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Comparison of Mechanical Properties and effect of sliding velocity on wear properties of Al 6061, Mg 4%, Fly ash and Al 6061, Mg 4%, Graphite 4%, Fly ash Hybrid Metal matrix composite.

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Abstract

This Metal matrix composites (MMCs) are of great interest in industrial applications for its lighter weight with high specific strength, stiffness and heat resistance. The processing of MMCs by casting process is an effective way of manufacturing. In this paper the effect of rpm on specific wear rate and comparison of mechanical properties of two metal matrix composites have been investigated. In first case AL6061, 4%MG chosen as a base metal and varying composition of Fly ash i.e. 10%, 15% and20% was taken as reinforcement in second case AL6061, 4%MG, 4%Graphite was taken as base material and varying composition of Fly ash i.e. 10%, 15% and20% as reinforcement. It was found that tensile strength increase with addition of fly ash. Similarly when graphite was added then a decrease in tensile and hardness was observed. The composite with 4%Mg, 15%Fly ash found to be maximum tensile whereas composite of 4%Mg, 20%Fly ash was found to be of maximum hardness. Specific wear rate decreases with addition of fly ash up to a certain volume whereas with graphite addition it also decreases.

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Keywords: Fly ash; Graphite powder; Magnesium turning; Stir casting; Tensile strength.

1. Introduction

The requirement of composite material has gained popularity in these days due to their various properties like low density, good wear resistance, good tensile strength and good surface finish. Among various particulates used, fly ash is one of the least expensive and low density reinforcement available in huge quantities as solid waste by-

