MECHANICAL AND TRIBOLOGICAL PROPERTIES OF AA7068 REINFORCED WITH TIC AND GR

Balaraju Ankam[1], Katla Rajendar[2]

[1]Mtech Student, Malla Reddy Engineering College.
[2]Assistant Professor, Department of Mechanical Engineering, Malla Reddy Engineering College.
E-mail: balarajuankam7@gmail.com

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ABSTRACT: The aim of the project is to investigate the effect of TiC and Gr on the AA7068 based metal matrix composition. Aluminum alloy MMC has a important role in aerospace and automobile applications due to its enhanced properties compared to base metal. In this work different reinforcement percentage of TiC and Gr were used to prepare the specimen by using stir casting method. For mechanical property investigation tensile strength, hardness test were conducted and micro structure study reveals the uniform distribution of the reinforcement of TiC and Gr in the composite. Combination of TiC and Gr improved the tensile strength and hardness of the AA7068/TiC/Gr composite compared to base metal. Tribological properties were studied on base metal and composites reinforced with TiC and Gr. Tests were conducted on pin on disc tribological machine where stationary pin is dry slide on rotating disc. The TiC content in composite reduces the wear rate and Gr content reduces the coefficient of friction due to its self lubrication property.

KEYWORDS: AA7068, Titanium carbide, Graphite, Hardness, Tensile, Tribology.

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I. INTRODUCTION

Aluminum is the strongly electro-negative material and it has strong affinity for oxygen. Although it is distributed widely among six most metals it is not isolated in nineteenth century, first unsuccessful attempt is made on alumina in eighteenth century in 1807 by Sir Humphrey Davy. Robert Bunsen and Deville showed the production of metal electrolytic ally then production of aluminum took further steps. Aluminum is well known for its low density, corrosive resistance and increase of mechanical properties by heat treatment and suitable alloying. Aluminum and its alloy are used by various industries like automobile, aerospace, building facades etc. some other valuable properties like high ductility, magnetic neutrality, high electrical and thermal conductance and usage in chemical and food industries due to its non poisonous and colorless nature of its corrosion. Aluminum is soft metal at pure stage with yield strength-34.5 N/mm2 (5,000 lb/in2) and tensile strength-90 N/mm2 (13,000 lb/in2). Pure metal has high corrosion resistance and need less protection compared to other metals. Development of various alloys to achieve good ductility and strength this result in various applications today like drink containers, electrical purposes, building industries, packaging industries etc.

Requirement of AMC's growing in aerospace and automobiles due to their superior properties. AMC's reinforced with various ceramics like Gr, sic, B4C etc, changes the characteristics of micro-structural and development of physical and mechanical properties [1]. Al 7068 alloy has a highest mechanical strength as steel compared to all alloys; it has good ductility and corrosion resistance equal to Al 7075 alloy, due to its high performance characteristics it is widely used in different automobile applications. This alloy has different anodizing techniques similar to 7075 [2]. The stir casting technique is used to achieve uniform distribution of the reinforced particles and it gives good inter-metallic bonding of material and mechanical properties [3]. In this method gating system, pouring rate and temperature affects the dispersion of the matrix particles [4]. Bottom pouring technique is best in furnace that could stop the slag in the furnace and is best suitable for die pouring [5]. Different wt%, size, shape, stirring time, temperature, etc are the major things for mechanical characteristics of the casted composites. Distribution of the reinforced particles in the composite has better fracture toughness. Hybrid composition would give better results compared to single reinforcement [6]. Addition of tic particle would increase the wear resistance compared to base metal as speed increase wear rate decrease and speed decrease wear rate increase. Wt% of TiC increase result in hardness of the alloy. Change in blade angle in stir casting would give 95% better result compared to base metal [7]. When the Gr particles are added to aluminium alloy coefficient of friction is decreased and minimum wear rate is obtained at 5wt% of Gr. As wt % of Gr increasing would result in decreasing the wear rate, ductility, yield strength takes place at critical speed wear rate and coefficient of friction would change dramatically. It avoids direct contact between stationary and rotating contact surfaces [8, 9, 10]. As the hybrid reinforcement of TiC and Gr would has better result compared to base metal and single reinforcement. Increase in mechanical and tribological properties is observed in hybrid composition [11, 12].

