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Parameters Identification for Weld Quality, Strength and Fatigue Life Enhancement on HSLA (S460G2+M) using Manual GMAW followed by HFMI/PIT

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ABSTRACT

This research is aimed to identify suitable parameters in achieving weld quality, strength and fatigue life enhancement for structural welding. The investigated material is High Strength Low Alloy Steel S460G2+M commonly used for harsh environment such as offshore structure or platform. Due to the extensive use in fabrication industry, the selected welding process is manual GMAW with filler wire ER80S-Ni1 and shielding gas 80%Ar + 20% CO_2. *The research initiates with the determination of suitable welding parameters such as Current, Voltage, welding speed etc. to attain good quality which refers to international welding standards AWS D1.1/D1.1M:2015. Further, the parameters of HFMI/PIT are to be investigated starting with the comparison of strength between untreated and treated tensile fatigue specimen. As the final results, the development of a conceptual WPS and PQR including HFMI/PIT-Procedure as an integrated model with regard to structural and fatigue life enhancement is presented for production purpose and for further use on application which is identical to this research.*
Keywords: *GMAW, HSLA S460G2+M, WPS, Fatigue life, HFMI/PIT*

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Introduction

Identifying appropriate combinations of welding parameters for welding quality and strength can be a time-consuming process relating to substantial trial and error method. It begins with preparing the written preliminary weld procedure specification (pWPS) and followed by the fabrication of weld test piece that subjected to nondestructive and destructive test such as radiography and tensile tests. The WPS is established upon the weld procedure approval certificate signed by authorized person such as welding engineer and supplemented with the welding procedure qualification record (WPQR) of the material being welded. In welded joint fabrication, the written welding procedure specification (WPS) is the 'recipe' for production of a particular weld quality that compliance with the standard fabrication requirements such as in AWS D1.1. However, lot of factors such as arc welding current, arc voltage, welding speed, torch angle, free wire length, nozzle distance, welding position etc. influenced the depth of penetration, bead geometry, heat input and the size of heat affected zone (HAZ) as well as the mechanical properties of the welded steel [12,3]. This sensation recognized that the WPS not only affect the weld quality but has the utmost effect on the fatigue life of welded structure. Minor differences in the welding process and in the weld geometry have a vast impact on the service life of the product [4,5].

Over the year, many steel structural fabricators basically produce a WPS solely to meet the requirement of standard used without assimilating the fatigue improvement technique in the WPS. Probably could be said so far in literature, discussion on the WPS that integrated with fatigue life enhancement is almost nonexistent especially for welded structure that exposed to dynamic loading such as offshore platform and bridges. Probably the reason behind that is due to minimize the cost of the WPS development. However, welding without any improvement somehow, gives raise the catastrophic fatigue failure of the welded structure leading to the loss of many lives. The weld profile is greatly dependent on the continuous development of welding techniques and production quality control especially when it is exposed to local stress concentration, residual stresses and different types of defects. These features as combining with high cyclic and complex service loading that will eventually initiate a trivial crack that finally cause to fatigue failure of the welded joint [6]. Recently new technology has been introduced by PITEC called High Frequency Mechanical Impact/ Pneumatic Impact Treatment (HFMI/PIT) to enhance the fatigue life of the welded structure as shown in Figure 1. It is a tool that user-friendly, effective and reliable method for post-weld fatigue strength improvement technique on welded structures.

Figure 1: Complete equipment set of HFMI/PIT

The HFMI/PIT treatment procedures, quality control measure and fatigue strength improvement assessment are now available in IIW recommendations for the HFMI/PIT treatment. It is applicable to steel structure of plate thicknesses of 5 to 50 mm and for yield strengths ranging from 235 to 960 MPa [7,8]. HFMI/PIT advantages are not only in the application for fatigue strength improvement but also for mitigating the weld induced distortion [9], simple maintenance concept, "slim" design and design optimization [10]. The industrial applications of HFMI/PIT include: Innovative maintenance in steel manufacturer, Steel bridge, Tower of wind energy plant, Duplex mixer shaft, Crane manufacturer, Compressor damper, Component of Press Machine, Steam boiler, Turbine housing, Crane Structure, Ship building, Mass Rapid Transit (MRT) and Roller shaft maintenance. Nevertheless, HFMI/PIT is also capable to be applied at atmospheric and in underwater condition.

