TURNITIN Analysis of Welding Procedure Specifications

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Analysis of Welding Procedure Specifications for steel line pipe material

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Abstract
This study proposes the welding process steel line pipe material of API5L Grade X52 diameter Ø8 inch SCH80 type, subjected to the good quality of the product by following the Welding Procedure Specifications (WPS). The purpose of welding using WPS is to ensure that the welding process follows the correct stages because the steps are proper. The weld results will be free from defects and safe for line pipes. In order to confirm the WPS quality, the characterisations of macrostructure, microstructure, and mechanical properties were analysed. The welding process results by following the procedure specifications, from macrostructure shown no porosity, and sample without following the welding procedure specifications shown porosity at weld metal position. The tensile test sample following the welding procedure specifications showed high strength and ductility compared with the samples without welding procedure specifications. This phenomenon occurs due to the grain size of the martensitic structure and a little bit of growth compared with a sample without following the welding procedure specifications. Furthermore, the bending test result shows that both samples have no crack at the weld metal position.

Keywords:
Bending test;
Macrostructure;
Microstructure;
Tensile Strength;
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INTRODUCTION

Oil and gas construction is the most important part of running the petroleum industry worldwide [1, 2, 3]. Along with technology development, today's constructions need effective methods to create efficient steps in the construction world [3, 4, 5, 6, 7, 8, 9]. The welding method is one of the methods that is an essential part of construction [10][11]. Almost all construction buildings use this joining by welding. For example, one of the access bridges at the jetty uses a construction weld joint type from a jetty bridge in the form of a truss made of high-strength steel. Steel element components of this bridge structure use the API5L Grade X52 standard. For that, it is necessary to have welding, which quality assurance refers to by the American Welding Society (AWS) [12]. In welding, there is a need for a Welding Procedure and Specifications (WPS) to get good and correct welding results [13]. Unfortunately, welding often fails due to not conforming to standards and specifications. For this reason, this study will review the welding standards for steel pipe materials API5L Grade X52 diameter Ø8 inch SCH80 type. WPS, which specifically refers to the application of pipe steel with API5L Grade X52, has never been carried out and discussed [14][15].

However, pipe steel welding is indispensable for industrial applications such as oil and gas fluid lines, bridges, and others that require a continuous welding process that meets standards [16][17]. WPS is a document containing welding parameter variables that aim to be used as a reference for a welder or welding operator in carrying out welding work or welding joints per the provisions in the code of

ASME, API and AWS. The result of the quality product is outstanding.

There is no porosity obtained in the welding result using the WPS method. This performance occurs due to following the welding parameters on the WPS and is carried out with a balanced welding speed at the liquid temperature. Therefore, this research aims to produce WPS, which can be used as the basis for implementing pipe steel welding fabrication in the form of catwalks (jetty bridges). In order to ensure the weld will be free from defects and safe for line pipe, the weld metal would investigate using macrostructure, microstructure, tensile and bending tests.

METHODS

The step by steps of the materials analysis using the welding procedure specification is first, compiling the draft welding procedure (WPS); the second step is performing welding by following the parameters in the draft procedure (WPS); the third step is preparing a test specimen for the destructive test; the fourth step is evaluating the results of the destructive test with all the standard code; the fifth step is recording and certify the test results on the Procedure Qualification Record (PQR) sheet. The WPS was made based on AWS D1.1 2015.

In making a WPS or welding procedure, many variables must be known so that the welding results obtained follow the criteria or acceptance criteria that the code has determined. Therefore, the variables contained in the WPS are divided into three parts: Essential Variables, Supplement Essential Variables and Non-Essential Variables.

Variable Essential Supplement

Definition of Essential Supplement Variable is a variable that will affect the results of welded joints if impact testing is carried out. So this variable will be essential if an impact test is carried out and becomes non-essential if an impact test is not carried out. Examples of Essential Supplement Variables are Group Number and Filler metal classification.

Non-Essential Variable

Definition of Non-Essential Variable is a variable that does not affect the mechanical properties of the welded joint. So, this variable is changed, so there is no need to requalify or create a new WPS. Examples of Non-Essential Variables are Type of welded joint or groove shape, Backing, Width of gap (root spacing), and welding position.

