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Mechanical Properties Comparison of Stainless Steel 304L and Carbon Steel BS1387 Prior to Orbital Welding

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Abstract. Dissimilar metal joint (DMJ) is one of many joining methods for welding processes which is common in the power plant, chemical and petrochemical industries. Stainless steel pipe and carbon steel pipe are the most widely used in this technique. In order to perform DMJ to these metals, it is important to understand the mechanical properties of both base materials. In this study, the characterizations of stainless steel (SS) 304L and carbon steel (CS) BS1387 were made. The SS 304L and CS BS1387 were cut out from pipes according to ASTM E 8M-04, before their tensile and microhardness properties were measured and evaluated. The results show that the SS 304L has better mechanical properties compared to the CS BS1387 pipe in terms of tensile strength and hardness. Due to the higher mechanical properties, SS 304L was selected to conduct higher temperature water, while CS BS1387 was selected to conduct room temperature water.

Introduction

The dissimilar metal joint (DMJ) is commonly used in the power plant, chemical and petrochemical industries to meet the design specification. This requires different materials for different purposes at different working environment. For example, these joints must meet severe service conditions requiring good heat transfer characteristics, oxidation and corrosion resistance and high temperature mechanical properties.

The DMJ can be applied with cheaper steels in place of high-alloy steels, made considerable savings on cost [1]. The common metals used in DMJ in power plant are stainless steel (SS) type pipe and carbon steel (CS) type pipe. Locally, such DMJ between SS 304L and CS BS1387 pipes have been used by TNB Manjung 4 Coal Fired Power Plant [2]. Austenitic stainless steels are commonly used in various fabrication industry such as high performance pressure vessels for nuclear, chemical, process and medical industry due to its high corrosion resistance and superior mechanical properties [3]. In 300 austenitic stainless steels series, type 304 with maximum 0.08 wt% C , is one of the most versatile and widely used of all the stainless steels. It is due to the SS 304L properties, which offer excellent combinations of mechanical properties, weldability and corrosion resisting properties and provide best all-round performance stainless steels at relatively low cost. The 304 stainless steel is usually applied for storage and transportation of water and liquefied natural gas [3-6]. CS BS1387 is similar to ASTM A53 steel, which is often selected to be used for pressurized equipment and pipes under 350 °C because it is a low cost material that is easy to work and weld [7].

Welding is one of the most widely used joining processes in the fabrication industry and the properties of the weldments are significantly inferior to the base metal, which may lead to the failure of the entire component. The shielded metal arc welding (SMAW) has been used to perform DMJ between SS 304L and CS BS1387 at TNB Manjung 4 Coal Fired Power Plant [8]. It requires high-skill welder and after weld process to remove slug. Out of many welding processes, gas metal arc welding (GMAW) is the most preferable welding due to its easy setup, ability to weld almost all type of thin or thick steel with higher travel speed as its wire are continuously added to the joint. As to reduce high skill welder requirement, rotational jig will be used to hold the tube and rotate the pipes during the welding process. By using the rotational jig, it should be able to ease the orbital welding of DMJ pipe. The main objective of this article is to study the mechanical properties of SS 304L and CS BS1387 pipe as it is essential to understand the mechanical properties of both base materials prior to performing the DMJ process as to evaluate the effectiveness of the DMJ, which will be conducted in our future study.

Methodology

Fig. 1 shows the SS 304L (left) and CS BS1387 (right) pipes from which the samples are cut out before being measured for their tensile and microhardness properties. Universal testing machine (UTM) was used to measure the tensile properties while the microhardness was measured using Vickers microhardness testing machine The chemical compositions of the SS 304L pipe and CS BS1387 pipe are given in Table 1. The type and size of the pipe used for this study is replicated from the real material used in TNB Manjung 4.The outer diameter of SS 304L pipe is 60.5mm and for CS BS1387 pipe is 60.0mm, and the thickness of SS 304L and CS BS1387 pipes are 3.75mm and 3.25mm, respectively.

a. 304L SS pipe

b. BS1387CSpipe

Fig. 1 Base material used for dissimilar metal joint

Table 1 Chemical composition (wt. %) of SS 304L and CS BS1387 pipe [9,10].

