Parametric Optimization of Orbital Welding on SS316L for Tensile Strength

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Abstract— In order to obtain a good weld, controlling the process parameters such as welding current, welding speed, cycle time become very crucial as it significantly influences the mechanical properties. Thus, the purpose of this study is to investigate the process-properties relationship of welded mild steel tube (SS316 L) of dissimilar thickness by using Metal Inert Gas (MIG) orbital welding. The effects of weld current and jig rotational speed to the tensile properties of welded mild steel tubes were studied. The mechanical properties were tested using Universal Tensile Machine (UTM). Also, in this study the most welding processes as well as the most pipe variations welded by orbital welding systems mainly for oil and gas pipeline applications are explained. So given standard input parameter which is given to Maximum Tensile strength & good finishing.

Key words: Welding, Orbital welding Machine, Design of Experiments, Minitab@16Software, Taguchi

I. Introduction

A. Project Background

In the orbital welding process, tubes/pipes are clamped in place, and an orbital weldhead rotates an electrode and electric arc around the weld joint to make the required weld. An orbital welding system consists of a power supply and an orbital weldhead[1].The power supply/control system supplies and controls the welding parameters according to the specific weld program created or recalled from memory. This supply provides the control parameters, the arc welding current, the power to drive the motor in the weldhead, and switches the shield gas on/off as necessary.

Orbital weld heads are normally of the enclosed type, and provide an inert atmosphere chamber that surrounds the weld joint. Standard enclosed orbital weld heads are practical in welding tube sizes from 1/16 inch (1.6 mm) to 6 inches (152 mm) with wall thicknesses of up to .154 inches (3.9 mm). Larger diameters and wall thicknesses can be accommodated with open style weld heads.

B. Principle

Generally, orbital welding technique covers two main fields of application:

- Tube to tube / pipe to pipe joining.
- Tube to tube sheet welding.

In the first group, all kinds of tube joining are included: butt welding and welding of flanges, bends, T-fittings and valves, i.e. the entire tubing and piping requirements. Fusion welds of thin-walled tubes cover a wide range of applications.

Clients include for example: semiconductor industry, biochemistry, instrumentation, food and beverage, pharmaceutical industry, chemical/sanitary industry, and aeronautics/aerospace. In most cases, the tubes are made of austenitic stainless steel, but nickel alloys as well as titanium and its alloys can also be found. The range covers diameters from 1.6 to 170 mm; with wall thicknesses of varying between 0.2 and 3.2 mm.

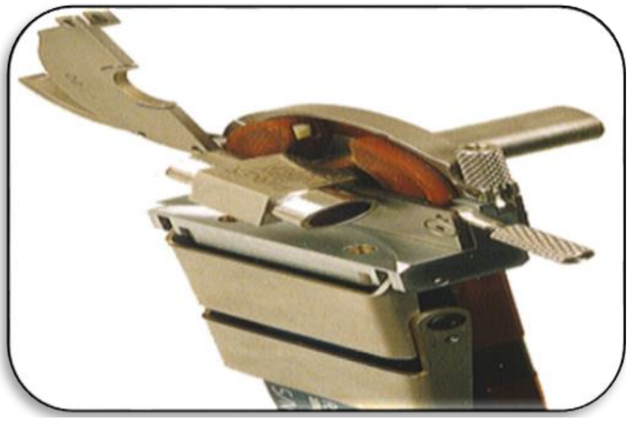


Fig. 1: Orbital welding [2]

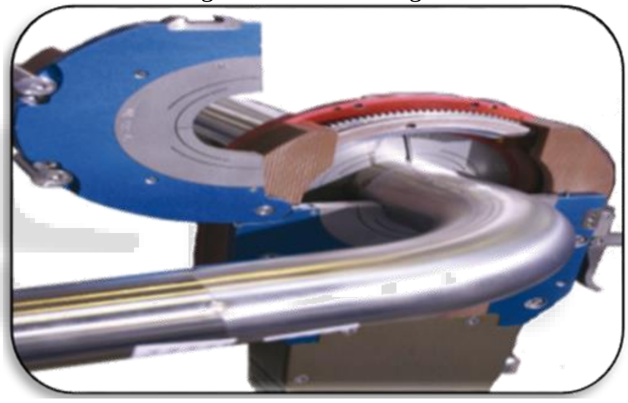


Fig. 2: Orbital welding fixture [2]

