

Studies on the Effect of Mechanical Vibration on the Microstructure of the Weld Metal

K. Balasubramanian^{1*}, S.Raghavendran¹ and V. Balusamy²

¹ Department of Mechatronics Engineering, Sri Krishna College of Engineering and Technology, Coimbatore-641 008, Tamilnadu, India

² Department of Metallurgical Engineering, PSG College of Technology, Coimbatore-641 004, Tamilnadu, India

Abstract

The present paper investigates the effect of mechanical vibrations on the microstructure of the different weld metal. In this work, an attempt is made to reduce the grain size of the solidification structure of the weld metal through vibratory treatment. The materials used for this investigation are super austenitic stainless steel and pure Nickel. Vibratory treatment was carried out in the frequency range of 100Hz to 1000Hz. Weldments made with and without vibratory treatment were compared using the characterization tests like microstructural analysis. Test results show that by applying vibratory treatment, the grain structure of the weld metal can be largely controlled in arc welding.

Keywords: microstructure, vibratory treatment, super austenitic stainless steel, Nickel

1. INTRODUCTION

The solidification process in the weld metal produces solidification structure. The solidification process depends on the thermal gradient, solidification speed and the alloy content. These structures can be planar, cellular, columnar dendritic and equiaxed dendritic. The solidification process may change from planar to cellular, columnar dendritic and equiaxed dendritic across the weld metal zone as shown in fig.1.

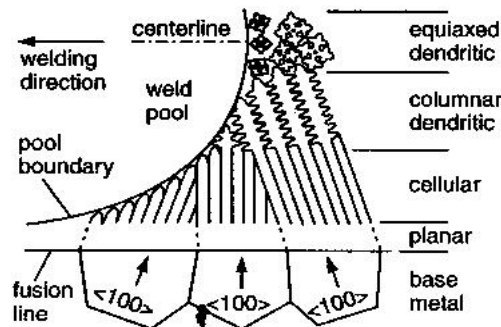


Fig.1.Variation in solidification mode across the fusion zone

Three grains are shown to grow epitaxially from the fusion line. A short distance away from the fusion line, solidification changes to the cellular mode. Further away from the fusion line, the solidification changes to columnar dendritic mode. Near the weld centre line equiaxed dendrites nucleate and grow, blocking off the columnar dendrites. Each one of these structures would affect the hot cracking susceptibility in greater or smaller extent.

The formation of fine equiaxed grains in the fusion zone has two main advantages. First, fine grains help to reduce the susceptibility of hot cracking during welding. Second, fine grains can improve the mechanical properties of the weld. Therefore, much effort has been made to try to grain refine the weld fusion zone. There are several techniques used to control weld metal grain structure.

1.1 Inoculation

This technique is most widely used in metal casting. It involves the addition of nucleating agents or inoculants to the liquid metal to be solidified. Similar to casting, inoculants are added into the liquid weld metal to promote heterogeneous nucleation and the liquid metal solidifies with very fine equiaxed grains. Ramanaiah et al [1] observed significant grain refinement and increase in hardness by adding Ti + B. In their work, Ti and B elements were added directly to the weld pools either as filler rods cut from master alloy or by pre placing correct amounts of pieces of master alloys along with 4043 fillers in a groove cut in the base material. Janaki Ram et al [2] induced grain refinement in weld fusion zone of 2090 Al-Li alloy through inoculation with Ti, Ti+B and Zr. The structural refinement was found to reduce hot cracking susceptibility which was measured by Vareststraint testing.

1.2 Weld pool stirring

Weld pool stirring can be achieved by applying an alternating magnetic field parallel to the welding electrode. Matsuda et al [3] obtained equiaxed dendrite zone for austenitic stainless steel of SUS 304, 316, 321 and 310S by application of electromagnetic stirring. Mousavi et al [4] achieved grain refinement in electromagnetically stirred AA7020 welds. They also proved that the grain refinement was due to the grain detachment.

1.3 Arc oscillation

Arc oscillation can be produced by either magnetically oscillating the arc column using a single or multiple magnetic probe or mechanically vibrating the welding torch. Kou and Le (5-7) studied the effect of magnetic arc oscillation on grain structure and hot cracking of the Aluminum alloys welds. Garland (8) produced grain refinement by vibrating arc during Autogenous GTA welding of Al-Mg alloys

1.4 Arc pulsing

Arc pulsation is obtained by pulsing the weld current (using peak and base current). Rajesh manti et all [9] observed that pulse TIG welding produced finer grain structure of weld metal than conventional TIG welding (without arc pulsation). An increase in the pulse frequency has been found to refine the aluminium and eutectic grain structure of weld metal especially when welding is done using short pulse duration.

In the present study, the hot cracking can be reduced by vibrating the specimen during the welding. The number of papers related to the formation of microstructures of welded joints by vibration is quite small. Tewari and Shanker [10], Hebel and Kreis[11] and Weite [12] described the benefits of vibration on grain refinement. The reason behind the grain refinement is breaking of dendrites, which causes more randomized, disoriented and smaller grain of weld bead microstructure. Hebel,T, and Kreis,R [11] pointed out that good mechanical properties can be attained during welding by sub resonant vibration due to the change of weld micro structure to fine grained. Also, the changes in grain size and orientation are more effective with sub-resonant vibration [11, 13].

This paper reveals the effect of vibration on grain structure of GTA welded super austenitic stainless steel and Nickel.

2. MATERIALS AND METHODS

2.1 Material

The materials used for the investigation are super austenitic stainless steel and pure Nickel. The chemical composition of super austenitic stainless steel is shown in table.1

Table.1. Chemical composition of Super Austenitic Stainless steel

Base metal	-----Composition, %-----										
	C	Si	S	P	Cr	Ni	Cu	Mo	N	Mn	Fe
SASS	0.014	0.24	0.008	0.018	20.24	17.42	0.59	6.78	0.25	1.71	53.54

2.2 Welding

Welded specimens were made using GTAW process. The main parameters used for welds the specimens are given in table.2.

