Mechanical and dry sliding wear behavior of cenosphere particulate reinforced Al-Si12 matrix alloy composites produced by squeeze casting

Presented by
S. K. ACHARYA
PROFESSOR
NIT ROURKELA

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Background/Origin of the work

Metal Matrix composites are good alternative to traditional materials due to their hardness, specific strength and creep resistance. Despite these properties ,materials are not widely used in industrial world due to their high cost.

Major application areas are :Automobile and aerospace

The need to reduce weight and improve fuel efficiency has made automobile and aero-industries to extensively used aluminium composites in recent years. The commonly used aluminium composites for these applications are the aluminium alloy based metal matrix composites.

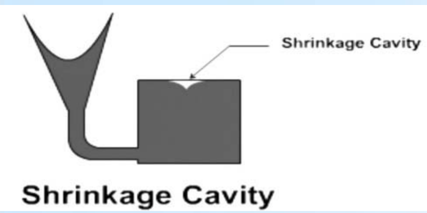
Particulate reinforced Al matrix composites are gaining importance because of their low cost with advantage like isotropic properties. The strengthening of aluminium alloys with dispersion of fine ceramic particulate composite materials were developed as an alternative of unreinforced alloy, for obtaining materials with high stiffness (high strength/modulus and low density) with special interest for the wear resistance and structural applications.

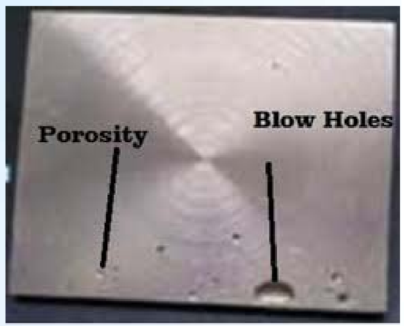
The commonly used aluminium composites for various applications are the aluminium alloy based MMCs with ceramic particles reinforcement, which are considerable more expensive. Ceramic particles derived from fly-ash are less costlier exclusive of mixing and processing costs compared to conventional Al-SiC materials.

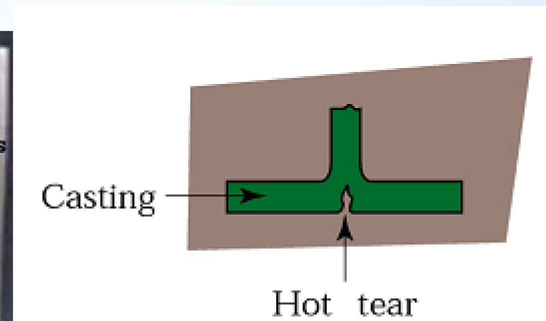
This study analyses a new composite material called cenosphere reinforced aluminium alloy LM6. Out of available manufacturing processes for MMCs squeeze casting technique have been adopted for fabricating the composites in the present work. The wear behavior of the composite has been studied and reported in this work.

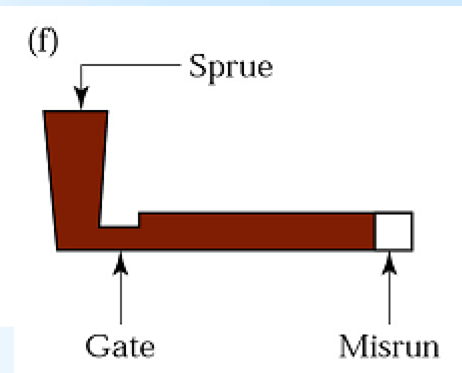
Drawbacks in the conventional castings

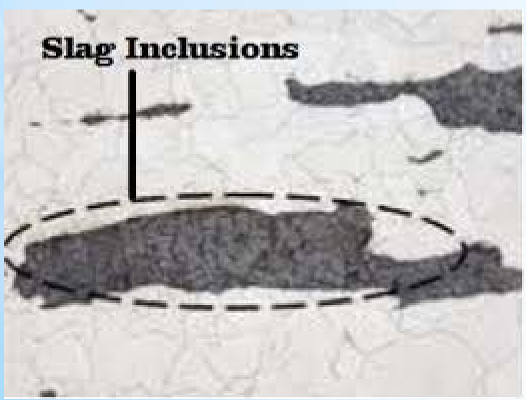
- Gas defects
- Shrinkage cavities
- Molding material defects
- Pouring metal defects
- Mold shift

