix material increases by 28% as load increases to 20N and when applied load boosted to 40N, the wear rate of copper - 5% tin matrix material increases by 28.12% with that of 20N loaded copper - 5% tin matrix material. The wear rate of copper - 5% tin - 9 wt.% nano Al2O3 MMC increases by 14.28% as load increases to 30N and when load increase to 40N, the wear rate of copper - 5% tin -9 wt.% nano Al2O3 MMC increases by 38.01 % with that of 20N loaded copper - 5% tin - 9 wt.% nano Al2O3 MMC.

The wear rate of copper - 5% tin -9 wt.% nano Al2O3 MMC at 30N decreases and copper - 5% tin - 6 wt.% nano Al2O3 MMC shows decrease in the wear rate as contrast to wear rate of copper - 5% tin matrix material at 10 N load and diminish in the wear rate of 40N loaded copper - 5% tin -9 wt.% nano Al2O3 MMC and diminish in the wear rate of 30N loaded copper - 5% tin -6 wt.% nano Al2O3 MMC with that of 20N loaded copper- 5% tin matrix material.

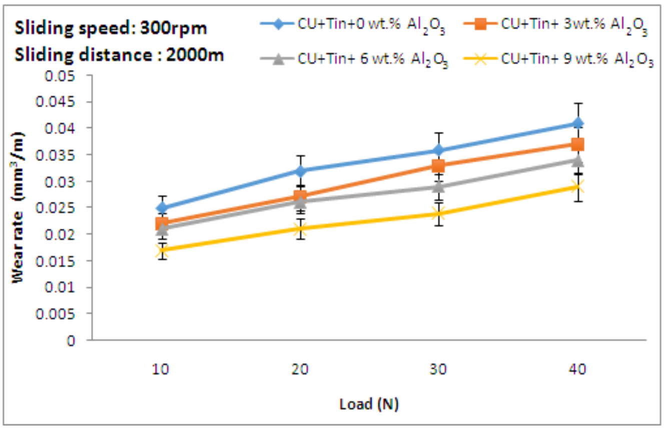


Fig 13: Effect of load on wear rate of the Copper – 5% Tin - Nano Al2O3 MMCs

Effect of sliding speed on wear rate

Figure 14 illustrates the consequence of sliding speed on wear rate of copper - 5% tin matrix material and the copper - 5% tin – nano Al2O3 composites. The figure indicates that as the sliding speed enhances further, the wear rate of both the copper - 5% tin - nano Al2O3 metal matrix composites and the matrix material amplifies. The wear rate of copper - 5% tin matrix material increases by 19.23% as sliding speed increases to 200rpm and when sliding speed boosted to 400rpm, the wear of copper - 5% tin matrix material increases by 30.76% with that of 100rpm sliding speed copper - 5% tin matrix material. The wear rate of copper - 5% tin - 9 wt.% nano Al2O3 MMC increases by 20% as sliding speed increases to 300rpm and when sliding speed increases to 400rpm, the wear rate of copper - 5% tin - 9 wt.% nano Al2O3 MMC increases by 15% with that of 100rpm sliding speed copper - 5% tin - 9 wt.% nano Al2O3 MMC. The wear rate of copper - 5% tin -9 wt.% nano Al2O3 MMC at a sliding speed 300rpm decreases and copper - 5% tin - 6 wt.% nano Al2O3 MMC shows decrease in the wear rate as contrast to wear rate of copper - 5% tin matrix material at 100rpm sliding speed and diminish in the wear of 400rpm sliding speed copper - 5% tin - 9 wt.% nano Al2O3 MMC and diminish in the wear of 300rpm sliding speed copper - 5% tin - 6 wt.% nano Al2O3 MMC with that of 100rpm sliding speed copper - 5% tin matrix material.