Numerous studies on HFMI/PIT treatment have been published during the past decade. Leitner et al. [11] investigated the local fatigue strength of welded and HFMI/PIT post-treated high-strength steel joints of steels S690 and S960, and compared with common construction steel S355. They concluded that HFMI/PIT post-treatment led to a significant fatigue enhancement especially in the high-cycle fatigue region due to a shift of the transition knee point (Nk) to lower load-cycles. In another study [12] on the butt joint and T joint with transverse and longitudinal attachment, they found that the butt joint treated with HFMI/PIT achieved fatigue life almost similar to the fatigue strength of base metal, the T-joint Transition knee point (Nk) shifts to a lower number of load cycles implying a significant increase in endurable strength limit, while the longitudinal attachment HFMI/PIT treated shows an increase of the slope k in the low-cycle fatigue regime. Another research [13] on investigation of the crack propagation of the welded structure of the carbon steel S355 and rehabilitate its using post treatment HFMI/PIT. After the fatigue test, they found the fatigue life of the specimen has a good agreement with the previous investigation.

Several prominent university in European countries also witnessed that the HFMI/PIT is effective method to improve the fatigue life of welded structure. At Belgian Welding Institute (BWI), an extensive investigation [14] was conducted to improve the fatigue properties of welded joints of high strength steels (HSS) by means re-melting techniques (TIG and Plasma dressing) and HFMI/PIT. They found the post-weld treatment techniques gain excellent potential on fatigue life improvement due to the increase in FAT class of dressed stiffeners compared to the current FAT class of 56 of Eurocode III (m=3). Investigation of effect of HFMI/PIT on fatigue life of the four different welded details made of ultra-high strength steels S960, S1100 and S1300 also conducted at the University of Duisburg-Essen in Germany [15]. They found that the fatigue strength of HFMI/PIT treated specimens was at least twice the fatigue strength of the as welded condition. At University of Aalto in Finland [16], they found out that the fatigue strength of improved welds increases with material yield strength, which is about 12.5% increase in strength for every 200 MPa in respect to all available data of fatigue analysis. At Montan University in Austria, the effect of HFMI/PIT for mild structural steel (S355) up to ultra-high strength steel (S960) on fatigue was investigated [17] and from the experimental they found that the base material stress range is increased with HFMI/PIT treatment while all fatigue test data points are above the IIW-recommendation.

Thus, based on these motivations the current project aims to produce a WPS for offshore steel HSLA s460G2+M by using GMAW process with integrating the fatigue life improvement technique using high frequency mechanical impact or pneumatic impact treatment (HFMI/PIT) in the WPS itself.

Process Parameter identification of Manual GMAW for HSLA S460G2+M with Evaluation

Offshore steel HSLA S460G2+M

Offshore steel S460G2+M was specially designed for use in harsh environment and typically used in construction of fixed offshore structures such as oil rigs and service platforms [18]. This steel was produced through Thermo-Mechanically Controlled Processed (TMCP) condition, which shows absolutely excellent mechanical properties and good weldability characteristics. Nowadays, it is common that the choice of material for offshore structure often optimized by choosing high strength material to allow for higher stresses and reduced dimension by taking advantage of the yield strength criterion. The mechanical properties and chemical composition of this material are tabulated in Table 1 and Table 2 accordingly.

Table 1: Mechanical properties of HSLA S460G2+M steel[5]

HSLA S460G2+M

Thickness, t	t<16
Yield strength (Ys)	460 MPa(min)
Tensile Strength (UTS)	540-700 MPa
Ys/UTS	Max.0.93
CVN (- 40°c)	>60J transverse
Elongation.%	17%

Table 2: Chemical composition of HSLA S460G2+M steel[5]

C%	Cu%	Mn%	V%	Si%	Al%	Cr%	Nb%	Ni%
0.19	0.11	1.62	0.10	0.6	0.032	0.10	0.012	0.09

Preliminary Welding Procedure Specification (pWPS)

Preliminary welding procedure specification (pWPS) is an important stage in WPS development. It is a document containing required variables of the welding procedure which needs to be qualified in order to create the qualified welding procedure specification (WPS). In this stage selection of the current and voltage is mostly obtained by trial and error of the currents of GMAW welding machine by using suitable size of filler metal and shielding gas. Somehow an engineer is also referring to parameter recommendation by manufacturer or welding text book. In pWPS all of the essential variable limitations of 4.8 in AWS D1.1 shall apply accordingly [19]. Some of the essential variables are as follows:

Selection of Filler Metal

A general rule for choosing a suitable filler material is to have a similar chemical composition to the base metal. The filler material in most cases should also have a yield and tensile stress value near that of the base metal in question. Some cases however would benefit from having the filler metal yield and tensile stress value slightly below the base metal in what is termed as "undermatched" combination. Having filler metal stress value higher than the base metal is however strongly discouraged as it can lead to complication in mechanical properties.

