Evaluation of Mechanical Properties for Bi-Metallic Welds

Shailja Mishra[1], Diyana Patel[1], Hiten Patel[1], Smit Patel[1], Mohit Teacher[2]
[1]Students, MED, Alpha College of Engineering & Technology, Gandhinagar, India-382721
[2]Assistant Professor, MED, Alpha College of Engineering & Technology, Gandhinagar, India-382721

Abstract

Bi-metallic welds (BMW) plays crucial and essential role in Pressurized Water Reactor (PWR) and Boiling Water Reactor (BWR), where heavy section alloys are connected to stainless steel piping systems. In Pressurized Boiling Reactor (PWR) and Boiling Water Reactor (BWR) are usually used where heavy steam flow is generated i.e. nozzles of Reactor Pressure Vessel (RPV), steam generators and pressurizers. Bi-metallic welds are often used to connect ferritic piping with austenitic piping. Recent study and experiments have shown that there are several cracking problems, fabrication induced defects, corrosion, ageing and thermal fatigue caused due to temperature changes during the whole process. Thus, here we are going to experiment with the mechanical properties and try to resolve all the above problems. The material used in present study is austenitic stainless steel 304L and carbon steel SA516 Gr.70. We welded these both materials through GTAW at different elevated currents i.e. 180 Amp, 200 Amp and 210 Amp. Filler rod used during GTAW was 309L.We made a butt joint on the plates. Hardness, Tensile and Impact test was conducted in the different parameters samples. From all the test result, it was concluded that highest heat absorption capacity was found in the sample that was welded at 200 Amp. The heat absorption capacity of the plate was 140.50 Joules. Also, lowest hardness observed was 198.33 HV 10 in the sample welded at 200 Amp. Thus, 200 Amp samples were most reliable and could reduce the above mentioned problems.

Keywords — *Bi-metallic welds, PWR- piping system, GTAW, mechanical properties, carbon migration*

I. INTRODUCTION

Pressurize Water Reactors (PWR) comprises the huge portion of nuclear power plant in PWR the main coolant is injected to the reactor core with high pressure and the main coolant is heated by the energy liberated by scission of atoms. Then the heated coolant transport to steam generator, where it conveys thermal energy to subordinate system where steam is produced and further transfer to turbine. As result of this, the electric generator is rotated in contrast to BWR. Also the pressure in the chief system creates the constant loop and it avoids getting the water to reach the boiling state within the reactor. Pressurized Water Reactor (PWR), were basically depicted to succour as marine impetus for nuclear submarine and were utilized in the authentic design of second commercial power plant at shipping port and Atomic power station.

PWR reactors are very steady as they have the propensity to generate less power as temperature increases. This shows those reactors are simple to operate from steady standpoint. In PWR's, Bi-metallic welds (BMW) have become necessity for the piping system to the various nozzles of the reactor pressure vessel (RPV), steam generators and pressurizers. Bi-metallic welds between ferritic low alloy steels such as SA516 GR.70 and austenitic stainless steel such as AISI 304L are used widely in PWR. In these power plants, austenitic stainless steel tubes are used in high temperature sections, where increased creep strength and resistance to oxidation are required. In the present study we have witnessed many literatures of different authors, who have excelled and brought appropriate conclusions regarding the mechanical behaviour of BMW. The following literature study is as follows:-

It was discerned in this study that BMW in Pressurize Water Reactors (PWR) are used in the piping systems where high temperature is observed and steam is produced at a high rate.

Here a simplified accelerated test procedure has been developed for testing hardness of Bi-metallic welds between Stainless Steel and Carbon steels. After conducting experiments on dissimilar metal joint samples, it was observed that hardness of these samples increased due to strain hardening. [1]

The essential concern of this work is to ameliorate the mechanical properties of the weld joint obtained by consolidating to dissimilar metals, because collapse of such metals at the weld joint is very ordinary in power plant and boilers where heavy start-up and shut down are required. Here it was concluded that maximum hardness and maximum energy stored in bi-metallic welding was obtained when the buttering process was performed on the plates. [2]

Here the mechanical behaviour of BMW used in nuclear power plant was discussed. Weld behaviour was contemplated in this work. It was perceived that carbon migration leads to formation of soft zone near interface which heads to drop of hardness zone. Thus, to prevent carbon migration, temperature should not be kept high and buttering layer thickness must be increased. [3]