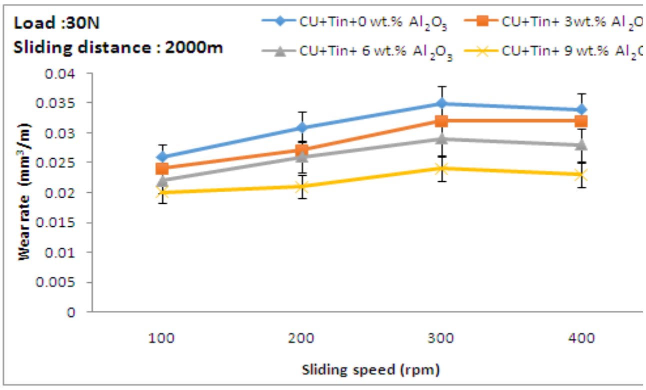


Fig 14: Effect of sliding speed on wear rate of the Copper - 5% Tin - Nano Al2O3 MMCs

IV. CONCLUSION

The copper - 5% tin – 3 to 9 wt. % nano Al2O3 metal matrix composite materials were developed by stir casting method. The nano Al2O3 reinforcement particles are uniformly allocated in the matrix material. As the percentage of reinforcement increases the hardness of NMMC'S increases. The improvement in hardness is due to the presence of hard reinforcement. The 9 wt.% of nano Al2O3 particulates reinforced copper - 5% tin –nano Al2O3 composites shows 25% boost in the UT Strength 22.73% boost in the yield strength as compared to the UTS and yield strength of the copper - 5% tin matrix material. The enhancement in the tensile strength was due to the inclusion of high strength reinforcement material in the matrix. The ductility declines by 25.18% by the addition of 9 wt.% of nano Al2O3 particulates in the copper - 5% tin matrix material. The decrease in the ductility may be due to the inclusion of brittle ceramic nano Al2O3 reinforcement in the matrix. The compression strength amplifies by 16.13% by the addition of 9 wt.% of nano Al2O3 particulates in the copper - 5% tin matrix substance. The enhancement in the compression strength was due to the inclusion of high strength reinforcement material in the matrix.

The wear rate of the matrix material is higher than that of the copper - 5% tin – nano Al2O3 metal matrix composites. The wear rate decreases by 33.33% by the addition of 9wt. % of nano Al2O3 particulates in copper - 5% tin matrix. The decrease in the wear rate was due to the presence of hard ceramic material in the matrix. The wear rate of nano MMC'S increases as the load increases. Wear rate of nano MMC'S with 3%, 6% & 9% reinforcement decreases when compare to matrix materials. The wear rate of nano MMC'S increases as the speed increases up to 100rpm to 300rpm, decreases at 400rpm. The wear rate of nano MMC'S increases in 3% of reinforcement up to 100rpm to 300rpm but decreases at 400rpm. The wear rate increases as the reinforcement increases.

REFERENCES

1. Anshuman Srivastava, "Metal Matrix Nanocomposites (MMCs): A Review of their Physical and Mechanical Properties", International journal Nano Med & Eng. 2:8, 152-154, 2017
2. Sanaty-Zadeh, A. Comparison between current models for the strength of particulate-reinforced metal matrix nano composites with emphasis on consideration of Hall–Petch effect. Mat. Sci. Eng. A 2012, 531, 112–118.
3. Luo, P.; McDonald, D.T.; Xu, W.; Palanisamy, S.; Dargusch, M.S.; Xia. K. A modified Hall–Petch relationship in ultrafine-grained titanium recycled from chips by equal channel angular pressing. Scripta Mater. 2012, 66, 785–788.
4. Riccardo Casati and Maurizio Vedani, "Metal Matrix Composites Reinforced by Nano-Particles—A Review" Metals 2014, ISSN 2075-4701 4, 65-83; doi: 10.3390/met4010065.
5. Joel Hemanth, "Development and property evaluation of aluminum alloy reinforced with nano- ZrO2 NMMC's", Material Science and Engineering, Volume 507, 2009, pp.10-113.
6. Sachin Malhothra, Ram Narayan, and R D Gupth, " Synthesis and characterization of aluminium 6061 alloy-fly ash and zirconia metal matrix composite", International journal of current engineering and technology, Volume 3, 2013, pp. 1716-1719.
7. Girisha K B and H C Chittappa, "Preparation, characterization and wear study of aluminium alloy reinforced with zirconium nano particles", International journal and innovative research in science, Engineering and technology, Volume 2, issue 8, 2013, pp.3627-3637.
8. P. Ashwath and M. Anthony Xavior, "Processing methods and property evaluation of Al2O3 and SiC reinforced metal matrix composites based on aluminium 2xxx alloys", Journal of Materials Research, Volume 31, Issue 9, 2016 , pp. 1201-1219.
9. Karbalaci AkbariM, O. Mirzaee and H R Baharvandi," Fabrication and study on mechanical properties and fracture behavior of nano metric Al2O3 particle reinforced A356 composites focusing on the parameters of vortex method", Material and design, Volume 46, pp 199-205.