

Notched tensile strength of SP-700 laser welds

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Abstract

Notched tensile tests were performed to evaluate the influence of post-weld heat treatments (PWHTs) on the notched tensile strength (NTS) of two $\alpha + \beta$ titanium alloy welds. The results indicated that SP-700 laser welds were notch brittle unless a high PWHT temperature, e.g. 760 °C, was applied. The lowest NTS was associated with the peak-aged weld, which was aged at 482 °C for 1 h. In contrast, Ti-6Al-4V welds did not exhibit notch sensitivity in the as-welded or in the PWHT conditions. The reduced plasticity due to the strengthening of fine α in the β matrix account for the observed notch brittleness of the SP-700 laser welds. Increasing the PWHT temperature associated with coarsening the $\alpha + \beta$ structure reduced the notch sensitivity of SP-700 laser welds.

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1. Introduction

SP-700, an $\alpha + \beta$ titanium alloy with a nominal chemical composition (wt.%) of Ti-4.5Al-3V-2Fe-2Mo, is designed to improve superplastic formability and lower the operating temperature as compared to Ti-6Al-4V alloy [1]. SP-700 exhibits superplasticity at about 700 °C, whereas the conventional Ti-6Al-4V shows superplasticity at approximately 900 °C [2,3]. As a result, the production cost of SP-700 alloy can be reduced significantly by lowering the operation temperature. In addition, SP-700 alloy offers several advantages over Ti-6Al-4V including higher hardenability, faster age-hardening response, and superior mechanical properties [2–6].

Laser welding is a mature technology and has become of great interest in various industries for precision welds. Nowadays, laser welding is used extensively owing to the ease of automation and improved product quality [7,8]. In the open literatures, rather few works have studied the mechanical properties of titanium welds, in particular this SP-700 alloy. This study focused on the notched tensile strength (NTS) of SP-700 laser welds which were post-weld heat-treated at various temperatures. The NTS results and

the microstructures of the welded SP-700 specimens were also compared to those of Ti-6Al-4V welds.

2. Material and experimental procedures

Two $\alpha + \beta$ titanium alloy sheets, were used in this investigation: SP-700 (3.4 mm), with an alloy composition (wt.%) of 4.70 Al; 2.45 V; 2.15 Fe and 1.82 Mo; and Ti-6Al-4V

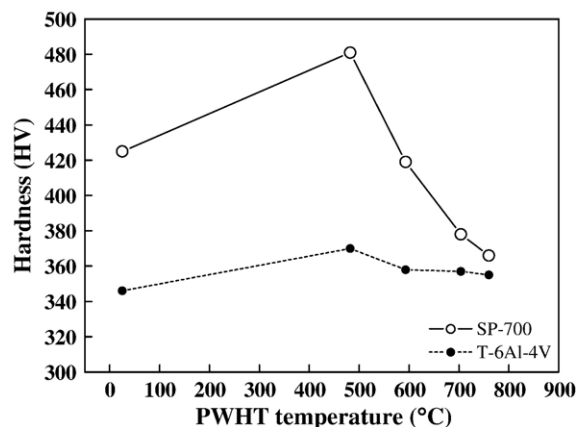


Fig. 1. Micro-hardness in the weld metal of SP-700 and Ti-6Al-4V welds at various post-weld heat treatment (PWHT) temperatures.

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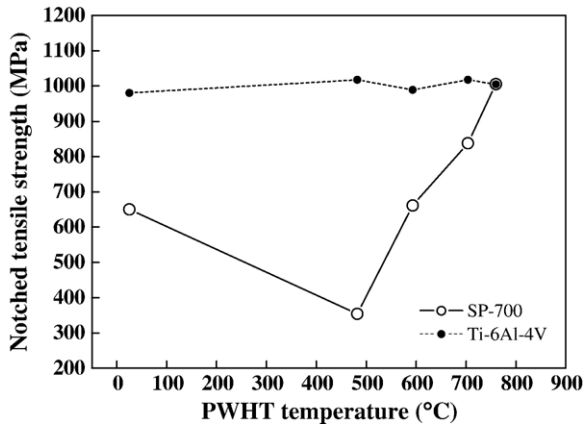


Fig. 2. The influence of post-weld heat treatment (PWHT) temperatures on the notched tensile strength (NTS) of laser welds.