In this literature, local mechanical properties of Alloy 52M dissimilar metal welded joints in nuclear power systems were determined using tensile specimens and microstructures in the joints were analysed. It was noticed that there were drastic fluctuations in the mechanical properties. Microstructures were identified at various locations in dissimilar metal welded joint (DMWJ). For complex microstructure, the main causes are heat flow and element migration during welding process. [4]

II. EXPERIMENTAL SET-UP

A. Base Materials

Bimetallic welds in PWR are usually utilized where the degree of heat is maximum and thus the welding done must be durable enough to sustain such a high amount of temperature. Usually in PWR, BMW are utilized in piping systems. In these pipes the flow of steam is immense and thus the joints between the pipes must be made sturdy and imperishable.

The materials used are carbon steel SA 516 grade 70 that is used in reactor pressure vessel and stainless steel type 304 L that is used in primary boiler tubes. There are three plates each received in form of rectangular block of 350*100*10 mm.

Fig. 1: SA 516 Gr70 and SS 304L as Base materials

Chemical compositions of base metal carbon steel SA516 Gr.70 and austenitic stainless steel 304L are given in the table.

Table 1: Chemical Composition of Stainless Steel and Carbon Steel SA516 Gr.70 (in %)

Type of Base Metal	C	Mn	Si	Cr	Ni	P	S
304L (Stainless steel)	0.03	2.00	1.00	18-20	8-12	0.045	0.03
SA 516 Gr 70 (Carbon steel)	0.2	1.05	0.32	0	0	0.015	0.008

B. Filler Metal

SS 309 L type of filer rod containing 24% Cr and 13% Ni is usually used as filler material in this type of welded joint for its thermal expansion coefficient laying between those of carbon steel and Austenitic Stainless Steel which is highly alloyed Austenitic Stainless Steel used for its excellent. Oxidation resistance, high temperature strength and creep resistance. The lower content of nickel in SS 309 L improves resistance to sulphur attached at high temperature. It is rough and ductile and can be readily fabricated and machined. Chemical composition of filler metal is given in table.

Table 1: Chemical Composition of Filler Metal SS 309L (in %)

Type of Base Metal	C	Mn	Si	Cr	Ni	P	S
309L (Stainless steel)	0.03	2.00	1.00	22-24	12-15	0.045	0.03

C. Mechanical And Physical Properties

The mechanical and physical properties of both the base material i.e. SA516 GR.70 carbon steel and austenitic stainless steel 304L and filler material i.e. Stainless steel 309L are as follows.

Table 3: Mechanical and Physical Properties of SS and Carbon Steel SA516 Gr.70

Type of Material	Tensile strength (MPa)	Yield strength (MPa)	Elastic Modulus (GPa)	Thermal Coefficient (10^{-5}m/m ^{o}c)	Density (Kg/m^3)
SA 516 Gr 70 (Base material)	510/650	260	190-210	11.7	7.85
304L (Base material)	480	170	193-200	17.2-18.4	7.8-8.0
309L(Filler material)	644	489	190-210	15.0-17.2	7.7-8.03

D. Shielding Gas

The shielding gas selected was commercially obtainable argon gas (99.97 % pure) with the rate of flow of gas 10 liter per minute after taking some trials on testing samples. This value was chosen because a good weld behavior is obtained on this value.

E. Sample Preparation

Both 304 L and SA 516 grade 70 steel plates of 10 mm thickness was available in pressure vessel

Table 4: Tensile Results for Three Samples

Sample ID NO.		180	200	210
Section Dimension (in mm)	Width	19.24	19.32	19.34
	Thickness	9.96	9.94	9.96
Area (in mm^2)		191.630	192.041	192.626
Ultimate Load (in KN)		111.980	110.720	111.360
UTS (in N/mm^2)		584.355	576.544	578.115
Location of Fracture		B.O.W	B.O.W	B.O.W

manufacturing industry were shaped and cut into 100*350*10 mm each plate. A single V groove of an angle 45^0 was created between these two plates. The base plates was welded to clench in appropriate alliance, so after welding the impact of deformation will be reduced of the accessibility of the root of the groove, for depositing the weld metal while the V groove geometry offers the better accessibility for up to the root of that groove, for depositing the weld metal and to bring that to the molten state.

