International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 17 (2015) pp 37799-37805
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Investigation On Variations In Geometry And Microstructure Of Weld Deposits Due To Interpulse Current And Its Frequency

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Abstract
Interpulse GTAW is a unique technique for arc constriction. Due to arc constriction the heat input to the work piece could be adjusted by the appropriate selection of interpulse GTAW welding parameters. This technique may widely be used for thin sheet welding applications and where the high quality weld joint required with reference to the code requirements. Considering this technique the present work describes the various weld deposition characteristics such as geometry and microstructure under different interpulse current and frequency along with conventional welding parameters. It is observed that the interpulse current and frequency has more influence on the weld bead geometry and microstructure than that of conventional welding parameters.

Keywords: Interpulse current, Interpulse frequency, welding current, welding speed, arc voltage.

1.0. INTRODUCTION

The Inter Pulse Gas tungsten Constricted Arc Welding process is an advanced modification of conventional GTAW, using magnetic constriction and high frequency (20,000Hz) modulation of the arc waveform to produce a constricted arc and greatly reduce the overall heat input during welding [1]. The basic operating principle of IP-GTAW process is shown in Fig. 1. From the figure 1, it is understood that, the strength of the electric field is directly proportional to the rate of change of the magnetic field, in other words, the weld arc is constricted by the magnetic field around the arc. In addition, super imposition of high frequency pulses enables the control of the constriction of the arc. The various high frequency waveforms super imposed in IP-GTAW system is shown in Fig. 2 [2]. The use of this techniques allows thin sheet application of titanium and its alloys to be successfully welded outside of a vacuum chamber, without a trailing gas shield, and thus with far greater versatility and precision than conventional processes. The process is also operate at low heat input.

However, the quality of weld joint largely determined by the optimum selection of welding parameters. In case of conventional welding techniques there are three primary welding parameters involved viz. welding current, arc voltage and welding speed to decide the various weld joint characteristics [3] whereas, in case of Inter-Pulse GTAW, in addition to the above, the Inter-Pulse current and its frequency is also involved [1,2]. Thus, the process is more complicated than conventional technique. Hence, it is felt that, the systematic understanding of various weld deposit characteristics under different IP-GTAW parameters such as welding current, arc voltage, welding speed, Inter-Pulse current and its frequency are important.

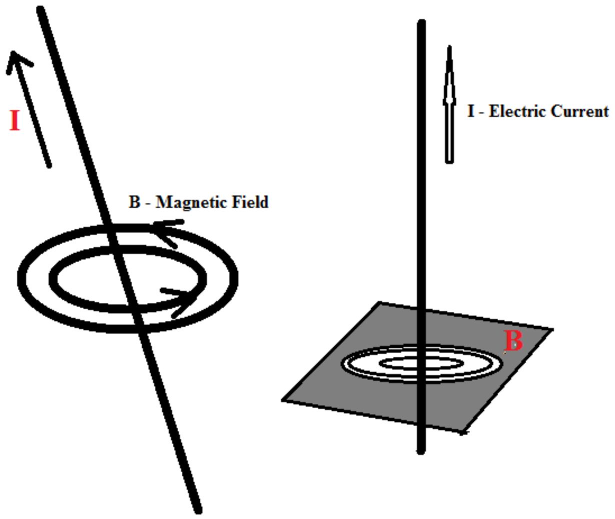
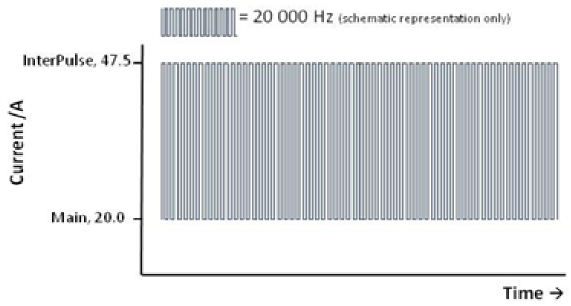


