Abstract

In this work, the properties of AZ91 alloy are controlled through heat treatment and defined aging, which leads to the distribution of $\gamma$-$\text{Mg}_{17}\text{Al}_{12}$ phase precipitates in bulk, and depositing hard coatings. The work has been classified into metallurgical, mechanical and tribological studies of the; (i) solution treated and peak aged AZ91 alloy, (ii) cermet coatings deposited on as cast AZ91 alloy, (iii) ceramic coatings deposited on as cast and microstructurally controlled AZ91 alloy and (iv) exploration of biomedical compatibility of newly developed coatings. Surface of AZ91 alloy was altered by deposition of cermet; Tungsten and Cobalt based coatings and ceramic; $\text{Al}_2\text{O}_3$ and $\text{CeO}_2$ doped $\text{Al}_2\text{O}_3$ coatings through thermal spray technique (D-gun). Surface and interface properties are critical to promote the tribological and anticorrosion applications.

In case of bare AZ91 alloy with controlled microstructure, the peak aged AZ91 alloy showed increase in wear resistance against Al6351 alloy as compared to solution treated AZ91 alloy. The formation of $\gamma$-$\text{Mg}_{17}\text{Al}_{12}$ phase precipitates in aged sample was found to be responsible for increased wear resistance. The specific wear rate for peak aged alloy was almost one-third than that of solutionized alloy. For both the alloys, i.e. solutionized and peak aged, the coefficient of friction decreases with increase in sliding speed at low load while behavior of peak aged alloy deviates at high load.

In case of cermet coatings, the SEM analysis and indentation hardness, measured at surface and coating-substrate interface, indicates that the good quality coatings were deposited. The scratch resistance of the coatings were found to be good, as under variable load the coatings did not fail. The X-ray mapping of scratched coatings indicate no failure of coatings. It was concluded that WC-12wt.%Co, Stellite 6 and $\text{Al}_2\text{O}_3$-$\text{TiO}_2$ coatings can be thermally sprayed using D-gun on AZ91 Mg alloy with uniform thickness and negligible defects. Further, It was observed that $\text{Al}_2\text{O}_3$-$\text{TiO}_2$ coating showed the less diffusion of particles in substrate as compared to the WC-12wt.%Co and Stellite 6. Also, thin splats layers were observed in case of $\text{Al}_2\text{O}_3$-$\text{TiO}_2$ coating which indicates that coating quality is better. Further, the frictional responses of coatings under lubricated condition were recorded and found to be controlled by polar component of surface energy. $\text{Al}_2\text{O}_3$-$\text{TiO}_2$ coating showed the lowest friction coefficient among the three.

For $\text{Al}_2\text{O}_3$ and CeO$_2$ doped $\text{Al}_2\text{O}_3$ based coatings, the role of CeO$_2$ was found to be crucial in controlling the metallurgical, mechanical and tribological properties of the coating. It was observed that, the superior mechanical properties of CeO$_2$ doped $\text{Al}_2\text{O}_3$ based coatings depends on the formation of new Ce containing phases. When rubbed against Al-11.3%Si alloy, under lubricated condition, CeO$_2$ doped $\text{Al}_2\text{O}_3$ coatings results in lowering of coefficient of friction and controlling wear even at high load and low sliding velocity. Microstructural and XRD analysis revealed the refinement of microstructure and formation of Ce containing phases, which can be considered as responsible for improved mechanical properties; hardness (H), elastic modulus (E) and H/E$^r$ ratio. The optimum concentration of CeO$_2$ was around 0.8wt % and beyond this concentration the deterioration in responses were observed. Also, the presence of second phase precipitates ($\text{Mg}_{17}\text{Al}_{12}$) in substrate matrix (peak aged alloy) is not desirable although the same can be good for stronger coating-substrate interface. The H/E$^r$ ratio mapping shows that coating containing 0.8wt.%CeO$_2$ doping in $\text{Al}_2\text{O}_3$ deposited on solution treated alloy can be good for tribological applications as it has obtained the highest H/E$^r \approx 0.1$.

The biocompatibility of the bare and coated AZ91 alloys was assessed using MTS, cytotoxicity and viability assays. It was observed that $\text{Al}_2\text{O}_3$ and CeO$_2$ doped $\text{Al}_2\text{O}_3$ coatings showed the 150 % and 250 % cell viability than bare AZ91 alloy. Further, the CeO$_2$ doped $\text{Al}_2\text{O}_3$ coating showed better biocompatibility in terms of cell growth and may be proposed for biomedical applications.