COBEM-2017-1468
Analysis of Welding Distortion in Inox Steel with Heat Input Variation the XXIV COBEM

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Abstract. Distortion phenomena occurs in large structures as bridges, ships compromising its integrity when under stress in its lifespan. Although with the thickness increases the distortions start to be more insignificant, thinner structures are more likely to deform during welding because of a lack of rigidity. Other important parameters when studying distortional behaviour is the heat input and the joint project, the first one has an opposite effect to the thickness and the second one influences on the thermal behaviour of the process. The aim of this study is to understand the distortional behaviour of a naval steel when the structure is assembled using flux cored metal arc welding in T joints with heat input variation, so for this purpose measurements of heat in the plates will be taken using thermocouple and the distortional data will be obtained by means of measuring the deviation of linearity on the plates as welded. Is expected that with heat input increases distortion increases.

Keywords: Welding Distortion, Gas-Metal Arc Welding, Heat Input, Inox Steel, Naval Industry.

1. INTRODUCTION

Usually, in welding processes, the heat transferred by the electric arc to the welded structure can cause undesired defects in the base metal such as formation of cracks, residual tensions and distortion. Those issues are commonly found in welding processes and can occur in various manners, in example, the distortion can vary in different patterns: longitudinal contractions, transversal, angular, bending, buckling or twisting, which are related to the heat input (1) (2). Therefore, the heat input, is the parameter that quantifies the heat involved in this process, has influence on defects and its control can be determinant on solving issues related to thermal gradient effects. In this context, controlling the heat input as a preventive mode, easing the effects of it, possibly will reduce the need of rework in affected components (3) saving time and production costs, not to mention the chance of wasting. Considering the dimensional tolerances of the manufactured components in industrial scale, the correction of distortion which is caused by thermal gradients in the welding process is, several times, responsible for the cost enhancement of the product due to needs such as tensions relief processes, machining, and so on (4)(5). This paper will analyse the effect of the variation of the heat input in a AISI 304L inox steel which is submitted to the Gas Metal Arc Welding process and is expected to suffer angular distortion.

Welding distortions can reduce the dimensional precision of naval components and its productivity when it comes to the assembly process due to rework activities(6). For instance, the construction of ship blocks represents one third of all the production of the shipyard, therefore the dimensional precision is directly related to the productive efficiency of the shipyard (7). During the welding process, the mechanical behavior of a component is too complex and so the distortion pattern which is investigated in this research is the angular distortion only.

In general, the welding distortion can be attributed to heating and cooling in localized regions of the piece, leading to

thermal expansion due to rapid heating and contraction due to cooling (8). Angular distortion is described as a rotation of the piece about the weld line, which is considered the rotational axis. This rotation is explained due to the thermal gradients in the welding process, which is non uniform.

The reduction of distortion is fundamental to control mismatching problems and there are a few methods that are commonly used to control distortion, that include but are not limited to: pre-setting, pre-heating, intermittent welding, sequencing (9) and controlling the heap input. Other methods might be used to control distortion such as fixturing the work piece although this creates another problem which is the build up of residual stresses. Some authors consider a variable restraint method claiming that at some point, unnecessary pressure applied to the work piece might lead to residual stress in that component, thus, the variation of the pressure might leave the piece in a low stress level compared to the non-variable restraining method.

This study aimed to gather distortion and heat input data and correlate them to understand how the heat input variation causes distortion to vary. For that, welding beads were performed in t-joint profiles, changing welding parameters to achieve different heat input values and therefore, different angular distortion measurements.

2. EXPERIMENTAL METHOD

To perform the study suggested in this paper it was used the austenitic inox steel AISI 304 with composition C: 0,08%; Cr:18-20%; Ni: 8-11%; Mn: 2% max; Si:1% max. The samples dimensions were 400x350x6.35 mm (base) and 100x50x6.35 mm (stiffener). Weld beads measuring 180mm were performed in T joints with GMAW process using 100% Argon as shielding gas.