Fig 1. Basic operation principle of IP-GTAW



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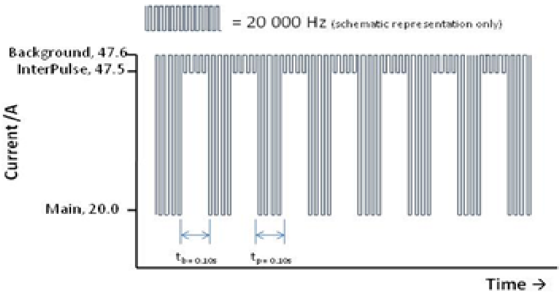


(b)

Fig. 2. Waveform of IP-GTAW (a) Continuous with high frequency and (b) Pulsed with high frequency

In this context, the present work describes the influence of various IP-GTAW parameters on bead geometry and microstructure of weld deposit during bead on tube welding of TP-347H austenitic stainless steel. The geometry of weld deposit considered for this investigation is bead width and depth of penetration. The TP 347H material widely used in thermal power generation where the operating temperature and pressure involves around 500º C and 320 bar respectively [4]. Due to high temperature operating conditions the material may fail under service conditions because of adverse change in microstructure and it is largely influenced by heat input of the process. The use of IP-GTAW process may provide better weld deposit characteristics.

2.0. EXPERIMENTAL

Super imposition of pulsed current referred as Inter-Pulse (IP) on conventional current is a unique feature of Inter-Pulse Gas Tungsten Arc Welding (IP-GTAW) process. Each mode of operations in GTAW have unique weld deposit characteristics in reference to the appearance, geometry and microstructure. Due to the superimposition of pulsed current in GTAW, it may give superior weld joint characteristics in comparison to that of the conventional GTAW technique. Hence, this investigation aims to carry out the comparative studies on various characteristics of weld deposits under different modes of operations such as 1) Conventional and 2) Conventional with Inter-Pulse in IP-GTAW process. The detailed experimental arrangements are as follows.

2.1. Bead on Tube Welding

Base metal used for present investigation is TP-347H austenitic stainless steel tube having outer diameter and thickness of 63.4mm and 4.5mm respectively. Typical microstructure of the base metal has been shown in Fig. 3. The IP-GTAW welding was carried out using direct current electrode negative (DCEN) polarity without filler wire addition (Autogeneous). The 2% ceriated type Tungsten Electrode (0.8mm Diameter) is used for various modes of operations such as: 1) Conventional and 2) Conventional with Inter-Pulse in the IP-GTAW process. During weld deposition the tube was rigidly fixed in a fully automated welding lathe. The welding power source, torch and automatic torch positioning system were connected to the welding lathe. The welding parameters such as welding current (I), Inter-Pulse current and its frequency as well as welding speed and arc gap were set through control panel attached with the IP-GTAW power source. Photographic view of IP-GTAW system for tube butt welding application is shown in Fig. 4. Welding was carried out at different welding parameters by using commercial pure argon (99.98%) as shielding gas at a gas flow rate of 15 lpm. Prior to welding, the base metal is cleaned with acetone to get clean weld. The welding parameters used for this investigation have been given in Table 1 and Table 2. In case of conventional GTAW the welding speed varied from 0.5 to 3 rpm to study the process stability whereas, Inter-Pulse GTAW the optimum welding speed kept as 1.5 rpm. Weld bead deposition were made over the entire (360°) surface of outer diameter of tube. The arc voltage (V) and welding current (I) under different welding parameter used in this investigation during welding were measured with the help of digital monitor fitted in the IP-GTAW system. To avoid experimental errors, three to four weld depositions were carried out in each welding parameters under different modes of operations and the results were statistically plotted.

