

# Seminar

---

---

## Institute for Plasma Research

---

---

**Title :** Mechanical and Electrochemical Performance of Aluminium Matrix Friction Stir Surface Composites

**Speaker:** Dr. Mahesh V. P.  
IIT, Gandhinagar

**Date :** 22nd January 2021 (Friday)

**Time :** 02.30 PM

**Venue :** Online - Join the talk:

[https://meet.ipr.res.in/Dr.MaheshVP\\_PDFTalk](https://meet.ipr.res.in/Dr.MaheshVP_PDFTalk)

### Abstract :

Aluminium (Al) alloys are used in transportation, defense, and aerospace applications owing to their lightweight and high specific strength. However, low surface hardness, wear and corrosion resistance limit the use of these alloys in various strategic applications. Microstructural modification by surface composite formation can overcome these limitations [1]. Metal matrix surface composites possess the combined properties of the base alloy and the reinforcement. Surface composites can be fabricated through the liquid and solid-state processing routes. Liquid state processing may result in the formation of different intermetallics which lead to deteriorated mechanical properties. Solid-state processing can avoid the drawbacks of liquid state processing such as reduced wettability and interfacial reaction between the matrix and the reinforcements. Friction stir processing (FSP) is an effective solid-state processing route to develop surface composites. Formation of intermetallics can be avoided as FSP is done at temperatures lower than the base material  $T_m$ . The processing generates a fine-grained microstructure due to severe plastic deformation. The presence of reinforcement particles in the fine grain matrix enhances the surface hardness and reduces the thermal effects [2]. Molybdenum (Mo) is a suitable metallic reinforcement for the surface composite owing to its high melting point, better wear and corrosion resistance compared to aluminium. Understanding the various parameters and their impact on the Al surface composites is important, yet not known. Here we present the effect of the friction stir processing parameters such as tool shoulder diameter, tool rotation speed, number of grooves, and number of processing passes as well as the reinforcement particle distribution on the resultant surface properties of Al surface composites.

Single and double groove FSP experiments are carried out to study the effect of the number of grooves on the hardness of surface composites fabricated using 22 mm tool shoulder diameter. The introduction of a second groove increases the Mo content in the surface composite. The incorporated Mo particles enhance the surface hardness of Al 1050 base alloy. The surface hardness of unprocessed material is 26Hv. The hardness increases to 42Hv on the top surface and 44Hv on the cross-section surface of SGC (Single Groove Composite). The top and cross-section hardness for DGC (Double Groove Composite) are 46Hv and 49Hv, respectively. Surface hardness improves due to the combined effect of Mo reinforcement and grain refinement induced by the friction stir processing. FSP incorporates about 8%wt Mo in SGC and 12%wt Mo in DGC. FSP reduces the average Mo particle size by mechanical shearing through severe plastic deformation. Mo particles are distributed in the elemental form without any intermetallic formation [3].

The combined effect of the number of passes and grooves on the corrosion resistance and surface hardness is also analyzed. Aluminium surface composites are prepared using the single-pass (SP) and double-pass (DP) FSP

groove method. Potentiodynamic corrosion testing of AlMo surface composites is carried out to study the change in the corrosion resistance. Surface composites exhibit better corrosion resistance with higher corrosion potential ( $E_{corr}$ ) and lower corrosion rate ( $i_{corr}$ ) compared to the unprocessed base alloy and friction stir processed materials without Mo addition. The amount of Mo particles is increased by the addition of a second groove. A second processing pass homogeneously distributes this higher amount of Mo particles. The double groove double pass sample exhibits the best corrosion resistance. Electrochemical Impedance Spectroscopy (EIS) analysis confirms the higher corrosion resistance of the surface composites. Surface composites with Mo particles show a charge transfer controlled corrosion behavior whereas the Al 1050 base alloy exhibits a mixed corrosion behavior. The initiation stage of pitting corrosion is restricted by the presence of evenly distributed fine Mo particles on the surface composites [4]. The second processing pass on the double groove composite also increases the hardness of the Al-Mo surface composite due to the uniform distribution of reinforcements in the grain refined Al matrix.

