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Influence of GMAW Process Parameters and Selection Techniques on the Quality of a Welded Joint

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Abstract: Metal inert gas welding is one of the important joining processes in the industry. There is wide range of applications of MIG welding to join similar as well as dissimilar materials. This process is also employed for thickness of sheets from lower to higher thickness. It is essential to have an appropriate quality of welded joints for each application. The quality of joints is dependent on various factors such as tensile strength of the joint, microstructure, hardness and penetration of the joint. These factors are affected by different welding input process variables or their combinations such as welding voltage, welding current, wire feed rate, welding speed, etc. Higher quality of the joints is ensured by accurate combinations of these variables. This method to find out combination of variables such that the value of input is lower and output is higher is called an optimization. Various optimization techniques are available to finalize the parameters, which are Taguchi DOE, Taguchi Grey based, ANN network, surface response methodology, regression analysis, mathematical modeling, etc. In this paper weight age of input variables, output variables and optimization technique is discussed per literature. The study is limited for Carbon steel sheets having thickness up to 6mm. Based on the weight age the parameters and method of optimization is suggested. An overview of various techniques of optimization have been studied, effects of different parameters on the quality output parameters are discussed and appropriate range is suggested based on the literature review.

I. INTRODUCTION

MIG welding [8] can be used as a manual welding operation as well as automatic process. Main advantage of the MIG welding is automatic continuous feeding filler wire. It can also be used to join unalloyed steel, aluminum alloy and stainless steels. Robotic MIG welding is found to be a very effective tool to attain required quality, higher productivity, better working condition, and semiskilled operators can cooperate. MIG welding [35] can be operated manually as well as in automatic way. The use of robotic welding increases the productivity and the quality of the welded joints. Semiskilled operator can operate the machine. But operator should have a proper knowledge of programming of the machine. Specific design of work piece, equipment, shielding gas, electrode size and type of equipment are discussed in this study. Due to flexibility [6] and higher speed, the MIG welding is one of the widely used processes among all the welding processes. Input process parameters such as weld current, voltage and preheat temperature are optimized in order to attain output properties such as tensile strength and percentage elongation. Here grey based Taguchi analysis is used to optimize the parameters and mathematical equation is formed by using a Regression analysis. Results shows that preheat temperature are most affecting factors on the tensile strength.

Quality of the welded joints [2] can be measured in terms of bead geometry. There are many input process parameters of MIG welding which affects this quality of weld. Here in order to optimize the different process parameters such as weld current, work piece thickness, voltage and wire feed rate, the Taguchi optimization is used with L27 array. For the same result, mathematical model was also developed. Voltage and weld current affects most on quality. Different input parameters [10] such as welding current, voltage, and welding speed are optimized to attain the output parameters such as fatigue strength, microstructure and its related properties. MIG welding with above parameters is carried out for joining of various similar and dissimilar metals. Results show that MIG welding can be applied to many similar and dissimilar materials. Input parameters of the TIG [21] welding such as current, time, speed, variation of oxide fluxes, electrode diameter and gas flow rate are optimized by using L9 orthogonal array in Taguchi technique in order to improve the output properties such as tensile strength, hardness and depth of weld.[29] Many input parameters of MIG welding are affected on the quality output parameters of a welded joint such as welding bead geometry, distortion, different mechanical properties and penetration. Now a day different techniques of optimization such as design of experiments, network analysis and algorithm is adopted by many researcher. The weld bead dimension [39] and bead mechanical properties are the important parameters of welding joint quality. Input parameters are affected on the quality of weld joint. Previously traditional methods were used to estimate the required input parameter of the welding process. This method was dependent on trial and error methods. So the new techniques such as Artificial Neural Networks (ANN), Design of Experiments (DOE) and Finite Element Modeling (FEM) are used for optimization of multiple variables.

[1] Optimization technique by using a Taguchi as well as Grey relational analysis in order to optimize the different process parameters to join the materials AISI1010 & AISI1018 with the MIG welding. After joining the output variables like hardness of metal and tensile strength are checked by varying the input parameters such as current, voltage, welding speed, and bevel angle. [3] MIG welding of the aluminum is very critical process. It is carried out to join the aluminum of grade AA219-T87 which is precisely used in aerospace applications. Optimization of different parameters such as welding current, Voltage and welding speed are carried out by using L9 orthogonal array in Taguchi method to improve its ultimate tensile strength and hardness. As there are two outcomes of the process, grey relational analysis was also used in addition with Taguchi. [4] Ultimate tensile strength, yield strength in tension and percentage elongation are taken as output parameters to judge the quality of MIG welded joints of material AISI 316L austenitic stainless steels. As here also there are three output variables so the grey relational analysis by Taguchi is used in order to optimize welding current, gas flow rate and nozzle to plate distance. Investigated [5] and used different optimization models such as ANN–Quasi Newton, ANN–GA, and ANN–SA in order to optimize the different process parameters of MIG welded joints of Aluminum alloy plates. In their study they observed that ANN GA model has given a best performance by giving minimum error and shows that most affecting factor on the welding strength was welding speed. Increase in welding speed will decrease in welding strength. Two stainless steel [7] plates of thickness 6mm are welding with MIG welding by mixing the fluxes as Sio2 and Cr2O3. Input parameters varied as weld current, voltage and welding speed in order to achieve the output parameters such as penetration depth, size of bead. Optimizations of parameters are carried out by using L9 orthogonal array using Minitab 16 software. All these parameters are used three times such as without flux, with Sio2 flux and with Cr2O3 flux.

[9] A plasma MIG hybrid welding is used to join the AL5083 materials. It is done by using combinations of 58 amp weld current MIG and 130amp plasma current. Quality of the weld is then checked by Microstructure and electrochemical impedance spectroscopy. Results shows that it has excellent corrosion resistance compared to other welding processes. [11] Optimization of welding parameters to join the stainless steel material 2205 by using the Tungsten Inert gas welding. The variation of input process variables such as current, time, speed, variation of oxide fluxes, electrode diameter and gas flow rate are designed to vary by using L9 orthogonal array of Taguchi and analysis of variance (ANOVA) method to improve the values of tensile strength, hardness and depth of weld. [12] Butt joints of material ISI 316L stainless steel are welded with MIG welding with a constant plate thickness of 3mm. The input parameters subjected to optimizations are welding current, gas flow rate and nozzle to plate distance. Three types of tests including visual, X-ray radiographic test and tensile test are taken on the samples to verify its ultimate strength, yield strength and percentage of elongation. The combination [13] of MIG welding and laser welding known as hot wire laser welding is used. Optimizations of different parameters such as laser power, welding speeds and hot-wire current is done to obtain the welding depth-to-width ratio, welding reinforcement, and tensile strength. Non-dominated sorting genetic algorithm (NSGA-II) method is used to find out the optimized parameters. Metal active gas [14] welding is also called as Co2 welding is adopted to join the two sheets of IRSM 41 COR-TEN A& COR-TEN B steel. Different properties such as micro structural characteristics, tensile properties, and hardness are tested for various combinations of tool design, materials, welding speed, feed rate and microstructure. Results show that IRSM 41 COR-TEN is having higher tensile strength and they are suitable for automobile applications. A two dimensional model of MIG [15] welding is prepared by using a Darcy model proposed for porous media. Computational fluid dynamics model has developed for simulation of mass and heat transfer in the welding process. The effects of input parameters such as groove depth, welding speed and groove angle is studied. The steel plates [16] of 10Ni5CrMoV material are joined by using single pass multi-layer MIG welding test. The input parameters such as welding energy input and speed of welding is varied to judge the output parameters such as microstructures, hardness and impact energy. Results of the experiment shows that low energy input and increase in the welding speed, the microstructures is converted from Bainite to Martensite. Optimization [17] of welding current, Voltage and welding speed was done by using Grey relational analysis and L9 orthogonal array to achieve the maximum values of ultimate tensile strength, yield strength and impact toughness for Incoloy 800HT as base material and N82 filler wire of diameter 1.2 mm by using a MIG welding. ANOVA method is also adapted to access the implications of parameters. [18] A Taguchi method was used to optimize the different input parameters such as welding current, gas flow rate and nozzle to plate distance on the output responses such as ultimate tensile strength (UTS) and Yield Strength (YS) by using a MIG welding on the AISI409 ferritic stainless steel to AISI 316L Austenitic Stainless Steel materials.

