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Study of Angular Distortion of SS 302 and MS Plate with GTAW

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Abstract: Gas tungsten arc welding (GTAW), also known as tungsten inert gas (TIG) welding, is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by an inert shielding gas (argon or helium), and a filler metal is normally used, though some welds, known as autogenously welds, do not require it. There are many types of distortion arises during welding any products. The main and major problem is Angular distortion. We can say the change in shape of a small circle on a sphere when it is transformed to a plane by a projection. This angular distortion is mainly due to non uniform transverse shrinkage along the depth of the plates welded. If the stresses generated from thermal expansion/contraction exceed the yield strength of the parent metal, localized plastic deformation of the metal occurs. Plastic deformation causes a permanent reduction in the component dimensions and distorts the structure. Due to high stress, the shape of original material is distorted. Because welding involves highly localized heating of joint edges to fuse the material, non-uniform stresses are set up in the component because of expansion and contraction of the heated material. It is impossible to find the complete optimal solution to predict angular distortion that may be reliable over a wide range of processes. This paper presents the transverse distortion of TIG; welding process was evaluated using weld current, filler rod diameter, length of plate and time gap between passes as the main parameters. Many mathematical and statistical approaches were developed to resolve the problem of angular distortion. Many parameters were analyzed using source code in MATLAB and presented with the help of graphs. Further, these mathematical models help to optimize the GTAW process and to make it a cost-effective one by eliminating the weld defects due to angular distortion.

Keywords: TIG, Angular distortion, GTAW , Mathematical Model

I. INTRODUCTION

Gas tungsten arc welding (GTAW), also known as tungsten inert gas (TIG) welding. It is an arc welding process that uses a non consumable tungsten electrode to produce the weld. A constant current welding power supply produces electrical energy, which is conducted across the arc through a column of highly ionized gas and metal vapours known as plasma.

GTAW[1] is most commonly used to weld thin sections of stainless steel and non-ferrous metals such as aluminium, magnesium, and copper alloys.

No slag, No splatter, good weld penetration, concentrated arc, little smoke or fumes, preferred for stainless steel alloys are the main advantages of TIG welding. Slow process, good skill requirement for manual operation is the main Disadvantages.

II. PREVENTION OR CONTROL MEASUREMENT OF DISTORTION

Distortion can be prevented or minimized during welding process using some strategies. During welding process, the total number of heating and cooling cycles should be minimized. Shrinkage or contraction cannot be prevented, but it can be controlled [2]. Distortion in a weld results from the expansion and contraction of the weld metal and adjacent base metal during the heating and cooling cycle of the welding process. Doing all welding on one side of a part will cause much more distortion than if the welds are alternated from one side to the other. During this heating and cooling cycle, many factors affect shrinkage of the metal and lead to distortion, such as physical and mechanical properties that change as heat is applied. The temperature distribution in the weldment is therefore non uniform. When metals are heated, then shrinkage of metal takes place. Upon cooling, the weld pool solidifies and shrinks, exerting stresses on the surrounding weld metal and heat affected zone. There are various types of distortion and dimensional change including longitudinal shrinkage; transverse; angular distortion; twisting and bowing.

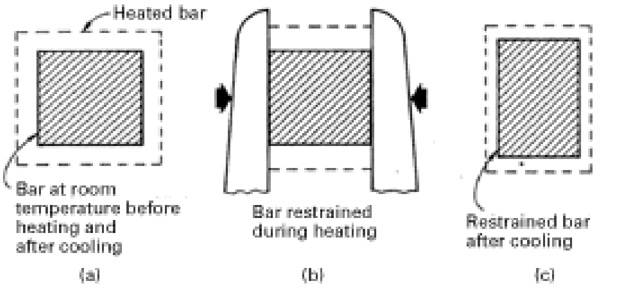

Figure 1: If a steel bar is uniformly heated while unrestrained, as in (a), it will expand in all directions and return to its original dimensions on cooling. If restrained, as in (b), during heating, it can expand only in the vertical direction - become thicker. On cooling, the deformed bar contracts uniformly, as shown in (c), and, thus, is permanently deformed. This is a simplified explanation of basic cause of distortion in welding assemblies.

