A STUDY ON WELD QUALITY CHARACTERISTICS OF PLASMA

ARC WELDING OF HASTELLOY C-276 SHEETS

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ABSTRACT

Plasma Arc Welding plays a vital role in attaining good weld quality in various engineering applications. The main objective of the present work is to optimize the parameter window for welding of Hastelloy c-276 of small thickness using plasma arc welding. Also, the paper focuses on studying the influence of various Plasma Arc Welding process parameters like welding current, welding speed, plasma gas flow rate, shielding gas flow rate on the weld quality characteristics like weld pool geometry, hardness etc. The results reveal that welding current and welding speed will affect the weld geometry more rather than the plasma as well as shielding gas flow rate also due to the grain refinement has taken place in weld fusion zone the hardness of the weldment also seems to be increased along with that improvement in weld quality characteristics have been observed.

KEYWORDS: PAW, Micro Hardness, Morphology & Hastelloy

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INTRODUCTION

Corrosion-Resistant HASTELLOY C-276 is widely used by the chemical processing industries. It is Nickel Based Super Alloy. The alloying elements are Cr, Mo, Fe, and W since it has a high chromium content it exhibits outstanding resistance to pitting and crevices corrosion this promotes the use of Hastelloy in chemical processing industries. The need for reliable performance leads to the acceptance and growth of Hastelloy in the areas of energy, health and environmental, oil and gas, pharmaceutical and flue gas desulfurization industries. M. J. Cieslak, et., al [1] described the welding metallurgy (solidification and solid-state transformations) of HASTELLOY Alloys C-4, C-22, and C-276. Hot-cracking tests performed on commercial alloys revealed a weld ability ranking as follows: C-4 > C-22 > C-276. All alloys would be expected to have good weld ability also they reported that in alloy c-276 is a combination of p and u phases. Also, Hastelloy C-276™ has been used as a substrate material for fabricating superconducting tapes J. Lu, et., al[2]also they reported that the hardness of the MZ is found to be 35% higher compared to an as-received alloy. Akhilesh Kumar Yadav [3] He pointed out the research trends In the field of Hastelloy in recent days, Hastelloy is the most corrosion resistant alloy available and has outstanding localized corrosion resistance, excellent stress corrosion cracking resistance. So that it found wide application and also noticed that only lesswork was done in welding thin Hastelloy sheets using plasma welding techniques. Dongsheng Chai et., al [4]conducted experiments on 0.5-mm-thick Hastelloy C-276 thin sheet via pulsed laser beam welding machine with filler wire and also investigated the effects of the pulse parameters on the weld bead geometry and microstructure and reported that it is difficult to perform laser beam welding by varying the pulse parameters. Vicente Afonso Ventrilo et. Al [5] studied welding of thin foils of Hastelloy and their

Results indicate that using a precise control of the pulse energy, it is possible to weld Hastelloy C-276 thin foil by pulsed Nd: YAG laser also. Remark that it is suited more for the weld of ultra thin foils about microns thickness. Damara Nagewaza Rao et. al [6] Through their review paper they stated that Plasma Arc welding has gained importance in small and large scale industries manufacturing Aerospace components, diaphragms etc because of less expensive and easy to operate comparing to laser beam welding. Fuxin Wang et. al [7] reported that extra thin foils can be nicely welded using micro plasma arc welding with fine weld quality. In addition, influences on welding quality induced by current type, current value, and gas shielded effect are analyzed. Ch. Srinivasan Rao et.al [8] They developed mathematical models to predicted values of weld pool geometry parameters were computed and found to be very close to actual values also their study is limited to four process parameters, namely peak current, back current, pulse and pulse width for predicting the weld pool geometry. They suggested that One may consider other factors like welding speed, nozzle stand off distance, plasma and shielding gas flow rates and more levels for improving the statistical mathematical model. M.J. Cieslak et.al [9] made studies and remarked that among the HASTELLOY C-type alloys examined, a resistance to hot-cracking ranking can be given as follows: C-4 > C-22 > C-276. All alloys would be expected to be readily weldable in most situations. Casper van der Eike [10] they did Plasma welding of nickel-titanium alloy with nickel; titanium alloy is somewhat easy but NITI-Hastelloy fusion weld is difficult, but Hastelloy sheets can be weld using plasma arc welding and welding current and weld speed are maybe the parameters which effect the weld bead geometry and strength. Based on the literature survey, it is observed that only a limited amount of research work has been reported in the area of experimental and characterization studies on Automated plasma arc welding of thin sheets of Hastelloy c-276 alloy. Hence, an attempt is made in this research work to improve the previous studies on plasma arc welding of thin Hastelloy sheets.

MATERIALS AND METHODS

Hastelloy c -276 was procured in the form of a sheet of 1.6 mm thickness. The chemical composition of c-276 alloy was indicated in Table 1.

