Microstructure and damage evolution of Ti6Al4V under fast forming conditions

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Abstract. The paper aims to investigate the nature of fracture behaviour through the microstructural and damage evolution analysis of a titanium alloy (Ti6Al4V) with tailored initial microstructures under FAST conditions. High-temperature uniaxial tensile tests with varying heating rates (4°C/s and 100°C/s) and temperatures (900 - 950°C) were conducted to study the effects of heating parameters on the formability and damage of the material. The microstructure and fracture morphology after high-temperature uniaxial tensile tests were characterised to reveal the evolution mechanisms of elongation and damage. It was found, that fast heating could restrain the phase transformation of α to β during the heating and therefore improve the formability of the Ti6Al4V titanium alloy under hot stamping condition.

Key words: Ti6Al4V, hot stamping, fracture behaviour, damage evolution

Introduction

Titanium alloys have become more popular in many industries due to their superior mechanical properties. One of the most used titanium alloys is Ti-6Al-4V (also called TC4), contributing to more than 50% of all titanium alloys usage. This is because its properties can be altered by producing a desired combination of HCP structure and BCC structure, as it experiences an allotropic transformation at elevated transformation [1]. A narrow hot stamping processing windows has been identified to Ti-6Al-4V for hot stamping process under the strain rates of 0.1 – 5 s^{-1} [2]. It was found, that surface cracks and springback occurred for m-shaped parts at the heating temperature up to 600ºC. On the other hand, the reduced formability was observed for the heating temperature above 900ºC due to excessive α to β phase transformation. Therefore, Fast light Alloy Stamping Technology (FAST) has been proposed for titanium sheet processing for its the precise phase transformation control. It should be mentioned that, ultra-fast heating of a dual-phase Ti alloy with tailored initial microstructure has led to over 30% improvement in ductility and approximately 25% reduction in flow stress [3].

Results

The effect of heating history on the formability of TC4 alloy under slow and fast heating conditions was studied through non-isothermal tensile tests using Gleeble 3800. The samples were heated to different temperature (900ºC / 950ºC) with different heating rates (4°C/s / 100°C/s), cooled to 700ºC after reaching the target temperature with or without soaking time, and subsequently stretched to failure with a constant strain rate of 1 s^{-1} (Fig.1a). The obvious differences in material elongation was found while using two different heating conditions. It was found, that fast heating could significantly enhance the elongation of material.

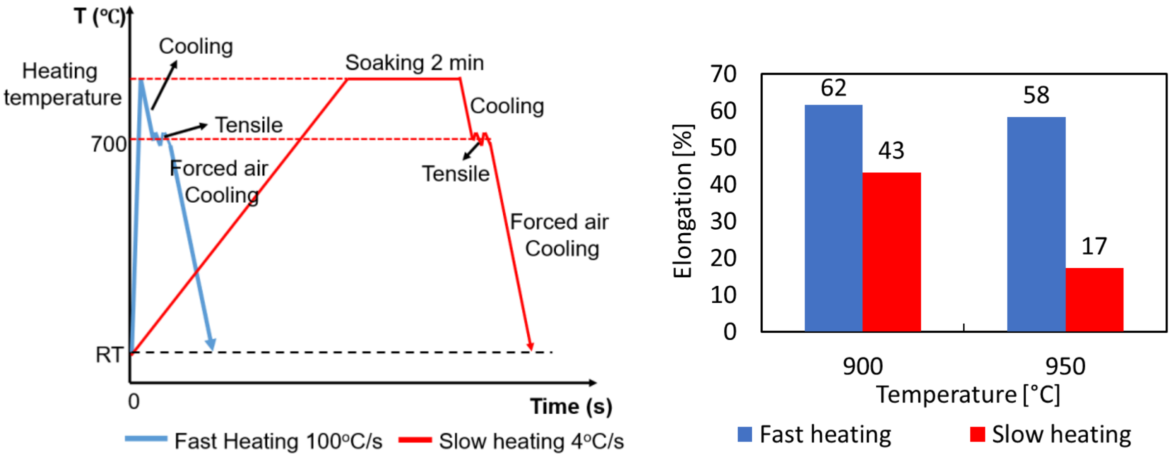

Fig. 1. Non-isothermal tensile tests program (a); effect of heating temperature on elongation (b).

