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Optimization of hardness test results in welding dissimilar metal S304 H and Incoloy 800H

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Abstract

Welding dissimilar metal SS 304H with Incoloy 800H is often used in industry. To find out the mechanical properties of the metal from the result of welding, an analysis of Vickers hardness test was carried out. Material Incoloy 800H is the one that undergoes a decrease in mechanical quality due to the operating load (Aging). Therefore, there were two methods conducted on Incoloy 800H material before the welding process was carried out, namely without heat treatment and with heat treatment. The results of the analysis with heat treatment showed that the hardness value of the parent material for SS 304H was 35.5 HRC while the average Incoloy 800H was 30.4 HRC, while in the heat-affected materials (HAZ) the hardness value of SS 304H was 32.4 HRC and the hardness value of Incoloy 800H was 28.2 HRC. In other words, there was a decrease in the hardness value.
Keywords: welding; dissimilar metal; aging; vickers hardness test; heat treatment.

Introduction

Welding is one of the metal joining techniques by melting the part of the parent metal and filler metal with or without pressure and with or without the enhancer metal and producing a continuous joint connection [1]. The piping system in the area of Reforming Ammonia Plant of PT. PUSRI used, a Transfer line which is a series of pipelines to transfer the gas product from the Primary Reformer to the Secondary Reformer for further processing. The primary reformer product is a mixture of 65-75% of Hydrogen gas (H_2), 8-9% of carbon dioxide (CO_2), and approximately 9-16% of Methane (CH_4) [2]. The Transfer Line has a design temperature of 850^0 C and a pressure design of 38 kg/cm^3. However, there must be a difference in shape between the welding result and the initial material. The structural changes can cause the strength to increase [3], Therefore, it requires particular specifications on the transfer line pipe material, namely high alloy steel. Material components that are resistant to high temperatures are needed in the fabrications and power plants. They are necessary to overcome the cracks, creeps or elongation changes, and material damage due to high loading by increasing the temperature before the welding [4]. Several welding technologies have succeeded in connecting different materials, for example Shield Metal Arc Welding (SMAW), Flux Cored Arc Welding (FCAW), Gas Metal Arc Welding (GMAW), Gas Tungsten Arc Welding (GTAW), and Laser Welding (LW) [5]. In the field application of the transfer pipeline, there often occur damage problems, one of which is the transfer line from the primary reformer to the Nozzle inlet of secondary Reformer. So far, the repairs to the unit have only been carried out using the Welding Repair method on materials that are detected to be damaged due to the operating loads, in which in the last repair of the item, the Nozzel inlet secondary reformer material was fatigue that on the next occasion a replacement was made to the Nozzle inlet Secondary

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reformer with a welding method to connect the Nozzle to the transfer pipeline. The problems of dissimilar welding are always related to the physical and chemical properties of the material [6]. Incoloy 800H material is a super alloy that is based on a mixture of nickel iron. This alloy has an FCC structure containing precipitate y' with a structure that hardens the material. Such precipitate can be seen using an optical microscope. The influence of tensile strength and surface roughness on the results of welding of different materials can be carried out and observed changes for their microstructure [20]. Added material metal welding alloy with $NicrMo_3$ electrode performed at PT. Pusri is used for welding the dissimilar metals. This filler metal produces high-quality deposits and the deposits can be diluted with a variety of different materials without compromising proper mechanical bonding. The selection of the right type of metal material and auxiliary material as well as the method of welding can affect the structure and quality particularly at the welding point or zone [21]. By paying attention to these conditions, the authors want to be able to optimize the hardness test results on the SS 304 H metal dissimilar welding with 800H Incoloy at PT. PUSRI.

Based on the design and manufacture, for efficiency in the use of materials [7], the two items do not have the same material composition where the reducer Nozzle inlet secondary reformer uses SS 304H pipe, while the line transfer of the primary reformer uses an Incoloy 800H pipe [8]. As a result the welding of two dissimilar materials have to be carried out. The welding of two different materials is found to be widely applied in various fields of industrial construction and manufacturing, where the characteristic features of different materials are optimized for the desired application in order to produce cost effectiveness and value added. The machining process utilize material types such as cutting and splicing according to the size and shape for the final conditions in the welding process [9]. To obtain optimal welding results in accordance with specified standards, there are many factors that can affect the results of welding products, namely the welding procedures or a planning for the implementation of research which includes how to make welding instructions in accordance with the welding procedure specifications (WPS) by specifying all the things needed in the implementation [10].

