ELSEVIER Science Press

Trans. Nonferrous Met. Soc. China 19(2009) s429−s433

Transactions of Nonferrous Metals Society of China

www.tnmsc.cn

Superplastic formability of Ti-6Al-4V butt-welded plate by laser beam welding

WANG Gang(王 刚), ZHANG Wen-cong(张文丛), ZHANG Gong-lei(张功磊), XU Zhi-liang(徐志良)

School of Materials Science and Engineering, Harbin Institute of Technology at Weihai, Weihai 264209, China

Received 10 June 2009; accepted 15 August 2009

Abstract: The superplasticity of Ti-6Al-4V butt-welded plates by laser beam welding (LBW) was studied in virtue of hot tensile tests and superplastic bulging tests. Furthermore, microstructural evolution of weld metal upon superplastic forming was systematically analyzed via metallographical tests and scanning electron microscope (SEM). The relation between the microstructure of weld metal and its superplastic ability was discussed. The experimental results show that Ti-6Al-4V butt-welded plates by LBW possess superplasticity. The maximum elongation is up to 154% and the maximum bulge height can be up to 1.81 times the internal radius of the female die. There is an optimum value of the bulge height for bulging gas pressure.

Key words: superplastic forming; Ti-6Al-4V; laser beam welding

1 Introduction

Ti-6Al-4V alloy is a dual phase alloys consisting of α and β phases. It has good mechanical properties, excellent corrosion resistance, outstanding specific strength and good superplastic ability. Thus it is widely used in the fields of aerospace, chemical engineering and navigation[1−2]. The superplastic forming (SPF) of plate has been utilized widely.

In some cases, such as manufacturing expansion bellows made of titanium alloy and large diameter thin-walled structure, the butt-welded plates and tube blanks are needed for superplastic forming[3−5]. High energy beam welding methods has been developed due to their finer weld metal microstructure and better plasticity[6−7].

Laser beam welding (LBW) is especially suitable to weld titanium alloy due to its excellent protection. The microstructure and mechanical properties for weld metal of Ti-6Al-4V by LBW have been studied[8−10]. However, few attentions focus on their superplastic formability[11−13].

In this work, the superplasticity of Ti-6Al-4V butt-welded plate by LBW was investigated by hot tensile tests and superplastic bulging tests.

2 Experimental

2.1 Experimental materials

Two kinds of mill-annealed Ti-6Al-4V plates were used as the experimental materials for hot tensile test and bulging test. The thickness of samples is 0.8 mm and 1.0 mm, respectively. The original microstructures are $\alpha+\beta$ equaled grain.

2.2 Experimental method

Pairs of mill-annealed plates with 130 mm×20 mm×0.8 mm and 125 mm×62.5 mm×1.0 mm were welded. The welding specimens were machined and thoroughly cleaned with a wire brush and emery paper, and then degreased with acetone prior to LBW. The welding parameters are shown in Table 1. The welding direction was perpendicular to rolling direction. All welded specimens were visually inspected and tested with dye penetrant for surface defects. They were also radiographed for internal soundness. As a result, superplastic forming specimens were prepared.

In order to investigate yield strength and elongation of weld metal, hot tensile tests were performed at 925 ℃ with different strain rates using Ti-6Al-4V butt-welded plate by LBW. The tensile specimens were removed

Foundation item: Project(50775052) supported by the National Natural Science Foundation of China
Corresponding author: WANG Gang; Tel: +86-631-5687324; E-mail: wg@hitwh.edu.cn

Table 1 Welding parameters

Sample type	Frequency/Hz	Power/W	Pulse width/ms	Welding velocity/(mm·min^{-1})	Fusion zone width/mm
Bulging sample	32	1 600	30	120−240	1.51−1.91
Hot tensile sample	−	1 300	−	110	1.80−1.82

from butt-welded plate using a wire cutting machine and edges were polished with emery paper. Tensile tests were performed using a SHIMADZU AG-1 250 kN tester with strain rates of 1.11×10^{-4}, 2.22×10^{-4} and 3.33×10^{-4} s^{-1}. The orientations of the tensile specimens taken from welded test pieces are shown in Fig.1. The specimens were 15 mm in gauge length and 6 mm in width. To measure the strain rate sensitivity index(m) of weld metal, velocity jump tests were performed by sudden increase of crosshead speed, i.e. 1 mm/min to 2 mm/min and then from 2 mm/min to 4 mm/min.