II. Literature Review

Literature survey is one of the scope studies. It will be helpful to give the information regarding to different methods of design of experiments and optimization techniques. From the earlier stage of project various literature studies have been done which included research journals, books, printed and online conference articles. We will use some the information from these literatures to achieve our target.

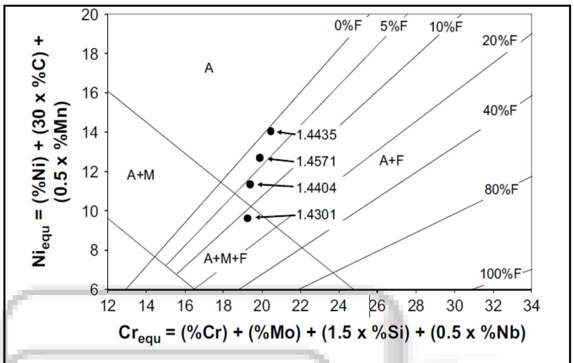
A. Herbert Schroeder and Wanpei Liu .[1].

The interest ra the low temperature tensile properties of candidate alloys for first wall and blanket structures of future fusion devices is due to the possible low pressure water cooling and the associated low operation temperature in recent design studies. Therefore, the tensile properties of hydrogen and/or helium implanted 316 L stainless steel and its weldments as a function of gas concentrations and temperature were investigated. The main effects of the implantation are hardening, resulting in large increases of the yield strength proportional to the implanted gas concentration, and a gradual decrease of the corresponding rupture strain. The ultimate tensile stresses are less affected.

The effect of helium implantation seems to be more pronounced than that of hydrogen implantation At 673 K most of the implantation induced changes are recovered. Generally parent material and welds still show large ductility (> 20%) under all conditions investigated.

B. Jorg naumann , Thorsten michler [4]

Different stainless steels were TIG orbital welded resulting in d-ferrite contents up to 5% in the weld seam. Tensile specimens tested in He atmosphere did fracture at the fusion line/ heat affected zone (FL/HAZ), which is the typical failure mode for welded structures. In contrast, all specimens (except the one made of 1.4301) tested in H2 did not fracture in the FL/HAZ but in the base material. These results clearly show that for the tests performed here d-ferrite contents up to 5% did not enhance susceptibility to HEE compared to the base material.



Schaeffler's diagram, A = austenite, F = ferrite, M = martensite.

Fig. 3: Schaeffer's diagram [4]

Different stainless steels were TIG orbital welded resulting in d-ferrite contents up to approximately 5% in the weld seam .Tensile specimens tested in the atmosphere did fracture at the HAZ, which is the typical failure mode for welded structures. In contrast, all specimens (except the one made of 1.4301) tested in H2 did not fracture in the FL/HAZ but in the base material (BM). These results clearly show that for the tests performed here d-ferrite contents up to 5% did not enhance susceptibility to HEE compared to the BM. It can even be concluded that other ''normal'' variations in the BM like variations in local Ni contents are more critical for HEE than welding.

C. Manoj Singla, Dharminder Singh, Dharmpal Deepak.[5]

Gas Metal Arc Welding is a process in which the source of heat is an arc format between consumable metal electrode and the work piece with an externally supplied gaseous shield of gas either inert such as argon, helium. This experimental study aims at optimizing various Gas Metal Arc welding parameters including welding voltage, welding current, welding speed and nozzle to plate distance (NPD) by developing a mathematical model for sound weld deposit area of a mild steel specimen. Factorial design approach has been applied for finding the relationship between the various process parameters and weld deposit area. The study revealed that the welding voltage and NPD varies directly with weld deposit area and inverse relationship is found between welding current and speed with weld deposit area.

