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Effect of welding repair on mechanical properties of ASTM A36 carbon steel weld joints

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Abstract

The welding repair process greatly affects the procedure of a welding process to be able to obtain the results of a connection that is safe and in accordance with its provisions. The strength of the welded joint must be considered and ensured that its strength is at least close to the original strength of the material used. In a welding process, errors or omissions are often made accidentally by the welder or the work environment and the selection of welding variable parameters is not appropriate so that welding defects occur. Welding defects can affect the strength of the weld joint. The purpose of this study was to determine the effect of welding repair on the mechanical properties of ASTM A36 material. The material used in conducting this research and testing is ASTM A36 steel plate. Welding was carried out on 4 specimens with the method without repair, repair 1x, repair 2x and repair 3x. Based on the test results, the number of repairs greatly affects the strength of the material connection. The highest maximum tensile strength value in 1 repair specimen is 501.90 Mpa and the lowest is in unwelded material or base metal of 467.97 Mpa. The results of the highest hardness test on the repair material 1 time of 30.83 HRC in the weld metal area and the lowest hardness value on the repair specimen 3 times in the HAZ area of 21 HRC. The results of the macro photo test on each specimen did not detect any welding defects on the inside of the welded material. the largest HAZ width in the 3 times repair material is 21.5 mm and the smallest HAZ width in the specimen without repair is 18 mm.

Keywords:
welding repair, ASTM A36, tensile strength, hardness, macro test

1 Introduction

At this time the scope of use of the welding process is very broad, including the shipping industry [1], oil and gas industry, pressure vessels, piping systems, heavy equipment, Heat Exchanger, and boiler. Almost every industry uses metal materials, welding technique is the most efficient and practical joining process compared to other metal joining techniques. ASTM A36 steel plate is a carbon structural steel that is often used in the manufacture of welded and bolted metal structures in the construction, oil and gas industry as well as structures from bridges. ASTM A36 steel is also used in the manufacture of products and parts for general construction purposes[2], [3].

In a welding process, errors or omissions are often made accidentally by the welder or the work environment and the selection of welding variable parameters is not appropriate so that welding defects occur, such as crack, porosity, incomplete fusion, undercut and so on so that repairs are needed. The welding repair process carried out will expose the material to repeated heat and will cause deformation, metallurgical changes, thermal stress, and structural changes. The welding repair process repeatedly affects the mechanical properties and microstructure of the base metal used, heat affected parts or HAZ (Heat Affected Zone) and weld metal parts (weld metal). Due to changes in the structure, the mechanical properties of the material will change and have an impact on the value of material hardness and material strength[4].

The welding repair process is also important in metal engineering and repair, making welds on tools, thickening worn parts, and various other repairs so that welding repairs must be carried out to repair them. The welding repair process greatly affects the procedure of a welding process to be able to obtain the results of a connection that is safe and in accordance with its provisions.[5]. The strength of the welded joint must be considered and ensured that its strength is at least close to the original strength of the material used.

Based on these problems, it is necessary to conduct a study to determine the appropriate number of welding repairs so that there is no decrease in the strength of the welding connection due to the excessive number of welding repairs[6][7]. Several studies on welding repair have been carried out to obtain suitable welding parameters[8]–[12]. From this research, it is hoped that the industry will get information about the effect of repair for the welding process of materials, especially on ASTM A36 steel material on the value of hardness, tensile strength of welding joints. So that later it becomes a benchmark for the industry, the material must be replaced or just repaired. With this research data, the industry can find out the number of welding repairs that are in accordance with the standards adopted specifically for ASTM A36 material connections. Because each standard follows data acceptance criteria according to the material being welded.

The purpose of this study was to determine the effect of welding repair on the mechanical properties of ASTM A36 material, namely tensile strength, hardness and metallography macro test.

2 Research methods

The method used in this study is an experimental method used to determine the effect of welding repair on the mechanical properties of ASTM A36 material[2]. This experimental study was also conducted to determine the consequences of a welding treatment given intentionally by the researchers to determine the difference in the mechanical properties of the ASTM A36 material due to the difference several times between the welding repair process and without welding repair using a tensile test and a hardness test. macro photo testing (Macro etching) to determine HAZ width propagation, and to detect inner weld defects.