The pictorial representation as mentioned in Figure 1 show that the shape of the components modify due to distortion. It shows basic cause of distortion in welding assemblies.

In the present reported work, transverse distortion is measured and expressed in angular distortion in degrees. Firstly heat was applied on the components uniformly and after that cooling is takes place; by this procedure distortion can be minimized. However, by this method, welding locally heats a component and the adjacent cold metal restrains the heated material. Some time, permanent distortion is caused due to stresses on the adjacent side [4]. The main cause of distortion is kind of restraint, welding procedure, amount of restraint properties of parent metal etc. Due to welding, the problem of joint edges, non uniform stresses set up in component [3]. So expansion and contraction of the heated material takes place. Figure2 represent, change in shape and orthogonal reduction in length, shrinkage occurs due to distortion. The smaller parts considered in this report result in a linear angular movement which is the response considered in this study. When metal is cooled, then tensile stress occurs or created on contradiction of weld and the immediate heat affected zone is resisted by the bulk of the cold parent metal [6]. When welding is applied on the metal then automatically thermal stresses created into material. Then it can be find out by change in volume in weld area on solidification and then cooling to room temperature.

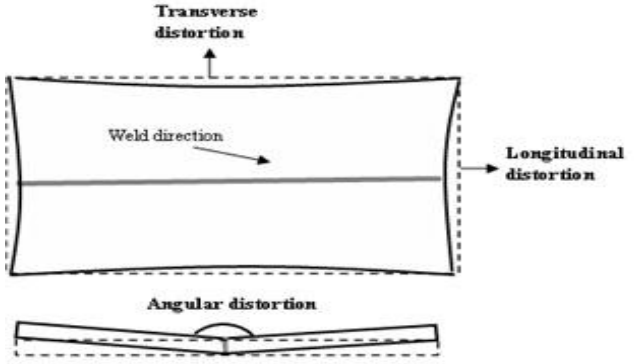

Fig 2: Distortion Caused by Welding

III. MATERIAL AND METHODOLOGY

TIG welding was carried out with SS 302 & MS samples of varying length, 50 mm width and 6mm thick. The SS and MS plates were prepared with V grove design and butt weld conditions with single pass filler wire. Then the distortions can be easily find in all the samples and are measured with dial gauge fitted to a height gauge. Tungsten Electrode was connected to the Negative charge of the DC hence, Tungsten Electrode Negatively connected, called EN type welding. The current variation was 70 to 100 Amps [7]. The filler material used was a carbon steel filler rod of 1.5-2.5 mm diameter. The process was stabilized to minimize the variation due to uncontrolled parameters or manual error bias. The Welding machine used was a Weld man EJM 300 TIG, an AC/DC, 3 Phase, 50 Hz, pulse controlled dual, TIG & Arc welding machine capable of welding 0.8 mm to 19 mm thick plates. The two plates placed with the root gap at the bottom and the angle provides a V groove for the weld bead. The weld bead will be the rectangular area of root gap and plate thickness, triangular bead area of V groove and the top bead chord area. The weld process parameters which are used as main factors are mentioned in Table 1 with details and rest other parameters are kept same throughout the experiments.

Sr. No.	Process Parameters	Notation	Units	Levels		
				-1	0	1
1	Length of Work piece	l	mm	75	100	125
2	Diameter of Electrode	d	mm	1.5	2	2.5
3	Weld Current	c	amps	70	85	100
4	Time gap between passes	t	min.	0	5	10

Table 1: Major Process parameters for TIG welding.

Genichi Taguchi has used the design of experiments effectively to improve quality, productivity, reliability, and cost and is extensively used in industry as a tool in their TQM or Six Sigma activities. The use of Orthogonal Arrays, in this study, an L9 experiment, was done is a fractional factorial methodology. L9 has designed 9 unbiased experiments which have been conducted randomly, not in 1 to 9 sequences to remove the experimental bias. The control factors are allotted to the columns as shown in Table 2. Four factors, length of work piece, Weld current, electrode diameter and time gap between passes were allotted to the columns, 1, 2, 3 & 4 respectively. Each of these factors has three levels of possible values and they are assigned to form the orthogonal experimentation. The output distortion is expressed in degrees of distortion, an angular unit obtained from Trigonometry of the measured values.

