



## Welding Defect Analysis on ASTM A106 Grade B with Inconel 82 Using Metallography Test and Microhardness Test

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### Abstract

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Welding inspection is an important practice to assess the integration of structures and their components in many industrial applications. This study aims to show the quality of ASTM A106 pipes after welding can withstand high pressure and temperature, such as in the riser tube primary reformer. This research method is to inspect the welding results on ASTM A106 grade B pipes with inconel 82 using metallography and microhardness. Based on the visual and penetrant test results, there were cracks in the meeting area between the Inconel 82 weld and ASTM A106 grade B. The results of the metallography test in the meeting area between Inconel 82 and ASTM A106 grade B showed continuous microcracks and continuous macrocracks. The microhardness test results in the area around the crack had a lower hardness value than the area far from the crack. ASTM A106 grade B welding joints with Inconel 82 cannot be used optimally at a temperature of 748oC because Inconel 82 has a silicon content of 0.5% which causes a difference in solidification between ASTM A106 grade B and Inconel 82

**Keywords:** Metallography Test, Microhardness, Welding

### Abstrak

Inspeksi pengelasan merupakan praktik penting untuk menilai integrasi struktur dan komponennya dalam banyak aplikasi industri. Tujuan penelitian untuk menunjukkan kualitas pipa ASTM A106 setelah pengelasan dapat menahan pada tekanan dan suhu yang tinggi, seperti pada riser tube primary reformer. Metode penelitian ini untuk melakukan inspeksi hasil pengelasan pada pipa ASTM A106 grade B dengan inconel 82 menggunakan metalografi dan microhardness. Berdasarkan Hasil visual test dan penetrant test menunjukkan adanya crack pada area pertemuan antara lasan Inconel 82 dengan ASTM A106 grade B. Hasil metallography test pada area pertemuan antara Inconel 82 dengan ASTM A106 grade B terdapat continuous microcrack dan continuous macrocrack. Hasil pengujian microhardness pada daerah sekitar crack memiliki nilai kekerasan lebih rendah dari daerah yang jauh dengan crack. Sambungan pengelasan ASTM A106 grade B dengan Inconel 82 tidak mampu digunakan secara optimal pada temperatur 748oC karena Inconel 82 memiliki unsur silicon sebesar 0.5% yang menyebabkan perbedaan solidifikasi antara ASTM A106 grade B dengan Inconel 82.

**Kata-kata kunci:** Metallography Test, Microhardness, Pengelasan



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## 1. Introduction

Welding is a metal joining technique by melting some of the parent metal and filler metal with or without pressure and producing continuous metal [1]. In other words, welding is a local connection of several metal rods using heat energy [2]. Welding production factors are the manufacturing schedule, manufacturing process, tools and materials needed, sequence of implementation, welding preparation (including: selection of welding machine, appointment of welder, selection of electrodes, use of weld type [3].

The welds must be placed so far that the heat affected zones do not overlap [4]. To determine the distance between joints in a weld is usually determined by the needs and conditions in the field, the welding joint may have a close distance to other joints. Minimum weld distance requirements are based on geometric reasons, such as avoiding overlapping stress concentrations at the weld end or providing adequate access for inspection equipment after welding, or this may be based on residual stress, and avoiding overlapping residual stress and distortion, which are influenced by pipe dimensions and welding procedures and the distance can approach several inches [5].

Bimetal welding is a welding process that connects two different types of metals [3]. Bimetal welding has a higher level of complexity than welding similar metals. Because dissimilar metals have different characteristics from each other [6]. So that the welding process of dissimilar metals requires several specific techniques, for example, the selection of the metal to be joined must be precise, the selection of the appropriate electrode, the correct heat input setting, and the selection of the correct post-welding heat treatment [7].

Refinery pipes are part of a unit that plays a very important role in the world of utilities Timothy, dkk [8]. Therefore, the quality of oil industry pipes must be able to withstand high pressure and temperature, in addition, the pipes are operated safely so that fatal errors do not occur and cause accidents. The materials often used for oil and gas production are carbon steel, which is relatively cheap, easy to obtain, and has low properties (workability). The pipe that is often used is the ASTM A106 Grade B type. ASTM A106 Grade B material is included in carbon steel with the Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service Dewi, dkk [9]. ASTM A 106 pipe made of carbon steel has a maximum carbon content of 0.30% and has a minimum tensile strength of 415 MPa [10]

Welding carried out on pipe joints produces a heating effect in one place from a high temperature, as a result the pipe experiences thermal expansion and contraction during cooling. This results in residual stress, namely changes in microstructure and high hardness in the heat-affected zone (HAZ) [5]. Residual stress from welding can cause weld cracks and endanger the welded structure when loaded. One of the best ways to avoid this is using a thermal method using the PWHT (Post Weld Heat Treatment) process [11].