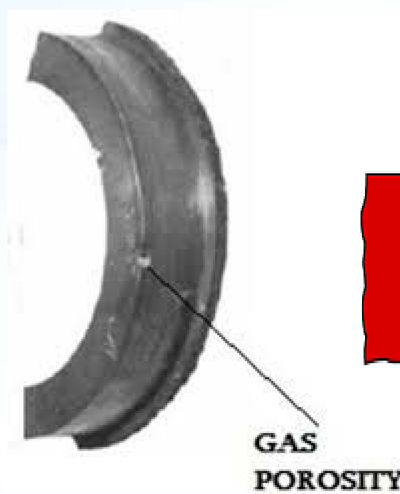


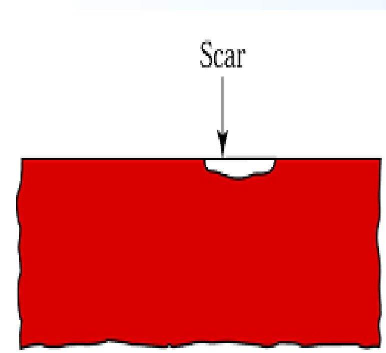


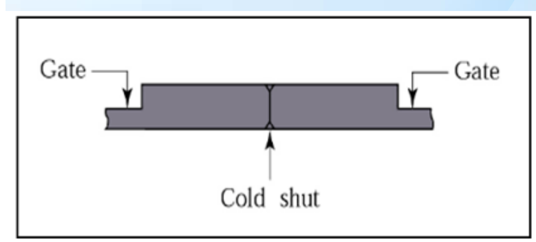












- Fabrication of Composites by squeeze casting method

- Squeeze casting method- Known as liquid metal forging, is a combination of casting and forging process. The molten metal is poured into the bottom half of the pre-heated die. As the metal starts solidifying, the upper half closes the die and applies pressure during the solidification process.

MATERIALS AND METHODS

Materials

- Matrix- Al-Si12 alloy
- Reinforcement- cenosphere fly ash

Table 1 Chemical composition of Al-Si12 alloy

Elements	Cu	Mg	Si	Fe	Mn	Ni	Zn	Pb	Ti	Sb	Al
Percentage (%)	0.1	0.1	10.0-13.0	0.6	0.5	0.1	0.1	0.1	0.2	0.05	remainder

- Al-Si12 alloy - The aluminium silicon alloys possess exceptional casting characteristics, which enable them to be used to produce intricate castings of thick and thin sections. Fluidity and freedom from hot tearing increase with silicon content and are excellent throughout the range. Their resistance to corrosion is very good, but special care is required in machining.

- Cenosphere Fly ash- Fly ash is typically produced as a by-product of coal combustion at thermal power plants can be classified into two categories; precipitator and cenosphere. Precipitator fly ash is solid and has a density of about 2.1 g/cm^3. Cenospheres are light weight inert hollow sphere consists largely of silica and alumina and filled with air or inert gas .

