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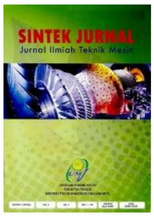

THE EFFECT OF HOLDING TIME ON STRESS RELIEF ANNEALING PROCESS TO HARDNESS OF CARBON STEEL SA.106 GRADE B AFTER WELDING

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ABSTRACT

Stress relief annealing (SRA) is a process of releasing residual stresses contained in the material due to the welding process. The need for SRA is due to heterogeneous changes in the microstructure when the material is exposed to the heat of welding so that it will cause the mechanical properties of the material to change. One of the mechanical properties that experience significant changes is hardness (hardness value) because it can experience an increase. Therefore it is necessary to decrease the hardness value using a heat treatment SRA that takes into account the appropriate holding time. The purpose of this study was to determine the effect of holding time variations on the value of the welding material hardness for the carbon steel case SA.106 Gr.B. During this time after welding SA106 material specifically under 19 mm thickness is not heat treatment after welding even though the welding effect will change the properties of this material, so it is necessary to heat treatment with certain holding time variations to determine its effect on the mechanical properties of the material. The welding process uses SMAW with E7018 electrodes. Specimen heating is carried out in a heating oven to a constant temperature of 650^{o}C with variations in the heating time of 15 minutes, 30 minutes, and 45 minutes. Furthermore, hardness testing is done by testing the base metal area, heat affect zone, and weldment. The results that SRA greatly influenced the hardness value of a welded material, based on testing the highest hardness value in the SRA heat treatment was obtained at a holding time of 45 minutes with a hardness value on the base metal of 67 HRC (BM), HAZ area of 65.25 HRC, and weldment area of 64.42 HRC. But at the holding time for 45 minutes, the value of material hardness tends to be more uniform compared to other variables.

Keywords*: Stress relief annealing; holding time; hardness; base metal;* SA.106 Gr.B.

1. INTRODUCTION

In oil companies, there are many uses of materials, especially steel as materials for installation, construction, pipelines, pressure vessels, and so forth. SA.106 Grade B carbon steel is one of the most widely used steels for the production of oil and gas pipelines.

In pipe joints carried out by the welding process to get the appropriate mechanical properties, it is necessary to pay attention to the welding procedures that are by the standards used such as the American Welding Standard (AWS) [1].

Welding gives rise to the effect of local heating with high temperatures which causes the metal to experience thermal expansion and shrinkage during cooling. This causes the occurrence of residual stresses and high hardness in areas of heat influence or Heat Affected Zone (HAZ). Residual stress is permanent and results from an uneven thermal cycle followed by an uneven cooling cycle.

Annealing is a heat treatment process that is used to negate the effect of cold work, and also serves to make the material softer and increase ductility. The type of annealing varies, depending on the condition of the workpiece, heating temperature, length of holding time, cooling rate, and so on [2]. The purpose of heat treatment annealing is to improve toughness and machinability, refine grain size, reduce the homogeneity of the structure, and reduce residual stress [3].

Stress relief annealing (SRA) is a type of annealing. SRA is the process of releasing residual stresses contained in the material due to the welding process. Stress relief annealing is very common in the field when welding carbon steel and alloy steel materials which have thicknesses above 19mm. The welding material is heated up to a temperature range of 593-718°C (below recrystallization temperature) and then a certain holding time is carried out to ensure the microstructure of the material becomes homogeneous. The need for SRA is due to heterogeneous changes in the microstructure when the material is exposed to the heat of welding so that it will cause the mechanical properties of the material to change. One of the mechanical properties that experience significant changes is hardness value. The value of violence is believed to increase. Therefore it is necessary to decrease the hardness value using a heat treatment SRA that takes into account the appropriate holding time. In the SRA process, holding time is the main parameter to produce optimum hardness value. Holding time will affect the value of violence.

Many studies have been carried out about heat treatment of annealing at the welded material joints [4][5][6][7][8] such as Dedy Hernawan in his research on the effect of variations in the annealing process temperature on the SMAW connection to the welding toughness steel K945 EMS45, the results of the study show the presence of the PWHT Toughness temperature of 5000°C up 49% from Non-PWHT, Compared to PWHT Temperature 6000°C has increased 24% and PWHT Temperature 7000°C has increased 16% from PWHT Temperature 6000°C. Annealing Process with Temperature 5000°C, 6000°C, 7000°C changes in the microstructure cannot yet be homogeneous, the welding area is still visible in the martensitic structure, the parent metal area does not change significantly. Cross-section broke on granular Non-PWHT specimens. Cross-section of broken specimens undergoing fracture ductile treatment [9].

