Effect of particle content and sliding speed on wear properties of Al-MoSi2 composites

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Abstract- Molybdenum disilicide (MoSi2) have great potential to improve performance of a tribosystem due to its physical and chemical properties. Presentwork represents effect of MoSi2 particle content and sliding speed on wear behavior of Al composites prepared by stir casting route. MoSi2content in the prepared composites are2, 5, 10 and 15wt%.Dry sliding wear tests were carried out at 90N load and sliding speedvaried as 1, 2 and 3m/s for each load. **All composites have shown better wear resistance that that of matrix alloy. Maximum wear resistance has been found for 5wt% MoSi2. Increase in MoSi2 content lead to increase in porosity and decrease in hardness which resulted in increased wear rate. Further,wear rate has been found to decrease with increase in sliding speed for a given reinforcement content of the composites.SEM examination of worn out surface and debris revealed thatploughingand delamination are the primary wear mechanisms.**

Keywords- Al composite, Sliding Wear, Microstructure, Hardness

I. INTRODUCTION

Higher wear resistance of Al composites is one of the most demanding property required in many industries like automobile and aerospace application due to higher strength to weight ratio.Wear resistance of Al composites has been improved by addition of different types of reinforcements like B4C, SiC, TiB2 and Al2O3[1-4]. In the presence of hard ceramic particles, wear resistance of Al composites are improved, but there is chance to damagethe counter surfacedue to higher hardness of reinforcement particles.Researchers are using intermetallic reinforcement particles to counter the disadvantage of hard ceramic reinforcements. Some frequently used intermetallic reinforcements particlesare NiAl, Ni3Al, Cr3Siand MoSi2[5-9].Wear resistance of Ni3Al reinforced Al alloy composite (powder metallurgy route) was studied by Wang Y et. al. at different loads and reported that at 42 and 91N load prepared composite showed superior wear resistance while at highest load of 140 Nmonolithsoffered superior wear resistance[7]. Aluminides and silisidesas intermetallic reinforcement are reported to be similarly improvement wear resistance as that of extremely hard SiC reinforced composite, but with less damage and transfer of material from the counter surface, this was due to relatively lower hardness of intermetallic reinforcement [6]. M. Sameezadeh reported that with increasing the volume fraction of nano-sized MoSi2 particles up to 3-4%, the hardness of the composites continuously increases and then declines because of particle agglomeration. They also reported that the volume loss decreases with increase in hardness of composite [8].

V. Gousia (2016)prepared Al-MoSi2composites by Stir casting method. They used Al alloy Al1050 as matrix and MoSi2 particle size varied between 1 to 10 µm. The processing temperature was 830OC. They reported that molten Al and the MoSi2 particles react with each other and formation of Al12Mo and Al4Monew phases have been observed[10].In view of above reportedliterature it can be concluded that MoSi2 reinforced Al alloy composite have great potential to improved wear resistance. However, only few literatures have been reported on stir casting route fabricated composite. In this paper,effect of MoSi2 content and sliding speed on wear resistance of prepared composites has been studied.

II. MATERIALS AND METHODS

Aluminum alloy 7075 isusedas the matrix alloy and its composition in weight percentageis given in table 1.MoSi2reinforcement particle size have varied from 40 to 50 µm. The stir casting process has been used for making the four different composites of varying MoSi2 content of 2, 5, 10 and 15wt%.

Table 1: Chemical composition of Al 7075 alloy determined by SEM-EDS.

Zn	Mg	Cu	Mn	Al
5.75	2.06	1.14	0.44	Balance

Pin-on-disc wear testing machine has been used for dry sliding wear behavior (DUCOM TR-20 PHM- 400). The disc material used was EN 31 steel having hardness of 60 HRC. Prepared composites and matrix alloy samples were tested at 90N load and sliding speeds were 1, 2 and 3 m/ s. The wear tests were carried out at room temperture (25°C) and humidity varied between 45 to 60%. The specimens were prepared as 12.5 mm diameter pin of 30 mm length. Scanning electron microscope (SEM-EDS) was used for chemical analysis and study of wear surface and debris. X-ray diffractometer (XRD) was used to identify phases present in composites.

III. RESULT AND DISCUSSION

3.1 Microstructure

The microstructures of Al-MoSi2reinforced AMMCs having 2, 5, 10 and 15 wt % of MoSi2 Particles are shown in Fig 1 a, b, c and d, respectively. These figures are showing uniform distribution of MoSi2 particles in the Al matrix. The figures are also showingthat with increases in MoSi2 content, more reinforcement particles are clarly visible.Further, porosity are also found to increses with increase in MoSi2content.