Table 1 lists the chemical composition of materials API5L Grade X52. Two specimen materials are used for API5L Grade X52 steel line pipe dimensions of 500 mm. The manufacturing process of a workpiece is carried out by a CNC cutting machine and then by welding [18]. The Shielded Metal Arc Welding (SMAW) is used in this research with the root pass location of ESAB OK 53.04 E7016 electrode type, and BOHLER E7016H4R is used for the filler and cap [19][20].

The welding sequence process is applied in this study. The welding for root pass uses electrodes with a diameter of 2.5 mm, and the step by step of welding sequence is shown in Figure 1. The welding sequence follows AWS standard WPS [12].

Figure 1 shows the photograph of the welding for root pass using the electrodes with a diameter of 2.5 mm and (b) Welding sequence step: (i) Strike the arc, (ii) Move the arc to create a bead, (iii) Shape the weld bead, (iv) Chip and brush the weld between passes.

Macrostructure, microstructure and mechanical properties are investigated as the characterisations of each welding process. The samples are polished at a welding metal position to analyse the microstructure. Tensile strength is measured as one of the destructive test procedures. The standard of ASTM E8/AWS D1.1 is confirmed applied for the tensile test material [13]. The type of tensile test is a reduced section tension test or transverse specimen at an ambient temperature of 25 ± 2 °C. The testing method uses used ASTM A370: 2016 standard.

Furthermore, the bending test material type is determined as a transverse specimen. The bending test is examined at a temperature of 25 ± 2 °C, by following the reference to the AWS code D1.1: 2015 on the ASTM E190-92 standard and the 180° of line pipe.

The dimension of the bending test specimen is shown in Table 2. Table 2 describes each test parameter, i.e. temperature test, test weld rebar, former diameter, shoulder distance, bend angle, and test specimen rebar ~25°C, 12.7, 38.1, 60.3 mm, 180°C and 10d, respectively.

Table 1. Chemical Composition of Materials API5L Grade X52 (mass%)

C	Si	Mn	P	S	Cu	Ni	Mo
0.26	-	1.4	0.03	0.03	0.05	0.05	0.15

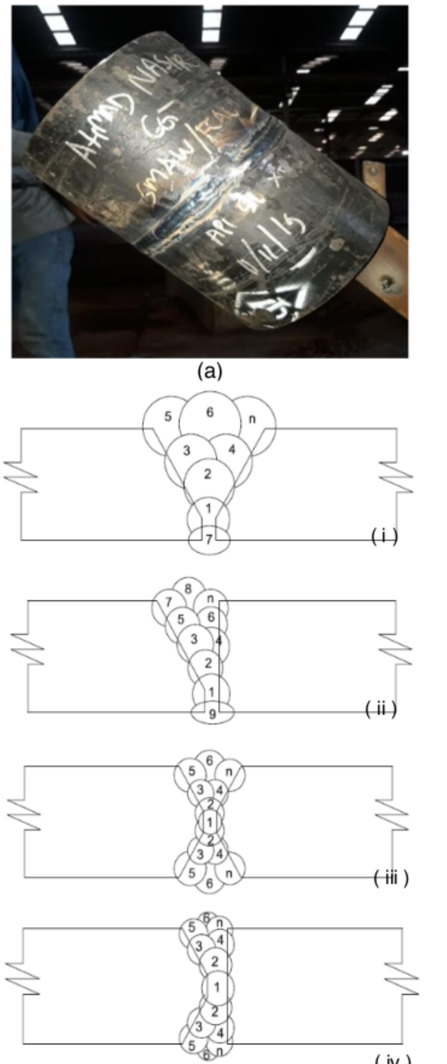


Figure 1. (a) Photograph of the welding for root pass using the electrodes with a diameter of 2.5 mm and (b) Welding sequence step: (i) Strike the arc, (ii) Move the arc to create a bead, (iii) Shape the weld bead, (iv) Chip and brush the weld between passes

Table 2. The Dimensions of the Bending Test Specimen

Test Parameter	Dimensions
Temperature test	25 ± 2°C
Test weld rebar	12.7 mm
Former diameter	38.1 mm
Shoulder distance	60.3 mm
Bend angle	180°
Test specimen rebar	10 d

RESULTS AND ANALYSIS

Welding Procedure and Specifications

The step by steps for creating the welding procedure and specifications are first by compiling a draft of the WPS. The second step is performing welding by following the parameters in the draft procedure (WPS). The third step is preparing a test specimen and examined with the destructive test. The fourth step is evaluating the results of the destructive test with all the standard code. The fifth step is recording and certifying the test results on the Procedure Qualification Record (PQR) sheet.