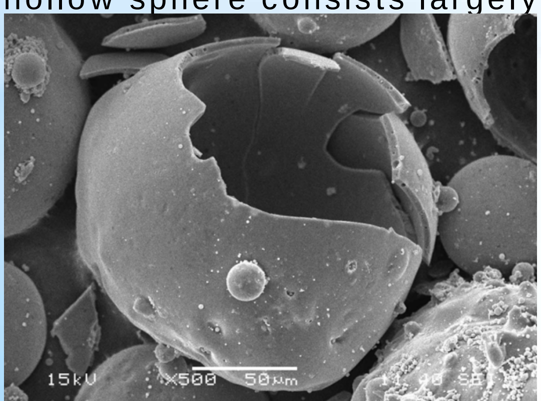


Figure 1: SEM micrograph of cenosphere

Composite fabrication by squeeze casting method

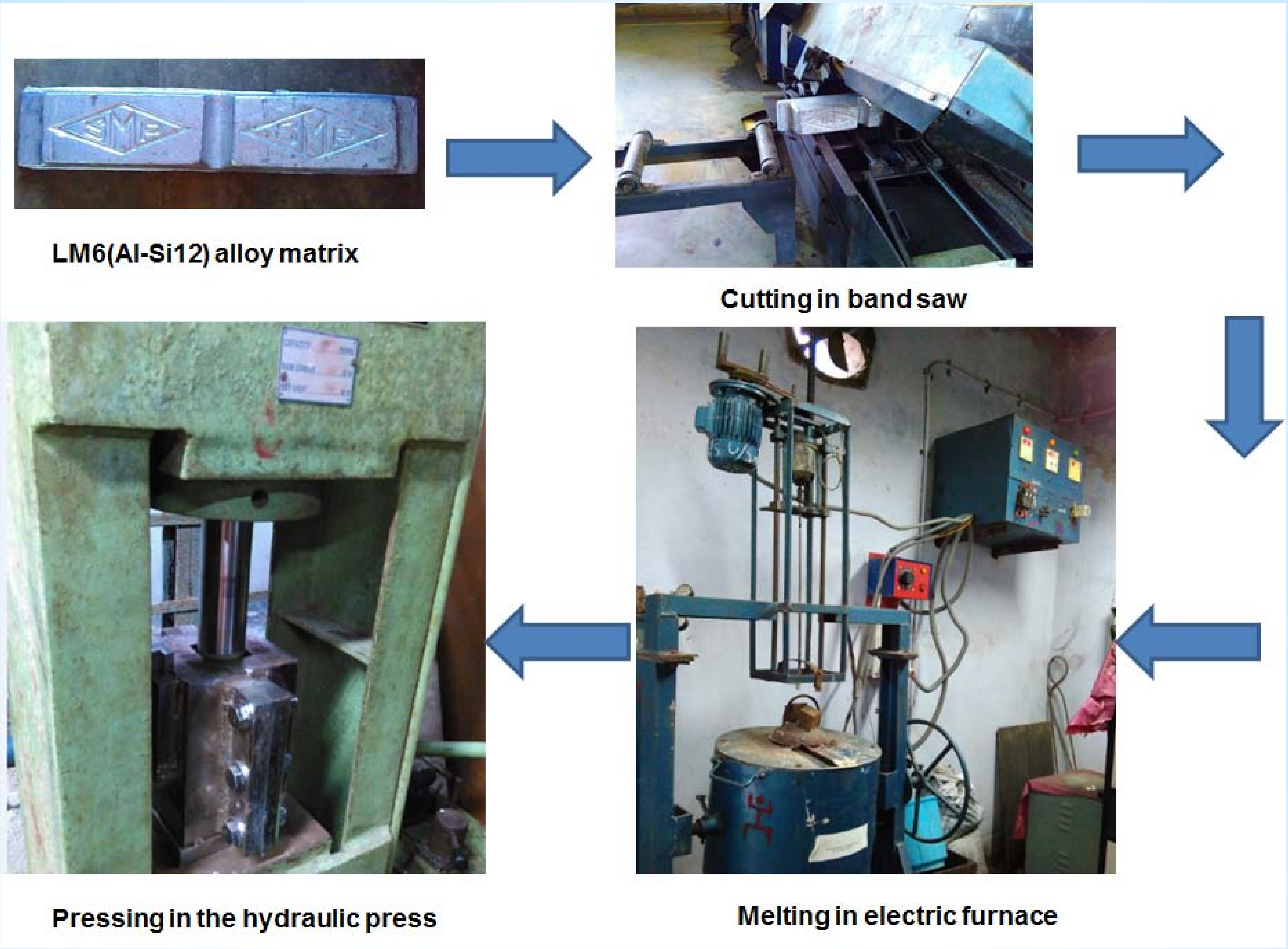


Figure 2: Complete procedure of sample preparation by squeeze casting

Squeeze casting parameters

- Die temperature maintained at about 100-120 ºC
- Constant pouring temperature composite matrix alloy mixture at 720 °C.
- Pressure of 50 MPa.
- Dwell period of 2 min.

DRY SLIDING WEAR TEST

The dry sliding wear tests were carried out on a pin-on-disc wear testing machine designed as per ASTM G-99 standard, supplied by Magnum Engineers, Bangalore, India. The tests were performed under dry condition at room temperature.

Dry sliding wear test

- Steel disc (EN 31)
- Average roughness (Ra %) is 1.2 µm

Parameters of dry sliding wear tests of samples

Test parameters	Units	Values
wt.% c/s	%	5,7.5,10,12.5
Load	N	5,10,15,20
Track radius	mm	50
Sliding velocity	m/s	0.5235,1.0472,1.5708,2.0944
Temperature	°C	Ambient

Figure 3: Experimental set up of pin-on-disc wear tester.