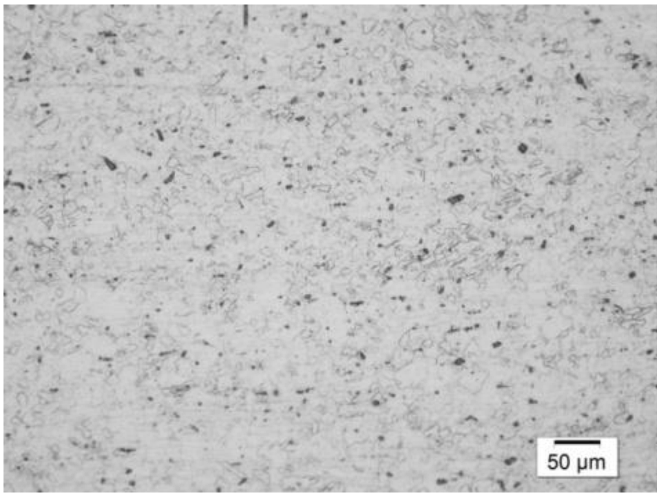


Fig. 3 Typical microstructure of TP-347H ASS base metal

Table 1 Welding parameters used for conventional GTAW in IP-GTAW system.

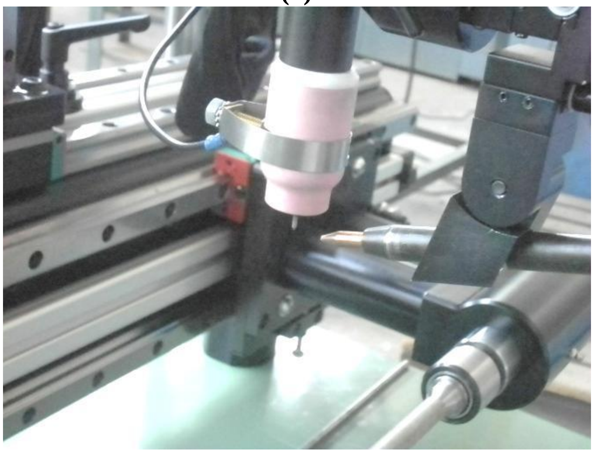
Mode of Operation	Set Current, A	Welding Speed, rpm
Conventional GTAW	60	0.5
	80	
	100	
	120	
	60	1
	80	
	100	
	120	
	60	1.5
	80	
	100	
	120	
	60	2

	80	
	100	
	120	
	60	2.5
	80	
	100	
	120	
	60	3.0
	80	
	100	
	120	

Table 2 Welding parameters used for conventional with Inter-Pulse in IP-GTAW system.

Mode of Operation	Set Current, A	Inter-Pulse Current, A	Inter-Pulse Frequency
Conventional With Inter-Pulse GTAW	60	25	20 kHz
	80		
	100		
	60		15kHz
	80		
	100		
	60		10kHz
	80		
	100		
	60	50	20 kHz
	80		
	100		
	60		15kHz
	80		
	100		
	60		10kHz
	80		
	100		
	60	75	20 kHz
	80		
	100		
	60		15kHz
	80		
	100		
	60		10kHz
	80		
	100		

(a)

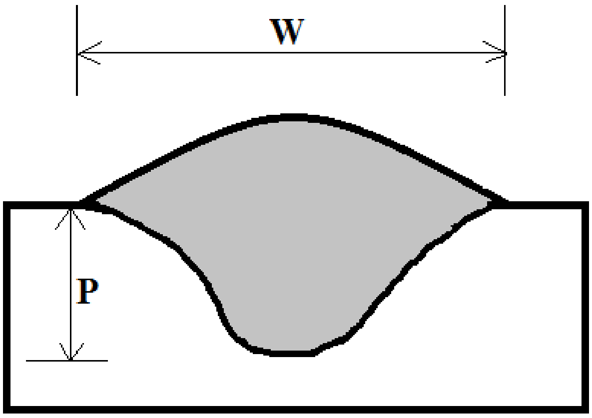


(b)

Fig. 4 Photograph of IP-GTAW setup

2.2. Studies on Bead Geometry

The geometry of weld bead was studied on polished and etched (10% Oxalic Acid) transverse section of weld bead as schematically represented in Fig. 5. The W is bead width (mm) and P is depth of penetration (mm).