(4.0 mm) with 6.20 Al; 4.22 V and 0.14 Fe. The microstructure of as-received SP-700 and Ti-6Al-4V sheets in the mill-annealed condition consisted of β distributed in the elongated α -grain boundaries. The major difference between these two alloys was that SP-700 contained more β than Ti-6Al-4V. The micro-hardness of the as-received alloys was approximately HV 340 for SP-700 and HV 360 for Ti-6Al-4V. Tensile properties of the two mill-annealed alloys were similar, and typically had an ultimate tensile strength of 970 MPa, yield strength of 940 MPa and 18% elongation. The materials exhibited a low anisotropy with respect to the rolling direction.

All specimens were welded in the mill-annealed condition with the welding direction normal to the rolling direction. A Rofin-Sinar RS 850 CO₂ laser was utilized for bead-on-plate welding of titanium specimens in one pass. The processing parameters (laser power and travel speed) were 2.7 kW and

1000 mm/min for SP-700, but 3.2 kW and 800 mm/min for Ti-6Al-4V. The accuracy of the moving table was within ± 0.1 mm/min for the specified travel speeds. Post-weld heat treatments (PWHTs) were performed on the welds in the temperature range of 482–760 °C (900–1400 °F) for 1 h under vacuum, followed by Ar-assisted cooling to room temperature. Double-edge notch specimens with the notches located at the weld metal, which were ground smooth prior to tests, were used in this study [9]. Notched tensile tests were performed in air at a constant displacement rate of 1.0 mm/min and the results were the average of at least three specimens for each testing condition. The dependence of PWHT temperatures on the NTS of laser welds was evaluated. In addition, the correlation between microstructures and the fracture characteristics of notched tensile specimens was examined.

3. Results and discussion

Fig. 1 shows the variation of micro-hardness with PWHT temperatures in the weld metal of the SP-700 and Ti-6Al-4V laser welds. The results indicated that the weld metal of SP-700 alloy was

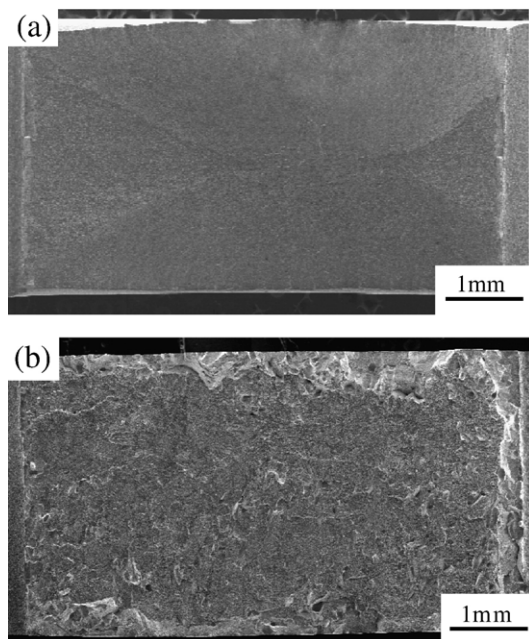


Fig. 3. Macroscopic fracture appearance of SP-700 specimens after notched tensile tests: (a) mill-annealed material; and (b) 482 °C-aged weld.

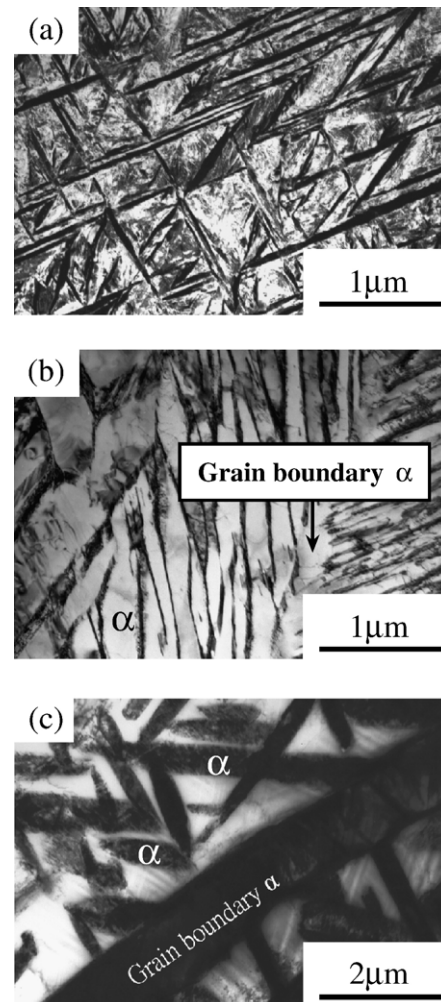


Fig. 4. TEM photographs showing the microstructures in the weld metal: (a) as-welded SP-700; (b) as-welded Ti-6Al-4V; and (c) 760 °C-aged SP-700 specimens.

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