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ScienceDirect
Materials and Design 29 (2008) 1359–1363
Materials & Design
www.elsevier.com/locate/matdes

Effect of pulsed gas tungsten arc welding on corrosion behavior of Ti–6Al–4V titanium alloy

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Received 20 February 2007; accepted 26 June 2007
Available online 13 July 2007

Abstract

Due to the excellent combination of properties such as elevated strength-to-weight ratio, high toughness and excellent resistance to corrosion, make titanium alloys attractive for many industrial applications. Advantages of pulsed current welding frequently reported in literature include refinement of fusion zone grain size, etc. Hence, in this investigation an attempt has been made to study the effect of pulsed current Gas Tungsten Arc (GTA) welding parameters on corrosion behavior of Ti–6Al–4V titanium alloy. Pulsed current gas tungsten arc welding was used to fabricate the joints. To optimize the number of experiments to be performed, central composite design was used. The investigation revealed increase in corrosion resistance with increase in peak current and pulse frequency up to an optimum value of the same and decrease in corrosion resistance beyond that optimum point. An increase in corrosion resistance with grain refinement was also detected.

Keywords: Pulsed current; Gas tungsten arc welding; Titanium alloy; Corrosion rate

1. Introduction

Localized corrosion, which usually appears as pitting or crevice is a multi-step process. It is generally accepted that the following four steps are involved in localized corrosion: (i) adsorption of the reactive anion on the oxide covered titanium; (ii) chemical reaction of the adsorbed anion with the titanium ion in the titanium oxide lattice or the precipitated titanium hydroxide; (iii) thinning of the oxide by dissolution; and (iv) direct attack of the exposed metal by the anion perhaps assisted by an anodic potential. This is some times called pitting propagation [1–3].

Because of their high chemical activity, titanium alloys are easy to absorb harmful gas and many problems such as low mechanical properties and unstable structure would result [4–6], hence Gas Tungsten Arc Welding (GTAW) is a usually preferred method. The drive to improve the weld quality associated with improvement in process parameters demands the use of improved welding techniques and materials. Unfortunately, welding of titanium alloy leads to grain coarsening at the fusion zone and heat affected zone (HAZ) [7,8]. Weld fusion zones typically exhibit coarse columnar grains because of the prevailing thermal conditions during weld metal solidification [8].

Ti–6Al–4V also have excellent specific tensile and corrosion resistance, mainly used for aircraft structural and engine parts, material for petrochemical plants and surgical implants. It has been reported that pulsed current variation results in grain refinement in mild steel, stainless steel, aluminium alloys and titanium alloys [9–11]. However, reported research work on relating the pulsed current parameters and fusion zone microstructure and corrosion behavior are very scanty.

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doi:10.1016/j.matdes.2007.06.009

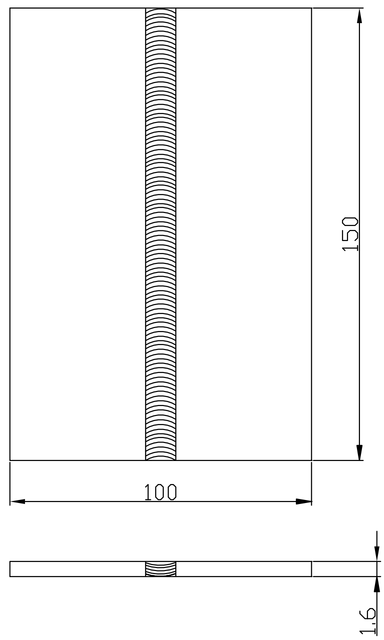

Fig. 1. Dimensions of joint configuration.

Table 1
Important factors and their levels

Coded levels	Peak current *P* (A)	Base current *B* (A)	Pulse frequency *F* (Hz)	Pulse on time *T* (s) (%)
−2	60	20	0	35
−1	70	30	3	40
0	80	40	6	45
1	90	50	9	50
2	100	60	12	55

Table 2
Chemical composition (wt%) of the base metal

Elements	Al	V	C	Fe	O	N	H	Ti
% by weight	6.3	4	0.006	0.17	0.166	0.006	0.002	Balance

Table 3
Mechanical properties of base metal

Ultimate tensile strength (MPa)	Notch tensile strength (MPa)	Yield strength (MPa)	Elongation (%)	Vicker's hardness (0.5 kg)	Charpy impact test (J)
998	1146	910	10	320	18

2. Methodology

2.1. Material and welding

The predominant factors which are having greater influence on fusion zone grain refinement of pulsed current GTA welding process have been identified from the literature survey [12–15]. They are peak current, background current, pulse frequency and pulse on time. The mill annealed sheets of Ti–6Al–4V titanium alloy were cut into the required sizes ($100 \times 150 \times 1.6$ mm). Square butt joint configuration, as shown in Fig. 1 was prepared to fabricate autogenous pulsed current GTAW joints. The initial joint configuration was obtained by securing the plates in position using tack welding. Since the plate thickness is 1.6 mm, the single pass welding procedure has been followed to fabricate all the joints. All necessary care was taken to avoid joint distortion and the joints were made after securing the plates with suitable clamps.

Large number of trial runs has been carried out using 1.6 mm thick sheets of titanium (Ti–6Al–4V) alloy to find out the feasible working limits of pulsed current GTA welding parameters. Different combinations of pulsed current parameters have been used to carry out the trial runs. The bead contour, bead appearance and weld quality have been inspected to identify the working limits of the welding parameters given in Table 1. Further details of observations made on trial runs and mathematical modeling are given elsewhere [15].

2.2. Conduct of the experiments

The base metal used in this investigation is a high strength titanium alloy of Ti–6Al–4V grade. By considering all of the above conditions, the feasible limits of the parameters have been chosen in such a way that the Ti–6Al–4V alloy should be welded without any weld defects. Due to a wide range of factors, it was decided to use four factors, five levels, rotatable central composite design matrix to optimize the number of experiments. The chemical composition of the base metal was obtained using a vacuum spectrometer (ARL-Model: 3460). Sparks were

(a) Potentiostat (b) Set up

Fig. 2. Photographs of potentiostat used for corrosion test.