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Influence of Heat Input On Mechanical Properties of Tungsten Inert Gas Welded Joint

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ABSTRACT: Welding is key sector in the manufacturing industry, and plays a critical role in making possible joints of different materials is achievable. Nevertheless, certain attributes of the welding process must be addressed, to ensure joints durable and reliable are produced. Hence, the objective of this paper is to evaluate the influence of heat input on the mechanical properties of a Tungsten Inert Gas (TIG) welded joint. Data obtained reveals that the most stable bead width is recorded at a low heat input. Therefore, maintaining and controlling the heat input is capable of guaranteeing the value of the bead width. Also the relatiobship between critical weld properties, which is the bead width and the tensile strength, as obtained from variation arising from the heat input, shows that the most maximum bead width is recorded at a very high tensile strength. An indication that the heat input has a corresponding effect on the bead width and tensile strength of the weld.

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Over the years, welding has been very essential to industries such as automotive industry, construction industry, aviation industry, etc. and their application in vehicles, bridges, offshore structures, aircraft, etc. but the service life of a welded joint is usually affected by some defects resulting from the welding process (Sada *et al.,* 2021). The quality of welds obtained from joining two or more similar or dissimilar materials together is mainly influenced by welding input parameters which, therefore, makes welding a multi-input, multi-output process (Sada 2018). These parameters; arc voltage and weld current, if not not properly controlled or regulated many times results in increase heat input, which in turn is capable of producing flat, wider, less penetrable weld beads, and as a result, poor mechanical and metallurgical properties of the weld metal.

According to Kamble and Rao (2013), heat distribution around the weldment usually alters the chemical and mechanical properties which depends upon the chemical composition of the bead and its geometry. HAZ of a welded joint can subject the parent material to heating at elevated temperature up to solidus (highest temperature at which a metal at solid state begins to transform into liquid), thereby causing varying degree of alterations on the microstructure as a result of the heating and cooling effect (Jain, 2001). Singh *et al.*, (2017) reports that the microstructures and mechanical properties obtained from welding steel materials depends on certain properties such as percentage of carbon and other elements such as sulfur, phosphorus etc. For example, low carbon steel materials with less than 0.25% carbon exhibits good welding characteristics

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with minor defects (Boumerzoug *et al.*, 2010). The temperature distribution around a metallic arc butt weld the leading edge of the temperature pattern is compressed, because the arc is continually moving cold metal and the trailing edge becomes extended because the arc leaves preheated metal in its wake (Yaghi and Becker, 2004). Due to the non-uniform temperature distribution during the thermal cycle, incompatible strains may result in temperature induced stresses (Sada and Achebo, 2022). These non-uniform heat distribution present in the welded parts can cause intensed thermal stress gradients around the weldment due to localised heating and subsequent cooling, thereby causing weld cracking or distortion, reduced service life and diminution of functionality in service condition (Fan *et al.*, 2013).

Therefore, it is essential to understand adequately the temperature trends, particularly in high integrity steel structures, where their interaction with heat source during welding sequence can cause phase transformations as well as microstructural changes that can lessen the structural integrity of steel components (Dai *et al.*, 2008). Hence, the objective of this paper is to evaluate the influence of heat input on the mechanical properties of a Tungsten Inert Gas (TIG) welded joint.

MATERIALS AND METHOD

The study adopted the follow approach; heat source analysis, development of the experimental matrix, identification of the process parameters. experimental runs and determination of the output parameters. To perform the experiment, a 10mm thick mild steel plate cut to a dimension of 120x30 mm (length x width) was produced, and chamfered 30 degrees at the edges to be welded. With the GTAW welding process as shown in Fig. 1, adopted for the experiment, the welding was carried out with the plates properly clamped to avoid misalignment during welding process.

