Effect of Graphite on Wear and Strength Properties of Hybrid Aluminium Matrix Composites

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Abstract- **Metal matrix composites (MMCS) have attracted considerable attention recently because of their potential advantages over monolithic alloys. The MMCS are commonly reinforced with high strength, high modulus, and brittle ceramic phases, which may be in the form of fiber, whiskers, or particulates. The addition of ceramic reinforcement to a metal matrix improves strength and stiffness, but at the expense of ductility. Compared to the continuous fiber-reinforced composites, particulate reinforced MMCS offer several advantages such as improved anisotropy, ease of fabrication, and lower cost.**

In light of this fact, the present project report describes the fabrication of Al6061 based hybrid matrix composites by stir casting technique. Since the presence of only hard particulate reinforcement in composite leads to poor surface finish and higher tool wear. Therefore composites were prepared with both hard reinforcement (SiC) and soft reinforcement (Gr).The content of SiC in Al6061 melt was maintained constant and Gr was varied from 1wt% to 4wt%, in steps of 1wt% and characterize their macro hardness, dry sliding wear and corrosive wear resistance properties.

Al6061-SiC-Gr hybrid composites have been successfully produced by vortex method. Microstructure studies clearly revealed uniformity in the distribution of reinforcements and excellent bond between the matrix and the reinforcement. Macro hardness of Al6061 based hybrid composites is higher when compared with that of the matrix alloy. Increased content of hard reinforcement in the hybrid composites leads to enhancement in macro hardness of the hybrid composites. With increase in graphite content there was declination in macro hardness. Material loss due to adhesive wear of Al6061 based hybrid composites is lower when compared with that of the matrix alloy. Increased content of Gr reinforcement in the hybrid composites leads to enhancement in adhesive wear resistance of the hybrid composites. Coefficient of friction of hybrid composites is lower than that of the matrix alloy. Increased content of hard reinforcement for a given volume fraction of soft reinforcement leads to lower coefficient of friction. There was fluctuation in the specimen-disc temperature with increase in sliding speed , load and sliding velocity. However drop in temperature was found in hybrid composites when compared to that of base material.

Keywords: **Metal Matrix Composites, Vortex Stir Casting, Macrohardness, Sliding Wear Resistance.**

I.INTRODUCTION

Metal composite materials have found application in many areas of daily life for quite some time. Often it is not realized that the application makes use of composite materials. These materials are produced in situ from the conventional production and processing of metals. Here, the Dalmatian sword with its meander structure, which results from welding two types of steel by repeated forging, can be mentioned. Materials like cast iron with graphite or steel with a high carbide content, as well as tungsten carbides, consisting of carbides and metallic binders, also belong to this group of composite materials. For many researchers the term metal matrix composites is often equated with the term light metal matrix composites (MMCs). Substantial progress in the development of light metal matrix composites has been achieved in recent decades, so that they could be introduced into the most important applications. In traffic engineering, especially in the automotive industry, MMCs have been used commercially in fiber reinforced pistons and aluminum crank cases with strengthened cylinder surfaces as well as particle-strengthened brake disks. These innovative materials open up unlimited possibilities for modern material science and development; the characteristics of MMCs can be designed into the material, custom-made, dependent on the application. From this potential, metal matrix composites fulfill all the desired conceptions of the designer. This material group becomes interesting for use as constructional and functional materials, if the property profile of conventional materials either does not reach the increased standards of specific demands, or is the solution of the problem. However, the technology of MMCs is in competition with other modern material technologies, for example powder metallurgy. The advantages of the composite materials are only realized when there is a reasonable cost – performance relationship in the component production. The use of a composite material is obligatory if a special property profile can only be achieved by application of these materials

The conventional aluminium based composites possess only one type of reinforcements. Addition of hard reinforcements such as silicon carbide, alumina, titanium carbide, improves hardness, strength and wear resistance of the composites. However, these composites possessing hard reinforcement do posses several problems during their machining operation. It is reported that the surface finish of the hard reinforced metal matrix composites are inferior when compared with the matrix alloy. Further it is absorbed that during turning, the hard reinforced metal matrix composites resulted in higher flank wear with increased content of the reinforcement.