The materials used in conducting this research and testing are ASTM A36 steel plates with a length of 100 mm x 150 with a thickness of 8 mm for 4 joints. Material composition as shown in table 1. Electrode E7016 AWS A5.1 E7016 with ø 3.2 and ø 2.6 mm. The E 7016 electrode is a type of E 7016 electrode in the AWS classification (American Welding Society)[13]. The flux of the material used for the E7016 type is High titania Potassium. This type of electrode can be used for welding any position. The potassium-containing E7016 facilitates the use of low engine parameters and is used for welding thin plates.

Table 1. Chemical composition of ASTM A36 material.

Element	Contents
Iron, Fe	98 %
Carbon, C	0,25-0,29 %
Copper, Cu	0,20 %
Manganese, Mn	1,03 %
Phosphorus, P	0,04%
Silicon, Si	0,28%
Sulfur, S	0,05 %

The first step of the research was to cut ASTM A36 steel with a size of 100 x 150 mm for 4 joints. Next, make a groove with an angle of 30˚ as shown in fig. 1 and welding parameters as shown in table 2.

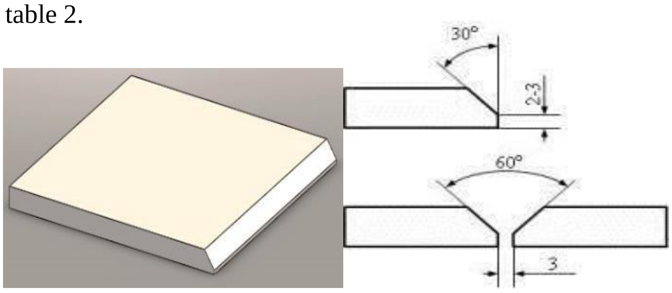


Fig. 1. Sudut kampuh V tunggal

Table 2. Welding Parameters

layer	Root	Filler	Capping
Welding process	SMAW	SMAW	SMAW
Travel speed (mm/s)	1.76	1.68	1.53
Polarity	DCEN	DCEP	DCEP
Current (A)	70A	85A	90A
Repair current A)	0	0	85
Voltage (E)	22-24	25 -27	27
Electrode (mm)	2.6		3.2

Welding with a current of 65-70 Amp for penetration (root) and 90-110 Ampere for filling and closing. Repair for 4 variations of welding, namely without repair, repair 1 time, repair 2 times, and 3 repair. The grinding technique is carried out for the repair process with a depth of 70% of the material thickness and re-welding until it reaches the capping. Welding is carried out for the four types of specimens with a total of 3 layers, starting from the penetration (root pass), filling and capping as shown in Fig. 2

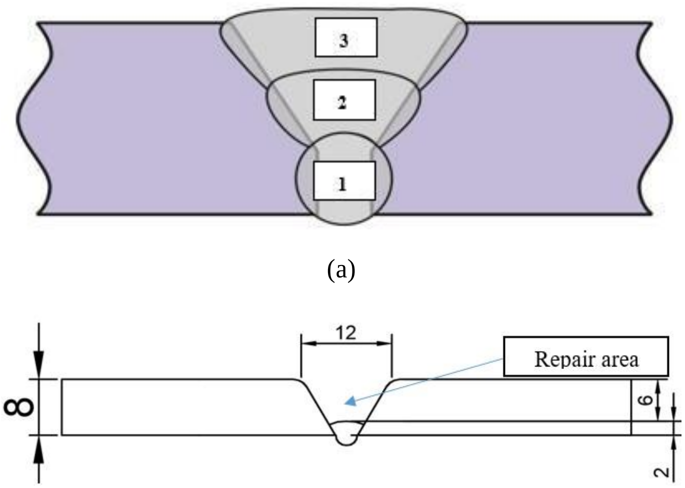


Fig. 2. (a) Number of welding layers. (b) *Repair area.*

After the welding process, mechanical testing is carried out to determine the strength of the load that occurs on the material and recognize the characteristics of the strength of the load that occurs on the material and recognize the strength characteristics of the material and the author uses the tensile test and hardness test methods to find the tensile strength and hardness of ASTM 36 steel. with the effect of variations in welding current on the mechanical properties of the SMAW welding process. [14]

The first test is a tensile test. The number of tensile test specimens is 2 tensile test specimens for each variation according to the ASME BPVC.IX-2019 standard[15] as shown in Fig. 3.