To ensure repeatability, the weld seams were performed in one pass by a semiautomatic welding trolley and a jig composed of a SAE 1045 plate with 2 bolts attached to it by 2 nuts, coupled to a cast iron 'L' profile mounted to stabilize the samples on the same pattern as shown below on Figure 1.Previously, to ensure the sample plates were mounted on the right position and aligned, tack welds were performed prior to the weld beads, as shown on Figure 2.
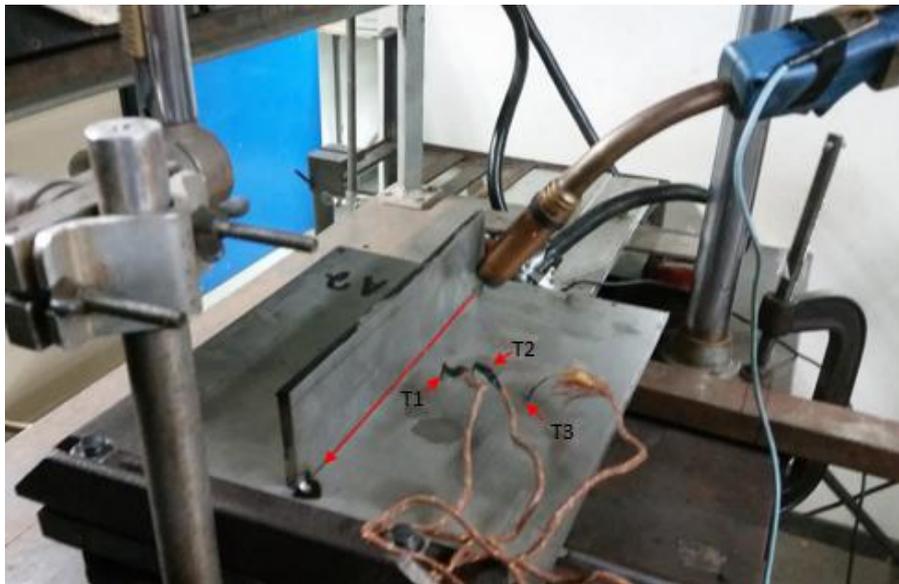

Figure 1. Semiautomatic welding device.

To execute the weld beads the trolley, once activated, starts to move linearly along with the jig while the welding torch remains static, 45 degrees inclined to the jig. A trigger was pushed to activate and deactivate the welding torch once each seam is finished. Once the first bead is finished, the sample is turned 180 degrees and the weld bead on the other side of the T joint is performed. The pictures to measure the angular distortion were taken right after the second bead of each sample was performed. The registered room temperature was 27.5 C.

The data was collected using an acquisition system and a photographic camera which were analysed with software Sap, and imageJ. It was gathered data of voltage and electric current from all welded samples, while the welding speed and gas flow remained the same and constant for all experiments. The heat input consequently was calculated by the parameters mentioned above, taking into account the electric current variation, using the Equation 1.

$Heat\ Input = (V\ x\ I)\ /\ Ws$ (Eq. 1)

Figure 2. Tack weld performed on sample mounted on the jig.

As shown the Table 1, three different heat input were selected for the analysis of angular distortion by quantifying this latter by measuring the profile linearity deviation of the samples through the use of ImageJ, shown in Figure 3.

Table 1. Parameters of the Process

| Samples | Variable Parameter | Fixed Parameters | |
	Current (A)	Stick Out (mm)	Gas Flow (l/min)
B (1/2/3)	200 10	15	20
C (1/2/3)	180 10	15	20
D (1/2/3)	160 10	15	20

It was used a horizontal line as a base line and other touching the bottom line corner of the sample, what gave in response the displacement angle caused by the welding procedure. The angular distortion was measured at the end of the flap on each sample. The parameters utilized on the process are presented in the table 1. As shown, the values of stick out and gas flow were fixed. Although the voltage was set constant at a 20V value, it eventually changed due to variation of electric current in response to its variation.
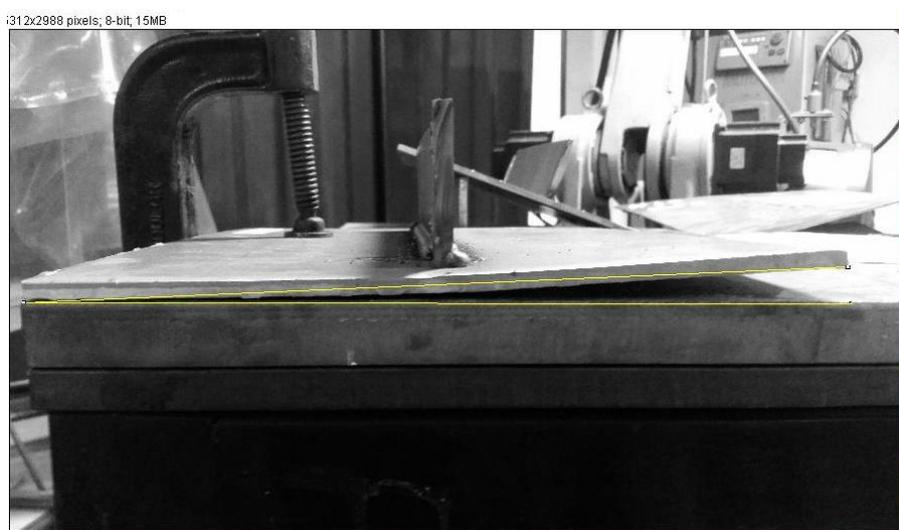

