

# Advantages of Vibration in the GMAW Process for Improving the Quality and Mechanical Properties

C. A. C. Castro, D. C. Urashima, E. P. Silva, P. M. L. Silva

**Abstract**—Since 1920, the industry has almost completely changed the rivets production techniques for the manufacture of permanent welding joint production of structures and manufacture of other products. The welding arc is the process more widely used in industries. This is accomplished by the heat of an electric arc which melts the base metal while the molten metal droplets are transferred through the arc to the welding pool, protected from the atmosphere by a gas curtain. The GMAW (Gas metal arc welding) process is influenced by variables such as: current, polarity, welding speed, electrode: extension, position, moving direction; type of joint, welder's ability, among others. It is remarkable that the knowledge and control of these variables are essential for obtaining satisfactory quality welds, knowing that are interconnected so that changes in one of them requiring changes in one or more of the other to produce the desired results. The optimum values are affected by the type of base metal, the electrode composition, the welding position and the quality requirements. Thus, this paper proposes a new methodology, adding the variable vibration through a mechanism developed for GMAW welding, in order to improve the mechanical and metallurgical properties which does not affect the ability of the welder and enables repeatability of the welds made. For confirmation metallographic analysis and mechanical tests were made.

**Keywords**—HAZ, GMAW, vibration, welding.

## I. INTRODUCTION

IN the current industrial scenario is a clear need for the development and implementation of new technologies to improve productivity with cost savings and the ability to found market demand while minimizing the problems [1]. The GMAW welding process is widely used in industry due to its versatility and easy automation can be applied to a variety of steels such as low carbon, stainless and other ferrous alloys [2].

The increased participation of welding process with solid wires around the world has taken place at the expense of the decrease of the coated electrode process. This is happening because in the welding process the arc with the gas protection has shown a continuous development due to the quality, cost and flexibility of this process is one of the most appropriate for mechanization [3].

The GMAW (Gas metal arc welding) process is influenced by variables such as: current, polarity, welding speed, and electrode: extension, position, moving direction; type of joint, welder's ability, among others [4].

The knowledge and control of variables in the electric arc welding process are essential to obtain satisfactory quality welds [5]. These variables aren't completely independent and require changes to others variables to produce the desired results. Considerable skill and experience may be required for selection of parameters for each application. The optimum values are affected by the type of base metal, the electrode composition, the welding position and the quality requirements.

However, there are differences in terms of microstructure and mechanical properties when welding manually or mechanically. This work has the intention to explore, analyze and justify in welds made using a vibrating system promoting a positive influence on the weld bead putting forward a better interaction between weld metal, Fig. 1, base metal and HAZ.

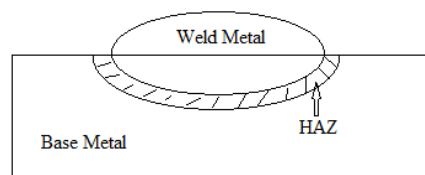


Fig. 1 Solder regions to be analyzed [6]

A few years ago, vibration was used for improving the quality of metal which solidified from the melt, especially to improve the microstructures, mechanical properties and relieve the residual stress. Over the past years, the use of vibration for stress relief or to enhance the properties of solidifying metal has become wide-spread throughout industry, despite the lack of scientific data regarding the phenomenon [7]. But when Gas Metal Arc Welding (GMAW) process under oscillatory condition is used then enhancement in mechanical properties noticed [8].

## II. MATERIALS AND METHODS

The assays were performed accordance with Fig. 2 (a) has the vibration system; Fig. 2 (b) welding machine used at work; Fig. 2 (c) fixing the support piece to be welded and Fig. 2 (d) a shifter car with variable speed.

A novel type of planar parts feeder consisting of a longitudinally vibrating flat plate and a part are placed on its surface.

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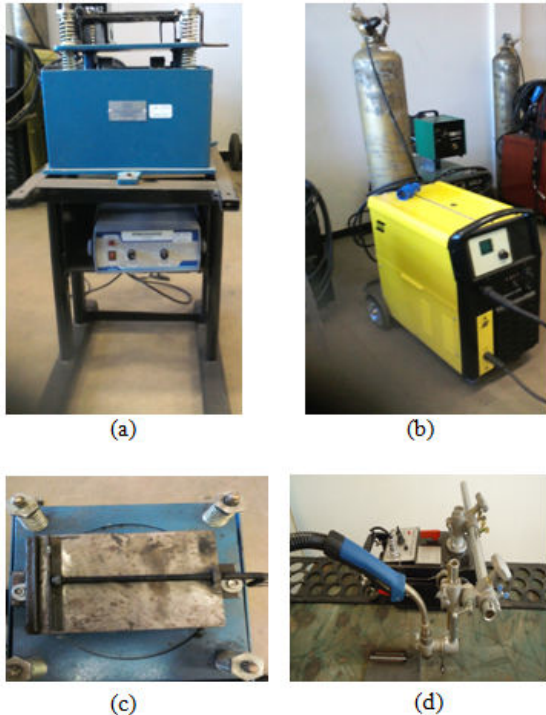