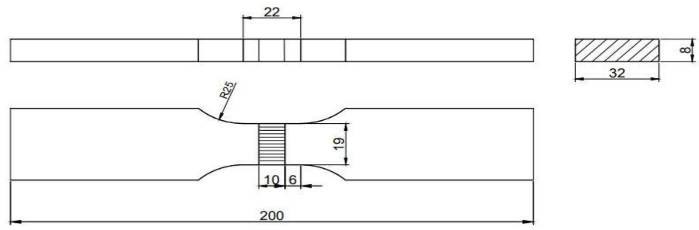


Fig. 3. Dimensions of tensile test specimen

The hardness test was then carried out. Rockwell hardness aims to determine the hardness of a material in the form of the material's resistance to an indenter in the form of a steel ball or diamond cone which is pressed on the surface of the test material. Hardness testing was carried out on specimens using the Rockwell hardness tester using the HRC method (*Hardness Rockwell Cone*) as shown in Fig. 4.

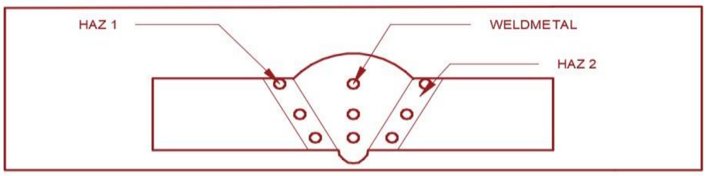


Fig 4. Hardness testing point

Furthermore, testing macro photos by taking macro photos on specimens using a camera and measuring the width of the HAZ [16] by measuring the width of the HAZ 3 on the left and right of the weldmetal using a caliper by placing the measurement position as shown in Fig. 5:

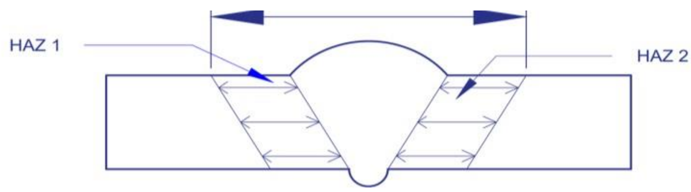


Fig. 5. HAZ area width measurement

3 Results and Discussion

Welding results are shown in Fig. 6:

Fig. 6. Root welding

The picture above is a welding process on the root or root pass. This is welding on the first layer which is the initial welding of a welding process. After root welding, before proceeding to hotpass and filler welding, a visual NDT inspection was carried out to see the potential for weld defects. If there is a welding defect, it will be repaired or repaired by grinding until all the weld metal is removed, then welding again. The results of the repair welding as shown in Fig. 7.