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product in thermal power plants. A literature survey on aluminium based matrix composite has been done and related brief data are given. S. Venkat Prasat (2011) observed that the incorporation of fly ash particles in aluminium alloy has the potential for conserving energy intensive aluminium, and thereby reducing the cost of aluminium products, and at the same time causing a reduction in the weight of the products. Graphite and graphite powders are widely used in industrial applications for their excellent dry lubricating properties. So, if a solid lubricant like graphite is contained in the aluminium alloy, it can be released automatically during the wear process. K. V. Mahendra (2010) concluded that HMMCs containing up to 15% fly ash and SiC particles could be easily fabricated. Uniform distribution of fly ash was observed in the matrix. The fluidity and density of HMMCs decreases, whereas hardness increases with increase in percentage of particulates. The tensile strength, compression strength, and the impact strength increases with increase in percentage of particulates. Adel Mahmood Hassan et al. (2007) opinion was Rockwell hardness decrease with the increase in graphite content. Rockwell hardness was increased with an increase in the SiC content due to its high hardness. The addition of SiC particles causes the Ra of the composites to increase. With graphite exceeding 4% more rapidly hardness decreases 4% mg is for better wettability. A.R.K. Swami et al. (2011) vary reinforcing particulate from 0% to 4% and found that as the graphite content was increased, there were significant reduction in hardness and monotonic increases in the ductility, ultimate tensile strength (UTS), The graphite contents used for the preparation of the composites were 0%, 1%, 2% and 4%. This is because graphite compositions of 7% and above would lead to rejection from the melt. Abdalla alarshdan et al. (2011) showed that the effect of the addition of copper as alloying element (up to 5 wt %) to Al–4 wt% Mg tends to decrease torque and thrust force. Also, it was found that the addition of SiCp (up to 10 vol. %) to the Al–4 wt% Mg–Cu alloys had little effect on the drilling torque and thrust force, but tends to improve the surface roughness. Joel Hemanth (2009) concluded that wear resistance of composites were remarkably improved by adding SiO2 particles. Y. Yang et al. (2010) resulted that in both peel test and tensile test specimens containing SiC fibers showed superior properties compared to those no SiC fibers. J.Babu rao et al. (2012) given results that with increasing the amount of fly ash the density of the composites was decreased and the hardness was increased. The increase in compression strength was observed with increase in amount of fly ash. Fly ash particles lead to an enhanced pitting corrosion of the aluminium–fly ash (ALFA) composites in comparison with unreinforced matrix (AA 2024 alloy). A. Anantha Moorthy et al. (2012) done experimental investigation of hybrid metal matrix composites with fly ash and graphite reinforced aluminium alloy (Al 6061) composites samples, processed by stir casting route are reported. The aluminium alloy was reinforced with 3 wt. %, 6 wt. %, 9 wt. % fly ash and fixed 3 wt. % of graphite to mixture the hybrid composite. Hardness of the hybrid composite were tested it was found that when the hardness of the hybrid composites can be increased when compared to (Al 6061). Rupa Dasgupta (2005) concluded that formation of composites does not necessarily improve upon the properties of base alloy used for making the composite. Hardness is appreciably improved on forming composites, the improvement being more pronounced in the cast composite. J.Babu rao et al. (2010) Found that there was a uniform distribution of fly ash particles in the matrix phase and also existing a good bonding between matrix and fly ash. The hardness of the composites increased whereas the density of the composites decreased with increasing the amount fly ash than the pure aluminium. Enhanced mechanical properties were observed with increasing amount of fly ash under compression. A. Manna et al. (2011) investigated that the hardness of Al/Al2O3-MMC increases on addition of Al2O3-reinforced particles. The hardness of Al/Gr MMC decreases initially with addition of 5 vol. % Gr-particles; but thereafter, hardness increases with increase in percentage of Gr-particles. UTS decreases on addition of reinforced particulates (Al2O3; Gr) with the matrix. Ravi Mishra et al. (2012) found that the Fly ash reinforced Al6061 alloy Metal Matrix Composite was prepared by the stir casting method with Al6061 as the matrix and Fly ash as the reinforcement. The results can be summarized as follows: Adding Fly ash in Al6061 alloys increases its Wear resistance. Hardened Steel counterface shows a minimum wear condition with 15% weight fraction of fly ash. Neeraj Sharma et al. (2013) investigate the effect of parameters on cutting speed and dimensional deviation for WEDM using HSLA as workpiece. Pradeep Gupta et al. (2012) analysed that spark gas voltage, pulse on time, peak current and pulse off time have a significant effect on Kerf Width. Neeraj Sharma et al. (2013) observed that metal removal rate and surface roughness increase with increase in pulse on time and peak current. Metal removal rate and surface roughness decrease with increase in pulse off time and servo voltage. J.I. Song et al. (1997) concluded that the tensile strength of $Al/Al_2O_3/C$ composites was decreased by increasing the addition of carbon fibre. The carbon fibre additions were seen to be less effective in strength than when only Al_2O_3 fibres were incorporated. The wear resistance of $Al/Al_2O_3/C$ composites was remarkably improved over Al/ Al_2O_3 composites by adding carbon fibres to $Al/Al_2O_3/C$ composites. V.C. Uvaraja et al. (2012) while studying the influence of operating parameters such as applied load, sliding speed, percentage of reinforcement content and sliding distance on the dry sliding wear of 6061 aluminium with SiC and B4C particulate reinforced composite observed that the reinforced composite with higher concentration of SiC (15%) shows better decrease in wear rate. At the maximum load of 40N, wear rate is high at the range of 30 to 40 % as compared to other load condition.

2. Raw material

2.1. Fly Ash

Fly ash used was manually sieved upto 100µm. Table 1 shows weight percentage of elements in fly ash. EDS and SEM of fly ash was done. Fig.1 shows SEM of fly ash. Fig.2 shows EDS of fly ash.

