Reduction of Defects in MIG Welding Process by Taguchi Method

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Abstract — Our project work done for minimizing the welding defects by taguchi method that occur during MIG welding Welding is the process of joining two similar or dissimilar metals permanently, where MIG welding uses inert gas for shielding and consumable metal for joining two metals. Metal Inert Gas welding (MIG) process is an important component in many industrial operations. The GMA welding parameters are the most important factors affecting the quality, productivity and cost of welding. This paper presents the influence of welding parameters like welding current, welding voltage, welding speed on penetration depth of MS material during welding. A plan of experiments based on Taguchi technique has been used to acquire the data. An Orthogonal array, signal to noise (S/N) ratio and analysis of variance (ANOVA) are employed to investigate the welding characteristics of MS material & optimize the welding parameters. Finally the conformations tests have been carried out to compare the predicated values with the experimental values confirm its effectiveness in the analysis of penetration. The effect of three parameters namely welding current, groove angle and gas flow rate was selected for making the welding joint using MIG welding process. These parameters were varied simultaneously using Taguchi method in order to investigate the effect of single factor effect and interactions on the tensile strength of the welded joint.

Keywords: MIG Welding, Taguchi Method, Orthogonal Array, S/N Ratio

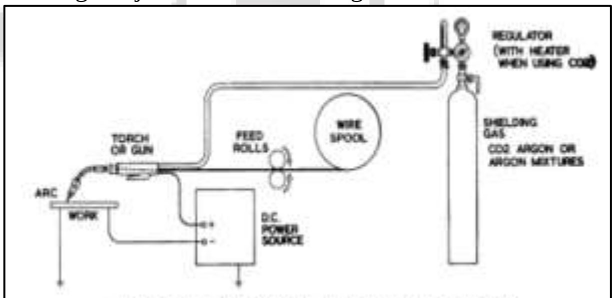
I. Introduction

Welding is a critical technique for the joining of materials in the Nation's major manufacturing industries. Welding, the fusing of the surfaces of two work pieces to form one, is a precise, reliable, cost-effective, and "high-tech" method for joining materials. No other technique is as widely used by manufacturers to join metals and alloys efficiently and to add value to their products. Most of the familiar objects in modern society, from buildings and bridges, to vehicles, computers, and medical devices, could not be produced without the use of welding. Welding is a joining process that produces a local coalescence of materials by heating, by applying pressure, or both. In essence, the welding process fuses the surfaces of two distinct elements to form a single unit. It encompasses a broad range of joining techniques that include fusion welding, solid state welding, weld bonding, diffusion welding, brazing, and soldering. Welding dates back to the earliest days of metalworking, and continues to be widely applied today due to its cost effectiveness, reliability, and safety. When compared wit other joining methods, such as riveting and bolting, welded structures tend to be stronger, lighter-weight, and cheaper to produce. More than 100 processes and process variants comprise the family of welding technologies, and include methods for welding metals, polymers, and ceramics, as well as emerging composite and engineered materials. These various technologies allow a great deal of flexibility in the design of components to be welded. They also encourage designing for optimal cost-effectiveness in productivity and product performance.

Welding and joining technologies pervade commercial and defense manufacturing, and are a significant source of value-added in the manufacturing process. Occurring late in the manufacturing stream, the joining process is typically the final step in assembly and plays the major role in ensuring structural performance. Additionally, the emergence of near-net-shape processes to produce sub-components has raised the importance of assembly processes as the next area for increased production efficiency. The role of welding and joining in the repair and life extension of manufactured products is even more critical since these processes are frequently used to repair structures and components that were not originally welded.

A. MIG 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. The essential feature of the process is the small diameter electrode wire, which is fed continuously into the arc from a coil. As a result this process can produce quick and neat welds over a wide range of joints as shown in fig.



