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Comparative Study on Dry Sliding Wear Behaviour of Metal Matrix Hybrid Composites at Room and High Temperature Conditions

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Abstract

In this present study, hybrid composites was used to fabricate Boron Carbide (B_4C) and Molybdenum disulfide (MoS_2) particles reinforced aluminium Al2219,to achieve wettablity among Al and B_4C the k_2TiF_6 halide salt was incorporated into Al 2219 alloy. The hybrid composites were successfully fabricated using stir casting technique and then casted samples were characterized by SEM examination. The microstructure examination demonstrate that uniform distribution of B_4C and MoS_2 particles in matrix Al2219.The monolithic Al2219 and prepared hybrid composites were subjected to Dry sliding wear test using pin-on disc tribometer as for ASTM G99-95 standard and comparative study between room temperature and high temperature(180^0C) wear test under different sliding situation were done. The examination room result revels that, the specific wear rate at temperature was found lesser as compared to high temperature 180^0C and the specific wear rate was found to increase with applied loads and sliding distances in both conditions. For both room temperature and high temperature the hybrid composites had lower specific wear rate when compared to Al2219.The specific wear rate increases with increases in load and sliding distance, the addition of reinforcing particles i.e B_4C and MoS_2 reduces specific wear rate of composites and the addition of secondary reinforcement MoS_2 has significant effect on reducing wear rate of prepared hybrid composites for both room temperature and high temperature. The worn surface of pin samples tested under both conditions were analyzed using SEM.

Keywords: *Stir casting technique, Specific wear rate, Worn surface.*

Introduction

In the industrial world, Aluminum metal matrix composites (AMMCs) are the capable material widely used in aerospace, marine, automobiles because of its outstanding excellent mechanical properties. The conventional alloys can strengthened while it is reinforced by means of hard ceramic particles like Al_2O_3, SiC, B_4C etc, as a result better wear resistance and strength to weight ratio in composites are archived [1].

Depending on size, reinforcements and morphology of the Aluminum metal matrix composites are fabricated by dissimilar techniques like stir casting, spray deposition, liquid infiltration, squeeze casting and powder metallurgy. Conventional stir casting technique is an attractive and comparatively economical technique for fabricate AMMCs [1].In stir casting technique, two step stir casting gives improved mechanical properties along with wettablity, homogeneous distribution of particles and reduction of porosity. This method is usual for the manufacture of huge quantity of composites [2].A new variety of highly developed materials in AMMCs reinforcements are B_4C and SiC particulates.AMMCs are reinforced with hard material due to development in mechanical properties like hardness and tensile strength, this are the good properties for tribological applications also[3].Aluminium and its alloys reinforced Boron carbide (B_4C) perform numerous physical and mechanical properties like high stiffness and hardness which is necessary of an effective reinforcement [4].The incorporation of graphite as a solid lubricant with SiC particle successfully developed the tribological properties of hybrid composites under sliding wear conditions [5].

In dry sliding wear of AMCs the addition of hard ceramic particles to unreinforced matrix material improves wear resistance and wear rate is associated to hardness, particle size, sliding velocity, matrix material chemical composition and normal load [6]. The wear resistance of MMCs shows 10 times higher than un-reinforced matrix materials in a few load ranges [7]. Due to increasing hardness and strength of composites the wear resistance increases and steady reduction in wear rate at sliding velocity from 1 to 7 m/s further the wear rate being rise than a sliding velocity 7 m/s [8].With increasing reinforcement the wear resistance increases, however the wear rate decreases by increasing both for track velocity and normal load. The MMC's worn surface examination demonstrates delamination, micro cutting, oxidation and thermal softening [9].The wear performance of Aluminium1060 reinforced with Al_2O_3, the wear mechanism was mild wear regime with in this regime the wear resistance increases and also wear rate decreases due to formation of MML.In additional as the load increases the mechanisms transform to a harsh mode and this create enormous instabilities which forbidden the growth of a defensive MML [10]. The wear behavior of 6061 Aluminum alloy matrix composite reinforced with 20% Al_2O_3 particulates at elevated temperatures ranging from 25°C to 300°C shows Mild and severe wear regions separated by a transition region with a dissimilarity of two orders of magnitude between mild and severe wear for all temperatures [11]. At the temperature 400^0C the wear resistance is decreases as compared to 200^0C. With increase in the reinforcement of ZrB_2, the specific wear rate of the composite decreases and at the same time increases with increase in temperature [12].The sliding velocity at 0.2 m/s and at 10 N load the transition begins at 180^0C in the matrix alloy and at a higher temperature of 230^0C in the composite. With increasing the applied load the transition temperature decreases [13].Though in the present research work an attempt is made to study the room and high temperature dry sliding wear behaviour of Metal Matrix Hybrid Composites reinforced with B_4C and MoS_2 particles.

