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Characterization of GTAW-Pulsed Weld Overlay with 97.5% Argon and 2.5% Hydrogen Gas Using Inconel 625 and Incoloy 825 Filler Wire

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ABSTRACT

Corrosion Resistance Alloy (CRA) are well known for its creep properties along with high corrosion resistance which finds a very large application in oil and petrochemical industries. However due to its prohibitive cost a cheaper alternative of cladding nickel based alloys on carbon steel substrate is widely used. Specialized cladding Equipment is used to deposit the weld overlay, because of its control penetration and high arc on time, a welding process of choice is Gas Tungsten Arc Welding (GTAW) pulsing to maximize weld deposit quality. In this investigation an attempt has been made to predict Hardness, Macro and Chemical Wet analysis of Inconel 625 and Incoloy 825 with Argon hydrogen gas mixtures. Efforts have been made to develop a welding procedure to determine the effect of shielding gas and major welding parameters on dilution using two different filler wires.

Keywords: GTAW. CRA, Characterization, Inconel 625, Incoloy 825

I. INTRODUCTION

The search for oil and gas has never been as intense as it is today, the growing demand of oil and gas resources has inevitably led the industries to explore and produce such resources from deeper and more complex reservoirs. This ever increasing demand often involves exposure of equipment to high level of gas and fluid of high pressure and high temperatures [1-3]. This environment is highly corrosive to many materials. In order to protect the service lines from corrosion, highly alloyed weld overlay materials are deposited on the less corrosion resistant materials through a process known as cladding. Such corrosion resistant overlay (CRA) material could be nickel-based alloy (UNS N08825 or UNS N06625) or stainless steel (AISI 316L). The carbon steel(C-Mn) backing provides the necessary strength and the CRA lining provides the adequate corrosion resistance from the products being transported [4]

A carbon steel pipe cladded with CRA provides a highly economical alternative to the use of solid CRA

pipes. There are different methods available to maximize the weld deposit quality, In that for CRA Weld overlay carried out using pulsed welding power supply when Inconel 625 and Incoloy 825 is used for weld deposit. Because of the changing demand in oil and gas exploration and transmitting, the need for cladding will intensify in coming years.

The hot wire pulsed TIG process is a widely used technique, which inherits the benefits of pulsed TIG. The advantages were usually reported including high efficiency and lower heat input and good quality of weld bead. Also, moderate investment of equipment and low running cost further boost the widespread application of the hot wire pulsed TIG in surface modification. However, the relevant published information regarding the weld overlay of Inconel 625 and Incoloy 825 using hot wire pulsed TIG is limited [5-9]. So to cover this important research gap, attempts were made to determine the behavior of Inconel 625 and 825 cladding by using different welding and wire feed speeds.

II. EXPERIMENTAL PROCEDURE

This Investigation was performed on API 5L GR.X60 pipe material which were cladded with two different filler wires; Inconel 625 and Incoloy 825. Claddings were deposited on the carbon steel substrate using a fronius hot wire pulsed TIG system. 97.5% Argon and 2.5% Hydrogen was selected as a shielding gas with a flow rate of 15-20L/minute. Diameter of the filler wire and tungsten electrode was 1.2mm and 3.2mm respectively. While welding interpass temperature maintained at 177^{0}C. The effect of weld quality is characterized with reference to input parameter like Voltage, current, Weld speed and travel speed. Welding was carried out considering the following input parameter.

a)

b)

Figure 1: a) Experimental setup **b)** sample after cladding

The value of weld input parameter arrived after conducting number of trail experiments. The tested parameter and values are described in table 1 and 2.

TABLE: 1 (Inconel 625)

Pass id	AWS No.	Layer	Amps		Volts	WFS mm/min	Travel speed mm/min	Heat input (KJ/mm)
	Class	No.	Base	Peak	(V)			
1st Layer	ERNiCrMo3	1st	140	229	13.5	2000	550	.337
2nd Layer	ERNiCrMo3	1st	140	230	13.5	2100	550	.338

TABLE: 2 (Incoloy 825)

Pass id	AWS No.	Layer	Amps		Volts	WFS mm/min	Travel speed mm/min	Heat input (KJ/mm)
	Class	No.	Base	Peak	(V)			
1st Layer	ERNiFeCr-1	1st	140	229	12.5	2000	650	.264
2nd Layer	ERNiFeCr-1	1st	140	230	12.5	2100	650	.265

Cladded samples were subjected to chemical and mechanical analysis (Hardness, Macro analysis). Optical emission spectrometer was used to determine the elemental composition of the weld overlay samples. Vickers hardness indenter (HV10) was used to determine the variation in hardness values of Heat Affected Zone (HAZ) and weld overlay. Cladded cross section samples was analyzed at the magnification of 10X using stereo microscope.

III. RESULTS AND DISCUSSIONS

Chemical wet analysis:

Chemical analysis was carried out on the samples extracted from both claddings. Results were obtained on location which was at a height of 2mm from fusion line. Chemical composition of weld overlay samples are in the range specified in ASME section II part C. Table 3 and 4 shows the chemical composition of cladded samples.