Different tool rotation speeds and tool shoulder diameters are used to fabricate defect-free Al-Mo surface composites. Molybdenum particles are uniformly distributed in the aluminum matrix without the formation of any intermetallics with various tool shoulder diameters (18, 20 and 22 mm) and tool rotation speeds (780, 900 and 1200 rpm). A higher amount of Mo is observed in the surface composite processed at higher tool rotation speed and lower tool shoulder diameter. Dynamic recrystallization during FSP and pinning effect due to the Mo particles results in the grain refinement. The hardness of surface composites increases with an increase in tool rotation speed and decreases with an increase in tool shoulder diameter. The surface composite hardness enhances due to the coupled effect of grain refinement and Mo reinforcement. A two-fold increase is observed in the average hardness of surface composites compared to the unprocessed Al 1050 base alloy [5].

The corrosion behavior of aluminium surface composites with metallic, ceramic, and hybrid reinforcement particles are also analyzed in this study. Molybdenum, possessing higher corrosion resistance compared to aluminium, is used as the metallic reinforcement and the third hardest known material boron carbide (B4C) is used as the ceramic reinforcement. The effect of hybrid reinforcement addition on the corrosion behavior of Al surface composites is studied by the combined addition of boron carbide and molybdenum particles. The electrochemical behavior of the developed composites is analyzed through potentiodynamic polarization and EIS. The reinforcement particles distributed in the Al matrix affect the pitting corrosion behavior of the surface composites. The base alloy and the hybrid surface composites show diffusion- controlled corrosion mechanism whereas the Mo and B4C reinforced composites exhibit charge transfer controlled behavior. Single reinforcement addition enhances the corrosion resistance of the base alloy whereas the hybrid reinforcement addition induces more corrosion. Post-corrosion microscopy analysis reveals the severity of pitting in hybrid composites. The surface composites developed with metallic, ceramic and hybrid reinforcements are free from any interfacial reaction products [6].

Al-Mo surface composites exhibit improved tensile strength and wear resistance compared to the unprocessed base Al 1050 alloy [7]. The improvement in the wear resistance and tensile strength in the surface composites are attributed to the combined effect of reinforcement particles and grain refinement. The improved ductility in the surface composites compared to the unprocessed base alloy corresponds to the better interfacial bonding between the matrix and the reinforcement particles. The knowledge, regarding the effect of processing parameters and type of reinforcements on the aluminium surface composite properties by FSP, will be very useful in developing optimized surface composites for strategic applications.

## REFERENCES

- [1] Z.Y. Ma, 'Friction Stir Processing Technology: A Review', *Metall. Mater. Trans. A*, 39 (2008) 642–658.
- [2] A. Arora, A. Astarita, L. Boccarusso, Mahesh V. P., 'Experimental Characterization of Metal Matrix Composite with Aluminium Matrix and Molybdenum Powders as Reinforcement', *Procedia Engineering*, 167 (2016) 245–251
- [3] Mahesh V. P., Amit Arora, 'Single and double groove friction stir processing of Aluminum-Molybdenum surface composites', *Metallurgical & Materials Transactions A*, 50 (11) (2019), 5373-5383
- [4] Mahesh V. P., J. Alphonsa, Amit Arora, 'Corrosion behavior of aluminium- molybdenum surface composites developed by friction stir processing', *Journal of Materials Engineering and Performance* (2020) (Under Review)
- [5] Mahesh V. P., Ashutosh Kumar, Amit Arora, 'Microstructural modification and surface hardness improvement

in Al-Mo friction stir surface composites', *Journal of Materials Engineering and Performance*, 29 (8) (2020), 5147–5157

[6] Mahesh V. P., Anurag Gumaste, Neha Meena, J. Alphonsa, Amit Arora, 'Corrosion behavior of aluminium surface composites with metallic, ceramic and hybrid reinforcements using friction stir processing', *Metallurgical & Materials Transactions B*, 51 (8) (2020), 2131–2146

[7] Mahesh V. P., A. Gumaste, N. Meena, Harpreet Singh Arora, A. Arora, 'Mechanical and wear behaviour of aluminium surface composites using friction stir processing', (Under Preparation (2020))

---