Affect of Vibratory Welding Process to Improve the Mechanical Properties of Butt Welded Joints

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***Abstract**: For improving mechanical properties of steels, vibration techniques have been used in the last few decades. During the welding of metals along with mechanical vibrations, uniform and finer grain structures can be produced. This increases the toughness and hardness of the metals, because of solidification effects at the weld pool surface. As the weld pool solidifies, grains are not only limited in size, but dendrites growing perpendicular to the fusion line are restricted. While the process is going on, dendrites can be broken up before they grow to become large in size. Hence, the microstructure of the weld metal is improved during the solidification process. In this work, we employed a dynamic solidification technology, by applying mechanical vibrations during the 'Arc welding' process. Analyses have been carried out for mild steel pieces having 5 mm. of thick butt joints. The results obtained from the current study pointed out that the butt welded joints fabricated with vibratory condition are found to possess relatively high hardness, without any considerable loss in its ductility.*

***Keywords:**Arcwelding,Vibratorywelding process, Hardness, Grain size.*

I. Introduction

In manual metal arc welding (MMA) process, an arc is drawn between a coated consumable electrode and the work piece. The metallic core-wire is melted by the arc and is conveyed to the weld pool as molten drops. The electrode coating is also melting to form a gas shield around the arc and the weld pool. Slag is formed on the surface of the weld pool, and the slag must be removed after each layer. Manual Metal Arc welding is still a widely used hard facing process. Due to the low cost of the equipment, the low operating costs of the process and the ease of transporting the equipment, this flexible process is ideally suited to repair work benefits of MMA Welding are: Flexible, Low Cost, and ease of Repairs.

Butt welding is used to connect parts which are nearly parallel and don't overlaps. It can be used to run a processing machine continuously, as opposed to having to restart such machine with a new supply of metals. Butt-welding is an economical and consistent way of joining process without using supplementary components. Usually, a butt-welding joint is made by slowly heating up the two weld ends with a weld plate and then combine them under specific pressure. This process suitable for prefabrication and manufacturing special fittings afterward, the material is usually ground down to a smooth finish and either sent on its way to the processing machine, or sold as a completed product.

Hardness is the Resistance of a material to deformation, indentation, or penetration by means such as abrasion, drilling, impact, scratching and/or wears. The relative toughness of the mild steel or base metal is affected by many variables including: the chemical analysis, micro structural constituents, and strength or hardness level and grain size [12].

Heat treatable steels [1] have improved strength along with good properties of toughness and fatigue strength. In situations when tensile strength and the yield strength of structural steels don't satisfy the design requirements, there is a need for heat treatable steels with higher carbon content. The improved strength allows the production of lighter structures, i.e. the usage of thin sheets. The problems that usually occur in welding of steels with higher carbon content are the following: weld cracking, weld metal porosity, high hardening of the weld metal, and cracking of the base material in HAZ [9]. The application of laser welding in industry is constantly increasing. The most important advantages of laser welding over other procedures include [5-9]: high welding speed, small or no deformations of the welded parts, and high quality of the welded joint. Laser welding of steels with higher carbon content, such as heat-treatable steels has not yet been applied in high-volume production [9].

Arc welding [2] differs regarding the power density and the volume of heat input into the material. High power density in laser welding allows welding with lower specific heat input than in other welding, which results in very high cooling rates [4]. The cooling rates in arc welding are faster than other welding, so that a lower value of maximum hardness in the welded joint is expected [10-12]. In vibratory welding, stirrer produce a disturbance in weld pool during solidification. After completion of nucleation, the solidification process will continue with nucleus growth. Increasing the growth rate will reduce the grain size of metal. In welding, as the heat source interacts with the material, the severity of thermal excursions experienced by the material varies from region to region, resulting in three distinct regions in the weldment [12].

The aim of this work is to obtain a modification of the microstructure by mechanical vibrations during the welding process. Because of microstructure changes, there is an improvement in the material's hardness and mechanical properties. This study was extended to investigate the effect of vibratory set up on the mechanical properties of 5 mm thick stainless steel (AISI202) butt joints. Low and high heat input combinations were used to study the effect of mechanical vibrations on small sized and large sized fusion zone respectively.

This paper is organised into five chapters. Chapter 2 describes the developed experimental setup and how the experiments have been performed for the considered metals; chapter 3 discusses the results obtained from the experimental analysis; chapter 4 illustrates the metallurgical effects of the various specimens and chapter 5 concludes the paper.

II. Experimental Work

The MMA welding process is an arc welding process which produces coalescence of metal by heating them with an arc between a covered metal electrode and the work. Shielding is obtained from decomposition of the electrode covering. Pressure is not used during the operation and the filler metal is obtained from the electrode. The MMA welding process can be used for welding most structural and mild steels. These include low-carbon or alloy steels; low-alloy, heat treatable steels; and high-alloy steels such as stainless steels. This welding process can be used in all positions flat, vertical, horizontal and requires only the simplest equipment. Thus, MMA welding lends itself very well to field work.

