# A Review on Parametric optimization of MIG Welding for Medium Carbon Steel using FEA-DOE Hybrid Modeling

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*Abstract*—Welding is a manufacturing process, which is carried out for joining of mostly all metals. Metal inert gas (MIG) welding also known as Gas Metal Arc Welding (GMAW) process consists of heating, melting and solidification of parent metals and a filler material in localized fusion zone by a transient heat source to form a joint between the parent metals. A consumable electrode is used which also plays the role of conductor. MIG welding gives little loss of material and can be operated as semi as well as fully automated. A review of the techniques used for Design of Experiment (DOE) for this work has been indicated in this paper. Also the techniques used for obtaining optimal process parameters with the use of experimental data have been reviewed. The success of MIG welding process in terms of providing weld joints of good quality and high strength depends on the process conditions used in the setup. This review aims at identifying the main factors that have significant effect on weld joint strength and weld pool geometry (depth of penetration, weld width, etc.). The aim of this paper is to review the techniques of optimizing process parameters of MIG welding process and compare the experimental result with FEA for optimizing parameter.

*Key words:* MIG welding, medium carbon steel, Process Parameter optimization, Design of experiment method – Finite Element Analysis by ANSYS software.

## I. INTRODUCTION

### A. Welding

Welding is 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. The process finds its applications in air, underwater and space.

Why welding is used- Because it is,

1) Suitable for thickness ranging from fractions of a millimetre to a third of a meter.
2) Versatile, being applicable to a wide range of component shapes and sizes.

As per American Welding Society (AWS)

It is defined weld as a localized coalescence of metals or non-metals produced either by heating the material to suitable temperatures with or without the application of pressure alone and with or without the use of filler material.

It is used in the manufacture of automobile bodies, aircraft frames, railway wagons, machine frames, structural works, tanks, furniture, boilers, general repair work and ship building.

### B. Metal inert gas welding

MIG (Metal Inert Gas) welding, also known as MAG (Metal Active Gas) and in the USA as GMAW (Gas Metal Arc Welding), is a welding process that is now widely used for welding a variety of materials, ferrous and non-ferrous. In gas shielded arc welding both the arc and the molten weld pool are shielded from the atmosphere by a stream of gas. The arc may be produced between a continuously feed wire and the work.

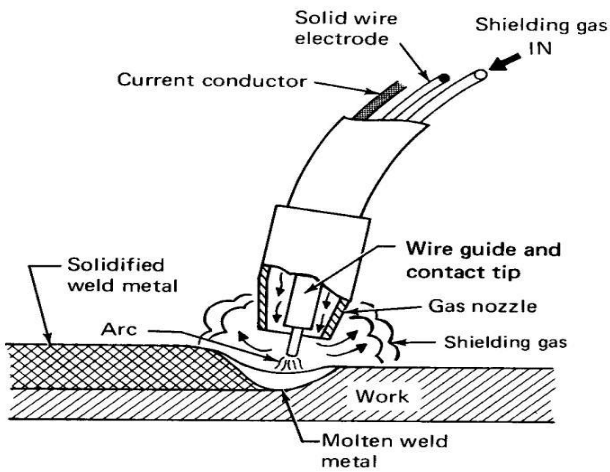


Fig. 1: Schematic diagram of MIG Welding Process

The shielding gas can be both inert gas like argon and active gases like argon-oxygen mixture and carbon-di-oxide which are chemically reactive. It can be used on nearly all metals including carbon steel, stainless steel, alloy steel and aluminum. Arc travel speed is typically 30-38 cm/minute and weld metal deposition rate varies from 1.25 kg/hr when welding out of position to 5.5 kg/hr in flat position. Metal transfer across the arc, is short circuiting transfer, globular transfer, spray transfer, pulsed spray transfer.

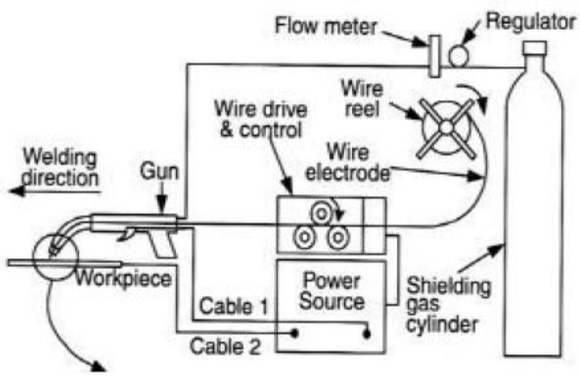


Fig. 2: Schematic diagram of MIG welding Equipment Arrangement

The made of weld metal transfer is determined by the following welding current, electrode size, electrode composition, electrode stick out, shielding gas. Joint type in

 

MIG welding, the most commonly used joint type are the butt joint, corner joint, edge joint, lap joint and T-joint. Here, in MIG the arc is maintained between a consumable electrode and the work piece in an inert gas atmosphere. MIG welding gives much greater penetration and higher speeds. There is no slag to clean off after welding because no flux used and no weld spatter. It is fast and more economical efficiency then TIG (Tungsten Inert Gas) Welding.

