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PARAMETRIC OPTIMIZATION OF SUBMERGED ARC WELDING ON STAINLESS STEEL-304

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Abstract: Welding is a manufacturing process, which is carried out for joining of metals by submerged arc welding. This is the one type of Arc Welding, in which both the Arc and the weld metal are submerged beneath a layer of flux. This layer protects the weld metal from contamination and Concentrates the heat into the joint. The molten flux rises through the pool, de-oxidizing and cleaning the molten metal. It then forms a protective slag covering over the newly deposited weld. All welds will be prepared by submerged arc welding technique. We studied Design of Experiments for this work and by use of the experimental data have optimize by any one optimization techniques which has decide later. In which inputs parameters for submerged arc welding are welding current, arc voltage and welding speed and the output parameter are hardness, tensile strength and microstructure of material. We use stainless steel-304 material for welding. Small scale trial welding experiments, in the light of field joint of plate have been planned to perform on 5 mm plate thicknesses and V-groove joint is used. For Experimental design full factorial method ($L=m^n$) to find out numbers of reading is used. To find out percentage contribution of each input parameter for obtaining optimal conditions, manually method will be used. Mathematical model regarding to different input parameter values by using of any one optimization techniques will be used

Keywords—SAW; submerge arc welding; optimization, manufacturing process

I. INTRODUCTION

For centuries, the only method man had for metallurgical joining metals was forge welding, a crude and cumbersome blacksmith-type operation in which heated metals were pounded or rammed together until they fused. Then within the span of few years prior to 1900, three new processes came into existence. Arc welding and resistance welding were developed in the late 1880’s and put to work in industry a few years later. Oxyacetylene welding was developed during the same period, and was first used industry in the early 1900’s. No one knows when man first learned to use forge welding. Few implements of iron or steel can survive corrosion over hundreds of years, so there remains little direct evidence of early attempts at the fusion joining of metals. The working and hardening steel – advanced arts that doubtless took centuries to evolve – were commonly practiced 30 centuries ago in Greece. But primitive tribes on different continents, and with no apparent means of communication, developed the same basic methods for smelting, shaping, and treating iron. Thus, the principles of welding probably were discovered, lost, and rediscovered repeatedly by ancient peoples. By the time of the Renaissance, craftsmen were highly skilled in forge welding. Parts to be joined were shaped and then heated in a forge or furnace before being hammered, rolled, or pressed together.
Vannoccio Biringuccio’s Pyrotechnic, published in Venice in 1540, contains several references to such operations. Biringuccio was obviously intrigued by the process. For many centuries thereafter, ordinary fire remained the principal source of heat for welding. The traveling tinker, a familiar figure on the dusty roads of the countryside, carried with him a small charcoal furnace for heating his irons. During this era, tinsmiths and other workers in metal often used the heat of burning gases to braze and solder. Welding and related thermal processes utilize compressed gas and/or electric current to provide a concentrated heat source which melts or burns away steel and other metals. Proper safety precautions are required to avoid accidents related to the gas and power supplies, to the sparks, heat, fumes, and visible and invisible rays from the heat source. Authorities in most countries have laid down regulations and guidelines related to welding and other hot work processes, their application onboard ships, the equipment to be used and the protection of the operator. These regulations must be available onboard, and be known and adhered to when hot work is to be done. A welded component that fails may represent a safety hazard to crew, ship and cargo. Classification societies and other authorities have consequently issued regulations and welding procedures for a number of applications onboard. These should be known and followed wherever applicable, and welding should be formed by qualified personnel under proper supervision. The joints produced by welding are permanent, strong, usually matching the strength of the components, leak tight, reproducible, and readily inspected by nondestructive techniques

A. Importance of Welding

Welding is used as a fabrication process in every industry large or small. It is a principal means of fabricating and repairing metal products. The process is efficient, economical and dependable as a means of joining metals. This is the only process which has been tried in the space. The process finds its applications in air, underwater and in space. Why welding is used-Because it is

- suitable for thicknesses ranging from fractions of a millimeter to a third of a meter

- Versatile, being applicable to a wide range of component shapes and sizes.

B. Definition of Welding

As per American Welding Society (AWS) Defines weld as a localized coalescence of metals or non-metals produced either by heating the materials to suitable temperatures with or without the application of pressure alone and with or without the use of filler material. Indian Slandered IS: 812-1957 Defines weld as "a union between two pieces f a metal at faces rendered plastic or liquid by heat or by pressure or both filler metal may be used to affect the union." International Organization for Standardization (ISO) It defines welding as "an operation by which two or more parts are united, by means of heat or pressure, or both, in such a way that there is continuity of the nature of the material between these parts. A filler material, the melting temperature of which is the same order as that of the present material, may or may not be used."

