High Frequency Gas Tungsten Arc Welding Process for Dressing of Weldment

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***Abstract*— *The present investigation aims to apply High frequency GTAW variants to apply for the purpose of dressing of weldments. Numerous studies has reviled that the different dressing techniques has improved the life for weldments by modifying the weld bead geometry. It is found that the cracks occur at the weld joints where the stress concentration of the weld geometries is very high. GTAW Dressing reduce the severity of the stress concentration at the weld, remove imperfections, and/or introduce local compressive stresses at the weld can be used for improvement of the fatigue life. This paper compares the variants of GTAW process used for Dressing process in a mild steel fillet welded plate and evaluates the weld bead geometry, microstructure and its surface hardness.*

Keywords*— *High Frequency, Dressing, Bead geometry, Toe radius, Surface toughness.

I. INTRODUCTION

Tungsten inert gas (TIG) welding is an arc welding process that produces coalescence of metals by heating them with an arc between a non-consumable electrode and the base metal. GTAW process is generally preferred because it produces a very high quality welds. The prpose of this investigation is to optimise the dressing technique usig variants of GTAW process. Implying dressing to a weld highlighted the fact that fatigue cracks that initiate very readily at the weld toe, virtually eliminating a crack initiation period and giving a fatigue life which is spent largely in crack propagation. The presence of these flaws, together with the stress concentration arising from the abrupt increase in section thickness at the weld joint, explained the relatively poor fatigue strengths of fillet welds.The flaws were not produced in TIG welding. This was thought to be due to the stable nature of the process. The above finding prompted the use of TIG simply to refine weld toes already deposited and confirmed the value of TIG dressing as an improvement techniques.

II. OBJECTIVE

The objective of the project is to perform High frequency Gas Tungsten Arc Welding process in the dressing application of fillet welded plate. Initially the Carbon plate is to be welded by GMAW welding process using ER-70s6 filler wire. Then dressing will done on the welded plate by conventional GTAW dressing, conventional GTAW dressing with High frequency, pulsed GTAW dressing and pulsed GTAW dressing with high frequency. Then sample specimens will be prepared for micro, macro structure analysis and micro hardness. Results will be obtained and conclusion will be arrived.

III. CHEMICAL COMPOSITION OF BASE METAL

ASME SA516 Grade 60 carbon steel plate	
Composition	**Percentage %**
C	**0.18**
Si	**0.4**
Mn	**0.95/1.50**
P	**0.015**
S	**0.008**
Al	**0.02 (Min)**
Cr	**0.3**
Fe	**Remaining**

IV. CHEMICAL COMPOSITION OF FILLER WIRE

ER 70S-6	
Elements	**Content**
Carbon	**0.06-0.15%**
Manganese	**1.4-1.85%**
Phosphorous	**0.025%**
Sulphur	**0.035%**
Silicon	**0.80-1.15%**

V. GMAW WELDING

The heat is produced by an electric arc between the continuously fed metal electrode and the base metal. Both the base metal and the filler are melt. The weld area is protected by inert shield gases. As per AWS5.1 standard ER70S-6 wire was selected to weld the carbon steels plates. The plates were arranged in the automatic GMAW machine. The weld was perfomed in 2G position. Initial connections were given and 100% argon gas cylinder was connected and shielding gas flow was ensured. The electrode spool was fixed and the feed rate was set in the GMAW machine. The

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plates supported in the fixture of the GMAW machine. The electrode tip was cleaned and the process was started

WELDING PARAMETERS FOR GMAW WELDING.

PARAMETERS	VALUE
ELECTRODE WIRE	ER70S6
WIRE DIAMETER	1.2mm
SHIELDING GAS	ARGON
GAS FLOW RATE	20 lpm
WIRE FEED RATE	7.5 mm/min
TRAVEL SPEED	300 mm/min
STARTING CURRENT	128 amps
STARTING VOLTAGE	25 volts
WELDING CURRENT	208-215 amps
WELDING VOLTAGE	25 volts
NO OF PASSES	3

VI. GTAW DRESSING

A standard TIG welding machine is used. Argon is normally used as shielding gas. Additions of helium is beneficial since this gives a larger pool of melted metal due to a higher heat input.

