INVESTIGATE WELDING PARAMETER OPTIMIZATION FOR WELD BEAD SURFACE QUALITY USING MIG TECHNOLOGY

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ABSTRACT

Investigation of MIG welding parameter optimization for surface quality is very important to improve the technology of MIG 3D welding application. Weld bead size and shape are one of important considerations for design and manufacturing engineers. These welding parameters affecting the arc and welding bath should be estimated and their changing conditions during process must be known before in order to obtain optimum results, in this case the quality surface of overlap weld beads. The process parameters such as welding voltage, welding travel speed and wire feet rate were studied. The experiments were conducted based on a Three-factor, three-level and L9 using Taguchi method.

Taguchi methods applied to improve the quality of welding bead. Carbon steel plate AISI 1015 is used as the work piece material for carrying out the experimentation to optimize the surface quality and hardness value. Taguchi orthogonal array is designed with three levels of welding parameters with the help of software Minitab 16. Nine run experiments of single beads and nine runs for overlap weld beads are performed, surface quality and hardness is calculated using the minitap 16 software.

The surface roughness was considered as the quality characteristic with the concept of "the smaller-the-better" and hardness “the larger-the-better. It is also predicted that Taguchi method is a good method for optimization of various input parameters as it reduces the number of experiments.

ABSTRAK

Kajian kimpalan MIG dalam pengoptimuman parameter proses kimpalan untuk kualiti permukaan adalah sangat penting dalam memperbaiki dan meningkatkan teknologi kimpalan MIG khususnya dalam bidang kimpalan 3D. Saiz kumai dan bentuk kumai adalah pertimbangan yang penting untuk rekabentuk dan pembuatan kejuruteraan. Parameter proses kimpalan yang memberi kesan kepada arka dan kumai harus dianggarkan dan perubahan keadaan semasa proses juga perlu diketahui. Usaha sekarang adalah untuk mendapatkan hasil yang optimum untuk kualiti permukaan kumai bertindih kimpalan. Parameter proses kimpalan seperti voltan, kelajuan kimpalan dan kadar kemasukan wayar telah dikaji. Kajian ini telah dijalankan berdasarkan tiga faktor, tiga peringkat dan L9 menggunakan kaedah Taguchi.

Kaedah Taguchi digunakan dalam kajian untuk meningkatkan kualiti kumai. Plat keluli karbon AISI 1015 digunakan sebagai bahan benda kerja bagi menjalankan ujikaji dalam pengoptimuman kualiti permukaan dan nilai kekerasan. Pelbagai ortogon Taguchi direka untuk tiga tahap parameter kimpalan dengan bantuan perisian Minitab 16. Sembilan ujikaji dilakukan dalam kumai lurus sementara sembilan lagi untuk kumai bertindih kimpalan. Kualiti permukaan dan kekerasan dikira menggunakan perisian MINITAB 16.

Kekasaran permukaan dianggap sebagai ciri kualiti dengan konsep "yang lebih kecil-lebih baik" dan kekerasan kumai "yang lebih besar-lebih baik. Kaedah Taguchi adalah kaedah yang baik untuk pengoptimuman pelbagai parameter input kerana ia mengurangkan bilangan uji kaji.

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CHAPTER 1

INTRODUCTION

1.1 Metal Inert Gas welding (MIG)

Metal inert gas welding (MIG) is one of the welding types of gas metal arc welding (GMAW). It is a welding process in which an electric arc forms between a consumable wire electrode and the metal work piece. In this welding process, the heat be will generate through the jumping current of the gap of wire electrode and the work piece metal, causing them to melt, and join. A shielding gas feeds through the welding gun along with the wire electrode. This shielding gas shields the melting metal from contaminants in the atmosphere air.

This welding method is a semi-automatic welding process which is continuous and consumable wire electrode. In Metal Inert Gas welding, a constant voltage, direct current power source is most commonly used with GMAW, but constant current systems, as well as alternating current, can be used (Ajit Hooda1*, 2012). Investigation of MIG welding parameter optimization for surface quality is very important in improvement of the 3D MIG welding technology application. Weld bead size and shape are important considerations for design and manufacturing engineers. These welding parameters affecting the arc and welding bath should be estimated and their changing conditions during process must be known before in order to obtain the optimum results, in this case the quality surface of layered weld bead.

1.2 Background of the study

In welding process, there are parameters need to be consider in concern to obtain the objective characteristic of weld bead. To develop 3-D welding technology, two characteristics of weld bead need to be improve, surface quality and mechanical strength. The shape and dimensions of the weld bead are very important in the use of 3-D welding as a Rapid Prototyping system, these will determine the strength of wall and shape produced product and this characteristic will influence the quality of the surface finish. To obtain this, optimization parameter in this MIG welding need to be study. These parameters affecting the arc and welding bath should be estimated and their changing conditions during process must be determine in order to obtain optimum results. A perfect arc can be achieved when all the parameters are in conformity. In MIG welding process, there is several important parameters need to concern. These parameters are arc voltage welding current, amperage, travel speed, wire feed speed, torch angle, free wire length, nozzle distance, welding direction, electrode extension, welding position and the flow rate of gas. However, wire electrode diameter and its composition, type of protective gas are the defined parameters before starting welding and cannot be changed during the process (Olabi).

Theoretical studies of a complex physical problem like MIG welding process are made based on a number of assumptions, to make the model simpler and as a result of which, it might be difficult to determine its input–output relationships accurately. Difficulties associated with the above theoretical studies will arise, some researchers have tried to establish input–output relationships of a process through statistical analysis of the parameter effect. The properties such as weld-bead geometry, mechanical properties can define the quality of weld bead. Generally, all welding processes are used with the aim of obtaining a welded joint and the weld bead with the desired parameters, excellent mechanical properties with quality surface. In order to determine the welding input parameters that lead to the desired weld quality, application of Design of Experiment (DOE), through Taguchi method are widely used to develop a mathematical relationship between the welding process input parameters and the output variables of the weld joint (Cary, 1989).