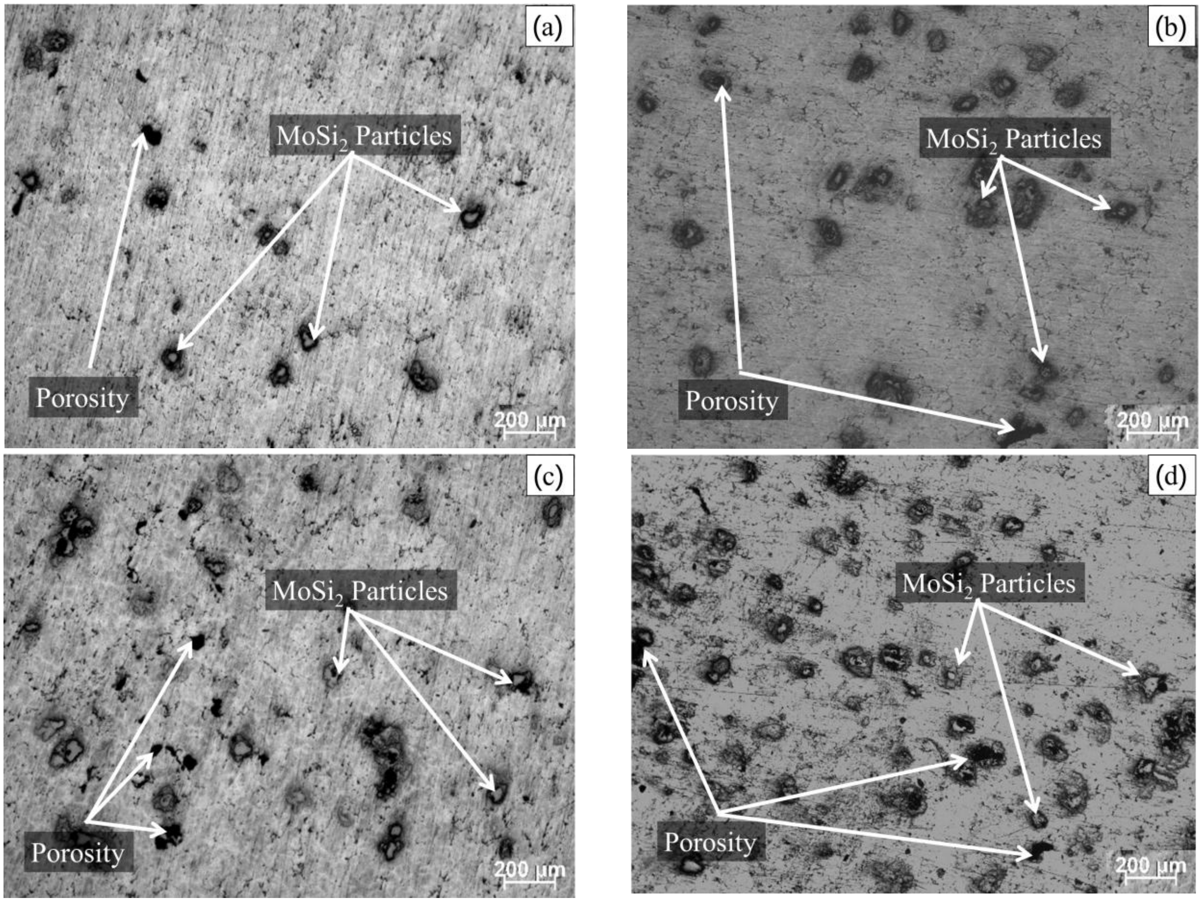


Fig 1: Optical microstructure of Al - MoSi2 composites for (a)2wt%, (b) 5 wt%, (c) 10wt% and (d) 15 wt% MoSi2content.