2.3. Studies on Microstructure

The microstructure of weld deposit and its adjacent to the fusion line of Heat Affected Zone (HAZ) as revealed in its metallographic polished and etched (10% Oxalic Acid) transverse section were studied under different modes of operations in the IP-GTAW system using optical microscope.

3.0. RESULTS AND DISCUSSION

3.1. Conventional GTAW

3.1.1 Bead Geometry

The effect of welding current on measured weld bead width under different welding speed has been shown in Fig.6. It is observed that the increase of welding current in the ranges from 60 to 120A enhances bead width irrespective of change in welding speed from 0.5 to 3 rpm. The figure further shows that at a given welding current, increase of welding speed decreases weld bead width. Such a variation of weld bead width as a function of welding current and welding speed is as follows. It is generally well known that increase of welding current enhances projected arc diameter to the work piece, which may increase significant lateral displacement of liquid in the weld pool resulting in relatively wider weld bead width. In addition increase of welding current also enhances the arc pressure and heat content of the weld pool. These may also contribute to the increase in weld bead width. Increase of welding speed reduces the heat input of the process. This means that the heat content per unit mass of the weld deposits decreases with increase of weld speed.

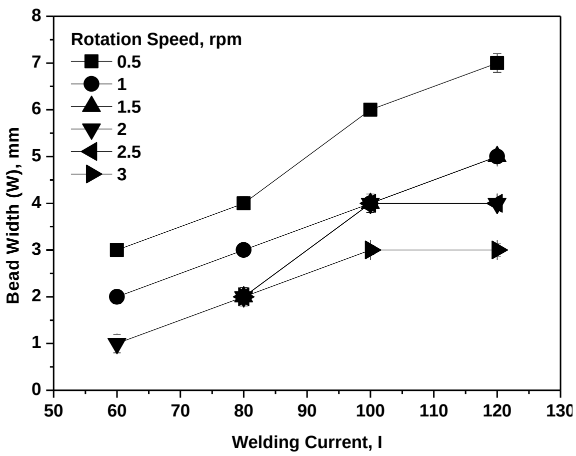


Fig.6 Effect of welding current on weld bead width under different welding speed

As in the case of weld bead width, the depth of penetration of weld deposit also correlated with welding current and welding speed has been shown in Fig.7. From the figure, it is observed that in general, increase of welding current as usual enhances the depth of penetration. From the Figure, it is further observed that at the given welding current, increase of welding speed reduces the depth of penetration. This may primarily happened due to the increase of formation of cavity underneath the arc with current which enhances heat content of weld deposit.

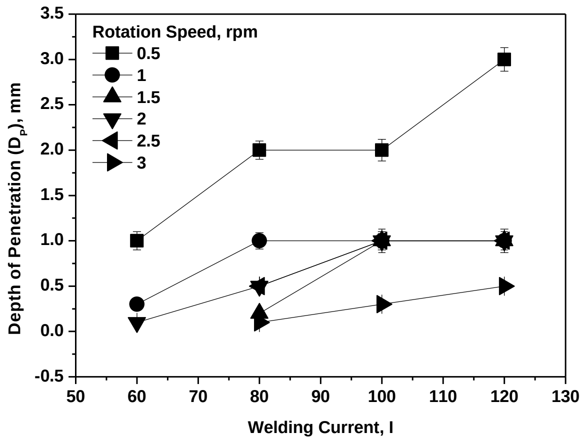


Fig.7 Effect of welding current on Depth of Penetration under different welding speed