New modified model [19] and equation is developed for MIG welding and regression analysis is used to formulate the model for lap joint. Total bead area is taken as a output parameters and current, time, speed, voltage are taken as input parameters. Welding speed [20] versus wire feed rate for MIG welding lap joints were tested for aluminum sheets of 1.6mm thickness. Weld bead, the bead width, back bead width, and bead cross-section area are the parameters taken for comparing different values of wire feed rate and welding speeds. Increase in the welding speed and wire feed rate have reduced the output parameter values. [22] MIG welding joints of AISI 316L (austenitic stainless steel) with AISI 409M (ferritic stainless steel) are prepared to optimize the notch angles and root gap in the welding process to improve ultimate tensile strength and yield strength of the welded joint. [23] MIG welding and Laser MIG welding is differentiated for various factors. Results show that welding time, consumption of filler material, stress and deformation of the material in MIG welding is more than that in laser-MIG welding. Studied the effects of welding speed versus wire feed rate for MIG welding of Aluminum alloy. It is seen that Increase in welding speed causes increase in the wire feed rate and decrease in required outcome value. Studied [24] the effects of welding speed versus wire feed rate for MIG welding of Aluminum alloy. It is seen that Increase in welding speed causes increase in the wire feed rate and decrease in required outcome value. AISI 1040 [25] sheets are welded by MIG welding. Input parameters like arc voltage, arc current, welding speed, nozzle to work distance and gas pressure are optimized for improving the quality of welded joints. L9 Taguchi method and regression analysis is adopted for optimization.

Flux core arc welding [26] of two steel sheets is carried out to optimize the input parameters such as welding current, arc voltage, and nozzle-to-plate distance, electrode-to - work angle and welding speed in order to achieve greater weld penetration. In this study the central composite rotatable design is used as a tool for optimization. [27] Taguchi and ANOVA methods of analysis to optimize the input process parameters of MIG welding for C20 mild steel such as weld current, voltage and welding speed in order to achieve higher values of penetration. [28] Taguchi L9 orthogonal array method of analysis to optimize the input process parameters of MIG welding for 5A06 Aluminum alloy such as weld current, voltage, wire feed rate and plasma current in order to achieve higher values of Tensile strength, % elongation and Macrostructure. [30] Used Taguchi orthogonal array method of analysis to optimize the input process parameters of MAG welding for stainless steel 304L and 308L such as feed rate, distance, welding speed, laser power and defocus laser in order to achieve higher values of penetration, bead cross section and macrostructure. [31] Used Taguchi L16 orthogonal array method of analysis to optimize the input process parameters of MAG welding for stainless steel 304L and 308L such as electrode size, voltage, current, shielded gas, travel speed in order to achieve higher values of hardness. [32] Used Grey based Taguchi method of analysis to optimize the input process parameters of MIG welding for steel plates such as feed rate, distance, welding speed, voltage and gas flow in order to achieve higher values of penetration, bead height and bead width.

[33] Grey comparative method of analysis to optimize the input process parameters of Laser MIG welding for magnesium alloy AZ31 such as laser power, weld current and welding speed in order to achieve higher values of microstructure, tensile strength and penetration. Grey comparative method [34] of analysis to optimize the input process parameters of MIG welding for AL 5083 and AL 5183 as filler wire such as weld current, welding speed, and feed rate in order to achieve higher values fatigue strength. Used mathematical modeling method [36] of analysis to optimize the input process parameters of MIG welding for AISI 416 and AISI 440 Fse such as lase power and welding speed in order to achieve higher values of weld bead size and penetration. [37] composite rotatable design of analysis to optimize the input process parameters of MIG welding for stainless steel 409M such as current, voltage, speed, nozzle to plate distance and work angle in order to achieve higher values of weld bead size and penetration. [38] Taguchi DOE of analysis to optimize the input process parameters of MIG welding for stainless steel 304L such as current, plate thickness, and gas flow rate and travel speed in order to improve microstructure and micro hardness. [40] Residual-stress field analysis to optimize the input process parameters of MIG welding for Al-2024 and Al-7150 aluminum alloy such as current, nozzle to plate distance in order to reduce the residual stresses.

Taguchi DOE analysis [41] to optimize the input process parameters of MIG welding for AA 7075-T6 Aluminum alloy such as peak current, base current, frequency, gas flow rate and welding speed in order to improve face width and penetration. Similar and dissimilar weld analysis [42] to optimize the input process parameters of MIG welding AISI 316L (austenitic stainless steel) and AISI 409M (ferritic stainless steel) such as root gaps and notch angles in order to improve microstructures and mechanical properties. Taguchi L8 DOE analysis [43] to optimize the input process parameters of MIG welding of steel sheets such as weld current, % of slag mix and Basicity index in order to improve bead width and depth of penetration. Principal component analysis [44] to optimize the input process parameters of MIG welding of Aluminum such as weld current, % of slag mix and Basicity index in order to improve bead width and depth of penetration. Response surface methodology [45] analysis to optimize the input process parameters of MIG welding of IS: 2062 mild steel such as weld current, speed, shielding gas, flow rate, voltage and distance in order to improve bead height, bead width and depth of penetration. Single & double pass HLAW process [46] analysis to optimize the input process parameters of MIG welding of NV E690 steel joint such as weld current, laser power and voltage and distance in order to improve Tensile strength, microstructure and micro hardness. Numerical simulation analysis [47] to optimize the input process parameters of MIG welding of NV E690 steel joint such as weld current, laser power and voltage in order to improve microstructure and to reduce residual stresses. X ray biography analysis [48] to optimize the input process parameters of MIG welding of Aluminum alloy such as weld current and keyhole in order to improve microstructure. Optimized the input process parameters [49] of MIG welding of pure copper such as bevel angle, distance between torch & work piece, laser power, welding speed in order to improve microstructure, surface morphology, micro hardness and mechanical properties. Taguchi 27 orthogonal array analysis [50] to optimize the input process parameters of MIG welding of Fe36 Ni Invar alloy such as weld current, laser power, welding speed and wire feed rate in order to improve microstructure and hardness. Optimized the input process parameters [51] of MIG welding of 304 (stainless steel) such as current, gas flow rate and welding speed in order to improve microstructure and tensile strength. Compare joints of copper base metal [52] and HS201 welding wire under traditional MIG welding and laser MIG welding by varying the process parameters such as weld current, arc voltage, wire feed, welding speed and gap size in order to improve its microstructure, micro hardness and tensile strength. Optimized [53] the input process parameters of MIG welding of steel such as current, arc voltage and welding speed in order to improve microstructure and weld formation (bead dimension).

II. EFFECTS OF INPUT PARAMETERS

[1-77] In order to get a higher penetration and higher strength in the welded joints many factors are responsible which are discussed below. The contribution of each welding parameter is presented on the histogram. By referring the literature on optimization it can be said that most weight age is given for mainly three parameters which are welding current, welding speed and welding voltage.

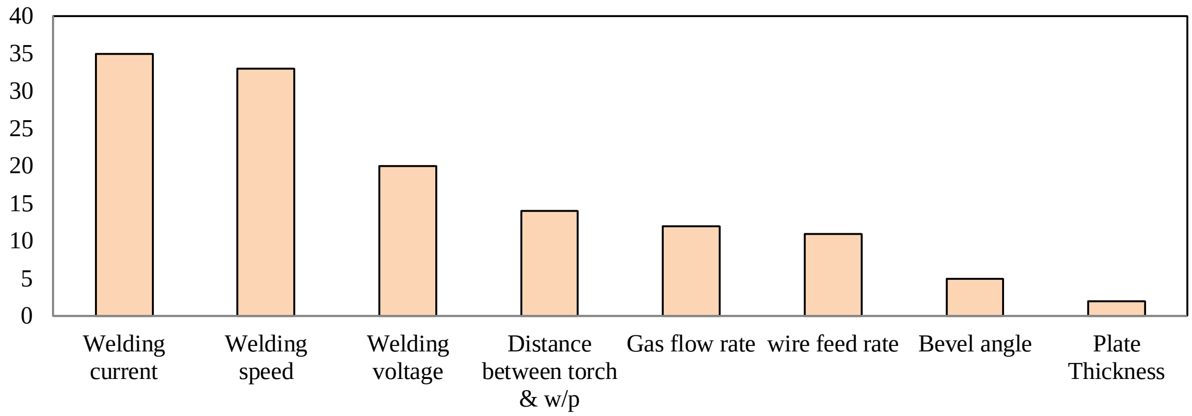

Fig.1 Weight age of welding input parameters

A. Current

Welding current is the most important factor to achieve a high penetration. In the MIG welding process as wire speed increases, welding current also increases. But with increase in the wire feed rate, the speed at which torch is traveled should also be increased in order to cope up with wire speed and more penetration. When the torch travel speed is less, penetration will decrease