Experimental Details

In this research, Aluminium Al2219 was used as matrix material and Table.1 shows measured Al2219 chemical composition using Atomic Absorption Spectroscopy (VARIAN). 3Wt% Boron Carbide (B_4C) with particle size 90µm and 3Wt% to 5 Wt% Molybdenum disulfide (MoS_2) with particle size 1.3 µm in a step of 1 Wt% was used as reinforcements. Liquid metallurgy technique generally called as stir casting technique was used to fabricate hybrid composites. The aluminium Al2219 in the form of ingots were placed in graphite crucible, then the alloy was melted for 750^0C in resistance furnace. The zirconia coated stainless steel stirrer was immersed 2/3 the depth of molten metal, then the pre heated reinforcements of B_4C and MoS_2 at 250^0C for 2 hr were added into melt. At 200 to 250 rpm the stirring is carried out for 8 to10 min.The mixture was poured into cast iron permanent mould.

Table.1:ChemicalcompositionofAluminum2219alloy.

Elements	Mg	Si	Cu	Z r	Fe	Zn	Ti	V	Mn	Al
% by weight	0.02 Max	0.20 Max	5.8-6.8	0.1-0.25	0.30 Max	0.10 Max	0.02-0.1	0.050 .15	0.10 Max	Remaining

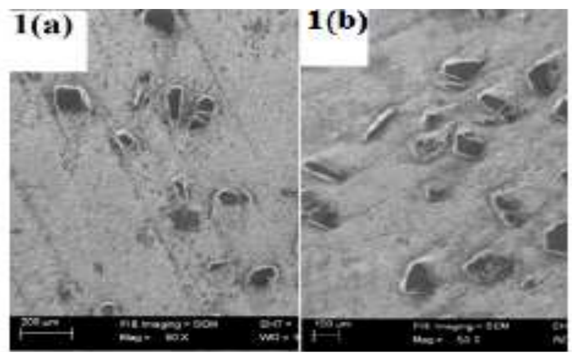
Wear Test

Dry sliding wear test were carried out on a DUCOM Pin-On Disc test rig as for ASTM G99-95 standard with 8mm diameter and 30mm length circular pin sample and track diameter 120mm kept constant. The tests were performed at room temperature and high temperature (180^0C).The variables chosen for tests are applied loads and sliding distances. Before conducting test for every pin samples weight was measured and also after completion of test the weight was measured using digital electronic balance with ± 0.0001gr accuracy. The weight loss and specific wear rate of every sample was caliculted.The worn surface of pins were analyzed using SEM.

Results and Discussions

1.1Micro structural Study

Micro structural examinations of prepared hybrid composites were examined by Scanning electron microscope. Fig1. (a) shows SEM image of Al+3%B_4C+3%MoS_2, uniform distributions of reinforcement particles of B_4C and MoS_2 were seen.Fig1. (b) and 1.(c) shows SEM image of Al+3% B_4C+4%MoS_2 and Al+ 3% B_4C+5%MoS_2, Fairly uniform distribution of B_4C and MoS_2 particles were seen in both images. The addition of K_2TiF_6 improves the wettablity of composites, their by improves the distribution of reinforcement particles in the matrix.



