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EXPERIMENTAL STUDY AND EFFECTS OF PARAMETERS OF DISTORTION CONTROL MEASURES IN HIGH-INTERMEDIATE PRESSURE TURBINE COMPONENT DURING FABRICATION

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***Abstract*: This paper contains experimental study of welding distortion and its parameters and control measures taken on prevention of dimensional changes in thermal shield which is part of high-intermediate pressure turbine. Distortion is a major problem and it has different types. The extent of distortion depends on some important parameters related to welding. The important parameters chosen for given study are thickness (T), heat input (P) and Clamping condition (A). The experiments are conducted based on three factor two level designs with full replicates technique. Analysis of variance (ANOVA) and F-test has been used for
determining most significant parameters affecting the welding distortion.***
Keywords: **ANOVA; Orthogonal array; Welding distortion; Welding parameters**

INTRODUCTION

In this paper the problems facing the fabrication industry with regards to distortion control and prediction have been set out. From the information presented it should therefore be clear that gaining a greater and earlier knowledge of distortion in the development and design process has significant benefits to successful project delivery of such jobs.

Earlier changes in design are more cost effective and it has to be proven at least for 10 years. Currently distortion problems typically are discovered when it is too late to redesign, and therefore modifications have to be made to tooling, fixtures and processes that already exist and have been facilitated for the job. Tooling modifications or additions of operations add costs, either of which can be catastrophically expensive or even eliminate profitability from the project. Early knowledge is the key to avoiding late changes and this project sets out to develop some fundamental step to facilitate prediction of weld distortion in the design stages. In order to do this it is necessary to review the current state of the art and practices for distortion control and simulation.

EXPERIMENTAL WORK

In order to carry out the experimental investigation, the following techniques/methods were utilized:

• Design of suitable test plates to be used for comparing welding variables.
• Design for fixture and component design work.
• Design of experiments (DOE) using Full Factorial Design.
• Shielded metal arc welding process to simulate welding technique used in high production component manufacture.
• Measurement processes to accurately measure test pieces before and after the welding processes.

Major welding distortion factors that affect distortion are heat input, thickness and restraints. These factors are selected as per product and developed study. There are studies available on predicting distortion which are having different factors and levels.

Table: 1 Factors and levels of welding distortion

Factors	Levels	
Heat Input (KJ/mm)	1	2
Thickness (mm)	12	22
Clamp Condition	With	Without

Raw material arrangement and sample preparation as per ASME section IX, Welding edge preparation is done by grinding and machining. It is to be checked for required size and shape.

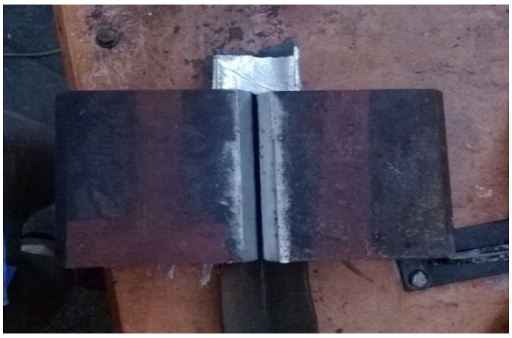

Figure 1 WEP for sample

- Width: 150 mm
- Length: 150 mm
- Thickness: 12 and 22 mm
- Material: P15E Grade 91
- Groove type: Single V Butt joint

RESULTS AND DISCUSSION

The observations recorded during the welding of P15E grade 91 plates are recorded as shown in Table 2 and heat input is being measured as per following equation. These 16 experiments are performed on flat surface and the plates are being machined to maintain surface flatness; Welder is remained same for all experiments to meet the requirements. The heat input is taken on average basis , it is calculated based on following formulae:

$$\text{Heat Input (KJ/mm)} = \frac{\text{Current (A)} \times \text{Voltage (V)} \times 60}{\text{Travel speed (mm/min)} \times 1000}$$

Table 2 Observation Table

DOE	Sr	T*	P* (KJ/mm)	A*	Distortion (mm)	
					N1	N2
1	1	12	1	1*	0.86	0.56
2	2	22	1	1*	0.21	0.34
3	3	12	2	1*	0.7	0.45
4	4	22	2	1*	0.98	0.79
5	5	12	1	0*	1.05	1.19
6	6	22	1	0*	2.51	3.01
7	7	12	2	0*	1.46	1.29
8	8	22	2	0*	3.22	3.09

*Notes:

T=Thickness; P=Heat input; A=Clamp condition; 1=With Clamping; 0=Without Clamping

Analysis of variance (ANOVA)

Analysis of variance for welding distortion is carried out using MINITAB software for experimental data obtained during SMAW process for distortion as listed in Table 2. To make the analysis simple and avoid longer procedure of carrying out three 2-Way ANOVAs and associated errors in calculation, 3-Way ANOVA technique is used for determining level of significance for individual parameters effect as well as the interaction effect of combination of input parameters. Results are represented in Table 3 for welding distortion.