Fig. 2 Equipment set

The steel chemical composition is shown in Table I.

TABLE I CHEMICAL COMPOSITION OF STEEL ASTM A-36						
MAIN ALLOYING ADDITIONS STEEL (WT.%)						
ASTM A-36	C max.	Mn	P max.	S max.	Si max.	Cu
	0.26	--	0.04	0.05	0.40	0.20

#### A. Planning

The implementation of welding tests was performed at LABSIT (Laboratory of Welding, Simulation and Technologic Innovation) at CEFET – Varginha - MG. It was simple deposition, i.e., a bead on plate (BOP), and the number of specimens will follow a designed factorial with three levels each being replicated in experimental conditions.

After welding, the specimens will be prepared for metallurgical and geometric analysis obeying the technical criteria for this purpose. The used BOP welding was carried out as illustrated in Figs. 3 and 4; the geometrical properties of the beads were assessed as shown.

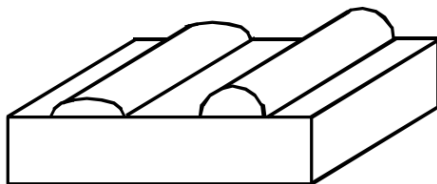


Fig. 3 Bead on plate [9]

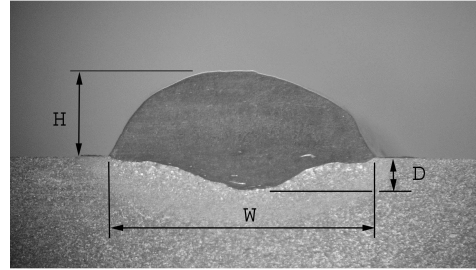


Fig. 4 Geometrical features on the bead: Width, Height and Depth

#### B. Parameters Variables

Welding speed (mm/min): The speed was varied in 3 levels. In the first 10 to 20% below the welding speed specified as a reference for preliminary tests, based on the recommendation of the manufacturer, according to Table II.

Voltage (V): The voltage was varied in 3 levels. In the first 10 to 20% below the welding voltage, as a reference set by preliminary tests and based on the recommendation of the manufacturer. The fact that the equipment used is constant voltage allowed us this variation, according to Table II.

Welding Current (A): Likewise the other parameters above, the values were used 10 to 20% below the reference determined by preliminary tests, based on the manufacturer's recommendations, according to Table II.

TABLE II VARIABLES USED			
Condition	Voltage (V)	Current (A)	Speed (mm/min.)
1	23.78	96.00	465.84
2	26.67	123.11	781.93
3	30.00	153.33	1180.00

#### C. Preparation of the Test Specimen for the Mechanical Tests

The micro hardness assessment was done through the Vickers method with a 0,5 N applied on the transversal surface of the specimen in several equally spaced points along it, from the metal base to the center of the weld, thus obtaining the hardness according to Fig. 5.

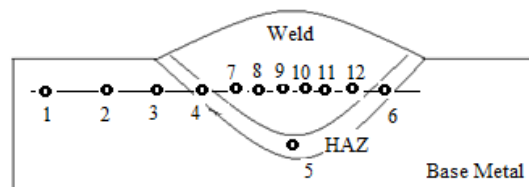


Fig. 5 Micro hardness test scheme

#### D. Preparation of the Test Specimen for the Mechanical Tests

The tensile test was accomplished in the specimen with transversal section, in which the longitudinal axis is perpendicular to the longitudinal axis of the weld. The specimens were taken from the GMAW process. One specimen was tested in each situation. Fig. 6 illustrates a specimen for the tensile test.