Table 1. Weight percentage of elements in fly ash

Element	Weight %
C	21.51
O	52.75
Al	12.05
Si	13.69

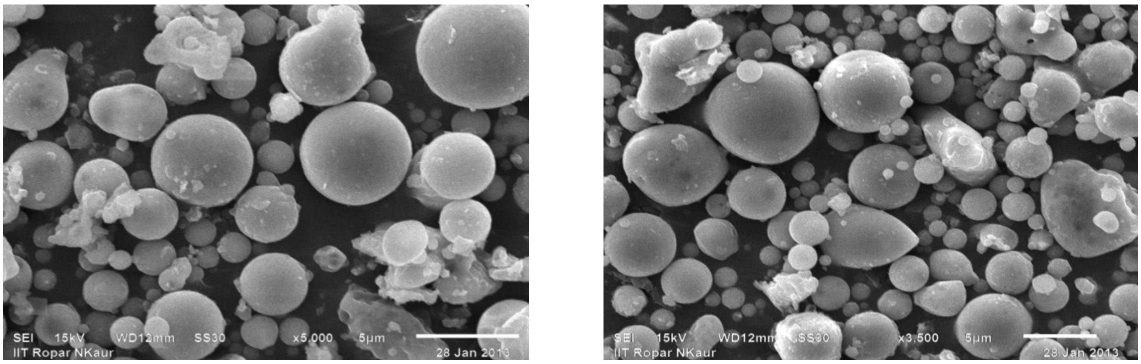

Fig. 1. SEM photographs

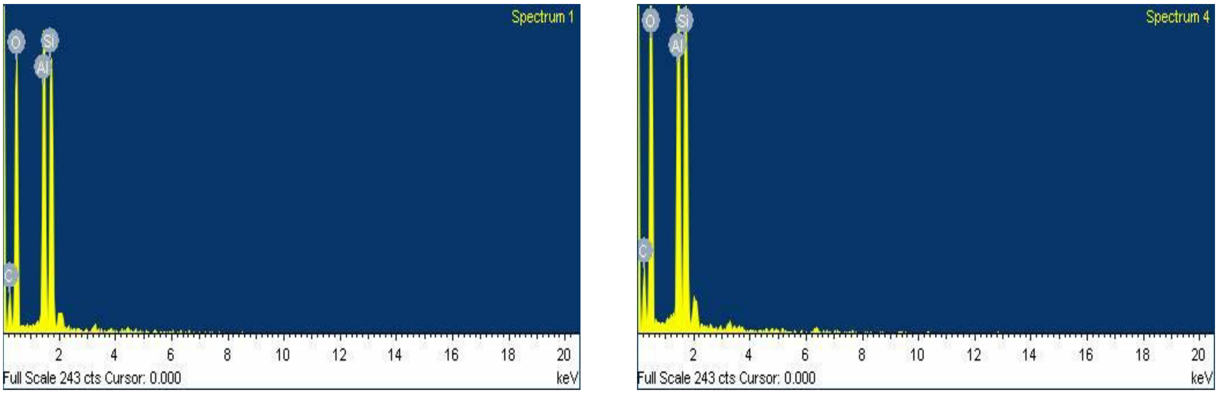

Fig. 2. EDS photographs

2.2. Graphite

Graphite was used in powder form. Its particle size was ≤ 50µm. Fig. 3 shows graphite in powder form.

Fig. 3. Graphite powder

2.3. Magnesium

Magnesium was used for wettability. Magnesium metal turning was used. Fig. 4 shows magnesium metal turning.

Fig. 4. Magnesium turnings

3. Sample preparation

Seven samples were prepared by stir casting. Table 2 shows composition of different raw materials which were added in base metal alloy AL 6061.

Table 2. Composition of different raw materials used

Sample No.	Fly ash Wt.%	Magnesium Wt.%	Graphite Wt.%
1	NIL	4	4
2	10	4	NIL
3	15	4	NIL
4	20	4	NIL
5	10	4	4
6	15	4	4
7	20	4	4

3.1. Stir Casting Procedure

Fly ash / graphite reinforced Aluminium alloy (Al6061) composites, processed by stir casting route were used in this work. Liquid metallurgy route was used to synthesize the hybrid composite specimens. The matrix alloy was first superheated above its melting temperature and then the temperature was lowered gradually until the alloy reached a semisolid state. The required quantities of fly ash (10, 15 and 20 Wt. %) and graphite (4 Wt % fixed) powder were taken in containers. Then the fly ash and graphite was heated to 450°C and maintained at that temperature for about 20 minutes. Fig.5. shows the furnace and stirrer.