1.(a) SEM Image Al+3 % B_4C+3%MoS_2 Fig(b). SEM Of Al+3% Al+ 3%B_4C+4%MoS_2

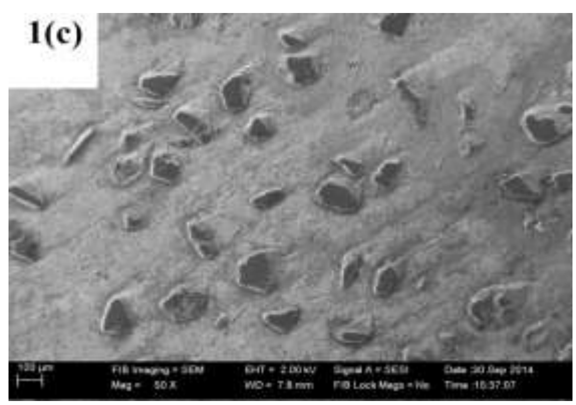


Figure.1.(c). SEM Image. Al+3%B_4C+5% MoS_2

2. Weigh Loss

The weight loss of Al2219 is more and with addition of B_4C and MoS_2 reinforcements to

Al2219 have less for both room temperature and high temperature (180^0C) conditions. But at room temperature the weight loss is comparatively less as compared to high temperature in both matrix Al2219 and hybrid composites. It is an evident from Fig:2 (a)-(b) as the applied load increases the weight loss of matrix Al2219 and prepared hybrid composites increases for both room temperature and high temperature. From Fig: 2(a) and 2(b) it can clearly seen that, the hybrid composites has lower weight loss when compared to matrix Al2219 for both room temperature and high temperature conditions, due to presence of hard B_4C and solid lubricant MoS_2 improves the strength and hardness of hybrid composites against plastic deformation. In case of matrix material Al2219 in Fig: 2 (a) at room temperature the weight loss is less as compared to high temperature because at room temperature there is less transfer of material from matrix to steel surface and this shows lower wear forms lesser weight loss.

In case of matrix material Al2219 in Fig:2 (b) the weight loss is more as compared to room temperature due to massive transfer of metal from matrix Al2219 to steel surface shows sever wear leads to higher weight loss. But for both room temperature and high temperature from Fig:2(a) and 2(b) for prepared composites the reinforcing particles (B_4C and MoS_2) avoid plastic deformation due to better load caring capacity, strength and thermal stability of matrix leads to lesser weight loss.

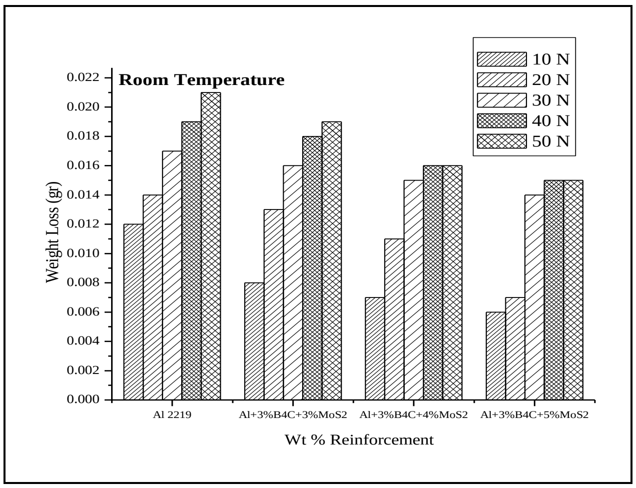


Fig.2 (a): Weight loss of Al2219 and Prepared hybrid composites under room temperature for different loads.