1.3 Problem Statement

Surface quality comes together with good mechanical properties is very important aspect in development of 3-D welding technology. This study will focus on overlap weld bead. By obtaining this good surface quality characters mean will save cost and production time of the production welding printing. The good surface quality of welding bead will lead to reduction of finishing process of the product by means the process of the milling process can be skip. The present work aim is to determine the input–output relationships of a MIG welding process. Without the optimization parameter to obtain best surface quality of weld bead, these two aspects will hard to be developed. Investigation in this project is to establish relations between the process parameters (inputs) and responses (outputs) for overlap welding bead in MIG welding process (Y.S. Tarng, 1998). This researcher tried to obtain the optimized weld bead geometry in GTAW by using the modified Taguchi method. The modified Taguchi method allowed the simultaneous consideration of all the weld pool geometry quality characteristics for optimization. In Tarng research, overlap surface roughness were not been determine.

In a related research (Wurikaixi Aiyiti, 2006), a simplified overlapping model between deposited tracks was established to investigate the relationships among the overlapping parameters, such as the ratio of width to height of the deposited track cross-section , scan spacing and overlapping ratio were studied and the finding was the overlapped surface smoothness, tensile strength and elongation of the parts built with larger width bead were better than those built with smaller width bead. The researcher was not study the welding process guideline to obtain the smoothness overlap weld bead in term of the angle setting of welding torch of overall overlap weld bead welding process. The combination between the process parameters (inputs) and responses (outputs) for overlap welding bead in MIG welding process are complete if there is no welding process technique being applied on the overlapping process such the setting of the torch angle and also the interval break time for every stringer bead.

1.4 Research Objectives

There are three (3) objectives in this research. The objectives are:

i. To investigate optimization parameter in MIG welding technology for surface quality of overlap welding beads.
ii. Evaluation the surface quality of overlap weld bead using the Taguchi method.
iii. To propose welding process guidance for having good surface finish of weld bead.

1.5 Scope of Study

There are several scopes of study in this investigation. The scopes are:

i. Study focus on welding parameter of Voltage, travel speed, and wire feed rate.
ii. The carbon steel metal wire feeler ER70S-6 used in this experimental work for investigates the optimization parameter of the overlap and single weld bead surface quality.
iii. Carbon steel plate AISI 1015 with the dimension of 50 X 100 X 5 mm was selected as subtract for as based metal for the samples of weld bead.
iv. Investigation focus on single weld bead and overlap weld bead.

1.6 Dissertation Summary

Investigation of MIG welding parameter optimization for surface quality is very important improvement the technology of MIG welding in 3D welding application. Weld bead size and shape are important considerations for design and manufacturing engineers. These welding parameters affecting the arc and welding bath should be estimated and their changing conditions during process must be known before in order to obtain optimum results, in this case the quality surface of overlap weld beads. The process parameters such as welding voltage, welding travel speed and wire feet rate were studied. The experiments were conducted based on a Three-factor, three-level and L9 using Taguchi method.

Taguchi methods applied to improve the quality of welding bead and engineering development of designs for studying variation. Carbon steel plate AISI 1015 is used as the work piece material for carrying out the experimentation to optimize the surface quality and hardness value for single and overlap weld bead. Different experiments are done by varying one parameter and keeping other two fixed so maximum value of each parameter was obtained. The combination between the process parameters (inputs) and responses (outputs) for overlap welding bead in MIG welding process are complete if there is no welding process technique being applied on the overlapping process such the setting of the torch angle and also the interval break time for every stringer bead.

CHAPTER 2

LITERATURE REVIEW

This chapter is presented the literature review of selected journal, articles, reference book, thesis and online source. Keywords of this study are welding parameter, weld bead geometry and Taguchi optimization.

2.1 3-D Welding

Rapid Prototyping systems based on 3D welding are now being attraction to some researcher groups because it can directly build fully dense metal components with relatively lower costs. As a production technique, 3-D welding offers significant advantages over conventional processing, these include the potential for robot control of the welding torch allowing large variation in part dimensions and geometry. This technique also can be highly automated system. Parts produce by 3-D welding will provide consistent properties with rapid processing times, hence vastly reduced development times besides efficient use of materials. Through the mass transfer by direct melting the welding electrode, direct production of a metal part are the most unique amongst current Rapid Prototyping (J.P. Ganjigatti).

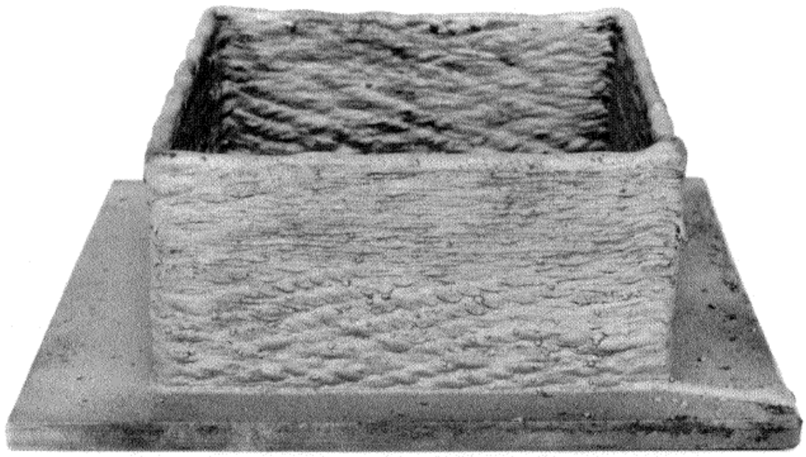


Figure 2.1: Square box formation by 3D formation (Dr P M Dickens)

Metal Inert Gas welding (MIG) offer a lot of advantages compare to other welding method to use in 3-D welding technology. The advantages of MIG welding are:

- High quality welds can be produced much faster
- Since a flux is not used, there is no chance for the entrapment of slag in the weld metal resulting in high quality welds
- The gas shield protects the arc so that there is very little loss of alloying elements. Only minor weld spatter is produced
- MIG welding is versatile and can be used with a wide variety of metals and alloys
- The MIG process can be operated several ways, including semi and fully automatic

2.2 Welding Parameter

In MIG welding, there are many parameter of the welding process. According to Miller, (Miller Electric Mfg Co., 2013) setting the correct parameter is the most important aspect in-order to get proper welding bead. Miller listed several parameters need to concern about, such as material thickness that will determines amperage setting, selection of proper wire size according to amperage, setting of the voltage and setting of the wire feed speed. The important problem in Metal Inert Gas (MIG) welding need to be solved is determining the optimization parameter value to achieve desire characteristic aspect of weld bead. According to Miller, setting the correct parameter is the most important aspect in-order to get proper weld bead. Miller listed several parameters need to concern about, such as material thickness that will determines amperage setting, selection of proper wire size according to amperage, setting of the voltage and setting of the wire feed speed.

Regarding to ugur etc, (Ugur Esme, Melih Bayramoglu, Yugut Kazancoglu, Sueda Ozgun, 2009) in similar research, affecting parameters on the arc and welding bath should be estimated and their changing conditions during process must be known before in order to obtain optimum results; in fact a perfect arc can be achieved when all the parameters are in conformity. These are combined in two groups as first order adjustable and second order adjustable parameters defined before welding process. Former are welding current, arc voltage and welding speed, and later are torch angle, free wire length, nozzle distance, welding direction, position and the flow rate of gas. However, wire electrode diameter and its composition, type of protective gas are the defined parameters before starting welding and cannot be changed during the process.

A common problem that has faced the manufacturer is the control of the process input parameters to obtain a good welded joint with the required bead geometry and weld quality with minimal detrimental residual stresses and distortion. It has been necessary to determine the weld input parameters for every new welded product to obtain a welded joint with the required specifications (Olabi). There are four primary methods of metal transfer in GMAW, called globular, short-circuiting, spray, and pulsed-spray, each of which has distinct properties and corresponding advantages and limitations (Radaj, 1992).

In research done by Dr P M Dickens (Dr P M Dickens) stated to produce single weld beads for a range of welding conditions, the parameters that involved are voltage, wire feed rate, wire stickout, wire diameter and welding velocity. The arc voltage and welding current under each condition was monitored and the dimensions of the bead produced (height and width) were subsequently measured using a shadowgraph technique.

Table 2.1: Effect on measured variable (Dr P M Dickens).

Increasing Variable	Effect on Measured Variable			
	Arc Voltage	Current	Bead Width	Bead Height
Voltage	↑	=/↑	↑	↓
Wire Feed	↓	↑	↑	↑
Stickout	↑	↓	↓	↑
Wire Diameter	↓	↑	↑	↑
Velocity	=	=	↓	↓

Voltage determines height and width of bead. There is a relationship between arc voltage and arc length. A short arc decreases voltage and yields a narrow, "ropey" bead. A longer arc (more voltage) produces a flatter, wider bead. Too much arc length produces a very flat bead and a possibility of an undercut (Miller Electric Mfg Co. , 2013)

There are several types of metal transfer modes in MIG welding. There are globular, short-circuiting, spray and pulse-spray metal transfer mode. In Globular mode, it produces high heat, a poor weld surface, and spatter. Welding speeds of up to 110 mm/s (250 in/min) allowing will high deposition rate in short-circuiting mode. The lower current than that is for the globular method. Lower current also makes the heat input for the short-arc variation considerably reduced, making it possible to weld thinner materials while decreasing the amount of distortion and residual stress in the weld area. Globular and short-circuiting metal transfer modes can only be used on ferrous metals. Short-circuiting metal transfer provides better weld quality and fewer spatters than the globular variation. To maintaining a stable arc, the setting of weld process parameters such as volts, amps and wire feed rate within a relatively narrow band is critical, generally between 100 to 200 amperes at 17 to 22 volts for most applications. The disadvantages of using short-arc transfer mode will lead to lack of fusion and insufficient penetration when welding thicker materials. This is due to the lower arc energy and rapidly freezing weld pool.

The other mode of metal transfer in MIG welding is spray mode. This mode well-suited to welding aluminum and stainless steel while employing an inert shielding gas. In MIG welding process, the weld electrode metal is rapidly passed along the stable electric arc from the electrode to the work piece, essentially eliminating spatter and resulting in a high-quality weld finish. Vaporized spray transfer mode in welding process requires higher voltage and current than short circuit transfer. This transfer mode commonly used only on work pieces of thicknesses above about 6.4 mm. Apart of that, the large weld pool in this mode often limit to weld the flat and horizontal welding positions and sometimes also used for vertical-down welds. The last metal transfer modes in MIG welding is pulse-spray mode. This mode is based on the principles of spray transfer but uses a pulsing current to melt the filler wire and allow one small molten droplet to fall with each pulse. During the welding process, the pulses allow the average current to be lower, decreasing the overall heat input. The lower heat input decreasing the size of the weld pool and heat-affected zone. This makes it possible to weld thin work pieces and provides a stable arc and no spatter, since no short-circuiting takes place.

The selection of shielding gas in MIG welding affected the welding bead. Referring to mig_handbook by Welding Guns Of Australia PTY LTD Pty Ltd there are four types of shielding gas of MIG welding process can be selected by depending on what purpose and type of material to be weld. Selection of shielding gas also affects the characteristic of weld bead. Pure inert gases such as argon and helium are only used for nonferrous welding. If the gas being used to weld steel, argon do not provide adequate weld penetration and can cause an erratic arc and while with helium it will encourage spatter (Ltd, 2012). Pure carbon dioxide allows for deep penetration welds but encourages oxide formation, which adversely affect the mechanical properties of the weld. Spatter is unavoidable and welding thin materials is difficult. As a result, argon and carbon dioxide are frequently mixed in a 75%/25% to 90%/10% mixture. Generally, in short circuit GMAW, higher carbon dioxide content increases the weld heat and energy when all other weld parameters (volts, current, electrode type and diameter) are held the same. As the carbon dioxide content increases over 20%, spray transfer GMAW becomes increasingly problematic, especially with smaller electrode diameters.

