PARAMETER OPTIMIZATION OF GAS METAL ARC WELDING PROCESS ON DUPLEX 2205 STAINLESS STEEL USING IRB1410 ARC WELDING ROBOT

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Abstract - *This review paper outline the recent research works on parameter optimization of duplex 2205 stainless steel using IRB1410 arc welding robot. Gas metal arc welding (GMAW) process has widely been employed due to the wide range of applications, cheap consumables and easy handling. A suitable model is needed to investigate the characteristics of the effects of process parameters on the bead geometry in the GMA welding process in order to achieve a high level of welding performance and quality. This paper is intended to represent new algorithms in the robotic GMA welding process to predict process parameters on top-bead distance. Not only the fitting of these models was checked and compared by using a variance test i.e. Variance analysis (ANOVA) but also the prediction of top-period width using the developed models were performed on the basis of the additional experiments. The models developed were used to investigate the characteristic between parameters of the method and the width of the top-bead. Resulting solutions and graphical representation have shown that the smart model built in the GMA welding process can be used to predict bead geometry. The study is gone through various parameter optimization processes which are to be included weld strength for duplex 2205 stainless steel using arc welding robot.*

Key Words: Duplex 2205 stainless steel, Arc welding robot, GMA welding process

1. INTRODUCTION

The Gas Metal Arc Welding (GMAW) is a process that melts and joins metal by heating them up with an arc between a continuously fed filler wire electrode and the metals. GMAWs are used as semi automatic and automatic operation modes. all the industrial metals and alloys such as, high strength low alloy steels, alloys of magnesium, copper, carbon steels, stainless steels, carbon steels, sstainless steels aluminium, nickel and titanium can be welded in all positions with this process by choosing the most suitable process parameters for the particular joint design and process . The Gas metal arc welding (GMAW)which is also sometimes referred by its subtypes metal inert gas (MIG) is welding process where an electric arc forms between the 6 (≤12 kJ/inch, 0.5 kJ/mm), preheating to the range of 200–300°F (95–150°C) can be useful. The purpose of this preheating is to avoid excessively rapid cooling and a consumable MIG wire electrode and the workpiece metal(s), which will heats the workpiece metal(s), causing them to melt and join. Gas metal arc welding, also known as metal inert gas (MIG) welding, uses a continuous solid wire electrode that travels through the welding gun, which is accompanied by a shielding gas to protect it from contaminants. Gas metal arc welding (GMAW) is a welding processby an arc in which the source of heat is an arc is formed between the consumable metal electrode and the work piece with an externally supplied gaseous shield of inert gas such as argon /or helium.

GMAW is the most common industrial welding process, preferred for its versatility, speed and the relative ease of adapting the process to robotic automation. Unlike welding processes that do not employ a shielding gas, such as shielded metal arc welding, it is rarely used outdoors or in other areas of moving air. A related process, flux cored arc welding, often does not use a shielding gas, but instead employs an electrode wire that is hollow and filled with flux.

2. DUPLEX STAINLESS STEEL

Duplex stainless steels are called "duplex" because they have a two-phase microstructure consisting of grains of ferritic and austenitic stainless steel. ... Strength: Duplex stainless steels are about twice as strong as regular austenitic or ferritic stainless steels."Duplex"describes a family of stainless steels that are neither fully austenitic, like 304 stainless, nor purely ferrite, like 430 stainless. The name 'duplex' for this family of stainless steels derives from the microstructure of the alloys which comprises approximately 50/50 mixture of austenite and ferrite.

These are all fully magnetic all the time. The best known duplex grade, 2205, resists corrosion even better than 316 because it contains 22% of chromium and 3% of molybdenum. ... Both are magnetic, because both are ferritic. If the 2205 is greater than about 0.625 inch (16 mm) thickness, and welding is to be done with very low heat input

resulting extremely high ferrite content. As all the corrosion-resistant alloys, the duplex stainless steels can also suffer corrosion when exposed to other suitably different corrosive conditions. As they also have a higher chromium content than the standard 3xx grades, their Pitting Resistance Equivalent Number (PREN) is greater, indicating high resistance to the pitting corrosion.

Table 1. Mechanical properties of 2205 grade stainless steels.

Grade	Tensile Strength (MPa)	Yield Strength (MPa)	Elongation %	HRC
2205	**621**	**448**	**25**	**31**

The duplex stainless steels (DSSs) which is mostly characterized by the ferrite-austenite dual phase microstructures, is mostly used for petrochemical, oil, nuclear chemical, marine and nuclear industries because of their merging of right good mechanical strength and high corrosion resistance in bizar environments .Anyway due to high chromium (~22%Cr) and molybdenum (~3%Mo) presence and its high diffusion rate on ferrite, DSSs consist of a tendency to form the unrequired secondary phases while the surroundingd of temperatures between 400 and 1000 ºC. The thermal processes which involves long period exposition of DSS to high temperature may the appearance of Mo-enriched χ phase. A high degree of χ phase precipitation is also because if the negative effects on corrosion and mechanical propertie.

