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Tensile test analysis for steel welding connections as a basis for compiling Welding Procedure Specification (WPS)

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KEYWORDS
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ABSTRACT Welding is the train manufacturing industry's most widely used method of joining metal plates. The welding method and the qualification of the weld results can be ascertained using the WPS document. The construction of WPS begins with setting up standards that will obtain the most appropriate welding procedures, then determining the type of material strength test to ensure the quality of the welds. This research was conducted to determine whether the S355 J2 steel can withstand the stress of the load before it is deformed by the welding procedure that has been determined. Tensile tests were carried out on welded S355 J2 steel. The tensile test results obtained a higher value than the standard material that is not welded. Therefore, it can be ensured that the welding procedure used is correct. This is caused by several factors, including the type of welding according to the material, the use of the type of electrode, the making of the joint design, and the correct welding parameters.

1. INTRODUCTION

The rapid development of technology and industry (Amalia & Soepriyanto, 2019). Welding is integral to developing industrial improvement in metal production engineering (Ediyansyah & Simanjuntak, 2020). Welding is a connection that connects two or more objects by heating parts or a combination of the two so that they unite like a whole object (Amalia & Rahmatilah, 2022). Welding is a metal joining technique that melting some of the parent metal and filler metal with or without additional holes in the castings, making a hard layer on the equipment, thickening worn parts, and various other repairs (Naharuddin et al., 2017). The working principle of metal involves metallurgy in metal joints which binds part of the metal and filler metal with or without an adder to produce a continuous connection.

In GMAW (Gas Metal Arc Welding) welding, the filler metal is channeled continuously due to heat from an electric arc coming from the tip of the electrode with the surface of the workpiece (Anwar & Ardiansyah, 2020). During welding, the electrode, which also functions as a filler metal, melts together with the parent metal (Ketaren et al., 2019). The shielding gas used in the GMAW mechanism is a noble gas with 97% argon for thin plates and 100% helium for thick plates (Cheng et al., 2021).

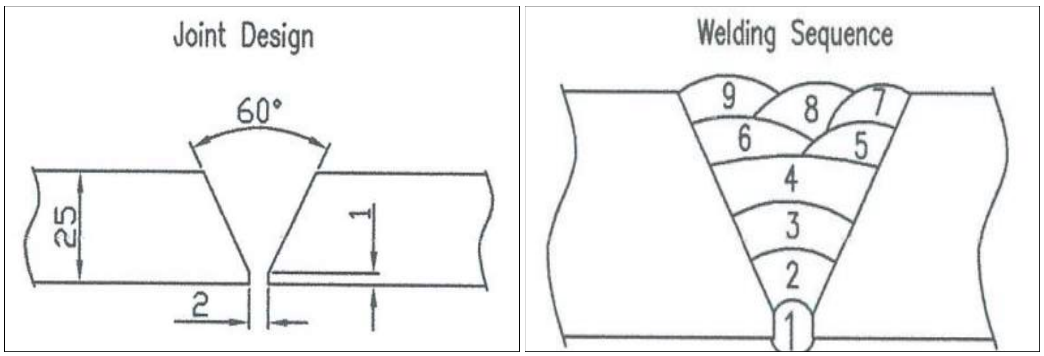
Each result of welding will have a quality based on several things. The quality of the welds is based on the quality of the material to be welded, the suitability of the process carried out, and the ability of a welder or welder. A standard with its parameters is needed to achieve the quality of welds that are always high and always the same. One of the parameters used to assess the quality of welds is the Welding Procedure Specification (WPS). This makes WPS very important in industrial welding, especially in industries where most production processes, such as automotive, ship, and train manufacturing, use weldings.

In the WPS preparation stage, both destructive (destructive) and non-destructive (non-destructive) material testing is required (Sodik et al., 2019). One type of destructive testing in the preparation of WPS is tensile testing (Rinaldi et al., 2019). The tensile test is a material test that pulls it to the point where the material experiences maximum stress and strain until it undergoes deformation (Rahmatika et al., 2021). Deformation experienced by a material is elastic or plastic deformation. The tensile testing process aims to determine the resistance's ability to pull at a specific power (Davis, 2004). Knowing the value of the material's tensile strength after being welded, a standard can be made, which is one of the parameters in compiling the WPS.

This study aims to determine the tensile test procedure performed on the welded material and the effect of welding on the tensile test results (Fakhri et al., 2022; Wijoyo et al., 2021). In addition, this study also aims to find out how the WPS preparation procedure is after the tensile test results are obtained on S355 J2 steel.

2. METHOD

The research method is observation and literature study based on welding experiments on the material and its tensile test. The experiment was performed by preparing a metal plate material to be welded using a steel plate S355 J2. After that, the plate is welded according to the proce-



(a) Design and Joint Setting, Source: PT. INKA, 2021

(b) Welding Layer Order, Source: PT. INKA, 2021.

