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Short Communication

Microstructures and mechanical properties of directionally solidified Ti–45Al–8Nb–(W, B, Y) alloys

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ABSTRACT

Intermetallic Ti–45Al–8Nb–(W, B, Y) (at.%) alloys were directionally solidified at growth rates of 10–400 μm/s with a Bridgeman type apparatus. Microstructures and room temperature (RT) mechanical properties of the directionally solidified (DS) alloys were investigated. The microstructures with different segregation morphologies were observed at different growth rates. Fully lamellar (FL) microstructure evolves into a massive microstructure when the growth rate is up to 100 μm/s. Both the width of columnar grain and the interlamellar spacing decrease with increasing growth rate. Compressive properties were not proportional to the growth rates but closely related to the segregation morphologies. Only the DS alloy with columnar pattern of Al-segregation had tensile ductility. A better RT tensile plastic elongation level of 2% and yield strength 475 MPa were obtained at growth rate of 10 μm/s. Cracks propagated in transgranular mode predominantly. Larger elongated B2 particles produced in the interdendritic regions were detrimental to the tensile ductility of the DS alloy.

1. Introduction

TiAl based alloys are attractive candidates for high temperature structural applications for their low density, high stiffness, good oxidation resistance, high specific strength, and good creep resistance [1,2]. High Nb addition can significantly improve high temperature properties of TiAl based alloys [3–5]. However, room temperature (RT) ductility and workability are poor which restricts their widespread applications on turbine engines and aerial materials. There have been many investigations to obtain balanced mechanical properties for strength and ductility. One efficient approach is directional solidification (DS) technique which allows a close control of the microstructure and thus of the properties of the material.

Polysynthetically twinned crystals (PST) of TiAl alloys exhibit an excellent tensile elongation and even can be deformed to 50% reduction in thickness at RT [6–8]. However, it is difficulty to fabricate the PST in practice of engineering, even by the DS with a seeding technique. Complicated microstructures with unaligned lamellar colonies are usually formed during directional solidification and subsequent solid-state transformations of peritectic TiAl alloys. A few people are interested in the DS-TiAl alloy with unaligned lamellar microstructure. Actually, columnar lamellar colonies and segregation patterns can possibly bring a special benefit for the orientated ductility and workability of the DS alloy. Therefore, investigations on mechanical properties are essential for processing and potential applications of the DS-TiAl alloys with unaligned lamellar microstructures.

In this paper, DS Ti–45Al–8Nb–(W, B, Y) alloys with different segregation morphologies were fabricated at a series of withdrawal rates by using a Bridgeman type apparatus. RT compression tests parallel and perpendicular to the growth direction, and tensile tests along the growth direction were separately conducted. Fractography and microstructure after the tensile test were also observed. The segregation morphologies and columnar grains of the alloys directionally solidified at different growth rates and their effects on the RT mechanical properties were investigated. These results may help to optimize the unaligned lamellar microstructure and then improve RT workability and applicability of the DS-TiAl alloys.

2. Experimental procedure

The master bars of Ti–45Al–8Nb–(W, B, Y) (at.%) alloy, typically 6.5 mm in diameter and 100 mm in length, were cut from a plasma arc melting (PAM) ingot. The chemical composition of the ingot was Ti–45.27Al–8.39Nb–(W, B, Y) (at.%) and the oxygen content was less than 640 wt. ppm. The bars were placed into alumina crucibles that had been coated by Yttria. After heating-up and after a holding period of 15 min, DS experiments were carried out with a Bridgeman type apparatus under protection of 380 Pa high-purity argon. These bars were grown under a measured temperature gradient in liquid $G_L = 3.8 \times 10^3$ K/m, which was determined by a W-Re5/26 thermocouple, and at the withdrawal rates of 10, 20, 30, 50, 80, 100, 200 and 400 μm/s respectively. Triple bars were prepared

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