Study on the influence of current strength, the metal type filler welding and tensile test on GTAW welding of Stainless Steel joints by Okonji, P.O et al. show that the highest tensile test results was the one using the high current strength [11] and the welding strength is influenced by the filler material [12]. The research by Isidro Guzman et al. on the heat treatment of material surfaces before the welding process shows that the heat treatment can affect welding strength and strength changes in the welding materal surface [13]. Tae-Hoon Nam et al. reviewed that the presence of higher surface hardness if conducted at a temperature of 850^0 C to 1050^0 C can affect delta-ferrite, Cr-Carbide and the result of the hardening on delta-ferrite and austenite matrices [14]. An analysis of the influence of types of welding on different materials on the Power Plant, Fabrication and influence of material structure by Sanjay Singh et al. show good welding results after the heat treatment is carried out [15]. The research by F. Vakili Tahami et al. on the influence of welding parameters on metal dissimilar using 304L stainless steel, show the high tensile test results in accordance with the material composition and high temperature strength [16].

The 304H Stainless Steel material is a variation of 8% chromium, 8% nickel austenitic, and Alloy 304, where the carbon content is controlled to the range of 0.04% - 0.1% to provide increased high temperature strength to the parts exposed to the temperatures above 1500° F (815°C). This material has a higher carbon content.

Austenitic nickel-chromium alloys and greater carbon content increase tensile strength and vessel strength [17]. This material is recommended for use in pressure vessels above 815^0 C due to the fact that this heat-resistant property, Stainless Steel 304H, is most often applied to Tube Superheater Boilers, Heat Exchangers, Condensers, Pipelines, Towers coolant, steam discharge and power plant [18]. In metal dissimilar welding, there are many factors that must be considered. The concentration in this welding is to maintain the occurrence of Under bead or cold cracking. This crack generally occurs in the area of Heat Affected Zone. It is an area where no melting or melted occurs during the welding process causing the microstructure in the HAZ area to change [19].

Methods

Research and data collection on welding of dissimilar metal SUS 304H and Incoloy 800H, were conducted in the equipment repair fabrication workshop and engineering laboratory of PT. PUSRI.

The main tools used welding machines, non-destructive test equipment and destructive test equipment. The method carried out is as follows:

1. The equipment consisted of:
   a. Gas Inert Tungsten Welding Machine (TIG), Model number YC-500TSP, type of Tyhristor, Power of 33.2 kVa (30.7kW), phase: 3 phases, 380 – 415 voltage, output current: DC Tig: 500 Amperes, for the GTAW process.
   b. DC Inverter Arc Welding. Model number XMT 304 miller, inverter type, input voltage: 208 Volts, phase: 3 phases, voltage of 220/230/240 volts, Output current: DC 300 Amperes, for SMAW process.
2. Preparation of the materials:The materials used in this welding were: Stainless Steel Pipe 304 H (6" Sch 120), Pipe of ASTM B407 Incoloy 800H (6" Sch 120), Filler Rod UTP A 6222 Mo TIG, Electrode NiCrMo 3, Argon High Purity Gas.
3. Welding working process:
   a. Heat treatment (Annealing)

Before welding, two methods of work were carried out, namely without heat treatment and with heat treatment (Annealing) on Incoloy 800H aging material.