The mixtures gas of argon, carbon dioxide and oxygen are marketed for welding steels. Other mixtures add a small amount of helium to argon-oxygen combinations, these mixtures are claimed to allow higher arc voltages and welding speed. Helium is less dense than air, thus it is less effective at shielding the weld than argon—which is denser than air. It also can lead to arc stability and penetration issues, and increased spatter, due to its much more energetic arc plasma.

2.3 Weld BeadGeometry

Control of weld bead shape is very important as the mechanical properties of welds will affected by the weld bead shape (Connor, 1991). Because of this, it is clear that precise selection of the process parameters is necessary. (S. Suryakumar, K.P. Karunakaran, Alain Bernard, U. Chandrasekhar, N Raghavender, Deepak Sharma, 2011) have been studied the bead profile above the subtrastrate and assumed to be a symmetric parabola of the form $y = a + cx^2$.

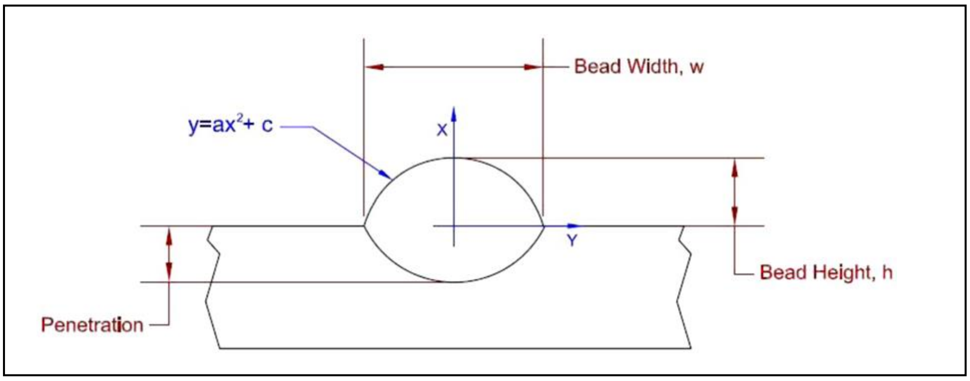


Figure 2.2: Simple overlapping parabolic pattern

The researcher also mentioned that a simple overlapping parabolic pattern shown in Figure 2.1 was assumed for the multiple bead deposition.

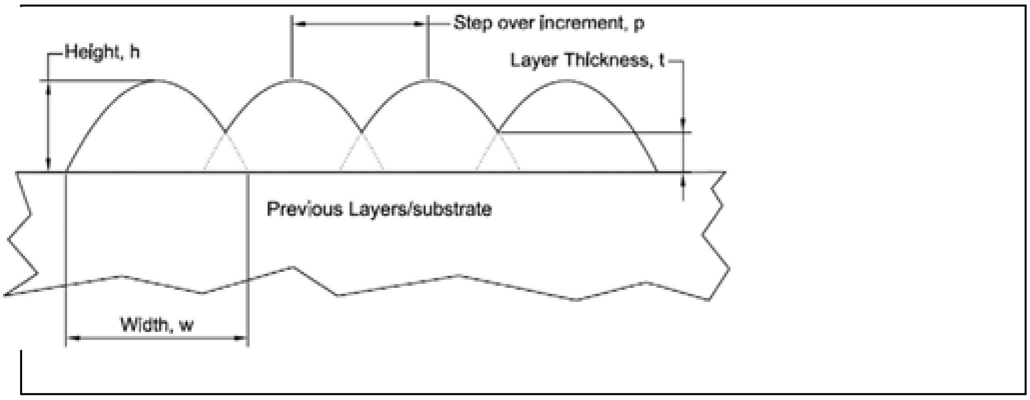


Figure 2.3: Multi bead profile in the initial model

The distance between the consecutive beads is referred as step over increment (p). In this model, it was assumed that: a) Every bead has same cross-sectional profile. b) The parabolic bead profile is unchanged during the overlapping process. S. Suryakumar et al has comeout with the improved model, as the step over increment decreases, the overlapping volume increases with a commensurate decrease in the volume of the valley. Therefore, the radius of the fillet increases with the decrease in the step over increment.

In order to find the parameter optimization, study on the weld bead profile is needed. (Yong Cao, Sheng Zhu, Xiubing Liang, Wanglong Wang, 2011) in their reseach mention that the sectional geometry of single-pass bead and the overlap of the adjacent beads have critical effects on the dimensional accuracy and quality of metalparts and the conclusion is that the edge detection of bead section with Canny operatoris continuous and distinct, and as compared with Gaussian function, logistic function and parabola function, sine function has higher accuracy to fit the measured data, and ‘‘surfacing of equivalent area’’ method shows to be rational and feasible by the experiments.