6.1) WELD PREPARATIONS

TIG dressing is sensitive to most types of common weld contaminants such as mill scale, rust, oil and paint. The weld and adjacent plate should be thoroughly de-slagged and wire brushed. If necessary light grinding should be used to obtain a clean surface insufficient cleaning tends to result in the formation of gas pores that can have a strongly detrimental effect on fatigue performance. The problem of porosity is particularly important in TIG dressed aluminium welds.

6.2) TUNGSTEN ELECTRODE FOR TIG DRESSING

The shape of the arc depends on the shape and condition of the electrode tip. If the tip is contaminated or rounded by wear (oxidation) the arc becomes concentrated, so that the remelted zone narrows with an unfavourable effect on the bead shape. It is also difficult to start the arc and keep it stable. These problems can be avoided by regrinding the tip or replacing the electrode.

6.3) SHIELDING GAS

If the gas flow rate is low or strong draughts disturb the gas shield the arc becomes unstable and defects such as surface pores are formed, or the electrode and bead oxidize. An adequate gas supply rate depends on many factors, including gas cup size, welding conditions and welding location (presence of draughts). An optimum flow rate should therefore be determined by trial dressing.

6.4) POSITION OF TIG TORCH AND DRESSING ZONE

For an optimum result the remelted zone has to be positioned carefully with respect to the original weld toe. Normally the best result is obtained when the arc centre is located a small distance away from the weld toe

6.5) WELDING CURRENT

Due to the Constant-Current (CC) process nature of GTAW, current is the main parameter determine the arc characteristic and the heat input, while other welding parameter is adjusted according to current change.Current is the measure of amount of electron flow per second, and related to amount of heat input. In direct-current process of electrode negative GTAW process, electron is flow from tungsten electrode to the workpiece. Higher current meaning more electron is flow through tungsten electrode and hit on the workpiece, in result of higher heat generated to melt the base metal. While voltage is potential different between tungsten electrode and workpiece, which direct related to the arc length. In Interpulse technique GTAW, there are main current , background current, and interpulse or delta current.

6.5.1)Main Current

Main current is the fundamental current or maximum weld current for GTAW. It can use alone in straight arc mode, or as peak current in pulse arc mode.

6.5.2)Background Current

Background current is the low current in pulse arc mode, use to maintain the arc during pulsing at low frequency of less than 50 Hertz. The greater the different between main current and background current, the greater pulse effect will be notice.

6.5.3)Delta Current

Delta current also known as interpulse current. This current runs on a 50% duty cycle with the Main current and/or background current at very high frequency of 20kHertz. This is the pulsing current generate magnetic force to constrict the arc, hence a stiff narrow arc

Delta straight arc unlike normal pulse arc, the waveform is taking shape of saw-tooth rather than square wave. This give a very special character to current waveform to behave differently when delta current is higher or lower than main current.The delta waveform has three sections. The rise in current time , fall in current time and the agitation current (flat wave).

The penetration weld or build up weld depends on whether the main current is higher that the delta current or lower than the delta current. In either case it is the speed at which the rise and fall times occur which influences the way in which the magnetic field works.

In the case where the main current is higher than the delta current, the waveform looks like the picture at left, thus the rise time is relatively slow compared with the fall time . This means that the magnetic field increases slowly, thus the arc is slowly constricted. This gives a gentle decrease in the arc width until the time of is complete. Then the fall in current happens fairly quickly, reducing the magnetic field and allowing the arc to get wider.

This cycle can be seen as slow compression of arc and a quick release to the original arc width. The agitation section acts as a small increase then decrease in current. This works a bit like the slow pulse and where the surface tension of the pool is agitated allowing the material is to "stirred" gently. This helps reduce the energy required for the next cycle to take place.

If delta current is higher than main current, a build-up configuration which exact opposite waveform is effectively occur as shown at right Figure. The rise time is relatively fast compared with the fall time. This means that the magnetic field increases quickly, thus the arc is quickly constricted and allowed to return to its normal state slowly. Thus this is good for build-up welds and filling small gaps inside materials.