Table 3 ANOVA (3-WAY) Using Adjusted SS FOR Welding Distortion

Factor	Degree	Seq.	Adjusted	Mean	Fexp =	P-Value
Thickness	1	2.7143	2.7143	2.7143	83.37	0.000
Heat Input	1	0.3164	0.3164	0.3164	9.72	0.014
Clamp	1	8.8953	8.8953	8.8953	273.23	0.000
Thickness*	1	0.1958	0.1958	0.1958	6.01	0.040
Thickness*	1	3.1418	3.1418	3.1418	96.50	0.000
Heat input*	1	0.0077	0.0077	0.0077	0.24	0.641
Thikness*Heat	1	0.0915	0.0915	0.0915	2.81	0.132
Error	8	0.2604	0.2604	0.0326		
Total	15	15.6231				

EFFECT OF PARAMETERS ON DISTORTION

Effect of Clamping on distortion

From the results for ANOVA of Data Means for Distortion listed in Table 3 and main effects plot shown in Fig. 2 and interactions plot in figure 3, it is clearly observed that Clamping is the most significantly affecting factor for Distortion in SMAW process. The Distortion increases without clamping condition for all levels of thickness and heat inputs. The nature of increase is observed to be non-linear with continuously increasing trend. The increase in distortion without clamping is because of restraint phenomena, if you apply proper restraints during welding. The resultant deformation will turn into residual stresses and this will turn major deduction in distortion which is residual strain. With clamping condition, it will reduce the distortion but the resultant residual stress can cause the problem of cracking so stress relieving treatment is done after the welding has been completed.