Rusiyanto in his research on the effect of post-weld heat treatment annealing temperature variations on the mechanical properties of EMS-45 steel material by shielded metal arc welding (SMAW) welding method obtained the results of the study that the highest hardness value after the welding process lies in the weld metal area [10].

Farid Wahyu Wibowo in his research on the effect of holding time annealing on the SMAW connection to the toughness of K945 EMS45 steel welding stated that PWHT annealing can increase the toughness and tenacity of K945 EMS45 steel. For a good PWHT annealing holding time in this study is to use 90 minutes and the one with the lowest toughness is a non-PWHT annealing specimen [11].

Prihanto Trihutomo in his research on the influence of the annealing process on the welding results on the mechanical properties of low carbon steel stated that the results of data analysis showed the highest average hardness value at 5000°C annealing temperature is 170.03 HVN. Whereas at 7000°C annealing temperature has the lowest average hardness value of 125.13 HVN [12].

Based on the above problems, it is necessary to further research on PWHT annealing type SRA, with the consideration that so far after welding for SA106 material specifically thicknesses below 25mm no heat treatment is carried out whereas the welding effect will change the mechanical properties of this material, so this requires a study to determine its effect on the mechanical properties of the material. The purpose of this study was to determine the effect of holding time stress relief annealing process on the hardness of carbon steel SA.106 GRADE B after welding.

2. METHODS

The method used in this study is an experimental and analysis method to determine the effect of holding time variations on the hardness value of the welding material for the SA106 grade carbon steel case B. The step begins with forming a seam on the material, determining the welding position, welding using SMAW welding, cutting of the welding material as many as 4 specimens for hardness test, 3 specimens were subjected to stress relief annealing heat treatment with variations in holding time and hardness testing for all four specimens.

The material used in this study is ASME SA 106 grade B carbon steel pipe with a diameter of ø 6 inches. ASME SA 106 grade B carbon steel material is a high strength steel pipe (seamless and welded pipe) for pipelines construction where high strength and pressure resistance are required. Fully killed is a type of steel that has been processed by adding elements of deoxidation (deoxidizer) such as aluminum (Al) and silicon (Si) at certain levels. The process is usually carried out in a mold where after freezing the steel is seen the existence of shrinkage at the top (top of the ingot). This was caused by the presence of a gas that evolved or came out entirely in the steel freezing process. The steel is generally applied to the cold forming process (cold forming process) such as cold expanding. Carbon steel SA materials and specifications. 106 Grade B as in table 1 below.

Table 1. Material and specifications [13].

Element	C Max	Mn	P Max	S Max	Si Max
A 106	0.30	1.29-1.06	0.035	0.035	0.10
Grade B	**Cr Max**	**Cu Max**	**Mo Max**	**Ni Max**	**V Max**
	0.40	0.40	0.15	0.40	0.08

The method of conducting research begins with the process of material preparation, welding of material connections, heat treatment of workpieces with variations in holding time for SRA, and testing mechanical properties in the form of hardness tests.

Hardness testing is a process to test the ability of a material to be subjected to constant change. The price of the hardness of the material can be analyzed from the amount of loading given to the area of the field that receives the load. Hardness is one of the mechanical properties of a material. The hardness of material must be known especially for material which in its use will experience friction (frictional force) and plastic deformation. Hardness testing uses the DIN 50103 standard.

The steps taken in the welding process are preparing the SMAW welding machine with DCEP (Direct Current Electrode Positive) polarity, the electrode used is E7018 with an electrode diameter of Ø 3.2 mm. Preparing 2 ASME SA 106 grade B carbon steel pipes with a diameter of ø 6 inches, 150 mm long, 8 mm thick, both sides of the pipe have been angled at a 35o angle. Setting the root gap between the 2 pipes to be welded with a distance of 3 mm, the welding position of the pipe 1G or under the hand by welding the pipe is rotated during the welding process. Then the welding process is carried out with an ampere meter 80 amperes.

After the welding process the workpiece is cut for the SRA process with variations in holding time temperature of 15, 30, and 45 minutes, the SRA temperature used is 6200^{o}C. The workpiece that has been in the SRA with variations in temperature holding time is tested by mechanical properties such as the Rockwell C hardness test in base metal, HAZ, and weld metal regions.