With regards to the yield and tensile stress value of HSLA S460G2+M steel and its chemical composition, it can narrow down the filler metal to at least ER80X as stipulated in AWS A5.28:2005 [20]. Considering the Nickel content of the base metal, the filler metal ER80S-Ni1 was deemed as the most suitable. The chemical composition and mechanical properties of this filler is shown in Table 3.

Table 3: Chemical & Mechanical Properties ER80S-Ni1 filler metal [20]

Chemical Composition

C%	Cu%	Mn%	Mo%	Si%	P%	Cr%	S%	Ni%
0.12	0.35	1.25	0.35	0.4-0.8	0.025	0.15	0.025	0.8-1.1
Mechanical Properties								
Min. Yield Stress			Min. Tensile Stress			Min. Elongation		
470Mpa			550MPa			24%		

Selection of Shielding Gas

In determining the suitability of the shielding gas combination, ideal process requirement must be balanced with practical consideration that real world welding process undergoes. The AWS A5.28 code specifies that the shielding gas for the filler metal verification process to be 95%-99% Ar and 1%-5% O_2 [20]. While oxygen is a reactive gas in a welding process, its introduction in a small amount helps stabilizes the arc and reduces undercut, resulting in a better weld in practice.

Another drawback of very high to pure level of argon as shielding gas is the shallow weld penetration. On the opposite end, the use of reactive gas such as CO_2 gives excellent penetration at the expense of mechanical weld integrity due to its oxidizing nature. The manufacturer recommended a mixture of 80% Ar and 20% CO_2 as a good compromise between weld quality and penetration while also allowing the arc to operate in short-circuit transfer mode as per AWS C5.6 [21].

Preheating and Interpass Temperature

The recommended preheat temperature of a base and filler metal combination is mostly a function of its carbon equivalent (CE), composition parameter (P_{cm}) and hydrogen level susceptibility index grouping. Annex H of D1.1:2015 (Guideline on Alternative Methods for Determining Preheat) outlines the method for determining the preheat and interpass for a particular type of steel.

For the S460G2+M steel, the CE is 0.28 and the P_{cm} is 0.20as given by the manufacturer. As the welding process involved in this test is GMAW with clean solid wire filler metal, this weld joint falls under group H1 – extra-low hydrogen. The P_{cm} value of 0.20 also puts this into group B of the Susceptibility Index Grouping, giving it the preheat and interpass temperature of 20˚C for all type of restraints or clamping with less than 20mm thickness.

Weld Specimen, Joint Design Preparation and welding process

The weld specimen was prepared in accordance to clause 5.14 preparation of base metal [22], which is the basic requirement is the base plate must be free form scale, rust and foreign material. Some of the variables of the weld specimen, joint design and welding process are tabulated in Table 4. The details concerning these variables are tabulated in PQR and WPS.

Table 4: Variables of the weld specimen, joint design and welding process

Material	: HSLA S460G2+M
Size (LxWxT) mm	: (300x180x10)mm
Joint design	: Single V groove
Groove angle	: 60˚
Roof face	: 2 mm
Roof gap	: 2.5 mm
Welding type	: GMAW
Shielding gas	: 80% Ar + 20% CO_2.
Filler metal	: ER80S-Ni1

Tensile and Side Bend Test Evaluation

Tensile Specimen results

As parts of the requirement of the WPS qualification in clause 4.9.3, the tensile tests were conducted on the two tensile samples of HSLA S460G2+M accordingly. The results of the S460G2+M are presented in Table 5. There are two specimens for tensile test. The specimen of T1 broke in base metal and the specimen T2 broke in HAZ area as shown in Figure 5. T1 obtained 600MPa while T2 obtained around 584MPa which is both specimens strength is complying with the raw material strength range (540MPa – 700MPa). Base on the acceptance criteria in section 4 clause 4.9.3.5 of AWS D1 [23]. Absolutely, the results are acceptable and proved that the welding parameters used to weld the HSLA S460G2+M seemly the right combination.