Figure 3. Schematic analysis of angular distortion on ImageJ.

3. RESULTS

This section presents the relation between angular distortion and heat input data collected from the experiments. The data presented in Figure 4 is the heat input obtained on each sample.
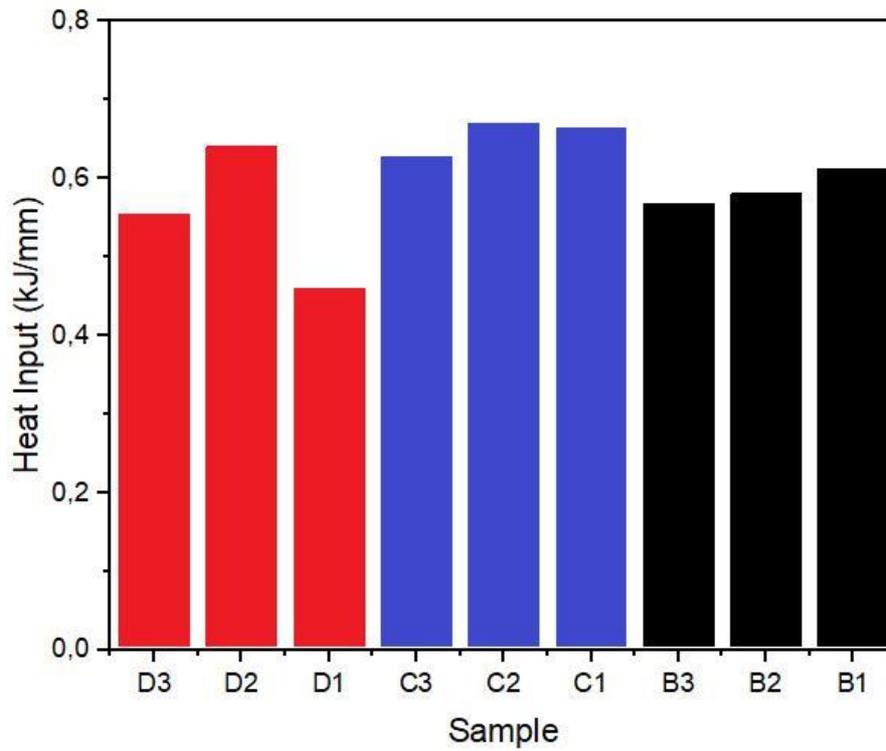

Figure 4. Heat Input on each sample.

As shown, it can be noticed that the 'C' samples presented the highest values compared to the others.
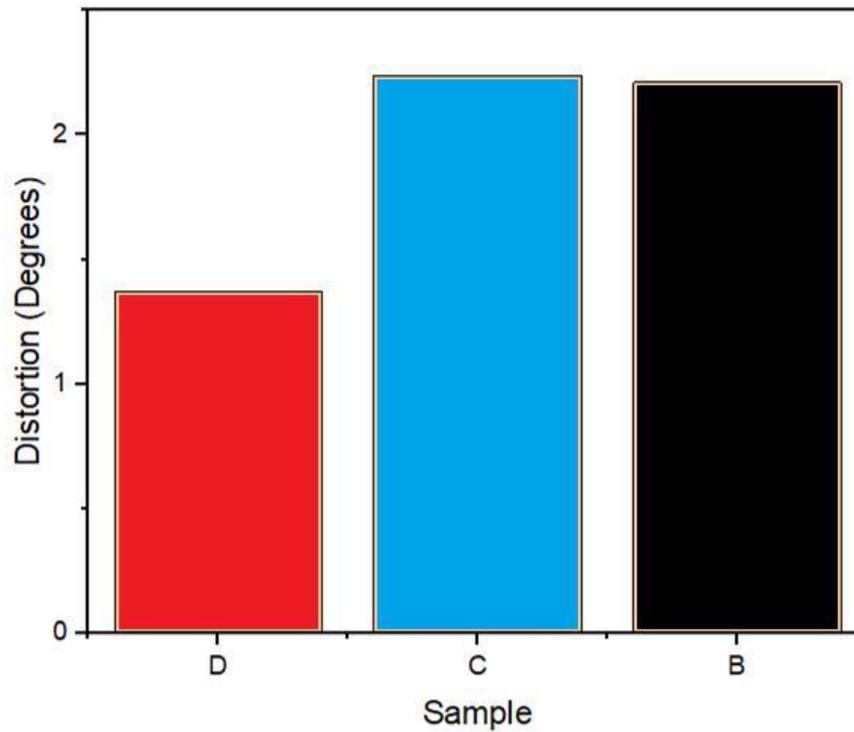