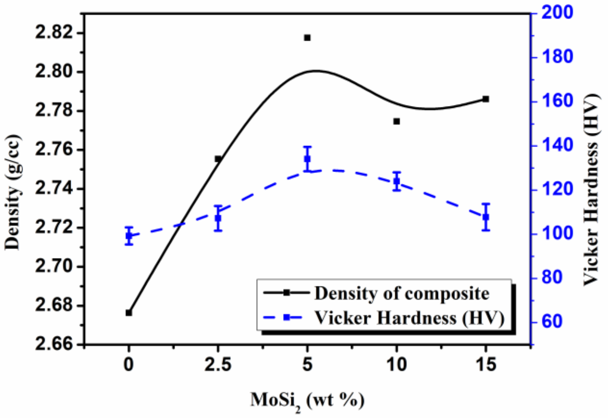


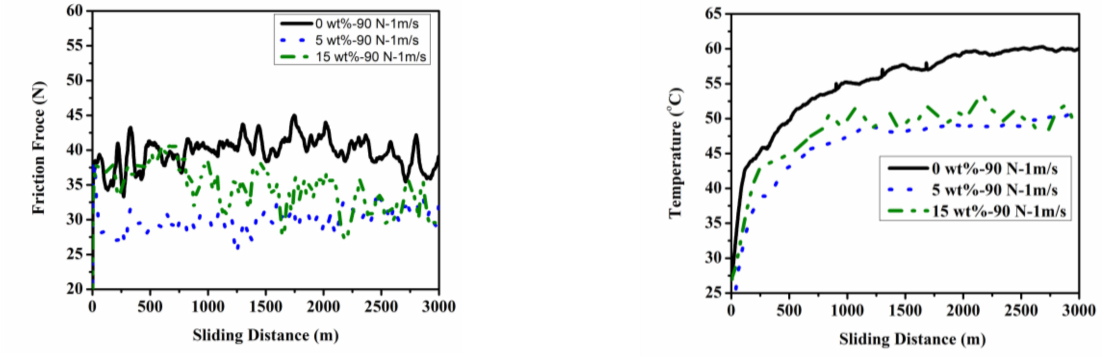
Fig 2: Variation in density and hardness with MoSi2 content for matrix alloy and composites.

3.2 Density and hardness

Figure 2 shows variation in density and hardness with MoSi2 content of composites. The fig is showing that density of composites increases with increase in MoSi2 content up to 5wt% and there after density of composite decreases. Similar trend has observed for variation in hardness i.e. hardness increases with increase in MoSi2 content up to 5wt% and further increase in reinforcement particle resulted in decrease in hardness. Highest density and hardness is observed for 5wt% MoSi2 content and found to be 2.82 g/cc and 134.1 HV, respectively. Whereas, these values for matrix alloy are 2.67 g/cc and 99 HV. The density and hardness of 5wt%MoSi2compositeis 5.6% and 35.5% higher, respectively, as compare to matrix alloy.

3.3 Wear Test

Wear tests have been carried out for matrix alloy and MoSi2 compositesat 90N load and sliding speeds varied as 1, 2 and 3 m/s.The variation in friction force and pin temperature with sliding distance are shown in Figs.3a and b, respectively,for matrix alloy, 5wt% and 15wt% MoSi2 composites for 1m/s sliding speed.Fig 3a clarly revealed that maxmium friction force is observed for matrix alloy, whereas miminum friction force is observed for 5wt% MoSi2 cpmposite. Figure 3b shows that temperature of pin sample increased from 25 to 60°C for matrix alloy whereas it increases from 25 to 45°C for 5wt% MoSi2 composite. Higher heat generation for matrix alloy compared to 5wt% MoSi2 composite is due to higher friction force acting on it. This may be due to higher real area of contact in case of matrix alloy compared to that of MoSi2 composite.



(a) (b)

Figure 3:Variation in (a) friction force and (b) pin temperature with sliding distance for matrix alloy, 5wt% and 15wt% MoSi2 composites for 1m/s sliding speed and 90N load.

Figure 4 shows variation in average friction force with MoSi2 content for applied load of 90N. The figure clearly shows that average friction force for all composites and matrix alloy decreases with with increase in sliding speed. Further, for a given sliding speed, friction force decreases with increase in MoSi2 content up to 5wt% and thereafter it increases with further increase in reinforcement content. Due to friction force, heat is generated and temperature of pin sample is increased. Figure 5 shows variation in peak temperature of pin samples for different MoSi2 wt%. From Fig. 5 it is clear that peak temperature oberved for all composites and matrix alloy decreases with with increase in sliding speed. Further, for a given sliding speed, peak temperature of pin samples decreases with increase in MoSi2 content up to 5wt% and thereafter it remins almost constent or fluctuate slightly. Moreover, for a fixed MoSi2 content, peak temperature is increased with increase in sliding speed.