C. Physical Nature of Metal

Below their melting point, all metals are crystalline solids made up of grains, i.e., the grains are crystalline. In a typical fine-grain metal, the individual grains are about 0.003 cm in diameter. The grains in turn are made up of atoms. A typical grain would, thus, have about 1015 atoms, the diameter of a typical atom being about 3x10-18 cm. Metal are made up of grains separated by grain boundaries. In a homogenous single phase alloy, all grains are identical in composition, differing only in size, shape and orientation. The individual grains are crystalline. If we were to draw an imaginary three dimensional network of lines, properly spaced within the grain, nearly all the atoms of the grain could be centered at or very near one of the intersections of these lines and nearly every intersection would be occupied by an atom. The network is called lattice and intersections are lattice points

D. Physical Nature of Joining

Theoretically, to produce a weld all that is necessary is that the atoms on the perfectly plane surfaces, if treated in this fashion, would be drawn together spontaneously until the distance between them corresponds to the equilibrium inter-atomic spacing. At this point, perfect coalescence would occur and two objects would merge to comprise a single solid body. The surface of a perfectly clean metal can be visualized as one half of a grain boundary. The lattice is perfect right up to or nearly up to the free surface. The surface atoms are probably in their lattice position. However, they are not completely surrounded by other atoms as are the interior atoms. They are, thus, capable of bonding to another piece of metal i.e., another aggregate of atoms. The energy of these unsatisfied bonds is the source of the surface tension of the metal. It is quite evident then that if we were to bring into contact two perfectly clean, atomically smooth surfaces of a metal, the resulting joint would be as strong as at a grain boundary.

E. Welding Metallurgy

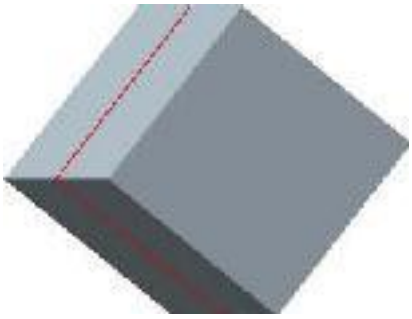
The formation of weld-metal occurs in various ways depending on the welding process. The resulting weld, in some cases, contains a minute portion of fussed metal called weld nugget. In dealing with the metallurgy of weld-metal, it is customary to refer to arc welding processes, in which the weld– metal is formed in superheated molten condition from the filler metal added. During its formation, it is exposed to gases which are present in the arc atmosphere and to slag (if flux is used) present in the weld pool. As the heat source moves further, the weld metal is cooled by the surrounding metal. The cooling rate, which influences the final structure and mechanical properties of the weld-metal, may be relatively slow or extremely fast, depending on the joint thickness. The weld – metal itself may be mixture of filler metal and base metal, depending on the depth effusion...Thus various metallurgical and other phenomena occur in the formation of weld, making it extremely complex material to understand. Weld-metal is often termed simply as weld. In arc welding, the molten weld pool is contained by the surrounding solid metal, which means that a liquid – solid interface is always present at the weld fusion boundary. This interface provides an ideal nucleation site. Hence during the solidification of weld – metal, there is no homogeneous nucleation and super cooling id negligible. As the nucleating grains grow, some of them are pinched off, causing fewer but larger grains in the weld-metal. The resulting grain size has marked effect on mechanical properties. Generally the heat flow in the weld zone is highly directional toward the adjacent cold metal and hence the weld acquires a distinctly columnar structure, in which the grains are long and parallel to the direction of heat flow. In the case of the deep peer-shaped weld shown on the right, it is seen that columnar grains growing from opposite side meet at the middle of the weld. This middle plane, where groups of intersecting columnar grains have solidified last, also often contains impurities and porosities. It is therefore prone to fracture at low strains.

II. WELDED JOINTS

(a) B Butt joint

(b) L Lap joint

(C) T Tee- joint



(d) E Edge joint

(e) C Corner joint

Figure 1: welded joints

Welds are made at the junction of the various pieces that make up the weldment. The junctions of parts, or joints, are defined as the location where two or more members are to be joined. Parts being joined to produce the weldment may be in the form of rolled plate, sheet, shapes, pipes, castings, forgings, or billets. The five basic types of welding joints are listed below.