RESULTS AND DISCUSSION

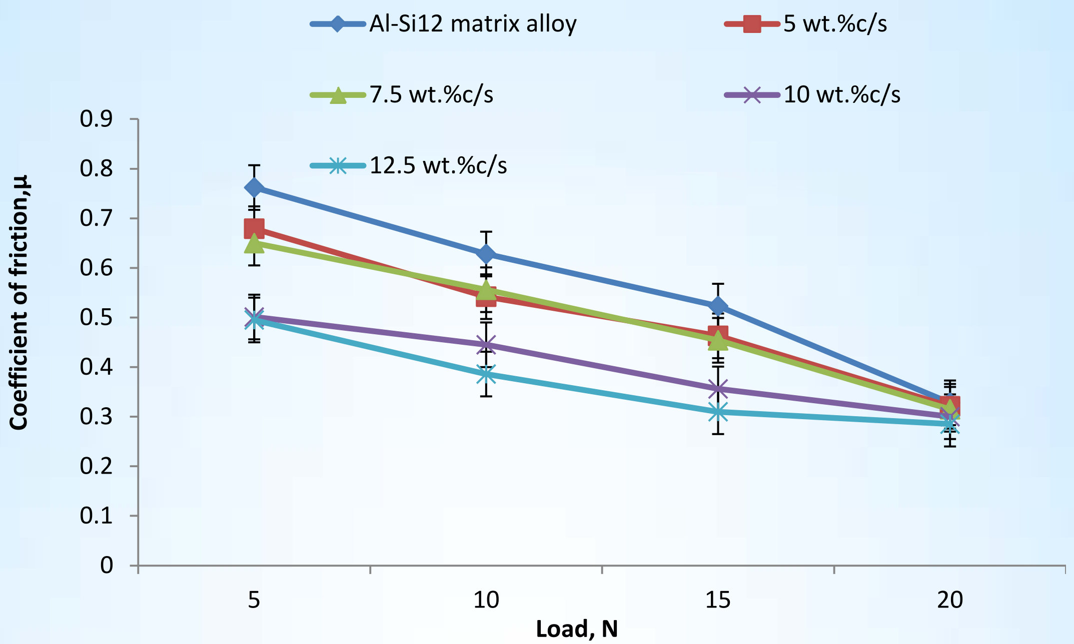


Figure 4: Variations in coefficient of friction with loads

- Due to increase in load the temperature of the contact surface increases and softens the surface of the pin. So, friction coefficient decreases.
- When the load increases more wear of pin surface occurs, and the wear debris stuck in between pin and counter surface and acts as roller ball. Therefore, the coefficient of friction decreases.