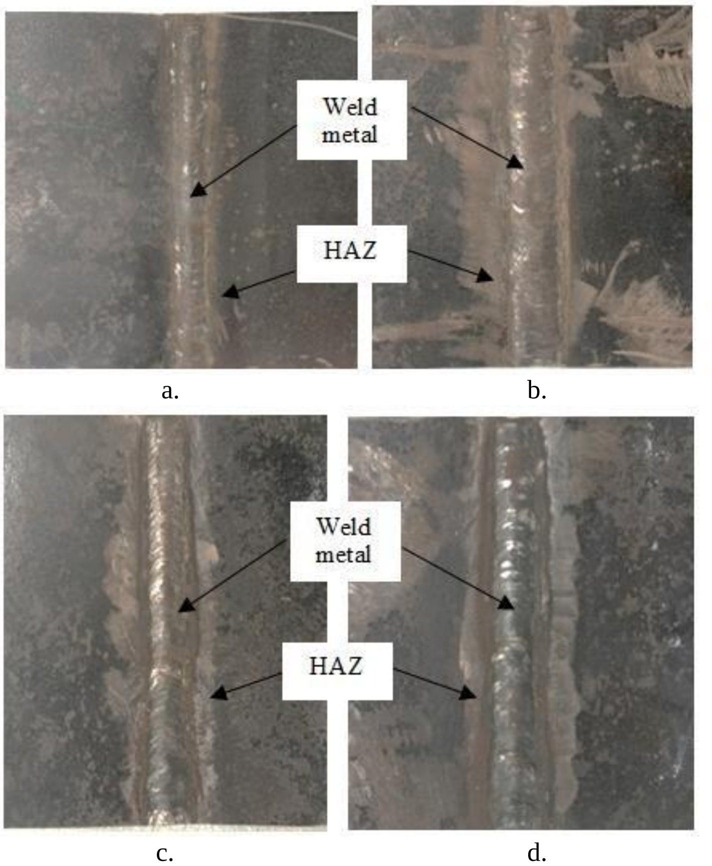


Fig. 7. Weld results. (a) Without repair, (b) repair 1x, (c) repair 2x and (d) repair 2x

Figure 7 is the result of welding with four variations as the focus of the research, namely without repair, 1x repair, 2x repair and 3x repair. The repair process is carried out at layers 2 and 3 or at the fill pass and capping positions. After visual observation, no welding defects were found so that it could be continued for the process of testing mechanical properties.

The results of the welding of the four specimens were tested for tensile strength, hardness and macro photos to see the welding profile and the HAZ area that occurred after welding.

Tensile testing on welded specimens is intended to determine the ultimate tensile strength of the welded joint material on ASTM A36 material. In the tensile test there are 8 test specimens based on 4 variations, namely welding without repair, 1 time repair, 2 repairs and 3 repairs plus 1 Base metal specimen to ensure the correctness of the ASTM A36 material and for comparisons between the tensile strength of the material used. without being welded with the material being welded and with the material being re-welded. The results of the tensile test are as shown in Fig. 8 where the fault location is located in the HAZ (Heat Affected Zone) area.

From the pictures and graphs Fig. 9 shows the level of tensile strength of the ASTM A36 material, whether undergoing welding treatment or not, the results show that the highest tensile strength value is found in the 1 Times repair material with a tensile strength value of 501.90 Mpa which is higher than the specimen without repair 477.24 Mpa, Base matal worth 450 MPa, 2 times repair 477.78 MPa and 3 times repair 469.79 MPa. Meanwhile, the average specimen point occurs in the HAZ and Base Metal border areas. Based on the results of the tensile test obtained test data as shown in Fig. 9.

From the data from the tensile test results show that the repair process greatly affects the strength of the material. The repair process on ASTM A36 material increases the tensile strength value higher than basemetal and increases the tensile strength value starting from without repair.