- B BUTT Join: it is a joint between two members lying approximately in the same plane
- L Lap Joint: it is a joint between two overlapping members.
- T TEE Joint: is joint between two members located approximately at right angle to each other in form of a T.
- E Edge Joint: it is a joint between the edges of two or more parallel or mainly parallel members.
- C CORNER Joint: it is a joint between two members located approximately at right angle to each other in form of an angle

II. INTRODUCTION TO SUBMERGED ARC WELDINGROCESS

A. The mechanics of Submerged Arc Welding process (SAW)

The mechanics of the Submerged Arc Welding process (SAW). Both the Arc and the weld metal are submerged beneath a layer of flux. This layer protects the weld metal from contamination and Concentrates the heat into the joint. The molten flux rises through the pool, de-oxidizing and cleaning the molten metal. It then forms a protective slag covering over the newly deposited weld. The range of applications can be anything from 2mm thick material, increasing with no upper limit. Sub-arc is one of the most versatile welding processes. All steel grades, from non to high alloyed including Ni-based, can be welded with a combination of various application techniques. Ranging from a single electrode-single power source to a combination of twin wire, tandem and multiple arc system applications, Lincoln Electric is proud to offer an extensive range of application solutions to the market. As a global supplier, Lincoln's knowledge in the SAW process will support you in reaching the toughest productivity and quality targets, with our range of consumables and equipment.

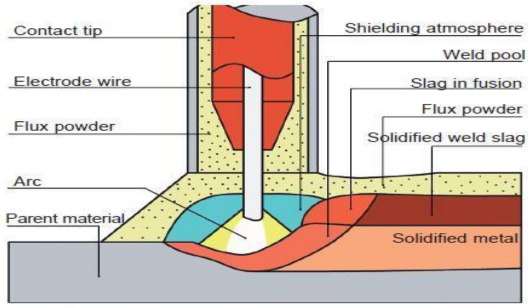


Figure 2: SUBMERGED ARC WELDING

B. Arc Characteristics

CV and CC Modes

Due to the wide range of wire diameter that can be used in SAW, this process can be performed either on CV or CC mode:

B.1 Constant Voltage mode (CV):

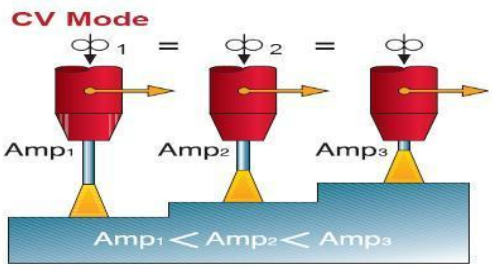


Figure 3: Constant Voltage mode

This mode fits perfectly with small diameter electrodes. It offers great arc stability and reactivity as it holds the wire feed speed ( ) constant and varies the current in order to drive the voltage to set point. This mode guaranties a constant deposition rate.

B.2 Constant Current mode (CC):
This mode is usually applied with large diameter electrode. It varies the wire feed speed in order to drive the voltage and current (Amps) to set point. This mode guaranties a constant penetration.

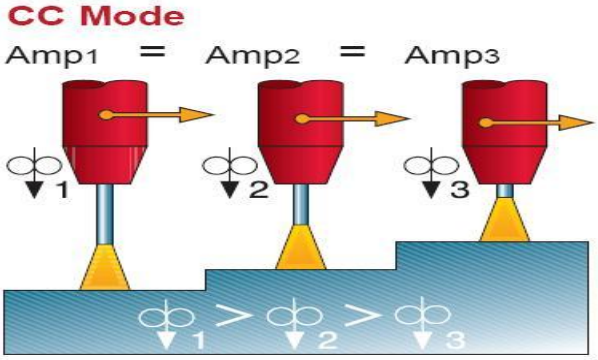


Figure 4: Constant current mode

C. Advanced Features
Strike time: Arc ignition can be improved by adjusting the wire feed speed at striking.
Arc start control / Crater control: Start and stop of the weld are always 2 transition periods. Welding parameters can be adjusted differently, during these welding sequences, to control penetration and filling.
Burnback time: This function prevents the wire to be stuck to the joint at the end of the weld.

D. Advantages
- High deposition rates (over 45 kg/h) have been reported.
- Deep weld penetration.
- Sound welds are readily made (with good process design and control).
- High speed welding of thin sheet steels up to 5 m/min (16 ft/min) is possible.
- Minimal welding arc light is emitted.
- The process is suitable for both indoor and outdoor works.
- Low distortion
- Welds produced are uniform, ductile, corrosion resistant and have good impact value.
- Single pass welds can be made in thick plates with normal equipment.
- The arc is always covered by flux, thus there is no chance of spatter of weld.
- 50% to 90% of the flux is recoverable.

E. Limitations
- Limited to ferrous (steel or stainless steels) and some nickel-based alloys.
- Normally limited to long straight seams or rotated pipes or vessels.
- Flux and slag residue can present a health and safety concern.
- Requires inter-pass and post weld slag removal.