Table 3. Welding Procedure Specifications of Line Pipe Material 8" API5L Gr X52 [20]

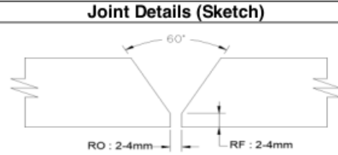
Base Metal	Specification	Type or Grade	AWS Group No.
Base Material	API 5L GB/T 1591	X52 Q35B	I or II or Equivalent
Welded to	API 5L GB/T 1591	X52 Q35B	I or II or Equivalent
Backing Material	If Required, Base Metal or Weld Metal		

Base Metal Thickness	As Welded	With PWHT
CJP Groove Welds	5 mm-Unlimited	-
CJP Groove Welds w/CVN	-	-
PJP Groove Welds	Any Thickness	-
Fillet Welds	Any Thickness	-
Diameter	≥4 Inch and over	-

Joint Details	
Groove Type	Any AWS D1.1 groove welded joint
Groove Angle	Any AWS D1.1 groove welded joint
Root Opening	Any AWS D1.1 groove welded joint
Root Face	Any AWS D1.1 groove welded joint
Back gouging	No or yes when required
Method	Arc Air Gouging + Grinding or only grinding

Post Weld Heat Treatment	
Temperature	None
Time at Temperature	-
Other	-

Joint Details (Sketch)



Welding Sequence

The WPS was made based on AWS D1.1 2015 standard, and the welding parameter could see in Table 3 and Table 4, respectively [21, 22, 23, 24]. Based on the WPS of line pipe material 8" API5L Gr X52, each base metal is defined in the AWS group number.

In addition, the requirement of PWHT is defined in the base metal thickness [25, 26, 27].

Table 4. Parameter of Welding Process [20]

PROCEDURE (WELDING PARAMETER)					
Weld Layer(s)	Root	Hot	Fill	Fill	Cap
Weld Pass(es)	All	All	All	All	All
Process	SMAW	SMAW	SMAW	FCAWgs	FCAWgs
Type (semiautomatic, mechanised, etc.)	Manual	Manual	Manual	Semiautomatic	Semiautomatic
Position	All, and PJP TKY only	All, and PJP TKY only	All, and PJP TKY only	All, and PJP TKY only	All, and PJP TKY only
Vertical Progression	Uphil l	Uphil l	Uphil l	Uphil l	Uphil l
Filler Metal (AWS Spec.)	A 5.1	A 5.1	A 5.1	A 5.36	A 5.36
AWS Classification	E7016	E7016	E7016	E71T1-C1A0-CS1-H8	E71T1-C1A0-CS1-H8
Diameter	2.5 ; 3.2 mm	2.5 ; 3.2 mm	2.5 ; 3.2 mm	1.2 mm	1.2 mm
Manufacturer / Trade Name	BOHLER FOX S EV 47 ESAB OK5 3.4 or Equivalent	BOHLER FOX S EV 47 ESAB OK5 3.4 or Equivalent	BOHLER FOX S EV 47 ESAB OK5 3.4 or Equivalent	BOHLER/Ti 71-T1C ESAB/Weld 71T-1 or Equivalent	BOHLER/Ti 71-T1C ESAB/Weld 71T-1 or Equivalent
Shielding Gas (Composition)	-	-	-	100% CO 2	100% CO 2
Flow Rate	-	-	-	15 – 36 L/min	15 – 36 L/min
Nozzle Size	-	-	-	#4 or Any	#4 or Any
Preheat Temperature Min	Ambient or ≥30°C (Removal Moisture)	Ambient or ≥30°C (Removal Moisture)	Ambient or ≥30°C (Removal Moisture)	Ambient or ≥30°C (Removal Moisture)	Ambient or ≥30°C (Removal Moisture)
Interpass Temperature Max	≤250°C	≤250°C	≤250°C	≤250°C	≤250°C
Electrical Characteristics	-	-	-	-	-
Current Type & Polarity	DCEP	DCEP	DCEP	DCEP	DCEP
Transfer Mode	Globular	Globular	Globular	Globular	Globular
Power Source Type (cc, cv, etc)	CC	CC	CC	CV	CV
Amp	60-95	70-120	70-120	130-220	130-220
Volts	18-25	19-26	19-26	20-26	20-26
Wire Feed Speed (mm/min)	-	-	-	-	-
Travel Speed	58-90	82-100	82-100	141-175	141-175
Heat Input (KJ/mm)	0.72-2.46	0.80-2.29	0.80-2.29	0.89-2.43	0.89-2.43
Technique	-	-	-	-	-
Stringer or Weave	Stringer or Weave	Stringer or Weave	Stringer or Weave	Stringer or Weave	Stringer or Weave
Multi or Single Pass (per side)	Single Pass	Single Pass	Multi & Single Pass	Multi & Single Pass	Multi & Single Pass
Oscillation (Mechanized, Automatic)	-	-	-	-	-
Number of Electrodes	-	-	-	1	1
Contact Tube to Work Distance	-	-	-	12mm – 25mm	12mm – 25mm
Peening	-	-	-	None	None
Interpass Cleaning	Grind & Brush	Grind & Brush	Grind & Brush	Grind & Brush	Grind & Brush