Material Used

Mild Steel, It is composed of (in weight percentage) 0.9% Carbon (C), 7.5-10.0% manganese (Mn), 1.00% Silicon (Si), 17.0-19.0% Chromium (Cr), 4.0-6.0% Nickel (Ni), 0.06% Phosphorus (P), 0.03% Sulphur (S), and the base metal Iron (Fe). Fig.1. shows a typical specimen used in the current study.

Fig 1 Specimen piece

Equipment Used

Fig 2 shows the experimental setup of the vibrator machine, its properties and welding process used for laying down the vibratory welding bead.

Fig.2 Experimental setup

2.3 Vibratory Setup for Welding

With an aim of improving the mechanical properties of weld joints through inducing of favourable changes in the weld microstructures, an auxiliary vibratory set up capable of inducing mechanical vibrations into the weld pool during manual metal arc welding is designed and developed. Different frequencies and with different amplitude are applied along the weld length, just trailing behind the welding arc so that weld pool could be mechanically stirred in order to induce favourable micro structural effects. This setup produces the required frequency with the amplitude in terms of voltages.

2.4 Butt welding by MMA welding Process

In the current investigation, 5 mm thick mild steel butt joints are used. Low and high heat input combinations are used to study the effect of mechanical vibrations. Figs.3 and 4 depict the joining of two mild steel strips during and after the welding process.

Fig.3 During welding

Fig.4 After welding

Butt Welded Joint (constant acceleration and at different voltages)

The prepared butt welded joints are under the low heat input (90-110 Amp).There are 2 number of passes to fill the gap, in which 1 main passes and 1is root pass. During the root pass there is no role of vibratory setup. After the root pass, vibratory setup come into action and moved just behind the arc and make a disturbance during the solidification of weld bead. Table 1 and Table 2 illustrate the parameters variation with respect to acceleration & amplitude during the process.

Table 1 Parameters variation with respect to acceleration during the analysis

	70 Volts	150 Volts	230 Volts
Acceleration (m/s^2)	18.3	49.1	32.6
	16.4	49.7	31.1
	19.9	48.7	30.4
	17.7	45.3	28.4
	18.6	51.9	28.3
	19.3	50.8	29.7
RMS value	18.4	49.29	30.33
Grms value	1.875g	5.02g	3.09g

Table 2 Parameters variation with respect to amplitude during the analysis

	70 Volts	150 Volts	230 Volts
Amplitude (in mm)	0.350	0.238	0.274
	0.348	0.233	0.269
	0.347	0.230	0.266
	0.349	0.235	0.270
	0.352	0.242	0.275
	0.351	0.240	0.273
RMS Value	0.350	0.236	0.273

III. Results And Discussion

For the fabricated specimens, tests have been conducted to measure the hardness of the weld bead along and perpendicular to its bead surface. From the initially considered points, acceleration being kept constant by varying the voltage, found the RMS value in terms of GRMS. The same process is repeated for several times, by amplitude keeping constant and varying in voltage. The hardness values are observed without vibration values are smaller than the with vibration hardness values. Here 7 samples are taken to found the hardness values at different locations along the weld bead and perpendicular to the weld bead surface.

Hardness Measurement

Micro-hardness measurement can be done by Lecco Vickers Hardness (LV 700) tester. In which, a diamond indenter in the form of a right pyramid with a square base and an angle 136^0 between opposite faces, is forced into the material under a load F. The two diagonals X and Y of the indentation left on the surface of the material after removal of the load are measured and their arithmetic mean L is calculated.

$$H_v = \frac{0.1889F}{L^2} \quad \text{and} \quad L = \frac{X+Y}{2} \qquad (1)$$

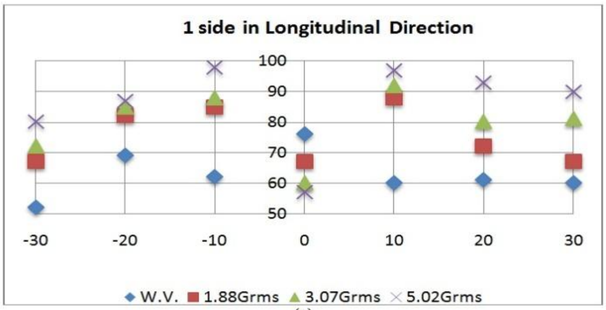
Where F is the applied load (N), L is the diagonal of square impression (mm), X is the horizontal length (mm) and Y is the vertical length (mm).