FIGURE 1. Design and Joint Setting

dure on Preliminary WPS. Then a tensile test is performed on the welded plate divided into two samples. The tensile test results will be considered in the WPS compilation.

3. RESULTS AND DISSCUSION

3.1 Tensile Test Procedure

The Procedure for carrying out the tensile test is the same as for other tensile tests. It is just that before the specimen is used as a coupon test, it must be welded first. In the case of tensile testing, it is executed as follows:

3.1.1 Preparation of Tools and Materials

The tools used in this experiment are GMAW and tensile test tool. The material used is S355 J2 steel with a thickness of 24,3 mm and a width of 25 mm. From the specification data obtained, the S355 J2 material with dimensions between 17 – 40 mm has a yield strength of 345 MPa and an ultimate tensile strength of 430 – 630 MPa. With this, we can assume the results obtained from the tensile test are not far from the number if the material used is appropriate and the welding carried out is running well.

3.1.2 Design and Joint Setting

The two plates to be welded are arranged to form a V connection, and both are clamped with clamps so as not to shift their position. Furthermore, the two plates are welded flatly (1G). The type of connection is butt joint/groove welded and welded up to nin layers, as shown in Figure 1a and Figure 1b below.

The butt joint/groove welded joint is the most efficient type of joint. Here, the penetration used is complete. The weld metal is formed in nine layers, reducing ductility but increasing the tensile strength and welding speed. This is because with the addition of layers will occur in the post-heat process in the layer below and preheat on the layer above it so that the heat input is lower and the cooling that occurs will be faster, which in turn will affect the structure granules where will be smaller and more evenly distributed.

3.1.3 Sample Making

Sampling is set up according to the AWS D1.1 standard. The sample was formed into two specimens with the same test to increase the results' accuracy. After the welding process with GMAW, the machining process is carried out to form the test sample withdrawal by creating a test coupon.

3.1.4 Tensile Test

After the test coupon is made, a tensile test is carried out on the sample. The purpose of the tensile test here is to determine the yield load and ultimate load before the sample breaks. Then the yield stress and ultimate stress can be calculated. The result of the strain is unnecessary because, as a side plate of the train carriage, it only needs how much force the material can withstand before it becomes plastic and breaks.

3.2 Tensile Test Results

The test specimen data for two experimental plates of S355 J2 steel carried out with a tensile test can be seen in Table 1. This data includes the dimensions of the specimen and the results of the tests performed.

Meanwhile, the graphs obtained from the tensile test equipment can be seen in Figure 2a and Figure 2b.

TABLE 1. The Occurrence of Conjunction

	Dimension (mm)			Test Result (kN)	
No	Thickness	Width	Area	Yield Load	Ult. Load
1.	24,30	25,00	607,50	245,83	339,79
2.	23,30	25,00	607,50	248,27	341,40

Calculations can be made by dividing the yield load or ultimate load by the sample surface area seen in Equation 1 to get the yield stress (YSS) and ultimate stress values (USS).

$$YSS1 = \frac{YieldLoad1}{Area} = \frac{245,83kN}{607.50mm^2} = 404,66MPa$$

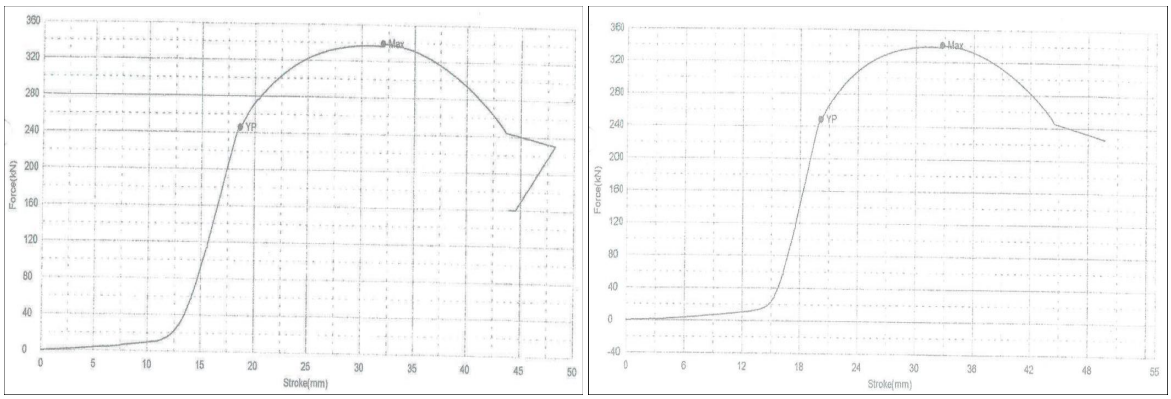
$$"USS1 = \frac{UltimateLoad1}{Area} = \frac{339,79kN}{607.5mm^2} = 559,32MPa$$

$$YSS2 = \frac{YieldLoad2}{Area} = \frac{248,27kN}{607.50mm^2} = 408,67MPa$$

$$"USS1 = \frac{UltimateLoad2}{Area} = \frac{341,40kN}{607.5mm^2} = 561,98MPa$$

3.3 Effect of Welding on Tensile Test Results

Referring to the results of the tensile test on the specimen, it can be assumed that the welds produced in this process



