Effect of Auxiliary Vibrations on Microhardness Properties of MIG Welded MS Plate Joints

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Abstract

The aim of this present study is to investigate the influence of inducing auxiliary vibrations into the weld pool during butt welding of 6 mm thick Mild Steel plates using MIG welding process. An auxiliary vibratory set up was developed which comprised of a metallic tip of tungsten that could be mechanically vibrated by a primary vibratory source which resulted into vibrations of around 150 Hz. While welding was carried out, the motion of the vibratory tip was immersed in the weld pool and synchronized in such a way that it trailed the welding arc by around 4-6 mm. The mechanical strength of these joints was evaluated by conducting through micro hardness test. Test result shown that by applying vibratory treatment Hardness value increased without any loss of ductility.

Keywords: **Auxiliary vibrations, Vibratory set up, Mechanical Vibrations, Microhardness, MIG welding process.**

Introduction

Properties of weld metals are greatly influenced by type of microstructure and grain size. Fine grained materials normally have higher strength and are more ductile than similar coarse grained materials. It is often intended to achieve fine grain structure in the weld bead because such structure leads to reduced susceptibility of the weld metal to solidification cracking during welding and fine grain helps to improve mechanical properties like ductility and toughness of weld metal. There are various mechanisms to produce the fine structures some of them are inoculation, arc oscillation, arc pulsation and also the generation of vibrating the welding torch, or vibrating the work piece, etc.[1,2] In vibratory welding, an external vibratory setup vibrates in the whole welding process and it mainly affects the welding solidification which improves the quality of microstructure. Since the cooling rate in case of welding is very fast this sometimes may be cause of residual stresses. Vibratory welding helps to reduce the effect residual stress in welding. Chih- Chuh Hsieh vibrates the work piece at high frequency range and investigates that at 375 Hz of frequency the residual stress get affected. He also mentioned that the hardness value and Young's Modulus increased using the vibrating welding.[3] The microscopic structure has dramatically changed after V-Welding. A. Mostafapour describes that the finest sizes of dendrites are obtained through the application of vibrations with the frequency of 350 Hz and amplitude of 7 μm, and at the welding speed of 8 cm/min.[2] The experimentation of Davis and Garland shows that vibrating torch of TIG welding operation reduces the solidification cracks during welding of Al-2.5% Mg alloy.[4] Ch. Vives et al studied the influence of electromagnetic vibrations (50 Hz) imposed during solidification on grain refinement in the 1085 and 2214 Al alloys. He observed extensive grain refinement in both the alloys due to imposed vibrations.[5] Since fine structure are formed after vibratory welding so mostly the effect of warm cracks during also reduces. Balasubramanian K. found that after the application of the vibration during welding of aluminum alloy there is large reduction of the warm cracks.[6] Many researchers have analyzed the effect of vibrations on microstructure and mechanical properties of welded joints and have reached a generic conclusion that vibrations are able to alter/ enhance the microstructure thus improving the mechanical properties of welds and cast elements due to the fundamental reason that mechanical properties of welds are influenced by the microstructure and grain size of welds. Sobolev studied the effect of liquid metal solidification during welding process in the ultrasonic field and analyzed that critical undercooling provoked volumetric nucleation and critical pressure which was near the cavitation bubbles caused breakage of the formed crystals.[8] Lu Qinghua et al. states that Vibration facilitates the release of dissolved gases and the resulting weld beads greatly exhibit reduced porosity.[9]

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Another beneficial effect is to facilitate drifting inclusions to the slag with the imposed vibration from the molten welding pool. Moreover, the mechanical energies provided by external vibration increase the boundary plastic deformation and dislocation density. Then the dislocations with high density will tangle and pile up to combine to make small- angle sub-boundaries .The welding maximum and minimum residual stresses have been achieved reduced through the application of vibratory welding and the vibration applied during welding has less influence on the axial residual stress than the radial one due to no constraint in axial direction. Jijin Xu, Ligong Chen and Chunzhen N found VWC can reduce the residual hoop stresses at the outer surface and the maximum residual stresses; but VWC has only a slight effect on the residual axial stresses at the outer surface.[10] The residual stresses are lower than the yield strength when using VWC, which improves the safety of welded structures VWC makes the residual stresses decrease and their peak values are lower than the yield strength. Therefore, VWC can decrease the susceptibility of a weld to fatigue damage, stress corrosion cracking and fracture, and improve the safety of welded structures. S. Spooner et al. analyzed 300- type stainless steel plates and found that the residual stresses within the HAZ and base metal in the conventionally welded plate and in the vibratory- treated plate exhibit small differences which are comparable to the estimate of experimental error.[11] From literature review it is found that no work has been reported on the use of inducing auxiliary mechanical vibrations into the weld pool for achieving better mechanical properties which probably could be due to the reason that in arc welding process the size of weld pool is small and hence solidification rate is too high. So on the basis of research gap, following objectives have been decided:

1) Design and development of a setup for inducing auxiliary mechanical vibrations into the weld pool during welding.

