Friction stir processing of aluminum alloys

by

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Abstract

This thesis aims to improving the mechanical properties of A384 aluminum-silicon alloy by means of grain refinement techniques. Friction Stir Processing (FSP) has the potential for locally enhancing the properties of Al-Si alloys castings for demanding applications within the automotive industry.

In this work, plates of A384 aluminum alloys were cast by conventional casting process. After that friction stir process was carried out using different rotational and travel speed as well as in process cooling with three different cooling systems. The microstructures of investigated alloys (cast and FSP at different conditions) were characterized by optical, SEM microscopes, EDS and Map analyzer, while mechanical properties were evaluated by using tensile and hardness tests.

Software package, Design-Expert 6.1 is used to obtain the start conditions. Experimental investigations were designed based on design of experiments (DOE) method. A three factor (tool rotation speed, travel speed and cooling rate) and three level (1200, 1000 and 800rpm- 80, 60 and 40mm/min-200^{o}C/min, 150^{o}C/min and 100^{o}C/min) central composite circumscribed technique (CCC), presents the design-matrix of different runs as well as the levels of each parameter.

The results indicate that; after friction stir processing, the microstructure of as-cast alloy was greatly improved. Needle-like eutectic Si and Chinese Script α-Fe were modified to fine precipitates. Meanwhile, coarse primary Si and large plate β-Fe phase were dissolved. Silicon particle size and aspect ratio were decreased from 49.33μm and 29.5 to 2.13μm and 1.44, respectively, compared with as-cast. While the mapping analysis shows homogenous distribution of different alloying elements through the matrix. Also, some alloying elements (Cu, Mg and Si) were dissolved after FSP in α-Al matrix resulting in solid solution strengthening.

The results of mechanical properties revealed that the YS, UTS, El% and HV increased with increasing tool rotational speed, travel speed and in process cooling. The optimum values of mechanical properties experimentally obtained at 1200rpm, 80mm/min. and in process cooling of liquid nitrogen. It was found that at the optimum conditions, the values of mechanical properties (YS, UTS, El% and HV) were 180 MPa, 360MPa, % and 117.8HV, respectively, with increasing ratio 80%,135.3%, 300% and 43.4%, respectively, compared with as-cast alloy. The response surface model predicted corresponding values of the experimental values for mechanical properties at different working conditions. The response surface model highly emphasizes the practical trend or behavior for the mechanical properties.