The microstructural analysis of material subjected to slow heating at 950ºC show that fracture region was found to contain mainly β phase thus limited elongation was observed (Fig.2a). During exposure to fast heating conditions, the fracture region was characterised by microstructure determined by target, heating temperature with relatively low volume fraction of β phase (Fig.2b). The fracture area of material heated to 900ºC at slow heating conditions was significantly reduced in comparison to that at 950ºC (Fig.2c). The same tendency for unchanged microstructure was found for titanium alloy subjected to fast heating to 900ºC (Fig.2d).

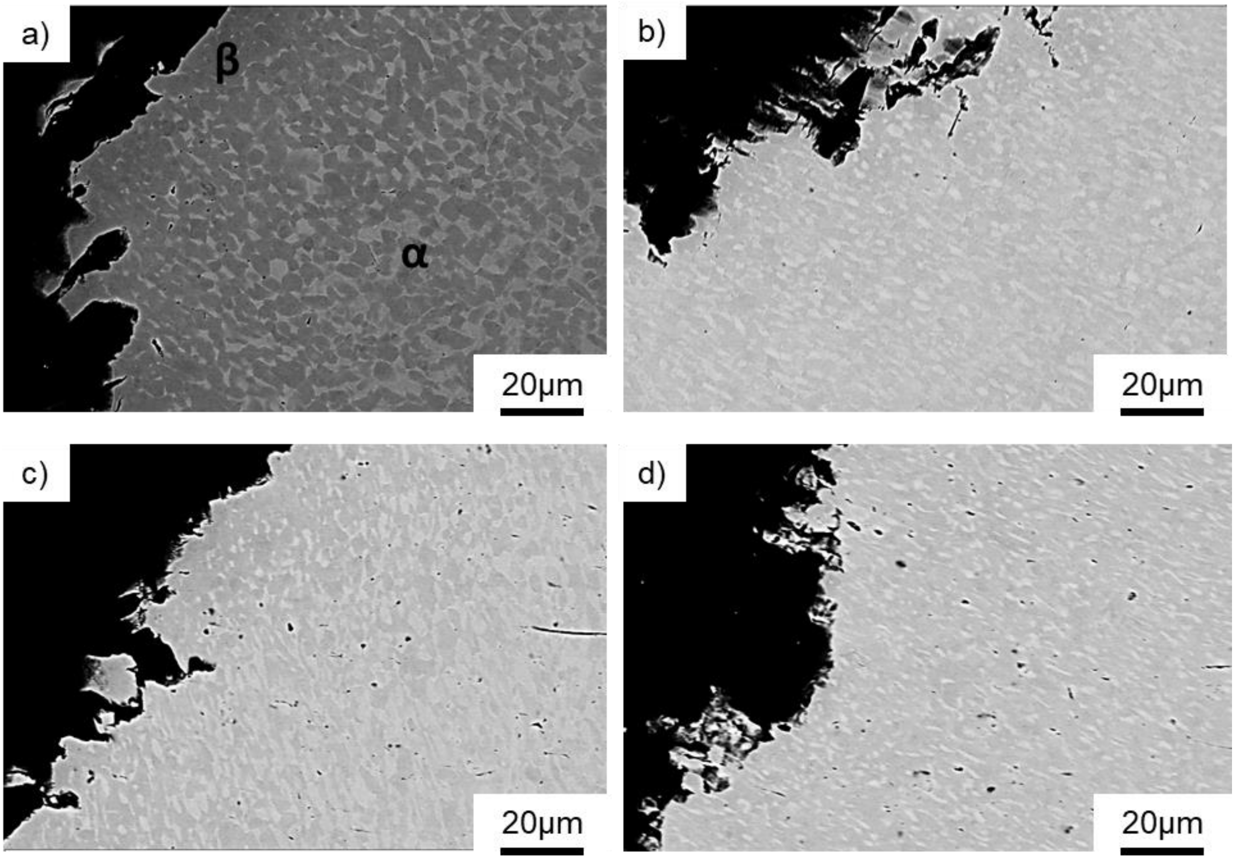

Fig. 2. Fracture area of material subjected to 950ºC using slow heating (a) and fast heating (b) conditions; and material subjected to 900ºC using slow heating (c) and fast heating (d) conditions.

Conclusion

It was found that microstructure of Ti6Al4V alloy was mainly determined by heating conditions. The fast heating could restrain the phase transformation of α to β during the heating stage and therefore improve the formability of the Ti6Al4V titanium alloy under hot stamping condition.

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