F. Segment and Applications
- Light & heavy industry with non-alloy products
- Pressure vessels with low alloyed products
- Pipe mills all grades
- Offshore with low alloyed products
- Process industry with low & high alloy products

G. Materials
- Carbon steel
- Stainless steel
- Nickel based alloys

H. Equipment Requirements
- Robustness
- Outstanding welding performance
- High duty cycle
- Versatility of welding mode
- Modularity

I. Saw Diversity

TABLE: saw diversity

Process	Equipment	Advantages
Single arc	1 power source 1 feeding head 1 wire	• Cheapest configuration
Twin arcs	1 power source 1 feeding head 2 wires	• High travel speed • Increased deposition rate • Low cost investment
Tandem arcs	2 power sources 2 feeding heads 2 wires	• Productivity improvement • Flexibility of welding configuration
Long Stick-out	Linc-fill torch	• Deposition rate improvement at low cost investment

III. LITERATURE REVIEW

This Section Briefly Discusses About the Previous Work Carried Out By the Researchers in the Various Fields Which Are Related To Topic and Helped One Gain to Build Platform for My Work

A. Literature Survey
[1]PRANESH B. BAMANKAR, DR. S.M. SAWANT. Had studied the effect on penetration depth of mild steel by SAW process. Using Taguchi method & considering three factors and three levels, process parameters like welding current, arc voltage and welding speed (Trolley speed) on mild steel of 12 mm thickness The results shows penetration will be at maximum value when welding current and arc voltage are at their maximum possible value and welding speed is at its minimum value.
[2]S. SHEN, I.N.A. OGUOCHA, S. YANNACOPOULOS. Had examine that how variation in heat input achieved using single and double wires affected bead reinforcement, bead width, penetration depth, contact angle, heat affected zone (HAZ) size, deposition area, penetration area and total

molten area of ASTM a709 grade 50. The level of dilution and different melting efficiencies were calculated and their variation with heat input was analyzed based on the acquired measurements. The cooling time from 800 to 500 ◦C was also related to various weld bead characteristics (e.g., total nugget area, heat transfer boundary lengths, bead width-to-depth ratio, and nugget parameter). The bead reinforcement, bead width, penetration depth, HAZ size, deposition area and penetration area increased with increasing heat input, but the bead contact angle decreased with it. The electrode melting efficiency increased initially and then decreased with increasing heat input, but the plate melting efficiency and percentage dilution changed only slightly with it. Cooling time exhibited a very good linear relationship with the total nugget area, heat transfer boundary length, and nugget parameter.

[3]CH.INDIRA PRIYADARSINI, N.CHANDRA SEKHAR, DR.N.V.SRINIVASULU. have conducted the experiments in order to assess the effects of heat input, speed rate, wire feed rate, plate thickness, and gap on arc welding responses as applied to steel (SA 516 gr 70)welding. The arc welding process is simulated using Finite Element Method (FEM) program ANSYS Thermal analysis is carried out and with the above load structural analysis is also performed for analyzing the stability of the structure The simulations were carried out using a two-step process; non-linear heat transfer, elasto-plastic analysis. as the distance increases from 5mm to 15mm of centre point of the base material temperature decreases

[4]JAI DEV CHANDEL & NAND LAL SINGH. have Used J-C-O-E technique, They have studied the heat input for LDSAW process has been optimized with respect to the toughness down to -20 *C in HAZ strength level. The effect of varying level of heat input similar to line pipe welding except line pipe formation of LDSAW process has been studied with three wire tandem system of SAW system. Found that the heat input level named “L-1-A” produce the minimum HAZ and highest toughness level and appropriate hardness.

[5]D.V. KIRAN, B. BASU, A. DE. They had studied that the weld bead profile and mechanical properties in the tandem submerged welding are significantly affected by the leading and trailing wire current transients and the welding speed. They presented a detailed experimental study on the influence of leading wire current, trailing wire current pulses, and welding speed on the weld bead dimensions and mechanical properties in single pass tandem submerged welding of typical HSLA steel. It is realized that the weld bead penetration is primarily influenced by the leading wire current while the weld bead width and the reinforcement height are sensitive to the trailing wire current pulses. Greater magnitude of trailing wire current pulses and shorter negative pulse duration increase the weld pool volume leading to reduced cooling rate and poor mechanical properties as the formation of the strengthening phases like acicular ferrite is inhibited. In contrast, increase in welding speed reduces the rate of heat input thereby enhancing the cooling rate and the weld bead mechanical properties. A set of empirical relations are developed to estimate the weld bead dimensions and mechanical properties as function of the welding conditions. The experimental results show that the final weld bead width and reinforcement height are primarily influenced by the trailing wire current while the penetration is influenced by the leading wire current with the other conditions remaining constant. Increase in trailing wire current pulses enhance the weld pool size that tends to reduce the cooling rate, inhibit acicular ferrite phases in weld microstructure and result in poor mechanical properties. In contrast, increase in welding speed tends to reduce weld pool size leading to higher cooling rate that encourages greater volume fraction of acicular ferrite phase and better weld bead mechanical properties. The predictions of weld dimensions and mechanical properties from the empirical relations, which are developed based on the experimental results, are in fair agreement with the corresponding measured values within the ranges of the welding conditions considered in this work.

