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ANALYSIS OF MECHANICAL PROPERTIES OF SS 400 STEEL MATERIAL WITH FCAW WELDING METHOD

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Abstract
Welding is a method of joining metals that involves metallurgical bonds at the metal joints by melting some of the parent metal and filler metal with or without additional metal and producing a continuous joint. Tensile strength is one of the things that is very much considered in the selection of a material for industry. SS 400 is a type of carbon steel that has a carbon content of 0.23%. For the repair industry, the most suitable is to use welding (MMAW), but the Flux-Cored Arc Welding (FCAW) process has more advantages and has been appreciated by the industry for years. The tests in this report are tensile and bending tests. In the Tensile test, the highest tensile strength was 567.5 N / mm2 on sample T1, the lowest tensile strength was 570.9 N / mm2 on sample T2 and the average tensile strength value was 569.2 N / mm2. In the Face Bending test, the maximum load on sample F1 is 135,227.00 N, on sample F2 is 131,877.70 N and the average value of the maximum load is 133,552.35 N with the test results being cracks at the joints of samples F1 and F2. In the Face Bending test, the maximum load on sample R1 is 123,828.400 N, on sample R2 is 131,624.40 N and the average value of the maximum load is 127,726.40 N with the test results being cracks at the joints of sample R1 and fractures at the joints of sample R2.

Keywords: *FCAW, WPS, , SS 400, Tensile Test, Bending Test*

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Introduction

Welding is a method of joining metals involving metallurgical bonds at the metal joints by melting some of the parent metal and filler metal with or without additional metal and producing a continuous joint. Good joint efficiency in simple geometric shapes without spending large costs, makes the welding process widely used in the fields of construction and fabrication. Among them are bridge construction, pressure vessel fabrication, oil and gas pipes, and so on. The quality advantage of the results of metal joining by welding cannot be separated from the quality of both the process procedure and the quality of the welder. Welding procedure qualification is very important in the welding process [1].

Tensile strength is one of the things that is very important in selecting a material for industry. Factors that affect the tensile strength of a material are very diverse, one of which is due to changes in structure due to the heating process. One of the heating given to a material is welding. Metals that experience the effects of heating due to welding will experience changes in the microstructure around the weld area. The shape of the microstructure depends on the highest temperature achieved during the welding process, the welding speed and the cooling rate achieved during the welding process [2].
SS 400 is a type of carbon steel that has a carbon content of 0.23%. It is a type of structural steel plate that is widely used in the construction sector. This type of steel has good weldability properties. However, high-speed welding has the potential for porosity defects. Because of its good weldability properties, this type of steel is still the most widely used in the construction sector [3].
The quality of the welding must be considered to maintain the quality produced, of course in accordance with existing standards, for the process must refer to WPS (Welding Procedure Standard) and WPQ (Welding Procedure Qualification). In the world of welding, the most common welding

process used in the metal and alloy joining industry is Flux-Cored Arc Welding (FCAW). Flux-Cored Arc Welding (FCAW) has several advantages such as high deposition rates, more tolerant to rust and large scale than GMAW, simpler and more adaptable than SAW, less operator expertise is needed than GMAW, has high productivity than SMAW and good surface results. For the repair industry, the most suitable method is to use welding (MMAW), but the Flux-Cored Arc Welding (FCAW) process has more advantages and has been appreciated by industry circles for many years [4].

Flux Cored Arc Welding (FCAW)

FCAW welding is an electric arc welding whose welding wire contains flux (center core protector). FCAW welding is a combination of GMAW, SMAW, and SAW welding processes. In FCAW welding, the energy source uses DC or AC electric current taken from a power plant or through a transformer and rectifier (Jones, 2015).

FCAW welding is a type of electric welding whose working process supplies filler electrodes or welding wires mechanically continuously into the electric arc. The welding wire used for FCAW welding is made of thin metal that is rolled cylindrically and then filled with flux according to its use. The FCAW welding process is actually the same as GMAW welding, but the difference is that the tubular welding wire contains flux while GMAW is solid (Jones, 2015).

Based on the protection method, FCAW welding can be divided into 2, namely:

1. Self shelding FCAW (Self-protection) is a process to protect the molten weld metal by using gas from the evaporation or reaction of the flux core.
2. Gas shielding FCAW (Gas protection) is protection with dual gas, namely protecting the molten weld metal by using its own gas and also added with protective gas from outside the system.

The two methods above both produce welding slag from the flux in the welding wire which functions to protect the weld metal during the solidification process. However, the difference in the methods above lies in the additional gas supply system and the welding torch (welding gun) used.