II. MATERIAL AND METHOD

The hybrid composite consist of AA7068 reinforced with (2.5, 5, 7.5 –wt %) of Gr and (7.5, 5, 2.5-wt %) of tic was prepared by using stir casting method. The fabricated metals are CNC machined to obtain required specimen for testing operation. Distribution of reinforced particles is observed under optical micro scope and mechanical properties like hardness and tensile strength are carried out under Brinell hardness and ultimate tensile machine. In addition to this tribological operations are carried out. The test results are compared with base metal to validate the experiment

In this hybrid MMC AA7068 is matrix material and its composition is mentioned in below (table 1). The reinforced metals are added according to the compositions the matrix metal is 90% and remaining 10% would be Gr and TiC in 2.5, 5, 7.5 wt%. The reinforcements are added in the increasing and decreasing order in a step of 2.5.

Required quantity of aluminium alloy rod is placed into Gr crucible of electrical furnace and the temperature is increased to 850 degree centigrade. As the alloy reaches to melting point the different wt % of TiC and Gr are added to molten metal and stirred continuously to obtain uniform distribution of the particles in the metal. The molten metal is then taken out from the crucible and poured into desired shaped die and allowed to cool at room temperature. The fabrication process is carried out multiple times with different wt% of TiC and Gr the composition of hybrid MMC is shown in table 2.

Table 1: Chemical Composition of AA7068

Materials	Zn	Mg	Cu	Fe	Zr	Si	Mn	Ti	Cr	Al
chemical composition	8.3	3	2.4	0.15	0.15	0.12	0.1	0.1	0.05	Balance

Table 2: Composites of different Compositions

S no	Sample	Different Composition
1	A1	AA7068
2	A2	AA7068+2.5%TiC+7.5%Gr
3	A3	AA7068+5%TiC+5%Gr
4	A4	AA7068+7.5%TiC+2.5%Gr

III.EXPERIMENTATION

The specimens are prepared by machining the composites material and performed different operations. As per the ASTM standards the specimens are prepared and tested for the results figure 1, 2, 3 are the hardness, tensile and tribological samples

The hardness of the material is tested using Brinell hardness tester and the same specimen is used for microstructure view upside down. The tensile strength is measured under Ultimate tensile machine (UTM) of 20KN. The Tribology is carried out using wear test machine with 10N and 50N with 200rpm and 600 rpm. The wear resistance and coefficient of friction is recorded for every individual test and verified with base metal.

Figure 1: Hardness samples

Figure 2: Tribology samples

Figure 3: Tensile Samples

IV. RESULTS AND DISCUSSION

- **Micro structural studies**

The sample were first roughly grounded, then polished for smoothness on emery papers, followed by disc polish procedure with implementation of diamond paste which it is etched with Keller's reagent prepared from 95ml distilled water, 2.5ml HNO3, 1.5ml hcl, 1.0ml HF in par with the standard ingredients. Then these sample particulates were inspected and scrutinized under a metallographic microscope. Figures 4 to 7 shows the microstructures images of the samples and it shows that mixing were done properly and distribution of reinforcements were done uniformly.