It is reported that composites possessing softer reinforcement- possess good machinability index. Hence the current interest is to produce hybrid metal matrix composites(HMMCs) were in more than one type, shape and size of the reinforcement are used to obtain synergistic properties of the reinforcement and the matrix chosen.
In the light of the above concept an attempt is made in the present project to fabricate hybrid aluminium matrix composites and to study dry sliding wear behavior in addition to micrographs and macro hardness and corrosive wear study

II.EXPERIMENTAL DETAILS

Composite Preparation

Al6061 was selected as a base metal matrix. Vortex method of liquid metallurgy route casting was adopted. An electric melting furnace with graphite crucible for melting which has a maximum temperature of 1000^0C was adopted. Silicon carbide particles of 10 micron size and graphite particles of 60 micron size were selected as reinforcements. The base metal was heated to temperature of about 710^0C. The preheated permanent molds of cast iron were used. hexachloroethane (C_2Cl_6) degassing tablet was used to remove impurities and unwanted gases. The preheated silicon carbide and graphite particles were added slowly into the vortex and were stirred for about 10 minutes keeping constant 7wt%SiC the amount of graphite reinforcement was varied from 1wt% to 4wt% in steps of 1wt%.

Sliding Wear Test.

Standard pin on disc tribometer was used to study friction and wear of both Al0601 and its hybrid composites as shown in fig. 2.1. Specimens with diameter of 10mm and height 23mm were developed. The specimens were finely grounded. Hardened steel disc of Rc 60 was used as counter disc. Friction and wear studies were conducted at load of 10N and sliding speed of 1.57m/sec with sliding distance of $5.655x10^3$m.