FCAW welding based on its operating method is divided into 2, namely:

1. Automatic (Machine Automatic).
2. Semi Automatic (Semi Automatic).

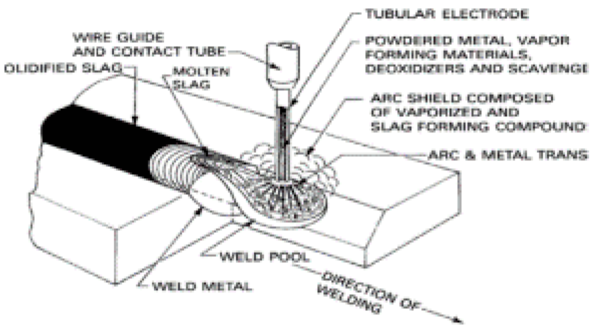
The main properties (Principal features) of FCAW in the welding process:

1. FCAW welding has welding metallurgical properties that can be controlled by selecting flux.
2. FCAW welding has high productivity, because it can supply continuous welding electrodes.
3. When forming beads or molten welding ridges can be protected by thick slag.

FCAW welding generally uses CO2 gas or a mixture of CO2 with Argon as a shielding gas. However, to avoid the weld metal being contaminated by outside air or to avoid porosity, a flux containing oxygen or deoxidizer binding properties must be selected (Jones, 2015).

The main applications and uses of FCAW welding:

1). Carbon steel.
2). Stainless steel.
3). Cast steel.
4). Low alloy carbon steel.
5). Thin steel spot welding.



FCAW Welding Process Image

FCAW Electrode

FCAW is a welding process that uses a continuous electrode wire, where the flux core will protect the welding fluid and then form a slag (thin) after the welding fluid solidifies, such as the manual arc welding process [6].

FCAW Welding Wire Image

Classification of FCAW Welding Wire Electrodes:
FCAW Welding Wire Electrode Classification Table [3]

AWS Classification	Welding Current	Shielding Gas	Single or Multiple Pass
EXXT-1	DCEP	CO_2	Multiple
EXXT-2	DCEP	CO_2	Single
EXXT-3	DCEP	None	Single
EXXT-4	DCEP	None	Multiple
EXXT-5	DCEP	CO_2	Multiple
EXXT-6	DCEP	None	Multiple
EXXT-7	DCEN	None	Multiple
EXXT-8	DCEN	None	Multiple
EXXT-9	DCEN	None	Multiple
EXXT-10	DCEN	None	Single
EXXT-11	DCEN	None	Multiple
EXXT-12	DCEN	None	Multiple
EXXT-13	DCEN	CO_2	Single
EXXT-14	DCEN	None	Single
EXXT-G	Not Specified	Not Specified	Multiple
EXXT-GS	Not Specified	Not Specified	Single

RESEARCH METHOD

1 Tools

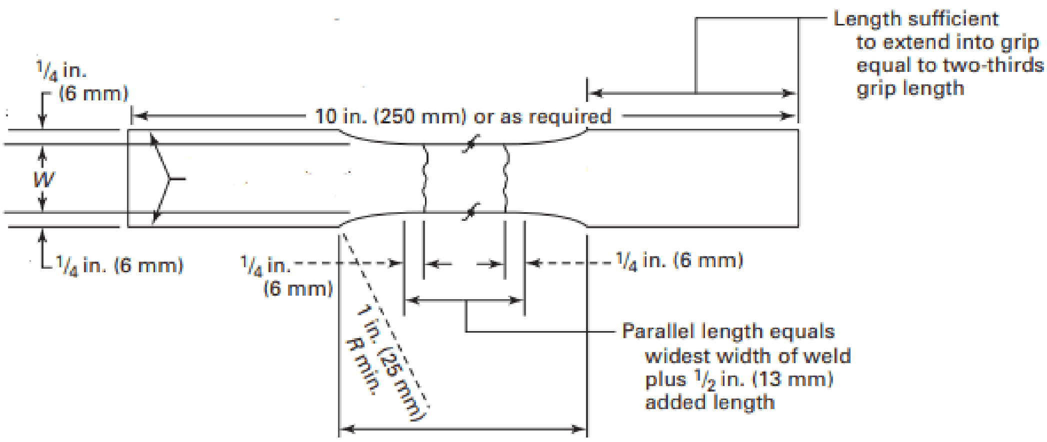
The tools used in the study are as follows:

a. FCAW Welding Machine is used for the welding process or to connect specimens
b. Vernier Caliper is used for measurements on specimens
c. Wire Cutting is used to cut specimens and to make 700 angle welds.
d. Cutting Grinder is used to tidy up the welding results on the specimen.
e. Tensile testing machine is used for testing the tensile stress and compressive strength of the welding material or material