a

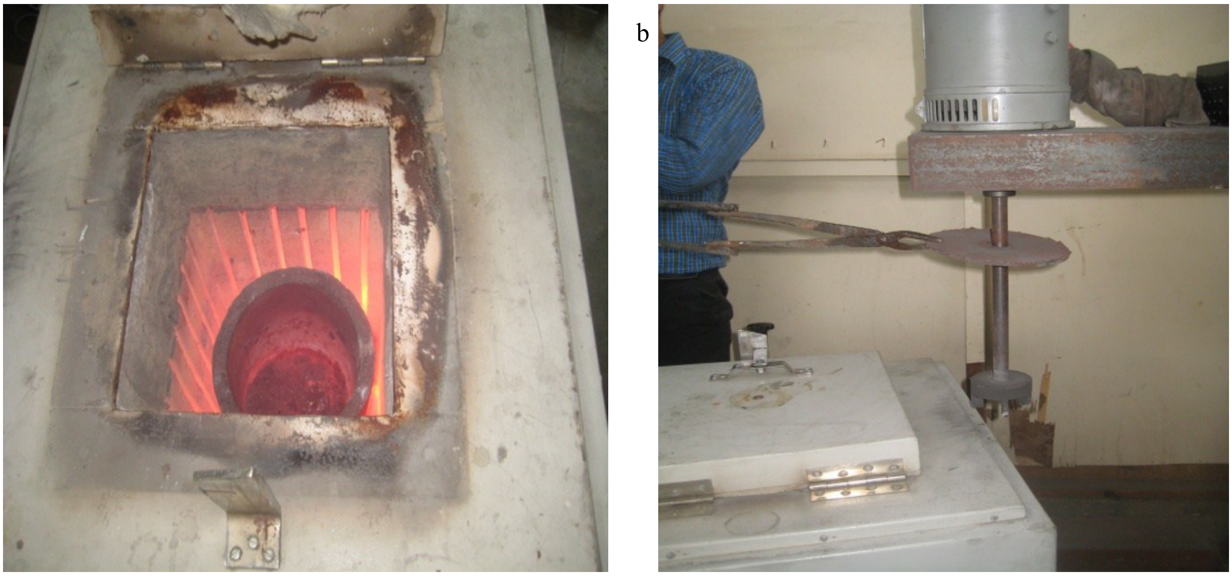

Fig. 5. (a) Metal in furnace; (b) Stirrer

A vortex was created in the melt due to continuous stirring by a mechanical stirrer. At this stage, the blended mixture of preheated fly ash and graphite particles were introduced into the slurry and the temperature of the composite slurry was increased until it was in a fully liquid state. Small quantities of magnesium (4 Wt % fixed) were added to the molten metal to enhance wettability of reinforcements with molten aluminium. Stirring was continued for about 5 minutes until the interface between the particle and the matrix promoted wetting and the particles were uniformly dispersed. The melt was then superheated above the liquid us temperature and solidified in mould to obtain desired samples. Nitrogen gas was used as a degassifire.

4. Results

4.1. Tensile and Hardness Test

4.1.1. Tensile Test

Tensile test was performed on FIE Make Universal Testing Machine, UTE-100 Fig.6. (a) and (b) shows specimens before and after testing.

