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Fabrication and Characterization of Aligned Carbon Nanotubes Cluster Reinforced Magnesium Composite Based On Ultrasound/Magnetic Compound Field

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Abstract

Carbon nanotubes (CNTs)-based materials have been the focus of intense research since their discovery because of their superior mechanical properties, good electrical conductivity and unique nano-effect of unique one dimensional nanostructures. Control and manipulation of the alignment of CNTs in the matrix can effectively affect the electrical, optical and mechanical properties of the composites. At present, there are many researches on the magnetic-field induced the alignment of CNTs in the polymer matrix, but less research on magnetic- field induced the alignment of CNTs in the metal matrix. In order to realize the alignment of CNTs in metal matrix, CNTs were firstly magnetically modified by electroless plating, and a uniform layer of cobalt nanoparticles was successfully plated on the surface of carbon nanotubes. For facilitating the macro-analysis of the different factors on the cobalt-carbon nanotubes directional effect, three kinds of matrixes (distilled water, vegetable oil and high viscosity glue) were used to simulate the magnesium alloy melt. The effects of ultrasonic, magnetic field and temperature on the Co coated CNTs dispersion and alignment in three kinds of matrix were studied by orthogonal test. It was found that the dispersion of CNTs was significantly affected by ultrasound and the alignment of CNTs affected by the magnetic field intensity. In this paper, the CNTs / Mg composites were prepared by liquid-state method and the wettability between CNTs and Mg alloy was improved by the modification of carbon nanotubes. Under the compound effect of ultrasonic and magnetic field, the alignment of the carbon nanotubes cluster in magnesium matrix composites was quantitatively characterized by Image J software. It is found that the Cobalt particles coated CNTs can respond well to magnetic field (typically 0.3–0.8T) .With the increase of magnetic field

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strength, CNTs show higher relative frequencies along the magnetic field direction. When the magnetic field strength was 0.8T, the relative frequencies within 20-50° was 0.7.This indicated that Co-CNTs can achieve obviously alignment in AZ91D alloy under a low magnetic field. In addition, the compressive specimens were prepared according to the optimum process parameters determined by the orthogonal test. The compressive properties of the composites parallel to and perpendicular to the direction of the magnetic field were studied. The results shown that the compressive strength of the Co-CNTs/Mg composites was obviously higher than that of the magnesium matrix and exhibited anisotropy due to directional aligned carbon nanotube.

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Keywords: Co-CNTs; Magnetic field; Ultrasound field; Alignment; Compressive strength; Anisotropy

1. Introduction

Since the discovery of carbon nanotubes (CNTs), there has been an increased interest in carbon nanotubes reinforced composites in both academic and industrial research laboratories [1-7]. The intense interest in these materials stems from the fact that carbon nanotubes have been considered as ideal reinforcements for composites due to excellent mechanical properties, good electrical and thermal conductivity. However, one important limitation for some potential applications of CNTs comes from the fact that randomly oriented nanotubes embedded in bulk samples have exhibited substantially lower characteristics than expected. To overcome this limitation, alignment of CNTs in the polymer matrix have been carried through extensive research [8, 9]. Especially in the magnetic field, the magnetic modified carbon nanotubes can be aligned in the polymer matrix, but the magnetic field response of the magnetic modified carbon nanotubes in the metal matrix has not been reported.

In this work, in order to achieve the orderly arrangement of carbon nanotubes in the magnesium matrix under the magnetic field (MF), an ultrasonic and magnetic field electromechanical integrated preparation device for carbon nanotubes reinforced magnesium matrix composites was designed and developed. The process parameters were optimized by orthogonal experiments. The orientation of carbon nanotubes in the magnesium matrix was preliminarily achieved. The alignment of the carbon nanotubes in the composites was quantitatively characterized by Image J software and the prepared samples were subjected to compression test. This work can provide a new route to realize the alignment of the reinforcements in the metal matrix composites.

2. Experimental details

2.1. Materials

Commercial AZ91D alloy was used as the matrix. The raw materials utilized were multi-walled carbon nanotubes (10 to 20 nm in diameter and approximately 30μm in length, purity > 95 wt.%, Chengdu Organic Chemicals Co. Ltd., Chinese Academy of Sciences, Chengdu, China). Co-coated multi-walled carbon nanotubes were used as reinforcements which were fabricated by electroless plating [10]. The distilled water, vegetable oil and high viscosity glue were used in the orthogonal test. A high-temperature petri dish with a diameter of 60 mm was used for the orthogonal test.

2.2. Experimental process

In order to analyze the influence of different factors on the orientation of cobalt coated carbon nanotubes and obtain the optimum process parameters for preparing aligned carbon nanotubes reinforced magnesium matrix composites. In this paper, three kinds of matrixes (distilled water, vegetable oil and high viscosity glue) were used to simulate the magnesium alloy melt and a L_{16} (4^5) orthogonal test was designed. In this experiment, the factors that influenced the distribution of carbon nanotubes in the matrix were: the magnetic field strength (A), the mass fraction (B), the temperature (C), the ultrasonic intensity (D), the ultrasonic time (E). Table 1 shows the factors and levels of orthogonal test. The experiment was carried out according to the parameters of Table 1, and the orientation degree of carbon nanotubes was characterized by Image J. The test results were processed by means of range analysis.