6.5.4)AVERAGE CURRENT CALCULATION

As there are 3 different current involve in GTCAW, the calculation of the average current become more complicated by the fact that the high frequency modulation of the current generate a saw-tooth waveform. For the analysis here, it is thought that it is sufficient to simplify the calculations by assuming that all the waveforms take the form of a square wave, though a better interpretation should take duty cycle of 54% of delta current. If this is assumed to occur with a square waveform, the average current of either weld is simply the mean of these values. When delta current is superimposed at high frequency between main current and background current,

When delta current is superimposed at high frequency between main current without pulse current. The average current can be simplify to mean of the main and delta current.

VII. ARC MODE FOR INTERPULSE WELDING

These 3 different current when integrate together, having it's on unique character waveform that contribute to different application of welding, and greatly reduce heat input as compare to main current alone.

7.1)STRAIGHT ARC

Straight arc is the most basic arc mode, and available in all GTAW welding machine. In straight arc, there is only main current. The arc character is spread wide, a lot of heat is dissipated and wasted in the outer flare.

7.2)DELTA STRAIGHT ARC

Delta straight arc is mode of arc when delta current is pulsing with main current. The arc is constricted by magnetic force, hence the heat is focus and less wasted heat on the outer flare. This allow heat to perform at lower heat input than straight arc required. As explain previously, delta straight arc can alter to activate penetration weld or build-up weld depend on whether delta current is higher or lower than main current.

7.3)PULSE ARC

In the pulsed-current mode, the welding current rapidly alternates between two levels at low frequency up to 50 Hertz. The higher current state is known as the pulse current, while the lower current level is called the background current. During the period of pulse current, the weld area is heated and fusion occurs. Upon dropping to the background current, the weld area is allowed to cool and solidify. Pulsed-current GTAW has a number of advantages, including lower heat input and consequently a reduction in distortion and warpage in thin workpieces.

In addition, it allows for greater control of the weld pool, and can increase weld penetration, welding speed, and quality. A similar method, manual programmed GTAW, allows the operator to program a specific rate and magnitude of current variations, making it useful for specialized applications

7.4)DELTA PULSE ARC

Delta pulse arc is combination of both delta arc and pulse arc, where the delta magnetic current is modulate at 20 kHz between both main current and background current.

As there are main current, background current and delta current present in the wave form, the delta current can be set at lower, in between, or higher than main and background current. These setting allow the arc mode being manipulate to meet certain application.

VIII. SPECIMEN PREPARATION

The specimen was prepared by cutting the GMAW welded specimen to 15 mm from the centre. The specimen was deburred by grinding wheel and was done surface milling. In the surface milling operation the thickness was reduced to 10 mm. This made the specimen surface smooth and free from visible cracks. Then the specimen was polished using emery and disc polishing wheel. This makes the workpiece mirror like surface. The polished surface is then etched in 15ml nital for a few seconds and washed with the water. Then the specimen is observed in macroscopic image viewer under proper illumination.

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IX. RESULTS AND DISCUSSION

9.1) WELDING PARAMETERS

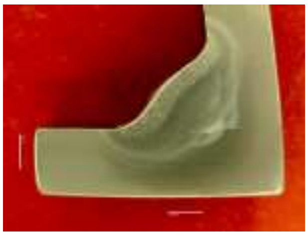
SI. No.	Processes	Welding Parameters					Heat Input, kJ/mm
		Welding Current, A	Arc Voltage, V	Welding Speed, mm/min	High Frequency current, A	High Frequency, Hz	
1	GMAW-Undressed	222	30	300	-	-	1.332
2	GTAW	150	16.8	129.47	-	-	1.167
3	GTAW + HF	120	16.4	129.47	50	20000	1.204
4	P-GTAW	110-140	15.7	96.32	-	-	1.055
5	P-GTAW + HF	130-150	16.8	90.4	100	20000	1.449

9.2) MACRO-PHOTOGRAPH OF WELD JOINT

Fig.1: Typical macrograph of Undressed weldment

The macro structure of undressed weldment reviles the base metal, weld metal and HAZ zones. It is clearly seen that the weld toe is highly stress concentrated due to its sharp toe

It is seen that the weld toe angle is higher any fracture would eventually start at the weld toe surface.




