ABSTRACT

Solid-state friction-based material processing strategies have the potential for locally enhancing the properties of various aluminium alloys for demanding applications within the automotive industry. In this thesis, the modifications in the existing friction-based strategies for the surface alteration of Al6061 alloys are discussed. The suggested modification techniques are:

(i) The surface modification of Al6061 alloy by fabricating hybrid composites with Silicon carbide (SiC) and various carbonaceous compounds as reinforcement through conventional friction stir processing (FSP).
(ii) The multiple microchannel reinforcement filling approach during FSP.
(iii) The development of powder metallurgy assisted friction surfacing (PMAFS) method for the impregnation of Graphene nanoplatelets (GNP) and graphite on the surface of aluminium substrate.

The influence of various reinforcements and their dispersion in the aluminium matrix has been investigated at the fundamental level. In the first part of the thesis, the surface alteration of Al6061 aluminium alloys has been carried out through reinforcing SiC and other carbonaceous compounds such as Graphite, GNP and Carbon nanotubes (CNT) during FSP. The detailed microstructural characterization and tribological performance of the fabricated hybrid composites are critically analyzed and reported. Among various material combinations, the hybrid composite of Al-SiC-GNP is the standout and delivers a maximum wear resistance and surface hardness to the aluminium alloys. The second objective of the thesis emphasizes on improving the particle distribution in the processing zone of the Friction stir processed composite. For this purpose, the reinforcements such as GNP and CNTs are placed on the substrate in the prefabricated microchannels instead of a single channel of large width (as it is generally done in conventional FSP). A homogeneous dispersion of the reinforcements is achieved which significantly improves the tribological as well as the tensile properties of the fabricated composites. Lastly, the third objective of this research work solved one of the critical problem associated with the conventional solid-state Friction surfacing (FS) process. The modification in the existing FS process is termed here as powder metallurgy assisted friction surfacing (PMAFS) methodology. The PMAFS eliminates the necessity of consumable materials to be available in the solid consolidated form for FS. The process comprises of two stages, where, in the first stage a conventional powder metallurgy technique is used to fabricate the tool for FS, and in the next stage the fabricated tool is utilized for FS. The PMAFS is optimized for the best process parameters and the weight fraction for GNPs in the tool made up of powder composite. Whereas, in the extension of this process for Al-Graphite surface composites, the influence of flake size of graphite is also evaluated. Successful impregnation of reinforcements (GNPs and graphite) is achieved up to several micrometers beneath the surface. The interfacial bonding, surface nano-hardness and wear performance of the modified surfaces are also documented.

Keywords: Friction stir processing, Friction surfacing, Surface nanocomposites Graphene, Graphite, Carbon nanotubes, hybrid composite.