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Fabrication of 5052Al/Al_2O_3 nanoceramic particle reinforced composite via friction stir processing route

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ABSTRACT

In this research, microstructure and mechanical properties of 5052Al/Al_2O_3 surface composite fabricated by friction stir processing (FSP) and effect of different FSP pass on these properties were investigated. Two series of samples with and without powder were friction stir processed by one to four passes. Tensile test was used to evaluate mechanical properties of the composites and FSP zones. Also, microstructural observations were carried out using optical and scanning electron microscopes. Results showed that grain size of the stir zone decreased with increasing of FSP pass and the composite fabricated by four passes had submicron mean grain size. Also, increase in the FSP pass caused uniform distribution of Al_2O_3 particles in the matrix and fabrication of nano-composite after four passes with mean cluster size of 70 nm. Tensile test results indicated that tensile and yield strengths were higher and elongation was lower for composites fabricated by three and four passes in comparison to the friction stir processed materials produced without powder in the similar conditions and all FSP samples had higher elongation than base metal. In the best conditions, tensile strength and elongation of base material improved to 118% and 165% in composite fabricated by four passes respectively.

1. Introduction

The strong demand for weight reduction in car and aircraft fabrication urges the optimization of the design of products employing low weight materials. Therefore, the replacement of conventional materials by lighter metals such as aluminum alloys is highly desirable. However, aluminum alloys are not sufficiently stiff or strong for many purposes and their reinforcement is necessary. Aluminum based metal matrix composites (Al-MMCs) are outstanding candidates for these applications owning to the high ductility of the matrix and the high strength of hard reinforcing phases. The attraction for such materials is also due to the very high specific modulus, strength to weight ratio, fatigue strength and wear resistance [1,2]. However dispersion of the reinforcements in a uniform manner in MMCs is a critical and difficult task. It should be pointed out that the existing processing techniques for fabrication of surface composites are based on liquid phase processing at high temperatures such as casting and plasma spraying. In these cases, it is hard to avoid the interfacial reaction between reinforcement and metal matrix and formation of some detrimental phases. Obviously, if processing of surface composite is carried out at temperatures below melting point of substrate, the problems mentioned above can be avoided. Recently, much attention has been paid to a new surface modification technique named friction stir processing [3–6]. FSP is a solid state processing technique to obtain a fine grained microstructure. This is carried out using the same approach as friction stir welding (FSW), in which a non-consumable rotating tool with a specially designed pin and shoulder is plunged into the interface between two plates to be joined and traversed along the line of the joint. Localize heat is produced by the friction between the rotating tool and the workpiece leading the local temperature of the material to rise. Also, the material is extruded around the tool before being forged by the large down pressure. During this process, the material undergoes intense plastic deformation resulting in significant grain refinement [7–9].

Though FSP has been basically advanced as a grain refinement technique, it is a very attractive process for also fabricating composites. Different procedures of applying reinforcement on substrate before performing FSP can be categorized as two main processes. The first results on the fabrication of surface metal matrix composite (SMMC) via FSP was reported by Mishra and Ma [9]. The reinforcements was added into a small amount of volatile solvent such as methanol and mixed, and applied to the surface of the plates, to form a thin reinforcement coating which was subsequently subjected to FSP. Non-uniformity and limitation of preplaced layer thickness are disadvantages of this method. The other alternative method is to cut one or more grooves along the FSP direction which are filled by reinforcing particles. Then, the FSP are conducted along the groove to produce a thick surface composite layer.

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