Effect of Different Preheating’s Temperature towards the Integrity of Weldment AISI 1045

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Abstract. The purpose of this paper is to show the effect of different preheating’s temperature for different thickness of AISI 1045 before it was welded by using Shield Metal Arc Welding (SMAW). The temperature of preheating approach that will be use are 200°C, 250°C and 300°C and were applied to pair of base plate metal with different thickness of 16mm, 22mm and 28mm. Then the pair samples had been welded by using Shield Metal Arc Welding (SMAW). To monitoring the temperature, non-contact type instrument which is thermomapping was used in this study. Time was recorded after preheating was applied and then was stopped when the desired temperature has been obtained. As to evaluate the weld quality, the macrostructure observation, dye penetration, hardness, and tensile test were conducted. As the result, it found that the electrode rod with size16mm and 22mm required temperature around 200°C while for 28mm required temperature up to 250°C. This paper will give a deeper understanding about the effect of preheating in term of strength of joining. The result obtained from this study can be used to assist welder while performing welding on medium carbon steel.

1. Introduction
Welding has been widely used in industry due to its strength to last longer in period. However, when it comes to weld material with higher carbon content, the possibilities of defects to occur is high. One of the defects that always associated with medium carbon steel is crack. The crack occurs when the hydrogen trapped inside the material, do not manage to fully escape. The crack occur at the weld bead obviously will affect the weld joint thus will decrease the strength and quality. As a response to that problem, preheating is applied to diminish the occurrence of crack. However, after doing some research, the suggested preheat provided just mentioned 200°C-300°C. The different thickness of medium carbon steel, for sure require different heat input. There were no duration time and temperature have been stated when preheating this material. To those welders who were not using temperature indicator like thermocouple or non-contact thermomapping, they were just rely on their experiences when performing preheat which sometimes not reliable. For this study, the scope was narrowed just to find the sufficient time taken and temperature for preheating towards different thickness (16mm, 22mm and 28mm) of AISI before it was welded by using Shield Metal Arc Welding (SMAW). Then, all the tests have been conducted to determine if there were differences in term of integrity of weldment for different thickness.
2. Research Work

The sample composition material need to first by undergoing Arc Spectrometer Test. Then sample will be preheating at several temperatures before weld. There are three stages need to be go through to get the good result in the research. The first stage is ensuring only the good welded sample will go through mechanical properties test. To determine the good welded sample, die penetration test will be perform to the sample. Two mechanical properties will be performed which are tensile test and hardness test. The last stage is to verify the sample that tested in mechanical test is good sample in term of material structure. Where in this test, the sample need to be cut and prepare for macrostructure observation. The material that had been used was medium carbon steel, AISI 1045. This research was done by applying preheat with temperature 200°C, 250°C and 300°C to the different thickness of 16mm, 22mm and 28mm before it was welded by Shield Metal Arc Welding.

2.1. Sample Preparation

All the specimen material with different thickness of 16mm, 22mm and 28mm was cut by using cutter into desired dimension for the welding requirement which is 10mm x 80 mm and also suitable use for testing requirement.

2.1.1. Arc Spectrometer Test. Some of the specimen material were cut, cleaning and do a facing process by using lathe machine. The material composition of this specimen will be checking to ensure it composition is following the composition of element that provided by AISI 1045. The Spectrometer test was conducted to get the chemical composition in medium carbon steel. The testing was carried out at foundry lab by using Arc Spark Optical Emission Spectrometer Tester. Measurement done by the specimen was placed on the support and then the Arc Spark Optical Emission Spectrometer Tester will spark on a few areas of the surfaces. As the specimen standard is confirm, then it can be proceed to preheating process.