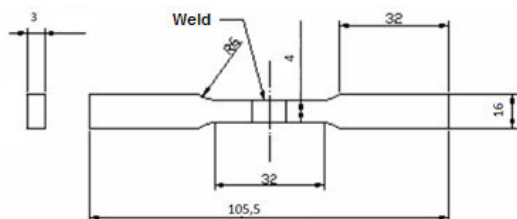


Fig. 6 Dimensions (mm) of the specimen with transversal section

### III. RESULTS AND DISCUSSION

After welding, all specimens were subjected to metallographic preparation steps for analysis. The analysis was performed on a stereoscopic Olympus SZ 61 linked with computer; making it possible to analyze Fig. 7. The images were obtained with 6,7x magnification.

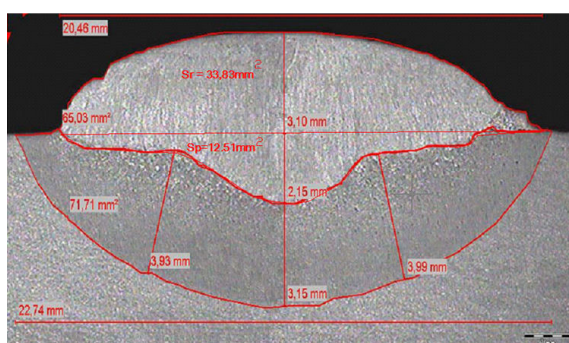


Fig. 7 Macrography of the beads and their measures

TABLE III  
RESULTS FROM TESTS

Specimens	1	2	3	4	5	6
Bead Height (mm)	4.32	3.27	2.87	4.36	3.14	2.89
Bead Width (mm)	6.92	5.98	5.53	8.55	6.38	6.4
Bead Area (mm²)	19.20	13.11	10.45	23.67	12.78	11.27
Deep Penetration (mm)	1.61	1.18	1.20	1.74	1.35	1.42
HAZ Height (mm)	1.21	0.66	0.52	0.88	0.64	0.74
Voltage	1	1	1	1	1	1
Condition Current	1	1	1	1	1	1
Speed	1	2	3	1	2	3
Vibration (Hz)	0.0	0.0	0.0	5.35	5.35	5.35

TABLE IV  
RESULTS FROM TESTS

Specimens	7	8	9	10	11	12
Bead Height (mm)	4.29	3.49	3.19	4.38	2.99	2.69
Bead Width (mm)	8.21	6.62	6.37	8.28	7.42	6.26
Bead Area (mm²)	22.55	14.8	13	24.35	15.08	11.21
Deep Penetration (mm)	1.86	1.47	1.33	0.97	0.78	0.88
HAZ Height (mm)	0.99	1.10	0.68	0.89	0.8	0.74
Voltage	1	1	1	1	1	1
Condition Current	1	1	1	1	1	1
Speed	1	2	3	1	2	3
Vibration (Hz)	6.82	6.82	6.82	8.5	8.5	8.5

The results are presented in Tables III and IV.

The following tables show the results. It is observed that as

the vibration intensity increases (within the limits used in the tests) and wettability of the weld metal increases and decreases the height of the HAZ.

Two major advantages provided by the vibration action, according to Tables III and IV.

The first refers to the width of the weld bead which increased due to the increase of vibration frequency providing greater wettability of the weld.

The second advantage is associated with the time of the HAZ which is inversely proportional to the variation of vibration frequency (within the limits used in the test-Table II). Increasing the frequency the height of the HAZ decreases considerably.

The improved weld wettability gives a better geometric characteristic decreasing the stress concentration in the bead side (HAZ), which usually starts the propagation of cracks.

Fig. 8 shows the influence of width with the increase of the vibration.

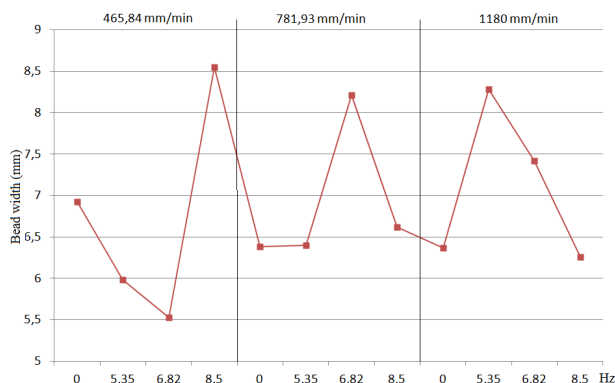


Fig. 8 Influence of vibration on width

In Fig. 9, the decrease in depth of penetration provides greater mechanical resistance welding without influencing the heat input in the material and thus with reduced energy consumption and greater efficiency of the process.