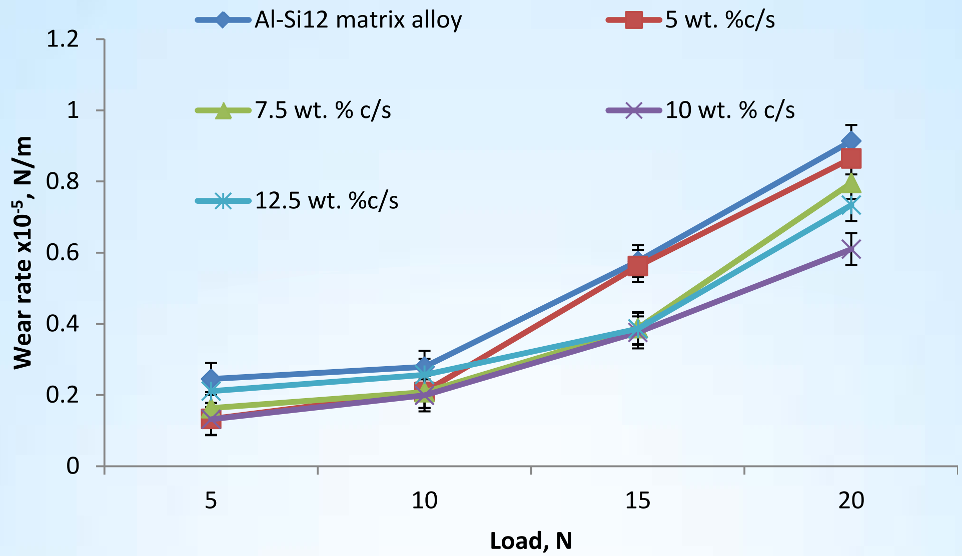


Figure 5: Variations in wear rate with loads

During the initial stage of abrasion, abrasive is in contact with the matrix, has less hardness as compared to angular silica sand (abrasive) particles. At that particular instance, the ratio Ha (hardness of the abrasive particle)/Hs (hardness of the surface) is much more than unity, resulting in severe matrix damage and the rate of material removal is very high. Thus, the specific wear rate is more. When the load increases, cenosphere particles get in contact with abrasive particles, Ha/Hs ratio is a little more than unity; as a result, cenosphere particles provide better resistance to the process of abrasion and reduce the wear rate.

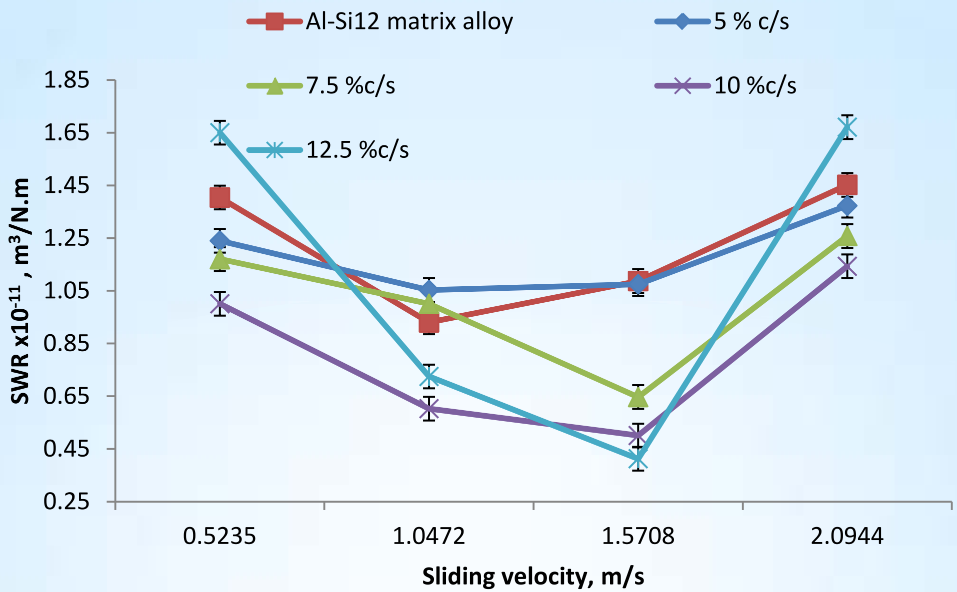


Figure 6: Variation in SWR as a function of sliding velocity

At slow sliding velocity, the sliding surface was covered with oxide like mechanically mixed layer (MML) formed at the sliding interface and minimized direct metallic contacts. This resulted in lower wear rate. At higher velocity thermal softening of the matrix and localized melting on the interface causes the breakdown of the MML and allows more metallic contact during sliding, and cenosphere particles became dislodged, and suddenly huge wear resulted.