After making the grooves, three plates of SA 516 gr.70 of dimension 100*350*10 mm were welded with the other three samples of austenitic stainless steel of same dimension. Here, the welding parameter i.e. current was selected and the voltage was noted down during welding. 180 Amp, 200 Amp and 210 Amp currents were considered and welding was done by considering three samples each for each parameter of current. Total 9 samples were obtained from this process. The welding used here was Gas Tungsten Arc Welding (GTAW).

Fig 2: Samples Prepared After Welding

III.EXPERIMENT RESULTS

A. Tensile Test

Tensile test is usually carried out to check that how the material react under different amount of forces. Tensile tests are also carried out to keep a check on the quality control of the components needs to be manufactured. Thus, here according to the ASME SEC IX tensile test method, tensile tests are carried out by using Universal Testing Machine. The dimensions of specimens after machining are shown in following table and graphs obtained after the tensile testing are as follows:

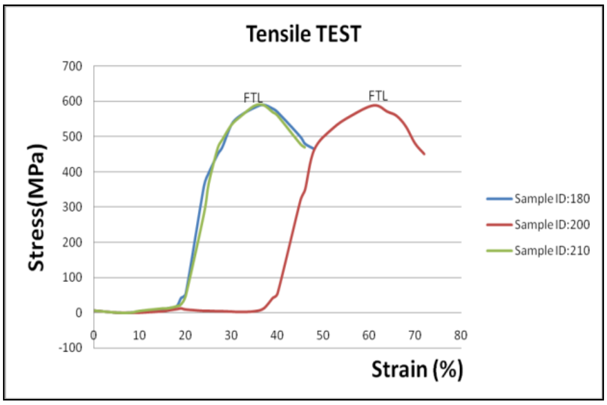

Fig 3: Stress- Strain Curve for All the Samples

B. Hardness Test

Hardness is the distinct feature of a material. It is defined as resistance to indentation. Here, ASTM E 384 Vickers Hardness Test is conducted applying a load of 10 Kg. The dimension of the sample prepared for this test was 10 mm thick and the readings were taken along the depth. When the load is applied by square base pyramid shaped diamond, permanent indentation takes place. The smaller the indentation, harder the material. Three readings for each point were taken along the weld zone, heat affected zone (HAZ) and base metal zone for both side which are noted and graphs are plotted accordingly on their average reading. The common results are as follows:

Table 5: Hardness Results for Three Samples

	VHN		
Sample ID No	180	200	210
BASE of Carbon Steel	173.33	171.33	171.67
HAZ of Carbon Steel	187.67	184.67	182.67
WELD	203.33	198.33	199.33
HAZ of Austenitic Steel	192.67	192.00	191.33
BASE of Austenitic Steel	188.00	186.67	184.00

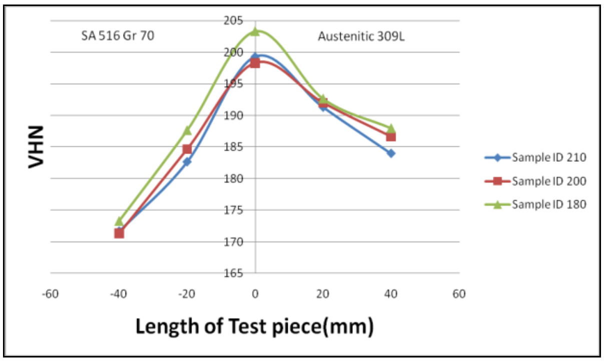

Fig 4: Graphs of the Hardness Results

C. Impact Test

Impact test also noted as toughness test which computes the amount of energy assimilated by a material during fracture. Here we decided to perform Charpy Impact Test and so the specimen prepared was in form of notch shape; thus when the pendulum of familiar mass and length is dropped from height which struck the specimen of the material. The energy transhipped to the material can be deduced by collating the deference of height before and after the fracture. ASTM A370 test method was utilized here. The test was conducted at room temperature. The specimen dimension was 10*10*55 mm.

The Charpy test conducted on the bimetallic weld samples yields the amount of energy absorbed by these materials. The results are as follows:

Table 6: Charpy Test Results for Three Samples

Sample ID No.	Impact Energy Absorbed (in Joules)			Avg. Joules
180	123.00	117.500	131.500	124.00
200	146.000	140.500	135.000	140.50
210	117.000	126.000	105.000	116.00

IV.CONCLUSIONS

Hardness and toughness observation was conducted on the Bi-metallic welds of austenitic stainless steel 304L and carbon steel SA516 Gr.70 at different parameters by GTAW (Gas Tungsten Arc Welding). The vital outcome and conclusion are outlined in the following:

- The hardness is maximum at weld zone and it continuously decreases towards base metal via HAZ.
- The lowest hardness was observed was 198.33 HV 10 in the sample which was welded at 200 ampere.
- The maximum energy stored during impact test was 140.50 Joule which was welded at 200 ampere.