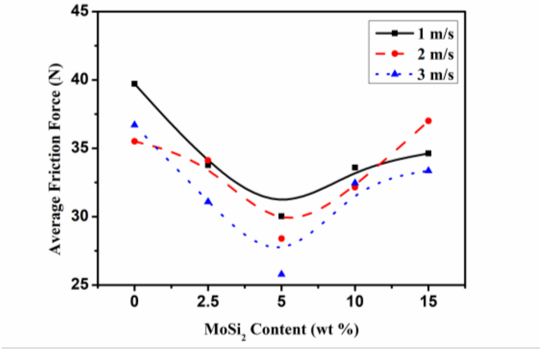


Fig. 4: variation in average friction force with MoSi2 content at applied load of 90N.

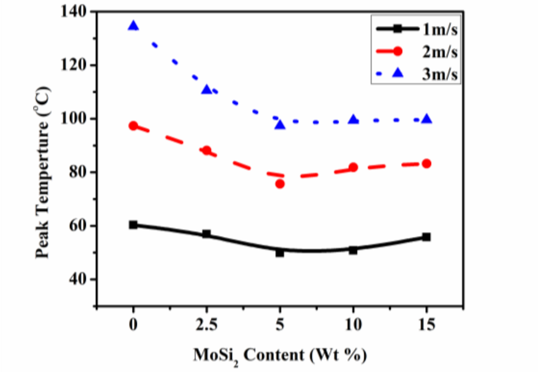


Fig. 5: variation in peak temperature of pin samples at applied load of 90N.

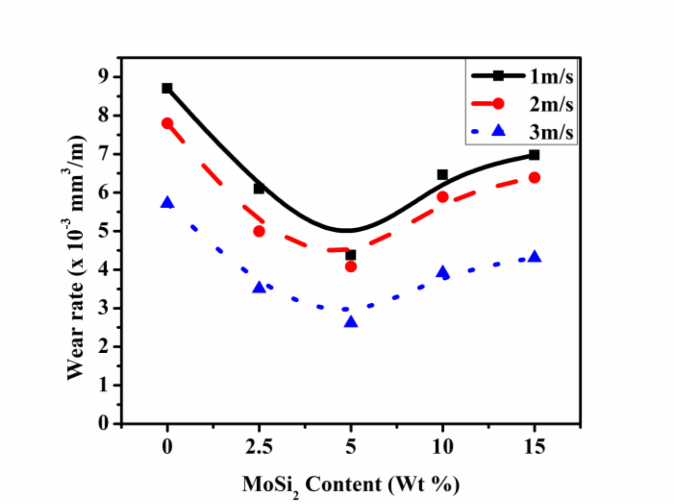
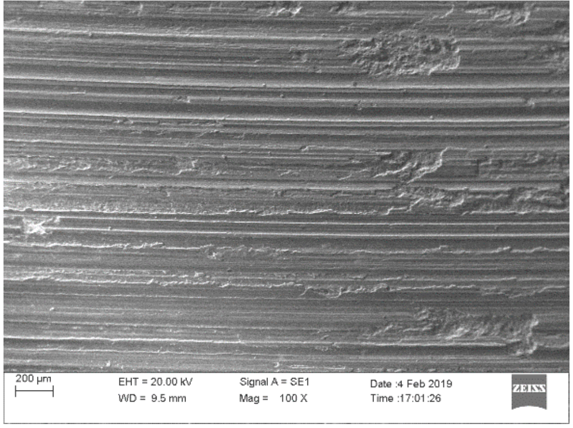


Fig. 6: Variation in wear rate with MoSi2 content for applied load of 90N.

Figures 6 shows variation in wear rate with MoSi2 content of different composites, for applied load of 90N. From Fig. 6 it is clear that wear rate decreases with increase in sliding speed for all samples. Similar trend has been observed in case of TiAl matrix self-lubricating composites [11].Further, for a given sliding speed, wear rate of pin samples