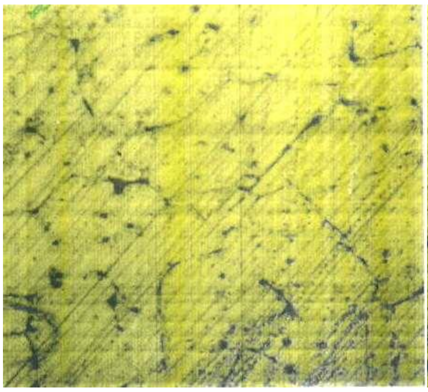

Figure 4: AA7068

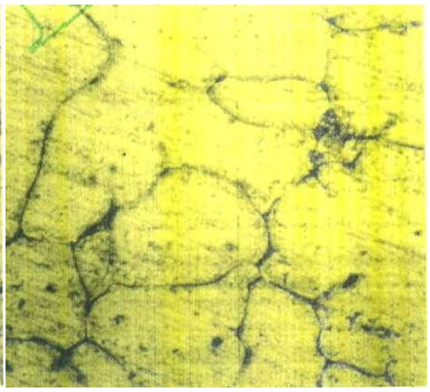

Figure 5: AA7068-2.5TiC-7.5Gr

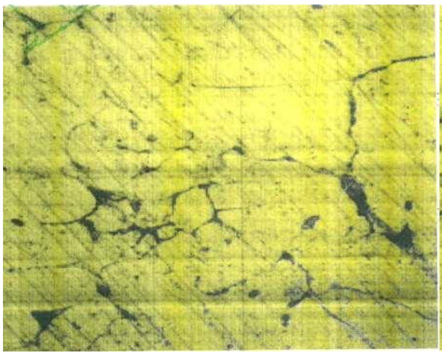

Figure 6: AA7068-5TiC-5Gr

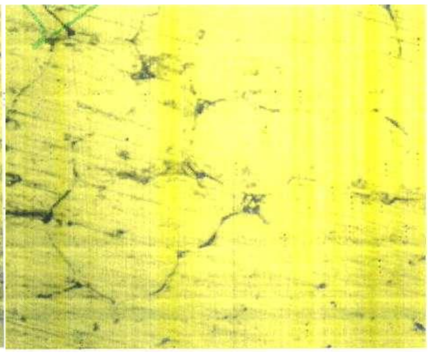

Figure 7: AA7068-7.5TiC-2.5Gr

- **Hardness behavior of the base metal and composites**

Brinell hardness test were used to determine the hardness behavior of the al alloy and composites shown below table 3

Table 3: Hardness of the Various Samples

S no	Sample	Hardness
1	A1	90
2	A2	95
3	A3	97
4	A4	99

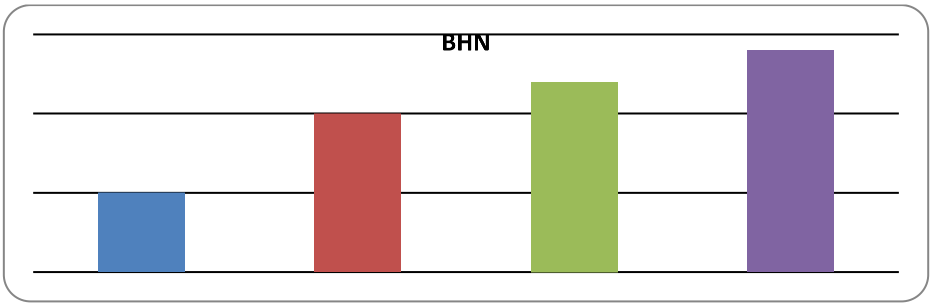

Figure 8: Hardness Comparison of Different Samples

Hardness of the base metal and composite metal is carried out by Brinell hardness tester. As many researchers mentioned TiC is hard ceramic material it helps in increasing the hardness of the base metal in hybrid composition. The above results show that the highest strength is obtained at AA7068-2.5%Gr-7.5%TiC where it has high amount of TiC. Compared to base metal AA7068-7.5%Gr-2.5%TiC increase with 5.55% hardness, AA7068-5%Gr-5%TiC increased by 7.77% hardness and finally AA7068-2.5%Gr-7.5%TiC increased with 10% hardness. It is clearly shows that increase in TiC content would result in hardness of the material

Tensile strength of the base metal and composites

Tensile strength of the different samples were determined by using computerized universal testing machine, table 4 shows UTS of various samples

Table 4: UTM of Various Samples

S no	Sample	Tensile strength
1	A1	86.23
2	A2	164.014
3	A3	145.143
4	A4	98.262

The tensile strength of the hybrid composite material is conducted on Ultimate tensile strength machine. The highest strength is observed in 7.5wt % of Gr and 2.5wt% of Tic with base metal. Compared to base metal the composite metal gave better results and strength but the reinforcement of AA7068-7.5%Gr-2.5TiC gave