### *C. GMAW / MIG welding applications*

MIG may be operated in semiautomatic, machine, or automatic modes. All commercially important applicable metals such as carbon steel, high-strength, low-alloy steel, and stainless steel, aluminum, copper, titanium, and nickel alloys can be welded in all positions with this process by choosing the appropriate shielding gas, electrode, and welding variables.

### *D. Process parameter selection*

The welding parameters are selected by operator based on experience or from a handbook. However, this does not ensure that the selected welding process parameters can produce the optimal or near optimal weld pool geometry for that particular welding machine and environment. A literature review has been done in this regards and an attempt has been made to analyse the effect of different process parameters on weld bead geometry, mechanical properties like strength, hardness, etc.

## II. LITERATURE REVIEW

Many investigators have suggested various methods to explain the effect of process parameter on mechanical properties and weld bead geometry, depth of penetration etc. S. R. Meshram, N. S. Pohokar used Taguchi optimization technique pair with grey relational analysis has been adopted for optimize parametric complex to carry out effect of process parameter on Penetration, Reinforcement and Bead width in GMAW welding process of stainless steel AISI410 (Dimension 70mm×25 mm×12mm thickness) The welding process parameters considered in this analysis are voltage, wire feed rate, Welding Speed, Nozzle to Plate Distance and Gas Flow. The Optimum welding Parameter combination was obtained by using analysis of signal to noise (S/N) ratio. The S/N ratio calculated and used to obtain the optimum level for every input factor. Using Analysis of Variance (ANOVA) the adequacy of develop model is checked and significant coefficient for each input factor on weld bead geometry were determined [1].

Pawan Kumar was worked carried out on plate welds AISI 304 & Low Carbon Steel plates using gas metal arc welding (GMAW) process. Taguchi method is used to formulate the experimental design. Design of experiments using orthogonal array is employed to develop the weldments. The input process variables considered here include welding current, welding voltage & gas flow rate. A total no of 9 experimental runs were conducted using an L9 orthogonal array and the ideal combination of controllable factor levels was determined for the hardness to calculate the signal-to-noise ratio. After collecting the data signal-to-noise (S/N) ratios were calculated and used in order to obtain optimum levels for every input parameter. Subsequently, using analysis of variance the significant coefficients for each input parameter on tensile strength & Hardness (WZ & HAZ) were determined and validated [2].

Vikram Singh was work carried out on AISI 1016 mild steel plates using gas metal arc welding (GMAW) process (Dimension of work piece length150mm,width75mm, thickness7mm) and selection of input parameters are used in GMAW like, Gas flow rate, Arc voltage, welding position gap. Taguchi optimization method was applied to find the optimal process parameters for Tensile Strength. A Taguchi orthogonal array, the signal-to-noise (S/N) ratio and analysis of variance were used for the optimization of welding parameters. A conformation experiment was also conducted and verified the effectiveness of the Taguchi optimization method. [3].

Mr. Parth D Patel, Prof. Sachin P Patel was investigated on Design of Experiments for this work and by use of the experimental data has performed ANN (Artificial Neural Network) prediction and makes comparison with experimental data. All welds were prepared by MAG-CO2 welding and TIG welding techniques using work piece material AISI 1020 OR C20 low carbon steel. Where inputs parameters for MAG-CO2 welding are welding current, wire diameter and wire feed rate and for TIG welding are welding current, wire diameter output parameter is weld strength for both MAG-CO2 welding and TIG welding techniques.[4].

S. R. Patil, C. A. Waghmare studied on the influence of welding parameters like welding current, welding voltage, welding speed on ultimate tensile strength (UTS) of AISI 1030 medium carbon steel material (Dimension 100x50 x10mm plate, single V-butt joint) during welding. A plan of experiments based on Taguchi technique has been used. An Orthogonal array, signal to noise (S/N) ratio and analysis of variance (ANOVA) are employed to study the welding characteristics of material & optimize the welding parameters are identified for maximum tensile strength [5].

Dinesh Mohan Arya, Vedansh Chaturvedi, Jyoti Vimal studied to search out the optimum process parameters for Metal inert gas welding (MIG). The optimization of MIG welding process parameters was carried out for alloy steel work piece using grey relational analysis method and Taguchi method. The effect of welding parameters like wire diameter, welding current, arc voltage, welding speed, and gas flow rate were optimized based on bead geometry of welding joint. The objective function was chosen in relation to parameters of MIG welding bead geometry Tensile strength, Bead width, Bead height, Penetration and Heat affected zone (HAZ) for quality target. The signal to noise ratio (S/N ratio) is also applied to identify the most significant factor and predicted optimal parameter setting. Optimal parameters collection of the MIG operation was obtained via grey relational analysis for this study [6].

Ajit Hooda, Ashwani Dhingra have studied, To develop a response surface model to predict tensile strength of inert gas metal arc welded AISI 1040 medium carbon steel joints. The process parameters such as welding voltage, current, wire speed and gas flow rate were studied. The experiments were conducted based on a four-factor, three-level, and face cantered composite design matrix. Response Surface Methodology (RSM) was applied to optimizing the MIG Welding process parameters to attain the maximum yield strength of the joint [7].