2) To study the effect of auxiliary mechanical vibrations on the mechanical properties of bead on plate and butt welded joints using MIG Welding.

This experimentation is a comparative study of two welded Mild steel Plates, one is welded by Metal Inert Gas welding operations under the conventional condition where as other was welded under the vibratory conditions under the same welding parameters.

Experimental Method

Design of Auxiliary Vibratory Setup

The main work of the vibratory setup is to produce vibrations into the weld pool only during the welding operation. Since the cooling rate of the weld pool is very fast so we have designed such an arrangement so that the vibratory setup can shake the liquid form of weld pool before its solidification. The vibratory setup works on the principle of rotation of unbalanced motor, it has a small motor with an offset weight on its drive shaft. When the device is switched on it results into a rotational movement of the object weight that causes resonance. When the motor spins, this weight causes vibrations due to its offset position. The rotation of mass around the shaft is the cause of vibration. This external mass produce a Sine Wave or we can say $A\mathrm{Sin}\omega t$ is the excitation input whereas speed and frequency of motor is directly proportional to the DC voltage. Vibratory setup works over the range of voltage. At constant voltage a constant value of frequency and amplitude forms and with increase its values increase or decrease. These vibrations are then transmitted to the tungsten rod and are continuously maintained while the setup is used during welding. Figure 1 is showing the schematic modal of a vibratory setup. The weld pool has very high temperature when it is in a liquid form so Thoriated rod having very high melting point was dipped into the molten metal during welding and helps to transmit the vibrations into the weld pool from vibratory setup. To prevent the vibratory setup from high heat during welding operation, ceramic pipes and piece of glasses were used. A 9 volts rechargeable battery was used to supply power to the vibratory setup. With an accelerometer, data acquisition and signal analysis the vibration frequency of this vibratory setup was determined. This setup produced a peak mechanical pulse of frequency 150 Hz approximately. Compared with the other method vibratory welding has good quality of less investment, more convenient operation, and pollution less, shorter manufacturing period. Few trail runs were conducted for getting familiarized with the setup and also check its efficacy and synchronization with the welding torch, so as to find out whether a stirring action was being inducted into the weld pool or not.

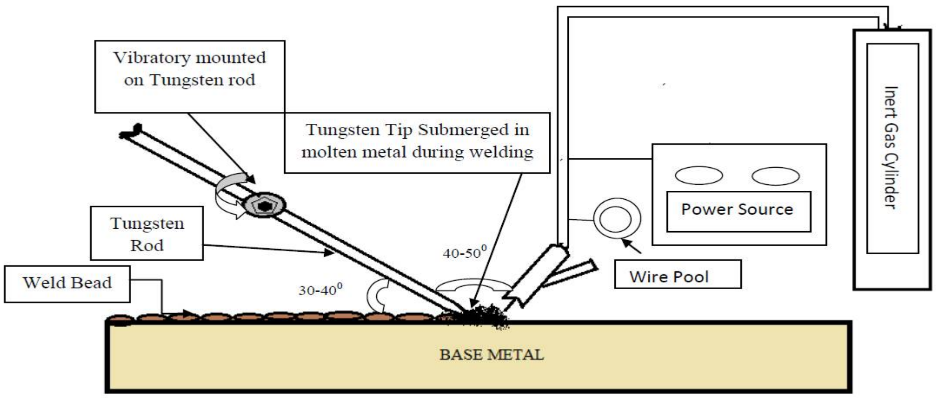

Figure 1.Schematic illustration showing the use of auxiliary vibratory set up used during MIG welding

Since the vibratory tip of the set up was to be immersed in the molten weld pool during welding, the material that would suit this application need had to be of a high melting temperature. So in view of this the material selected for this purpose was thoriated tungsten (table 1).

Material	Thoria	Tip color	Melting temp.	Diameter
Tungsten + 2% Thorium	1.7-2.2	Red	3410° C	2 mm

Table 1.Specification of Tungsten Rod

Joint Design

Mild steel plate was used as a base plate. The welding parameters are same for both of the welding conditions which are mentioned in table 2. Single V joint design with a 2 mm root face and 2.5 mm root gap with a groove angle of 60° was used whose schematic is shown in fig.2. The base plates were tack welded to maintain a constant root gap of 2 mm and also to avoid any misalignment during welding operation, the photo of which is shown in fig. 3.