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90.205% improvement in strength where as AA7085-5%Gr-5%TiC gave 68.320% and AA7068-2.5%Gr-7.5%TiC gave 13.953% better result. It is clearly observed that increase in Gr content result in increasing the tear resistance of the material and able to withstand the load applied

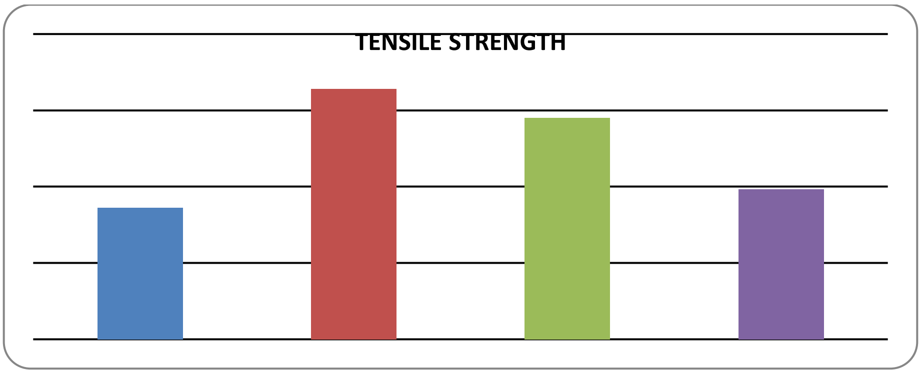

Figure 9: Tensile Strength Comparison of different Samples

Comparison of Wear Behavior of base metal alloy with Composites at various loads and speeds

- **Wear behavior at 10N-600rpm**

Table 5.1: Samples and Results at 10N-600rpm

S no	Sample	Wear at 10N-600rpm
1	A1	0.0003724
2	A2	0.0002731
3	A3	0.0002597
4	A4	0.0001523

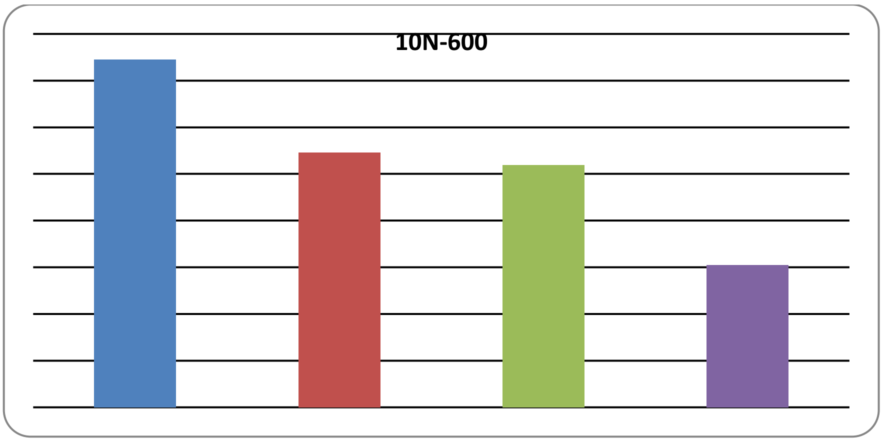

Figure 10: Wear Rate at 10N-600rpm

Wear of the composite are conducted on Pin on disc machine in a dry sliding condition. Wear resistance of the composite is improved by addition of TiC particles as compared to base metal the unreinforced metal is smoother than the reinforced material. Above figure show that increase in TiC particles result in decrease in wear rate. AA7068-2.5%Gr-7.5%TiC has 59% less wear rate compared to AA7068 metal. The uniform distribution of TiC particle generates interlocking capacity of the material and good wear resistance is obtained