(a) Graph of Tensile Test Results of Specimen 1, Source: PT. INKA, 2021

(b) Graph of Tensile Test Result of Specimen 2, Source: PT. INKA, 2021

FIGURE 2. Tensile Test Results Specimen

are good. Based on the standard, it is known that the yield stress on S355 J2 with dimensions between 17 – 40 mm is 345 MPa, where the tensile test results for specimen 1 is 404,66 MPa and for specimen 2 is 408,67 MPa. This value is higher than the standard material before welding. Judging from the specification of the base metal's tensile strength, the break's location is in the base metal area, which has lower tensile stress than the welded area.

The ultimate stress value was obtained in specimens 1 of 559,32 MPa and 2 of 561,98 MPa. These two values are still in the standard category of S355 J2 material, which is between 470 – 630. This means welding does not reduce the ultimate yield stress of the base metal and is still within the standard range. For a more straightforward comparison, see Figure 5.

According to the existing theory, the welding factors that can affect the results of this weld are the type of electrode used, the shape of the connection, the number of weld layers, and the absence of weld defects formed. The electrode used during welding is ER 70 S-6, an electrode rod with a minimum tensile strength of 70.000 psi or 482 MPa of weld metal in solid wire and a grade 6 chemical composition. The connection form used is a single V butt joint. The number of weld layers is nine, which increases the tensile strength, and no weld defects occur. All of these aspects are by the material used as a welding material arranged in Preliminary WPS, causing the tensile test results of the specimen to be estimated to match or exceed the material standard even before being welded.

3.4 Preparations of WPS After Getting Tensile Test Results

Several criteria must be met in compiling and ratifying a WPS, including a draft or Preliminary WPS and recording test results on the PQR or Procedure Qualification Record. Preliminary WPS that has been made will underlie aspects of specimen determination and testing, which will be recorded on the PQR. Preliminary WPS is made based on the standards used when welding, which in this case is AWS D1.1. In addition to standards, another thing that underlies the preparation of Preliminary WPS is the decision of the compiler to find a match between the welding material and the welding procedure to be carried out. Meanwhile, PQR is a record of data from the results of welding tests that have been carried out based on WPS, which contains variables that will be used during the welding of the test plate. After

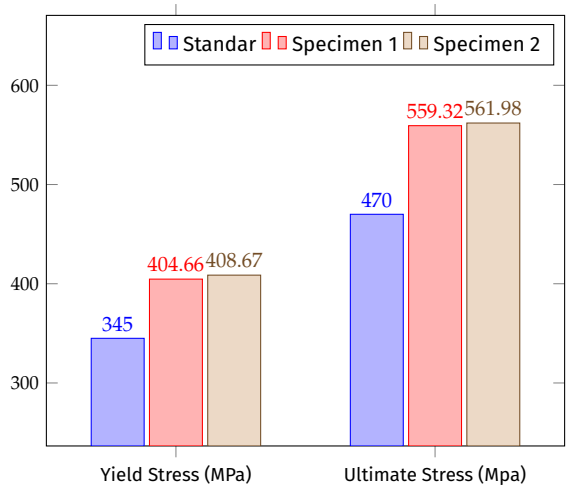


FIGURE 3. Graph of Comparison of Test Results With Standards, Source: Tensile test result

getting the tensile test results, it must be recorded on the PQR.

The tensile test results obtained are yield stress and ultimate stress. Both these variables are declared acceptable if they have a value according to or above the base metal standard, which can then be recorded in the PQR. Because the test results can be accepted in PQR, the previous Preliminary WPS can be validated as WPS by adding additional variables.

4. CONCLUSION

From the results of research and experiments that have been obtained, it can be concluded: The procedure for carrying out a tensile test for welded materials starts from preparing material with sizes according to Preliminary WPS, preparing the design and joint settings that will be carried out during welding, paying attention to the welding parameters to be used, doing welding on the specimen, machining the specimen to form a test coupon, performing a tensile test on the tensile test equipment, and record the results in the PQR.

Yield stress obtained from the test results on specimen 1 is 404,66 MPa, and on specimen 2 is 408,67 MPa. These results are more significant than the standard material before welded, which is 345 MPa. The ultimate stress obtained

from the test results on specimen 1 is 559,32 MPa, and on specimen 2 is 561,98 MPa. These results are still within the standard material's scope before welding, which is between 470 – 630 MPa.

The results obtained are by or above the standard so that they can be recorded on the PQR, and the WPS document can be validated, which can be used as a guide in welding S355 J2 material as train carriage wall plates.

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