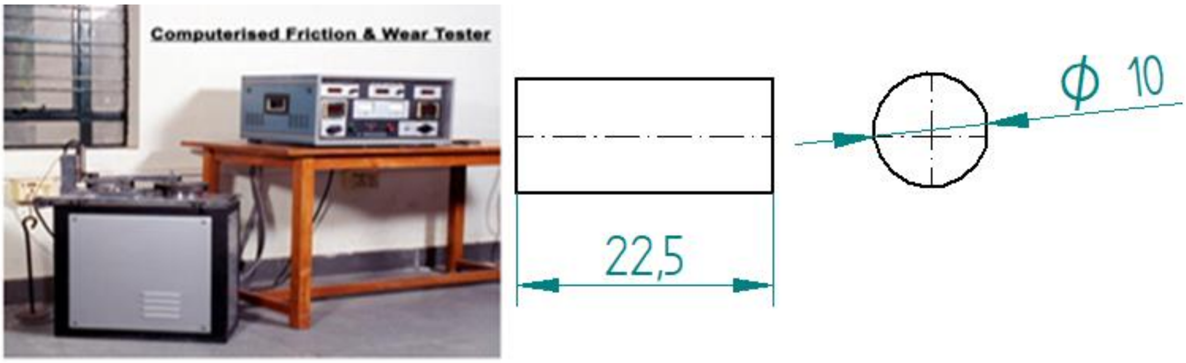


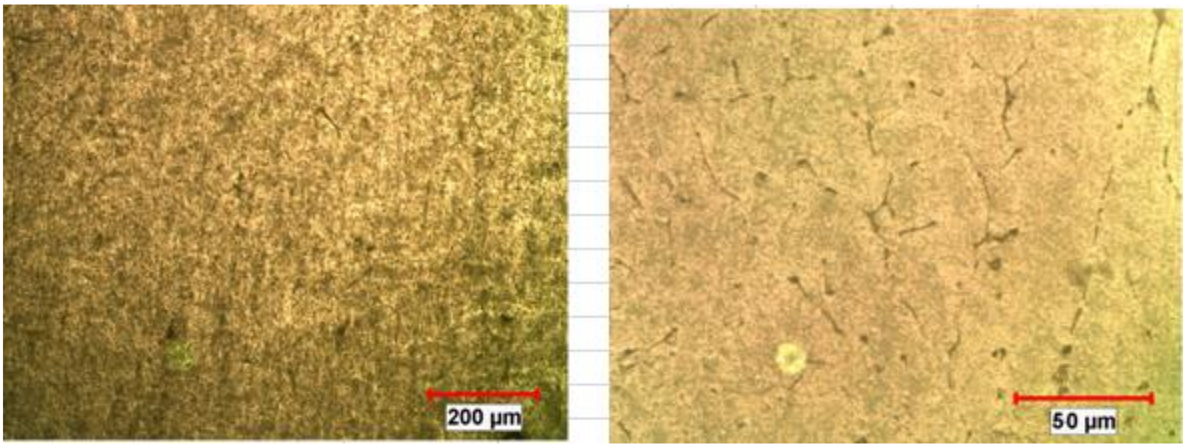
Fig. 2.1 Friction and wear monitor.

III. RESULTS AND DISCUSSIONS

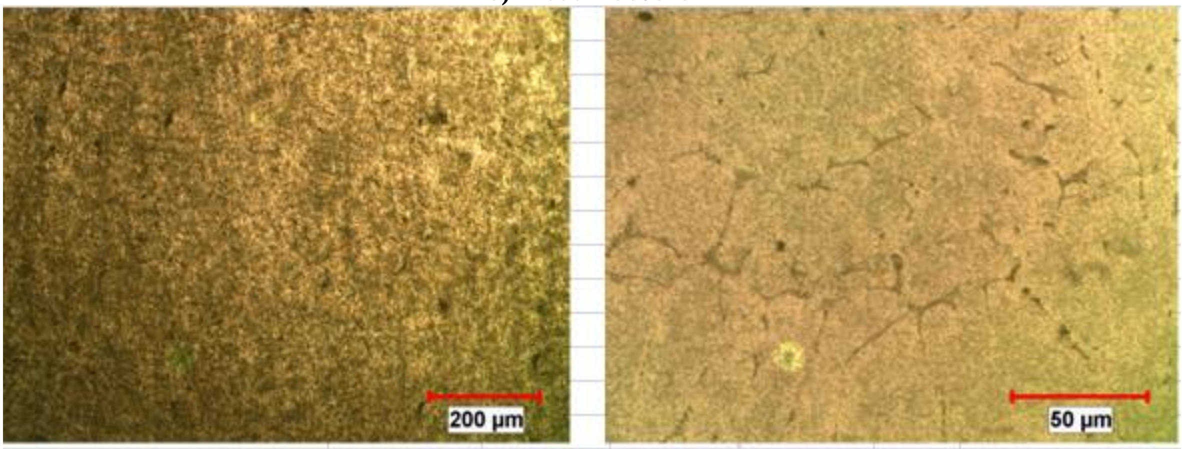
Microstructure Studies.

The specimens for micrograph studies were prepared from the cast composites and the polishing was done as per the ASTM recommendations. The specimens were etched with picric acid and were tested on metallurgical microscope as shown in figure 1.(a-f)