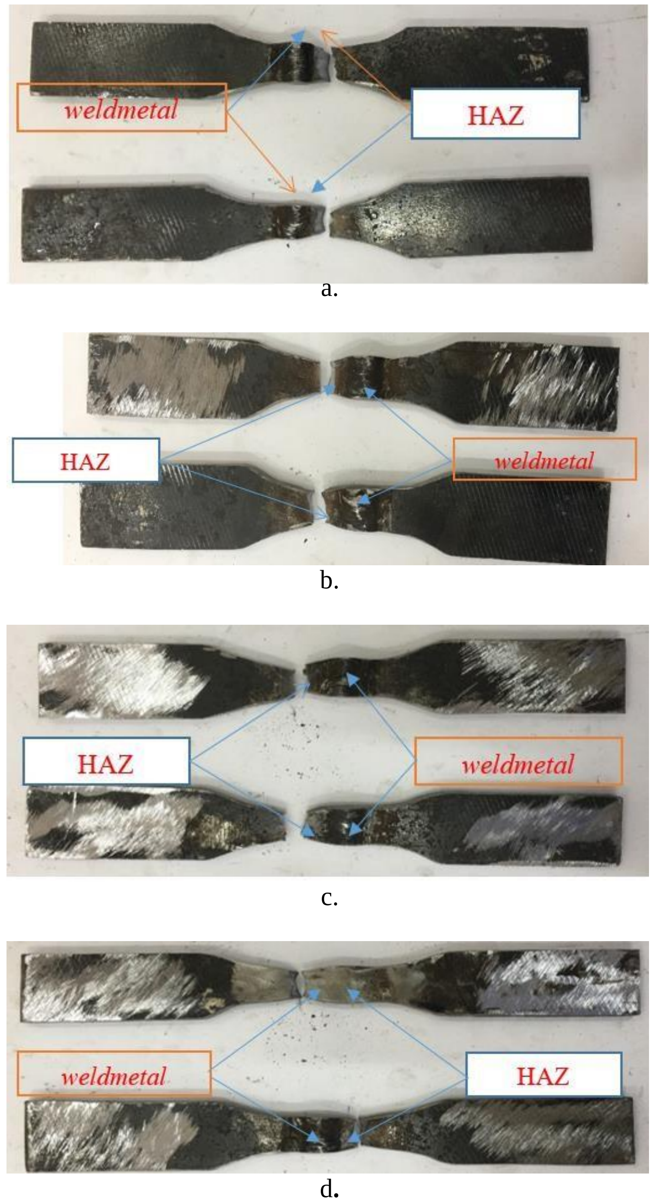
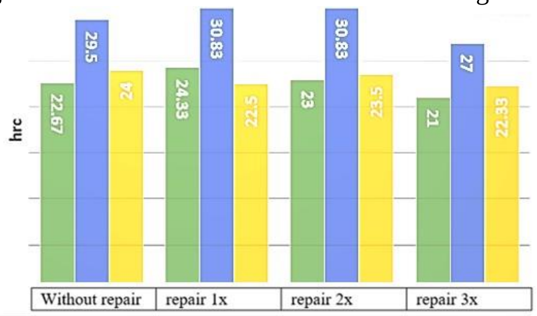


Fig 8. Tensile test results. (a) Withour repair, (b) Repair 1x, (c) Repair 2x and (c) Repair 1x

Fig. 9. Tensile test data

There is a very significant increase after the material has undergone welding for 1 repair and then decreasing again after being repaired 2 times, and repairing 3 times. The lowest tensile strength value from the repair process 3 times is 469.79 Mpa but is still above the tensile strength value of basemetal 467.97 Mpa, so the ASTM A36 material is repaired 3 times still feasible to use because the value of the tensile strength is still above the value of the tensile strength of the base metal material ASTM A36. With these results, hopefully it will be information for the industrial world in the field of welding, especially in the process of re-welding or welding repair to find out the number of repairs determined by an industry, especially welding joints using ASTM A36 material.

Furthermore, the Rockwell method hardness test was carried out. The purpose of the hardness test is to determine the hardness of a material in the form of the material's resistance to an indenter in the form of a steel ball or diamond cone which is pressed on the surface of the test material. Hardness testing was carried out on the specimens with a Rockwell hardness tester. The method of measuring hardness is the HRC (Hardness Rockwell Cone) method. A diamond cone with an angle of 120°. Hardness testing was carried out at 9 area points, weldmetal, HAZ 1, HAZ 2 with a total of 9 test points as shown in Figure 4 and also tested on RAW material to be able to compare changes in the hardness value of the material without treatment and material that has undergone welding treatment. Hardness test data as shown in Fig. 10.



	Without repair	repair 1x	repair 2x	repair 3x
HAZ 1	22.67	24.33	23	21
WELD	29.5	30.83	30.83	27
HAZ 2	24	22.5	23.5	22.33

Fig. 10. Tensile test data

The highest average hardness value is found in the weldmetal area with repair welding as much as 2 times of 30.83 HRC and in the weldmetal area the specimen is repaired once at 30.83 HRC and the lowest hardness value in the weldmetal area is found in the specimen 3 times repair, namely 27 HRC and an average of – The lowest average was found in the HAZ 1 area of 21 HRC in the 3 repair specimens, and the highest hardness value in each specimen was found in the weldmetal area. So it can be concluded that the effect of repair welding on the hardness value of the SMAW welding material is very large, when viewed from the results of hardness testing, the hardness value of the material that has undergone a repair process 2 times and 1 time repair has a higher hardness value than the specimen without repair and 3 times repair so that it can be concluded that the repair process twice will result in a decrease in the hardness value, especially in the weldmetal and HAZ areas. The decrease in hardness value is caused by repeated heat input due to re-welding that exceeds 2 repairs. With these results, it becomes a guideline for the industrial world, especially in the welding field when doing repair welding on ASTM A36 material.