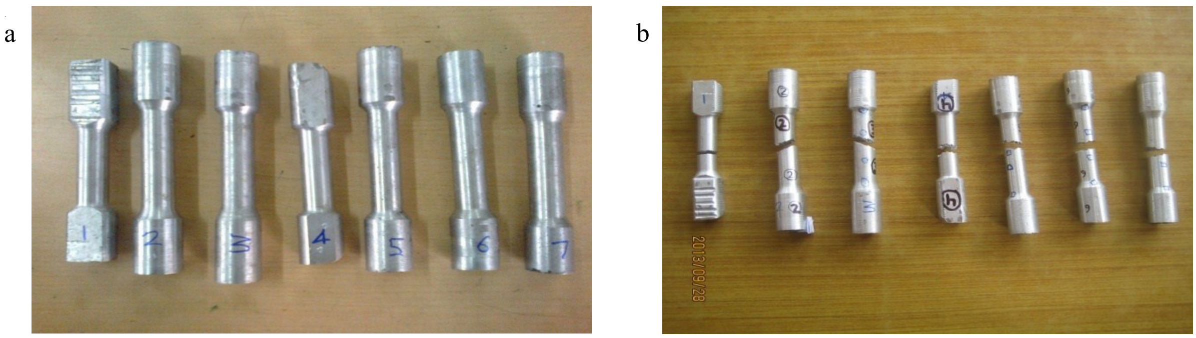

Fig. 6. (a) Specimens before testing; (b) Specimens after testing

4.1.2. Hardness test

Hardness of the seven stir casted HMMC samples was tested on FIE make Vickers Hardness Tester. Readings on 2 to 3 locations were taken and average reading of each sample was considered. Fig. 7 shows hardness testing machine apparatus.

Fig. 7. Hardness testing machine

Table 3. Result of tensile test

Sr. No.	Sample No.	Tensile Strength (kN/mm^2)
1	1	0.098
2	2	0.102
3	3	0.124
4	4	0.104
5	5	0.095
6	6	0.108
7	7	0.096

Table 4. Result of hardness test

Sr. No.	**Sample No.**	**HV Average of 3 Readings**
1	1	57.1
2	2	68.0
3	3	69.6
4	4	71.3
5	5	65.0
6	6	64.0
7	7	69.0

4.2. Wear Test

The dry sliding wear tests were performed on Ducom made pin-on-disc apparatus. Pin-on-disc apparatus is shown in Fig. 8. Wear test samples were made of size ø10×35mm. The test surface was well polished on different grades of abrasive paper to ensure the proper contact with steal disc. The test surfaces were cleaned with acetone after each run on machine to remove any wear waste. Sliding wear tests were conducted on track diameter 80mm, load 30N with varying r.p.m i.e. 1000, 1500, and 2000. The rotating disc material was EN-31. The sliding wear loss was measured. Weight loss of pins was converted into volume loss using density of specimens. The specific wear rate was calculated as

$$\text{Specific wear rate} = \frac{\Delta V}{(L \times D)}$$

where ΔV is volume loss, L is load and D is distance.

Fig. 8. Pin-on-disc apparatus

Fig. 9. Pins for wear test

Fig.9. shows pins as the specimens for wear test and their remaining material.

4.2.1. Effect of r.p.m. on Specific Wear Rate

From Fig. 10 it is clear that specific wear rate increases with increase of r.p.m. in sample 2, 3, 4 and 7. However, in sample 5 and 6 specific wear rate decrease with increase of r.p.m. (upto 1500).

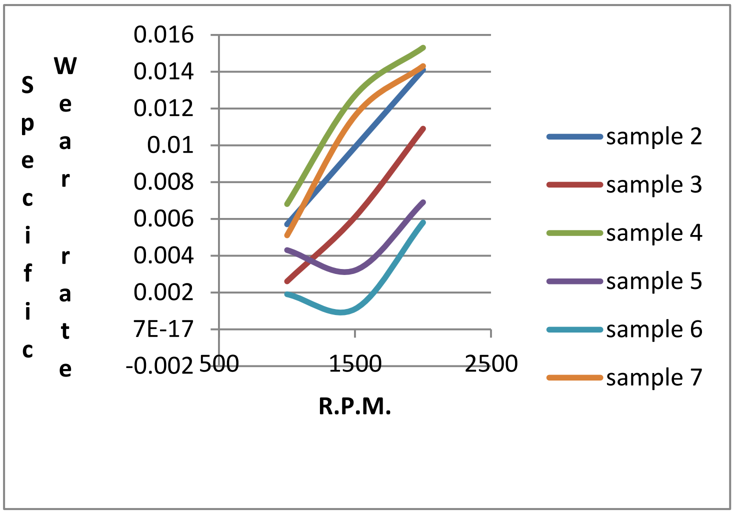

Fig. 10. Effect of r.p.m. on specific wear rate

4.2.2. Effect of volume percentage of reinforce particulates on specific wear rate

In samples 2, 3 and 4 volume percentage of fly ash was 10%, 15% and 20% respectively. Fig. 11. shows that for the same r.p.m. specific wear rate decrease with increase of volume percentage of fly ash (upto15%) and thereafter with further addition of fly ahs specific wear rate increases.