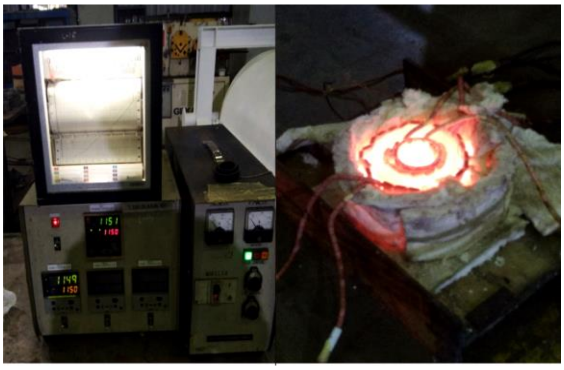

Figure 1. Process annealing on incoloy 800H aging material.

b. Weldability test

After both methods were carried out, the work continued by conducting a weldability test which aimed to ensure that the material was able to receive the heat treatment on the welding.

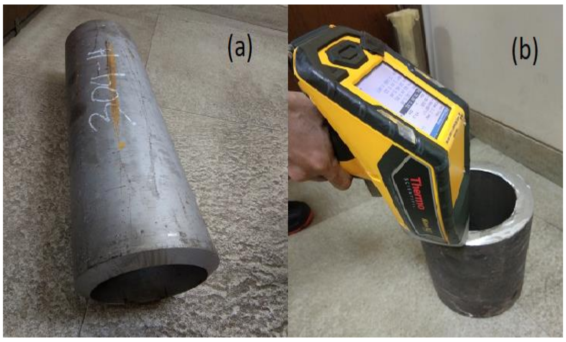

Figure 2.(a) ASTM A312 TP304H pipe (SS 304H) (b) ASTM B407 incoloy 800H (Incoloy 800H) pipe

Welding design. The design used in the dissimilar welding of metal SS304H with Incoloy 800H (Figure 3).

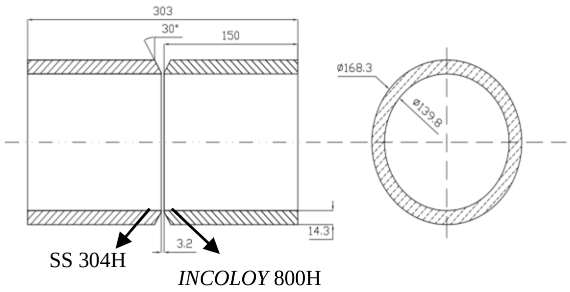

Figure 3. Welding scheme of dissimilar metal SS 304H with incoloy 800H

Table 1. Material composition test results (%)

Material Composition	Incoloy 800H	SS 304H
Ferro(Fe)	30,500	65,0000
Carbon ©	1,100	0,1560
Silika (Si)	4,340	2,2700
Mangan (Mn)	2,010	1,8000
Crhromium (Cr)	26,20	20,0000
Molybdenum (Mo)	0,103	0,1470
Nikel (Ni)	28,000	8,6600
Allluminium (Al)	0,058	0,0221
Cobalt (Co)	0,106	0,4140
Copper (Cu)	0,426	0,8640
Niobium (Nb)	> 3,500	0,0732
Titanium (Ti)	0,344	0,0855
Vanadium (V)	0,118	0,1560
Tungsten (W)	0,946	0,2440
Lead (Pb)	0,134	0,0229

(Laboratorium Teknik PT. Pusri, 2022)

Research preparation

Welding Dissimilar Metal SS 304H and Incoloy 800H. The implementation of dissimilar metal SS 304H and Incoloy 800H welding was carried out by a combination welding process, where the Root Pass and Hot Pass were carried out with the process of Gas Tungsten Arc Welding (GTAW). The welding was carried out using two-cylinder Argon High Purity, where one cylinder as shielding gas which was flowed through the welding handlebar, and another cylinder was used as Purging Gas which was flowed into the pipe.

The protective gas flow capacity was regulated using a valve regulator where in Shielding Gas the volume of outflow capacity was set at 10 L/Min while in the Cleaning Gas (Purging Gas) the capacity volume of the flow was set at 5 L/Min.

Hardness test process. Hardness testing was carried out using the Vickers hardness test method. It used the Micro Vickers Hardness Tester carried out at the Engineering Laboratory of PT. PUSRI.

Figure 4. Micro vickers hardness tester

Results and Discussion

From the series of work processes, the following are the obtained results and data:

Result of weldability test. The results of the weldability test showed that there was no micro crack or longitudinal crack in the materials receiving the heat treatment. This Incoloy 800H material was able to receive the heat treatment in the welding. Several treatments before and after the welding of the different types of material using filler metal produced the mechanical properties such as strength, hardness and desired material structure change [22].