Macrostructure

ASTM E3, ASTM E407, and ASTM E340 are observed and followed as the standard for preparing the metallographic specimens, indicating the welding zone. Figure 2 presents the welding zone's macrostructure photo without following the WPS method. The small black spot indicates the porosity of the weld. Porosity occurs due to rapid cooling then air entrapped during the welding process.

Figure 3 depicts the macrostructure photo of welding following the WPS method. The black spots or porosity, as presented in Figure 2, disappear. This phenomenon occurs because when welding is carried out with various parameters. The different welding parameters are tested, such as speed and liquid temperature. This result is obtained by appropriate welding conditions balance.

Microstructure

Figure 4 presents the microstructure of the base metal location. The microstructure indicates the black color as perlite and the white color as ferrite. Figured 5 depicted the Heat-affected Zone (HAZ) area's microstructure for the material without following the WPS. The microstructure is pointing to the white needle as the martensitic structure.

This phenomenon occurs due to the rapid cooling during the welding process or the phase liquid change to the phase solid with a faster solidification process.

Figure 6 shows the microstructure at the Heat Affected Zone (HAZ) area, which follows the WPS method. The result could be seen that the martensitic structure size is larger than the microstructure without following the WPS method. This phenomenon is occurring because the cooling speed was not too fast.

Figure 7 depicts the microstructure of weld metal without following the WPS method. The result is indicating that the magnificent martensitic structure occurs due to an increase in temperature during welding, and then a rapid cooling process happens.

Figure 8 presents the microstructure of weld metal which uses the WPS method. The size of martensitic structures is shown as bigger. These phenomena occur due to an increase in temperature during welding and a slower cooling process.