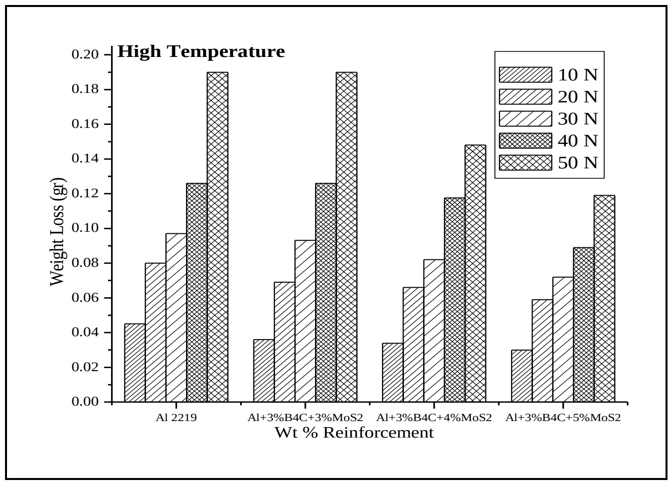


Fig.2 (b): Weight loss of Al2219 and Prepared hybrid composites under high temperature for different loads.

3. Specific Wear Rate

3.1. Effect on specific wear rate on load for room and high temperature conditions.

Fig: 3(a) and 3(b) clearly shows as the load increases the specific wear rate increases and as the % of reinforcement i.e MoS_2 increases in Al2219 and Al2219+3%B_4C+3%MoS_2 the specific wear rate decreases for both room temperature and high temperature conditions. For both conditions the specific wear rate is lower for prepared composites and for Al2219 is higher. Also it is an evident from Fig: 3 (a) and (b) the specific wear rate is less for room temperature condition and more for and high temperature condition. Fig: 3(a) and 3(b) shows effect of specific wear rate for room temperature and high temperature condition at a sliding distance 1500m under different sliding condition and at sliding speed 3.78m/s, specific wear rate increases with increasing applied load, as the applied load increases the penetration of hard asperities of counter face of softer pin surface leads to increase the specific wear rate.

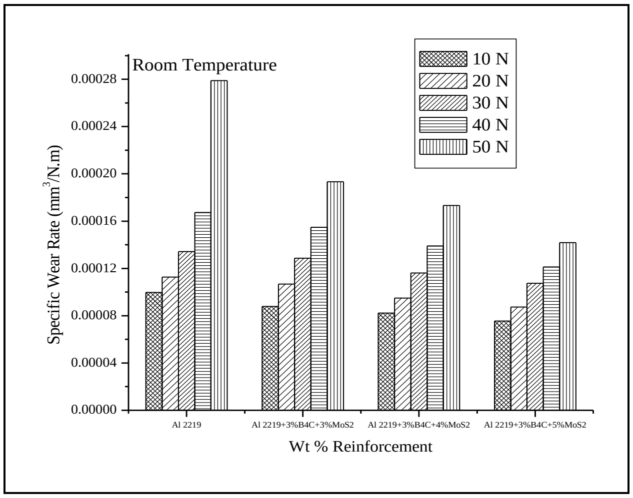


Fig.3 (a): Effect of normal load at sliding speed 3.78 m/s with 1500m sliding distance for Al2219 and Prepared hybrid composites under room temperature.

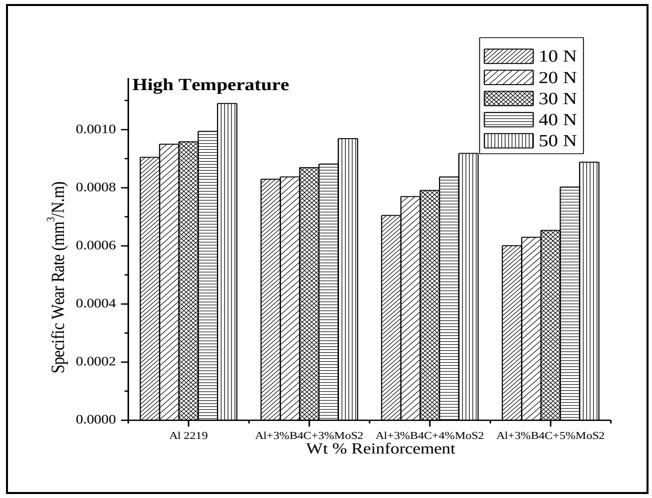


Fig. 3(b): Effect of normal load at sliding speed 3.78 m/s with 1500m sliding distance for Al2219 and Prepared hybrid composites under high temperature.

