Available online at www.sciencedirect.com

ScienceDirect

Materials and Design 29 (2008) 92–97

Materials & Design

www.elsevier.com/locate/matdes

# Developing mathematical models to predict tensile properties of pulsed current gas tungsten arc welded Ti–6Al–4V alloy

M. Balasubramanian [a,*], V. Jayabalan [b], V. Balasubramanian [c]

[a] Department of Production Engineering, Sathyabama University, Old Mamallapuram Road, Chennai 600 119, India
[b] Department of Manufacturing Engineering, Anna University, Guindy, Chennai 600 025, India
[c] Department of Manufacturing Engineering, Annamalai University, Annamalai Nagar 608 002, India

Received 4 April 2006; accepted 1 December 2006
Available online 21 December 2006

## Abstract

Titanium (Ti–6Al–4V) alloy has gathered wide acceptance in the fabrication of light weight structures requiring a high strength-to-weight ratio, such as transportable bridge girders, military vehicles, road tankers and railway transport systems. The preferred welding process of titanium alloy is frequently gas tungsten arc (GTA) welding due to its comparatively easier applicability and better economy. In the case of single pass GTA welding of thinner section of this alloy, the pulsed current has been found beneficial due to its advantages over the conventional continuous current process. Many considerations come into the picture and one need to carefully balance various pulse current parameters to arrive at an optimum combination. Hence, in this investigation an attempt has been made to develop mathematical models to predict tensile properties of pulsed current GTA welded titanium alloy weldments. Four factors, five level, central composite, rotatable design matrix is used to optimise the required number of experiments. The mathematical models have been developed by response surface method (RSM). The adequacy of the models has been checked by ANOVA technique. By using the developed mathematical models, the tensile properties of the joints can be predicted with 99% confidence level.

© 2006 Elsevier Ltd. All rights reserved.

*Keywords:* Pulsed current; Gas tungsten arc welding; Design of experiments

## 1. Introduction

Titanium and its alloys have been considered as one of the best engineering metals for industrial applications [1]. Ti–6Al–4V have excellent specific tensile and fatigue strengths and corrosion resistance, mainly used for aircraft structural and engine parts, material for petrochemical plants and surgical implants [2]. This is due to the excellent combination of properties such as elevated strength-to-weight ratio, toughness and excellent resistance to corrosion make them attractive for many industrial applications. However, welding of titanium alloy leads to grain coarsening at the fusion zone and heat affected zone (HAZ) [3]. Weld fusion zones typically exhibit coarse columnar grains because of the prevailing thermal conditions during weld metal solidification. This often results in inferior weld mechanical properties and poor resistance to hot cracking. It is thus highly desirable to control solidification structure in welds and such control is often very difficult because of higher temperatures and higher thermal gradients in welds in relation to castings and the epitaxial nature of the growth process. Nevertheless, several methods for refining weld fusion zones have been tried with some success in the past: inoculation with heterogeneous nucleants [4], microcooler additions, and surface nucleation induced by gas impingement and introduction of physical disturbance through techniques such as torch vibration [5].

In this process, two relatively new techniques namely, magnetic arc oscillation and current pulsing, have gained

---

* Corresponding author. Tel.: +91 44 25026503; fax: +91 44 24819579.
*E-mail addresses:* manianmb@rediffmail.com (M. Balasubramanian), jbalan@annauniv.edu (V. Jayabalan), visvabalu@yahoo.com (V. Balasubramanian).

0261-3069/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.matdes.2006.12.001

wide popularity because of their striking promise and the relative ease with which these techniques can be applied to actual industrial situations with only minor modifications of the existing welding equipment [6,7].

Pulsed current gas tungsten arc (PCGTA) welding, developed in 1950s, is a variation of GTA welding which involves cycling of the welding current from a high level to a low level at a selected regular frequency. The high level of the peak current is generally selected to give adequate penetration and bead contour, while the low level of the background current is set at a level sufficient to maintain a stable arc. This permits arc energy to be used efficiently to fuse a spot of controlled dimensions in a short time producing the weld as a series of overlapping nuggets and limits the wastage of heat by conduction into the adjacent parent material as in normal constant current welding. In contrast to constant current welding, the fact that heat energy required to melt the base material is supplied only during peak current pulses for brief intervals of time allows the heat to dissipate into the base material leading to a narrower heat affected zone (HAZ). The technique has secured a niche for itself in specific applications such as in welding of root passes of tubes, and in welding thin sheets, where precise control over penetration and heat input are required to avoid burn through [7].

Extensive research has been performed in this process and reported advantages include improved bead contour, greater tolerance to heat sink variations, lower heat input requirements, reduced residual stresses and distortion. All these factors will help in improving mechanical properties. Current pulsing has been used by several investigators to obtain grain refinement in weld fusion zones and improvement in weld mechanical properties [8]. However, reported research work on relating the pulsed current parameters and mechanical properties are very scanty. Moreover, no systematic study has been reported so far to correlate the pulsed current parameters and mechanical properties. Metallurgical advantages of pulsed current welding frequently reported in the literature include refinement of fusion zone grain size and substructure, reduced width of HAZ, control of segregation, etc., [5]. Statistical tools have been used by many investigators [9–11], which has gained wide acceptance.

Hence, in this investigation an attempt has been made to develop mathematical models to predict the tensile properties of pulsed current GTA welded titanium alloy using statistical tools such as design of experiments, analysis of variance and regression analysis.

## 2. Scheme of investigation

In order to achieve the desired aim, the present investigation has been planned in the following sequence:

(i) Identifying the important pulsed current GTA welding parameters that which are having influence on fusion zone grain refinement and tensile properties.
(ii) Finding the upper and lower limits of the identified parameters.
(iii) Developing the experimental design matrix.
(iv) Conducting the experiments as per the design matrix.
(v) Recording the responses.
(vi) Identifying the significant factors.
(vii) Developing the mathematical models.
(viii) Checking the adequacy of the developed models.

### 2.1. Identifying the important parameters

From the literatures [5–8] and the previous work [9–11] done in our laboratory, the predominant factors which are having greater influence on fusion zone grain refinement of pulsed current GTA welding process have been identified. They are (i) peak current, (ii) background current, (iii) pulse frequency and (iv) pulse on time.

### 2.2. Finding the working limits of the parameters

A large number of trial runs have 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 under the welding conditions specified in Table 1. Different combinations of pulsed current parameters have been used to carryout the trial runs. The bead contour, bead appearance and weld quality have been inspected to identify the working limits of the welding parameters. From the above analysis following observations have been made:

(i) If the peak current is less than 60 A, then incomplete penetration and lack of fusion was observed. At the same time, if the peak current is greater than 100 A, spatter was observed on the weld bead surface.
(ii) If the background current is lower than 20 A, the arc length is found to be very short. On the other hand, if the background current is greater than 60 A, then arc becomes unstable and arc wandering is observed due to increased arc length.

Table 1
Welding conditions

| Power source | Lincoln, USA |
|---|---|
| Polarity | AC |
| Welding current | 60–100 A pulsed current |
| Arc voltage | 22 V |
| Electrode | W + 2% thoriated (alloy) |
| Electrode diameter | 2.5 mm |
| Shielding gas | Argon |
| Gas flow rate | 10 l/min |
| Torch position | Vertical |
| Operation | Automatic |
| Welding speed | 300 mm/min |

Download English Version:

https://daneshyari.com/en/article/833235

Download Persian Version:

https://daneshyari.com/article/833235

Daneshyari.com