[6]RATI SALUJA, K M MOEED, have applied Factorial design approach for optimizing four submerged arc welding parameters viz. welding current, arc voltage, welding speed and electrode stick out by developing a mathematical model for sound quality bead width, bead penetration and weld reinforcement on butt joint. Response surface methodology (RSM) technique is applied to determine and characterize the cause and effect relationship between true mean responses and input control variables influencing the responses. For butt joint, Welding current has more predominant effect on the weld geometry than that of other parameters. Welding current and welding speed have major influence on bead penetration whereas electrode stick out has minor effect. Welding speed and electrode stick out had little or negligible effect on weld reinforcement

[7]SHAHNWAZ ALAM, MOHD.IBRAHIM KHAN. Used arc voltages, current, welding speed, wires feed rate and nozzle-to-plate distance as process parameters & two level full factorial technique for experiment design. Multiple regression analysis has been used to develop a mathematical model to predict weld width using 12mm plate. Model has been checked by using analysis of variance, F-test and t-test respectively. Weld width has been found to increase with increase in voltage, current and wire feed rate and decreases with increase in welding speed and nozzle-to-plate distance. Weld width rapidly increases with voltage slowly increases with current and wire feed rate and decreases with welding speed and nozzle to plate distance. The developed model can be effectively used to predict the weld width within the range of parameters used.

[8]RAVINDER PAL SINGH, R.K.GARG, D.K.SHUKLA have studied that Welding input parameters play a very significant role in determining the weld bead geometry, mechanical properties and distortion of a weld joint. Comprehensive review of parameters of submerged arc welding and their effect on weld quality have been reported. efficient metal transfer behavior enables uniform stream of small droplets transferred from the electrode at given current The material transfers across the arc gap influences the chemical composition and metallurgy of weld metal, arc stability, weld bead geometry as well as strength of the weld.

Polarity change affects the amount of heat generated at welding electrode and work piece and hence influences the metal deposition rate, weld bead geometry and mechanical properties of the weld metal. Dynamic characteristics of an arc welding power source are determined by the transient variations in output of current and voltage that appears in the arc.

[9]SAURAV DATTA AND SIBA SANKAR MAHAPATRA have studied that an integrated approach capable of solving the simultaneous optimization of multi-quality responses in SAW was suggested. In the proposed approach, the responses were transformed into their individual desirability values by selecting appropriate desirability function. Assuming equal importance for all responses, these individual desirability values were aggregated to calculate the overall desirability values. Quadratic Response Surface Methodology (RSM) was applied to establish a mathematical model representing overall desirability as a function involving linear, quadratic and interaction effect of process control parameters. This model was optimized finally within the experimental domain using PSO (Particle Swarm Optimization) algorithm. A confirmatory test showed a satisfactory result.Weld quality in SAW depends on features of bead geometry, mechanical-metallurgical characteristics of the weld as well as on weld chemistry. The weld quality improvement is treated as a multi-factor, multi-objective optimization problem. The practical application of SAW requires efficient optimization methodology because process parameters are expected to interact in a complex manner. Therefore, any optimization algorithm must seek to identify interaction effects of input factors and be incorporated in the course of an optimization procedure in a convenient way for developing an efficient methodology. The developed methodology based on RSM, desirability function and PSO algorithm can be applied in practice for continuous quality improvement and off-line quality control.

[10]IWATA SHINJI, NISHI YASUHIKO, OZAMOTO DAISUKE. Have developed a system to control the penetration depth of the welding and its associated system, and have adopted them into commercial projects. It was confirmed that satisfactory and stable performance of welds, which was used to be highly dependent on the skill of experienced operators, have been achieved by the system. They had described the development and practical application of a welding condition monitoring and penetration control system for submerged arc welding (SAW) with multiple electrodes in welding of the corner joints of box columns for structural steel. Among other benefits, the introduction of this system has demonstrated effectiveness in securing stable welding quality and enabling early mastery of operating procedures by non-skilled operators