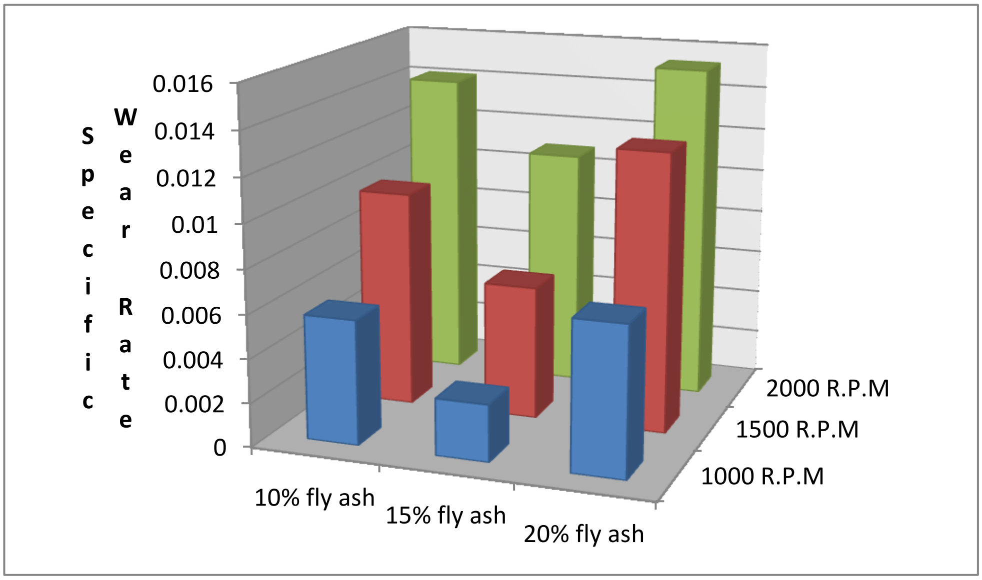

Fig. 11. Effect of Volume percentage on specific wear rate

4.2.3. Comparison of specific wear rate by addition of fixed quantity of graphite to the varying volume percentage of fly ash in composite

From Fig. 12, 13 and 14 it is clear that with addition of graphite when compared with same percentage of fly ash specific wear rate decreases.