Neha Bhadauria, Prof. R. S. Ojha was investigated on optimization of process parameters using Response Surface Methodology. Experiments were conducted based on central composite Face Centered Cubic design and mathematical models were developed correlating the important controllable GMAW process parameters like Voltage (V), welding speed (S) and gas flow rate (G) with weld bead penetration. The thickness of the plate taken is 5mm and a 0.8 mm diameter filler wire has been used to weld it. Using these models the direct and interaction effects of the process parameters on weld bead penetration of work material IS2062 mild steel were studied and further the process parameters were optimized [8].

Amudala Nata Sekhar Babu was investigated on a 3- dimensional finite element model was developed for the analysis of hybrid welding process. The combination of laser and Arc (MIG/TIG) welding processes in a same process zone is known as Hybrid Welding. ANSYS Parametric Design language (APDL) code was developed for the same. The FEA results were validated with experimental results showing good agreement. Hybrid welding Simulations were carried out for AISI 304 Austenitic stainless Steel plate. The effects of laser beam power, Arc Welding and torch angle on the weld-bead geometry i.e. penetration (DP), welded zone width (BW) were investigated. The experimental plan was based on three factor 5 level central composite rotatable design. Second order polynomial equations for predicting the weld-bead geometry were developed for bead width and depth of penetration. A design matrix was developed by identifying proper control variables and bead dimensions were obtained from the simulations using ANSYS. The developed ANSYS result was compared with the Experimental [9]

Rabih Kamal, Henri Champliaud, Jacques Lanteigne studied the Finite Element (FE) modelling of a two-seam welding process for a T-joint with a V chamfer preparation and using material AISI 1018 steel plate(size 254×254×9.5mm). The aim of the model is to predict the deformations, distortions and residual stresses resulting from the welding of the plates and experiments have been carried out in order to compare to the FE model. The simulated model was done using ANSYS software with the “birth and death” method to simulate the filler metal deposition; also it uses the double ellipsoid model to simulate the heat in the weld pool. The results of the numerical model are compared to experiments. [10].

### A. *Research Methodology*

The research work can be carried to predict and obtain the optimum solution of process parameters of GMAW using following steps:

*Step. 1 :* Formulation of the problem – the success of any experiment is dependent on a full understanding of the nature of the problem

*Step. 2 :* Identify the importance MIG welding process parameters(Selection of base material after understanding problem)

*Step. 3 :* Select the Design of Experiment. And Development of design matrix and conducting an experiments as per design matrix

*Step. 4 :* Identify the significant factors and Recording the responses

*Step. 5 :* Developing DOE-FEA hybrid modelling

*Step. 6 :* Conformation test: This step is to predict and verify the improvement of quality characteristic using the optimal level of the welding process parameters.

*Step. 7 :* To Perform FEA with appropriate set of parameters.

*Step. 8 :* Modelling and FEA with optimum parameter set for validation

## III. CONCLUDING REMARKS

From above literature review it is indicated that

1) There are many researches done on DOE or optimization techniques for Process parameter for mechanical Properties and weld penetration, weld bead geometry. But I found that are very few researches done on AISI1045 Medium carbon steels so we want to do research on this material. We like to use DOE-FEA hybrid modelling for parametric optimization.
2) Welding current, arc voltage, welding speed, type of shielding gas, gas flow rate, wire feed rate, diameter of electrode etc. are the important control parameters of Metal Inert Gas Welding process.
3) They affect the weld quality in terms of mechanical properties and weld bead geometry.
4) The Factorial Design, Taguchi Method and Artificial neural network can be applied as the DOE (Design of Experiment).
5) The methods that can be applied for welding process parameter optimization work are Grey Relation Analysis and ANOVA (Analysis of variance).
6) MINITAB software is a useful aid for the above purpose.
7) To Perform FEA with appropriate set of parameters and experiment result can be compared with ANSYS14.5 software (FEA).

## IV. SCOPE OF WORK

Metal inert gas welding is one of the widely used techniques for joining ferrous and non-ferrous metals. MIG welding offers several advantages like joining of dissimilar metals, low heat affected zone, there is no slag to clean off after welding because no flux used. MIG weld quality is strongly characterized by weld bead geometry.

In MIG Welding method, we will optimize other parameters which are not used in this experiment and This experiment will be done for same method or workpiece by other DOE method or other optimization techniques and also if you can be compared Experimental result with FEA.

Artificial neural network or grey relation analysis shall be used to conduct the experiments. The parameters selected for controlling the process are welding speed, current and gas flow rate, wire feed rate. Strength of welded joints shall be tested by a UTM. From the results of the experiments, FEA models shall be developed to study the effect of process parameters on tensile strength and weld pool geometry. Optimization shall be done to find optimum welding conditions to maximize tensile strength and weld pool geometry, depth of penetration etc. of welded specimen. Confirmation tests shall also be conducted to validate the optimum parameter settings.

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