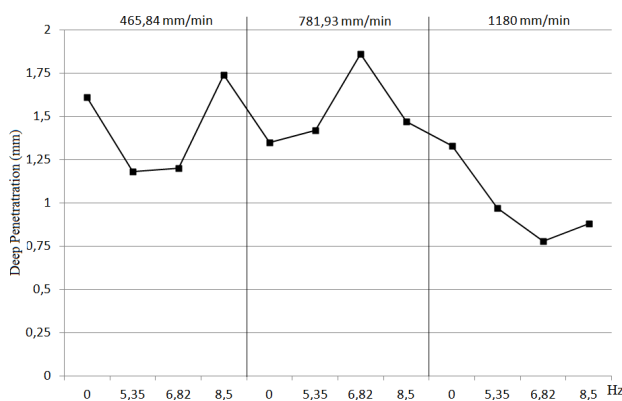


Fig. 9 Influence of vibration on deep penetration

In Fig. 10, the decreasing in the HAZ incurs due to the vibration.

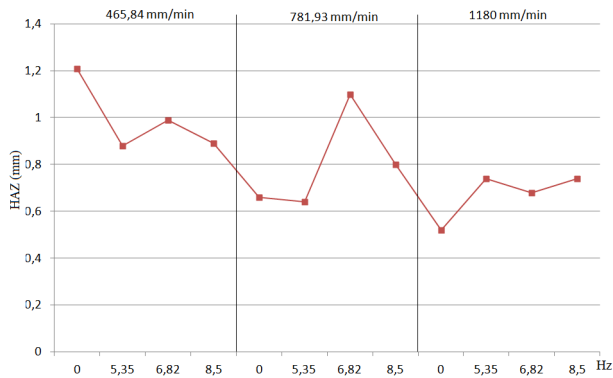


Fig. 10 Influence of vibration on HAZ

In Fig. 11 are the results of hardness of welds.

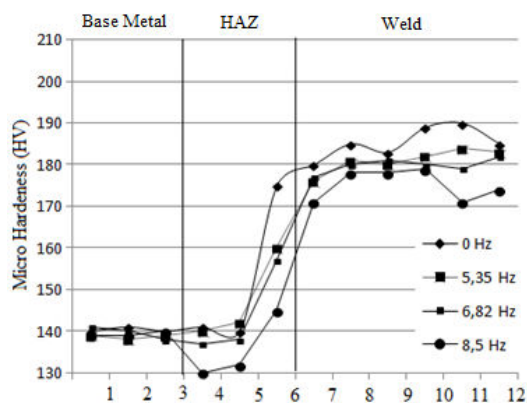


Fig. 11 Comparison between micro hardness profile for each vibration

In Table V, the micrographs obtained by the optical microscope under certain conditions weldments, specifically: Base Metal, HAZ and Weld Metal are shown. It was observed changes in the microstructures only the variation of the frequency. The micrographs are underlined on a scale of 0.02mm.

The micrograph shows that with increasing frequency, the HAZ and the Weld Metal had a microstructure improved over conventional welding.

Another important fact is related to the dilution, when considering only the frequency. The dilution was improved by the presence of the frequency increased.

The tensile test proved the integrity of the welded joints, because all the specimens fractured in the metal base or the HAZ, with maximum strain above the minimum value of 400 MPa according to expected.

TABLE V  
COMPARISON BETWEEN VIBRATIONS

	Weld Metal	HAZ	Base Metal
V:23.78V i:153.33A S:465.84mm/min freq:0			
V:23.78V i:153.33A S:781.93mm/min freq:0			
V:23.78V i:153.33A S:1180mm/min freq:0			
V:23.78V i:153.33A S:465.84mm/min freq: 5.35 Hz			
V:23.78V i:153.33A S:781.93mm/min freq: 6.82 Hz			
V: 23.78V i: 153.33A S:1180mm/min freq: 8.5 Hz			

#### IV. CONCLUSION

It follows that when the vibration within controlled parameters, exerts beneficial influence in welding. It can optimize the process and the acquired mechanical characteristics and reduce the costs associated with the manufacturing process.

Vibration affects the welding pool shape and the convection of welding pool strongly. It will affect the solidifying parameter and metallurgic properties.

The application performed of the welding process does not suffer interference from the welder, and this implies that you do not need more skilled labor than the conventional process (no vibration).

The first advantage, the width of the weld increased with the increase in the vibration frequency.

The second advantage is associated with increasing the frequency the height of the HAZ decreases.

The mechanical properties improve with increasing frequency.

Finally, the decreasing in the HAZ incurs due to the vibration.

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