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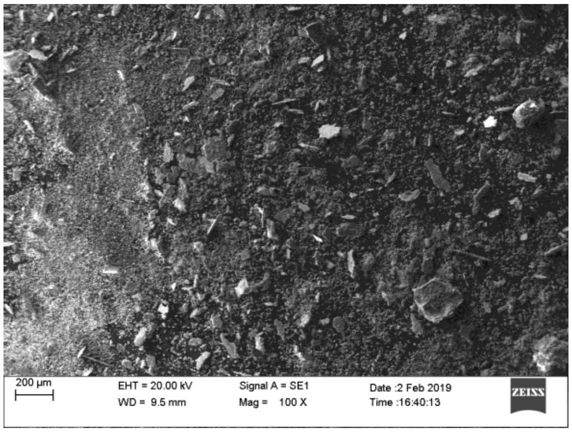
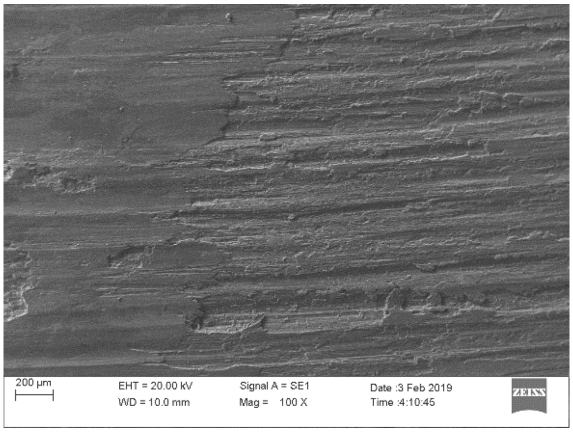


(8a)



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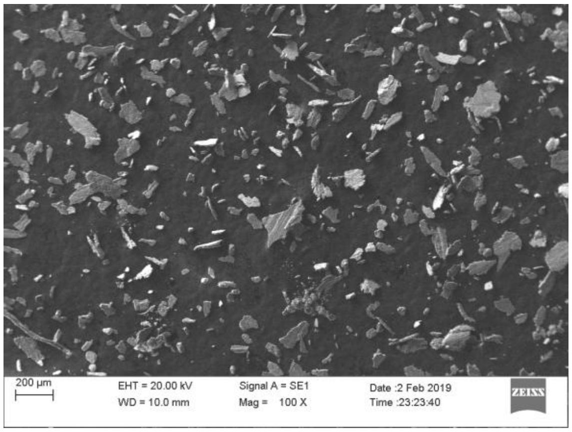

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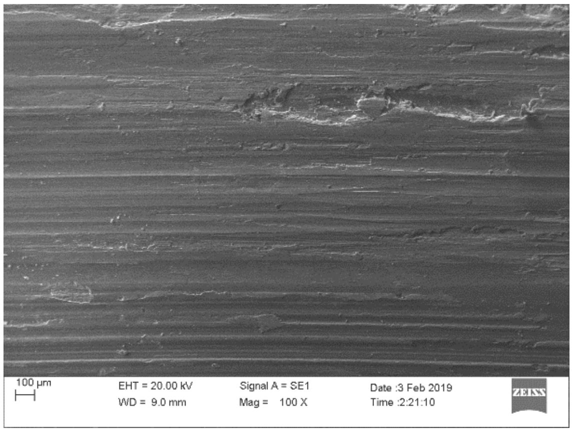

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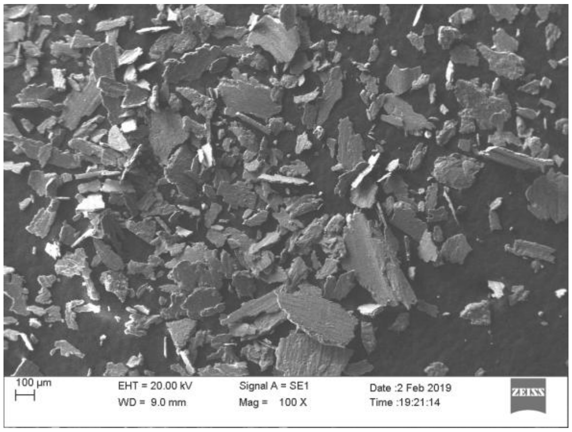

(8c)

Fig. 7: SEM image of worn out surface of 5wt% MoSi2 composite for sliding speed (a) 1 m/s, (b) 2 m/s and(c) 3m/s.

Fig. 8: SEM image of wear debris generated for 5wt% MoSi2 composite for sliding speed (a) 1 m/s, (b) 2 m/s and (c) 3m/s.

decreases with increase in MoSi2 content up to 5wt% and thereafter it increased. Increase in wear rate beyond 5wt% MoSi2 is due to increase in porosity and decrease in hardness.