(a) **(b)**


(c) **(d)**

Fig.2: Typical Macrograph of dressed weldment (a) GTAW, (b) GTAW + HF, (c) P-GTAW and (d) P-GTAW + HF

The above macro graphs shows the dressed weldment which shows the remelted weld toe this reduces the stress concentration at the weld toe and improves the fatigue life. There is a reheat region which occurred due to dressing and the heat affected zone is further increased considerably the dressing reduces the throat length and the weld area this reduces the internal tensile residual stress developed during welding.

9.3) METALLOGRAPHY

9.3.1) MICRO STRUCTRE OF GMAW WELDED SPECIMEN

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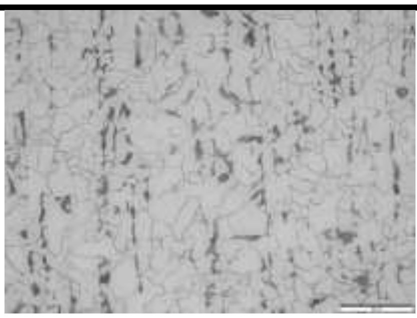

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Fig.3: Microstructure of base metal

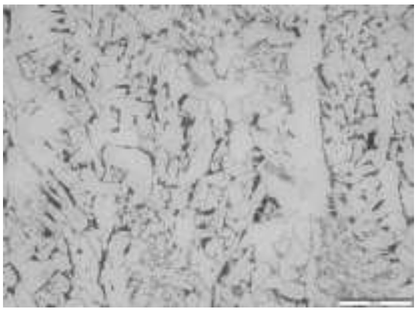

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Fig.4: Microstructure of as-welded GMA weld deposit

9.3.2) MICROSTRUCTURE OF CONVENTIONAL GTAW DRESSED

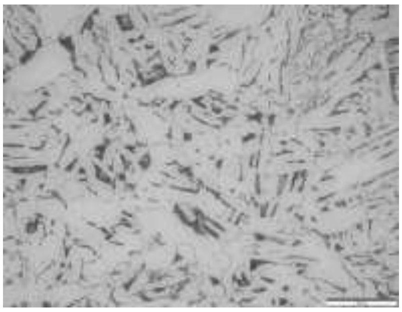

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Fig.5: Microstructure of as-welded HAZ near to top surface of the fusion line

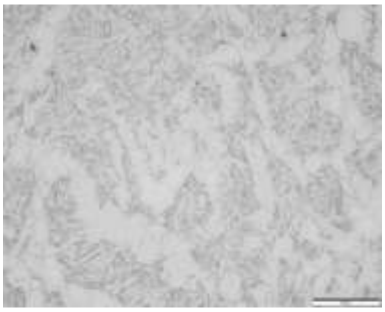

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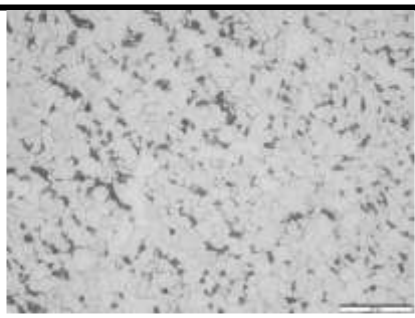
Fig.6: Microstructure of dressed weld deposit by conventional GTAW



(b) 500X

Fig.7: Microstructure of re-heat refined zone in weld deposit due to conventional GTAW dressing

9.3.3) MICROSTRUCTURE OF CONVENTIONAL GTAW WITH HF DRESSED

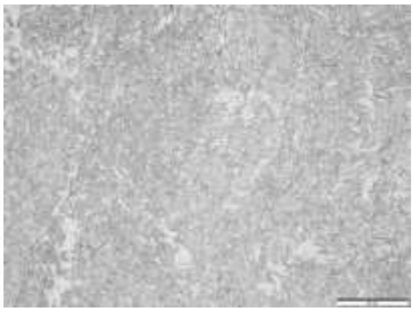


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Fig.8: Microstructure of undressed GMA weld deposit