Results indicate that processes variables influence the weld bead area to a significant Extent .Various welding variables which influence WDA were identified and their quantitative influence on the same was investigated. Welding current was found to be most influencing variable to WDA. For a constant heat input, welds made using electrode negative polarity (DCEN), a small diameter electrode, long electrode extension, low voltage and low welding speed produce large bead area. The two level fractional half area fractional designs is found to be very effective tool for quantifying to main and interaction effects of variable on weld bead area .The model is problem specific however the technique can be applied very effectively

D. Talabi, Owolabi ,Adebisi, Yahaya [5]

In this paper discussed the effect of welding variables on the mechanical properties of welded 10 mm thick low carbon steel plate, welded using the Shielded Metal Arc Welding (SMAW) method. Welding current, arc voltage, welding speed and electrode diameter were the investigated welding parameters. The welded samples were cut and machined to standard configurations for tensile, impact toughness, and hardness tests. The results showed that the selected welding parameters had significant effects on the mechanical properties of the welded samples. Increases in the arc voltage and welding current resulted in increased hardness and decrease in yield strength, tensile strength and impact toughness. Increasing the welding speed from 40-66.67 mm/min caused an increase in the hardness characteristic of the welded samples. Initial decrease in tensile and yield strengths were observed which thereafter increased as the welding speed increased. An electrode diameter of 2.5 mm provided the best combination of mechanical properties when compared to the as received samples.

This behavior was attributed to the fact that increased current and voltage meant increased heat input which could create room for defect formation, thus the observed reduced mechanical properties.

The effect of varied welding parameters was examined and discussed in other to be able to predict the service behavior (performance) of welded low carbon steel samples. The results have shown that the selected welding parameters have significant effect on the mechanical properties of the welded samples. Increase in the arc voltage and welding current result in increased hardness values and decreased yield strength, tensile strength and impact toughness. This behavior was attributed to the fact that increased current and voltage means increase in the heat input which can create room for defect formation, thus the observed reduced mechanical properties. The increased hardness may be due to electrode coating which provides alloy addition to the weld deposit. In the future work, the authors plan to report the effect of this welding variable on the microstructure of the steel sample. The structure-properties relationship will also be characterized.

E. N. I. S. Hussein, M. N. Ayof, and S. Nordin [6]

Lightweight trend leads to new trend of welding in which optimizing tubes or pipes thicknesses due to its respective workloads. Thinner tube can be used in parts with low working loads and thicker tube for high working loads parts. In order toobtain a good weld, controlling the process parameters such as welding current and welding speed become very crucial as it significantly influences the mechanical properties. Thus, the purpose of this study is to investigate the process-properties relationship of welded mild steel tube of dissimilar thickness by using Metal Inert Gas (MIG) orbital welding. The effects of weld current and jig rotational speed to the tensile properties of welded mild steel tubes were studied. MIG welding was used to weld 26.70 mm diameter of mild steel tubes, which has dissimilar inner diameter of 2.87 mm and 3.90 mm, respectively. The mechanical properties were tested using Universal Tensile Machine (UTM) Instron 8802 model. Design of Experiment (DoE) was used to design the experiment as well as to analyze the data. It was found out that, tensile properties of welded tubes increase with increasing of welding current between 60 and 80 A. On the other hand, increasing in jig rotational speed between 40 and 50 rpm decreases the tensile properties of the welded tubes .Empirical mathematical model was generated and verified.

It can be concluded that, tensile strength of the welded tubes increase with increasing of welding current between 60 and 80 A due to deeper penetration which leads stronger weld joint. On the other hand, increasing in jig rotational speed between 40 and 50 rpm decreases the tensile properties of the welded tubes due to decreases in penetration which resulting weaker weld joint. This study also indicates that welding current is the most significant parameter which influenced tensile properties of welded mild steel tubes by MIG orbital welding compared to jig rotational speed. The optimum parameter setting to get the maximum tensile strength for this study was 80 A welding current and 40 rpm jig rotational speed. The mathematical empirical model was developed and verified. Accuracy of the model was 96.8%.