Furthermore, the Macro Etching test is carried out which is one of the metallographic material tests directly or by using visuals. This test is carried out to determine the quality of the weld and material without treatment through a cross section of the weld and material. After obtaining the cross section, it is etched and what has been etched will be observed manually/visually. Some of the welding defects that can be seen from this test are *porosity*, *incomplete penetration (IP)*, *incomplete fusion*, crack dan *undercut*. From this test can be known about the weld profile so that it can be seen the dimensions of the leg length, size of weld, dan throat of weld and width HAZ (Heat Affected Zone)

In this etching macro test, the HAZ and Weld Metal areas will be seen, and from the results of observations for 4 types of specimens, no weld defects were found after re-welding, and measuring the extent of the HAZ widening as for how to measure the spread of the HAZ width from the macro test results shown in the Fig. 11.

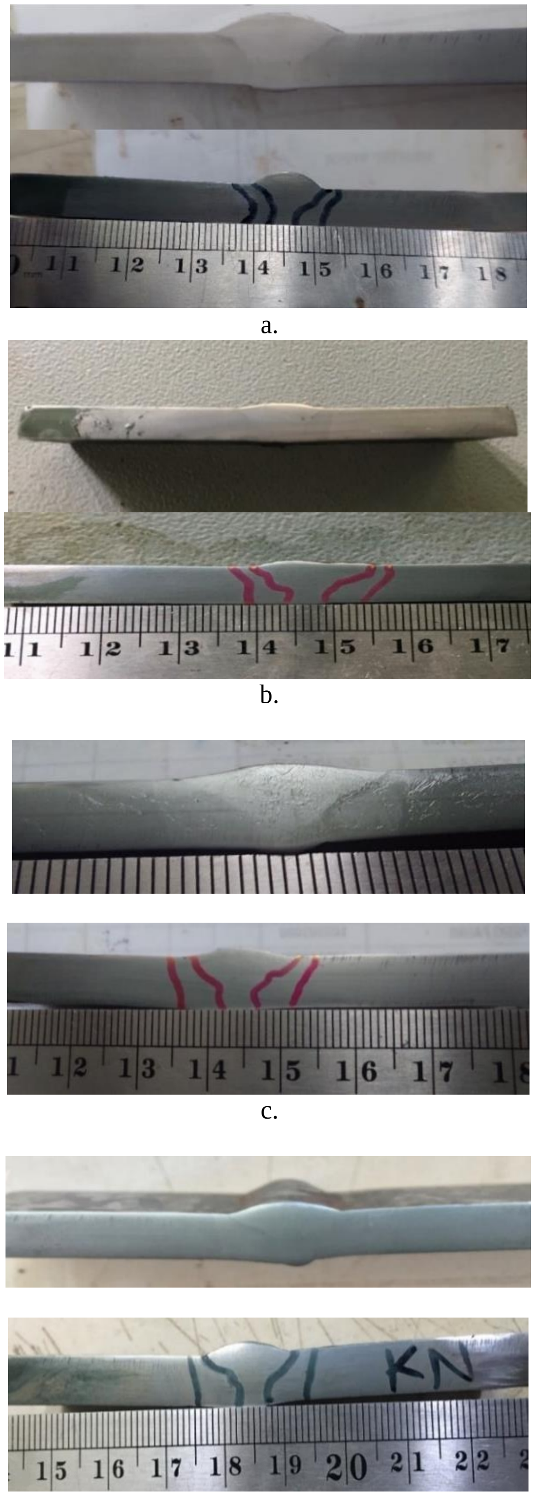


Fig. 11. Macro shot. (a) Without Repair, (b) Repair 1x, (c) Repair 2x and (d) repair 3x

Based on the results of macro photos, data on the HAZ width comparison between the left and right of the weldmetal is shown in Fig. 12. It can be explained that the results of measuring the HAZ width from the left and right of the weldmetal and the results obtained were a widening of the HAZ specimen for 1 repair and then increased in the 2 repair specimen and the highest HAZ width was in the 3 repair specimen.