Steel Type	Composition in wt. %							
	C	Si	Mn	P	S	Cr	Ni	Pb
SS 304L	0.025	0.33	1.40	0.030	0.002	18.20	8.04	<0.10
CS BS1387	0.040	0.010	0.150	0.006	0.004	-	-	-

The tensile specimens were prepared by using wire-cut electric discharge machine. The image of the pipe after removal of the sample is shown in Fig. 2. The schematic representation of tensile specimen is shown in Fig. 3. The tensile specimens are prepared in accordance to ASTM E 8M-04.

Fig. 2 Pipe with cut-out area

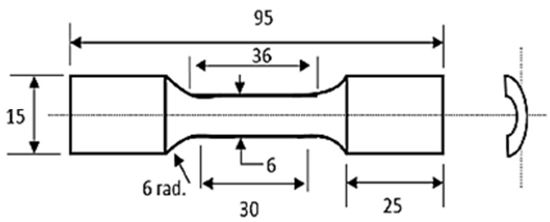

Fig. 3 Tensile specimen dimension (mm) [11].

Results and Discussion

The tensile tests were carried out in accordance to the ASTM E 8M-04 by using Universal Testing Machine. Results of tensile test on SS 304L and CS BS1387 pipes are shown in Table 2. Based on the results of tensile test, the SS 304L pipe shows better mechanical properties compared to CS BS1387 pipe. As shown in Table 2, the mechanical properties of SS 304L pipe with 14.0625kN of maximum force, 135.216 MPa of yield strength, and 50.2622 % of maximum strain are better than CS BS1387 pipe with 8.2250 kN of maximum force, 87.8739 MPa of yield strength, and 7.8911 % of maximum strain. The yield strength of SS 304L is almost 54% higher than that of CS BS1387.

Table 2 Tensile test results of SS 304L and CS BS1387 pipes.

Steel Type	Maximum Force (kN)	Yield Strength (MPa)	Maximum Strain (%)
SS 304L	14.0625	135.216	50.2622
CS BS1387	8.2250	87.8739	7.8911

The hardness measurement was carried out on the base material specimen using Vickers microhardness testing machine with load of 0.5kg and dwell time of 15 second at 3 points.The hardness values for SS 304L and CS BS1387 pipes are shown in Table 3. Average HV for SS 304L pipe is 271.6 HV and average HV for CS BS1387pipe is 187.1 HV. Similar to tensile test result, the hardness test result also shows SS 304L pipe has higher hardness compared to CS BS1387 pipe. As shown in Table 3, average hardness for SS 304L is 271.6 HV, while the average hardness for CS BS1387 is 187.1 HV.

Table 3 Vickers microhardness test result of SS 304L and CS BS1387 pipe.

Steel Type	Hardness Vickers (HV)			
	Point 1	Point 2	Point 3	Average
SS 304L	270.6	271.3	272.8	217.6
CS BS1387	202.3	188.9	170.0	187.1

The SS 304L different stress-strain behaviour of stainless steel which is different from the carbon steels. While carbon steel typically exhibits linear elastic behaviour up to the yield stress and a plateau before strain hardening, stainless steel has more rounded response with no well-defined yield stress. Fig. 4 below shows the example of stress-strain curve for stainless steel and carbon steel.

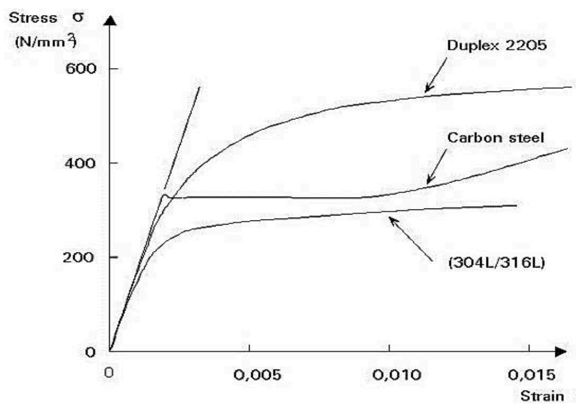

Fig. 4 Typical stress-strain curves for stainless steel and carbon steel [3].