BASIC REQUIREMENTS FOR SEMI-AUTOMATIC MIG WELDING

B. Welding Process Variables

During a manual welding operation, the welder has to have control over the welding variables, which affect the weld penetration, bead geometry and the overall weld quality. A proper selection of welding variables will increase the chances of producing welds of a satisfactory quality. However, these variables are not completely independent and changing one variable generally requires the changing of some of the others in order to achieve the desired result. When all these variables are in proper balance, the welder can deposit higher quality weld metal and produce sound welds.

The welding process variables mainly affect the geometry of the weld bead such as the penetration, bead reinforcement, bead Welding Current, Welding Voltage, Travel Speed, Wire Electrode Size
Type of Shielding Gas
– Electrode Extension

– Electrode Angle

C. Inspection and Testing of Welds

Weld inspection and weld testing are two different terms with their function somewhat overlapping.

1) Inspection before Welding

a) Check the drawings in respect of weld details, dimensional tolerances, process specifications, etc.
b) Examine the specification given by the customer applicable to the class work, quality required, end use of the product
c) Select the welding process to obtain welds of the desired quality.
d) Only the tested and defect-free materials and as per the approved specification or drawing should be used for the structure to be welded.
e) Consumables such as welding electrodes, flux gases etc. to be used shall be as per standards. Deteriorated or spoilt consumables should not be used.
f) Welding Procedure should be laid down. Preferably it should conform to some standard
   The procedure should give preparations and tolerances to be achieved during production work.
g) Welding equipment should be in satisfactory working condition and be able to produce right quality welds.
h) Welders and operators employed for the work shall be trained tested and certified to the appropriate standards.

2) Inspection during Welding

a) The weld groove should be free from dirt, rust, oil, slag or any other foreign matter which may affect the quality of the weld.
b) Job edge preparation should be as per approved welding procedure.
c) The fit-up, gap, orientation welding position, method and sequence of assembly all should be as per approved welding procedure.
d) Tack welds should be of adequate size.
e) Fittings, clamp, fixtures, etc should not interfere with welding.
f) Methods should be adopted to minimize distortion.
g) If during welding certain consumables are found defective they should be replaced by another brand of identical type.
h) Welding procedure may be modified if it is found during welding that's welds of acceptable qualities are not being produced.
i) Slag should be thoroughly removed from each pass in multi pass arc welds and spot welding electrodes should be dressed periodically.
j) Welds which would become in accessible or more difficult to inspect at a later stage shall be inspected at this stage.
k) Visual inspection during welding will reduce the chance of rejecting the weldment at the final stage.

D. Inspection after Welding

Testing and Inspection is carried out after the jobs have been welded with a view to

1) Assess the properties and quality of the welded joints.
2) Assess the suitability of the weldment for the intended purpose.

II. LITERATURE REVIEW

Studies have been conducted on establishing the welding defects analysis and determining the various process parameters. The experimental studies were conducted under varying electrode forces, welding currents, electrode diameters, and welding times. The settings of welding parameters were determined by using the Taguchi experimental design method. The level of importance of the welding parameters on the tensile shear strength is determined by using analysis of variance. The work is carried out in almost all welding processes. This chapter illustrates the review of the earlier work done on the proposed topic.

A. Current Status of Research

1) A brief review of current status of research is discussed below:

J.S. de Jesus et al.[8] developed several tool geometries and their effect on weld morphology, material flow, microstructure and hardness of processed regions. Their effect on fatigue strength of welds was also examined for the most promising tools. The feasibility of FSP MIG T welds was proved. Quality of processed regions is very influenced by tool geometry. FSP removes defects in the MIG weld toe and increases its radius of curvature. Also promotes significant grain refinement in processed regions, reduces hardness in welds on AA 6082-T651 and hardens AA 5083-H111 welds. Only tools with concave and rounded edge shoulder and cylindrical threaded pin allow the improvement of fatigue strength of MIG welds on both alloys.