Trails	l	d	c	t	dis
1	75	1.5	70	0	6.16
2	75	2	85	5	4.30
3	75	2.5	100	10	6.73
4	100	1.5	85	10	5.80
5	100	2	100	0	4.80
6	100	2.5	70	5	2.83
7	125	1.5	100	5	5.37
8	125	2	70	10	4.70
9	125	2.5	85	0	4.35

Table 2: L9 Orthogonal array experimental lay out

Model was developed by the method of regression. Adequacy of the model and significance of coefficients was tested by the analysis of variance technique and regression method respectively. By finding the regression coefficients we get the mathematical model.

$$D_2 = b_0 + b_1 l + b_2 d + b_3 c + b_4 t + b_{12} ld + b_{13} lc + b_{14} lt + b_{23} dc + b_{24} dt + b_{34} ct$$

Regression Equation (using MINITAB 16):

$$\text{Distortion } (D_2) = 61.2644 - 0.154571\, l - 18.4462\, d - 0.766333\, c + 0.129\, t - 0.0322286\, ld + 0.00280762\, lc + 0.253905\, dc$$

The scatter diagram Fig4.represent the measurement of observed values and predicted values of angular distortion. To determine accuracy of the model conformity, test runs were conducted. For these runs, process parameters were assigned some intermediate values within their limits. Many statistical approaches have been used for predicted values and observed values. The result shows that the model accuracy is above 95%.

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	7	10.7765	10.7765	1.53950	17.0801	0.184258
l	1	1.2788	0.1574	0.15742	1.7465	0.412377
d	1	1.9494	3.3673	3.36734	37.3592	0.103241
c	1	1.7174	2.1602	2.16025	23.9670	0.128274
t	1	0.6144	0.3566	0.35659	3.9562	0.296570
ld	1	0.9506	0.0947	0.09467	1.0503	0.492184
lc	1	0.0352	0.6466	0.64663	7.1741	0.227479
dc	1	4.2307	4.2307	4.23069	46.9377	0.092271
Error	1	0.0901	0.0901	0.09013		
Total	8	10.8666				

Table 3: Analysis of variance

Where,
DF - degrees of freedom,
SS - sum of squares,
MS - mean squares (Variance),
F-ratio of variance of a source to variance of error,

D_1	D_2	
Observed values of Angular distortion	calculated values of Angular distortion	% error
6.16	6.133278	0.434
4.30	4.514007	4.977
6.73	6.703313	0.396
5.80	5.693063	1.844
4.80	4.693080	2.227
2.83	2.723055	3.779
5.37	5.423563	0.997
4.70	4.753540	1.139
4.35	4.403558	1.231

Table 4: values of distortion observed (from experiment) and calculated (mathematical model)

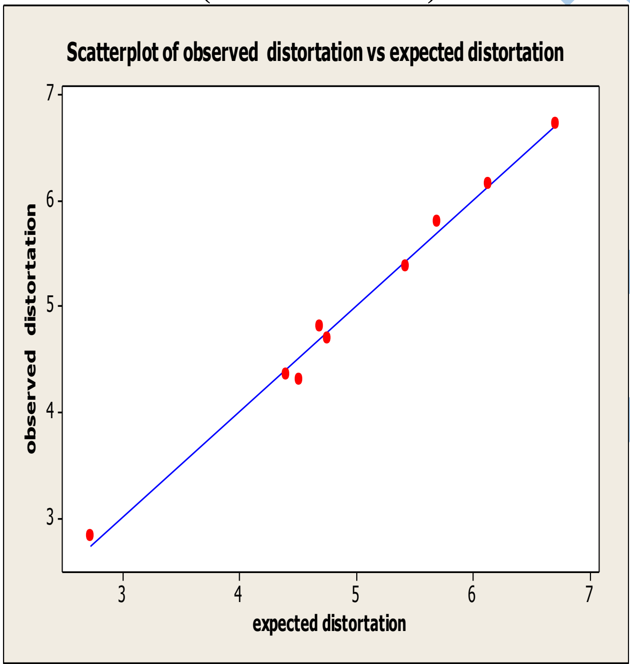

Figure 3: plot between observed and calculated values of distortion.