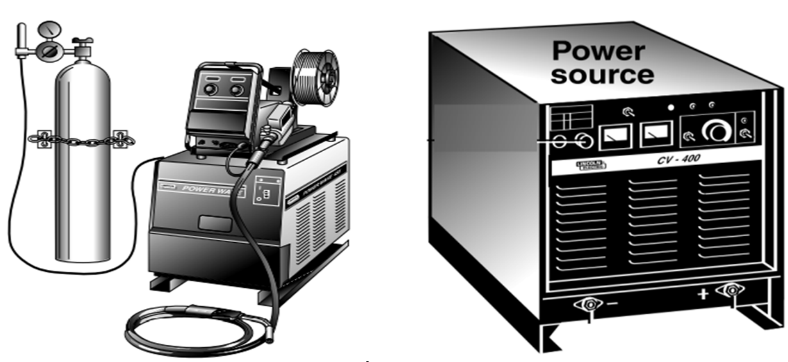

Fig. 2 MIG controller

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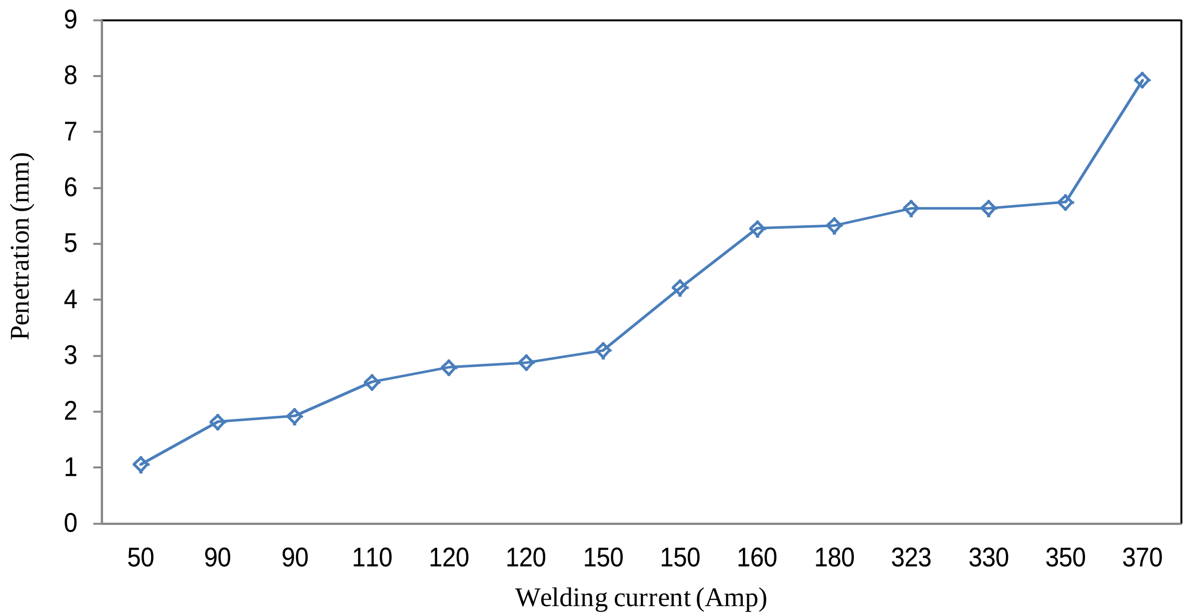

Fig.3 Variation of penetration with welding current

B. Voltage

Welding voltage is also dependent on the arc length. Voltage parameter directly affects on the heat input of the process. Very high voltage causes excessive spatters and undercut. Similarly too low voltage also causes to increase the defects like porosity and overlapping of edges of weld joint.

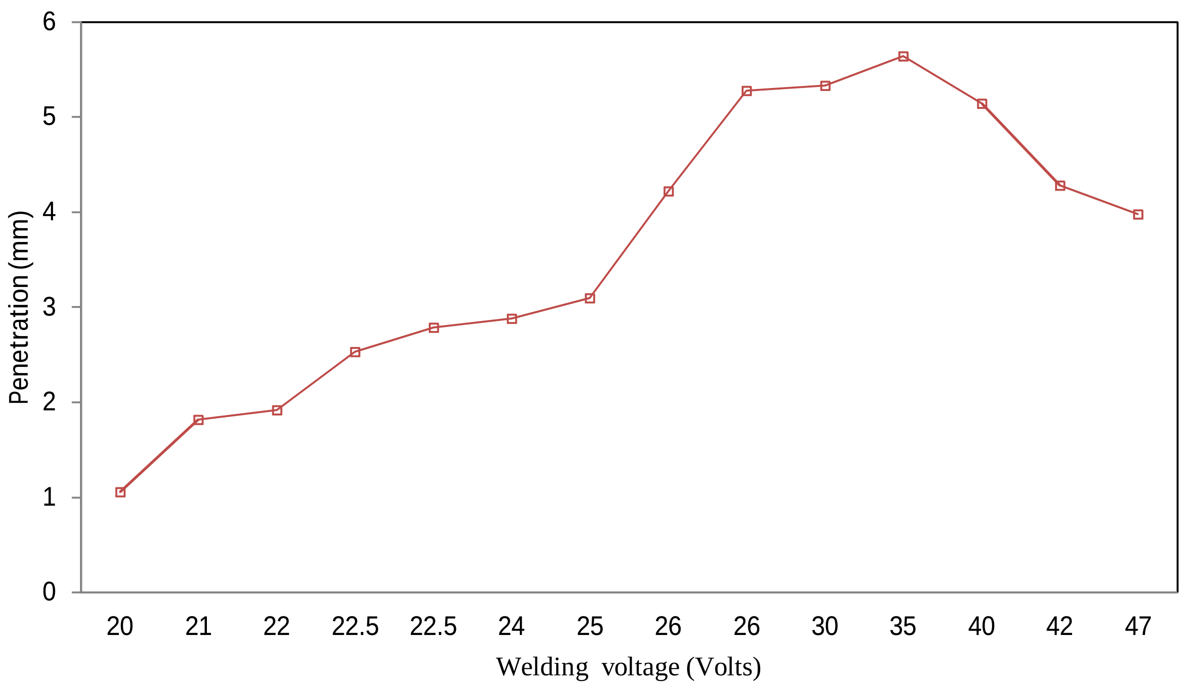

Fig. 4 Variation of penetration with welding voltage

C. Travel Speed

More torch travel speed reduces the heat input and fusion of the work piece and penetration increases with the decrease in travel speed. But too low speed also causes excessive heat inputs which also decreases the penetration.

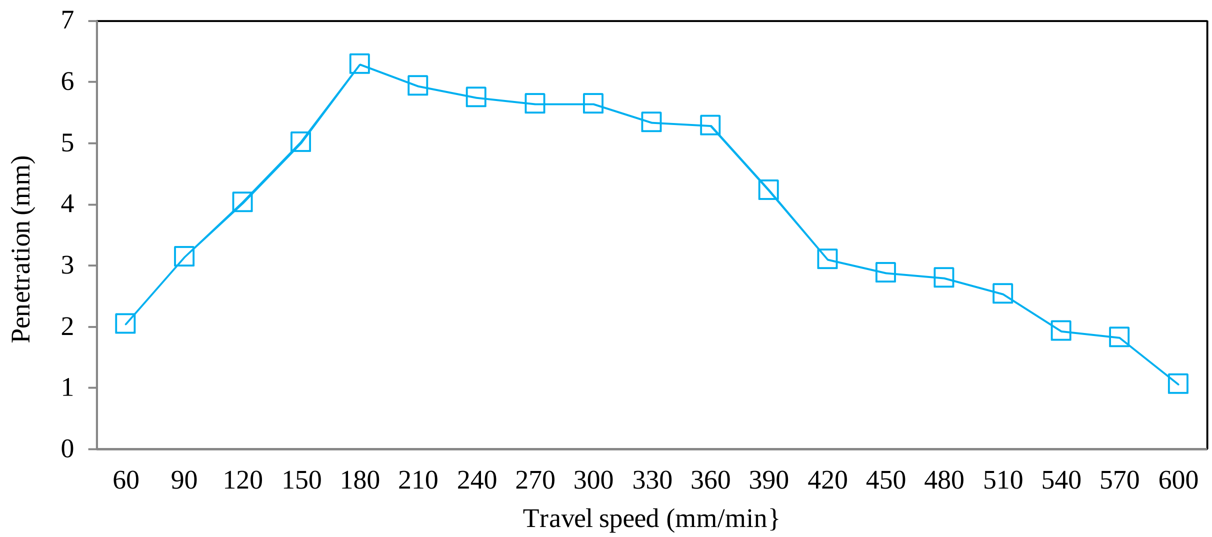

Fig.5 Variation of penetration with travel speed

III. SELECTION OF OUTCOME VARIABLE

[1-77] Similar to the input parameters output parameters can also be selected by using histogram prepared by reviewing various literatures. As by observing histogram, the most important parameters are Tensile strength, Microstructure, Hardness and penetration. Let us discuss one by one.