It is obvious from Fig:3(a) and 3(b) the lower specific wear rate for hybrid composites in room and high temperature condition is due to hard dispersoids B_4C and solid lubricant MoS_2 present on surface of composites protects the contact with counter face leads to lesser specific wear rate. In case of high temperature the specific wear rate for Al2219 matrix is higher as compared to prepared composites because at180^0C the matrix Al2219 contact surface strength, hardness and resistance to deformation decreases considerably. But in prepared hybrid composites at 180^0C the pin material become softer and as the applied load increases the pressure at pin-disc interface increases, this leads to increases in specific wear rate in prepared hybrid composites at high temperature (180^0C).

4. Effect on specific wear rate on sliding distance for room and high temperature conditions.

Fig 4 (a) and 4(b) clearly shows as the sliding distance increases the specific wear rate increases and as the % of reinforcement i.e

MoS_2 increases in Al2219 and Al2219+3%B_4C+3%MoS_2 the specific wear rate decreases for both room temperature and high temperature conditions. For both conditions the specific wear rate is lower for prepared composites and for Al2219 is higher. It is obvious from Fig 4 (a) and 4(b) the specific wear rate is less for room temperature condition and more for and high temperature condition. Fig 4 (a) and (b) shows effect of specific wear rate for room temperature and high temperature condition at a load 30N under different sliding condition and at sliding speed 3.78m/s, the specific wear rate at room temperature for Al2219 is higher as compared to prepared hybrid composites. But as compared to room temperature the specific wear rate at high temperature for Al2219 matrix is higher because at 180^0C the matrix Al2219 the wear changes from mild to sever. In case of room temperature prepared hybrid composites specific wear rate reduces due to reinforcing particle i.e B_4C and MoS_2 projected out and that particles were trampled and forms protecting layer, this leads to lesser specific wear rate. In high temperature at 180^0C the prepared hybrid composites material did not sustain and form the disc the pin sample squeezed out due to running period, this leads to increasing specific wear rate as compared to room temperature specific wear rate.

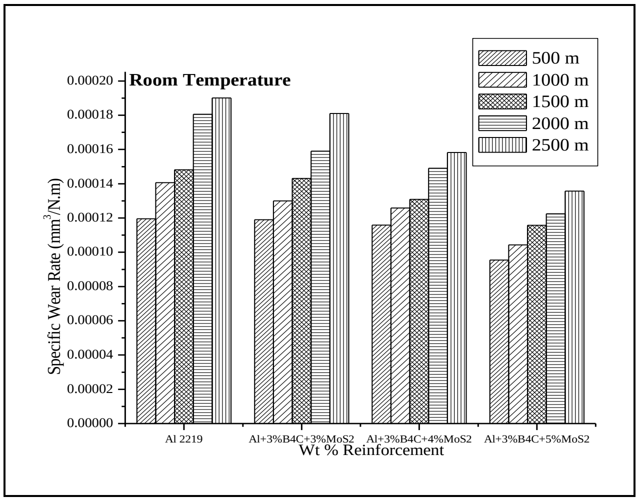


Fig.4 (a): Effect of sliding distance at normal load 30N with 3.78 m/s sliding speed for Al2219 and Prepared hybrid composites under room temperature.