TABLE 3: (Inconel 625)

Chemical Analysis – ICP – OES + Combustion													
	C %	Si %	Mn %	P %	S %	Cr %	Mo %	Ni %	Al %	Cu %	Nb %	Ti %	Fe %
001	0.013	0.08	0.04	0.01	0.004	22.3	8.55	63.1	0.14	0.01	3.43	.19	2.13

TABLE 4: (Inconel 825)

Chemical Analysis – ICP – OES + Combustion													
	C %	Si %	Mn %	P %	S %	Cr %	Mo %	Ni %	Al %	Cu %	Nb %	Ti %	Fe %
001	0.021	.410	0.72	0.01	0.004	22.6	2.86	42.34	0.02	2.12	.005	.82	27.8

Chemical analysis of both the samples revealed dilution of Iron (Fe) in the weld overlay to be in the acceptable range. Weld overlay parameters for nickel 625 and Incoloy 825 that can be independently controlled were identified based on influence of PREN.

It is noteworthy that the %Fe using Inconel 625 obtained below is <5% to maintain good corrosion resistance.

IV. HARDNESS SURVEY RESULT

Vickers hardness testing machine was used to measure the hardness of the weld metal with a 10kg load. Hardness survey was conducted on weld overlay and heat affected zone (HAZ 0.2mm from the fusion line) with 3 points at each location as per Figure 2. Table 5 shows hardness values recorded in both samples.

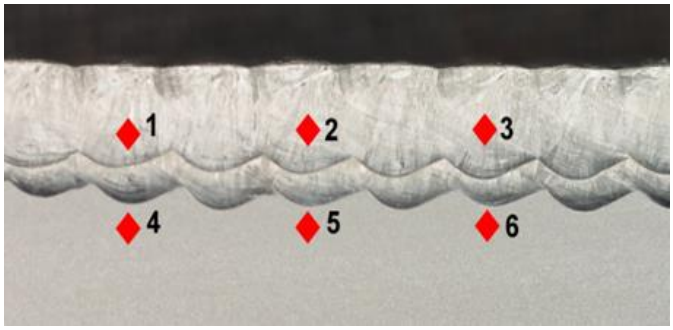

Figure 2: Hardness Indent location in cladded samples

TABLE 5: Vickers Hardness values HV10

Hardness Values HV10						
	Weld Overlay			Base Metal (HAZ)		
Indent No.	1	2	3	4	5	6
Inconel 625	194	170	182	166	150	172
Incoloy 825	180	182	160	147	154	149

From Table 5 it is clear that hardness value of weld overlay is better than the parent metal, which indicates higher strength of the weld overlay.

V. MACRO STRUCTURE EXAMINATION

Samples extracted from Inconel 625 and Incoloy 825 claddings were subjected to macro examination at low magnification of 10X. The objective of macro examination was to determine the quality of the weld and to calculate the depth of fusion between weld overlay and base metal. Figure 3 & 4 shows macro photographs of the cross sectional samples.

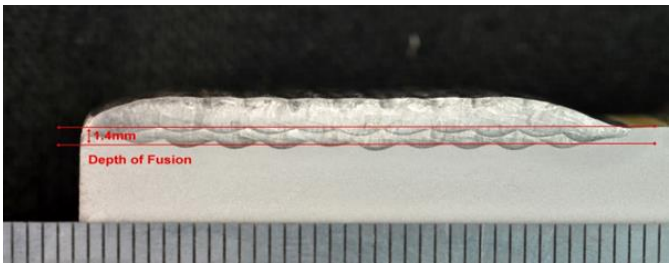

Figure 3: Macro photograph of sample extracted from Inconel 625 cladding

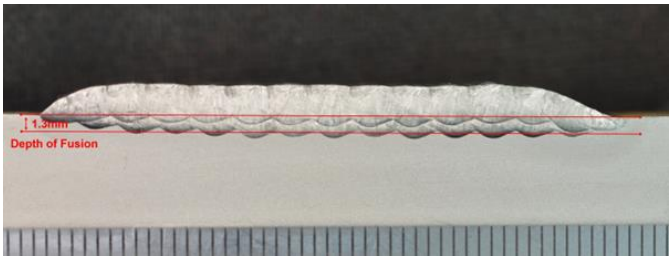

Figure 4: Macro photograph of sample extracted from Incoloy 825 cladding

Macro examination revealed fusion between weld overlay and base metal to be quite good with no lack of fusion was observed in the samples. Depth of fusion was also measured in both samples and found to be 1.4mm and 1.3 mm respectively. No abnormal indications were observed. Depth of fusion values further confirms that the addition of hydrogen has a positive effect on the depth of fusion. Also Hydrogen addition to argon provides a reducing atmosphere during welding which in turns removes any oxides from the weld area hence keeping weld pool free from any oxide defects [10].

VI. CONCLUSION

In this research, various properties of Inconel 625 & Incoloy 825 Weld overlay on carbon steel substrate were studied using GTAW-Pulsed process. The research revealed that by using Argon and Hydrogen as a shielding gas and by controlling the welding parameters, good quality with broader weld bead profile permitting faster travel speed was obtained in which the Fe content was found to be acceptable range The dilution imparts better corrosion

resistance with increased depth of fusion. Also, the hardness value of the weld overlay were found to be better than the values of HAZ which indicates weld overlay of better strength and resistance to corrosion. Macro examination of the weld joint also revealed excellent depth of fusion between the parent material and weld overlay.

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