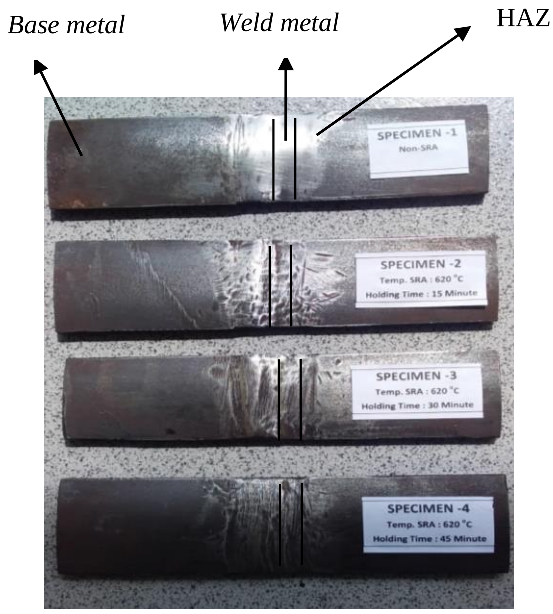


Figure 1. Specimens without SRA and SRA treatment.

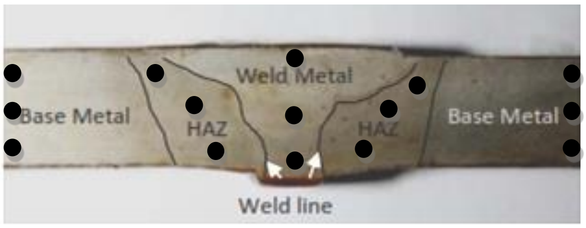


Figure 2. Hardness test point area.

3. RESULTS AND DISCUSSION

The hardness test produces data from the hardness value of specimens without stress relief annealing (SRA) and specimens performed by variations in temperature SRA with holding time of 15, 30, and 45 minutes. The hardness value of each specimen can be seen in Figure 3.

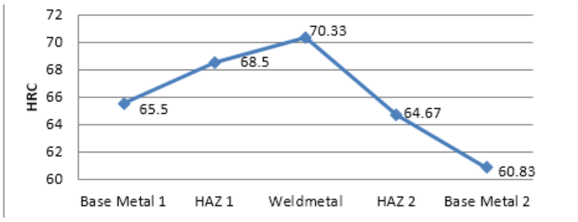


Figure 3. Value of hardness without SRA.

The objective without SRA is to determine whether there is an influence of the value of violence after SRA on weld results. Figure 2 above shows the base metal 1 hardness value of 65.5 HRC and the base metal 2 hardness value of 60.83 HRC, this shows a decrease in hardness value of 4.87 HRC in the base metal area 2. The HAZ 1 hardness value of 68.5 HRC and the HAZ 2 hardness value of 64.67 HRC, there was a decrease between HAZ 1 and HAZ 2 hardness of 3.83 HRC. The highest hardness value occurs in weld metal areas with a hardness value of 70.33 HRC. The hardness value between base metal 1 and HAZ 1 region experienced an increase in hardness value by 3 HRC, conversely what happened in HAZ 2 hardness area and base metal 2 area had a significant decrease in hardness value that was 3,84 HRC.

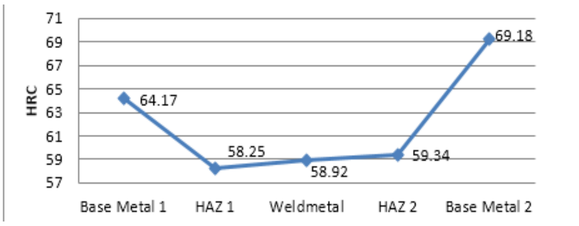


Figure 4. Value of SRA hardness 30 minutes.

Figure 4 shows the base metal 1 hardness value of 64.17 HRC and the base metal 2 hardness value of 69.18 HRC, it was seen that there was a significant increase in hardness value of 5.01 HRC in the base metal area 2. The HAZ 1 hardness value was 58.25 HRC and the HAZ hardness value 2 amounted to 59.34 HRC, there was a not too significant increase between HAZ 1 and HAZ 2 hardness of 1.09 HRC. The hardness value of the weld metal area is 58.92 HRC. The lowest hardness value occurred in the HAZ 1 area of 58.25 HRC, weld metal of 58.92 HRC, and HAZ 2 of 59.34 HRC. The highest hardness value occurred in the base metal area with a hardness value of 69.18 HRC.

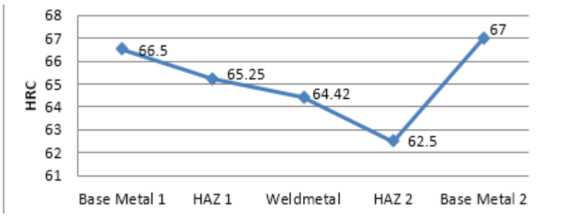


Figure 5. Value of SRA hardness 45 minutes.