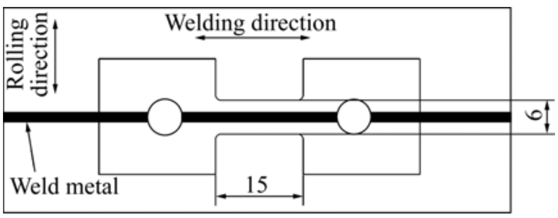

Fig.1 Schematic of sample fabrication (Unit: mm)

Superplastic gas pressure bulging tests were carried out using a 500 kN superplastic forming machine with a 18 kW furnace in Harbin Institute of Technology (HIT). Its schematic diagram is shown in Fig.2. The dies are composed of an air-in plate and a female die. The dimensions of female die are 75 mm in internal diameter and 40 mm in height. The maximum bulge height after rupture was considered the mark for superplastic bulging capacity.

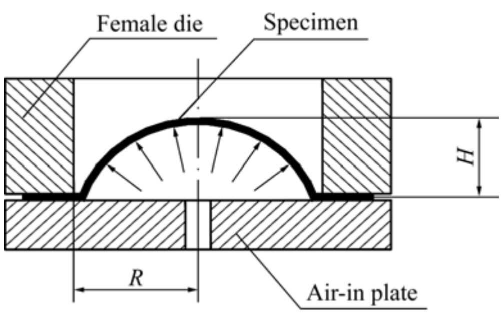

Fig.2 Schematic diagram of superplastic bulging test

Firstly, specimens were heated up to 180 ℃ and held for 10 min, and taken from furnace to paint high temperature antioxidant. And then specimens were put into dies and removed into furnace to heat up to 925 ℃, which is the optimum superplastic forming temperature for Ti-6Al-4V alloy. The furnace was sealed by load and held for 30 min. Finally, the inflated argon was input into specimens to bulge until burst.

The microscopic specimens of weld metal were cut from post-weld line, undeformed weld metal and deformed weld metal with different thinning rates. Specimens were ground, polished and etched using etchants with following chemical composition: 10%HNO_3+2%HF+88%H_2O (volume fraction). The microscopic specimens were examined using an optical microscope BH2UMA.

3 Results and discussion

3.1 Test results

The hot tensile experimental results show that the elongations of weld metal are between 101% and 154% and their yield strengths are between 21.5 and 34.4 MPa. Fig.3 depicts the effect of strain rate on the elongation of weld metal. It represents that the elongation increases with the decrease of strain rate. When the strain rate decreased to one third of the original one, the elongation increased by about 50% and the yield strength decreased by about 35%.

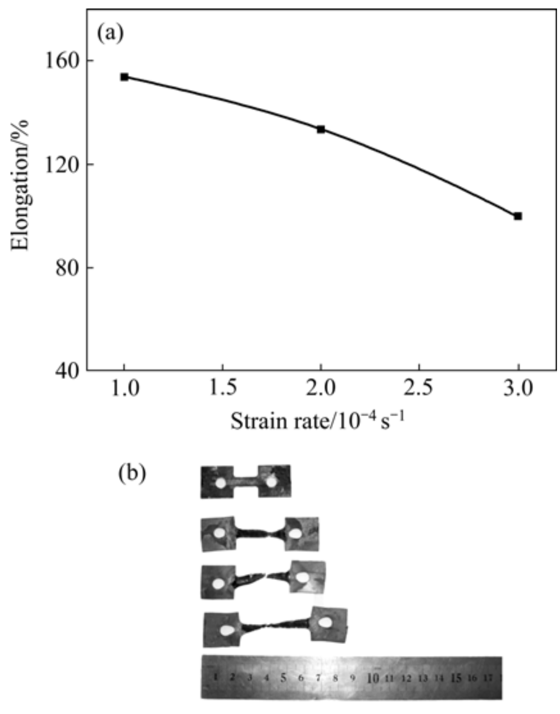

Fig.3 Effect of strain rate on elongation: (a) Relationship between strain rate and elongation; (b) Tensile samples