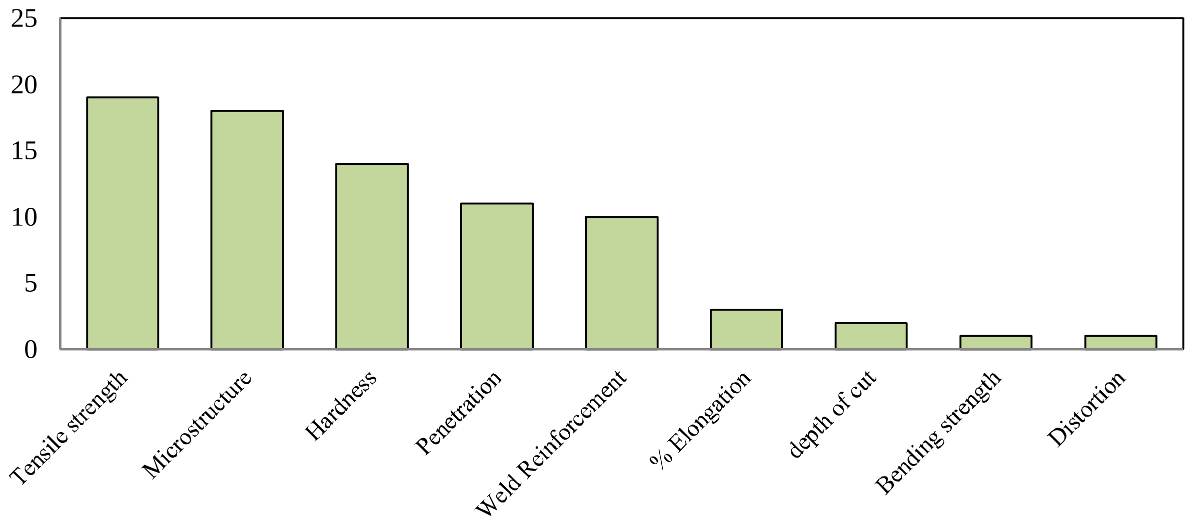

Fig.6 Outcomes of the MIG welding

A. Tensile Strength

It is the measure of resistance of that joint towards the tensile force exerted during application. Most suitable term to describe the tensile strength is Ultimate tensile strength and yield strength. Ultimate tensile strength describes the stress value just before the failure where as yield strength describes indication of future failure. The yield strength is generally taken to design the welded joint. Generally, welded joints should have a higher strength than the base metal of the work piece. It can be increased by increasing the welding current generally up to 300 amps. However, best results for current are achieved at around 180amps to 240amps in terms of tensile strength.

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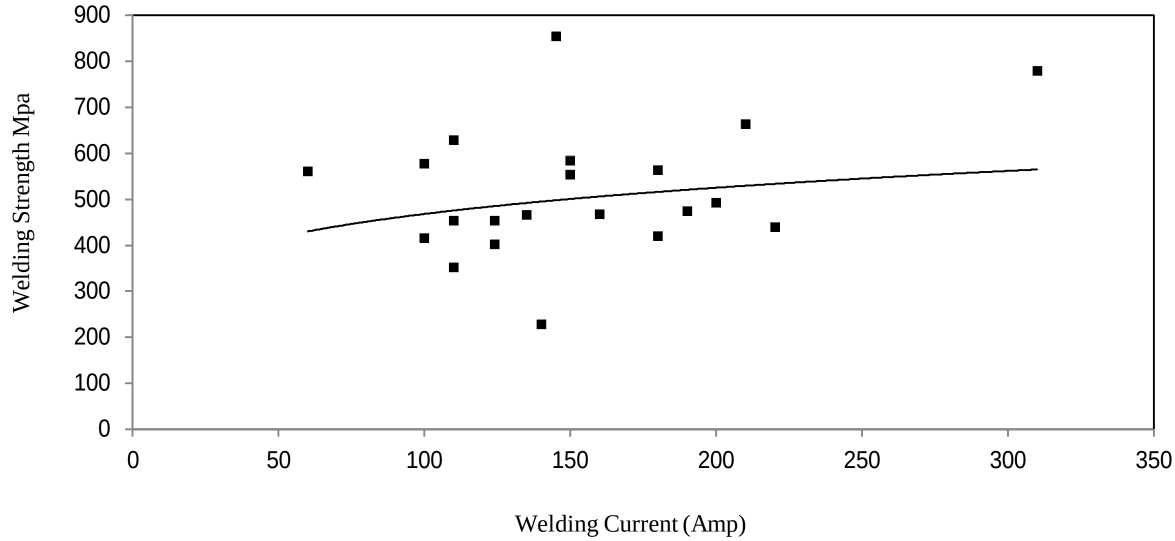

Fig. 7 Welding strength Vs welding current

Tensile strength can also be increased by increased in the welding voltage up to 40 volts. Beyond this value an excessive heat will reduce the bonding and which reduces the tensile strength. A voltage from 25 Volts to 35 volts will give our required value.

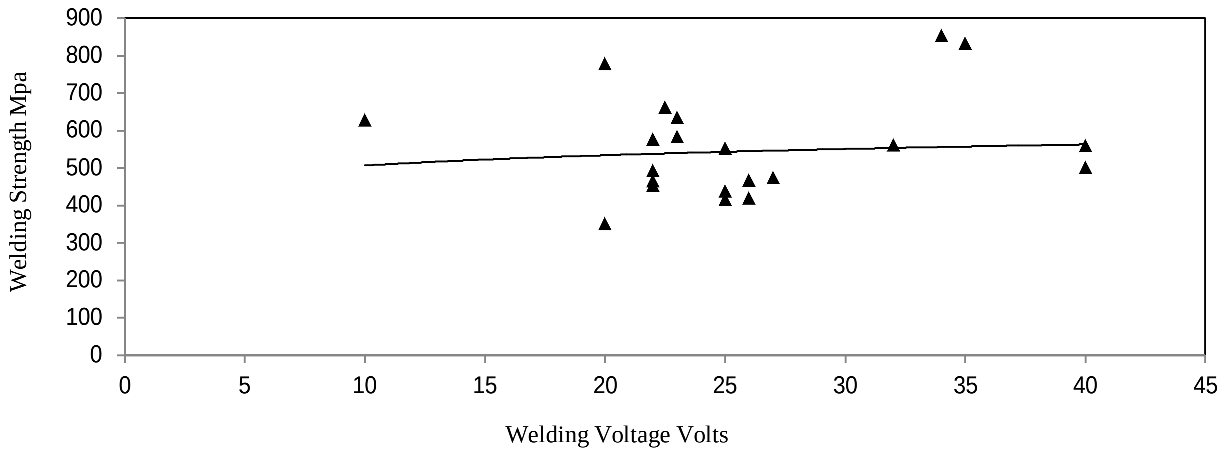

Fig. 8 Welding strength Vs welding voltage

Next term which affects on the tensile strength is welding speed. Tensile strength decreases as welding speed increases. So, lower welding speed about 200 to 300mm/min will give us required value of output.

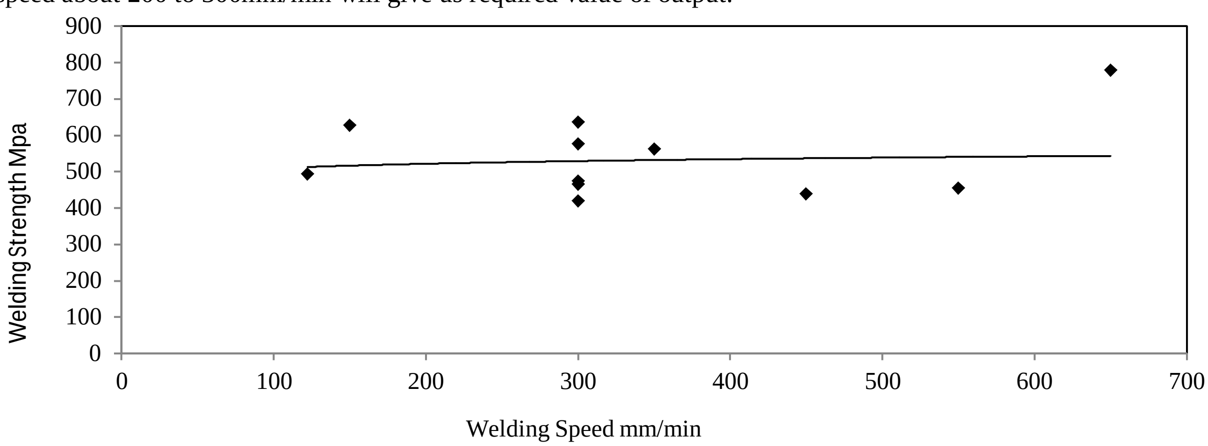

Fig. 9 Welding strength Vs welding speed

Wire feed rate is the one more factor which affects nearly same as that of welding current. For wire feed rate up to 4m/min strength increase and beyond this value strength decreases. Best results are obtained at 2 to 4 m/min.