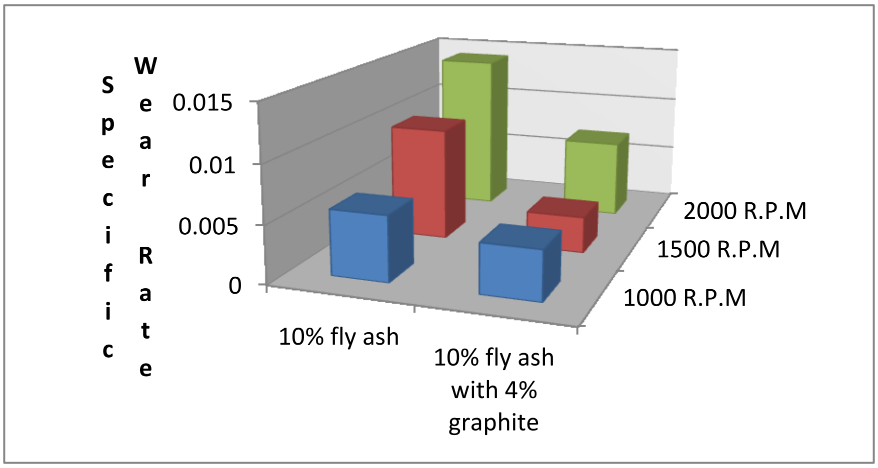

Fig. 12. Comparison of 10% fly ash to 10% fly ash with 4% graphite

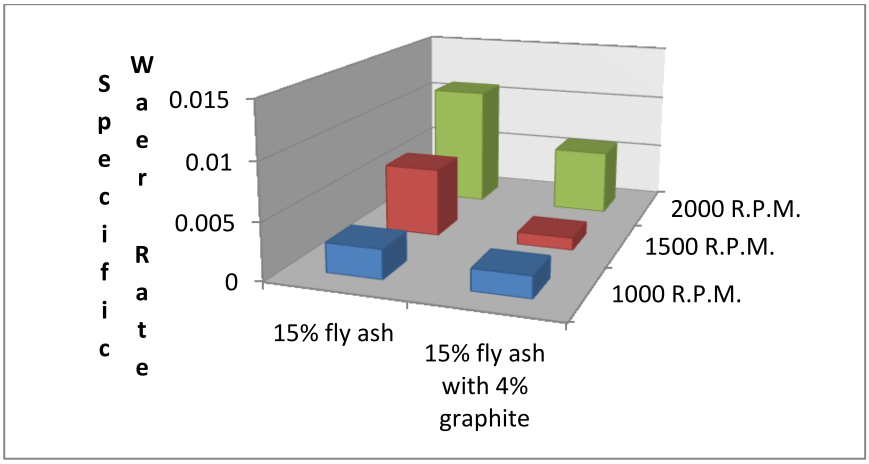

Fig. 13. Comparison of 15% fly ash to 15% fly ash with 4% graphite

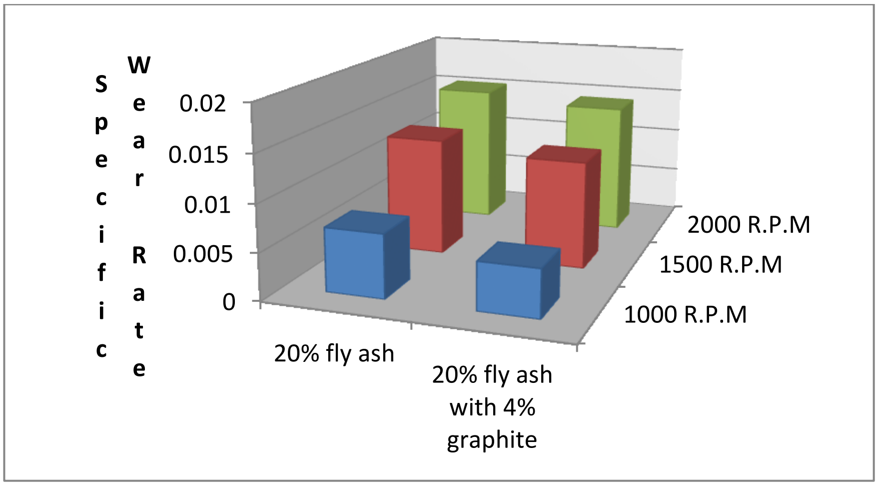

Fig. 14. Comparison of 20% fly ash to 20% fly ash with 4% graphite

4.3. Conclusions

- With upto 15% addition of fly ash tensile strength increases.
- With further addition of fly ash tensile strength decreases.
- By addition of fixed quantity of graphite i.e. 4% tensile strength decreases but is still more than the base metal.
- Graphite addition smoothens the machining.
- Hardness of sample no. 4 i.e. 20% fly ash is maximum.
- Fly ash increases hardness whereas graphite decreases hardness in a little amount but improves machining.
- Specific wear rate decrease with increasing percentage of fly ash(upto 15% fly ash).
- With further addition of fly ash, composite's hardness increases and this may be concluded that material becomes less ductile that is why on increasing addition of fly ash specific wear rate increases.
- With addition of a fixed quantity of 4% graphite with same volume percentage of fly ash when compared; specific wear rate decreases.

- Specific wear rate increases with increase of r.p.m. in sample 7(20% fly ash and 4% graphite). This is due to excess amount of fly ash which makes material so brittle.
- Specific wear rate decreases upto 1500 r.p.m. in sample 5(10% fly ash and 4% graphite) and sample 6(15% fly ash and 4% graphite). This is due to lubricant behaviour of graphite. As r.p.m. increases, due to heat generated by high speed graphite diffuses which makes the composite more ductile.

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