Fig. 1: Tungsten Inert Gas Welding Machine Employed for the Experiment

Table 1: Welding Input Variables

Exp. No	Weld Current (Amp)	Arc Voltage (V)	Gas Flow Rate (lt/min)
1	180	15	15
2	150	18	15
3	120	20	15
4	90	24	15
5	180	15	15
6	150	18	18
7	120	20	18
8	90	24	18
9	180	15	18
10	150	18	18
11	120	20	20
12	90	24	20
13	180	15	20
14	150	18	20
15	120	20	20
16	90	24	24
17	180	15	24
18	150	18	24
19	120	20	24
20	90	24	24

Prior to joining, the following variable were selected as process parameters; voltages 15-24V, weld current 90-180A, gas flow rates 15-24 L/min. With Design Expert 7.01, 16 experimental runs, based on the taguchi orthoagonal array as presented in Table 1 was generated.

Heat Input: In arc welding, the source of energy come from electricity that converted to heat energy, which comprises of current, voltage and speed of welding. The speed also affect the welding energy because the heating process doesn't move with a certain speed. The relationship between these three parameters produces an energy often defined as heat input expresses as shown equation (1)

$$Heat\ Input = f_i \frac{60EI}{v} \qquad (1)$$

where: HI = Heat Input (joule/mm), f_i = Weld Heat Efficiency (GTAW 0.9 – 1.0), E = Arc Voltage (volt), I = Welding Current (ampere), v = Welding speed (mm/min)

RESULTS AND DISCUSSION

The result obtained from the experiment conducted, is recorded and tabulated as shown in Table 2. The table 2, shows results for each of the (20) sixteen experimental run for the responses; heat input, tensile strength and bead width of the welded plate. Figure 2, presents a pictorial view of the welded metal plate**.** Fig. 3, and 4 presents the plot of the bead width and heat input, the plot of the tensile strength and heat input, and the plot of the bead width and tensile strength respectively.

Table 2: Experimental Result for the Mild steel welded plate

Exp. No	Weld Current Amp	Arc Voltage V	Gas Flow Rate lt/min	Heat Input (kJ/mm)	Tensile Strength N/mm²	Bead Width (mm)
1	180	15	15	1458	389.86	6.15
2	150	18	15	1458	334.56	6.55
3	120	20	15	1296	343.76	5.8
4	90	24	15	1166.4	147.98	5.81
5	180	15	15	1458	317.02	6.05
6	150	18	18	1458	316.33	6.13
7	120	20	18	1296	314.37	6.13
8	90	24	18	1166.4	204.54	6.15
9	180	15	18	1458	337.45	6.42
10	150	18	18	1458	350.21	6.1
11	120	20	20	1296	340.77	6.02
12	90	24	20	1166.4	346.95	6.05
13	180	15	20	1458	340.27	6.51
14	150	18	20	1458	207.99	5.9
15	120	20	20	1296	302.36	5.83
16	90	24	24	1166.4	263.31	6.51
17	180	15	24	1458	357.16	6.16
18	150	18	24	1458	325.88	6.15
19	120	20	24	1296	229.27	6.2
20	90	24	24	1166.4	327.19	6.19