Table 5: Tensile test result of welded S460G2+M

Properties	:	As welded	
		T1	T2
Width , mm	:	20.15	20.12
Thickness , mm	:	9.98	9.97
Cross sectional area (A) , mm^2	:	201.10	200.60
Yield Load, N	:	107580.28	107704.53
Yield stress, N/mm^2	:	534.97	536.92
Maximum Load, N	:	120785.98	118238.91
Tensile strength , N/mm^2	:	600.64	589.44
Position of Fracture	:	Broke at the BM	Broke at HAZ

Figure 5: Tensile test of the welded specimen of S460G2+M

<u>Side Bend Test Specimen results</u>

As shown in Table 6, there were four samples designated as S1, S2, S3 and S4 for side bend test in order to determine the soundness of the welded joint as shown in Figure 6. From the observation, all the samples are in excellent condition, no sign for cracks or defects in the bend areas which are comply with the acceptance criteria in section 4 clauses 4.9.3.3 of AWSD1.1 [23]. However for sample S2 there is a sign of discontinuity below 3mm which is still acceptable by the standard.

Table 6: Tensile test result of welded S460G2+M

Bend Test			
Diameter of Former	:	50.8mm	
Angle of Bend	:	180º	
Type of Bend	:	Result	Remarks
Side Bend (S1)	:	Satisfactory	No open discontinuity
Side Bend (S2)	:	Satisfactory	No open discontinuity
Side Bend (S3)	:	Satisfactory	Visible open discontinuity 2.63mm at weld metal
Side Bend (S4)	:	Satisfactory	No open discontinuity

Figure 6: Bend test samples of the welded S460G2+M

Base on the results of the side bend tests, the selection of the welding parameters combinations for manual GMAW is suitable for the material HSLA S460G2+M.

Process Parameter identification of HFMI/PIT with Evaluation

Welds Specimen Preparation for HFMI/PIT treatment

The weld specimen for HFMI/PIT parameter identification is shown in Figure 7. This weld specimen is made from HSLA S460G2+M.

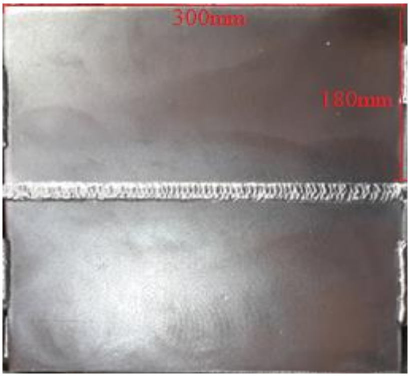


Figure 7: Welds specimen of HFMI/PIT

The welds should be cleaned from traces of oxide, scale, spatter and other foreign material by using wire brushed or grinding before the HFMI/PIT treatment as required by the standard requirements in IIW section XIII [24][27]. The weld bead profile also should meet the acceptance limits for weld profile quality level of acceptance in AWSD1.1 section 4.9.1 [23].

<u>HFMI/PIT Treatment</u>

The HFMI/PIT treatment is conducted along the weld toe of the butt joint. For this treatment, the pneumatic air pressure is 6 bars, velocity is 20 to 30 cm per minute and a frequency of 90 Hz is suggested. The radius of the hardened pin used is R = 2 mm with 30° to 60° of pin movement along the weld toe the welds. These particular parameters are also written in HFMI/PIT procedure treatment.

Tensile Fatigue specimen and evaluation

To ensure the selected HFMI/PIT parameter suitable to use as fatigue life improvement for the material S460G2+M, pre-test treatments is applied on untreated and treated tensile fatigue specimens and compare the tensile values of raw and as welded tensile fatigue specimens as shown in Table 6 accordingly. The tensile fatigue specimen geometry is shown in Figure 8, which is prepared based on the recommendation of fatigue design specimen of IIW section XIII.

