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Beta to alpha transformation kinetics and microstructure of Ti-6Al-4V alloy during continuous cooling

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HIGHLIGHTS

- The kinetics of the β → α phase transformation is investigated.
- An approach is proposed to adapt the KJMA model for continuous cooling.
- The model permits the determination of the kinetics parameters for each cooling rate.
- The growth of α_W plates may obey a combined displacive-diffusional growth mode.
- The growth involves shear mechanism and partitioning of vanadium between α_W plates.

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ABSTRACT

In the present paper, an approach based on the Kolmogorov-Johnson-Mehl-Avrami (KJMA) model has been developed and applied to study the transformation kinetics of the β phase in Ti-6Al-4V titanium alloy during cooling. To this purpose, Differential Scanning Calorimetry (DSC) tests have been conducted using a set of cooling rates ranging from 10 to 50 °C/min. This approach allows the kinetics parameters, particularly the activation energy, to be calculated from a single DSC test using a simple linear regression. The microstructural analysis indicates that the microstructure is dominated by the α Widmanstätten morphology (α_W). Microstructural observations along with the calculated values of the Avrami index and of the activation energy suggest that the growth of the α_W platelets obeys a mixed mode combining the vanadium diffusion and a displacive mechanism.

1. Introduction

Titanium and its alloys are broadly used in many structural applications such as aerospace, chemical and biomedical industries due to their outstanding properties (lightweight, high strength, corrosion resistance and excellent biocompatibility) [1–3]. They are characterized by an allotropic transformation in which high temperature stable β phase (bcc) transforms into low temperature stable α phase (hcp) during cooling. The transformation temperature is called beta transus (T_β) and is strongly influenced by the chemical composition of the alloy [4]. Controlled amounts of α, β stabilizing elements permit α and β phases to coexist at room temperature resulting in a two-phase system. Among α + β titanium alloys, Ti-6Al-4V is the most developed and tested alloy that offers a well-balanced property profile combining attractive properties with inherent workability.

The final microstructure and properties of this alloy are greatly influenced by thermochemical and thermomechanical processing [5,6]. Gil et al. [7] studied the effect of cooling from temperatures above the T_β on the microstructure of Ti-6Al-4V alloy and found that high cooling rates generate entirely martensitic microstructures. For slow cooling rates, they noticed that α phase nucleates within the β grains and, then, grows and coarsens in form of plates or needles. Ahmed and Rack [8] highlighted two morphologies of α phase nucleating during slow cooling rates from temperatures

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