ABSTRACT

Surface modification of engineering materials is a continuously progressing field of current research. It involves mechanical, chemical, thermal, and electrical based processing of materials to meet the final product requirements. In particular, the metals and alloys are in need of thermal and mechanical based surface modification process based on its applications; mainly in the case of components which get exposed to wear and tear. Some of the processes are in need of pre – and post – processing for carrying out surface modifications. On other hand, some of the process like thermal spray, electro – electroless processes for the surface modification have to be quantified for adhesion and delamination effect. To overcome the above said issues, mechanical surface modification offers a promising solution for improving/developing wear resistant engineering components.

Most of the researchers adopted liquid state processing (Plasma arc surface alloying, Laser surface processing, and Electron beam irradiation) and solid state processing (Ball collision). The above said techniques involve high temperature during processing which leads to the formation of certain undesirable phases caused by chemical reactions between the incorporated particles and matrix metal. Thickness of the coatings developed through the above said properties is limited to a very few micrometres and at the same time the inhomogeneous distribution of reinforced particles also significantly affects the required properties.

Difficulties involved in liquid phase technique have led to the evolution of solid state processing approach. An emerging technique called Friction Stir Processing (FSP) has been developed based on the working principle of Friction Stir Welding (FSW) for fine microstructural modification at near surface layer of materials. The mechanical properties and microstructural refinement can be precisely controlled by optimizing the process parameters. Addition of hard oxides / carbides particles during surface modification produces modified surface composites.

In this research, FSP was adopted to produce surface composite on CuNi alloy with different carbide / ceramics processed using different combination of processing parameters. Since FSP is carried out below the melting temperature of the matrix metal, formation of detrimental phases were avoided.

The Primary objective of the proposed research is to study the relationship of FSP process parameters on 90/10 Copper–Nickel (CuNi) alloy with different carbide particles (TiC, SiC, B_4C, Cr_3C_2 and ZrC) as reinforcement. Process parameters chosen for experimental investigation included tool rotational speed, traverse speed, and width of the groove. From the investigations, response such as sliding wear, Ultimate Tensile Strength (UTS), microhardness, and modified stir regime cross sectional area were studied in detail. Analysis of the developed process showed that FSP parameters such as tool traverse speed, tool spindle rotational speed, and groove width are the predominant parameters which highly influence the sliding wear, microhardness, and UTS of the developed surface composites. Simultaneously, controlled dispersion of reinforcement in the surface has also influenced metallurgical changes at stir regime leading to change in properties. To validate the above results and to study the microstructural aspects, selected specimens were subjected to metallographic study and the obtained results were put forward in detail in the discussion chapters.

A mathematical model method was developed to evaluate the surface modification process and optimal sets of process parameters were identified. The mathematical model was developed with 5 levels having 4 factors namely, tool rotational speed, traverse speed, groove width, and ceramic particles. Design of Experiment (DOE) and modelling tools were effectively used to reduce the number of experiments, fast processing, and validation of the model, accuracy, and reliability in predicting the results.

A digital optical scanner was used to carry out the macrostructure analysis of the CuNi surface composites. Area of the surface composite was measured using an image analyser. Optical Microscope and Field Emission Scanning Electron Microscope were used to study the microstructure of the specimens. Micrographs were taken from various zones of developed surface composites including Heat Affected Zone (HAZ), Thermo Mechanically Affected Zone (TMAZ), Stir Zone (SZ) and Base Metal (BM). Spectroscopic analysis and X-ray diffraction analysis were carried out to confirm the absence of intermetallic compounds found in the friction stir processed specimen. The X-ray diffraction analysis was done to confirm the presence of Cu, Ni, and different carbide particles in the surface composite.

Microhardness of the surface composite was measured at various zones in stir area of modified surface composites and the average value was noted. Among the different composites produced, CuNi/B_4C composite gave the best mechanical and tribological behaviour. Higher tool rotational speed (1200 rpm), lower traverse speed (30 mm/min), minimum groove width (0.7 mm) and B_4C particles resulted in higher microhardness (183 HV), lower wear rate (245.7 x 10^{-5} mm^3/m) and higher mechanical strength (293 MPa). Hence, this composite was considered for further

investigations. Investigations on specimens with and without reinforcement of B_4C particles were carried out. The influence of process parameters on responses such as FSP area, microhardness, UTS, and wear behaviour of CuNi/B_4C surface composite has also been discussed in detail. Higher microhardness, lower wear rate, and higher UTS are obtained at optimized range of tool rotational speed (1200 rpm) and traverse speed (30 mm/min) and groove width (0.7 mm).