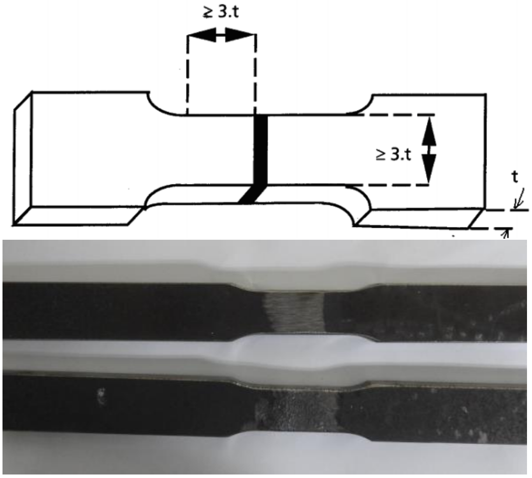


Figure 8: Tensile fatigue specimen geometry

Table 6: Comparison of tensile fatigue specimen value between untreated and treated with HFMI/PIT of specimen S460G2+M

Condition	ID	Tensile Strength (MPa)	Average (MPa)	Position of Fracture
Raw Material	T1	585.65	584.20	Base Metal
	T2	582.75		Base Metal
As Welded	T1	600.64	595.04	Base Metal
	T2	589.44		HAZ
PIT Treated	T1	592.55	605.11	Base Metal
	T2	617.66		Base Metal

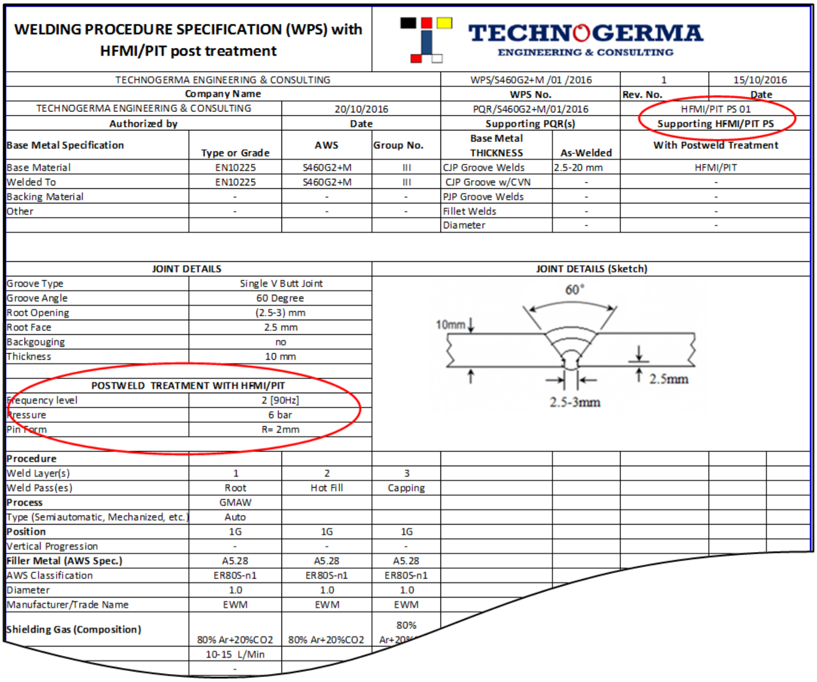
Figure 10: Untreated Specimen –break in weld metal and HAZ

From the Table 6, it is obviously the tensile strength of the HFMI/PIT treated of the fatigue tensile specimen was slightly increased around 605MPa, which is around 2% higher compare to the raw and as welded tensile specimens. Even though the increment is shallow it proved that the HFMI/PIT treatment parameter is seemly suitable for fatigue improvement for welded joint. However, further investigation of these HFMI/PIT parameters will be conducted to transverse and longitudinal in future to confirm the fatigue improvement using HFMI/PIT.

Results and Discussion

Conceptual Welding Procedure Specification (WPS) With Integrated Fatigue Life Improvement

WPS could be contains a welding parameters for best welds quality and strength of the welded joint. But, when the welded structure subjected to cyclic loading some adjustment should be made on the WPS. Hence, conceptual WPS with integrated fatigue life improvement using HFMI/PIT is recommended to cope with the effect of cyclic loading to welded joint as shown in Figure 11.



