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Structural investigations of mechanical properties of Al based rapidly solidified alloys

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ABSTRACT

In this study, Al based Al–3 wt.%Fe, Al–3 wt.%Cu and Al–3 wt.%Ni alloys were prepared by conventional casting. They were further processed using the melt-spinning technique and characterized by the X-ray diffraction (XRD), scanning electron microscopy (SEM) together with energy dispersive spectroscopy (EDS), transmission electron microscope (TEM), differential scanning calorimetry (DSC) and the Vickers microhardness tester. The rapidly solidified (RS) binary alloys were composed of supersaturated α–Al solid solution and finely dispersed intermetallic phases. Experimental results showed that the mechanical properties of RS alloys were enhanced, which can be attributed to significant changes in the microstructure. RS samples were measured using a microhardness test device. The dependence of microhardness H_V on the solidification rate (V) was analysed. These results showed that with the increasing values of V, the values of H_V increased. The enthalpies of fusion for the same alloys were determined by DSC.

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1. Introduction

Metallurgists and materials scientists have been striving for several centuries to develop new materials which are stronger, stiffer, more ductile and lighter than existing materials which can be used at high temperatures. It is very important to develop structural materials that require less processing cost, and also to improve their properties as elevated temperature strength, density and stiffness. Improved properties can lead to weight reductions resulting in extended lifetime, fuel reduction, etc. The need for these improvements is of particular importance in developing structural aluminum alloys [1]. One way of achieving this objective is to use the rapid solidification processing method to synthesize the fine-grained microstructure and obtain a large fraction of phases in solidified condition. Among the rapid solidification techniques, the melt spinning is most commonly used method that can significantly modify the structure of materials [2]. Rapid solidification processing (RSP) involves exceptionally high rates of cooling (10^4–10^8 K/s) during solidification from the molten state. RS allows the synthesis of materials (powders, foils, scales, ribbons) with refined microstructures and extended solid solubility of their constituent elements. The result is materials with enhanced mechanical, physical and chemical properties compared with those that are conventionally processed [3]. The precipitation of a supersaturated solid solution in melt-spun alloys is usually accompanied by recrystallization, affecting aging microstructures and corresponding properties. The mutual actions between precipitation and recrystallization have been studied for steel, cooper, nickel and aluminum based alloys [4–8].

However, the use of aluminum has been restricted by its low degree of strength and poor corrosion resistance. Both properties can be enhanced by adding certain alloying elements. Iron, copper and nickel have been used to increase the surface hardness of aluminum based intermetallic alloys. These elements have a significant influence on the mechanical properties of the alloy. Similarly, an appropriate selection of the different processing stages can lead to a significant strengthening by grain size refinement and/or fine dispersion of hard second-phases.

The intermetallic compounds have long been recognized as potentially useful structural materials for high temperature applications [9]. The great interest in aluminum-based intermetallic systems is due to the important properties they process for potential technological applications, such as high melting temperature, comparatively low density, good oxidation resistance, increase in yield strength with increasing temperature and extreme hardness [10]. It is therefore important to refine the size and change the morphology of intermetallic compounds. They have been employed in the aerospace, mechanical, electro-chemical and environmental industries [11]. In this study, we used Al–3 wt.%Fe, Al–3 wt.%Cu and Al–3 wt.%Ni because it is known that the

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