[11] SERDAR KARAOGˇ LU, ABDULLAH SEC¸GIN. They focused on the sensitivity analysis of parameters and fine tuning requirements of the parameters for optimum weld bead geometry. Changeable process parameters such as welding current, welding voltage and welding speed are used as design variables. The objective function is formed using width, height and penetration of the weld bead. Experimental part of the study is based on three level factorial design of three process parameters. In order to investigate the effects of input (process) parameters on output parameters, which determine the weld bead geometry, a mathematical model is constructed by using multiple curvilinear regression analysis. Effects of all three design parameters on the bead width and bead height show that even small changes in these parameters play an important role in the quality of welding operation. The results also reveal that the penetration is almost non-sensitive to the variations in voltage and speed. Mathematical modeling using curvilinear regression equations were developed from experimental data. Then, sensitivity analysis of weld bead parameters such as bead width, bead height, and penetration to variations in current, voltage, and speed in submerged arc welding process were performed. Welding process parameters, required for desired weld bead geometry, can effectively be predicted using mathematical models developed in this study. These mathematical models can also be used to optimize processes and to develop automatic control systems for welding power sources. Bead width is very sensitive to all process parameters. Current, voltage and speed are the determining parameters for bead width. Bead width is more sensitive to voltage and speed variations than that of bead height and penetration. All three process parameters have effects in determining the bead height. In order to decrease the bead height, higher values of voltage and speed can be considered. Since bead width and penetration are more sensitive to current variations than bead height, arc current can be used effectively for any adjustment in bead width and penetration. Current is the most important parameter in determining the penetration. Penetration is almost non-sensitive to variations in voltage and speed. Therefore, voltage and speed cannot be effectively used to control penetration. At maximum heat input level (higher levels of current and voltage, and lower level of welding speed), current sensitivity of penetration, and speed sensitivity of bead width reach their maximum values.

[12] P. KANJILAL, T.K. PAL, S.K. MAJUMDAR studied Rotatable designs based on statistical experiments for mixtures have been developed to predict the combined effect of flux mixture and welding parameters on submerged arc weld metal chemical composition and mechanical properties. Bead-on-plate weld deposits on low carbon steel plates were made at different flux composition and welding parameter combinations. The results show that flux mixture related variables based on individual flux ingredients and welding parameters have individual as well as interaction effects on responses, viz. weld metal chemical composition and mechanical properties. In general, two factor interaction effects are higher than the individual effect of mixture related variables. Amongst welding parameters, polarity is found to be important for all responses under study. They conclude that among the welding parameters, polarity has a profound influence on weld metal chemical composition. Welding speed influences weld metal carbon content through oxidation reaction; whereas weld metal sulphur and

phosphorous content are affected by dilution of weld deposit. Welding current influences weld metal manganese content through slag–metal reaction. Transfer of nickel from flux to weld, is found to be impeded by oxides formed during slag–metal reaction. Weld metal yield strength and hardness are mainly determined by welding parameters; whereas the impact toughness is determined by flux mixtures variables.

[13]JERZY NOWACKI, PAWEŁ RYBICKI. Had studied that the influence of the heat input submerged arc welding (SAW) of duplex steel UNS S31803 on kind and quantity of welded butt joints defects has been determined. Defects were identified by a radiographic method. For the defectiveness rate in the ratio of quantity negative test results RN to complete radiographic test RC were taken. The mechanical properties of the joints and value of ferrite share test have been done. Analysis of welding heat input influence on mechanical properties of test joints using heat input from 2.5 to 4.0 kJ/mm. For analysis of welding heat input influence on creation of welding imperfections, there were executed welding of sheet of thickness 10–32mm using two ranges of the welding heat input: up to 2.5 and up to 3 kJ/mm. It was shown that submerged arc welding of duplex steel with the heat input from 2.5 up to 4.0 kJ/mm has no negative influence on mechanical properties of the joints. Experiment showed, that welding with heat input up to 3.0 kJ/mm reduces welding defects of joints, e.g. slags, lack of a joint penetration for plates of thickness of 10–23 mm, as well as sticks, cracks, and the thoroughly decrease of other defects existence. Usage of larger welding heat input provides the best joints quality, what decreases the joints control and repair costs. As a result of the tests, it can be stated that increase of plate thickness increases weld defectiveness of duplex steel. Increase of welding heat input reduces the occurrence of inadmissible welding imperfections in joints, which reduces the costs of testing and repairs.