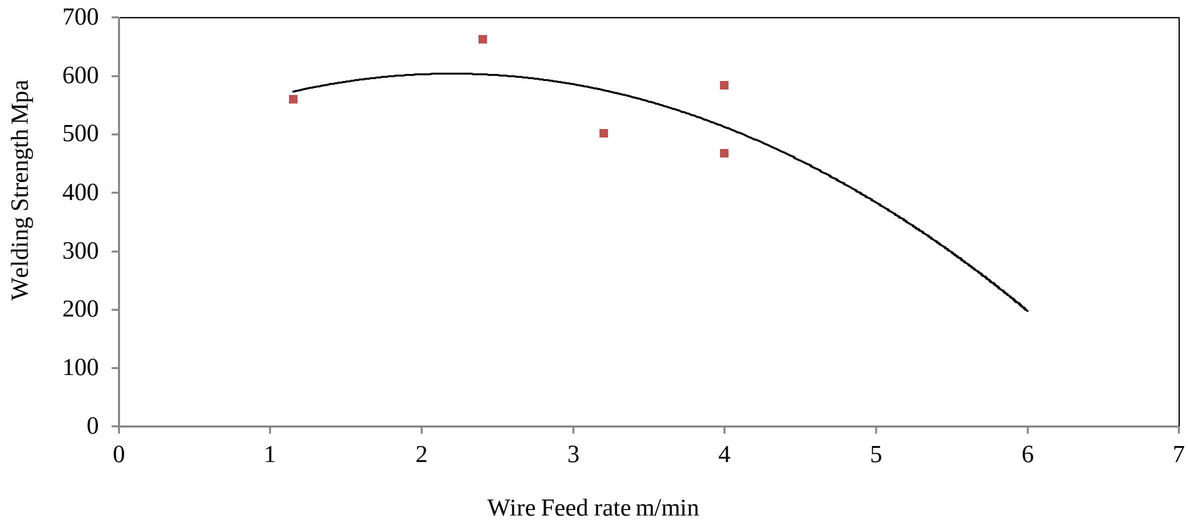

Fig. 10 Welding strength Vs wire feed rate

B. Measurement of Tensile Strength

Tensile strength is measured on a equipment called as universal testing machine as shown in figure. Welded specimen is loaded between upper & middle crosshead and load applied gradually. Load cell attached to the machine records the changes in gradually applied load values.

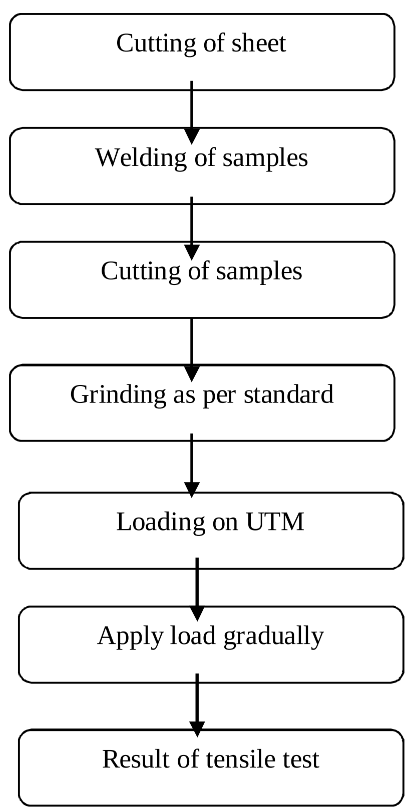

Fig.11 Measurement of tensile strength

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C. Microstructure

Microstructure of the material is study of metals by eyes or with the help of microscope having > 60 x magnification. This inspection is required to detect the non uniformity in the material as well as in the welded joint. It indicates the heat treatment process done on the metal. Specimen preparation and procedure is given as below.

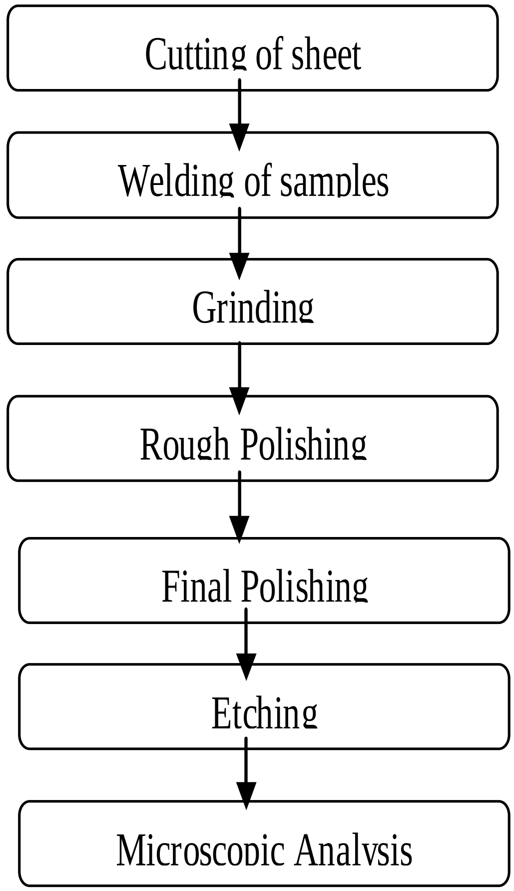

Fig.12 Microstructure study of welded joints [75]

D. Result of Microstructure

Fig.13 a) Base metal (BM) b) Heat affected zone (HAZ) c) Fusion zone (FZ)

Microstructure of the specimen is taken at three different locations. First is the base metal as it will be compared with the other two locations. Second is heat affected zone that is exactly adjacent area of the base metal or area in between base metal welded joint. Finally third location is at welded joint location which is also called as fusion zone. Requirement for result of the microstructure shows that base metal of the steel shows a fine Pearlite, heat affected zone shows a fine Cementite while a fusion zone shows a fine tempered martensite. As martensite is harder than Cementite and Cementite is harder than Pearlite the fusion zone should be a stronger and harder than heat affected zone and base metal.

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E. Hardness

[67] hardness of the metal is defined as the resistance to wear, scratches or indentation. A Brinell hardness test is suitable for MIG welded joints. Whatever the observations in microstructure test can be validated by a hardness test.

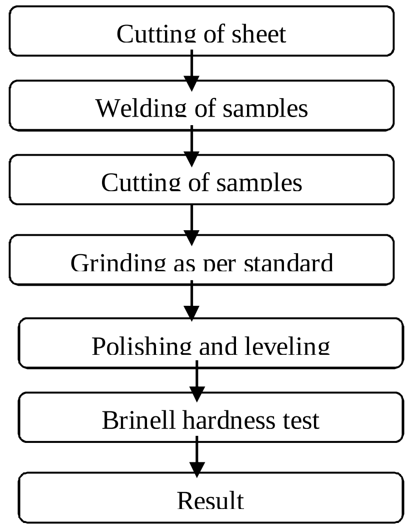

Fig.14 Hardness test of specimen.[74]

Effects of parameters on hardness: By observing the graphs below the average value of Brinell hardness number are 157 for base metal, 163 for heat affected zone and 211 for fusion zone. That means welded joint is harder than HAZ and the base metal. It is also seen that value of BHN is more up to 228 at 150amps to 220amps. Beyond this value, increase in hardness will cause increase in brittleness of a metal. So it should be restricted up to 220amps.