WELDING PROCEDURE SPECIFICATION (WPS) with HFMI/PIT post treatment

TECHNOGERMA ENGINEERING & CONSULTING

TECHNOGERMA ENGINEERING & CONSULTING	WPS/S460G2+M /01 /2016	1	15/10/2016
Company Name	WPS No.	Rev. No.	Date

TECHNOGERMA ENGINEERING & CONSULTING	20/10/2016	PQR/S460G2+M/01/2016	HFMI/PIT PS 01
Authorized by	Date	Supporting PQR(s)	Supporting HFMI/PIT PS

Base Metal Specification	Type or Grade	AWS	Group No.	Base Metal THICKNESS	As-Welded	With Postweld Treatment
Base Material	EN10225	S460G2+M	III	CJP Groove Welds	2.5-20 mm	HFMI/PIT
Welded To	EN10225	S460G2+M	III	CJP Groove w/CVN	-	-
Backing Material	-	-	-	PJP Groove Welds	-	-
Other	-	-	-	Fillet Welds	-	-
				Diameter	-	-

JOINT DETAILS	
Groove Type	Single V Butt Joint
Groove Angle	60 Degree
Root Opening	(2.5-3) mm
Root Face	2.5 mm
Backgouging	no
Thickness	10 mm

JOINT DETAILS (Sketch)

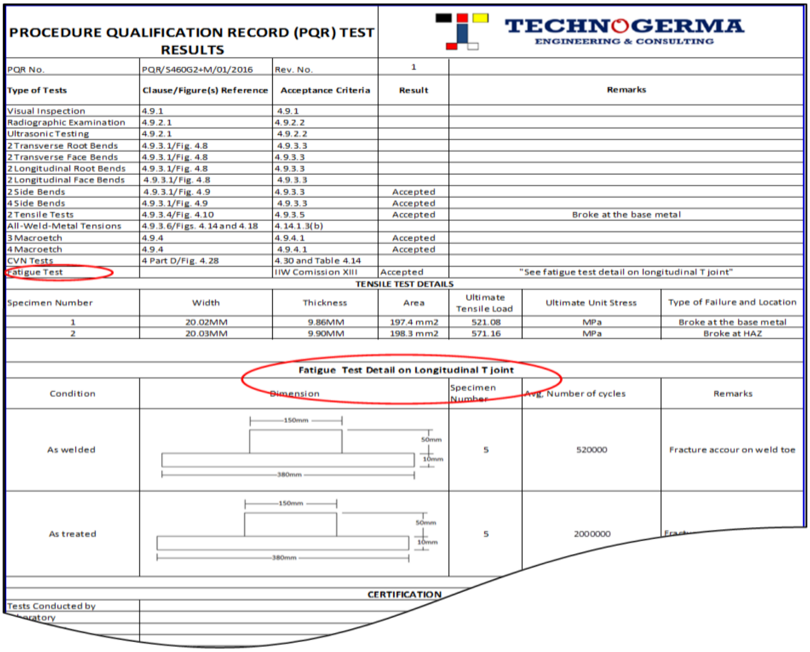
POSTWELD TREATMENT WITH HFMI/PIT	
Frequency level	2 [90Hz]
Pressure	6 bar
Pin Form	R= 2mm

Procedure			
Weld Layer(s)	1	2	3
Weld Pass(es)	Root	Hot Fill	Capping
Process	GMAW		
Type (Semiautomatic, Mechanized, etc.)	Auto		
Position	1G	1G	1G
Vertical Progression	-	-	-
Filler Metal (AWS Spec.)	A5.28	A5.28	A5.28
AWS Classification	ER80S-n1	ER80S-n1	ER80S-n1
Diameter	1.0	1.0	1.0
Manufacturer/Trade Name	EWM	EWM	EWM
Shielding Gas (Composition)	80% Ar+20%CO2	80% Ar+20%CO2	80% Ar+20%...
	10-15 L/Min		
	-		

Figure 11: Conceptual WPS with fatigue integrated treatment.

In section 8.4 of AWS D1.1M 2015 [25] stated that the reconditioning of critical weld details geometry for fatigue improvement such as profile improvements, toe grinding, peening, TIG dressing and toe grinding plus hammer peening may be used when written procedures have been approved by the Engineer. However it is less popular due to the consequences arise from these treatment methods for instant TIG dressing will be imparting another residual stress on the surface treated and toe graining caused excessive surface removal etc. Therefore, these factors maybe one of the reasons why almost development of WPS not assimilating those method broadly. But for HFMI/PIT post treatment nowadays it was recognised in European countries as anti-aging, fatigue life extension and strength improvement [7]. Thus, assimilating this post treatment method into WPS should not become a problem. In addition, the quality assurances of this method recently have been publishing in IIW commissions XIII accordingly.