2) Xiangmeng Meng et al. [9]

Proposed TIG–MAG hybrid arc welding process to achieve high speed welding. The influences of hybrid arc welding parameters on welding speed and weld appearance were studied through orthogonal experiment and the microstructures and mechanical properties of weld were tested and compared with that of the conventional MAG weld. The TIG–MAG hybrid arc welding speed could reach up to 3.5 m/min for bead-on-plate welding of 2.5 mm thick mild steel plate under the condition of high quality of weld appearance and 4.5 m/min for butt welding of 2 mm thick mild steel plate, respectively. The mechanical properties of hybrid arc weld were not lower than that of the conventional MAG weld. The assistant TIG arc could effectively stabilize the MAG welding current and MAG arc voltage in high speed TIG–MAG hybrid arc welding process. The stable hybridization obtained by balance between TIG and MAG welding current and proper wire-electrode distance was a key factor to stabilize the welding process.

3) Peter Groche et al.[10]

Are study an efficient and sustainable use of energy and resources for technical products. An even more consequent use of light-weight construction and so-called smart structures are two examples of this. Both approaches lead to hybrid components consisting of dissimilar materials. Joining processes based on plastic deformation of at least one joining partner promise great potential regarding the production of multi material joints. This paper first examines in detail the basic plastic joining principles for force- and form-closed joints as well as for solid state welds and presents a systematic classification. Subsequently, the joining processes based on these principles are discussed along with their specific potentials and limitations. Additionally, industrial applications of these processes are presented. Future trends in joining by forming based upon current research developments are finally highlighted. Despite these extensive research activities the outlook shows that gaps of knowledge still exist and hinder a broad industrial application so far

4) V. Villaret et al.[11]

Study on the best welding conditions for homogeneous welding, by Gas Metal Arc Welding (GMAW) process, of a modified AISI 444 ferritic stainless steel dedicated to automotive exhaust manifold applications. The patented grade is know under APERAM trade name K44X and has been developed to present improved high temperature fatigue properties. All filler wires investigated contained 19% Cr and 1.8% Mo, equivalent to the base metal K44X chemistry, but various titanium and niobium contents .Chemical analyses and micro structural observations of fusion zones revealed the need of a minimum Ti content of 0.15% to obtain a completely equi axed grain structure. This structure conferred on the fusion zone a good ductility even in the as-welded state at room temperature. Unfortunately, titanium additions decreased the oxidation resistance at 950 _C if no significant Nb complementary alloying was made. The combined high Ti and Nb additions made it possible to obtain for the welded structure, after optimized heat treatment, high temperature tensile strengths and ductility for the fusion zones and assemblies, rather close to those of the base metal. 950 _C aging heat treatments were necessary to restore significantly the ductility of the as welded structure. Both fusion zone and base metal presented rather homogenized properties. Finally, with the optimized composition of the cored filler wire – 0.3 Ti minimum (i.e. 0.15% in the fusion zone) and high Nb complementary additions, the properties, including the thermal fatigue strength, of the K44X assemblies are excellent.

5) Mousavi et al. [12]

Are designed a predictive functional controller based on ARMarkov model structure has been to control welding current and arc voltage in a GMAW process .The closed loop system performance is investigated through computer simulations and is compared by those achieved from implementing two commonly used controllers i.e. PI and feed back linearization based PID. The local stability of the closed loop system is analyzed in the presence of uncertainties in the linearized model of the process as well as the control parameters. Finally it is shown that the proposed controller performs like a PI controller along with apre-filter compensator.

6) Uğur Eşme et al. [13]

Optimized the effect of welding parameters on the tensile shear strength of spot welded SAE 1010 steel sheets. The level of importance of the welding parameters on the tensile shear strength is determined by using ANOVA. Based on the ANOVA method, the highly effective parameters on tensile shear strength were found as welding current and electrode force, whereas electrode diameter and welding time were less effective factors. The results showed that welding current was about two times more important than the second ranking factor (electrode force) for controlling the tensile shear strength. An optimum parameter combination for the maximum tensile shear strength was obtained by using the analysis of signal-to-noise (S/N) ratio. The confirmation tests indicated that it is possible to increase tensile shear strength significantly by using the proposed statistical technique.