Figure 5. Average Angular Distortion.

In Figure 6, the distortion observed on sample B1 was very inconsistent with the average value, presented above, in Figure 5.
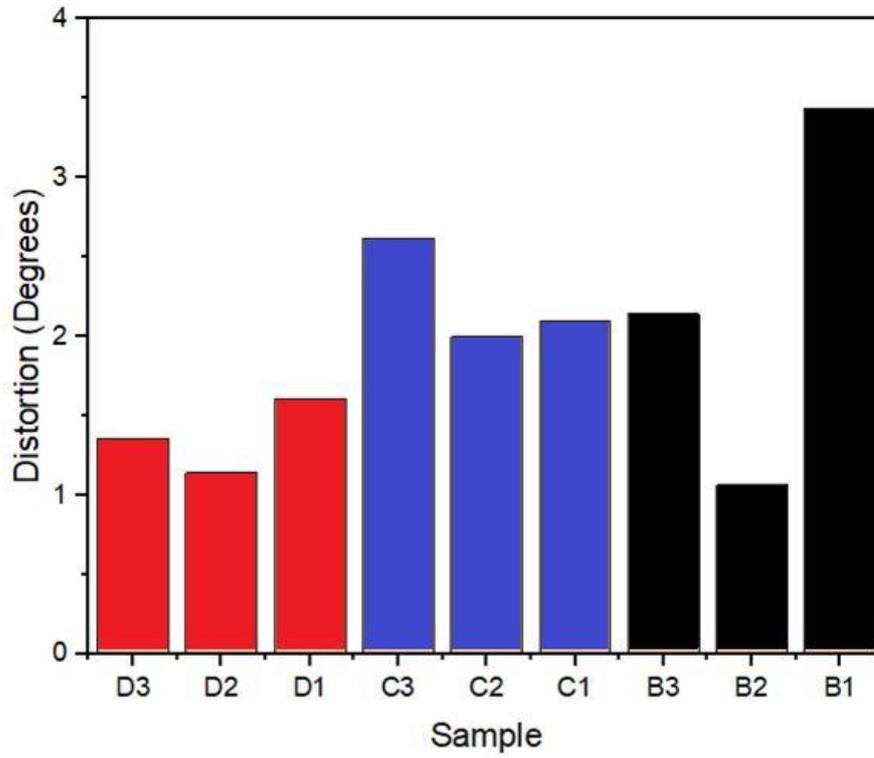

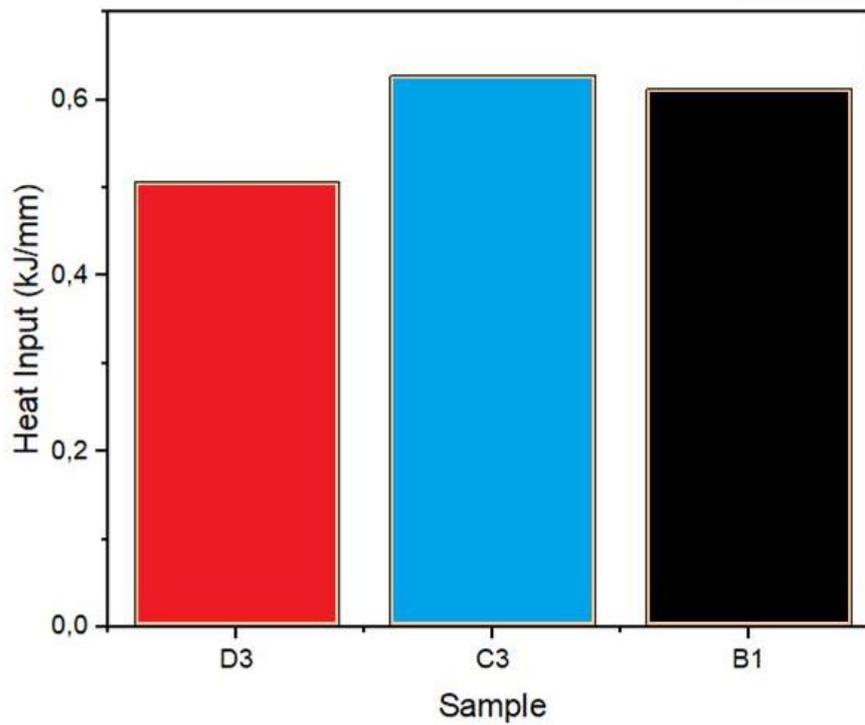Figure 6. Angular Distortion on each sample.