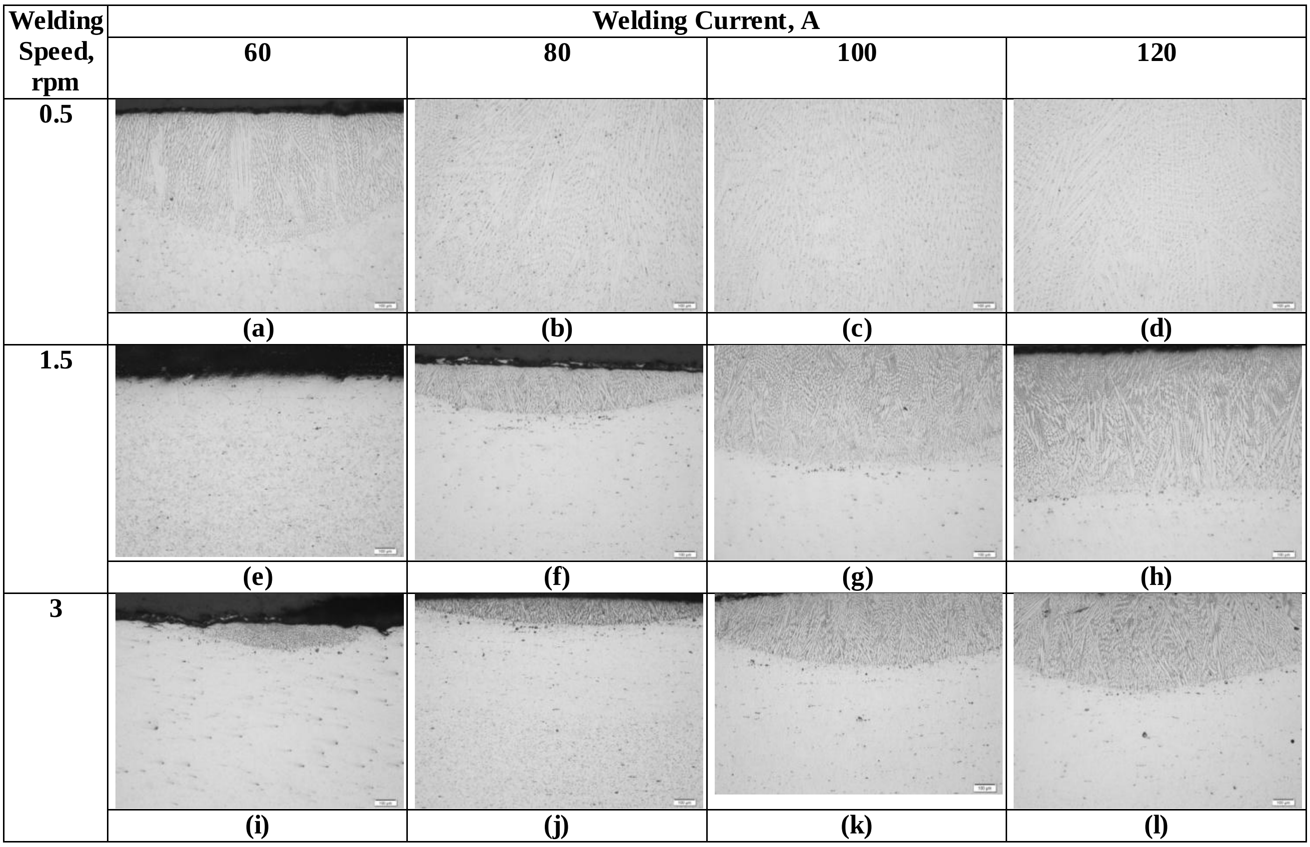


Fig. 8 Typical microstructure of conventional GTAW weld deposit under different welding current and welding speed.