WPS is not complete without PQR. It is a document that checks whether the standard is being followed by inspecting and answering the document regarding specific areas and tests. An inclusion of the HFMI/PIT treatment in recommended WPS in Figure 11 previously. The PQR also should have the results of fatigue improvement of the weld specimen as illustrated in Figure 12.



PROCEDURE QUALIFICATION RECORD (PQR) TEST RESULTS

TECHNOGERMA ENGINEERING & CONSULTING

PQR No.	PQR/S460G2+M/01/2016	Rev. No.	1	
Type of Tests	**Clause/Figure(s) Reference**	**Acceptance Criteria**	**Result**	**Remarks**
Visual Inspection	4.9.1	4.9.1		
Radiographic Examination	4.9.2.1	4.9.2.2		
Ultrasonic Testing	4.9.2.1	4.9.2.2		
2 Transverse Root Bends	4.9.3.1/Fig. 4.8	4.9.3.3		
2 Transverse Face Bends	4.9.3.1/Fig. 4.8	4.9.3.3		
2 Longitudinal Root Bends	4.9.3.1/Fig. 4.8	4.9.3.3		
2 Longitudinal Face Bends	4.9.3.1/Fig. 4.8	4.9.3.3		
2 Side Bends	4.9.3.1/Fig. 4.9	4.9.3.3	Accepted	
4 Side Bends	4.9.3.1/Fig. 4.9	4.9.3.3	Accepted	
2 Tensile Tests	4.9.3.4/Fig. 4.10	4.9.3.5	Accepted	Broke at the base metal
All-Weld-Metal Tensions	4.9.3.6/Figs. 4.14 and 4.18	4.14.1.3(b)		
3 Macroetch	4.9.4	4.9.4.1	Accepted	
4 Macroetch	4.9.4	4.9.4.1	Accepted	
CVN Tests	4 Part D/Fig. 4.28	4.30 and Table 4.14		
Fatigue Test		IIW Comission XIII	Accepted	"See fatigue test detail on longitudinal T joint"

TENSILE TEST DETAILS

Specimen Number	Width	Thickness	Area	Ultimate Tensile Load	Ultimate Unit Stress	Type of Failure and Location
1	20.02MM	9.86MM	197.4 mm2	521.08	MPa	Broke at the base metal
2	20.03MM	9.90MM	198.3 mm2	571.16	MPa	Broke at HAZ

Fatigue Test Detail on Longitudinal T joint

Condition	Dimension	Specimen Number	Avg. Number of cycles	Remarks
As welded	150mm; 50mm; 10mm; 380mm	5	520000	Fracture accour on weld toe
As treated	150mm; 50mm; 10mm; 380mm	5	2000000	Fra

CERTIFICATION

Tests Conducted by	
Laboratory	

Figure 12: Conceptual PQR with test results of the HFMI/PIT treatment

Base on the fatigue test results of the untreated and treated with HFMI/PIT of the longitudinal Fillet joint reported in PQR in Figure 12. It is obvious that the HFMI/PIT treatment capable to increase the strength of the tensile fatigue specimen. Thus, inclusion of HFMI/PIT treatment in recommended WPS is reasonable and comprehensible.

HFMI/PIT Procedure Specification

HFMI/PIT procedure specification for fatigue improvement is a guideline to conduct the appropriate post treatment process when integrating the HFMI/PIT treatment in recommended WPS in Figure 11. The suitable HFMI/PIT treatment parameters are written and shown in Figure 13.