f. Bending testing machine is used for bending testing on specimens

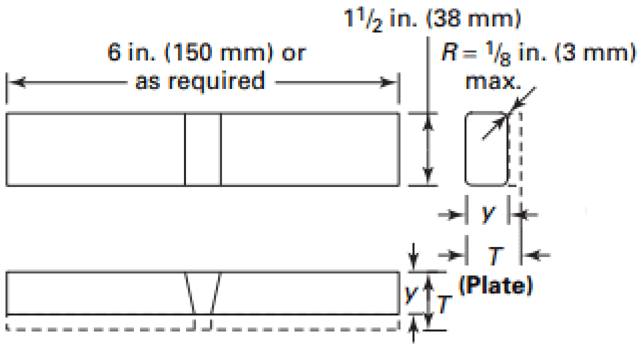
2 Materials
a. Materials used in this study SS 400 STEEL
b. Welding electrodes

Test Specimen Specifications
The specifications of the test materials to be used are as follows:
Tensile Test (Tensile Test)
The manufacture of tensile test specimens refers to QW 462.1(a) ASME BPVC Standard section IX as shown in Figure 5.



Tensile Test Specimen Dimensions

Based on QW-463.1(a) in the ASME BPVC section IX standard, the bending test conducted consisted of 4 specimens consisting of 2 root bend test specimens and 2 face bend test specimens. For cutting the test specimens, refer to QW-462.3(a) shown in Figure 6 for details of the size of the face bend test specimen and Figure 7 for details of the size of the root bend test specimen.



Face Bend Test Specimen

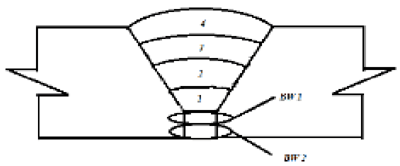
Welding Procedure
Experimental research was conducted on SS 400 Material with dimensions of 292x304x25 with the following WPS (Welding Procedure Specification) welding parameters:

Process	: FCAW
Position	: 3G
Material	: SS 400 thk. 25 mm
Type of Groove	: Single V Groove Butt Joint

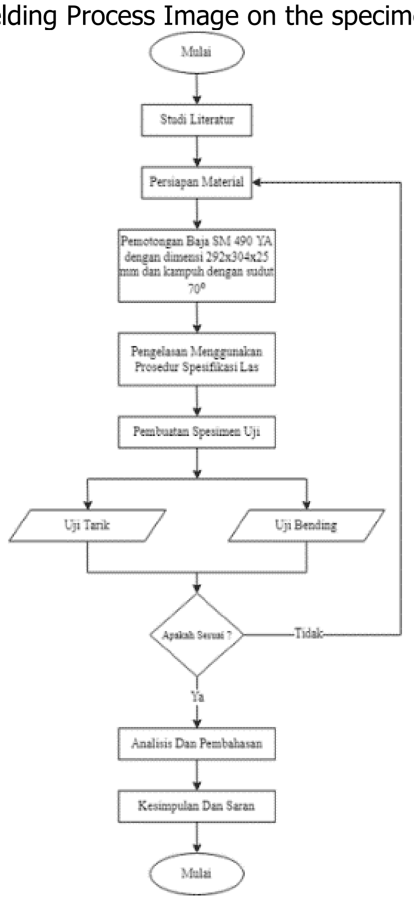
Machine : AOTAI MIG500
Wire : A5.20 E71T-1C

Tabel Welding Procedure Specification.

Pass (es)	**1**	**2**	**3**	**4**	**5**	**6**
Layer (s)	M	M	M	M	BW1	BW2
Welding Process	FCAW	FCAW	FCAW	FCAW	FCAW	FCAW
Wire Diameter	1,2	1,2	1,2	1,2	1,2	1,2
Polarity	DCEP	DCEP	DCEP	DCEP	DCEP	DCEP
Ampere	180	215	210	205	211	209
Voltage	25	26	27	28	26	26



Welding Process Image on the specimen.



Flowchart Image.