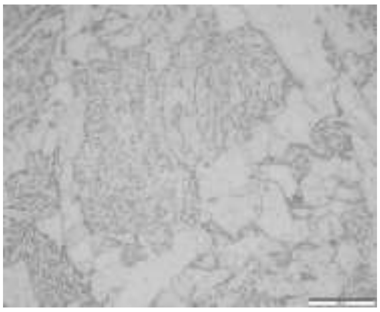

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Fig.9: Microstructure of dressed weld deposit by conventional GTAW + HF

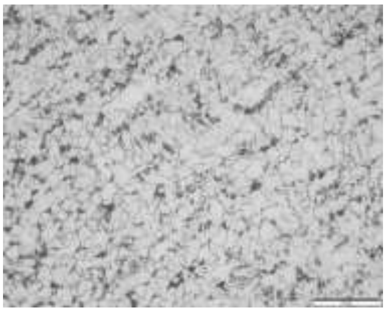

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Fig.10: Microstructure of re-heat refined zone in weld deposit due to GTAW + HF dressing

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9.3.4) MICROSTRUCTURE OF PULSED GTAW DRESSED

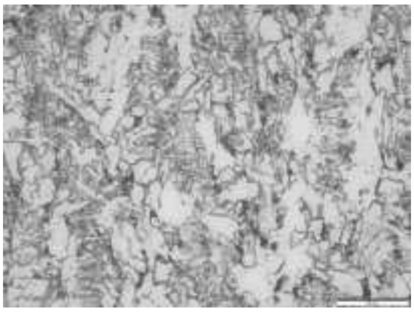

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Fig.11: Microstructure of undressed GMA weld deposit

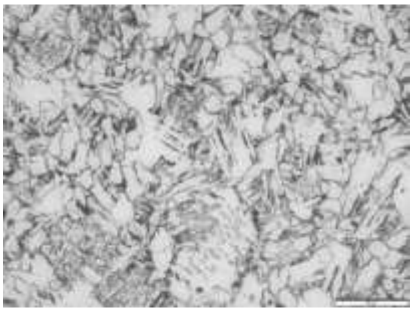

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Fig.12: Microstructure of dressed weld deposit by P-GTAW

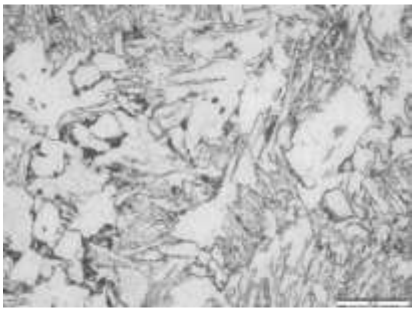

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Fig.13: Microstructure of re-heat refined zone in weld

9.3.5) MICROSTRUCTURE OF P-GTAW WITH HF DRESSED

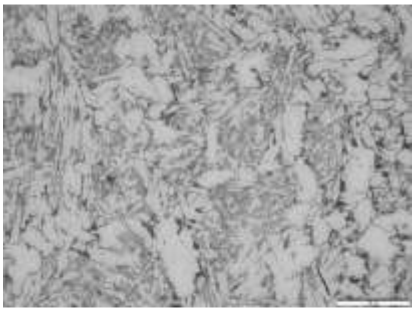

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Fig.14: Microstructure of undressed GMA weld deposit

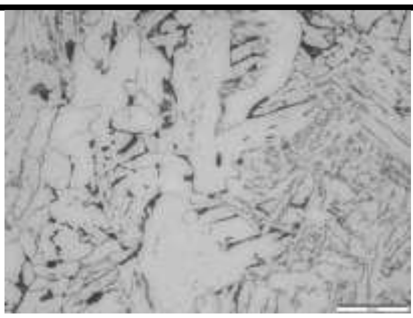

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Fig.15: Microstructure of dressed weld deposit by P-GTAW + HF