2.1.2. Preheating and Welding. Preheating of the specimen conducted by using oxy-acetylene flame combine with a rotating chamber machine were the specimen will be place inside it. The temperature of preheating that applied to the specimen will be monitor by using thermomapping device. This to ensure the entire specimen will absorb the same heat level that already set in this research. Shield Metal Arc Welding (SMAW) was using to joining the specimen pair. The welding technique and position for welding used was stringer 5G. The constant parameter for SMAW are shown at the below:

| Table 1. Constant Parameter. |
|-------------------------------|
| Parameter Setting             |
| Type of Parameter             |
| Current                       |
| Voltage                       |
| Type of Weld Joint            |
| Type of Electrode             |

| Type of Parameter | Parameter Setting |
|-------------------|-------------------|
| Current           | 100A              |
| Voltage           | 25V               |
| Type of Weld Joint| Double Butt Joint |
| Type of Electrode | Low hydrogen E7016|

Preheating process begin by set the consumption of combination oxygen and acetylene to get the desired flame as in table 2. Then the torch was pointed to the material with a fixed distance 15mm. As to get the uniform temperature, the specimen was clamped to the machine which will assist the specimen to rotate. The torch was maintained at fixed point for 2 minutes. Then, non-contact thermomapping will measure the temperature as it dropped time by time. This same process was performed for 200°C, 250°C and 300°C towards different thickness of 16mm, 22mm and 28mm.

After that, the welding process can be proceed to join the specimen pair. The power supply of the machine was turned on and the equipment was setup as mention in table 1. For leading direct current straight polarity (DCSP), the electrode was clamped at positive (+ve) terminal while the base metal was clamped at negative (-ve) terminal. The current and voltage was set to 110 A and 25 V. For the materials, the root distance was set to 1mm. For a good quality weld bead, the rod was positioned at angle of 45 from the horizon. The rod then was tapped to produce a welding arc before welding took place. The arc gap was constantly maintained 1.5mm as possible and the rotating machine’s speed was
controlled. The stringer technique was used along the welding process. Once finished, the slag was removed out by using chipping hammer and wire brush.

| Table 2. Preheating Parameter Setting |
|--------------------------------------|
| Preheating Parameter | Thermal Setting          |
| Type of gas            | Oxygen and Acetylene     |
| Pressure               | 2 bar (Oxygen), 0.5 bar (acetylene) |

2.2. Checking sample condition

Once all the samples were completely welded, second stage of testing then was performed to check and select the good for mechanical properties test. This test is known as NDT (Non Destructive Testing) because it does not destruct the physical properties of the specimen. Basically, it will show up any defects where a very fine dye can penetrate. The steps taken involving pre-cleaning, apply the penetrant and post cleaning.

Dye penetrant examination is one of the most popular nondestructive testing (NDT) methods in the industry. It is economical, and just require minimal training when compared to other NDE methods. The purpose is to check for material flaws open to the surface. Welds are the most common item inspected. Once cleaned, apply the penetrant (a bright red liquid dye). Spray plenty on the welds. Leave the dye to penetrate, normally for about 20 minutes. The time scale is usually printed on the can or on the product data sheet. Cleaning again. It need to remove excess dye from the area. Use a dry tissue to remove excess dye, then spray cleaner onto a clean cloth for final cleaning. Once it's all clean again, it need to spray on the developer, a white substance that dries slightly powdery after a few minutes. The developer draws the remaining dye from any flaws, showing them as very red marks in the brilliant white developer. This particular test had no issues to resolve. The edges of the cleaned area showing a slight redness. If there had been a hole in the weld it would have shown up very clearly as a pink-red spot.

2.3. Mechanical Properties Test

2.3.1. Tensile Test and Hardness Test. The test was performed using Instron 8802 with ±500 kN (112,500 lbf) axial force capacity. According to ASTM E8 Standard Test Methods, the specimen must be shaped in Tension Testing of Metallic Materials. Setting up the specimen by gripping both ends parallel with software set up which include the speed, dimensions and type of material. The test begins by continually increasing uni-axial 34 load until failure occurs. The stress-strain graph was obtained once completed this test. The tensile test is probably the simplest and most widely used test to characterize the mechanical properties of a material.