Duplex stainless steel (DSS) grade 2205 is widely used in the energy sector because of its high strength and excellent corrosion resistance. The outstanding resistance to environmentally-assisted cracking (EAC) is a result of the dual phase microstructure, a balanced ratio of austenite (γ) and ferrite (δ). In particular, resistance to hydrogen embrittlement (HE) makes it a viable choice for subsea application, where cathodic protection (CP) systems are often applied. Welding can alter the phase balance and produce secondary phases and precipitates, for example, sigma-, chi-phase, and chromium nitrides (Cr2N, CrN). Hydrogen diffusion in DSS is complicated, due to disparity in properties between the major phases. The ferritic phase shows high diffusion rate and low solubility, whereas, diffusion in austenite is slower and the solubility greater. Lean Duplex Stainless Steel (LDSS) is developed to overcome the difficulty of ever increasing alloy prices. Due to an attractive combination of better mechanical strength and good corrosion resistance, LDSS serves as a potential replacement for both Duplex Stainless Steel (DSS) and commonly used stainless steel types in applications such as pressure vessels, bridges, structural elements and storage tanks.

Table 2. Tensile properties of DSS welds

S.No	Type of welding	Yield strength MPa	Ultimate tensile strength MPa	% of elongation
1	DSS 2205 parent metal	450 (min)	620 (min)	25 (min)
2	GTAW	450	621	25
3	MIG	-	730	18.06
4	FCAW	757	890	25
5	SAW	-	795	-
6	LBW	453	623	26
7	EBW	509	735	44
8	Friction weld	664	852	38

Table 3. Chemical composition of duplex stainless steel alloy 2205.

Elements	C	Si	Mn	S	P	Cr	Ni	Mo	Cu	Co	Ti	V	Fe
% by weight	0.018	0.512	1.256	0.005	0.029	22.856	5.152	3.169	0.362	0.086	0.009	0.019	66.32

3. ROBOTIC GMA WELDING PROCESS

Gas Metal Arc Welding (GMAW) is the best welding method because of its high speed and feasibility of both the manual and the automatic welding modes for wide ranges of ferrous and the non-ferrous metal parts. Nowadays, demand for automated GMAW is getting bigger and consequently needs of intelligent systems are grown to ensure the accuracy of the procedure. The welding pool geometry has been the biggest used factor in the quality assessment of the intelligent welding systems. However, an intelligent algorithm that predicts bead geometry and accomplishes the desired mechanical properties of the weldment in the automated GMA (Gas Metal Arc) welding should be developed to cover a wide range of material thicknesses and be applicable for all welding position.

Therefore the neural network, one of AI (Artificial Intelligence) technologies has been developed to study the effects of welding parameters on bead height and predict bead height for lab joint in the robotic GMA welding process. Fig. 1 and 2 shows a block diagram of the robotic GMA welding process and a schematic diagram for relationship between input and output parameters in the robotic GMA welding process respectively. Robotic automated welding can be considered as an alternative to manufactured large scale metal parts with layer. The Robotic hot-wire Gas Tungsten Arc Welding (GTAW)which is with low frequency vibrating filler wire is been used to deposit a metallic alloy . A novel robot welding monitoring system which is capable to detect abnormalities during the welding process. The welding monitoring system assesses the weld quality and provides a real-time feedback to the welding robot.