IV. RESULTS AND PLOTS

The mathematical model given above can be used to predict the angular distortion by substituting the values of the respective process parameters. Also, the values of the process parameters can be obtained by substituting the value of allowable angular distortion values. The angular distortions calculated from the final model for each set of coded values of welding parameters are represented graphically in Figs 3-8. These graphs show generally convincing trends between cause and effect.

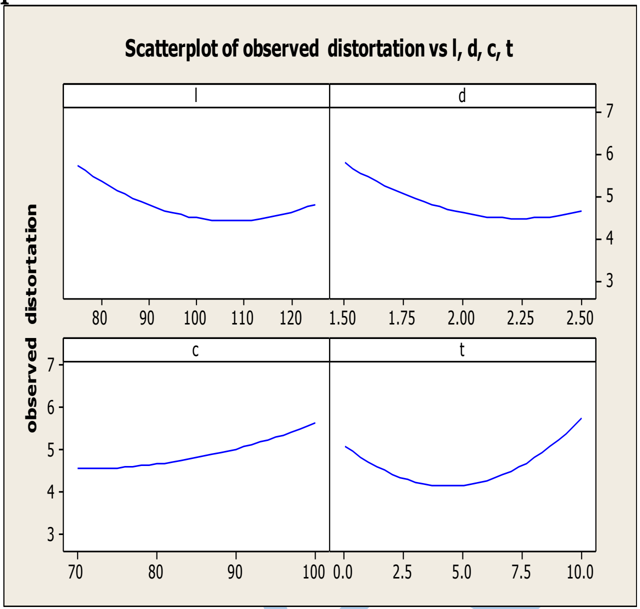

Figure 4: Scatter plot of angular distortion vs factors.

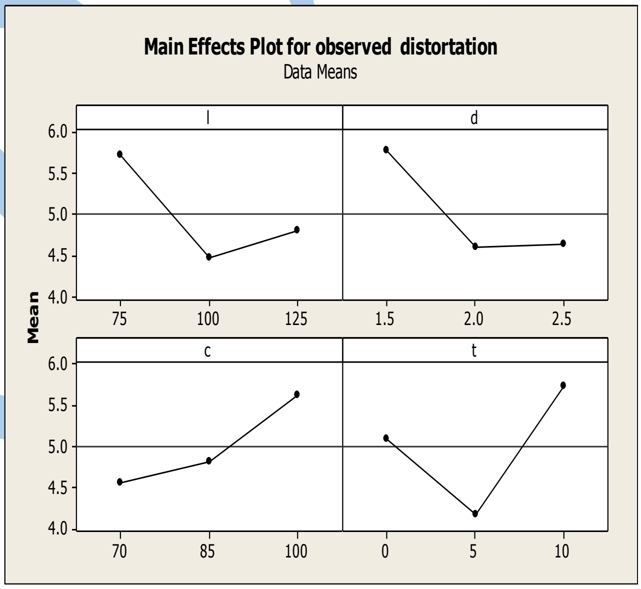

Figure 5: Mean effects plot for angular distortion.

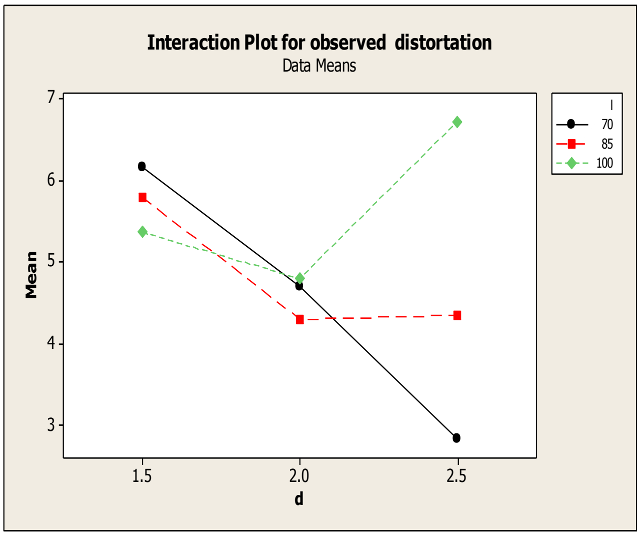

Figure 6: Interaction effect of length of plates and diameter of electrode on Angular distortion.