Figure 7. Average Heat Input.

As it can be seen, the other samples of each sampling family (D,C and B) had a proportional behavior in relation to each other. The average heat input is consistent with the average angular distortion, which means that the bigger the heat input is, the bigger is the angular distortion, as shown in Figures 6 and 7. The heat input on family 'C' samples were, on average, greater than on 'B' and 'D' family samples.
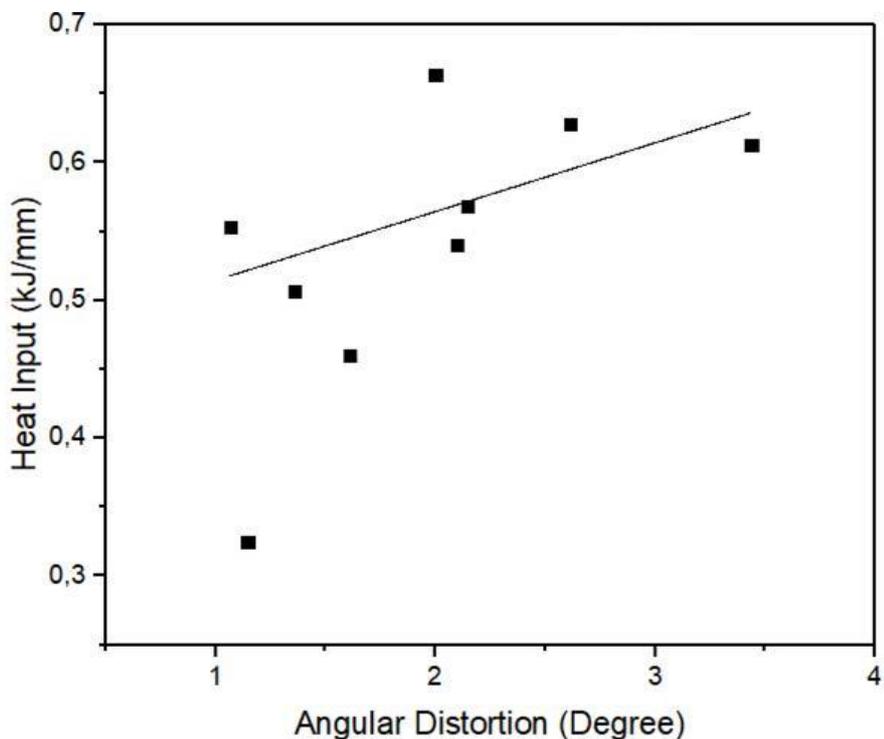

Figure 8. Relation Between Heat Input and Angular Distortion.

Figure 8 shows the correlation between the analysed parameters. The trendline confirms the information shown in Figures 5 and 6, as the angular distortion arises by increasing the heat input.

4. CONCLUSION

As shown in the experiment, the heat input affects the angular distortion in a negative manner, as it increases distortion if not controlled. As can be inferred from the data gathered, small variations of electric current and consequently of heat input produce an insignificant variation of angular distortion.

In adittion, a larger sampling would possibly allow a better mapping of the angular distortional behavior which was unpredictable as we can see in the sample "B1".

The next goal of this research will be to analyse the thermal gradient along the samples which were measured by thermalcouples type k, as shown in Figure 1 and relate it to the distortional behavior.

5. ACKNOWLEDGEMENTS

6. REFERENCES

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