F. Joseph Achebo, William Ejenavi Odinikuku[7]

Welding technology is very vital for the industrial development and technological advancement of any country. In this regard achieving good quality machine manufactured products cannot be over emphasized. Since welding is a very reliable method of joining metals together permanently, several methodologies have been adopted to improve the quality of weldments, such as the neural network, fuzzy logic, surface response methodology, full factorial method, and so on. In this case, the multi-objective optimization on the basis of ratio analysis (MOORA) is applied. MOORA is used to solve multi-criteria (objective) optimization problem in welding. MOORA in combination with standard deviation (SDV) was used for the optimization process. SDV was used to determine the weights that were used for normalizing the responses obtained from the mechanical test results. From applying the SDV-MOORA method, it was found that welding current of 350 A, welding voltage of 22 V, an electrode diameter of 3.2 mm and welding speed of 100 mm/s produced the weldment with the best mechanical properties. The mechanical properties compare very well with those obtained from other literature. It is, therefore, concluded that the SDV-MOORA method has successfully optimized the welding process parameters used in this study.

III. GAP ANALYSIS

GAP analysis means the analysis of the research done already and the possible work that can be done after today. This kind of analysis helps the researcher to find out the way of doing the research.

Here according to above research paper, it is noted that the since today all research was done on the ultrasonic welding for majorly on metals and also some on plastic materials. There are various methods which is used to optimize the parameters. Some of the researchers used the taguchi method else some used response surface method with ANOVA. ANOVA means analysis of variance. It is Statistical technique for comparing means for multiple (usually $\geq$ 3) independent populations. Here some research paper is following the GA-genetic algorithms.

By doing the literature survey it is found that, there are always two types of factor that affect any process one is the controlled and another is uncontrolled factors. Here in the Orbital welding process, the controlled factors are welding time, welding pressure, input power, frequency, amplitude etc. the uncontrolled factor are that factors which can't be controlled during process. In this paper, the uncontrolled factors are neglected and controlled factors are selected for study. It is noted that mostly affected parameters are welding time, welding pressure and amplitude of sonotrode.

As per the literature review consort, in many researchs the output parameter is the joint strength. It also known as the tensile strength of the welding joint. Orbital welding is widely used in the pharma & other industries for weld the different parts. So it is require to have a good Strength of joint. All the studied research papers are providing the optimum values of their input parameters for maximizing the output parameter.

IV. EXPERIMENTAL SETUP

A welding quality is good when weld have enough penetration, desired microstructure, and right welding profile without any spatter typically, pipe welding equipment manufacturers suggest a series of pre-calculated weld program for different tube wall thicknesses, diameters and materials.

Fig. 4: Orbital welding machine[2]

This test method describes a laboratory procedure for determining the Tensile strength of materials during UTS machine testing. The principal areas of experimental attention in using this type of apparatus to measure tensile strength are described. The Tensile strength may also be determined. The pin specimen is pressed against the disk at a specified load usually by means of an arm or lever and attached weights. Other loading methods have been used, such as, hydraulic or pneumatic. Tensile strength results are reported as break or crack in tube.

Fig. 5: UTS machine[16]

V. FACTORS INFLUENCING THE WELDABILITY

Dependent welding parameters for this study were welding current and jig rotational speed. Welding current was set for low and high level at 40 A and 80 A, respectively. While for jig rotational speed, 45 rpm and 65 rpm were set as low and high level, respectively. Same as cycle time 60 sec to 120 sec. (refer to Table I).

PARAMETERS	LEVEL - 1	LEVEL - 2	LEVEL - 3
Current (A)	40	60	80
Tungsten wire speed (RPM)	45	55	65
Cycle time(Sec)	60	90	120

Table 1: Parameters

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