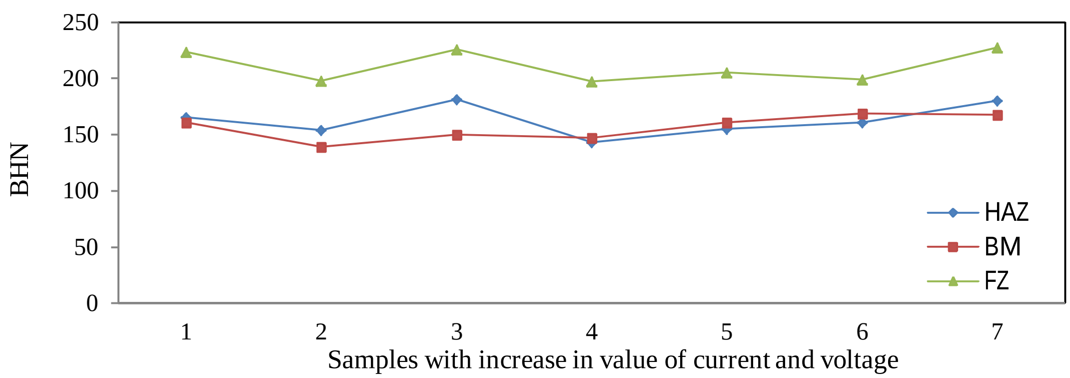

Fig.15Harness Vs welding current / voltage

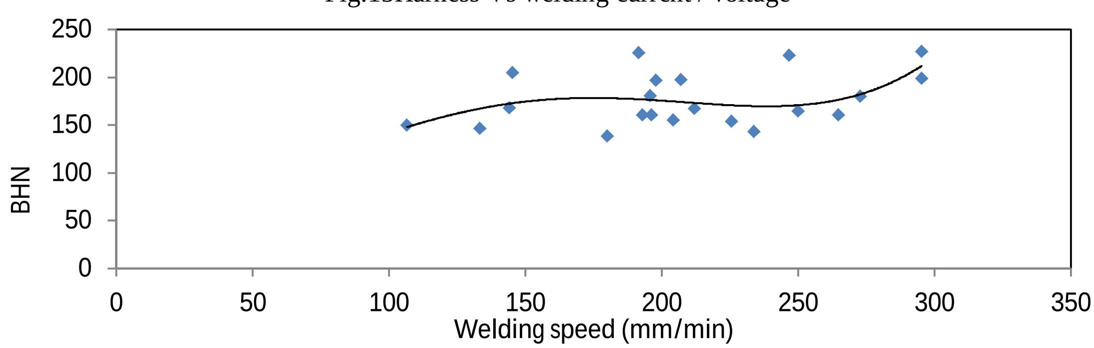

Fig.16 Harness Vs welding speed

Similarly voltage of the welding source 22 Volts to 30 Volts and travel speed should be 150mm/min to 300mm/min in order to achieve better hardness and microstructure.

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IV. SELECTION OF OPTIMIZATION TECHNIQUE [1-77]

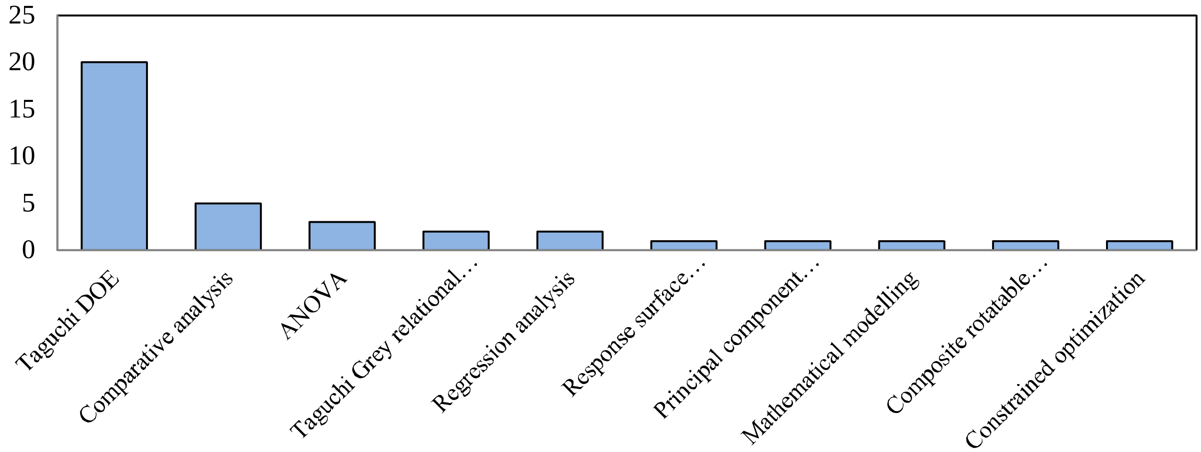

Fig 17 Methods of optimization

A. *Taguchi Design of Experiment*

This method was founded by Dr. Genechi Taguchi. As so many experimentation is needed in trial and error method, so to avoid this delay and to reduce the cost of experimentation he suggested a DOE method. The process of selection of parameters and analysis is shown by flowchart.

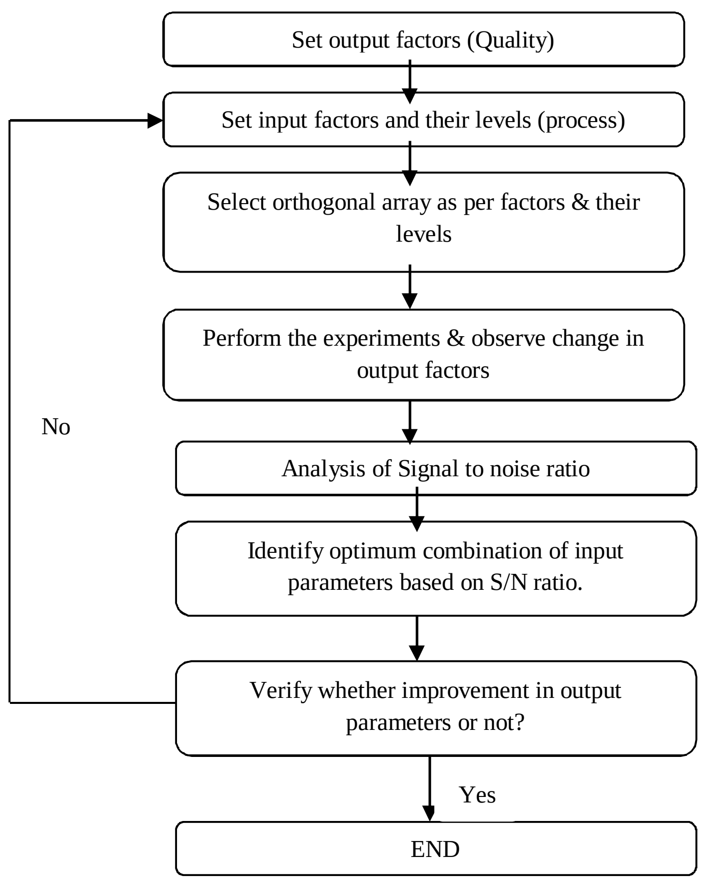

Fig.18 Flowchart of Taguchi design of experiment

This method is suitable for single output factors and multiple input factors. According to number of input factors an orthogonal array is to be selected.

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Table No 1 Orthogonal array selection for Taguchi DOE.

	PARAMETERS											
LEVEL	1	2	3	4	5	6	7	8	9	10	11	12
	2	L4	L4	L8	L8	L8	L8	L12	L12	L12	L12	L16
	3	L9	L9	L9	L18	L18	L18	L18	L27	L27	L27	L27
	4	L16	L16	L16	L16	L32	L32	L32	L32	L32		
	5	L25	L25	L25	L25	L25	L50	L50	L50	L50	L50	L50

B. Taguchi grey Relational Analysis

Taguchi design of experiment was insufficient for analysis as it can optimize only one parameter at a time. To optimize multiple outcomes variable in a single experiment the Grey relational analysis is used. It works by combining all the output variables into a single common factor. Procedure for Grey relational analysis is as shown below:

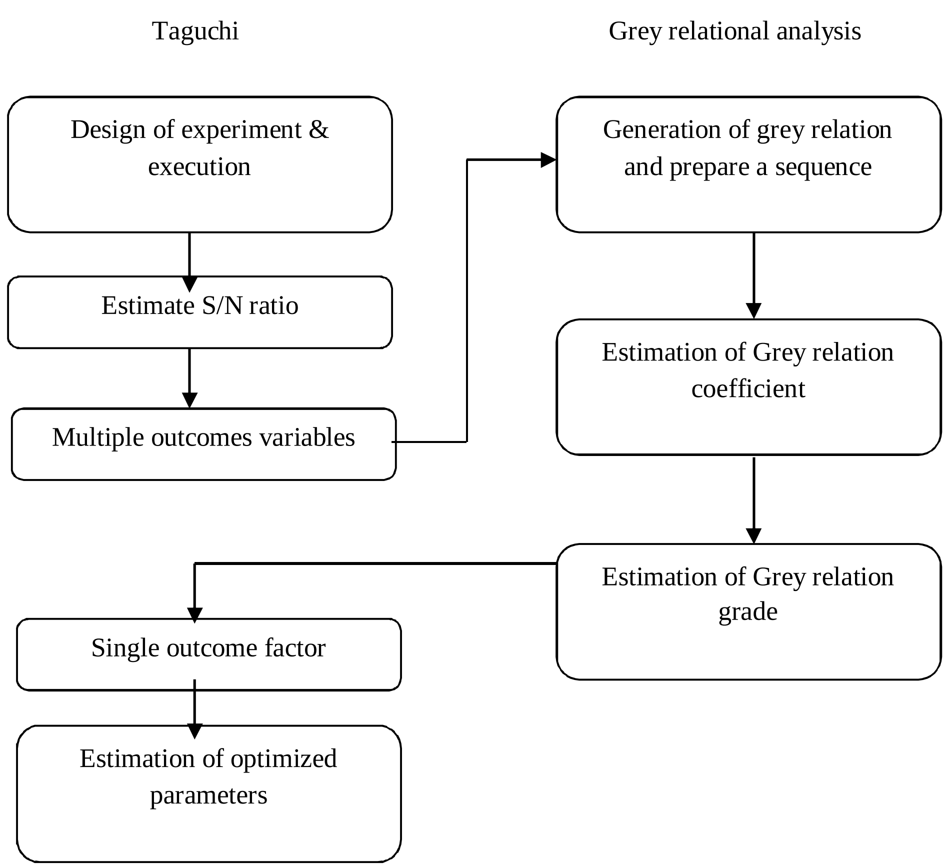

Fig. 19 Flowchart of Taguchi Grey based method

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C. Factorial Design

In this type of design multiple factors are optimized having interrelation between each other. Multiple outcomes with multiple input process variables can be optimized.

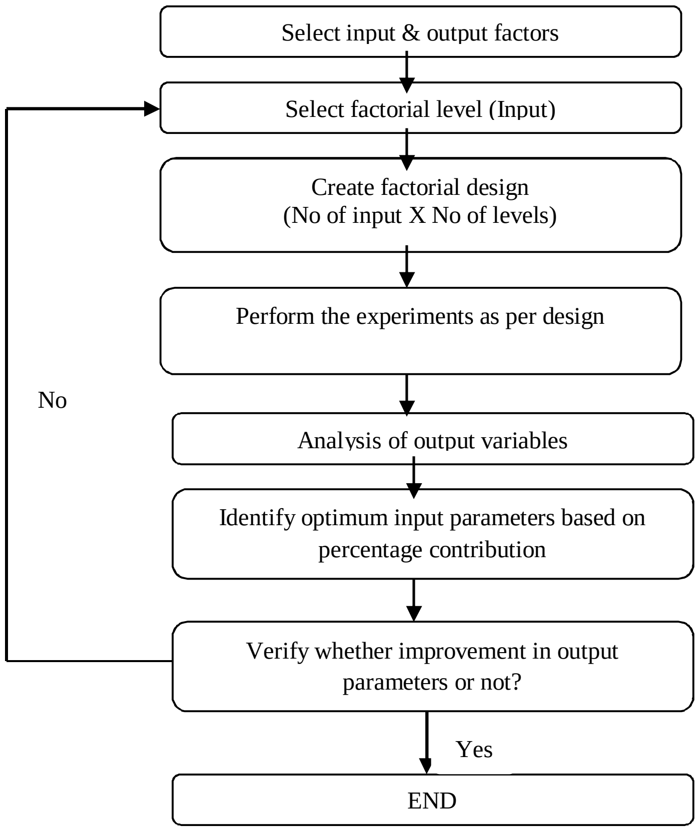

Fig.20 Flowchart of factorial design of experiment

V. SUMMARY OF OPTIMIZATION TECHNIQUES

K.Y. Benyounis, A.G. Olabi (2008), "Optimization of different welding processes using statistical and numerical approaches – A reference guide" [29]

Table No 2 Difference between various optimization techniques

Comparison	Taguchi design	Factorial design	Response surface methodology	Genetic algorithm	Artificial neural network	Regression	Principal component analysis
Time for calculation	Very Short	Short	Short	Very long	Long	Medium	Long
Level of understanding	Easy	Easy	Easy	Difficult	Moderate	Easy	Difficult
Accuracy of result	Normal	Very high	Very high	High	High	Normal	High
Frequency of usage	More	More	More	Less	More	Less	Very less
Availability of model	No	Yes	Yes	No	Yes	Yes	Yes

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A. Summary Of Input / Output Parameters Relationship [77]

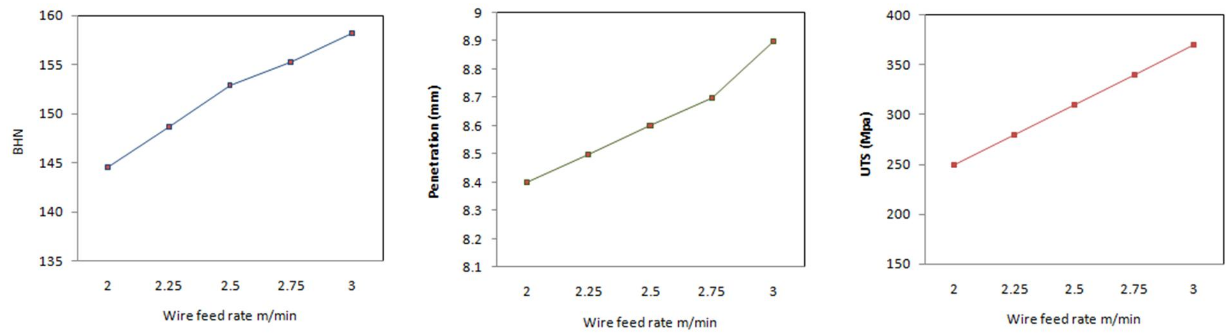

Fig.22 a) BHN Vs Wire feed rate b) Penetration Vs Wire feed rate c) UTS Vs Wire feed rate