2.4. Macrostructure observation

This macrostructure observation test is a test to ensure the welded sample that perform in mechanical properties test is a good sample where there is no porous or any defect inside the material structure after welded. The purpose of using a Microscope after the mechanical properties test is to let the specimen test first. It not possible to run the mechanical properties test for the cut specimen. In this test, it required to cut and prepare the specimen surface with mirror finish and place under microscope. The observation test was performed by using Olympus BX 60 M microscope with NK Vision NZM7045-T1 Microscope and supported by software IMAPS version 4.0 Professional. The mechanical properties test data that produce in tensile and hardness test is depending on this observation test. Only specimen without any microstructure defect will be used to analyse.

3. Research Finding

The data and result obtain in this experiment were recorded and tabulated in table and visualized in the graph from which all the result arranged consecutively section by section as followed:
3.1. Arc Spectrometer
The first step of this research was to ensure the material used was as required. By demonstrating arc spectrometer test, the carbon composition obtained can be compared with standard composition. The number 45 of AISI 1045 indicated 0.45% of carbon. From the result obtained, the carbon composition was still in range as shows in table below:

| Element | C  | Si  | Mn  | P    | S     | Cr  | Ni  | Mo  | Fe     |
|---------|----|-----|-----|------|-------|-----|-----|-----|--------|
| %       | 0.448 | 0.255 | 0.65 | 0.0040 | 0.0032 | 0.0064 | 0.0037 | 98.5 |

3.2. Hardness Test
The hardness test was conducted to determine the hardness of the joining. The value was collected at three spots which are base metal, heat affected zone and weld metal. The test is to show the quality of the welding zone and quality of affected area near to welding zone. The result of the Hardness test is shows in table 4, 5 and 6.

| Temperature | Base Metal | Heat Affected Zone | Weld Metal |
|-------------|------------|---------------------|------------|
| Value | Average | Value | Average | Value | Average |
| 200 | 232.5 | 219.1 | 187.3 |
| 221.7 | 223.0 | 176.8 | 176.3 |
| 219.4 | 210.5 | 164.7 |
| 250 | 222.1 | 216.6 | 178.1 |
| 245.9 | 209.6 | 183.4 | 183.3 |
| 233.0 | 209.3 | 188.4 |
| 300 | 241.8 | 207.4 | 210.1 |
| 277.5 | 203.8 | 193.4 | 202.1 |
| 252.9 | 199.5 | 197.1 |

| Temperature | Base Metal | Heat Affected Zone | Weld Metal |
|-------------|------------|---------------------|------------|
| Value | Average | Value | Average | Value | Average |
| 200 | 239.6 | 209.5 | 168.9 |
| 231.8 | 212.6 | 160.9 | 169.4 |
| 211.0 | 221.7 | 178.4 |
| 250 | 222.1 | 210.6 | 168.4 |
| 245.9 | 197.3 | 203.2 | 183.7 | 176.7 |
| 228.6 | 201.7 | 178.1 |
| 300 | 233.8 | 207.4 | 210.6 |
| 273.5 | 195.8 | 202.1 | 192.8 | 197.1 |
| 244.3 | 203.1 | 187.7 |

| Temperature | Base Metal | Heat Affected Zone | Weld Metal |
|-------------|------------|---------------------|------------|
| Value | Average | Value | Average | Value | Average |
| 200 | 228.6 | 207.1 | 175.2 |
| 233.9 | 223.8 | 209.7 | 163.5 | 175.8 |
| 218.0 | 198.2 | 188.7 |
| 250 | 219.7 | 218.3 | 175.3 |
| 240.1 | 205.5 | 206.9 | 158.4 | 162.6 |
| 227.7 | 197.0 | 154.2 |
| 300 | 224.1 | 197.3 | 208.8 |
| 230.8 | 206.5 | 201.5 | 196.6 | 193.7 |
| 246.2 | 200.7 | 175.7 |
3.3. Tensile Test Result
Table 7, 8 and 9 show the result for tensile test for welded specimens with different preheat. For 16mm, the tables show that material of 200°C preheating temperature was the highest tensile stress, followed up by material with 250°C and 300°C preheating temperature. The highest point for tensile stress is 428.49 MPa while the other two appeared just 10.1%, lower which the strength owned by 300°C is 273.318 MPa.