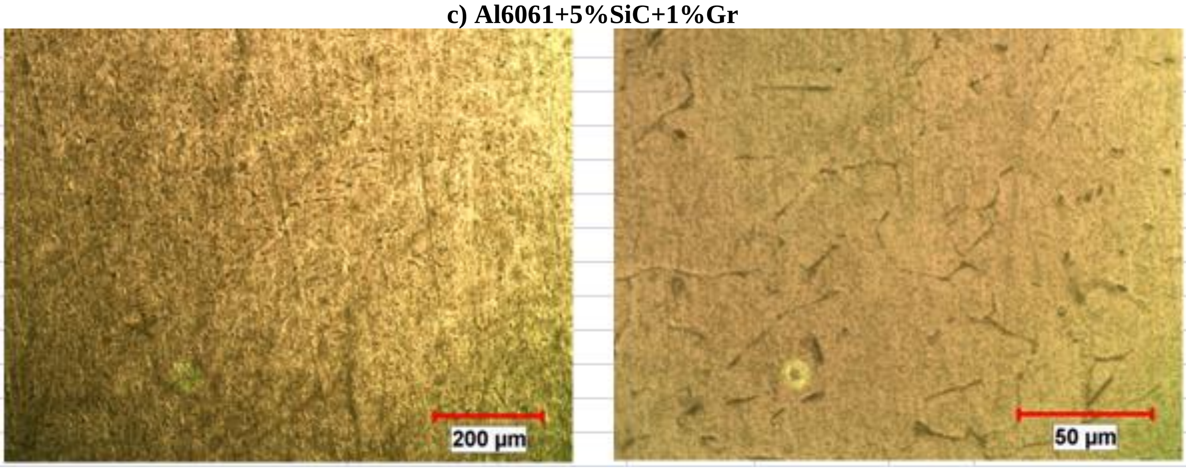
(a) Al6061 alloy



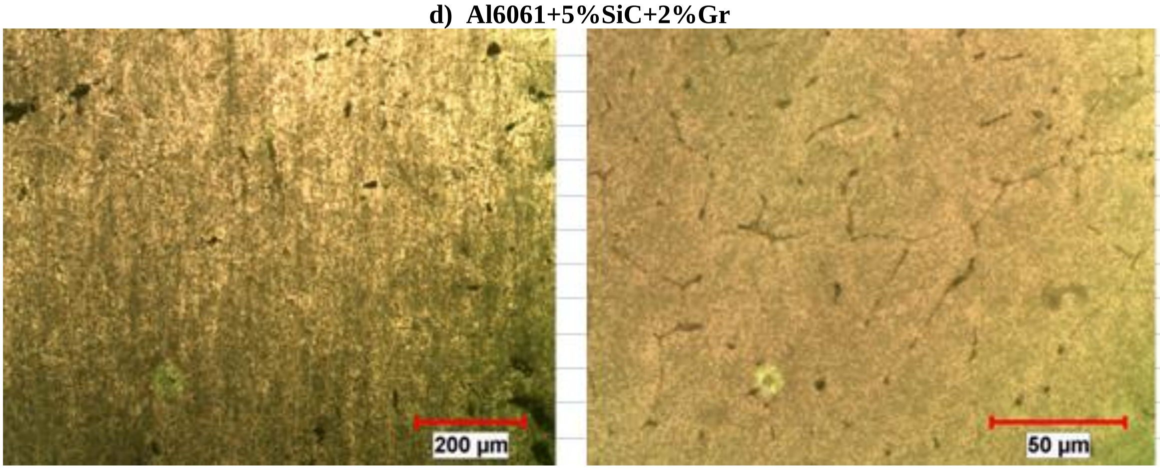
b) Al6061+5%SiC



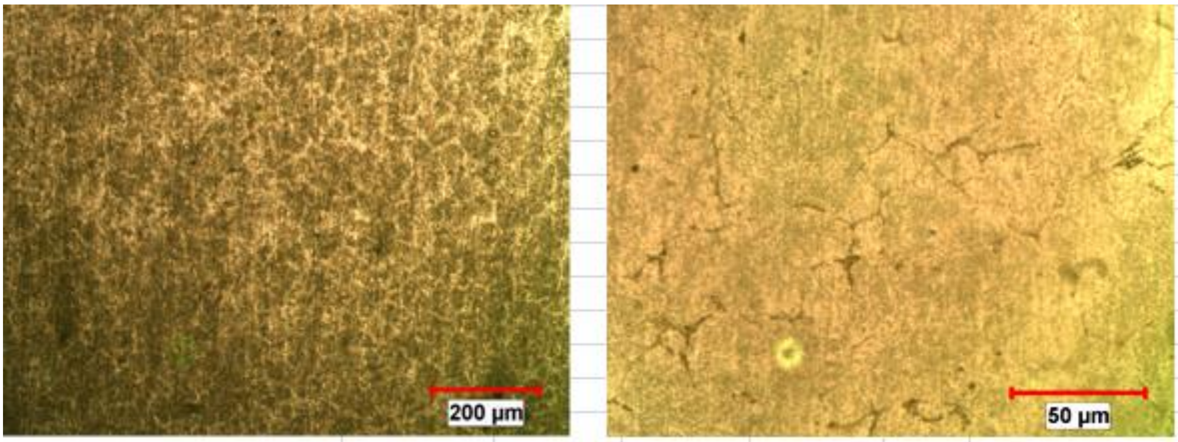
c) Al6061+5%SiC+1%Gr



d) Al6061+5%SiC+2%Gr



e) Al6061+5%SiC+3%Gr



f) Al6061+5%SiC+4%Gr

Fig.1 (a-f): Micrographs of Al6061 alloy and its composites

It is observed from figure 1 that the particles are uniformly distributed. The extent of porosity noticed is also less. There is a clear evidence of homogeneous distribution of reinforcements though graphite and silicon carbide cannot be differentiated so easily.

Macro hardness (RHN)

The variation of macro hardness with increased content of Gr particles at constant 5wt % SiC in the matrix Al 6061 is as shown in figure 2.

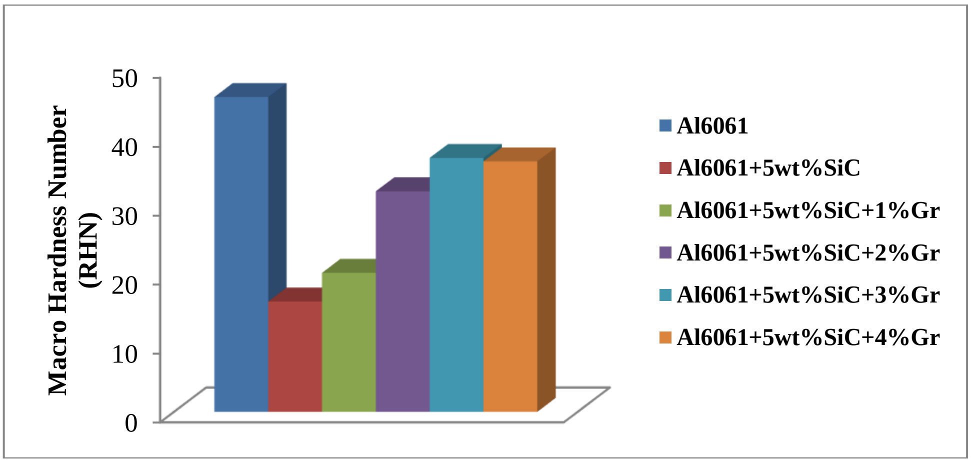


Fig.2 Macrohardness (RHN) of Al6061 alloy and its composites.

It is observed from figure 2 that with increase content of reinforcement particles in the matrix alloy, there is a significant improvement in the macro hardness of the composites. But with increase in Gr there is decrease in macro hardness. An improvement of about 65% is observed in Al6061-5wt % SiC composites, while about 20.43% in Al 6061- 5wt% SiC- 5wt% Gr hybrid composites. The improvement in hardness due to SiC content may be due to the hardness of SiC. While decrease in hardness due to increase of Gr is due to soft nature of Gr.

Effect of Sliding Distance on Wear

The effect of increase in sliding distance on material loss due to wear for Al6061 alloy and its composites is as shown in figure 3.