In the present study we tested the mechanical properties of BMWs at different parameters hence sample which were welded at 200 ampere are best reliable according to the results obtained.

ACKNOWLEDGMENT

We are fortunate to be the students of Prof. Mohit Teacher. It is a great privilege to work under his guidance and we hope we can take full advantage of this opportunity. We also express our gratitude to Prof. Rahul Thaker who helped us all along the way during the course of this project and we look forward to learn more from him. We would like to express special thanks to our HOD Prof. Vijay Bariya, who gave us this opportunity to do this project, which helped us in learning new things.

We are thankful to Chirag Industries, who helped us in getting appropriate material for experiment and machining the material in limited budget. We would deeply thank Mr. Parth Patel for granting the permission to do our project at Premier Engineering and providing all the amenities and Mr. Bharatbhai Patel who guided us and being a familiar with latest technology. Also the staff of Industry helped us at the crucial stage of this task and sharpened our knowledge.We would like to thanks Divine Metallurgical services Pvt. Ltd. for helping and guiding us in experimental results for this project.

REFERENCES

[1] Manoj Saini, Navneet Arora and Amit Dhiman; "Evaluation of Hardness of Dissimilar Metal Joint Subjected to Thermal and Mechanical Loading", MIT International Journal of Mechanical Engineering, Vol. 4, No.2, August 2014

[2] Mudit Sharma, Rahul and Arshad Mehmood; "Evaluation of Hardness of Bi-metallic weld Joint between SA-508Gr3 and SS-304L", International Research Journal of Engineering and Technology (IRJET), Vol. 4, Issue 2, Feb-2017

[3] Manoj Saini, Navneet Arora, Chandan Pandey and Hussain Mehdi; "Mechanical Properties of Bi-Metallic Weld Joint between SA-516 Gr 65 CARBON STEEL and SS-304L for Steam Generator Application", International Journal of Research in Engineering and Technology (IJRET).

[4] H. T. Wang, G. Z. Wang, F. Z. Xuan, C. J. Liu, S. T. Tu; "Local Mechanical Properties of a dissimilar metal welded joint in nuclear power systems", Key Laboratory of Pressure Systems and Safety, Ministry of Education, East China University of Science and Technology, Shanghai 200237, China

[5] K. Gupta, R. Chhibber; "Structural Integrity Of Bimetallic Welds At Elevated Temperature", International Journal Of Mechanical Engineering And Technology (IJMET), Volume 3, Issue 1, January-April (2012), pp.235-243

[6] M. K. Samal, M. Seidenfuss, E. Roos, and K. Balani; "Investigation of failure of ferritic-austenitic type of dissimilar steel welded joints", journal homepage: www.elsevier.com/locate/engfailanal

[7] W. Brocks, A. Cornee and W. Schonfeld; "Fracture Mechanics Assessment of a Bi-Metallic Welded Joint", GKSS Research Centre, Geesthacht, Germany

[8] Claude Faidy; "Structural Integrity Of Bi-Metallic Welds In Piping Fracture Testing And Analysis", Proceedings of PVP2008, 2008 ASME Pressure Vessels and Piping Division Conference, July 27-31, 2008, Chicago, Illinois, USA.

[9] H. T. Wang, G. Z. Wang, F. Z. Xuan, S. T. Tu; "Fracture mechanism of a dissimilar metal welded joint in nuclear power plant", journal homepage:- www.elsevier.com/locate/engfailanal

[10] R. Chhibber, N. Arora, S R Gupta and B K Dutta; "Use of bimetallic welds in nuclear reactors: associated problems and structural integrity assessment issues"

[11] H. T. WANG, G. Z. WANG, F. Z. XUAN, S. T. TU, "Numerical investigation of ductile crack growth behavior in a dissimilar metal welded joint", Nuclear Engineering and Design, journal homepage: www.elseiver.com/locate/nucengdes.

[12] Husain Mehdi, Shwetanshu Gaurav, Teetu Kumar, Prasoon Sharma, "Mechanical Characterization of SA-508 GR3 and SS-304L Steel Weldments", International Journal of Advanced Production and Industrial Engineering (IJAPIE)