SEM images of worn out surfaces of 5wt% MoSi2 composite for sliding speeds1, 2 and 3m/s are shown in Fig.7. The figures are is showing ploughing grooves and delaminated regions. ploughing grooves are formed by counter surface asperities and form fine debris particle. Whereas, debris generated in the form of flakes are removed from the delaminated regions. Presence of ploughing grooves is evidence of plastic deformation on wear surface. At lower sliding speed the material removal mechanisms are ploughing and delamination. As the sliding speed increase the pin sample tends to roll on debris which reduces the stress acting on surface the wear loss. Increase in temperature of pin sample due to friction may lead to formation of alumina oxide at the surface which further prevents its wear. SEM images of wear debris generated from the wear surface (shown in Figs. 7a, b and c) are shown in Figs. 8a, b and c, respectively. It is observed that very fine size wear debris has been generated for 1m/s slidding speed (Fig. 8a) along with some flake. Athigher sliding speed i.e. 2and3m/s, only flake is observed. This indicates that at higher sliding speed rolling action is increased and therby wear rate is decreased.

IV. CONCLUSION

MoSi2 reinforced Al composites were successfully developed (2, 5, 10 and 15wt% MoSi2 content) by stircasting technique .Reinforcement particles were uniformly distributed in the Al 7075 matrix alloy. The 5wt%MoSi2composite has highest density and hardness. Higher MoSi2 content lead to higher porosity and thereby hardness is decreased.

Average friction force for matrix alloy is higher than that of composites for all sliding speed.It decreases with increase in MoSi2 content up to 5wt% and thereafter it increases.

Temperature of pin sample increased with increase in sliding speed. For a given sliding speed, peak temperature decreased with MoSi2 content up to 5wt% thereafter it remains almost constant.

Wear rate decreases with increase in MoSi2 particles upto5wt% and thereafter it increases due to increase in porosity. Higher sliding speed lead to rolling action and thereby wear rate is decreased.

SEM examination of wear surface and debris revealed that ploughing and delamination are primary wear mechanisms.

V. REFFERANCES

[1] Abdollahi A, Alizadeh A and Baharvandi H R,“Dry sliding tribological behavior and mechanical properties of Al2024–5wt.%B4C nanocomposite produced by mechanical milling and hot extrusion”, Mater. Des, 55, pp 471–81, 2014.
[2] Balaji V, Sateesh N and HUssain M M,“Manufturing of aluminium metal metrix composite (Al7075-SiC) by stir casting techanique”, Mat Today , 2 pp 3403-3408, 2015.
[3] Gao Q, Wu S, LÜ S, Duan X and An P,“Preparation of in-situ 5vol% TiB2 particulate reinforced Al–4.5Cu alloy matrix composites assisted by improved mechanical stirring process”, Mater. Des., 94,pp 79–86, 2016.
[4] Baradeswaran A and Elaya Perumal A, “Study on mechanical and wear properties of Al 7075/Al2O3/graphite hybrid composites”, Compos. Part B Eng., 56,pp 464–471, 2014.

[5] Torres B, Lieblich M, Ibáñez J and García-Escorial A, “Mechanical properties of some PM aluminide and silicide reinforced 2124 aluminium matrix composites”, Scr. Mater., 47, pp 45–49, 2002.
[6] Baradeswaran A. and Elaya Perumal A “Study on mechanical and wear properties of Al 7075/Al2O3/graphite hybrid composites Compos”, Part B Eng., 56,pp 464–71, 2014.
[7] Wang Y, Rainforth W M, Jones H and Lieblich M, “Dry wear behaviour and its relation to microstructure of novel 6092 alunimium alloy-Ni3Al powder metallugy composite”, Wear, 251, pp 1421-1432, 2001.
[8] Sameezadeh M, Emamy M and Farhangi H, “Effects of particulate reinforcement and heat treatment on the hardness and wear properties of AA 2024-MoSi2 nanocomposites”, Mater. Des., 32, pp 2157–2164, 2011.
[9] Corrochano J, Walker J C, Lieblich M, Ibáñez J and Rainforth,“Lubricated sliding wear behaviour of aluminium alloy composites”,Wear, 259, pp 577–89, 2005.
[10] Gousia V, Tsioukis A, Lekatou A and Karantzalis A E, “Al-MoSi2Composite Materials: Analysis of Microstructure, Sliding Wear, Solid Particle Erosion, and Aqueous Corrosion”, J. Mater. Eng. Perform, 25, pp 3107–20, 2016.
[11] Zeegshi X, Xiaoliang S,Qiaoxin Z and Yecheng X, effect of sliding speed and applied load on tribological performance of TiAl matrix self-lubricating composites, 55, Tribology Letter, pp 393-404, 2014.