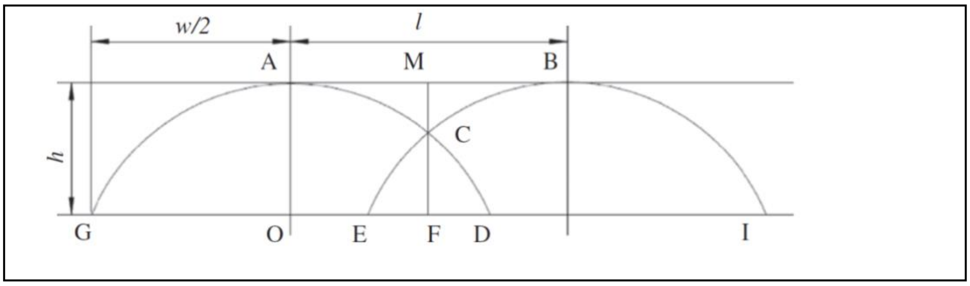


Figure 2.4: Sketch of overlapping model by yong Cao et al

2.4 Taguchi OptimizationMethod

Juang and Tarng (Tarng, 2002) have adopted a modified Taguchi method to analyze the effect of each welding process parameter (arc gap, flow rate, welding current and speed) on the weld pool geometry (front and back height, front and back width) . Their research was to determine the TIG welding process parameters combination associated with the optimal weld pool geometry. It was experimentally reported that, the four smaller-the-better quality characteristics, ‘four responses’ of the weld pool in the TIG welding of S304 stainless steel of 1.5 mm in thickness are greatly improved by using this approach.

In the related research of parameter optimization, H. K. Lee (H. K. Lee, 2006) have used the Taguchi method and regression analysis in order to optimize Nd-YAG laser welding parameters (nozzle type, rotating speed, title angle, focal position, pumping voltage, pulse frequency and pulse width) to seal an iodine-125 radioisotope seed into a titanium capsule. The accurate control of the melted length of the tube end was the most important to obtain a sound sealed state. It was demonstrated that the laser pulse width and focal position were the laser welding parameters that had the greatest effects on the S/N ratios of the melted length.

Taguchi approach to design of experiments in easy to adopt and apply for users with limited knowledge of statistics, hence gained wide popularity in the engineering and scientific community. This is an engineering methodology for obtaining product and process condition, which are minimally sensitive to the various causes of variation, and which produce high-quality products with low development and manufacturing costs. Signal to noise ratio and orthogonal array are two major tools used in robust design. The S/N ratio characteristics can be divided into three categories when the characteristic is continuous

a) Nominal is the best
b) Smaller the better
c) Larger is better characteristics.

In robust parameter design, the primary goal is to find factor settings that minimize response variation, while adjusting (or keeping) the process on target. A processdesigned with this goal will produce more consistent output. A productdesigned with this goal will deliver more consistent performance regardless of the environment in which it is used. Engineering knowledge should guide the selection of factors and responses. The experimental works on determination of surface quality is surface roughness measurement. Surface roughness measurement should measured more than one line of surface, at least three difference lines on the tested surface to get the average value which will be considered for further analysis (BADRU DOJA, 2012).

In the experimental process, control factors will be being scale and so that responses interactions are unlikely. If the interactions among control factors are likely or not well understood, the design that is capable of estimating those interactions should be choose. The goal of robust experimentation is to find an optimal combination of control factor settings that achieve robustness against (insensitivity to) noise factors.

CHAPTER 3

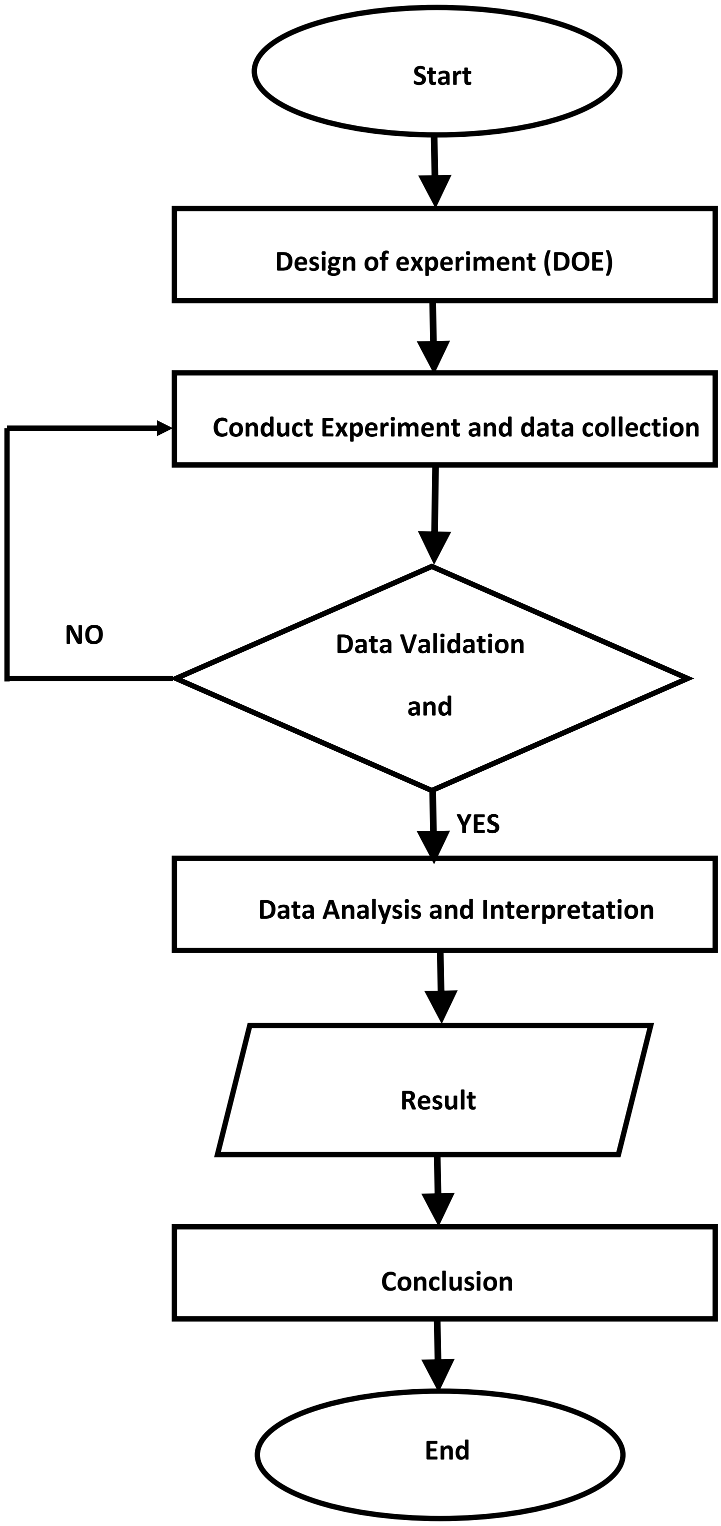
METHODOLOGY

This section will discuss on the description of the methods, procedures to obtain and how the data was analyzed and interpreted.