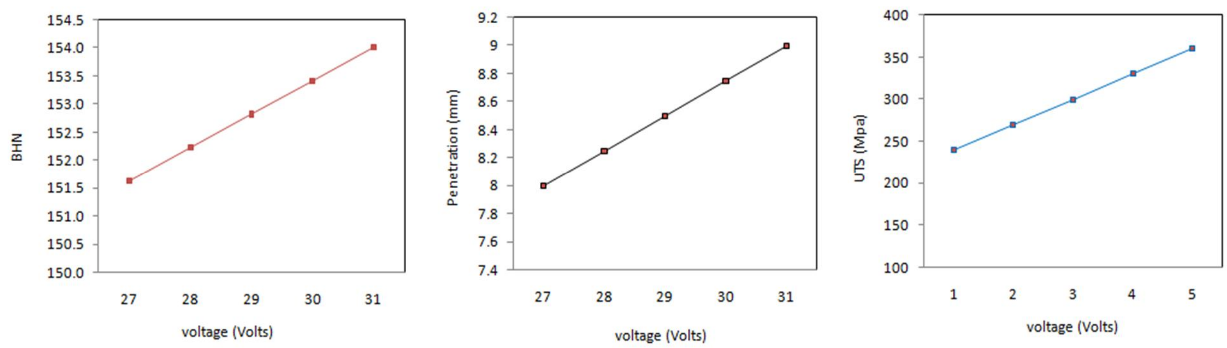

Fig.23 a) BHN Vs Voltage b) Penetration Vs Voltage c) UTS Vs Voltage

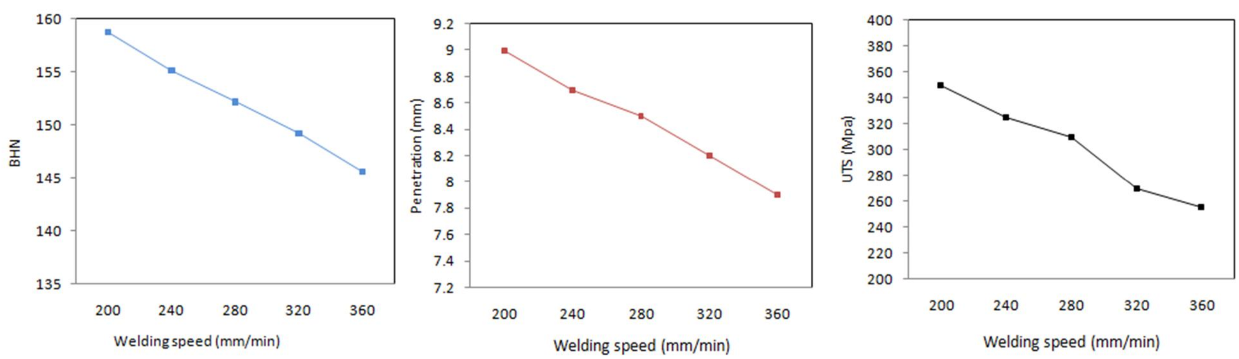

Fig. 24a) BHN Vs Speed b) Penetration Vs Speed c) UTS Vs Speed

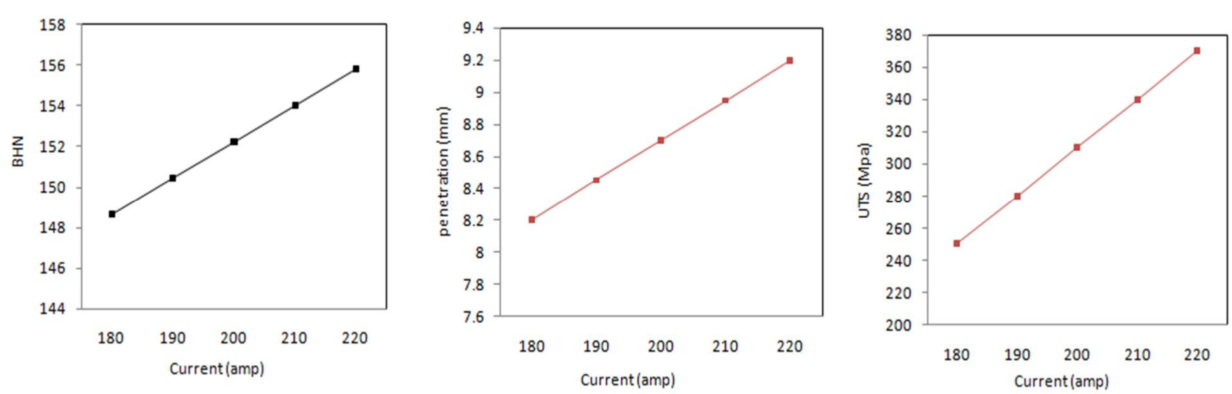

Fig. 25a) BHN Vs current b) Penetration Vs current c) UTS Vs current

VI. DISCUSSION

Summarizing the techniques of optimization, for a very accurate result Factorial design or response surface methodology can be used as the time required for calculation is less and accuracy is very high. Whenever a requirement of accuracy is moderate or normal the Taguchi method is suitable as it is easy to understand, time required for calculation is very less, as per the literature review it has used very frequently more than any other method. Also it does not involve any mathematical model so quick result is possible. In case of multiple output variables, the Taguchi method is used with Grey analysis as discussed in Fig. So the recommendation is for quickest result Taguchi or Grey relational analysis and for accurate result where time is not a major concern ANN, Genetic algorithm, Principal component analysis can be a best solution.

Summarizing an input & output variables relationship, wire feed rate is directly proportional to the output parameters of the joint which are Hardness, penetration and ultimate tensile strength. Voltage and current are also directly proportional to all the output variables while welding speed is inversely proportional to the output variables. The recommended values of input parameters are Gas Metal Arc Welding Guidelines (2014), Publication C4.200, Lincoln Global Inc, PP [29, 30 and 67] gives

Table No 3 Input parameters range for steel sheets having thickness 1 to 6mm [76]

Material	Sheet thickness mm	Wire Feed m/min	Current (amp)	Travel speed (mm/min)	Voltage (volts)
Carbon steel sheets	1	2.5	80	330	18
	1.5	3.8	120	500	19
	2	3.8	130	450	20
	3	4.4	160	500	21
	4	5	175	450	22
	5	5.7	200	380	21
	6	6.4	220	350	22

VII. CONCLUSION

A review is carried out for welding output parameters, input parameters as most influencing parameters and most used parameters. Similar review has also carried out for optimization technique as most fast and most accurate technique by referring the literature. Among the output parameters selected parameters such as Tensile strength, Microstructure, hardness and penetration are the most important parameters to specify the quality of joint. The input parameters which affects mostly on above output parameters are identified as welding current, voltage, speed and wire feed rate. The effects of all above input parameters on output parameters is discussed and excluding welding speed rest all parameters are directly proportional to output. Welding speed is inversely proportional to the output. The study is limited for Carbon steel sheets having thickness up to 6mm so range for values of input parameters is also given as per literature review.

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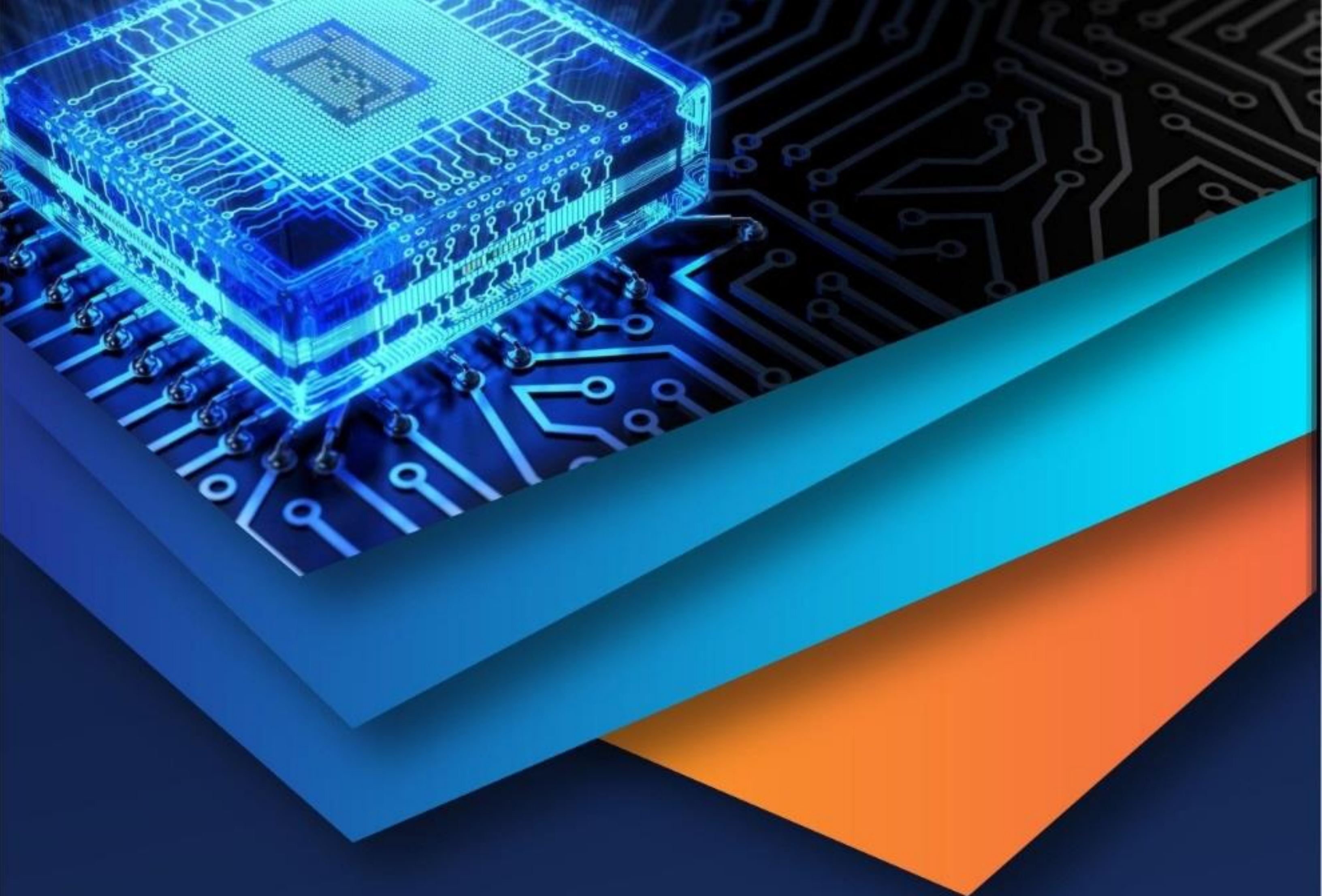

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