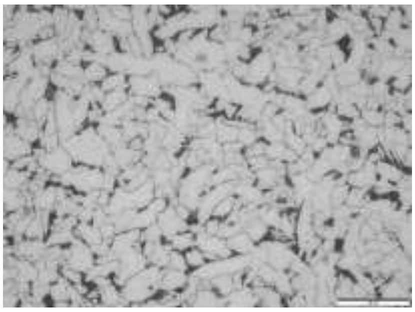

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Fig.16: Microstructure of re-heat refined zone in weld deposit due to P-GTAW + HF dressing

The reduction in the weld flaws and inclusion in combination with the increase in the weld toe radius is assumed to create the beneficial behaviour of the GTAW dressed specimen compared to as welded specimen.

The microstructure of the carbon steel depends upon the carbon content, temperature, and cooling rates. Austenite is formed above the transition temperature and will transfer back to ferrite and pearlite when cooled down. Carbon causes cementite to form.

The microstructure study revealed that the structure is distributed with ferrite and pearlite. The grains of the Reheat region in finer than the deposited metal. Hence the toughness of the surface is improved. In contrast in pulsed GTAW dressing process due to sudden cooling and heating the grains become finer hence hardness has improved suppressing the toughness.

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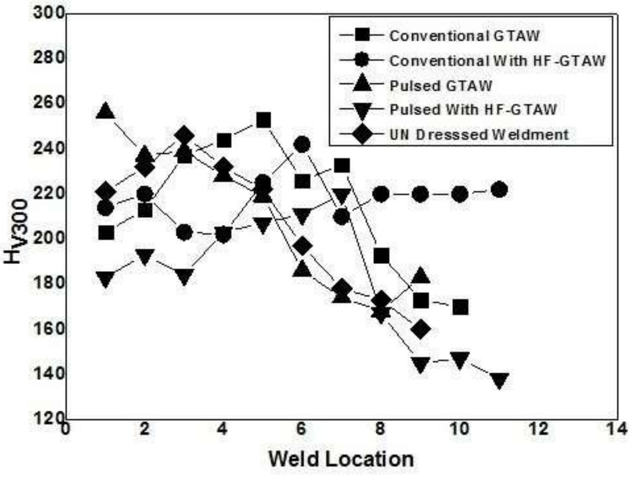
X. MICROHARDNESS



The micro hardness was done using the Vickers hardness test machine. The hardness was examined from the top surface of the weld bead and throughout its throat length. It was found the surface hardness decreased because of the dressing process. In contrast in pulsed GTAW dressing the hardness of the surface has been increased considerably. Through the result it is noted that the hardness of the conventional GTAW dressed specimen and conventional GTAW with High frequency dressed specimen have the most desired hardness profile.

XI. CONCLUSION

The dressing technique was applied on the fillet welded carbon steel plate using various arcs such as conventional tungsten arc, conventional tungsten arc with high frequency, pulsed tungsten arc, pulsed tungsten arc with high frequency. The initial fillet weld was welded by automatic metal inert gas welding.

1) The typical macro graph revealed that the dressed surface is smooth and uniform throughout the cross section. The sharp comers at the weld toe has been eliminated the weld bead angle has been decreased due to dressing process. The reduction in the weld area indicates reduction of tensile residual stress. The macro image further revels in improvement of symmetric of the weld bead.
2) The typical microstructure of the dressed specimen was studied under the magnification of 200x and 500x. The microstructure was examined at the top surface of the dressed zone, re heat affected zone, weld metal deposited region and base metal. The microstructure revels that the base metal and the weld metal are of same composition of ferrite and pearlite. The formation of acicular ferrite implies that toughness has been improved in the surface of the metal.
3) The micro hardness test was conducted on the prepared specimen. The resulted were displayed in the form of graph hardness vs distance. Expect pulsed GTAW dressing all the other dressing process the surface hardness was reduced by the dressing process. The conventional gas tungsten arc dressing process showed considerable uniformity in the hardness throughout the thickness.

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