IV. METHODOLOGY

A. Background & Overview of Design of Experiments

Design of experiments was developed in the early 1920s by Sir Ronald Fisher at the Rothamsted Agriculture field Research Station in London, England. His initial experiments were concerned with determining the effect of various fertilizers on different plots of land. The final condition of the crop was not only dependent on the fertilizer but also on the number of other factors (such as underlying soil condition, moisture content of the soil, etc.) of each of the respective plots. Fishers used DOE which could differentiate the effect of fertilizer and the effect of other factors. Since that time the DOE has been widely accepted in agricultural as well as Engineering Science. Design of experiments has become an important methodology that maximizes the knowledge gained from experimental data by using a smart positioning of points in the space. This methodology provides a strong tool to design and analyze experiments; it eliminates redundant observations and reduces the time and resources to make experiments.

B. Methods for D.O.E

The design of experiment based on

- Factorial design
- Taguchi method
- Response surface method

The technique is applied in different steps:

- Brainstorming the quality characteristics and design parameters,
- Design the experiments using suitable method of software,
- Conduct the experiments,
- Analyze the results to determine the optimum conditions.

C. Key Terms:

Factor: An element of the experimental unit that will be varied. Here in my experiment factors are welding currents, arc voltage, welding speed, material thickness.

Level: The possible value of a factor.

Combination: An instance of the experimental unit with a particular level from each factor applied. We have used factorial design, and used full factorial design. For a full factorial design, if the numbers of levels are same then the possible design N is N = Lm Where L = number of levels for each factor, and m= number of factors.

Fractional factorial designs are good alternatives to a full factorial design, especially in the initial screening stage of a project. It is used to simplify the experiment. Fractional factorial experiments investigate only a fraction of all the possible combinations. This approach saves considerable time and also money in case of costly materials, but requires rigorous mathematical treatment, both in the design of experiment and in the analysis of the results. Each experimenter may design a different set of fractional factorial experiments. Taguchi simplified and standardized the fractional factorial designs in such a way to engineers conducting tests thousands of miles apart, will always use similar designs and tends to obtains similar results. Taguchi developed a family of fractional factorial experiments matrices which can be utilizes in various situations. These matrices reduce the experiments numbers but still obtain reasonably rich information. In Taguchi methodology specially design table known as “orthogonal arrays” are used. The use of this table makes the design of experiments vary easy and consistent.

D. Steps To Perform Full Factorial Design Of Experiments:

- Identify the importance statistical analysis variables.
- Statistically analyze a data set.
- Explain the proper steps in developing a full factorial design of experiments.
- Design a full factorial experiment.
- Evaluate the results of experimental data.
- Organize technical information into a clear and concise formal laboratory report.

E. Doe for Saw Welding
3Factors and their levels SAW welding.

TABLE 1: Factors and their levels SAW welding

SR NO.	INPUT FACTOR	LEVEL		
1	plate thickness (mm)	10	12	14
2	Arc Voltage (Voltage)	30	32	34
3	Welding Speed (mm/Min)	420	440	460

Finally total 27 readings on submerged arc welding machine will be taken.

F. Material Selection:

- Stainless steel -304
- Thickness for material is 5 mm.
- V-groove weld joint design is selected.

G. Chemical Composition:

ELEMENTS	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Nitrogen
%	0.08	2.00	0.045	0.03	0.75	18-20	8-12	0.10

TABLE 2: Chemical Composition.

PHYSICAL PROPERTIES OF MATERIAL Density: - 0.29 lbs/in3 8.03 g/cm3
Melting Range, °F (°C) – 2550 – 2650 (1399 - 1454)

H. Application Of Material:

- Food processing equipment, particularly in beer brewing, milk processing & wine making.
- Kitchen benches, sinks, troughs, equipment and appliances
- Architectural paneling, railings & trim
- Chemical containers, including for transport
- Heat Exchangers
- Woven or welded screens for mining, quarrying & water filtration
- Threaded fasteners
- Spring

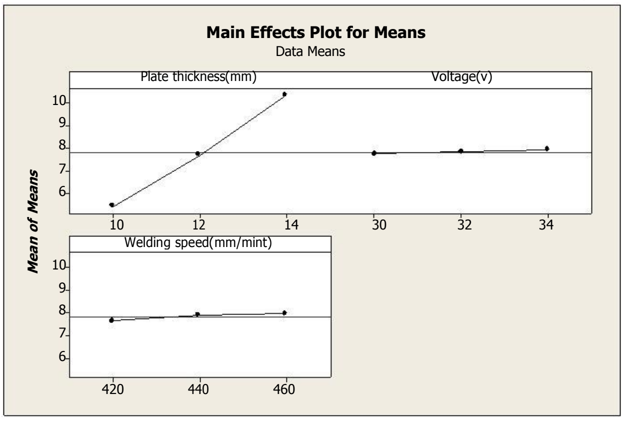
I. Data Obtained From Experimental Work For Depth Of Bed Width In Saw