7) Garcia-Allende et al. [14]

Discussed a spectroscopic approach based on feature selection and the line-to-continuum method for on-line detection of welding defects. Compared with the determination of the plasma electron temperature, the main advantage of the line-to-continuum method is its computational efficiency, since it does not imply the identification of the atomic emission lines. However, its defect detection capability highly depends on the chosen emission lines. Therefore, an initial stage is required to determine those spectral bands from the welding plasma that best discriminate among correct welding and the appearance of defects.

III. PROBLEM FORMULATION

Randomness and heterogeneity are inherent uncertainties in manufacturing process. Uncertainties during processing may come from variations in material composition, variation in billet dimension, variation in processing conditions and variations in environment. The variations because of varying environmental conditions can be classified as common causes. While identifiable instances, such as wear of the tools, different material suppliers etc., can be called assignable causes. Unfortunately, these variations can be measured, quantified, even reduced, but can never be eliminated. This uncertainty or variability is always unwanted in manufacturing.

Variations are root causes for defects. They result in scraps, downtimes and quality problems. All of these are regarded as waste, which brings companies extra cost, and impair companies' competitive ability and customers' satisfaction. However, defect rates in final products are not entirely determined by variations, but also the interactions of variations with tooling and process design. A typical manufacturing process is really complex multistage process with physical or chemical changes, which involve many factors that affect the quality of final product. The tooling design together with the process design determines the geometry, structure and mechanical properties of final product. If the desired properties are not satisfied, changes are made to tooling and/or process condition parameters, again, according to past experience and guidelines. This trial and error process continues until the required goals are satisfied.

M/s CIMMCO is manufacturing different type of wagons and wagon parts as per requirement of the customers. The research focus is to reduce the rejection rate of under frame assembly. The main parts of under frame assembly are Sole bar, Bolster, Head stock, Guest plate, Bottom flange as shown in fig. 3.1 to 3.5. In the current problem the total production and rejection data for the past three months were collected. Table 3.1shows the data which are collected were for the month of Aug.2014, Sep. 2014 and Oct. 2014.

Cut Material (Profile cut)

Bolster

Head Stock

A. Objective of the Study

It has been observed that the defects which are contributing to the total rejection of the component are;

- Blow Holes
- Spatter
- Chipping
- Undercut

The basic objective of the study is to reduce the rejection due to these defects

IV. Methodology

Multiple failure mechanisms frequently occur in the same component at different locations. Thus, it is crucial to identify the factors related to different failure modes so that the process can be modified and controlled in order to improve productivity.

A. Proposed Methodology

The proposed methodology for the present work is given below.

1) Identification of the problem: Identifying which type of welding defects are occurring in railway wagon assembly in industry.
2) Data Collection: Collecting information on defects of wagon manufacturing. It is related to recording the observations in appropriate way and organizing it for optimal use. The information regarding the welding process is gathered from all sources and observations.
3) Data Analysis: A number of methods have been suggested by Taguchi for analyzing the data observation method, ranking method, column effect method, ANOVA, S/N ANOVA, plot of average response curves, interaction graphs etc. However, in the present investigation the following method will be used:
   - Plot of average response curves
   - ANOVA for raw data
   - ANOVA for S/N data
   - S/N response graphs
   - Interaction graphs
4) Corrective Action: Taking the corrective action during welding of wagon. Assembly component and changing the different properties of welding.
5) Monitoring the System: During operation monitoring all operation very carefully.