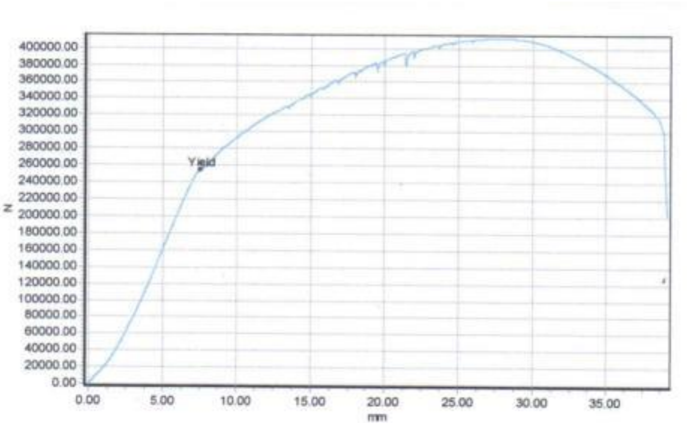
RESULTS AND DISCUSSION

Specimen Testing

1. Tensile Test Specimen

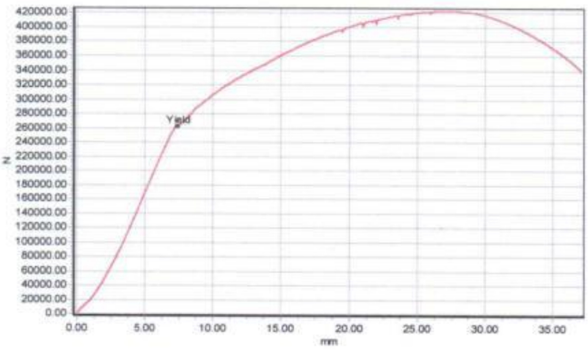
In the tensile testing of sample specimens 1 and 2, the image below is a comparison of the specimens before and after the tensile test.

(1) **(2)**



Tensile Test Graph Image (1)

shows the tensile strength graph with a maximum load obtained at 412113.60 N and cracks immediately occur at an elongation of more than 35.00 mm



Tensile Test Graph Image (2)

shows the tensile strength graph with a maximum load obtained at 423192.80 N and cracks immediately occur at an elongation of less than 40.00 mm.

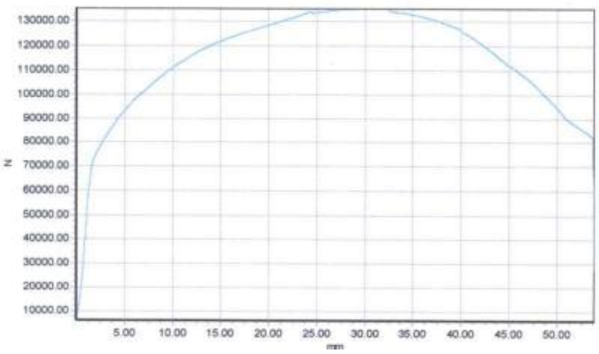
No	**Sample uji**	**Max Load (N)**	**TensileStrength (N/mm^2)**	**Elongation (%)**
1	SAMPLE T1	412113.6	567.5	32.76
2	SAMPLE T2	423192.8	570.9	30.96
Mean		417653.2	569.2	31.86

2. Face Bending Test Specimen
In the bending test of sample specimens 1 and 2, the image below is a comparison of the specimens before the Face Bending test and after the Face Bending test.

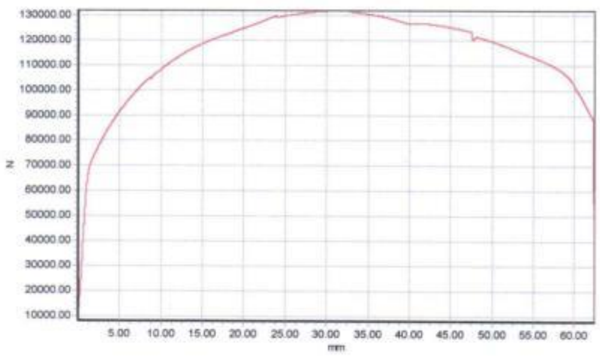
Images of Specimen F1 and F2 Before Face Bending Test

Specimen Image After Face Bending Test

From the image shows the Face Bending strength graph with a maximum load obtained at 135,227.00 N and immediately caused a crack at the joint.



From the image, it shows the Face Bending strength graph with a maximum load obtained at 131,877.70 N and immediately caused a crack at the joint.



No	**Sample uji**	**Max Load (N)**	**Sudut Lengkung**	**Diameter Penekuk (mm)**
1	SAMPLE F1	135,227.00	180^o	40
2	SAMPLE F2	131,887.70	180^o	40
Mean		133,552.35	180^o	40

CONCLUSION

After conducting tensile testing and bending testing with 2 samples for tensile testing and 4 samples for bending testing provided in each test by finding the average value, the test results state:

1. In tensile testing, the highest tensile strength is 567.5 N / mm2 on sample T1, the lowest tensile strength is 570.9 N / mm2 on sample T2 and the average tensile strength value is 569.2 N / mm2.
2. In the Face Bending test, the maximum load on sample F1 is 135,227.00 N, on sample F2 is 131,877.70 N and the average maximum load value is 133,552.35 N with the test results being cracks at the joints of samples F1 and F2.
3. In the Face Bending test, the maximum load on sample R1 was 123,828,400 N, on sample R2 was 131,624.40 N and the average value of the maximum load was 127,726.40 N with the test results being cracks at the R1 sample joints and fractures at the R2 sample joints.

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