<table>
<tr><td colspan="3">HFMI/PIT Treatment Procedure</td><td colspan="3">TECHNOGERMA
ENGINEERING & CONSULTING</td></tr>
<tr><td colspan="3">Costumer:</td><td colspan="3">XX SDN BHD</td></tr>
<tr><td colspan="3">Reference No:</td><td colspan="3">HFMI/PIT PS 2</td></tr>
<tr><td>Purchase Order No:</td><td colspan="2">-</td><td colspan="3">Project Description</td></tr>
<tr><td>Description:</td><td colspan="2">Fillet Joint</td><td colspan="3" rowspan="2">To elimimite the hpt spot of the butt joint uding HFMI/PIT tool</td></tr>
<tr><td>Material:</td><td colspan="2">S460G2+M</td></tr>
<tr><td colspan="3">Objective of treatment:</td><td colspan="3">Fatigue life enhancement by inducing compressive residual stress on the critical area (hot spot) and producing smooth transition of the weld toe</td></tr>
<tr><td colspan="6">Treatment Parameter</td></tr>
<tr><td rowspan="2">Operator & Inspector:</td><td colspan="2">Device Identification</td><td colspan="3">Parameter Setting</td></tr>
<tr><td>Model:</td><td>Device No:</td><td colspan="2">Frequency:</td><td>Pressure:</td></tr>
<tr><td>Technogerma and Consultant</td><td>PIT Weld Line 10</td><td>Tec-1</td><td colspan="2">2 (90Hz)</td><td>6 bar</td></tr>
<tr><td colspan="3">Treatment angle</td><td colspan="3">Feed Speed</td></tr>
<tr><td colspan="3">30-60 degrees</td><td colspan="3">5-20cm/min</td></tr>
<tr><td colspan="6">Pin Holder and Pin</td></tr>
<tr><td>Pin Holder</td><td>Pin</td><td>Diameter</td><td colspan="2">Length of Pin</td><td>Pin form</td></tr>
<tr><td>Standard BH8-S10--01-A</td><td>SB8-S20-01-B</td><td>8</td><td colspan="2">80 mm</td><td>R= 2.0 mm</td></tr>
<tr><td colspan="2">Treatment Standard:</td><td colspan="4"></td></tr>
<tr><td colspan="6">Treatment contributed by:</td></tr>
<tr><td>Organization</td><td colspan="2">Name</td><td colspan="3">Function</td></tr>
<tr><td>Technogerma and Consultant</td><td colspan="2">Mr.Azzriq</td><td colspan="3">Director</td></tr>
</table>

PIT Tool Calibration Report				TECHNOGERMA ENGINEERING & CONSULTING			
Costumer:				XX SDN BHD			
Report No:				1			
Purchase Order No:		-					
Treatment Parameter							
		Device Identification			**Parameter Setting**		
Operator & Inspector:		**Model:**		**Device No**	**Frequency:**		**Pressure:**
Dahia A		PIT Weld Line 10		Tec-1	2 (90Hz)		6 bar
Pin Holder and Pin							
Pin Holder		**Pin**		**Diameter**	**Length of Pin**		**Pin form**
Standard BH8-S10--01-A		SB8-S20-01-B		8	80 mm		R= 2.0 mm
Report							
Curvature before treatment	Curvature after treatment		Difference/result		Test Result (Ok/NOK) ok if ≥0.8mm	Name(QM)	Date:Tool Working Hour count
0	1.33		1.33		ok	Ackiel Azzriq	-

Figure 13: HFMI/PIT-PS treatment procedures

In HFMI/PIT treatment procedure, the important parameters consisting of air pressure, velocity, frequency, treatment angles and the pin diameter. For this treatment, the pneumatic air pressure is 90 psi or 6 bars, velocity is 20 to 30 cm per minute, 90 Hz frequency, 30°to 60° treatment angle and 2 mm pin radius is suggested. The treatment is applied on welded specimens without additional static pre-stressing. The HFMI/PIT treatment procedures are also complemented with the tool calibration report of the HFMI/PIT equipment. It is essential to ensure the resulting of the HFMI/PIT groove dimension for a specified power setting and treatment are consistence with pre-determined limits.

To attain optimum results, quality controls by mean of visual inspection is carried out using digital or manual magnifier and the groove depth must be smooth and shiny without line along the defined welds toe. No thin line representing original fusion line should visible in the groove as and The HFMI/PIT groove must be continuous with no breaks.

Conclusion

In this study identification of welding parameter of manual GMAW processes for offshore plate S460G2+M and HFMI/PIT fatigue improvement parameters have been made in the favour of qualification of welding procedure specification (WPS) as well as the tensile strength improvement using HFMI/PIT. From this identification parameter processes some conclusions arise as follows:

1. The good combination of the welding parameter for offshore material S460G2+M can be obtained by substantial trial and error of the current and voltage of the GMAW welding machine.
2. Integrate the HFMI/PIT treatment in WPS is essential for welded structure exposed to dynamic loading.
3. HFMI/PIT treatment is effective for fatigue and strength improvement of the welded joint.
4. HFMI/PIT treatment on the welded joint is reliable on the view point of potential fatigue failure such as at the weld toe, edges etc.
5. Inclusion of HFMI/PIT treatment procedures in WPS is important in order to be aligned with the quality assurance requirements in IIW section XIII recommendation. Hence, it is proposed in form of conceptual WPS with treatment procedure.

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