B. Taguchi's Experimental Design and Analysis

1) Taguchi's Philosophy

Taguchi's comprehensive system of quality engineering is one of the greatest engineering achievements of the 20th century. His methods focus on the effective application of engineering strategies rather than advanced statistical techniques. It includes both upstream and shop – floor quality engineering .Upstream methods efficiently use small scale experiments to reduce variability and remain cost effective and robust design for large scale production and market place. Shop – floor technique provide cost- based, real time methods for monitoring and maintaining quality in production. The farther upstream a quality method is applied, the greater leverages it produces on the improvement, and the more it reduces the cost and time. Taguchi's philosophy is founded on the following three very simple and fundamental concept.

- Quality should be designed into the product and not inspected into it.
- Quality is best achieved by minimizing the deviations from the target .The product or process should be so designed that it is immune to uncontrollable environmental variable.
- The cost of quality should be measured as a function of deviation from the standard and the losses should be measured system –wide.

2) Experimental Design Strategy

Taguchi recommends orthogonal array (OA) for lying out of experiments. These OA's are generalized Graeco–Latin squares. To design an experiment is to select the most suitable OA and to assign the parameters and interaction of interest to the appropriate columns. The use of linear graphs and triangular tables suggested by Taguchi makes the assignment of parameters simple. The array forces all experimenters to design almost identical experiments.

- In the Taguchi method the results of the experiments are analyzed to achieve one or more of the following objectives:
- To established the best or the optimum condition for a product or process.
- To estimate the contribution of individual parameters and interactions.
- To estimate the response under the optimum condition.

3) 8 – Steps in Taguchi Methodology

Taguchi method is a scientifically disciplined mechanism for evaluating and implementing improvements in products, processes, materials, equipment, and facilities. These improvements are aimed at improving the desired characteristics and simultaneously reducing the number of defects by studying the key variables controlling the process and optimizing the procedures or design to yield the best results.

Taguchi processed a standard 8-step procedure for applying his method for optimizing any process,

- STEP-1: Identify the main function, side effects and failure mode.
- STEP-2: Identify the noise factors, testing conditions and quality characteristics.
- STEP-3: Identify the objectives function to be optimized.
- STEP-4: Identify the control factors and their levels.
- STEP-5: Select the orthogonal array matrix experiment.
- STEP-6: Conduct the matrix experiment.
- STEP-7: Analyze the data; predict the optimum levels and performance.
- STEP-8: Perform the verification experiment and plan the future action.

4) Confirmation Experiment

The confirmation experiment is a final step in verifying the conclusions from the previous round of experimentation. The optimum conditions are set for the significant parameters (the insignificant parameters are set at economic levels) and a selected number of tests are run under specified conditions. The average of the confirmation experiments results are compared with the anticipated average based on the parameters and levels tested. The confirmation experiment is a crucial step and is highly recommended to verify the experimental conclusion.

a) Objective of the Present Investigation

- Experimentally determining the effects of the various process parameters viz welding current, welding voltage, travel speed, wire electrode size, gas flow rate, type of shielding gas on the welding process.
- Optimizing of performance measures using Taguchi method.
- Predicting the optimal value of each response characteristic correspond to their optimal parameter setting using QUALITEK 4/MINITAB 15.0/SPSS 17.0.
- Comparing the experimental result with the predict optimal value implementation steps in this phase are to select the critical- to- quality (CTQ) measures, determine deliverables, and quantify the measurability.

V. EXPECTED OUTCOME

The analysis of welding defects of UNDER FRAME ASSEMBLY during the welding due to various defects and reduction in same for productivity enhancement will be carried out as per the methodology briefed in the previous chapter or any some extra method if needed at the appropriate stage. After carrying out the above work in the industry, the following outcomes are expected:

- The extra cost incurred on welding of defective parts will be saved by reduction of welding defects.
- Overall Welding cost will be decreased.
- Rejection
- Quality of the component will be improved.
- Customer satisfaction will be increased.
- Reduction in the time of overall production cycle.
- Component cost would be decreased.
- Reduction in expenditure incurred due to inspection and quality control as the parts produced by removing the defects would be perfect.

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