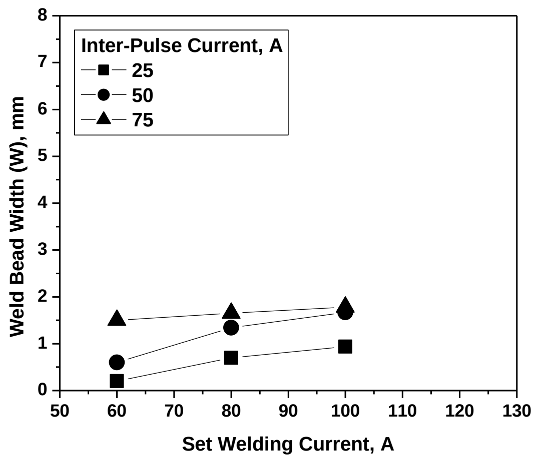
3.1.2 Metallography

The effect of welding current on variation of microstructure of weld deposit under different welding speed has been shown in Fig. 8 (a). The figure 8 shows that, the cellular dendritic region primarily exists in upper part of weld bead because of comparatively slower cooling of this region. Whereas, as one proceeds towards inner part of weld deposit the solidification becomes largely dictated by the heat flow to base metal giving rise to a growth of co-axial dendritic structure in the matrix. However, the morphology of both the microstructural regions varies insignificantly with the change in welding current and welding speed due to stable V-I characteristics.

3.2. Conventional with Inter-Pulse GTAW

3.2.1 Bead Geometry

The effect of welding current on variation of weld bead width under different interpulse current and its frequency has been shown in fig.9.(A-C). Significant variation in bead width observed with addition of interpulse current but, as for as the change in welding current and frequency are concerned, the bead width change shows insignificant variation in it. However, in comparison to the conventional GTAW, the bead width reduces by adding interpulse current due to arc constriction as explained earlier.



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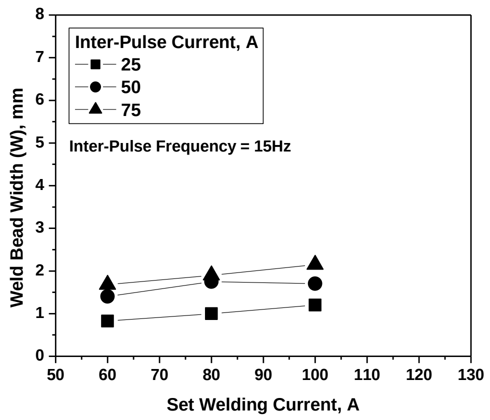

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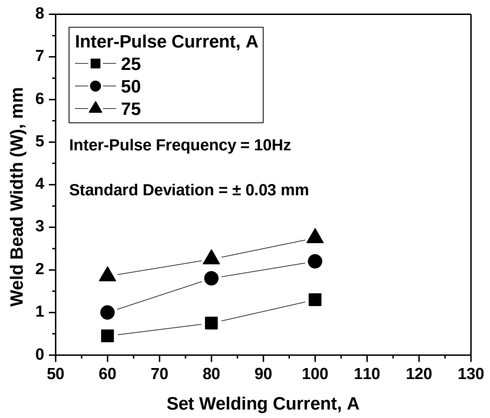
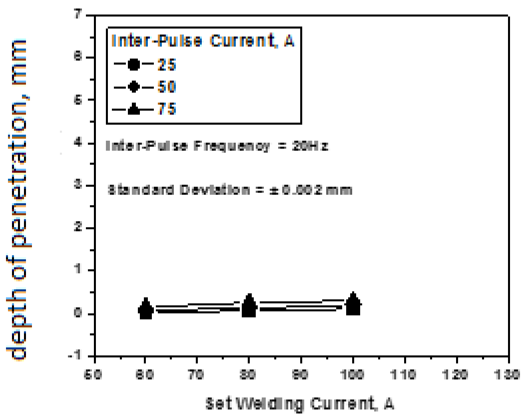


(c)

Fig.9 Effect of welding current on weld bead width under different welding conditions



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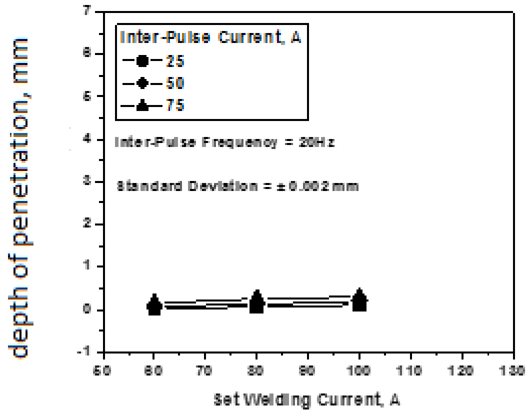