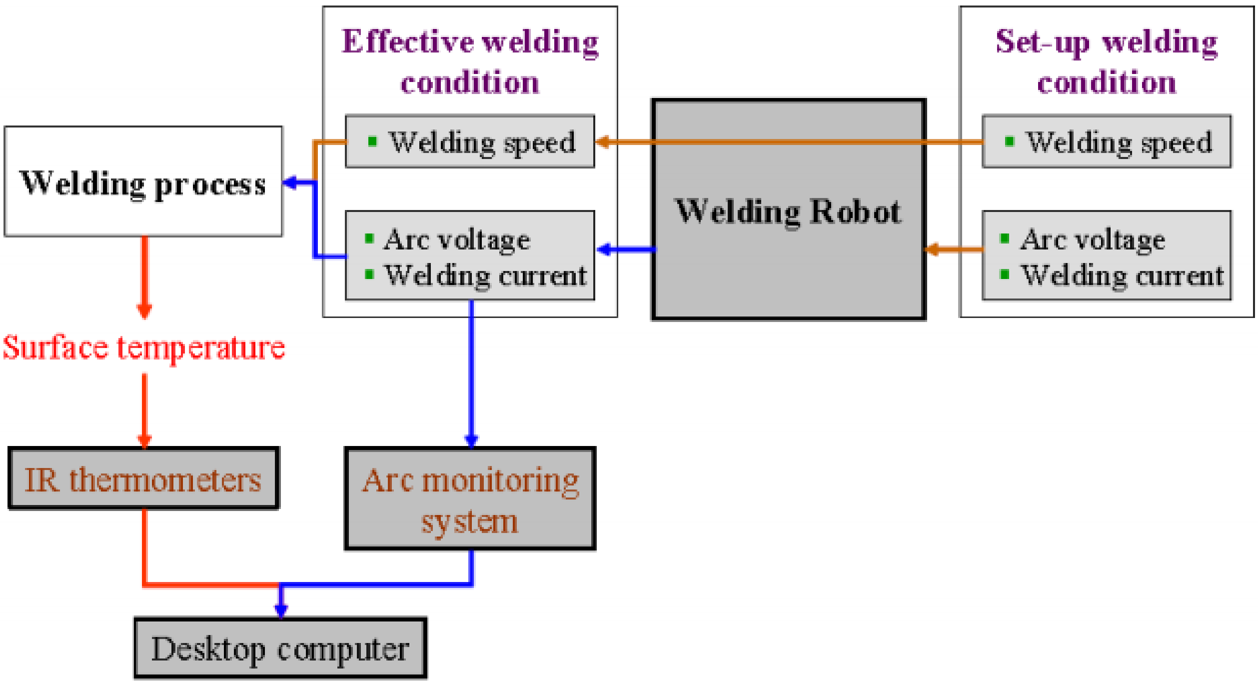

Fig 1. Block diagram of the robotic GMA welding process

Welding filler material was selected for welding because of specific chemical composition, that promotes the austenite formation and achieving the balance between austenite and ferrite in the weld metal. The geometry of welded joints was also influenced by the use of filler material . Various researchers reported that controlled heat input is the most important factor in order to maintain the phase balance after the welding process of DSS and the cooling rate is the parameter that controls the phase balance in weldments, and also dictates the heat input range to be used. Heat input has a significant impact on the bead geometry, metallurgical, mechanical and corrosion resistance properties of the welds

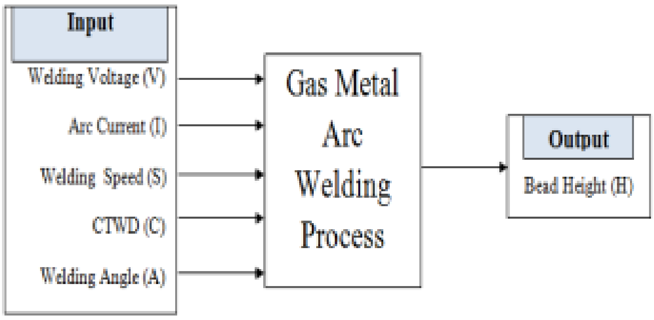

Fig 2. A schematic diagram for relationship between input and output parameters

4. OPTIMIZATION TECHNIQUES OF DSS 2205

Many optimisation methods are available to optimise the parameters. Various optimization methods can be applied to define the desired output variables through the development of mathematical models to specify the relationship between the input parameters and output variables. One of the most powerful and widely used methods to solve this problem is the Taguchi method and it offers efficient and quality results. Process parameters optimisation is the key step in the Taguchi method in achieving elevated quality without escalating the cost. Taguchi method can be applied to optimise input welding parameters. Weld bead geometry is major factor that has to be considered when it comes to the quality of the weld [36]. The Weld bead geometry is affected by the input process parameters which have to be optimized for better weld bead quality. Response Surface Methodology is the method has to be used to find the optimized value using the Minitab tool. In automated MIG Welding process, besides the chemical composition, the weld bead shape is considered as an important factor for better quality. In MIG welding process, when RSM is applied, the relationship of welding with the bead geometry is found and individual variable is controlled for improving the bead geometry.

To understand now the effects of number of both the double pulse and the welding speed on the welded seam aping, MIG welding is also performed on the 2205 duplex stainless steel through various numbers of strong and weak pulses. The tensile fracture occurred in the base material part of the duplex stainless steel, indicating that the welded seam region had a higher tensile strength than the base material . Response surface methodology (RSM) is the vital technique of the design of experiment (DOE) used to establish the relationship between the controllable input welding process parameters and the desired responses. RSM is very important for optimization and analysis of the industry-related problems in which a response of significance is influenced by a number of process parameters and the objective is to optimize the response. The major objective of RSM is to estimate the input process parameters at which the responses achieve their optimum . Fig 3 shows the flow of methodology involved in the optimisation process. For the development of mathematical relationship between the GMAW and bead width, the first step is diagnosis of assumptions of analysis of variance.

