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Title: Investigations on Surface Modification Using Friction Stir Processing (FSP)

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ABSTRACT

Friction Stir Processing (FSP) is an improvisation of Friction Stir Welding (FSW) process. FSP is an emerging surface modification technique and widely recognized as the development in the areas of surface composite fabrication. FSP has found several applications for microstructural modification in metallic materials such as microstructural refinement, fabrication of surface composite, homogenization of microstructure, and property enhancement of cast aluminum alloys. FSP is capable of modifying the surface properties of marine grade aluminium alloys (AAs) and finds its extensive application in automobile, shipbuilding and offshore construction.

The present work endeavoured to investigate the strength enhancement task through the fabrication of surface composites (SCs) using a hybrid FSP route. Hybrid FSP process was performed on AA5083-H111 using mechanical alloyed reinforcement with high carbon steel tool with scroll on shoulder and cylindrical pin on a retrofitted vertical milling machine. Hybrid FSP process comprises of two part i.e. mechanical alloying (MA) and friction stir processing.

By using MA, $Fe_{60}Al_{40}$ reinforcement were prepared under different parameters in planetory ball mill. The resulted MAed $Fe_{60}Al_{40}$ powder was used as the reinforcement for surface modification using fabrication of surface composites. To perform the FSP process, a new tool with a scrolled shoulder and plain cylindrical pin was designed and developed.

For FSP, three variable process parameters, namely shoulder diameter, tool rotational speed and tool traverse speed, were selected after rigorous pilot experimentation. Three sets of values selected for each parameter and their respective level was designated. The range of shoulder diameter, tool rotational speed and tool traverse varied between 16-21 mm, 710-1120 rpm and 63-100 mm/minute, respectively. The surface modification and fabrication SCs was performed using two pass experiments were performed as per Taguchi's L_{27} orthogonal array (OA). Tensile properties, microstructure, and micro-hardness, of the friction stir processing samples were analyzed. From the results of microstructural examinations, grain refinement is observed at the stir zone due to continuous dynamic recrystallization caused by severe plastic deformation. After second pass average grain size was drastically reduced to 5.08 μm in SZ as compared to 41.49 μm of BM.

Taguchi's analysis was used to study the effect of input parameters, i.e., shoulder diameter of the tool, tool rotational speed and tool traverse speed, on output responses like grain size, MH, and UTS. It included computation of the signal-to-noise (S/N) ratio, analysis of Means (ANOM), response graph, analysis of variance (ANOVA) and confirmatory test. Signal-to-noise (S/N) ratio calculated from the ANOM table defines the optimal combination of parameters that substantially influence the particular output response. From the result of ANOM, the optimal combination of a parameter to higher-the-better characteristic for microhardness during fabrication of SC was $A_3B_2C_1$, i.e., shoulder diameter (A) at 21 mm, tool rotational speed (B) at 900 rpm and tool traverse speed (C) at 63 mm/min. For higher-the-better characteristics, it was found that tool shoulder diameter is the most significant FSP parameter. Then conformation test was carried out to validate the experimental result obtained at the optimum combination of the FSP parameters i.e. $A_3B_2C_1$ with the result predicted by the Taguchi approach. Further, a paired two tailed t-test was used to check whether the difference between the microhardness, UTS and grain size of first and second FSP passes was statistically significant or not at a significance level (α) of 5%.

So, a surface modification of AA5083 was achieved by using hybrid friction stir processing approach. The present study successfully investigated major areas of the MA and FSP.