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OPTIMIZATION OF ANGULAR DEFORMATION OF TIG WELDED JOINT OF STAINLESS STEEL AND MILD STEEL

Sanjay Kumar[a] and Dr.BhupenderSingh[b]
[a]M.Tech Scholar, RPSCET,M.Garh, Haryana

[b]Asst. Professor JCBUSTYMCA, Faridabad

Abstract

Deformation and residual stresses are two major perennial problems faced by engineers in welding works in fabrication & joining process of metals. The change in the shape and dimensions that occur after welding is known as deformation, causing to various undesirable and un predictable problems in above said practice. So it is very imperative to control or eliminates deformation within desired limits. When deformation parameters cross the acceptable limits, correction of deformation after the complete fabrication cause in major reworking to the process to complete the process that may cause in larger operation time and cost of the process will increase the cost of the process also. Welding deformation control in fabrication of complex structures has always been a challenge for fabrication engineers, especially to those who are dealing with ship structures, machinery constructions, railroad, aerospace, pressure vessels, pipes and automotive parts fabrication.

Introduction

Welding is used extensively in the fabrication of many structures, buildings, ships, pressure vessels etc., due to many advantages it has, over the other fabrication processes. However, distortion is a problem encountered during welding. The presence of distortion in weldments poses problems in further assembly and in aesthetics. Correcting unacceptable distortion is often costly and in some cases may induce cracking, when improper methods are followed. It is better to control the distortion during welding, through adoption of proper techniques and procedures. The development of proper techniques for reducing and controlling distortion calls for fundamental knowledge on residual stresses, distortion and other factors, which influence them. While welding joins the components of a structure together, the complex thermal cycles from welding results in the formation of residual stresses in the joint area and distortion of the welded structure of the elements. Both weld lingering pressure and bending can altogether weaken the execution and dependability of the welded structures.

1.1 Factors Affecting Angular deformation

1.2 If a metal is uniformly heated and cooled, there would be almost no distortion. However, because the material is locally heated and restrained by the surrounding cold metal, stresses are generated higher than the material yield stress causing permanent distortion. The principal factors affecting the type and degree of distortion are:

1. Parent material properties
2. Amount of restraint
3. Joint design
4. Edge preparation and Part fit-up
5. Welding procedure

Design of Experiment

A scientific approach to plan the experiments is a necessity for efficient conduct of experiments. The experiments are carried out by using the statistical design of experiments, so that appropriate data have been collected and analyzed by statistical methods resulting in valid and objective conclusions. When the problem involves data that are subjected to experimental error, statistical methodology is the only objective approach to analysis. Thus, there are two aspects of an experimental problem: the design of the experiments and the statistical analysis of data. These two points are closely related since the method of analysis depends directly on the design of experiments employed.

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 production and market place. Shop-floor techniques provide cost-based, real time methods for monitoring and maintaining quality in production. Taguchi's philosophy is founded on the

following three very simple and fundamental concepts:
- 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 variables.
- The cost of quality should be measured as a function of deviation from the standard and the losses should be measured system-wide.

The Taguchi method involves reducing the variation in a process through robust design of experiments. The overall objective of the method is to produce high quality product at low cost to the manufacturer. He observed that poor quality cannot be improved by the process of inspection, screening and salvaging. No amount of inspection can put quality back into the product. Taguchi recommends a three stage process: system design, parameter design and tolerance design. In the present work Taguchi parameter design approach is used to study the effect of process parameters on the various responses of TIG welding.

Experimental Design Strategy

The experimental design proposed by Taguchi involves using orthogonal arrays to organize the parameters affecting the process and the levels at which they should be varied. Instead of having to test all possible combinations like the factorial design, the Taguchi method tests pairs of combinations. This allows for the collection of the necessary data to determine which factors most affect product quality with a minimum amount of experimentation, thus saving time and resources. The Taguchi method is best used when there is an intermediate number of variables (3 to 50) and when only a few variables contribute significantly.

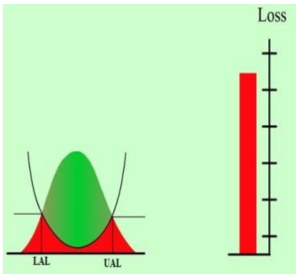
Loss Function

Definition:
A parabolic representation that estimates the quality loss, expressed monetarily, that results when quality characteristics deviate from the target values. The cost of this deviation increases quadratically as the characteristic moves farther from the target value. - Ducan, William.