3.1 Introduction

The systematically organization of this study is represented in flow chart. The investigation of welding parameter optimization for weld bead surface quality using MIG welding technology started with customize the semi-automated MIG welding machnine where the welding travel asist by the travel control car. This customize system to ensure the travel speed of welding process of weld bead experiment specimen. Semi-automatic mechanized MIG welding is extensively used for making straight welds. The work pieces are then clamped in a steady position on the working bench. The filler wire is fed from a unit that controls feed speed and that compensates automatically for variations in mains voltage and for the friction of the rollers. The parameters that are machine-controlled are the wire feed speed, the arc voltage, gas flow rate and the diameter of the wire. During the welding process, the MIG welding set will adjust the relationship between these parameters. The manual setting of the process are on the length of the stick out, the angle of the welding gun and the welding travel speed. In this study works, carbon steel plate AISI 1015 was chosen as an experimental work piece. Diameter of the wire is 0.8mmtypeER70S-6 and shielding gas used in the process is argon.

Methodology Flow Chart



3.2 Research Methodology

The research project work starts with the implementation concept of Design of Experiment (DOE). The preliminary result determines the selected parameter levels selection. After the preliminary results are known, levels of parameter are then entered into robust design Taguchi Method (Minitab 16) to generate the design matrix table. Then the experiments are conducted based on input parameter and level setup.

3.3 Design of Experiment (DOE)

In this project, DOE considers multiple factor interaction effects. The experimental design simplifies the use of DOE by automating the process of designing experiments and analyzing the results. The experiment is carried out by running the complete set of noise factor settings at each combination of control factor settings (at each run). The response data from each run of the noise factors in the outer array are aligned in a row, next to the factors settings for that run of the control factors in the inner array. Taguchi Technique is applied to plan the experiments. The Taguchi method will provide good improvement productivity during this research and development, so that high quality of surface quality can be produced quickly and at low cost. The DOE using Taguchi approach can significantly reduce time required for experimental investigations. In this investigation, in the first stage, Taguchi's orthogonal arrays were used to conduct the experiments to find the contributions ofeach factor and to optimize the parameter settings. Analysis using Taguchi design L9 (3**3) which REPRESENTS:-

- L9 9 RUNS
- 3 3 LEVELS
- 3 3FACTORS

The following are the 3 Levels which are considered in Taguchi design

- High
- Medium

- Low

The combination Design of Experiments with optimization of welding control parameters to obtain best results can be achieved in the Taguchi Method and table 3.1 below shows the selected welding parameters and their level.

Table 3.1 Welding parameters and their level.

Welding parameters	**Level 1**	**Level 2**	**Level 3**
Voltage (V)	18.7	19.8	20.9
Travel Speed(mm/min)	247.5	312.5	377.5
Wire Feed Rate(m/min)	8.5	9.9	11.3

3.4 Conduct Experiment and Data Collection

Nine set of specimen of welded AISI 1015 work piece with different set of combination of parameter had been carried out. The distorted specimen due to other effects had not been considered in the experiment, as the condition was not the result from any of the specified parameters that had made up. There are 9 runs of single weld bead and another 9 runs for overlap weld bead are conducted base on L9 3 Level Taguchi Orthogonal Array.

Table 3.2: Taguchi design L9(3**3) for input value parameter setting of single bead

Sample of single weld bead	**Voltage (V)**	**Travel Speed (mm/min)**	**Wire Speed rate (m/min)**
A	18.7	247.5	8.5
B	18.7	312.5	9.9
C	18.7	377.5	11.3
D	19.8	247.5	9.9
E	19.8	312.5	11.3
F	19.8	377.5	8.5
G	20.9	247.5	11.3
H	20.9	312.5	8.5
I	20.9	377.5	9.9

Table 3.3: Taguchi design L9(3**3) for input value parameter setting of overlap welding bead

Sample of overlap weld bead	Voltage (V)	Travel Speed (mm/min)	Wire Speed rate (m/min)
1	18.7	247.5	8.5
2	18.7	312.5	9.9
3	18.7	377.5	11.3
4	19.8	247.5	9.9
5	19.8	312.5	11.3
6	19.8	377.5	8.5
7	20.9	247.5	11.3
8	20.9	312.5	8.5
9	20.9	377.5	9.9

While the hardness of the welded bead surface was using Hardness Rockwell A (HRA). The surface roughness of the welded bead surface that showed highest reading of HRA value was the most preferable criteria. The data was collected were the surface roughness and the hardness of the welded bead surface. Each test specimen will be conducted surface roughness test and hardness test. Test data will be collected and recorded for results observation and data validation and optimization.

3.5 Data Validation and Optimization

In this stage, the data collection must be through data validation process ensuring that that a study collect a clean, correct and useful data. Once surface roughness and hardness of a welding beads experiments been completed results are analyzed by calculating the signal-to-noise (S/N) ratio for each factor and each level in these experiments. This ratio is the reciprocal of the variance of the measurement error which is maximal for the combination of parameter levels that has the minimum error variance. Calculating the average of S/N value for each factor and plotting them for each level will reveals the effect of the factor on the variable used to evaluate these experiments on value of surface roughness and hardness. Analysis of variance (ANOVA) techniques will be used to study the fractional factorial experiments and identify the significance of each factor. In statistical significance testing, the p-value is the probability of obtaining a test statistic at least as extreme as the one that was actually observed, assuming that the null hypothesis is true. The p-value must turn to be less than a certain significance level 0.05. If the P value above this level, the data must be recollect again by using difference approach in the same experiment. In this study would be the method of surface roughness and hardness value.