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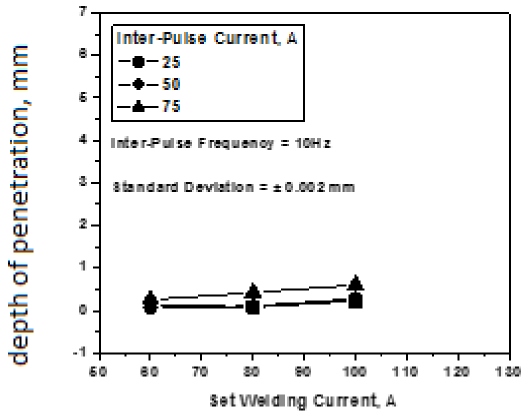

(c)

Fig. 10 Effect of welding current on Depth of penetration under different welding conditions

3.2.2. Metallography

The morphology of dendritic cast structure of weld deposit forms during solidification and it is largely depends upon locally dominating constitutional and thermal super-cooling dictated by the heat input and thermal shock exerted by the Inter-Pulse current and its frequency. Typical microstructure of conventional with Inter-Pulse GTAW under different interpulse current and different welding current at a given interpulse frequency of 20kHz has been shown in fig.10. The refinement of such microstructures primarily depends upon the thermal shock arising out of characteristic interruption in metal deposition resulting in super imposition of arc governed by the variation of Inter-Pulse current and its frequency. Addition of Inter-Pulse current the weld metal deposited primarily starts solidifying with coaxial growth of dendrite under a condition of practically no heat gain from outside because of the existence of a comparatively low arc current of pulse off period with practically no or insignificant metal transfer. However, when the subsequent pulsation sets in the deposition of weld metal on the earlier one causes a localized melting and produces a thermal shock to its adjacent region. The local melting may lead to necking and pinching of the solidifying dendrite arms, and the crystallites may get

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 17 (2015) pp 37799-37805
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distributed in liquid melt by an agitation sets in it resulting from development of a thermal gradient. Many of these crystallites survives from re-melting and becomes active to promote wide spread growth of new randomly oriented crystals resulting into a comparatively finer cast structure of the weld by grain multiplication process.

4. Conclusions

Based on the present investigation, the following conclusions were arrived.

1. In case of conventional GTAW, the increase of welding current as usual enhances the bead width. It is further noticed that at the given welding current, increase of welding speed decreases the bead width.
2. As in the case of bead width, the depth of penetration is also showing similar trend with welding current and welding speed.
3. The microstructure of weld deposit is finer when the welding current is lower and the welding speed is higher.
4. In case of Interpulse GTAW, the bead width and depth of penetration increases with increase of welding current and interpulse current. However, the magnitude of width and depth of penetration in Interpulse GTAW is less than that of the conventional GTAW. This is primarily due to arc constriction by interpulse current and interpulse frequency.
5. The impact of arc constriction behavior is largely reflected in the form of finer microstructure of weld deposits.

Acknowledgements

The authors thankfully acknowledge Welding Research Institute, BHEL, Trichy to carry out welding trials and valuable guidance.

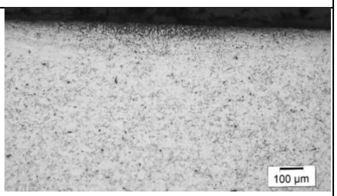
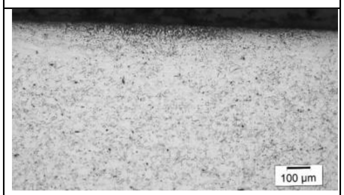
Set Current, A	Inter-Pulse Current, A	Inter-Pulse Frequency	Typical change in microstructure
60	25	20 kHz	
80			
100			

Fig. 11 Typical microstructure of conventional with Inter-Pulse GTAW under different interpulse current and different welding current at a given interpulse frequency of 20kHz.

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