Table 1: Chemical Composition (Wt. %) of Hastelloy c-276

Elements	C	Ni	Cr	Mo	Mn	Fe	Co	W
Wt. %	0.01	Bal.	15.9	15.6	0.52	5.35	1.51	3.38

Since it has high chromium and molybdenum content it exhibits outstanding resistance to pitting and crevices corrosion. The welding of alloy c 276 was done using plasma arc welding techniques. The experiments were conducted using plasma arc welding machine with water cooled torch head (Fronius magic wave 400 attached with a plasma module (plasma module 10) as indicated in figure 1.

Figure 1: Welding Setup

A numerical control unit is used for controlling the travel speed of the gun. Based on literature survey, weld experiences and by initial trials it is found that among the possible paw input parameters welding current, and travel speed are the parameters which have effect on the energy input to the workpiece and it is decided to conduct experiment trial by varying the welding current and travel speed for the c-276 alloy plates as described in table 2.

Table 2: Paw Process Parameters

Welding Current (A)	40,50,60
Travel Speed (Mms ⁻¹)	200,250,300
Plasma Gas (l/min)	Industrial Pure Argon (99.9%)
Shielding Gas (l/min)	Industrial Pure Argon (99.9%)

A three-level experiment is planned with the welding current and travel speed in full factorial array (2 variables with 3 levels). The parameters are selected to conduct the bead on plate trials with the aim of producing beaded with full penetration and it planned to do further studies on the effect of parameters on weld geometry Prior to that, few trials are carried out based on trial and error to identify the range of each parameter between which the optimization is to be carried out in order to improve the performance and weld efficiency. The primary shielding gas flowing from the covers the weld pool area so that the region is prevented from contamination as shown in figure 2

Figure 2: Plasma Arc Welding Process (Courtesy: TWI)

From initial trials itself, it is identified that the better results are obtained when the plasma gas flow is set at 1.5l/min. Before conducting the trial, the samples are cleaned using acetone. With the help of above-described arrangements bead on plate, trials were conducted for alloy c-276 by a PAW process with the parameter combinations from table 2.

After these trials, the specimens are prepared using wire EDM, and the samples were mounted polished using a twin disc polisher and my emery papers. The specimens are etched by using a solution of (15 ml HCl, 10 ml HNO₃, 10 ml Acetic acid) and it's cured for the time period of 10 minutes so that the bead profile can be raveled better. The bead obtained are compared with the help of the weld expert system (stutters weld expert) with a magnification of 2.5x - 50x and a conventional. Samples for microscopic examination are prepared by using standard procedures. Micro hardness of the weldments is measured at the fusion zone(FZ), heat affected zone(HAZ) and the base metal.

RESULTS AND DISCUSSIONS

The weld samples were prepared to study the effect of parameters of the weld bead geometry and its strength. The bead shapes were obtained by using the weld expert system in order to get a better understanding of the shape and depth of penetration the bead produced by paw on the plates.

Weld Appearance and Geometry

A number of BOP trials were conducted by varying the welding current and the travel speed. And also, it is noted that better beads were obtained, when the plasma gas flow rate and the shielding gas flow is kept constant. All welded sheets show good dimensional accuracy

In visual inspection also, no distortion was found in the plates. And also, it is found that the weld beads are free from defects.

Table 3: Bead Shapes

Parameters used: 60A-1.5mm/min-200w/

The weld bead seems to be good and uniform. Depth of penetration and width can be estimated using a weld expert system. Also, the crack can be detected using the same system.

Table 4: Weld Experts Image of Bead

	Depth of penetration: 1.833 Width :4.2829

From the weld expert image, it is understood that the specific parameter shows optimum penetration and good bead width are obtained. It can also be observed that complete fusion is achieved between the fusion zone and the base plate. But for some parameters undercut was observed and for some, no undercut was obtained. The average bead width of the weldments for PAW trials are around 1.7532 mm. The HAZ for the samples is observed to be narrow that the TIG welded samples of similar materials. For the butt welding of 1.6mm sheets using welding current 60A, travel speed 200mm/minute and the plasma gas flow of 1.5l/min smoother and uniform weld surface is obtained

Micro Hardness Test

The average hardness value of the c-276 alloy of 1.6 mm thickness as received condition is 220hv. The hardness measurements are carried out across the entire width of the weldments and the results are plotted in the graph as shown below.

The average microhardness value of the weld zone found out be 38% greater than from the base metal area. The higher values for hardness is obtained may be due to the refinement in grain structure during welding. The hardness value seems to be slightly increased at the interfaces ie along the heat affected zone.

CONCLUSIONS

From the experimental characterization following conclusions can be drawn

- Defects Free Weld Joints with Full Penetration Is Obtained at 60a current, 200mm/min speed and at plasma gas flow of 1.5 l/min.
- The weldments show good geometrical consistency and most of them are free from defects.
- There is comparatively narrow heat affected zone observed than other welding processes such as gas tungsten arc welding process.
- Hardness is higher in the weld zone comparing to the base metal region due to the refinement of microstructure in the welded region.

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