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The superplasticity and microstructure evolution of TC11 titanium alloy

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ABSTRACT

The superplasticity is the capability of some metallic materials to exhibit very highly tensile elongation before failure. The superplastic tensile tests were carried out at various deformation conditions in this paper to investigate the superplastic behaviors and microstructure evolution of TC11 titanium alloy. The results indicate that the smaller the grain size, the better the superplasticity is, and the wider the superplastic temperature and strain rate is, in which the superplastic temperature is ranging from 1023 to 1223 K and the strain rate is ranging from 4.4×10^{-5} to 1.1×10^{-2} s^{-1}. The maximum tensile elongation is 1260% at the optimum deformation conditions (1173 K and 2.2×10^{-4} s^{-1}). For further enhancing the superplasticity of TC11 titanium alloy, the novel tensile method of maximum m superplastic deformation is adopted in the paper. Compared with the conventional tensile methods, the excellent superplasticity of TC11 titanium alloy has been found with its maximum elongation of 2300%.

1. Introduction

Titanium alloys have been widely used in the aerospace, automotive, chemical and bio-medical engineering due to their excellent properties, such as high strength to weight ratio, excellent resistance against corrosion and good high heat-durability [1]. However, it is difficult to form the complex geometry of parts under the conventional deformation conditions because of their high resistance of deformation in the forming process. Therefore, the applications of titanium alloys are limited to a certain extent.

Superplasticity refers to the capability of a polycrystalline material to exhibit very high tensile elongation before failure [2], which has been observed in several kinds of materials, such as metals (including titanium, aluminum, magnesium, iron and nickel-based alloys), ceramics (including monoliths and composites), intermetallics (including iron, nickel and titanium base) and laminates [3]. Superplastic deformation is characterized by low flow stress and the high uniformity of plastic flow, so superplastic forming shows promise as a main approach for producing light, complex-shaped parts in many industries, especially in aerospace industry [4,5]. In the past several years, a number of research efforts have been made to investigate the superplastic deformation process of titanium alloys. The microstructures evolution and superplastic properties have been reported for Ti–6Al–4V alloy [6–8], and the superplastic behaviors of titanium alloys have been investigated in some reports [9,10]. In addition, the ways and means for enhancing the superplasticity of titanium alloys are also extensively investigated. Sergueeva et al. processed Ti–6Al–4V alloy by severe plastic deformation and its superplasticity was enhanced greatly [11,12]. The ductility of commercially pure titanium alloy was increased by a two-step deformation method [13]. The superplasticity of titanium alloys was improved significantly by thermomechanical treatment [9,14] or additions of small amounts of hydrogen [15,16].

TC11 is a kind of two-phase titanium alloy, which consists of α phase (hexagonal close-packed, hcp) and β phase (body-centered cubic, bcc). It has been used to form turbine disk and blade of aeroengine due to its excellent thermal stability, moderate strength at room and high temperatures. The aim of the present work is to explore its superplastic behaviors and microstructure evolution in the superplastic deformation process, providing superplastic forming parameters for isothermal forging or superplastic isothermal forging.

2. Experimental material and procedures

TC11 titanium alloy used in the study was supplied by Beijing Institute of Aeronautical Materials. The chemical compositions of as-received TC11 titanium alloy are shown in Table 1. The β-transus temperature is about 1281 K with the quantitative metallography technique. The coarse microstructure of as-received TC11 titanium alloy is shown in Fig. 1a, in which the grain size is about 100 μm. A fine and equiaxed microstructure is desirable for the superplasticity [10–12]. In order to obtain a fine and equiaxed microstructure, the three-dimensional upsetting and cogging was applied to deform TC11 titanium alloy uniformly in three directions, *X*, *Y*, *Z*, reiteratively. The billets were forged in the β

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