- **Wear behavior at 50N-600rpm**

Table 5.2: Samples and Results at 50N-600rpm

S no	Sample	Wear at 50N-600rpm
1	A1	0.0001133
2	A2	0.0001054
3	A3	0.0000904

4	A4	0.0000814

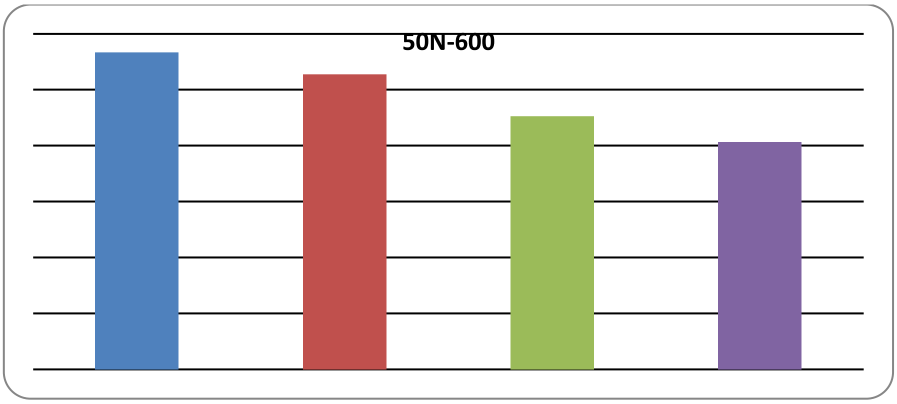

Figure 11: Wear Rate at 50N-600rpm

Wear rate of the different composite are tested by pin on disc machine. At 50N, 600Rpm the wear resistance has slight difference the above figure shows that as % of TiC increased the interlocking of the elements are produced and wear rate is decreased highest TiC content of AA7068-2.5%Gr-7.5%TiC has improved 28.155% of wear resistance compared to AA7068 material

- **Wear behavior at 10N-200 rpm**

Table 5.3: Samples and Results at 10N-200rpm

S no	Sample	Wear at 10N-200rpm
1	A1	0.0004178
2	A2	0.0003848
3	A3	0.0002348
4	A4	0.0001249

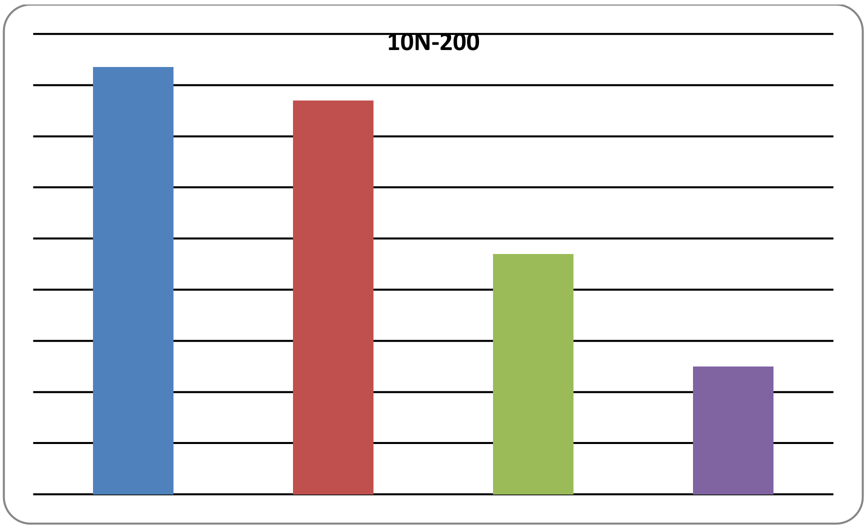

Figure 12: Wear Rate at 10N-200rpm

As TiC particles increase the hardness of the metal increase and decrease in wear rate. From the above figure when 10N of load is applied and the rpm is 200 the highest wear resistance is observed in AA7068-2.5%Gr-7.5%TiC almost 70% of wear resistance is increased from base metal. As TiC content is greater than or equal to Gr good wear resistance is observed but if Gr is more than TiC less wear resistance is developed. Compared to base metal all the composite metal has better wear resistance

- **Wear behavior at 50N-200rpm**

Table 5.4: Samples and Results at 50N-200rpm

S no	Sample	Wear at 50N-200rpm
1	A1	0.0007656
2	A2	0.0003537
3	A3	0.0003205
4	A4	0.0002418

Wear resistance of the composite is increased with increasing of TiC particle reinforcement with base material. In this the test is conducted with 50N load and 200 rpm speed wear resistance is improved in all the cases and highest wear resistance is observed in AA7068-2.5%Gr-7.5%TiC with 68% improvement compared to base metal and AA7068-7.5%Gr-2.5%TiC with 53% and AA7068-5%Gr-5%TiC with 58% wear resistance is improved.