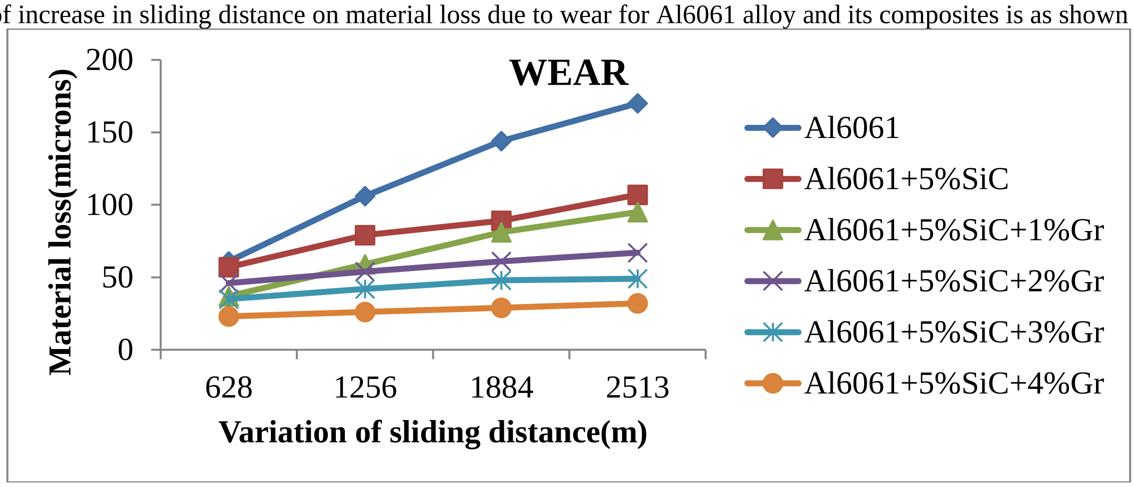


Fig:3 Variation of material loss of Al6061 matrix alloy and its hybrid composite at constant 5wt%SiC with increased content of Gr without heat treatment

It is observed from figure 3 that there is increase in the wear as we increase the sliding distance for both the base material and composite material. However at all the sliding distance studied the material loss due to sliding wear with increase in sliding distance of composite material was found less compared to that of the base metal. Also with increase in Gr there was improvement in sliding wear resistance of the composite material. About 81% improvement in sliding wear resistance was found for a sliding distance of 2513 m when compared with Al6061 alloy and Al6061+5%wtSiC+4%wtGr material.

Effect of Sliding Distance on COF

The effect of increase in sliding distance on coefficient of friction for Al6061 alloy and its composites is as shown in figure 4

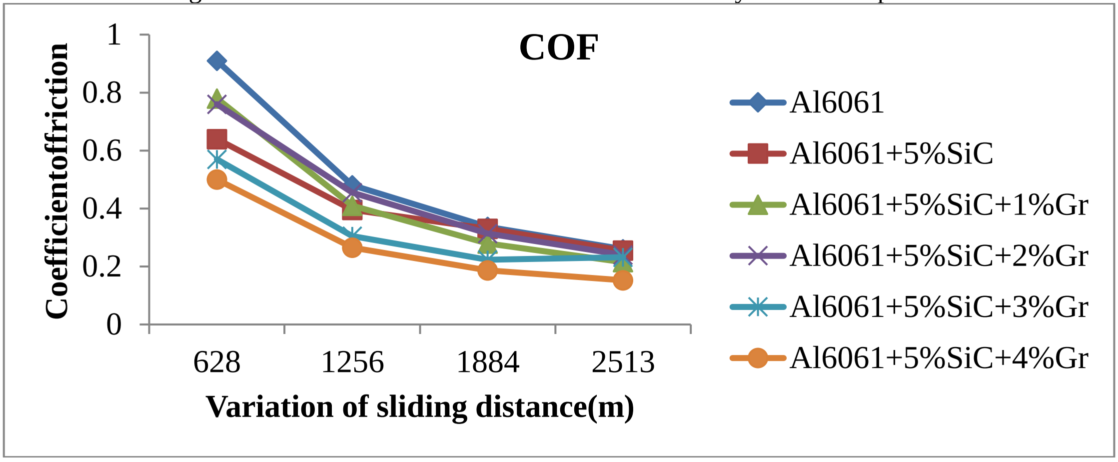


Fig: 4 Variation of coefficient of friction of the matrix alloy and its hybrid composites with increasing percentage of Gr at constant 5wt%SiC

It is observed from figure 4 that there is decrease in coefficient of friction as we increase the sliding distance for both the base material and composite material. However at all the sliding distance studied the COF due to sliding wear with increase in sliding distance of composite material was found less compared to that of the base metal. Also with increase in Gr there was improvement in COF of the composite material. About 42% improvement in COF was found for a sliding distance of 2513m when compared with Al6061 alloy and Al6061+5%wtSiC+4%wtGr material.