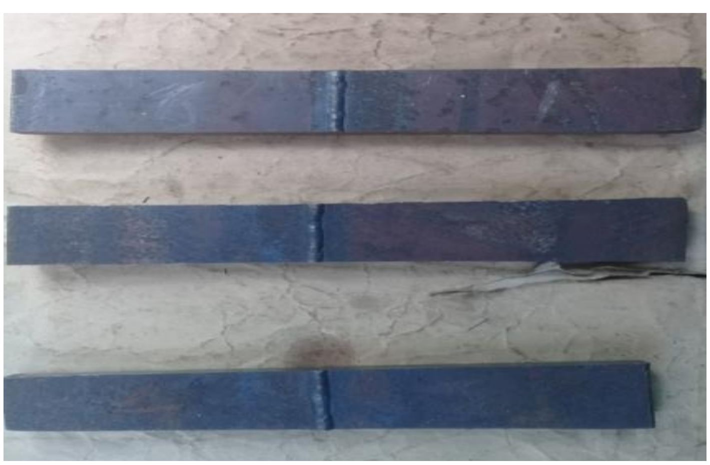

Fig. 2: Pictorial View of the Welded Metal Plate

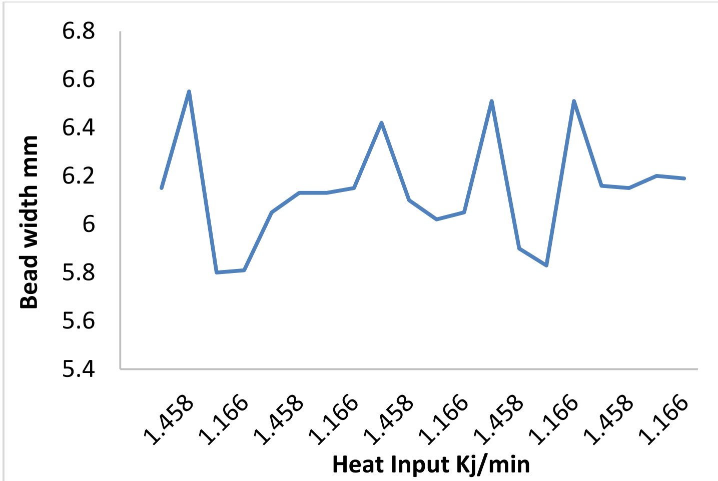

Fig. 3: Plot of the bead width and heat input

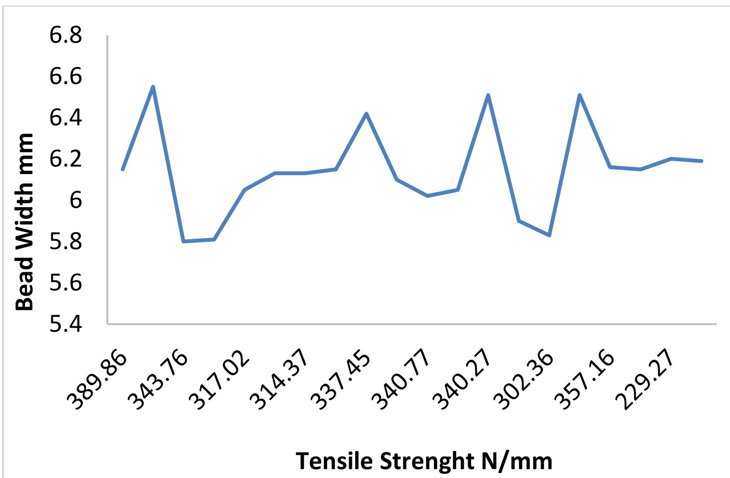

Fig. 4: Plot of the tensile strength and bead width

Results presented in Figure 3 show that the bead width which is a critical factor in expressing the quality of the weld, is greatly affected by the variation arising from the heat input. From the plot, it can be observed that, the most stable bead width is recorded at a low heat input. Therefore, maintaining and controlling the heat input is capable of guaranteeing the value of the bead width. From Figure 4, shows the relatiobship between critical weld properties, which is the bead width and the tensile strength, as obtained from variation arising from the heat input. From the plot, it can be observed that, the most maximum bead width is recorded at a very high tensile strength. An indication that the heat input has a corresponding effect on the bead width and tensile strength of the weld.

Conclusion: The study on the influence of heat input on the weld parameters of a Gas tungsten arc welded joint was successfully investigated. The findings obtained shows that, the bead width which is a critical factor in expressing the quality of the weld, is greatly affected by the variation arising from the heat input. From the plot, it can be observed that, the most stable bead width is recorded at a low heat input. Therefore, maintaining and controlling the heat input is capable of guaranteeing the value of the bead width. Also the relatiobship between critical weld properties, which is the bead width and the tensile strength, as obtained from variation arising from the heat input, shows that the most maximum bead width is recorded at a very high tensile strength. An indication that the heat input has a corresponding effect on the bead width and tensile strength of the weld.

Declaration of conflict of interest: The authors declare no conflict of interest.

Data availability statement: Data are available from the corresponding author on request

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