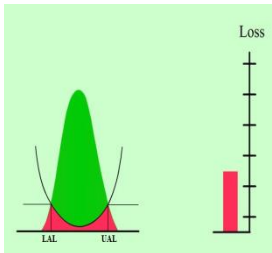
Taguchi defines quality loss via his "loss function". He unites the financial loss with the functional specification through a quadratic relationship that comes from a Taylor series expansion. The quadratic function takes the form of parabola. Taguchi defines the loss function a quantity proportional to the deviation from the nominal quality characteristics. He has found the following quadratic form to be a useful workable function:

$$L(y) = k(y - m)^2$$

L = Loss in monetary units
m = value at which the characteristic should be set
y = actual value of the characteristic
k = constant depending on the magnitude of the characteristic and the monetary unit involved. The loss function represented in equation (3.1) is graphically shown in fig. 3.1(a).
The farther the products characteristic varies from the target value, the greater is the loss. The loss must be zero when the quality characteristic of a product needs its target value. The loss is a continuous function and not a sudden step as in the case of traditional (goal post) approach (fig. 3.1(b)). This consequence of the continuous loss function illustrates the point that merely making a product within the specification limits does not necessarily mean that the product is of good quality.



(a)



(b)

Fig.(a)Taguchi's Loss Function Fig.(Traditional (Goal Post) Approach

Average loss-function for product population

In a mass production process, the average loss per unit is expressed as:

$$L(y) = \frac{1}{n}\{k(y_1 - m)^2 + k(y_2 - m)^2 + \ldots + k(y_n - m)^2$$

Where,
y_1, $y_{2\ldots}y_n$ = Actual value of characteristic for unit 1,2…n respectively
n = Number of units in a given sample
k = Constant depending on the magnitude of the characteristic and the monetary unit involved
m = Target value at which the characteristic should be set

The Eq.canbe simplified as:

$$L(y) = k(MSD_{LB})$$

Where,
MSD_{LB} = Mean squared deviation or the

average of squares of all deviations from the target or nominal value
LB = "lower is better"

The loss-function can also be applied to product characteristics other than the situation smaller is better.

Signal to Noise Ratio

The loss-function discussed above is an effective figure of merit for making engineering design decisions. However, to establish an appropriate loss function with its k value to use as a figure of merit is not always cost effective and easy. Recognizing the dilemma, Taguchi created a transform function for the loss-function which is named as Signal-to-Noise (S/N) ratio.
The S/N ratio, as stated earlier, is a concurrent statistic. A concurrent statistic is able to look at two characteristics of a distribution and roll these characteristics into a single number or figure of merit. The S/N ratio combines both the parameters (the mean level of the quality characteristic and variance around the mean) into a single metric.
A high value of S/N ratio implies that signal is much higher than the random effects of noise factors. Process operation consistent with highest S/N ratio always yields optimum quality with minimum variation.
The equation for calculating S/N ratios for "smaller is better" (LB), "larger is better" (HB) and "nominal is best" (NB) types of characteristics are as follows:

1. Larger is better:

$$(S/N)_{HB} = -10\,log(MSD_{HB})$$

Where,

$$MSD_{HB} = \frac{1}{R}[\sum_{i=1}^{R}\frac{1}{y_i^2}]$$

2. Smaller is better:

$$(S/N)_{LB} = -10\,log(MSD_{LB})$$

Where,

$$MSD_{LB} = \frac{1}{R}[\sum_{i=1}^{R}(y_i^2)]$$

3. Nominal is better:

$$(S/N)_{NB} = -10\,log(MSD_{NB})$$

Where,

$$MSD_{NB} = \frac{1}{R}[\sum_{i=1}^{R}(y_i - y_0)^2]$$

R = Number of repetitions

The Mean Squared Deviation (MSD) is a statistical quantity that reflects the deviation from the target value. The expressions for MSD are different for different quality characteristics. For the ""smaller is better", the unstated target value is zero. For "nominal is best", the standard deviation of MSD is used. For "larger is better", the inverse of each large value becomes a small value and again, the unstated target value is zero.
All the sub topics should be numbered as shown above. Numbering should be made. All the mathematical equations should be numbered as shown above.

Conclusion

The following conclusions were arrived at from the above investigation:

1. The Taguchi's design of orthogonal arrays can be employed easily for developing mathematical model for optimizing the distortion within the workable region of the control parameters like length of work piece, diameter of electrode, time gap between successive passes and welding current in Tungsten arc welding.
2. Angular distortion decreases with the increase in length within the design range of parameters.
3. With the increase in electrode diameter, the angular distortion increases within the design range of parameters.
4. Angular distortion decreases with the increase in time gap between successive passes within the design range of parameters.
5. With the increase in current, the angular distortion increases within the design range of parameters.
6. The process parameter current has the highest effect on angular distortion.
7. Within the design range of parameters, the least effect on angular distortion is found of diameter of electrode.
8. The angular distortion is minimum when the length of plate is 135, electrode diameter is 1.5 mm, time between successive passes is 7, and welding current is 80 amp.

The optimum value of angular distortion is 2.828^0

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