Figure 5. Incoloy 800H weldability test results

Welding Results. The implementation of the SMAW and GTAW combination welding process against the Dissimilar Metal SUS 304H and Incoloy 800H produced the following data:

Table 2. Output data of the welding of dissimilar metal SUS 304H and incoloy 800H

Weld Layer	Welding Process	Filler Metal		Ampere		Volt Range	Travel Speed (mm/min)	Heat Input (kJ/mm)
		clasification	Ø (mm)	Polaritas	(A)			
1	GTAW	AWS A.514	2.4	SP	110	20-23	50	2.64
2	GTAW	AWS A 5.14	2.3	SP	140	20-23	56	2.66
3	SMAW	AWS A.5.11	3.2	RP	85	22-26	113	1.03
4	SMAW	AWS A.5.11	3.2	RP	85	22-26	124	0,94
5	SMAW	AWS A.5.11	3.2	RP	85	22-26	91	1.28
6	SMAW	AWS A.5.11	3.2	RP	85	22-26	77	1.51

Figure 6. Result of the welding of dissimilar metal SUS 304H and incoloy 800H

Result of hardness test. In the welding of dissimilar metal, there was a change in the decrease in hardness of SS 304H and Incoloy 800H materials after having the heating treatment, but there was an increase in the most intense hardness particularly in the HAZ area.

The hardness test result of dissimilar metal SUS 304H and Incoloy 800H is shown in Table 3.

Table 3. Hardness test results

Speciment		Hardness Value (HRC)			
		1	2	3	average
Base Metal	SS 304H	35.0	34.7	36.8	35.5
	Incoloy 800H	30.4	30.1	30.7	30.4
HAZ	SS 304H	32.7	33.1	31.6	32.4
	Incoloy 800H	31.9	28.5	28.0	28.2
Weld Metal		39.5	39.5	38.9	40.8

There was a change of hardness in the HAZ area as a result of changes in the molecular structure affected by the heating on the material [23]. The relationship of hardness with the welding strength due to the heating of the metal caused structural changes in the HAZ area to be evenly distributed.

The hardness value of the base material for SS 304H was 35.5 HRC while the average Incoloy 800H was 30.4 HRC, while in the heat-affected materials (HAZ) the hardness value of SS 304H was 32.4 HRC and the hardness value of Incoloy 800H was 28.2 HRC. In other words, there was a decrease in the hardness value.

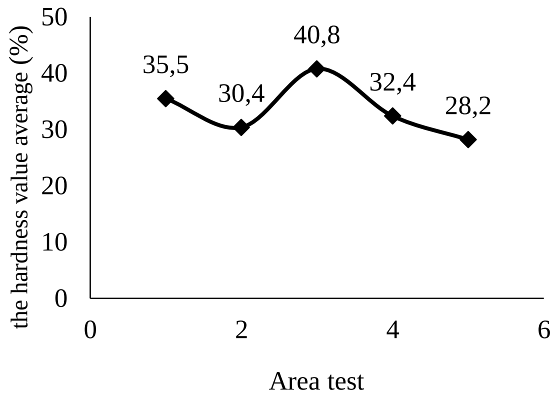

Figure 7. Hardness testing of SS 304H and Incoloy 800H

The changes in the welding temperature and current impacted on increasing the welding strength [24].

Changes in the strength and hardness of the welding in dissimilar metal also occurred due to the changes in the structure and influence of filler metals [25].

Conclusion

The result of connecting dissimilar metal with heat treatment before the welding resulted in the structure changes and the addition of the most important filler metal to the HAZ area making hardness in the area as well as changes. There was a decrease in the value of hardness of the material. The lower hardness occurred in HAZ and base metal Incoloy 800H areas after the welding by using the heat treatment method before the welding process of dissimilar metal SUS 304H with incoloy 800H. The toughness of the welding result against the plastic deformation was more improved compared to the method without utilizing the heat treatment.

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