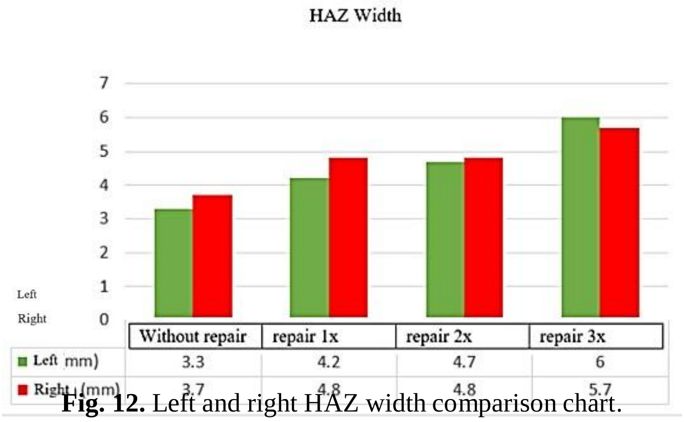


Fig. 12. Left and right HAZ width comparison chart.

The cause of the increasing HAZ widening, starting from the lowest in the specimen without repair and the highest in the 3 repair specimen, was caused by repeated heat input due to repeated welding processes at the same point according to the number of repairs in each type of repair variation. The HAZ overall width comparison chart as shwon in Fig. 13.

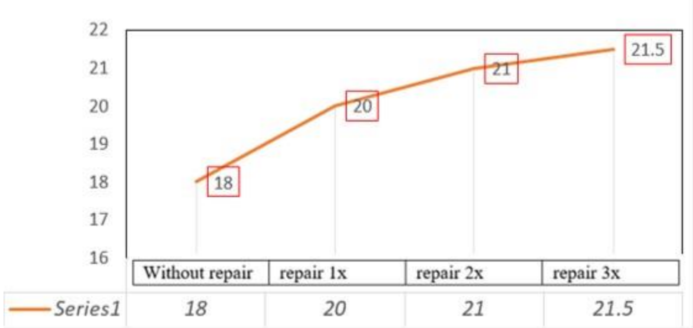


Fig. 13. HAZ overall width comparison chart.

From fig 13, it can be concluded that there is no welding defect in the test specimen. The widest HAZ propagation area was found in 3 repair specimens with a total length of HAZ and weldmetal of 21.5 mm, followed by 2 repair specimens of 21 mm, 1 repair specimen 20 mm and the smallest HAZ propagation area was found in unrepaired specimens with a length of 20 mm. only 18mm. so it can be concluded that the result of the welding repair process greatly affects the widening of the HAZ area due to repeated heat input to cause the width of the HAZ of a welded joint and when associated with the tensile test value and hardness test which decreases the hardness value and hardness value that occurs in specimen 3 repair times while the wider HAZ width is found in the 3 repair specimens. It can be concluded that the more the repair process, the lower the hardness and tensile strength values and the increasing widening of the HAZ width.

4 Conclusion

The conclusion of this study is that the highest maximum tensile strength value is found in the 1-time repair specimen, namely 501.90 Mpa, the 2-time repair specimen 477.78 Mpa, the 477.24 Mpa specimen without repair and the lowest is the untreated material, which is 467.97 Mpa and the 3 repair specimen with a value of 469.79 MPa. The results of the Hardness test show that the highest hardness value is found in the material that undergoes a repair process of 1 time 30.83 HRC and specimens 2 times repair of 30.83 HRC. Precisely in the weld metal area, and the lowest hardness value is found in the re-welding specimen 3 times to be precise in the HAZ area, which is 21 HRC, RAW hardness value of ASTM A36 material 24.43 HRC. The results of the macro photo test on each specimen did not detect any internal welding defects, and the largest haz width occurred in the material that was re-welded 3 times for repairs along 21.5 mm and the smallest HAZ width was in the specimen without repair, which was 18 mm.

Reference

[1] H. Sunaryo, “Teknik Pengelasan Kapal,” *Jakarta Direktorat Pembin. Sekol. Menengah Kejuru.*, 2008.

[2] ASTM International, “Standard Specification for Carbon Structural Steel A 36/A 36M – 04,” *ASTM Int.*, vol. 70, pp. 1–2, 2004.