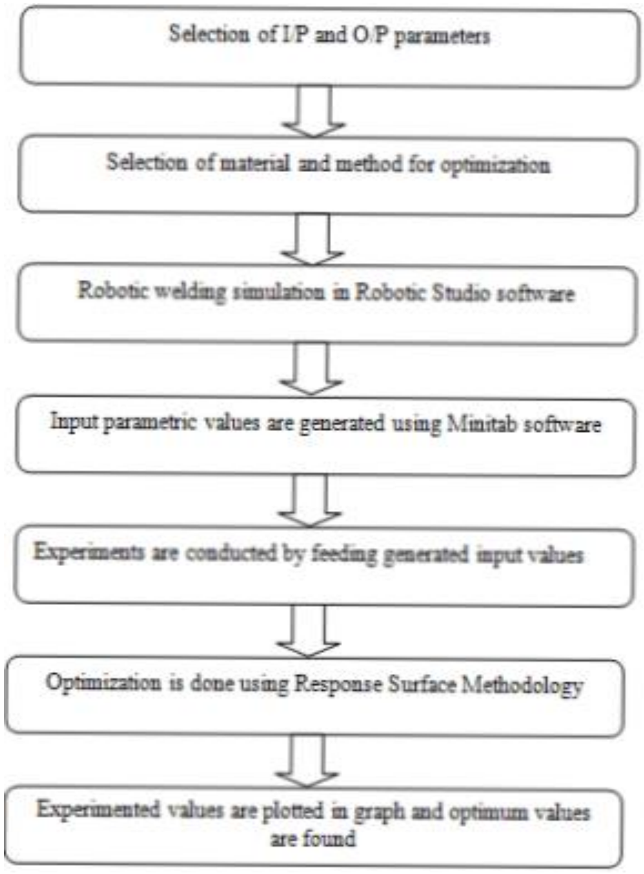

Fig 3. Flow chat of Methodology

The analysis of variance depends on three assumptions:

(1) Assumption of "normal distribution of population".

(2) Assumption of "homogeneity of variance"

(3) Assumption of "independence".

In welding, the weld metal area is an important parameter to be considered for optimization. Hence the weld metal area, if optimized (minimized), obviously minimizes other bead quality parameters such as width and reinforcement. Also it reduces the welding cost through reduced consumption of consumables such as electrodes and flux. The heat input and energy consumption are reduced Bead on plate which initiates the tungsten inert gas (ATIG) welding on the duplex stainless steel (DSS) 2205 was performed to determine the thermal history,temperature distribution and the weld bead geometry. Finite element (FE) simulations are carried out using the SYSWELD software, which takes the temperature dependent mechanical and thermal properties of the base material. The percentage error in depth of penetration obtained at 100A by FE simulation and experimental is 2.91%. The percentage error in bead width obtained at 100A by FE simulation and experimental is 0.52%. The presence of hydrogen reduces the toughness fracture of the welded joints of super duplex stainless steel, even for small hydrogenation times. The plasma transferred arc technique has been used for the production of high nitrogen surfaces on 2205 duplex stainless steel substrates. The Nitrogen gas was introduced into the melt with Arz5%N2 and Arz10%N2 gas mixture. Also the change of austenite crystal lattice, which was due to absorption of nitrogen and was determined by X-ray diffraction. Pin on disc test also showed that the wear resistance was increased. The corrosion in 3.5%NaCl and 1 N H2SO4 aqueous solutions was also slightly improved. RSM is found to be an accurate method for optimizing the A-TIG welding process parameters in order to obtain the desired DOP in duplex stainless steel alloy 2205. The second order quadratic model is successfully used to predict the DOP during A-TIG welding of DSS plates. A second order response surface model was developed to predict the response for the set of given input process parameters. Then, numerical and graphical optimization was performed to obtain the maximum DOP using desirability approach.

5. CONCLUSION

This article outlines some of the greatest high quality scientific contributions made to DSS 2205. Undoubtedly creativity is still there, and new standards and applications are now emerging. The so-called duplex ones are aimed at replacing the Austenitic 304 and 316. Cost savings are starting to become more attractive, however much needs to be done by steelmakers to reduce production costs and increase availability. Further clarification is needed to clarify the true characteristics of each quality and to improve material selection. Properly covered, it will withstand a great deal of adverse conditions. Finally positive field experiences, over many decades, in most erosive environments, have been presented about the Classical 2205 standards, confirming the research missions and beliefs of the dual pioneers.

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