SURFACE MORPHOLOGY

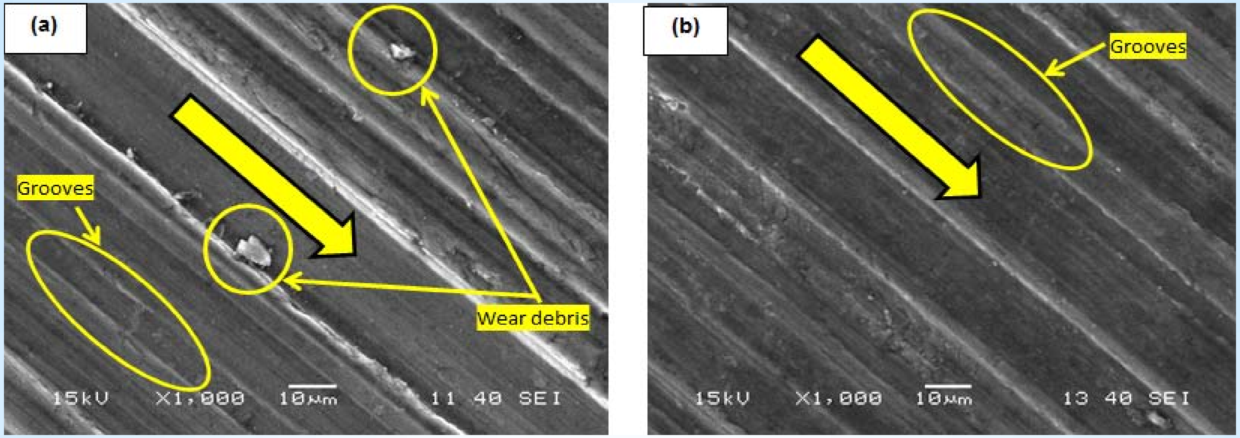


Figure 7: SEM morphology of (a) matrix alloy (b) composite at 5N load and 0.5235 m/s sliding velocity

At low loads along the rolling directions some grooves and debrises of different sizes were formed for the matrix material. Where as for the composite shallow and narrow grooves were formed with out any wear debrises. This is due to hardness of the composite with cenosphere particles.

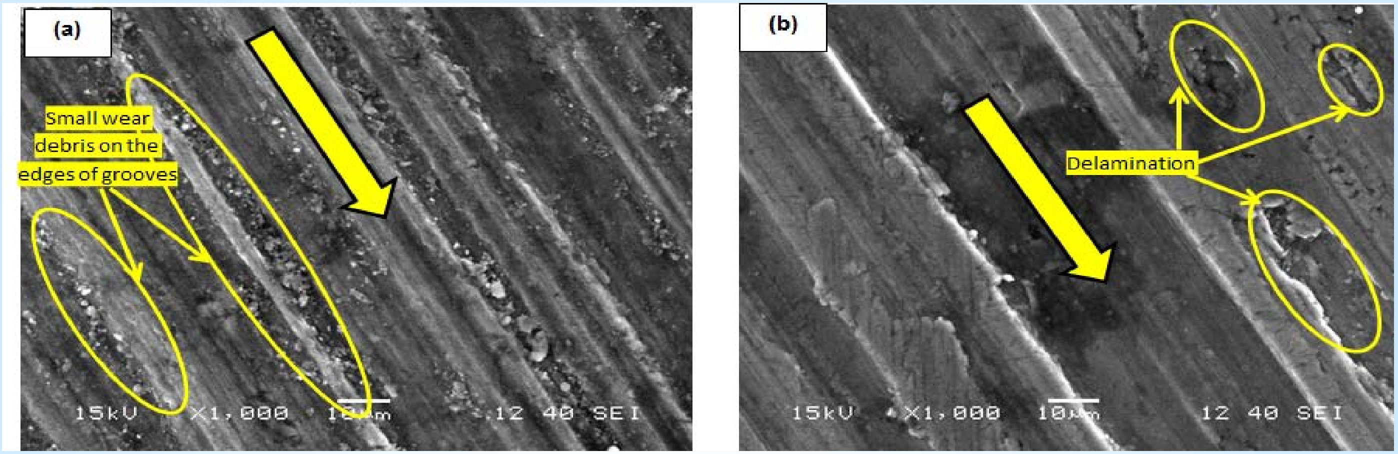


Figure 8: SEM morphology of (a) matrix alloy (b) composite at 10N load and 1.0472 m/s sliding velocity

At 10N load the matrix material shows no of wear debrises along the edges of the grooves formed whereas for the composite grooves formed were very wide and craters were formed. The grooves reveal the presence of abrasive wear mechanism and craters shows delamination.