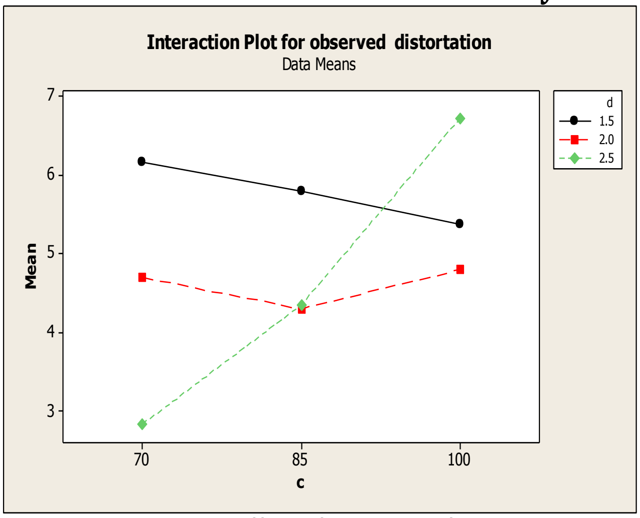

Figure 7: Interaction effect of diameter of electrode and current on angular distortion.

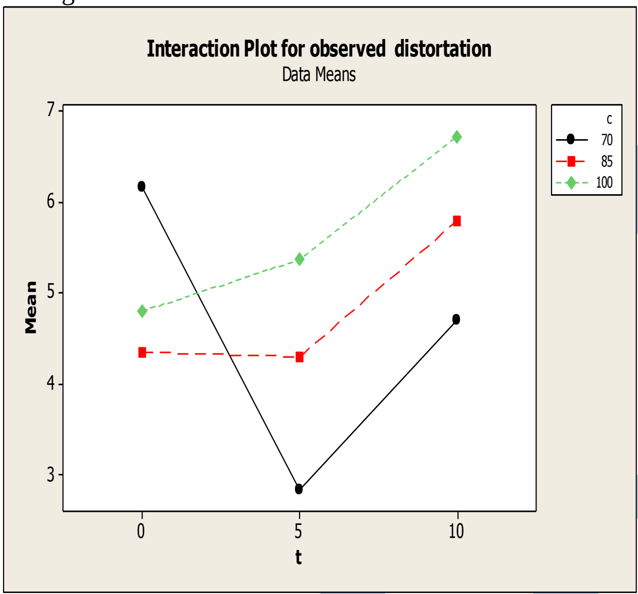

Figure 8: Interaction effect of current and time between passes on Angular distortion.

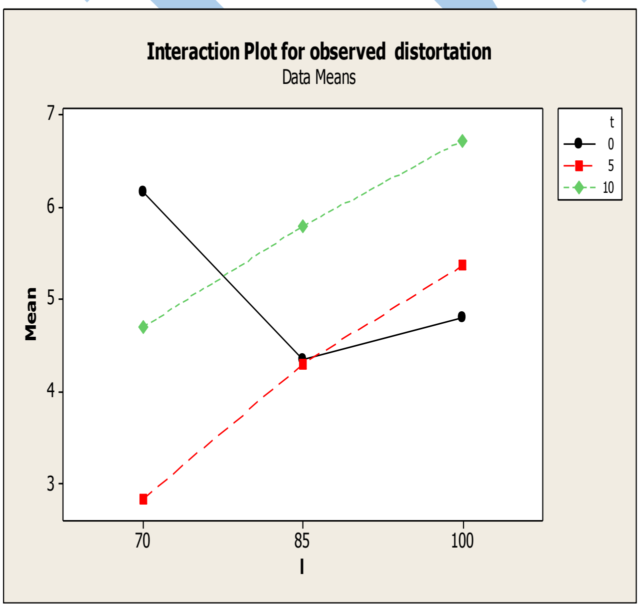

Figure 9: Interaction effect of time between passes and length of plates on Angular distortion.

V. CONCLUSION

The main conclusions are:-

1. The positive effect of angular distortion takes place when length of plates and diameter of electrode increases.
2. The negative effect of angular distortion takes place when current and time gap between passes increases.
3. The highest effect on angular distortion is observed on diameter of the electrode using within the design range of parameters.
4. The least effect on angular distortion is observed of time between successive passes using within the design range of parameters.

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