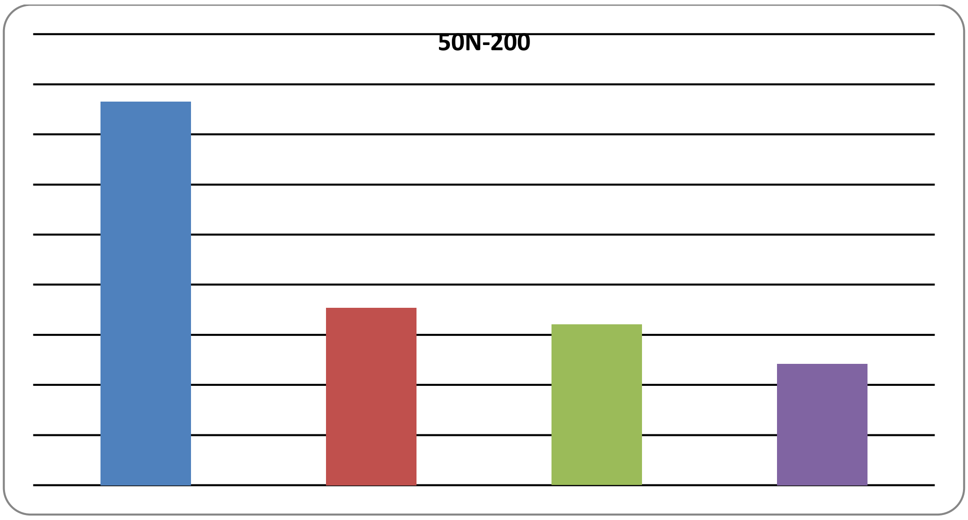

Figure 13: Wear Rate at 50N-200rpm

Comparison of friction Behavior of base metal alloy with Composites at various loads and speeds

- **Coefficient of friction at 10N-600rpm**

Table 6.1: Samples and Results at 10N-600rpm

S no	Sample	COF at 10N-600rpm
1	A1	0.510851
2	A2	0.311483
3	A3	0.41153
4	A4	0.498378

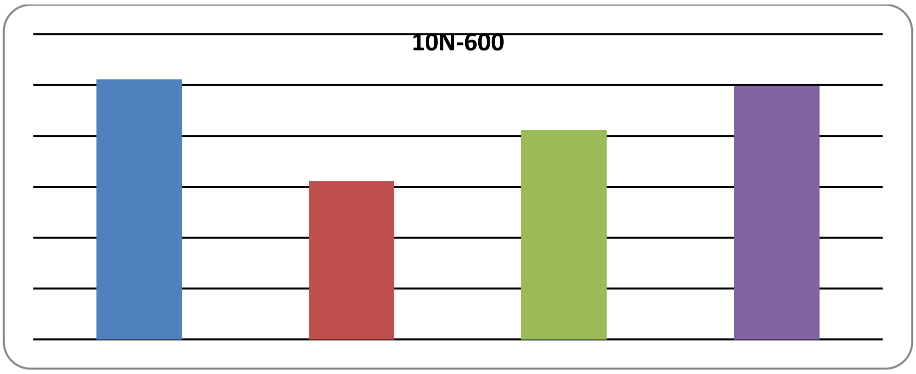

Figure 14: COF at 10N-600rpm

The coefficient of friction is slightly decreases with increasing if Graphite particles. The Gr particle has a self lubrication capacity which helps in reducing friction. Compared to unreinforced material the reinforced material has less coefficient of friction. As shown in above figure the least coefficient of friction is obtained at AA7068-7.5%Gr-2.5%TiC with 40%, AA7068-5%Gr-5%TiC with 19.4% and AA7068-2.5%Gr-7.5%TiC with 2.4% compared to base metal.