Conclusion

The application of dissimilar metal joint of SS 304L and CS BS1387 will reduce the total piping cost as CS BS1387 is much less expensive than SS 304L. In price comparison, CS BS1387 is cheaper with RM 276.00 per 6.0 meter as compared to SS 304L with RM 2456.00 per 6.0 meter. Based on the study, it is found that the SS 304L has better mechanical properties compared to the CS BS1387 pipe. As SS 304L shows higher mechanical properties, it will be used to conduct high temperature water from boiler for certain length and once the water cool down, the piping system will be extended by using CS BS1387 to conduct room temperature water. By reducing the length of SS 304L used, the cost of boiler piping system can be significantly reduced.

References

[1] C.R. Das, A.K. Bhaduri, G. Srinivasan, V. Shankar, S. Mathew, Selection of filler wire for and effect of auto tempering onthe mechanical properties of dissimilar metal joint between403 and 304L(N) stainless steels, J. Mater. Process. Technol. 209 (2009) 1428-1435.

[2] TNB Manjung 4, WPS and PQR for Pressure Parts and Non Pressure Parts.

[3] R. Unnikrishnan, K.S.N. Satish Idury, T.P. Ismail, A. Bhadauria, S.K. Shekhawat, K. R. Khatirkar, S. G. Sapate, Effect of heat input on the microstructure, residual stresses and corrosion resistance of 304L austenitic stainless steel weldments, Mater. Charact. 93 (2014) 10-23.

[4] AK Steel, 304/304L Stainless Steel Product Data Sheet. Information on http://www.aksteel.com/pdf/markets_products/stainless/austenitic/304_304L_Data_Sheet.pdf.

[5] North American Stainless, Flat Product Stainless Steel Grade Sheet for 304, 304L and 304H. Infromation on http://www.northamericanstainless.com/wp-content/uploads/2010/10/Grade-304-304L-304H.pdf.

[6] The International Nickel Company Inc., Types 304 and 304L Stainless Steels Low Temperature Data Sheet.

[7] J. Lee, S. Han, K. Kim, H. Kim, U. Lee, Failure analysis of carbon steel pipes used for underground condensate pipeline in the power station, Eng. Fail. Anal. 34 (2013) 300-307.

[8] ASTM E 8M-04. Information on www.astm.org.

[9] Choo Bee Metal Industries, Mill Test Certificate.

[10] Pantech Stainless and Alloy Industries, Inspection Certificate.

[11] M.V., Kumar and V. Balasubramanian, Microstructure and tensile properties of friction welded SUS 304HCu austenitic stainless steel tubes, Int. J. Press. Vessels Pip. 113 (2014) 25-31.

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DOI References

[11] M.V., Kumar and V. Balasubramanian, Microstructure and tensile properties of friction welded SUS 304HCu austenitic stainless steel tubes, Int. J. Press. Vessels Pip. 113 (2014) 25-31.
http://dx.doi.org/10.1016/j.ijpvp.2013.11.005
[7] J. Lee, S. Han, K. Kim, H. Kim, U. Lee, Failure analysis of carbon steel pipes used for underground condensate pipeline in the power station, Eng. Fail. Anal. 34 (2013) 300-307.
http://dx.doi.org/10.1016/j.engfailanal.2013.08.005
[3] R. Unnikrishnan, K.S.N. Satish Idury, T.P. Ismail, A. Bhadauria, S.K. Shekhawat, K. R. Khatirkar, S. G. Sapate, Effect of heat input on the microstructure, residual stresses and corrosion resistance of 304L austenitic stainless steel weldments, Mater. Charact. 93 (2014).
http://dx.doi.org/10.1016/j.matchar.2014.03.013