Optimization of control parameters to obtain best results for surface roughness and highest value of hardness is achieved by using the Taguchi Method.
In Taguchi method, there are 3 Signal-to-Noise ratios of common interest for optimization. There are 3 Signal-to-Noise ratios of common interest for optimization

i. Smaller-The-Better:
n = -10 Log10 [mean of sum of squares of measured data]

ii. Larger-The-Better:
n = -10 Log10 [mean of sum squares of reciprocal of measured data]

iii. Nominal-The-Best:
n = 10 Log10 square of mean
variance

3.6 Project Sample

In this study, two groups of samples will be produced; single weld bead and overlap weld bead. For each run setting of single weld bead and overlap weld bead, three (3) replicate samples been produced. Single and overlap weld shown in Figure 3.1 and Figure 3.2**.** For each replication, the observatory data will be recorded for three (3) times. The samples of overlap weld bead were produced by overlapping five stringer beads together to form a layer of new platform.

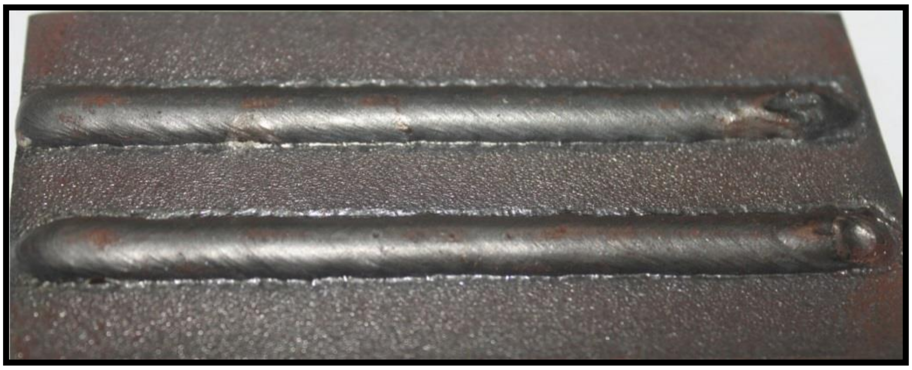


Figure 3.1: Single weld bead sample

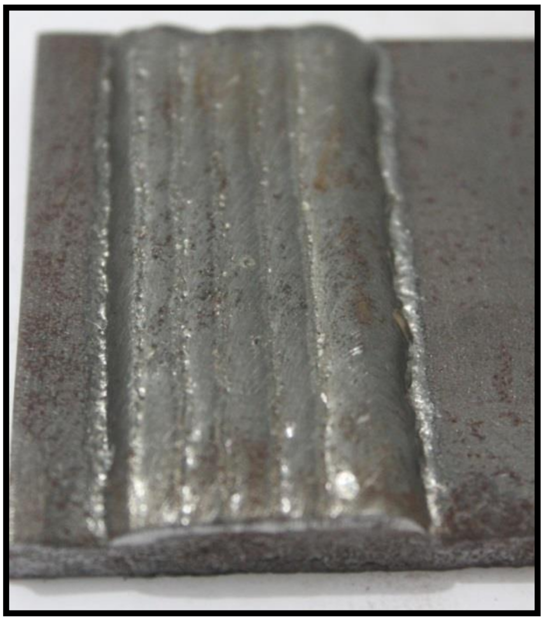


Figure 3.2: Overlap weld bead sample

3.6.1 Validation of the Sample

All samples must undergo the validation filtration before it can be select as study sample for data collection. These to ensure the samples are produced follow the specification before analyzed. Weld bead height are measured by using TWI Welding Gauge (Cambridge Gauge) (GAU/0002) and standards height weld bead for both single and overlap weld bead samples must be not over than 3.2mm according to (Examination Book of Specifications, 2008). It measures angle of preparation, 0 to 60 ^{o}, excess weld metal (capping size), depth of undercut, depth of pitting, fillet weld throat size, fillet leg length, misalignment (high-low), and linear measurements up to 60mm or 2 inches. Average value of 4 different point of weld bead height was takenin this validation process. To measure the height of the bead, weld gauge were placed on the flat surface of based metal or subtract and weld gauge pointer point the on top of the pitch of the weld bead.

All the welding samples were follow the inspection criteria of American Welding Society where:

i. No incomplete joint penetration in groove welds, except as permitted for partial joint penetration groove welds.
ii. No cracks or incomplete fusion.
iii. Undercut shall not exceed the less than 10% of the substrate (base metal) thickness or 1/32 in. (0.8 mm).

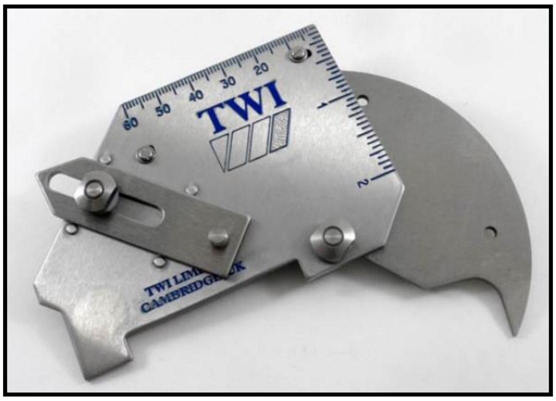


Figure 3.3: TWI Welding Gauge (Cambridge Gauge) (GAU/0002)

3.7 Laboratory Testing

3.7.1 Surface Roughness Test

All 18 runs of both for single bead and overlap weld bead were undergoing the surface roughness test. Nine (9) samples of overlap weld bead surface roughness were taken in two (2) difference direction. Specimen for overlap weld bead, surface roughness test will be run in two directions, the direction of longitudinal and vertical. These two directions give difference range of surface roughness value. The surface roughness reading of vertical measurement direction is influenced by the position of stringer bead overlapping point or also known as overlaps bead scan spacing. Surface roughness of longitudinal measurement direction, the reading value were much influent by the characteristic of the stringer bead surface roughness.