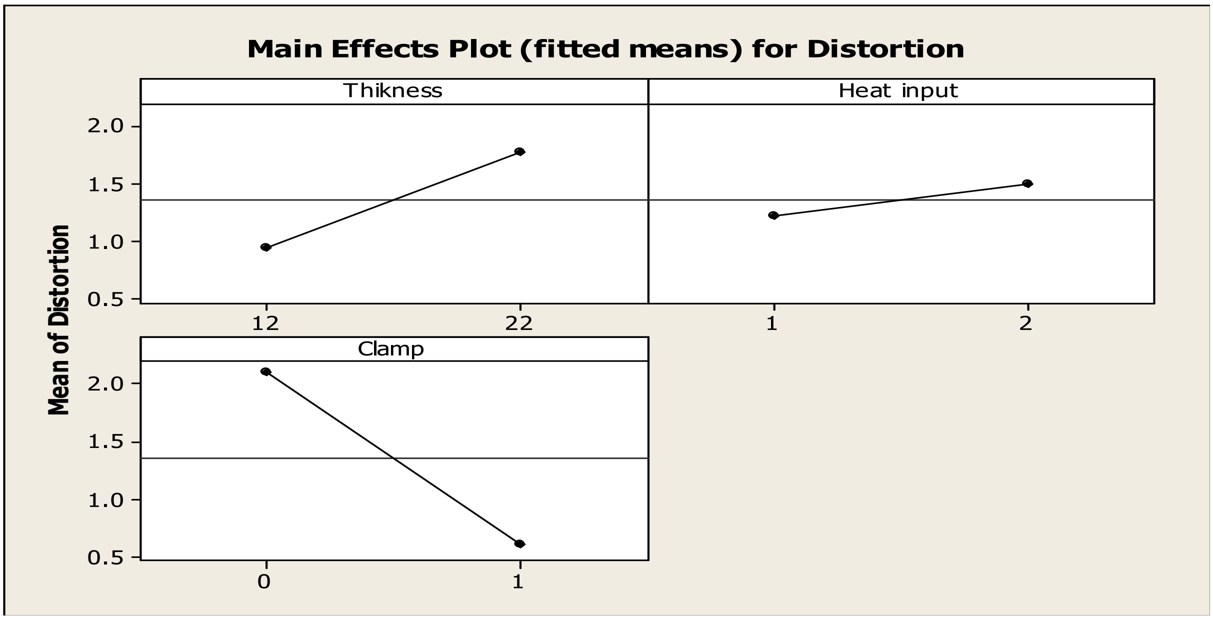

Figure 2 Main Effect Plot: Data using distortion

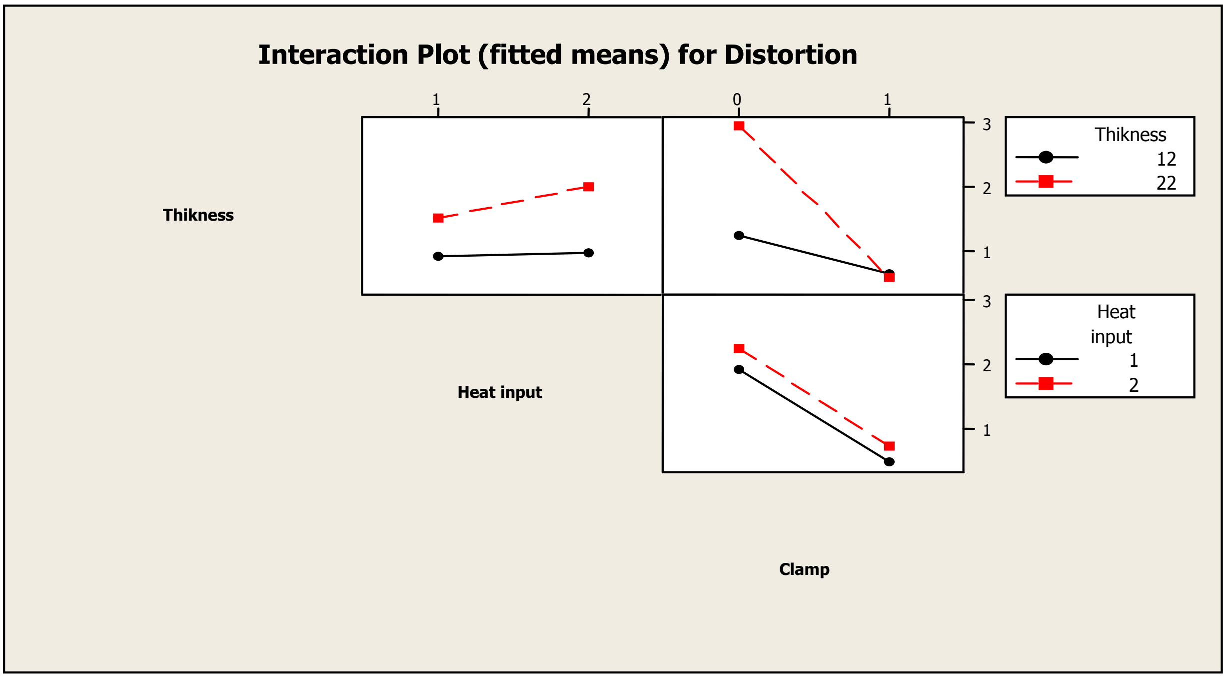

Figure 3 Main Effect Plot: Data using distortion

Effect of Thickness on distortion

From the results for ANOVA of Data Means for Distortion listed in Table 3 and main effects plot shown in Fig. 2 and interaction plot in figure 3, it is clearly observed that thickness is the second most significantly affecting factor for Distortion in SMAW process. Now as shown in figure 4.3(a) by considering the with clamp condition, the distortion will reduce with an increase in thickness. This will reflect that there is certain limit or factor that causes this variation in distortion. It is also obsevered that with increase in heat input in with clamping condition, the distortion will increase for this size of welding. The moment of inertia is main factor for unusual behavior of distortion in terms of thickness. While maintain same heat input as P=1 KJ/mm, there is lesser moment of inertia in thickness T=12 mm compared to

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T=22 mm causing less distortion. There will be deduction in distortion if there will be higher thickness beyond creation limit based on torque required to cause the acceleration.

Effect of Heat input on distortion

The heat input is found to be affecting the distortion less significantly compared to clamping conditions and thickness of job. From the results for ANOVA of Data Means for distortion listed in Table 3 and main effects plot shown in Fig. 2 and interaction plot in figure 3, the F-value and p-value show that heat input affects the distortion less significantly than other parameters With increase in heat input, the more heat is added to material causing sudden expansion of molecules in the material which in turn result in distortion as after cooling some molecules which has crossed the limits of yield strength. These molecules are plastically deformed and it won't return to original shape as it results in distortion If proper clamping is not done.

CONCLUSION

From the experiments we can conclude that the most significant factor affecting among these three factors is Clamp condition. It is suggested to clamp the welding plates to reduce the welding distortion. Second significant factor is thickness of the welding joint and third effective parameter is heat input given to welding joint to reduce the welding distortion.

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