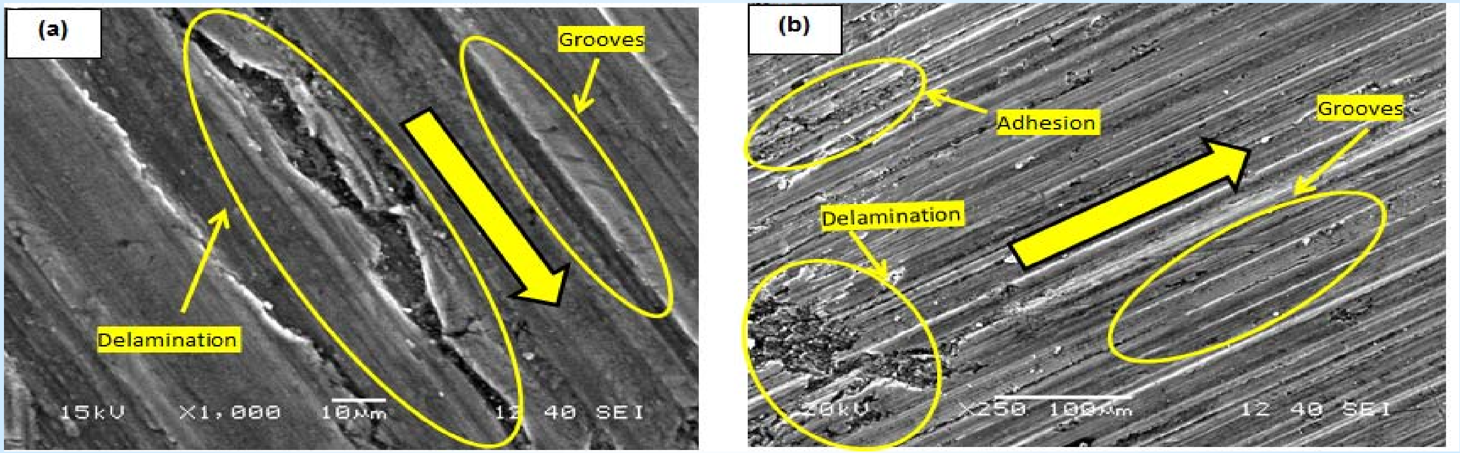


Figure 9: SEM morphology of (a) matrix alloy (b) composite at 15N load and 1.5708 m/s velocity

The morphology of the matrix showed very long and wide cracks with deep grooves along the sliding direction because of matrix breaking during sliding. For the composite grooves were shallow and transfer of material and crater formation are also less.

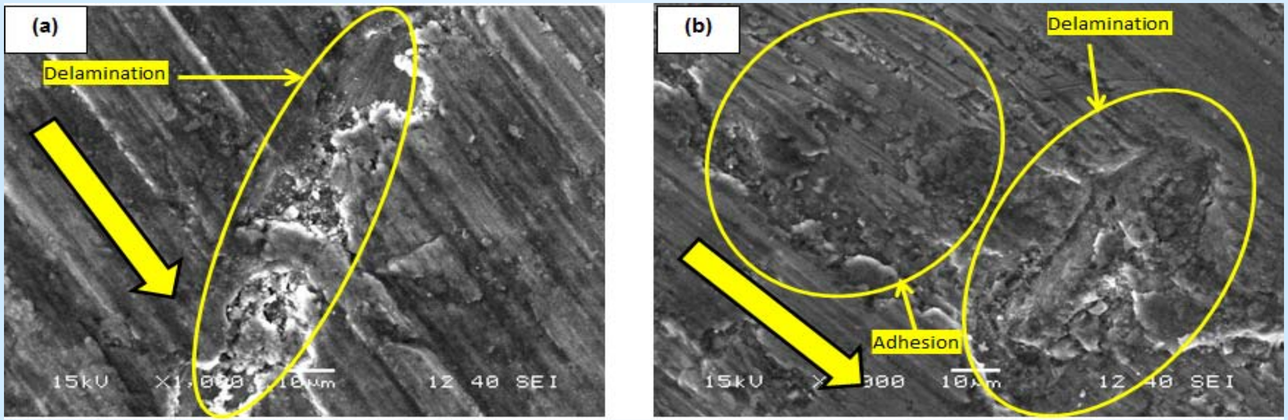


Figure 10: SEM morphology of (a) matrix alloy (b) composite at 20N load and 2.0944 m/s velocity

At a load of 20 N the matrix wear surface shows very deep and wide craters with huge transfer of material. The wear debrises that comes out from the composite material due to adhesive mechanism forms a hard protective layer known as MML. At lower loads the tribology is stable but at higher loads the thermal softening of the matrix causes a break down in the tribolayer resulting in more wear rate

CONCLUSIONS

- The coefficient of friction of the matrix alloy and composites decrease with increasing load.
- The wear rate increases with increase in the load.
- The SWR increases with increase in the sliding velocity.
- The SEM analyses of the worn out samples indicates the presence of abrasive wear mechanism, adhesive wear mechanism, and delamination mechanism.

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