Table 2

Parameters	Base materials	
	Super austenitic stainless steel	Pure Nickel
Welding current	150Amps	150Amps
Travel speed	3.75mm/s	3.75mm/s
Electrode	EWTh-2, 3mm diameter	EWTh-2, 3mm diameter
Shielding gas	Argon	Argon
Polarity	AC	AC

2.3 Vibration treatment

The vibration generator cum analyzer used in this work consists of a piezo electric transducer capable of producing mechanical vibration in the frequency range of 100Hz to 3000Hz. The transducer is made to transmit the vibratory energy to the weld plate through a welding fixture. The welding fixture and the specimen holding method are such that the energy loss during transmission from transducer to the weld plate is kept to the lowest value. The arrangement of this vibratory treatment unit is schematically shown in figure.2.



Fig.2. Experimental set up

2.4 Characterization tests

The extend of grain refinement due to vibratory treatment is determined through micro structural analysis. The welded specimen, after sectioning and polishing, were etched with a solution containing 15ml HCl, 10ml HF and 90ml water, cleaned with water, cleaned with concentrated HNO₃ and rinsed with water again. Micro structural analysis was conducted on the etched specimens, mainly to compare the grain size of specimen welded with different vibration frequencies.

3. RESULTS AND DISCUSSION

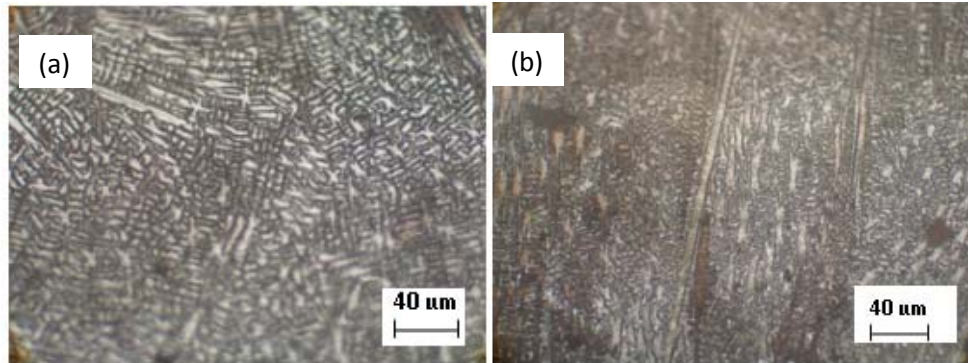


Fig.3. Metallographs of super austenitic stainless steel weld metal
(a) without vibration(200X) (b) Vibrated specimen of 500Hz (200X)

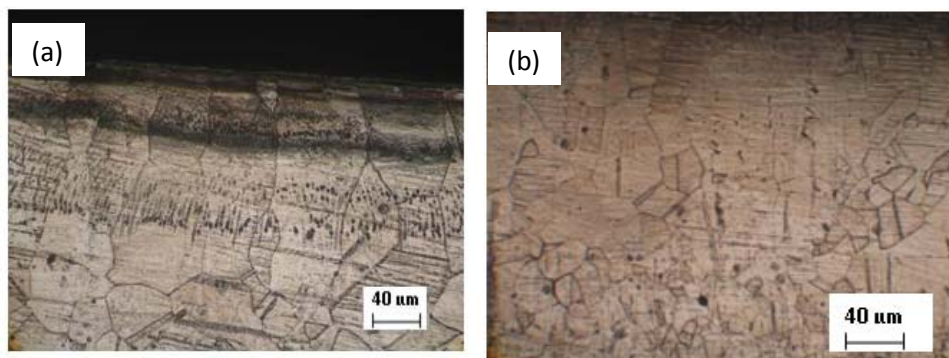


Fig.4. Metallographs of pure Nickel weld metal
(a) without vibration (200X) (b) Vibrated specimen of 100Hz (200X)

Figure 3 and 4 shows a comparison between microstructure of specimen welded without and with vibration. Figure 3 and 4 shows the microstructure of super austenitic stainless steel weld metal and pure Nickel weld metal respectively. Coarse grains were observed in the specimen welded without vibration (fig.3.a and 4.a). On the other hand, the grains were disturbed due to vibration treatment and forms finer grains in the frequency range of 500Hz in case of super austenitic stainless steel and 100Hz in case of pure Nickel (fig.3.b and 4.b). The finer sub grain structure in the vibrated weld was explained by Lu Qinghua et al [14] that the weld pool has two velocity components: one in the welding direction and the other perpendicular to the welding direction with the help of vibration. The resultant velocity is greater than the velocity of the non-vibrated weld pool. This significantly higher weld pool velocity apparently produced a higher cooling rate during solidification, resulting in a finer sub grain structure in the vibratory weld. According to the principles of solidification (15), higher cooling rate allow less time for the coarsening of sub grain to occur during solidification. Thus, the higher cooling rate during solidification, the faster the heat removal, the more the nuclei coming into play, resulting in finer the resulting sub grain structure.

4. CONCLUSION

The effect of vibration on grain structure has been investigated and found that:

- The non vibrated specimen both super austenitic stainless steel and pure Nickel were composed of coarse grains.
- Grains were disturbed and smaller grains were formed when the vibration is in the frequency range of 500Hz for super austenitic stainless steel and 100Hz in case of pure nickel. The structural refinement of both super austenitic stainless steel and pure nickel were achieved by the imposition of vibratory treatment during GTAW process.

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