[3] A. Nugroho, “Pengaruh Variasi Kuat Arus Pengelasan Terhadap Kekuatan Tarik dan Kekerasan Sambungan Las Plate Carbon Steel ASTM 36,” *J. Rekayasa Sist. Ind.*, vol. 3, no. 2, pp. 134–142, 2018.

[4] A. B. Anggoro, “KUALITAS REPAIR WELDING DENGAN METODE OKSI-ASETILIN DAN PERLAKUAN PREHEATING PADA CAST WHEEL ALUMUNIUM SEBAGAI SUPLEMEN MATERI MATA KULIAH TEKNIK PENGELASAN,” *J. Nosel*, vol. 3, no. 4, 2015.

[5] P. A. Rometsch, Y. Zhang, and S. Knight, “Heat treatment of 7xxx series aluminium alloys—Some recent developments,” *Trans. Nonferrous Met. Soc. China*, vol. 24, no. 7, pp. 2003–2017, 2014.

[6] M. P. Nascimento, H. J. C. Voorwald, and J. D. A. C. P. FILHO, “Effects of several TIG weld repairs on the axial fatigue strength of AISI 4130 aeronautical steel- welded joints,” *Fatigue Fract. Eng. Mater. Struct.*, vol. 35, no. 3, pp. 191–204, 2012.

[7] A. Assar, B. Nami, N. B. M. Arab, and I. Khoubrou, “Effect of heat input of TIG repair welding on microstructure and mechanical properties of cast AZ91 magnesium alloy,” *Weld. World*, vol. 65, no. 6, pp. 1131–1143, 2021.

[8] G. Trisdyanto, M. Choifin, T. Mesin, U. Maarif, and H. Latif, “ANALISA PENGARUH VARIASI MULTIPLE REPAIR DAN TANPA REPAIR PADA PENGELASAN FCAW BAJA KARBON JIS G3106 SM 490 YB TERHADAP SIFAT MEKANIK,” vol. 2, no. 2, pp. 153–162, 2019.

[9] M. Fisk and A. Lundbäck, “Simulation and validation of repair welding and heat treatment of an alloy 718 plate,” *Finite Elem. Anal. Des.*, vol. 58, pp. 66–73, 2012.

[10] I. AghaAli, M. Farzam, M. A. Golozar, and I. Danaee, “The effect of repeated repair welding on mechanical and corrosion properties of stainless steel 316L,” *Mater. Des.*, vol. 54, pp. 331–341, 2014.

[11] M. N. Juanda and H. Oktadinata, “PENGARUH WELDING REPAIR TERHADAP SIFAT MEKANIK PADA PENGELASAN GTAW BAJA DUPLEX UNS S32760,” *J. Ilm. Tek. MESIN*, vol. 7, no. 2, pp. 87–93, 2019.

[12] P. W. Bimantoro, “PENGARUH MULTIPLE REPAIR WELDING PADA PENGELASAN GTAW DAN SMAW TERHADAP STRUKTUR MIKRO, FERRITE NUMBER, SIFAT MEKANIK DAN LAJU KOROSI PADA MATERIAL PIPA SA 312 TYPE 304L.” POLITEKNIK PERKAPALAN NEGERI SURABAYA, 2016.

[13] I. A. Faqih, S. Ma’arif, and H. Sukarjo, “The Effect of Current Variation on MMA Welding to Mechanical Properties and Microstructure of Mild Steel,” *Proceeding Int. Conf. Mater. Sci. Technol.*, vol. 1, no. 1, pp. 21–26, 2019.

[14] A. Azwinur, S. A. Jalil, and A. Husna, “PENGARUH VARIASI ARUS PENGELASAN TERHADAP SIFAT MEKANIK PADA PROSES PENGELASAN SMAW,” *J. POLIMESIN*, vol. 15, no. 2, p. 36, Sep. 2017, doi: 10.30811/jpl.v15i2.372.

[15] A. Boiler, *Section ix*. 2019.

[16] K. Fecl, G. Anggaretno, and I. Rochani, “1619-5791-1-Pb,” vol. 1, no. 1, pp. 3–7, 2012.