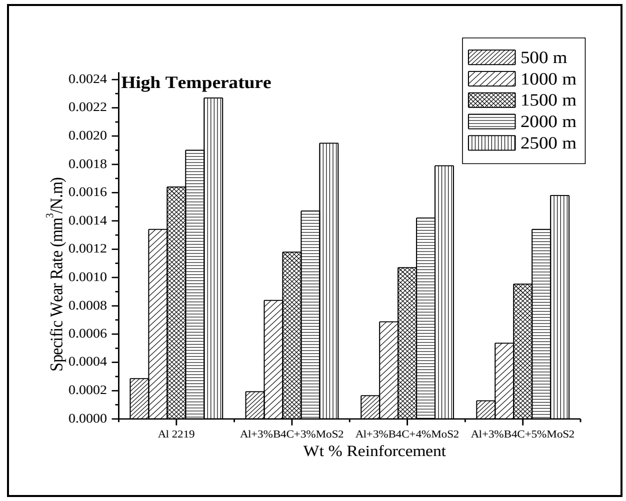


Fig.4 (b): Effect of sliding distance at normal load 30N with 3.78 m/s sliding speed for Al2219 and Prepared hybrid composites under high temperature.

5. Worn surface morphology

Room and high temperature worn surface SEM images of Al+3%B_4C+5%MoS_2 pin samples tested at higher load 50N, sliding speed 3.78 m/s and sliding distance1500m is shown in Fig 5(a) and 5(b). It is an evident from Fig. 5 (a) at room temperature minute quantity of material was removed from worn pin and towards the route of sliding the grooves and scratches is all most parallel. The hard reinforcement particles are approach in makes contact with surface which forms wear. This feature is expressed as Abrasion. It is an evident from Fig.5(b) at high temperature, at some stage in sliding the insufficient plastic deformation happened and plastic deformation traces by means of cracks on the worn surfaces connected to delamination wear. Room and high temperature worn surface SEM images of Al+3%B_4C+5%MoS_2 pin samples tested for a sliding speed 3.78 m/s, load 30N and higher sliding distance 2500 m is shown in Fig 6(a) and 6(b). It is an evident from Fig.6(a) at room temperature the sub surface cracks develops progressively and shear to the surfaces appearance extensive thin wear in Al+3%B_4C+5%MoS_2, it is mainly due to crack growth & crack formation, This feature is expressed as delamination process. Also it is evident from Fig.6 (b) at high temperature, the wear tracks are not capable to be seen because of coalescence of wear cracks the sub-surface delamination is produced. By means of this delamination of the sub-surface layers the material removal takes place.