Table .3 Hardness values in longitudinal direction

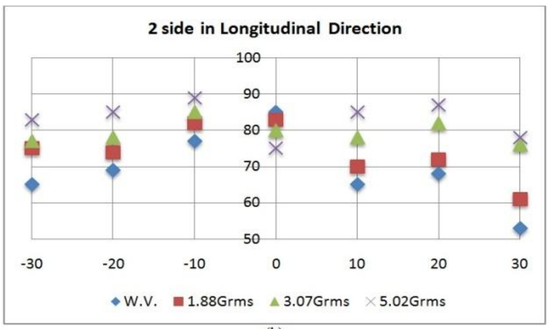
W.V	First side	52	69	62	76	60	61	60
	Second side	65	69	77	85	65	68	53
1.88 Grms	First side	67	82	85	67	88	72	67
	Second side	75	74	82	83	70	72	61
3.07 Grms	First side	72	85	88	60	92	80	81
	Second side	77	78	85	80	78	82	76
5.02 Grms	First side	80	87	98	57	97	93	90
	Second side	83	85	89	75	85	87	78

Table .4 Hardness values Along Weld bead direction

W.V.	1 side	85	88	89	82	76	84	92	79	90
	2 side	90	93	91	90	85	94	89	95	92
1.88 Grms	1 side	75	77	73	69	67	73	81	67	81
	2 side	83	85	84	86	83	90	80	91	86
3.07 Grms	1 side	70	700	65	64	60	66	71	62	74
	2 side	78	78	76	81	80	83	73	87	82
5.02 Grms	1 side	62	57	56	55	57	61	58	46	64
	2 side	72	71	71	69	75	78	68	82	76



(a)



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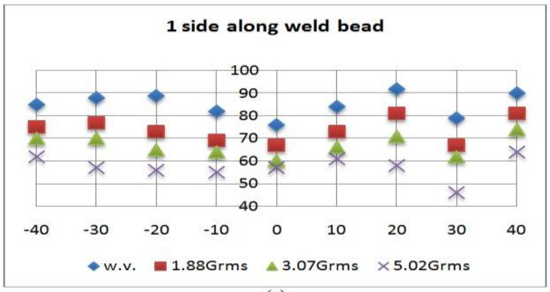

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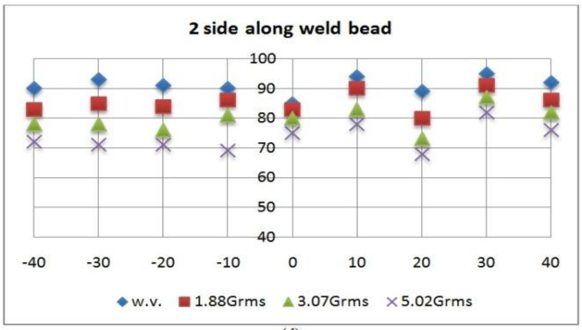

(d)

Fig. 5 variation of hardness values with and without vibration

IV. Metallurgical Study Of Specimens

Metallographic study shows that during conventional butt welding the uniform long dendrites which show that a uniform solidification process took place with uniform dentrites shown in the fig.7 and fig 8 with acceleration and amplitude kept constant during welding current respectively. Long dendrites show Corse structure of the weld joint. The microstructure shows the uniform solidification process. Under vibratory conditions with acceleration and amplitude kept constant, the microstructure of vibratory butt-weld joints, long dendrites get fragmented and break in to small dendrites and forms a new nucleation sites. Here dentritic fragmentation took place due to which fine structures form. This enhances the hardness and mechanical properties of weld joints.

Fig.6 Microstructure of manual metal arc welding without vibration (constant acceleration and amplitude)

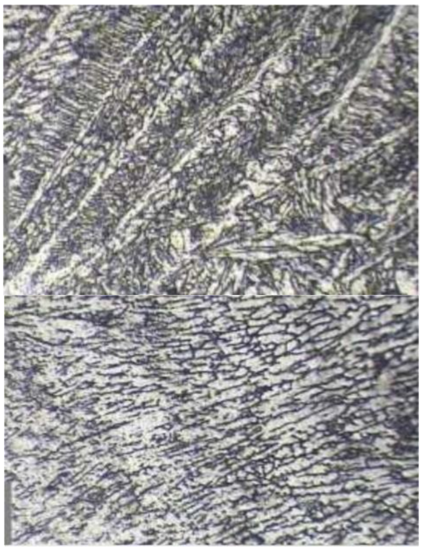

Fig.7 Microstructure of manual metal arc welding with vibratory (constant acceleration and amplitude)

V. Conclusions

In the present study, welding is performed along with the vibrations for improving the mechanical properties of the base material and the weld metal micro hardness was calculated under vibratory condition. Along the weld bead the hardness value decreases when compared from without vibration. Metallurgical study showed that small grain structure is attained due to the effect of vibration.

Increase in hardness leads to crack initiation along the weld bead, so it is not preferable. During manual butt weld joints uniform long dendrites which show that a uniform solidification process took place with uniform dentrites. Due to auxiliary mechanical vibrations long dentrites break and forms a new nucleation sites. Finally, paper concludes that the Hardness of the parent metal increases under MMA welding with vibration.

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