- **Coefficient of friction at 50N-600rpm**

Table 6.2: Samples and Results at 50N-600rpm

S no	Sample	COF at 50N-600rpm
1	A1	0.464642
2	A2	0.447276
3	A3	0.45059
4	A4	0.45122

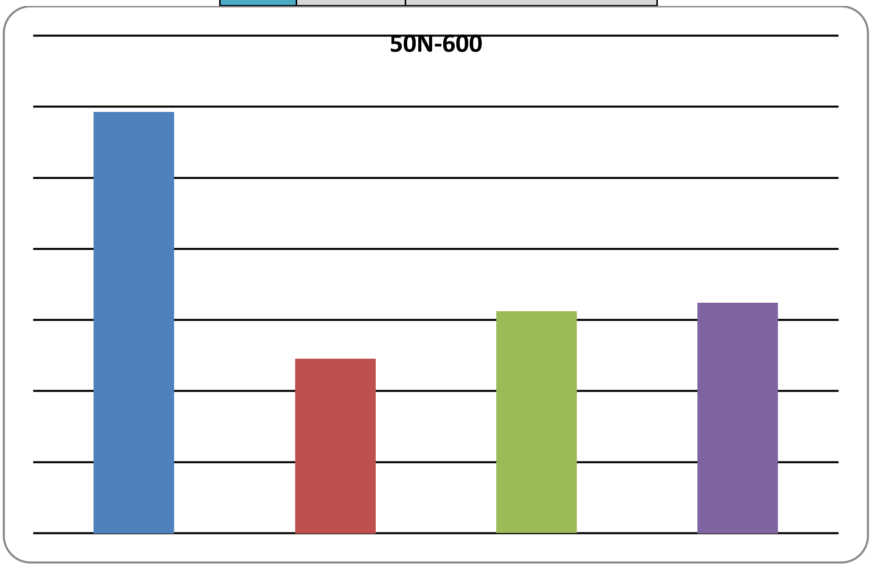

Figure 15: COF at 50N-600rpm

Improvement in coefficient of friction is observed from the above figure. The least coefficient of friction takes place at AA7068-7.5%Gr-2.5%TiC with 3.7%, AA7068-5%Gr-5%TiC with 3.2 and AA7068-2.5%Gr-7.5%TiC with 2.88% decrease in coefficient compared to base material. The load imposed on the material is low the friction generated is also low.

- **Coefficient of friction at 10N-200rpm**

Table 6.3: Samples and Results at 10N-200rpm

S no	Sample	COF at 10N-200rpm
1	A1	0.518733
2	A2	0.271867
3	A3	0.396186
4	A4	0.476834