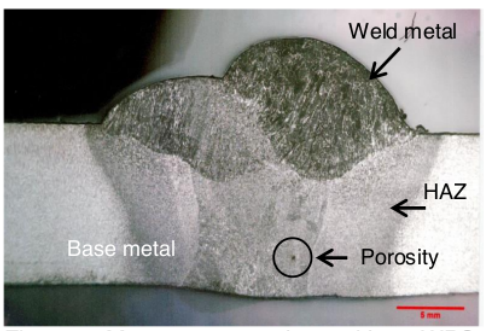


Figure 2. Macrostructure photo without WPS

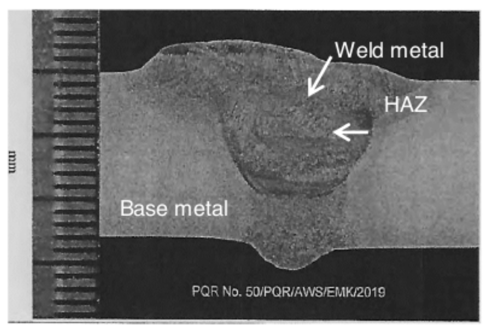


Figure 3. Macrostructure photo with WPS

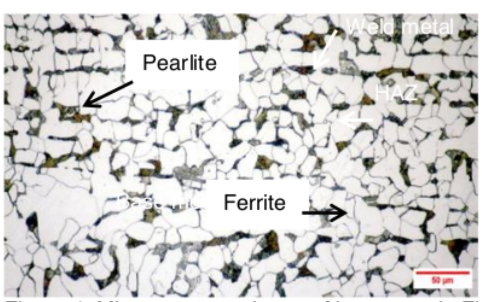


Figure 4. Microstructure photos of base metal

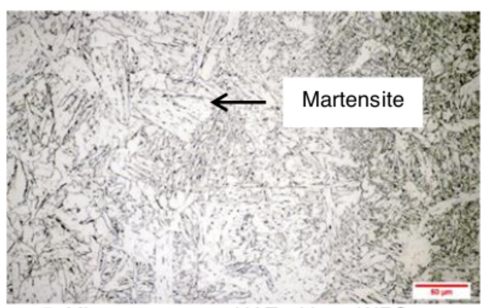


Figure 5. Microstructure at HAZ without WPS

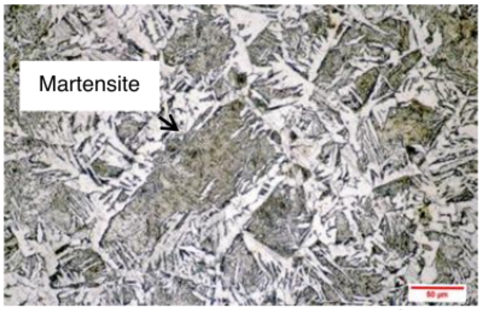


Figure 6. Microstructure at HAZ with WPS

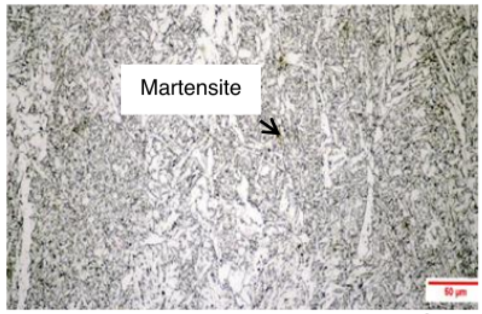


Figure 7. Microstructure at weld metal without WPS

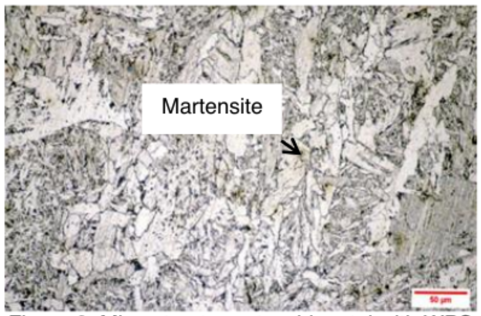


Figure 8. Microstructure at weld metal with WPS

Tensile and Bending Test

The result of the tensile test is listed in Table 5. The Ultimate Tensile Strength (UTS) of the weld specimen without following the WPS is 550 N/m^2, the yield strength is 432 N/m^2, and the elongation is around 23%. Meanwhile, the weld specimen follows the WPS, the UTS is 557 N/m^2, the yield strength is 450 Nm^{2,} and the elongation is 29%. The weld specimen that follows the WPS has higher ductility. There is no crack or porosity in the weld metal area found on both specimens. However, a fracture is found on the base metal.

Bending test parameters are by ASTM E190-92 standards and carried out in a temperature test set of 25 ± 2° C and bending of the 180°-line pipe.

Table 5. Result of Tensile Test.

Specimens	Non-WPS	WPS
Tensile Strength (kN)	550 N/m^2	557 N/m^2
Yield Strength (kN)	432N/m^2	450 Nm^2
Elongation (mm)	23%	29%
Location of Failure	Base Metal	Base Metal

Table 6. Observation result of Bending Test.

No. of Spec.	WPS or Non WPS	Bending Type	Obser vation	Result
SB1	Non WPS	Side Bend	Good	Accepted
SB2	Non WPS	Side Bend	Good	Accepted
SB3	WPS	Side Bend	Good	Accepted
SB4	WPS	Side Bend	Good	Accepted

Table 6 shows the bending test result for the weld specimens with and without following the WPS. The result obtained for the line pipe specimen material of API5L Grade X52 diameter Ø8" are both has no crack at the weld metal as resulted in [28][29].

CONCLUSIONS

The analysis of WPS for steel line pipe material of API5L Grade X52 diameter Ø8 inch SCH80 has been reported in this study. The conclusion from the macrostructure analysis is the specimens following the WPS have no porosity and larger martensitic areas, compared with the sample without following the WPS. The tensile test specimen with WPS has higher strength, and good elongation compared with the specimen without following the WPS. Both specimens with and without WPS have almost similar bending test results, and no crack was found on the weld metal.

Further, WPS is used for high-pressure pipeline construction, one of the applications in oil and gas construction that requires safety and high quality in the facilities. Therefore, the future study of this research is the usage of the WPS for critical equipment such as oil and gas facilities.

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