The 200°C preheat was also be the highest tensile stress with 22mm diameter and the value is 399.662MPa. According to the table, it can be stated that the material with preheat 250°C and 300°C was less about 18.8% and 28.2 %. Both of the material merely recorded 324.47 MPa and 286.99 MPa respectively.

The tensile test for 28mm, the preheat 200°C was no longer recorded as the maximum tensile strength which only 349.882 MPa, 7.9% less than the highest tensile strength which recorded with preheat 250°C. It obtained 379.945 MPa, distinguished the minimum strength with 7.9%. There were not much different in term of strength of material with 200°C and 300°C when there differed by 0.06%.

Preheat temperature is highly effected the changes of tensile strength value for each thickness. It can be a benchmark if the data recorded at macrostructure and it obviously signified that the material with a maximum tensile strength was not having any or less defects compared to other material with different temperature. It clearly implies that the defect occurred has correlation with the tensile strength of material.

Table 7. Tensile Test for 16mm AISI 1045.

| Temperature | Tensile Stress at Maximum load (MPa) | Tensile Strain at Maximum load (mm/mm) | Modulus (MPa) | Tensile Extension at Maximum Load (mm) |
|-------------|-------------------------------------|--------------------------------------|--------------|--------------------------------------|
| 200         | 428.788                             | 0.026                                | 49782.551    | 1.586                                |
| 250         | 304.176                             | 0.020                                | 51498.619    | 1.208                                |
| 300         | 273.318                             | 0.009                                | 65559.948    | 0.555                                |

Table 8. Tensile Test for 22mm AISI 1045.

| Temperature | Tensile Stress at Maximum load (MPa) | Tensile Strain at Maximum load (mm/mm) | Modulus (MPa) | Tensile Extension at Maximum Load (mm) |
|-------------|-------------------------------------|--------------------------------------|--------------|--------------------------------------|
| 200         | 399.662                             | 0.014                                | 68418.881    | 0.899                                |
| 250         | 324.466                             | 0.001                                | 74764.340    | 0.615                                |
| 300         | 286.99                              | 0.001                                | 67705.461    | 0.609                                |

Table 9. Tensile Test for 28mm AISI 1045.

| Temperature | Tensile Stress at Maximum load (MPa) | Tensile Strain at Maximum load (mm/mm) | Modulus (MPa) | Tensile Extension at Maximum Load (mm) |
|-------------|-------------------------------------|--------------------------------------|--------------|--------------------------------------|
| 200         | 349.882                             | 0.010                                | 77531.209    | 0.625                                |
| 250         | 379.945                             | 0.015                                | 69521.831    | 0.930                                |
| 300         | 349662                              | 0.013                                | 77515.805    | 0.796                                |

4. Conclusion
After preheated for 1 minute, the time taken the material to accomplish a desired temperature will give a different value according to the thickness. The experiments show that the thickness of material tend to possess less time to get the desired temperature. Also, the least flaw occurred during dye penetration test was at thickness 28mm when the flaw merely appeared on the specimen at 250°C. The effectiveness of this method relies on many factors that involve cleanliness of the part, skill of the
welder, and the procedure that was used to perform welding. This test is appropriate to be performed at the earlier stage, so that the welder can examine the occurrence of imperfection prior.

In this study, the influence of niobium addition on the microstructure of austempered ductile iron was investigated and the following conclusion could be obtained:

The microstructure of austempered ductile iron consist of nodular graphite surrounded by retained austenite and acicular ferrite while the addition of niobium to austempered ductile iron promoted the formation of Niobium carbide (NbC) to the microstructure.

The addition of niobium resulting in much finer retained austenite and acicular ferrite structure but reduced the nodularity, nodule count and graphite area due to the presence of niobium carbide.

Acknowledgement
The authors would like to express their gratitude to the ministry of science and technology, Malaysia (MOSTI) and Ministry of Higher Education Malaysia (MOHE), and Universiti Teknologi MARA for the financial support given to this work through research grant of 600-IRMI/FGRS 5/3 (003/2019).

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