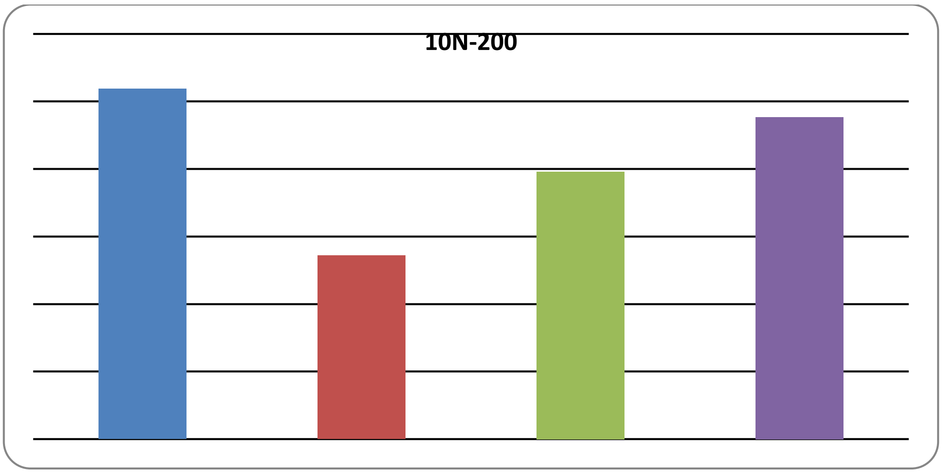

Figure 16: COF at 10N-200rpm

Increase in Gr content would reduce the coefficient of friction due to its self lubrication nature. The above figure shows that the decrease in coefficient of friction is observed in the reinforced composite. The least coefficient of friction is produced at AA7068-7.5%Gr-2.5%TiC where Gr content is highest. The difference in coefficient of friction compared to unreinforced metal is AA7068-7.5%Gr-2.5%TiC with 47%, AA7068-5%Gr-5%TiC with 23% and AA7068-2.5%Gr-7.5%TiC with 8%. The high amounts of graphite particle addition reduce more coefficient of friction.

- **Coefficient of friction at 50N-200rpm**

Table 6.4: Samples and Results at 50N-200rpm

S no	Sample	COF at 10N-200rpm
1	A1	0.518733
2	A2	0.271867
3	A3	0.396186
4	A4	0.476834

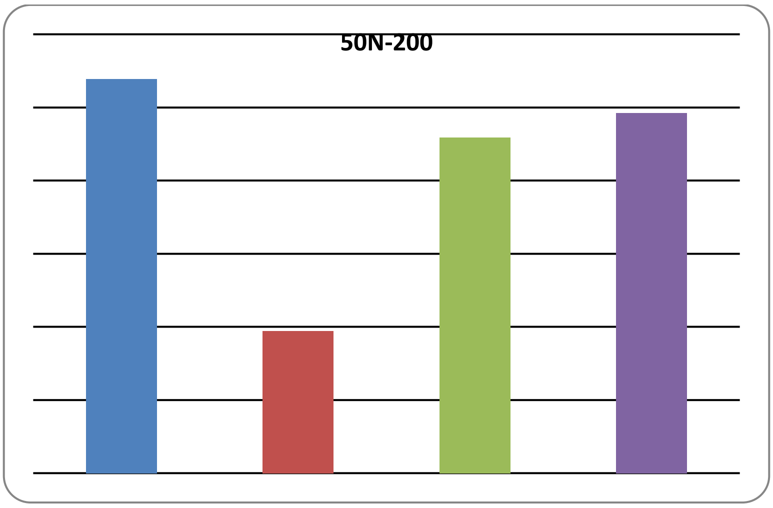

Figure 17: COF at 50N-200rpm

Increase in graphite particles decrease the coefficient of friction by generating the interlocking capacity of the reinforced metal compared to unreinforced metal. The above figure shows that better interlocking is observed at AA7068-7.5%Gr-2.5%TiC with high amount of graphite. The least coefficient of friction is produced at AA7068-7.5%Gr-2.5%TiC with 7.8%, AA7068-5%Gr-5%TiC with 1.9% and AA7068-2.5%Gr-7.5%TiC with 1.8% compared to base metal.

V. CONCLUSION

In this work stir casting method was successfully used for preparing the Al 7068 metal matrix composites of four different samples and the following are major conclusions

- Microstructure studies reveal that there is a uniform distribution of reinforcements on base metal.
- Mechanical characteristics of AA7068 reinforced with TiC and Gr hybrid composites exhibit better ultimate tensile strength compared to unreinforced aluminum alloy. Among all the composites the highest content of graphite added specimen AA7068-7.5%Gr-2.5%TiC gave high tensile strength.
- Hardness of the reinforced composite gave good result compared to unreinforced metal. Increase in hardness is observed clearly in hybrid composite metals. The maximum content of TiC added composite AA7068-2.5%Gr-7.5%TiC gave high hardness compared to all the composites.
- AA7068 alloy reinforced with high content of TiC and least content of Gr gave better wear resistance compared to all the reinforced and unreinforced metals. The TiC gave better hardness so the wear resistance is increased in AA7068-2.5%Gr-7.5%TiC.

Due to the self lubrication characteristic of Graphite included in reinforcement the coefficient of friction is decreased gradually as Gr content is increased. The least coefficient of friction is observed at AA7068-7.5%Gr-2.5%TiC which has high content of Gr.

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