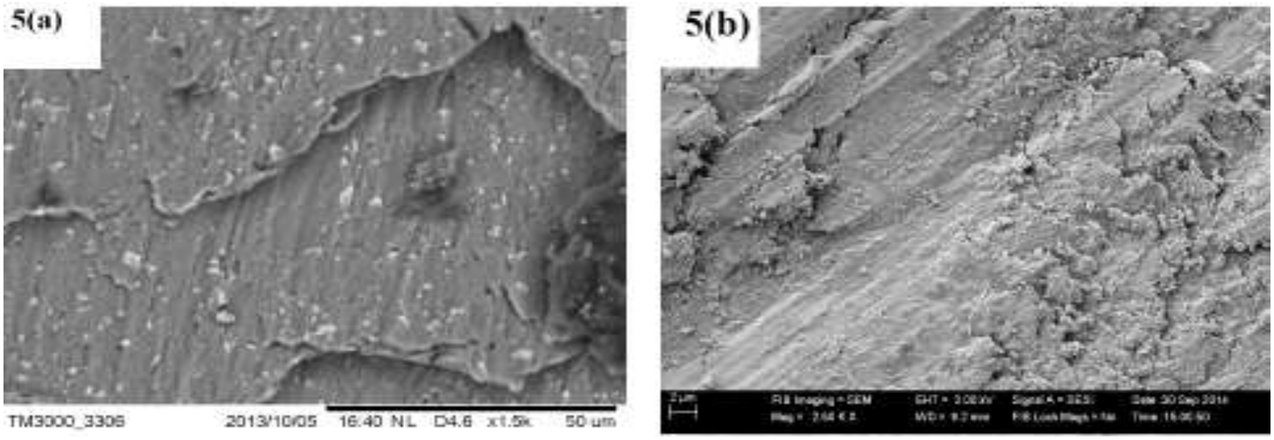


Fig.5. Wear Surface of Al+3%B_4C +5%MoS_2 (a)Room Temperature (B) High Temperature Load: 50N, Sliding Speed: 3.78m/s and Sliding distance 1500m.

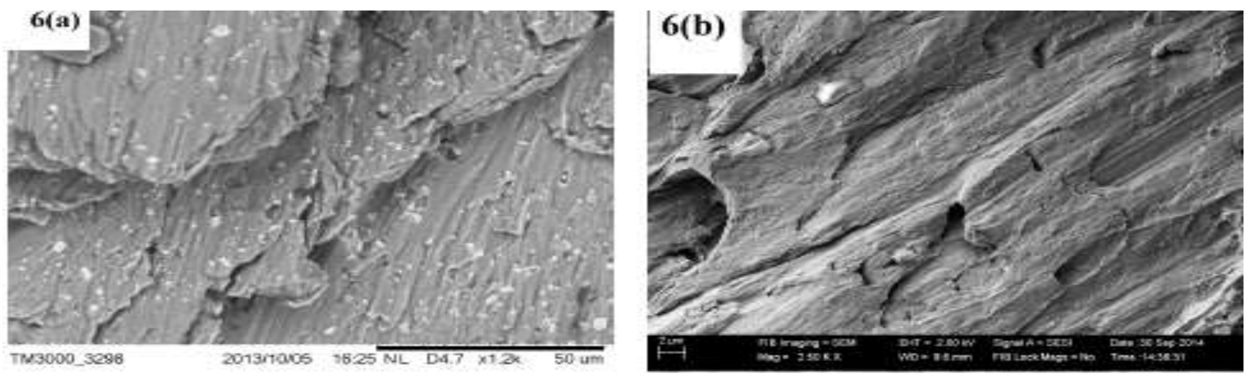


Fig.6. Wear Surface of Al+3%B_4C +5%MoS_2 (a)Room Temperature (B) High Temperature Load: 30N, Sliding Speed: 3.78m/s and Sliding distance 2500m.

6. Conclusions

The hybrid composites were successfully fabricated by taking Boron Carbide (B_4C) and Molybdenum disulfide (MoS_2) particles reinforced aluminium Al2219 using stir casting technique.K_2TiF_6 halide salt was incorporated in order to improve wettablity between Al and B_4C and also to achieve uniform and fairly uniform distribution of reinforcements i.e. Boron Carbide (B_4C) and Molybdenum disulfide (MoS_2).The weight loss is less at room temperature as compared to high temperature since at room temperature there is less transfer of material from matrix to steel surface, but in high temperature due to massive transfer of metal from matrix Al2219 to steel surface shows sever wear leads to higher weight loss. Specific wear rate increases with increasing applied load and sliding distances in both room and high temperature condition. Lesser specific wear rate of hybrid composites at room and high temperature condition is due to hard dispersoids B_4C and solid lubricant MoS_2 present on surface of composites protects the contact with counter face. In room temperature specific wear rate decreases but in high temperature pin material become softer and as the applied load increases the pressure at pin-disc interface increases leads to increases in specific wear rate. The wear rate decreases with increase in % reinforcement, wear rate is maximum for Al 2219 & minimum for Al2219+3%B_4C+5%MoS_2 for both room temperature & high temperature conditions. The inclusion of reinforce ment particles B_4C &

MoS_2 reduces the wear rate of composites by forming protecting layer between pin & counter face. The SEM worn surface of pin samples shows Abrasion and Delamination wear mechanism.

7. Acknowledgement

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