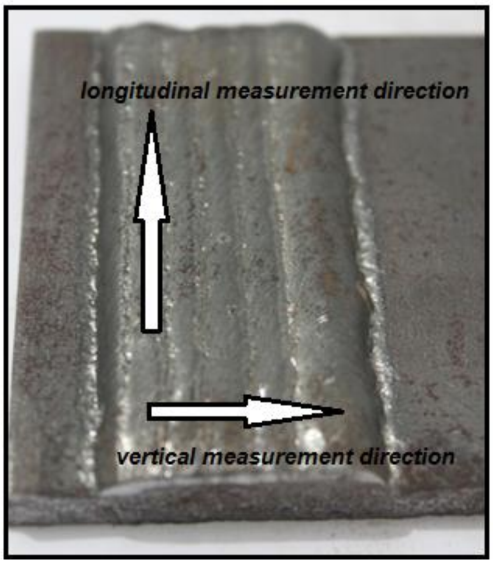


Figure 3.4: Vertical and longitudinal surface roughness measurement direction

Surface roughness measurement on single weld bead were done by measured the surface roughness of the single weld bead peak as show in Figure 3.5

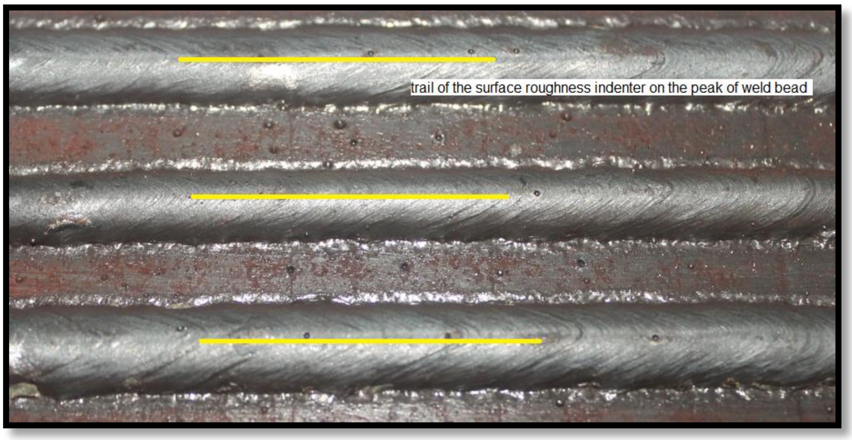


Figure 3.5: Trail of surface roughness indenter on the weld bead peak.

The surface roughness of the welded bead surface had been measured using Roughness test JIS1994 gauss standard. Lower surface roughness of the welded bead surface was the preferable criteria that put into measured. Definitions and indications for surface roughness parameters (for industrial products) are specified. They are arithmetical mean roughness (Ra), maximum height (Ry), ten-point mean roughness (Rz), mean spacing of profile irregularities (Sm), mean spacing of local peaks of the profile(S) and profile bearing length ratio(tp). Surface roughness is given as the arithmetical mean value for a randomly sampled area. Mean center line roughness (Ra) is defined in the annexes of JIS B 0031 and JIS B 0061. A portion stretching over a reference length in the direction in which the average line extends is cut out from the roughness curve.

In this lab testing, samples of single and overlap weld beads were inspected using Mitutoyo SJ-400 surface roughness machine. Data are measured at the top pitch of the weld bead. All data are measured 3 times for each sample at the 3 different pitches. The machine is set to follow JIS 1994 standard (Misumi Corporation, 2014). Figure 3.7 shows the machine for the roughness test.

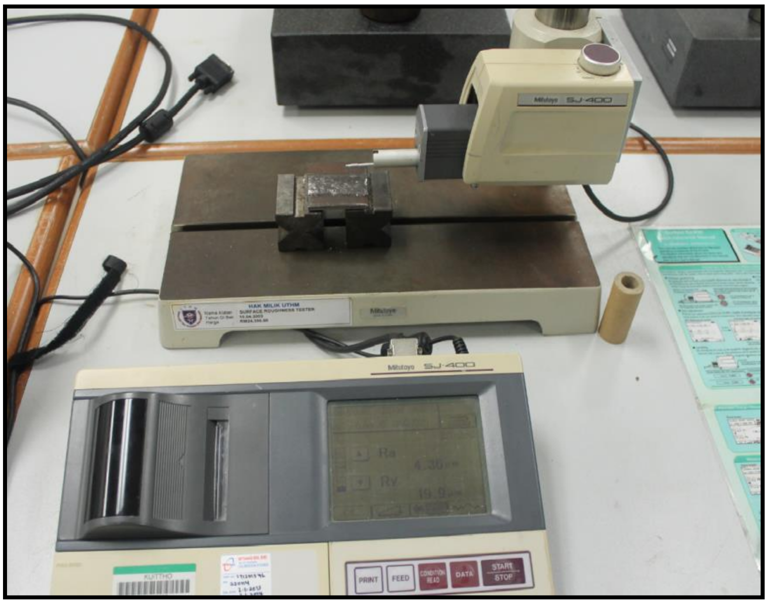


Figure 3.6: Mitutoyo SJ-400 machine

3.7.2 Hardness Test

In this lab test, the hardness of the sample is valuated using Rockwell harness test. The **Rockwell scale** is a hardness scale based on indentation hardness of a material. The Rockwell test determines the hardness by measuring the depth of penetration of an indenter under a large load compared to the penetration made by a preload.There are different scales, denoted by a single letter, that use different loads or indenters. The result is a dimensionless number noted as HRA, where A is the scale letter. Due to the hardness value of weld bead range, the HRA were chosen to conduct the measurement. A Rockwell scale A (HRA) using load 60 kg to force on 120° diamond

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