Plate thickness (mm)	Voltage (v)	Welding speed (mm/mint)	Depth of Penetration	BED WIDTH
10	30	420	4.72	12.62
10	30	440	6.02	11.92
10	30	460	6.28	11.78
10	32	420	5.28	13.34
10	32	440	4.84	12.76
10	32	460	4.52	12.44
10	34	420	5.38	13.68
10	34	440	5.68	13.4
10	34	460	6.12	13.14
12	30	420	7.2	10.62
12	30	440	7.96	10.48
12	30	460	7.42	9.98
12	32	420	7.72	10.54
12	32	440	8.88	9.62
12	32	460	7.82	8.62
12	34	420	7.46	12.66
12	34	440	7.42	11.22
12	34	460	7.34	10.9
14	30	420	9.52	10.82
14	30	440	9.4	10.44
14	30	460	11.02	9.82
14	32	420	10.3	10.4
14	32	440	9.9	10.28
14	32	460	11.18	9.8
14	34	420	11.2	10.58
14	34	440	10.58	9.96
14	34	460	10	9.8

J. Mean Effect Plots Analysis For Saw:
The analysis is made with the help of a software package MINITAB 16. The main effect plots are shown in Fig.4.1 and Fig.4.2 these show the variation of individual response with the three parameters i.e. plate thickness, voltage, and welding speed separately. In the plots, the x-axis indicates the value of each process parameter at three level and y-axis the response value. Horizontal line indicates the mean value of the response. The main effects plots are used to determine the optimal design conditions to obtain the optimum surface

finish.

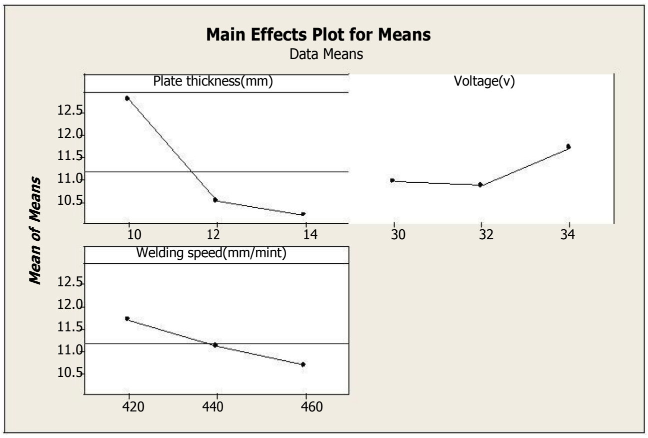
MAIN EFFECT PLOTS FOR PENETRATION,



According to this main effect plot, the optimal conditions for maximum penetration are:

- Plate thickness at level 3 (14 mm),
- voltage at level 3 (34 volts),
- welding speed at level 3 (460 mm/mint)

MAIN EFFECT PLOT FOR BEAD WIDTH



According to this main effect plot fig.5.2, the optimal conditions maximum bead width is:

- plate thickness at level 1(10 mm),
- voltage at level 3 (34 volts),
- welding speed at level 1 (420 mm/mint)

V. CONCLUSION

A. PENETRATION:

- Plate thickness, voltage & welding speed significantly effects on penetration.
- Plate thickness is found the most significant effect on penetration. Increase in plate thickness value of penetration is increase.
- Voltage is found to have effect on penetration. Increase in voltage, value of penetration is increase.
- Welding speed is found to have effect on penetration. Increase in welding speed, value of penetration is increase.
- The optimal combination of high plate thickness and high voltage with high welding speed is beneficial so penetration is increase.
- The percentage contribution of plate thickness is 92.20 %, voltage of 0.1 % and welding speed of 0.4 % on penetration for submerged arc welding.
- In multi response optimization the optimum parameter combination for SAW is meeting at experiment 25 and its parameter value is 14 mm plate thickness, 420 mm/min welding speed and 34v voltage.

B. BEAD WIDTH:

- Plate thickness, voltage & welding speed significantly effects on bead width.
- Plate thickness is found the most significant effect on bead width. Increase in plate thickness value of bead width is decrease.
- Voltage is found to have effect on bead width. Increase in voltage, value of bead width is increase.
- Welding speed is found to have effect on bead width. Increase in welding speed, value of bead width is decrease.
- The optimal combination of low plate thickness and low welding speed with high voltage is beneficial so bead width is increase.
- The percentage contribution of plate thickness is 92.20 %, voltage of 0.1 % and welding speed of 0.4 % on bead width for submerged arc welding.
- In multi response optimization the optimum parameter combination for SAWis meeting at experiment 7 and its parameter value is 10 mm plate thickness, 420 mm/min welding speed and 34v voltage.

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