Figure 5 shows the value of violence in the base metal 1 area of 66.5 HRC and the base metal 2 area of 67 HRC, seen an increase in violence in the base metal 2 area of 0.5 HRC. The value of violence in HAZ 1 was 65.25 HRC and in HAZ 2 was 62.5 HRC, this showed a decrease in the value of violence by 2.75 HRC in HAZ 2. Furthermore, the value of violence in weld metal was 64.42 HRC. The SRA Holding Time 45 minute graph shows a decrease in the value of the results of base metal 1 hardness and HAZ 1 area of 1.25 HRC, from HAZ 1 area and weld metal area of 0.83 HRC, and from weld metal area to HAZ 2 area of 1.92 HRC.

The combined value of non-SRA violence, SRA holding Time 15, 30, and 45 minutes looks like Figure 7 below.

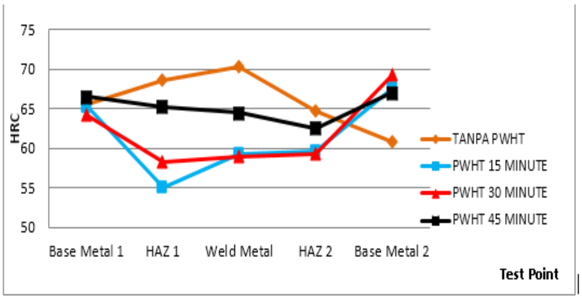
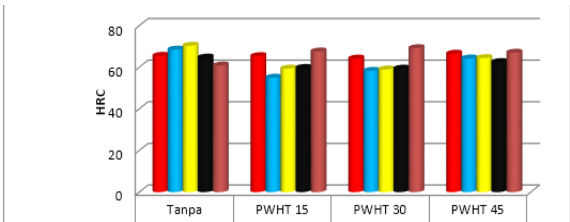


Figure 6. Hardness value without SRA, SRA holding time 15, 30, and 45 minutes.

Figure 6 is the combined value of the yield without SRA, SRA 15, 30, and 45 minutes. The highest hardness value occurs in specimens that are not carried out by SRA, which is equal to 70.33 HRC in the weld metal area. The lowest hardness value occurred in specimens carried out by SRA 15 minutes at 55 HRC in the HAZ 1. As with the base metal 2 region, the highest value of hardness occurred in specimens performed by SRA for 30 minutes at 69.18 HRC, followed by SRA 15 minutes at 67.59 HRC then followed by a 45-minute SRA of 67 HRC. The lowest hardness value on base metal 2 occurred in specimens that were not carried out by SRA at 60.83 HRC. From the graphic image above it can be seen that the SRA is very influential on the value of hardness in a welded material. The 15-minute SRA hardness value is the lowest compared to SRA 30 and 45 minutes. This happens because the 15-minute SRA specimen has been subjected to heat treatment which has not exceeded the austenitization temperature so that it cannot result in changes in the microstructure of a welded material.



	Tanpa PWHT	PWHT 15 Menit	PWHT 30 Menit	PWHT 45 Menit
Base Metal 1	65.5	65.34	64.17	66.5
HAZ 1	68.5	55	58.25	64.25
Weldmetal	70.33	59.34	58.92	64.42
HAZ 2	64.67	59.68	59.34	62.5
Base Metal 2	60.83	67.59	69.18	67

Figure 7. The average value of hardness without SRA, SRA 15, 30, and 45 minutes.

Furthermore, the hardness value on specimens carried out by SRA with a holding time of 45 minutes on average is 65.13 HRC, meaning an increase of 3.74 HRC between the holding time of 15 minutes and an increase of 3.16 HRC between the holding time of 30 minutes. The increase in the value of violence occurs based on variations in holding time, increasing the holding time then the value of violence also increases. The bar diagram above shows that the SRA process is very good for increasing the hardness value of a material or welded specimen. An increase in the value of hardness in the SRA group is due to the metal experiencing work hardening which has increased the strain energy to cause new grains to undergo a recrystallization cycle, this process causes a change in mechanical properties ie the hardness value will increase.

4. CONCLUSIONS

The welding process will increase the hardness value of the material or weld results because it is caused by the shape of the microstructure of the material is dominated by more ferrite and the granules get smaller so that it will increase the hardness value of a material. But after SRA, the value of violence will decrease according to the holding time. The highest value of hardness in the SRA process temperature of 620^{o}C occurred in specimens conducted holding time for 45 minutes with an average hardness value of 65.13 HRC. The lowest hardness value result occurs in the specimen which is held for 15 minutes with a hardness value of 61.39 HRC. Whereas on material connections where SRA is not carried out the hardness value is 65.97 HRC. But at holding time for 45 minutes the value of material hardness tends to be more uniform compared to other variables

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