This can be attributed to the fact that, with addition of hard reinforcement into the soft matrix alloy there is decrease in frictional force. This is because of the Gr acting as a solid lubricant, which melts due to frictional heat.

Effect of Sliding Distance on Temperature

The effect of increase in sliding distance on specimen disc temperature for Al6061 alloy and its composites is as shown in figure 5

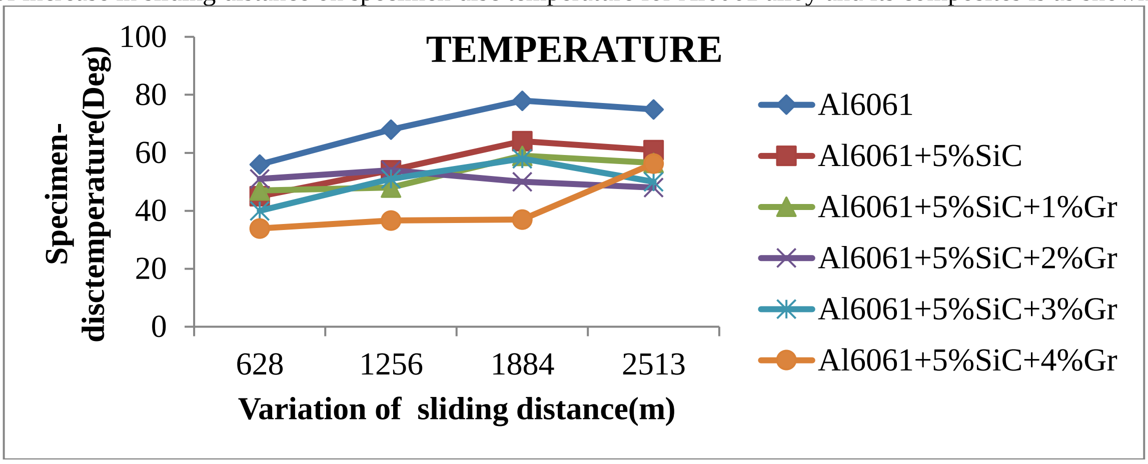


Fig:5 Variation of temperature of the matrix alloy and its composites with increased content of Gr at constant 5wt%SiC

From the fig.3.5 it can be found that there is fluctuation in the specimen-disc temperature with increase in sliding distance. However drop in temperature was found in hybrid composites when compared to that of base material. This can be attributed due to the self lubricating effect of Gr as well as accumulation wear debris particles at the specimen-disc interface.

IV. CONCLUSIONS

Al6061-SiC-Gr hybrid composites have been successfully produced by vortex method. Microstructure studies clearly revealed uniformity in the distribution of reinforcements and excellent bond between the matrix and the reinforcement. Macro hardness of Al6061 based hybrid composites is higher when compared with that of the matrix alloy. Increased content of hard reinforcement in the hybrid composites leads to enhancement in macro hardness of the hybrid composites. With increase in graphite content there was declination in macro hardness. Material loss due to adhesive wear of Al6061 based hybrid composites is lower when compared with that of the matrix alloy. Increased content of Gr reinforcement in the hybrid composites leads to enhancement in adhesive wear resistance of the hybrid composites. Coefficient of friction of hybrid composites is lower than that of the matrix alloy. Increased content of hard reinforcement for a given volume fraction of soft reinforcement leads to lower coefficient of friction. There was fluctuation in the specimen-disc temperature with increase in sliding speed , load and sliding velocity. However drop in temperature was found in hybrid composites when compared to that of base material.

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