Microhardness Studies

For microhardness testing the specimens were prepared using standard procedures like belt grinding, polishing using successively fine grades of emery upto 1500 grit size. This helped in removing coarse and fine oxide layers as well as scratches on the surfaces that were to be metallographically analyzed. Microhardness tester (Make: Omnitech, Capacity: 1000grams) was used to measure microhardness at various zones of interest in different weldments. A load of 500 grams and a dwell time of 20 secs were used for these studies. A flow chart of experimentation is given in fig. 4.

Base Metal	Current	Voltage	Diameter of Filler metal	Frequency
Mild Steel	110Amp	20	1.2 (mm)	150 Hz

Table 2.Welding Parameters Used During Welding Operations

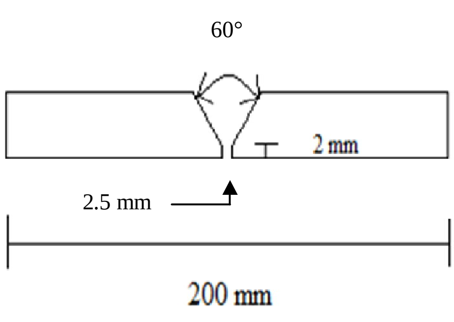

Figure 2.Joint Design

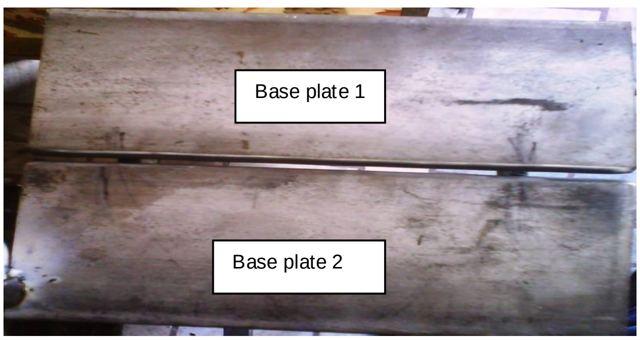

Figure 3.Base metal Positioning

Result and Discussion

Microhardness Studies

The results of microhardness testing as carried out on different welded specimens. Microhardness across different zones of the weldments was measured in the longitudinal as well as transverse direction the same are shown graphically in figures 4 and 5. It was observed that microhardness of the weld metal/ zone was found to increase in almost all the cases where vibratory conditions were applied. When auxiliary mechanical vibrations are induced into the weld pool during welding, a ripple like disturbance is created which tends to pose a hindrance to the solidifying dendrites, which as a consequence are not able to reach their original dendritic lengths as they are able to do in the conventional condition i.e. when vibratory setup is not used. However from these plots it is also observed that in certain directions microhardness did not very much, the reason for which is that these areas were not stirred/ influenced by the vibratory disturbance as the vibratory set up was inclined towards the welding direction.

Solidification Behavior in Vibratory Welding

Solidification follows mainly two stage first is nucleation and second is growth. In welding operation epitaxial growth occurs from liquid to solid. There is a mushy zone form at the solid liquid interface which helps for nucleation mechanism. For nucleation process the supercooling temperature is necessary. During welding the grains propagate in perpendicular direction of heat flow. After applying vibrations more dendritic fragmentation took place and more new nucleation sites forms. These large number of nucleus forms large number of grains and resulting formation of fine structures. Weld pool convection causes fragmentation of dendrite tips in the mushy zone and then carried into the bulk weld pool, acting as nuclei for new grains. These dendrite fragments are carried into the bulk weld pool and act as nuclei for new grains to form if they survive the weld pool temperature. Alloys with a fine-grain- structure, associated with superior mechanical properties, are the ultimate goal of a solidification process. It is generally accepted that the grain refinement is caused by dendrite fragmentation.[7]Principle of solidification states that high cooling rate forms fine grain structure, during vibratory welding there is some disturbance produced by external applied vibrations which causes cooling to be faster than that in the conventional welding process. The vibratory setup shakes the molten pool causing faster cooling rate resulting in the formation of finer sub grains structure.[9] In brief, the solidification behavior drastically changes by using vibrations during welding operations. It has following causes:

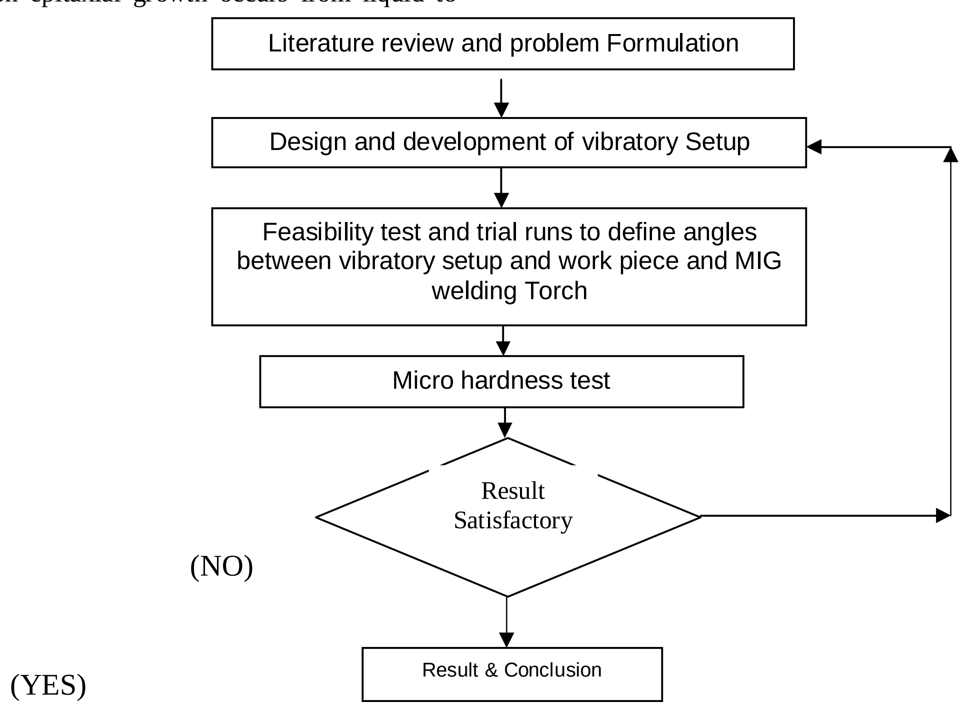

Figure 4.Flow chart showing the sequence of Investigations

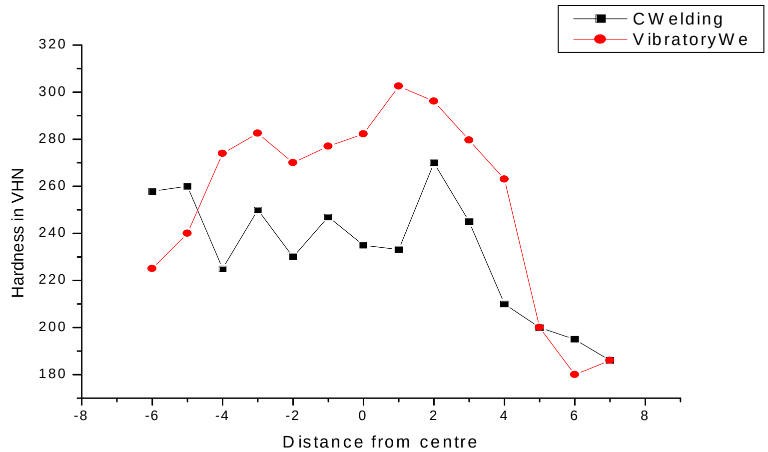

Figure 5.Measurement of hardness in Longitudinal Direction

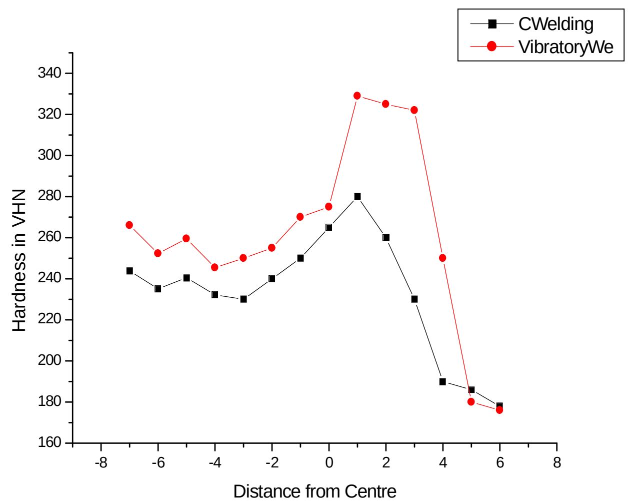

Figure 6.Measurement of hardness in Transverse Direction

Conclusion

1. The vibratory setup used in present work indicates that it is possible to alter/ enhance mechanical properties of the welds.

2. The efficacy of the vibratory setup developed and used in the present work was found to be satisfactory in terms of giving better weld properties.

3. The auxiliary vibrations induced into the weld pool resulted in increased micro hardness of the weld metal.

4. Solidification behavior in weld bead drastically changes after application of vibrations.

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