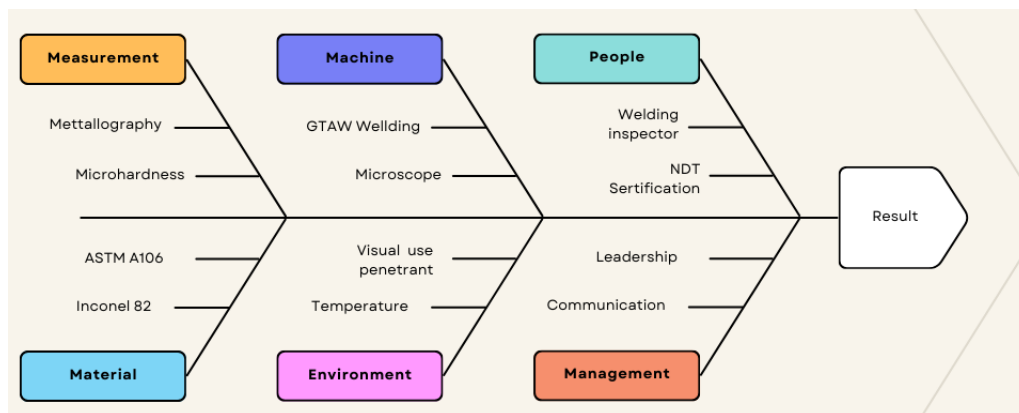
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There is a Primary Reformer tool, which is operated at a temperature of 600-800°C and a pressure of 30-40 Kg/cm<sup>2</sup>. This tool is in the form of a tube that functions to break down hydrocarbon gas into hydrogen. This process is then called reforming, and this reaction process requires high temperature and pressure. The connection on the primary reformer is connected using GTAW (Gas Tungsten Arc Welding) welding with Inconel 82 filler metal [12].

Welding research on ASTM A106 pipes was carried out using a magnetic particle test and found porosity indications [13]. The porosity part was the primary reformer at the riser tube weld joint. Then, cutting was carried out in the area around the failure of the riser tube. A continuous crack was found inside the riser tube primary reformer, so re-welding was carried out on the weld joint. Therefore, a case study was carried out to analyze the failure of the riser tube primary reformer at the ASTM A106 grade B carbon steel weld joint with Inconel 82 weld metal.

## 2. Method

The primary reformer is a tube that breaks down hydrocarbon gas into hydrocarbons that require high temperature and pressure. The connection between the tube metals is expected to be free of cracks or welding failures. Testing is needed to determine welding failures in ASTM A106 grade B carbon steel using GTAW (gas tungsten arc welding) with Inconel 82 filler metal.



**Figure 1.** Fishbone diagram

First, cut the primary reformer riser tube in the area around the ASTM A106 grade B welding joint with Inconel 82. Measure the inside and outside diameters of the primary reformer riser tube. Then, clean the cut results of the primary reformer riser tube and perform a visual test. Measure the crack distance from the inside of the primary reformer riser tube using a ruler and continue the penetrant test.

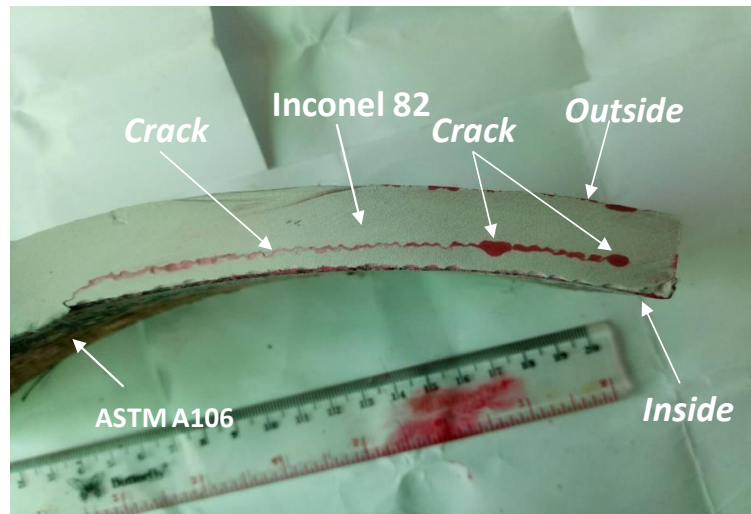
Make metallographic specimens by taking the area identified by the penetrant, then mounting using a mixture of resin and catalyst. Grinding process using sandpaper grade 80, 120, 150, 300, 500, 800, 1000, and 1200 and sanding machine at 200 rpm. Polishing process using

DP Nap, DiaPro Dac 3  $\mu\text{m}$ , and lubricant and sanding machine with a speed of 150 rpm. Then do etching according to ASTM E407-07 using Etchant 61 solution or a mixture of 60 ml of HNO<sub>3</sub> with 40 ml of HCl for 15 seconds. Next, metallography test with 100x and 200x magnification. and microhardness test using HRC

### 3. Results and Discussion

#### 3.1 Visual Test and Penetrant Test

The visual test results showed that the riser tube with a cross-section had a crack in the meeting area between the Inconel 82 weld metal and the A106 grade B base metal as evidenced by the results of the penetrant test. In addition, the results of the penetrant test showed that the riser tube with a cross-section had a crack in the inside diameter (ID) of the Inconel 82 weld metal. The indications obtained from the penetrant and visual tests were the same: a crack in the Inconel 82 weld metal. The crack in the weld metal area caused the riser tube to be unable to withstand the temperature of hydrogen gas.

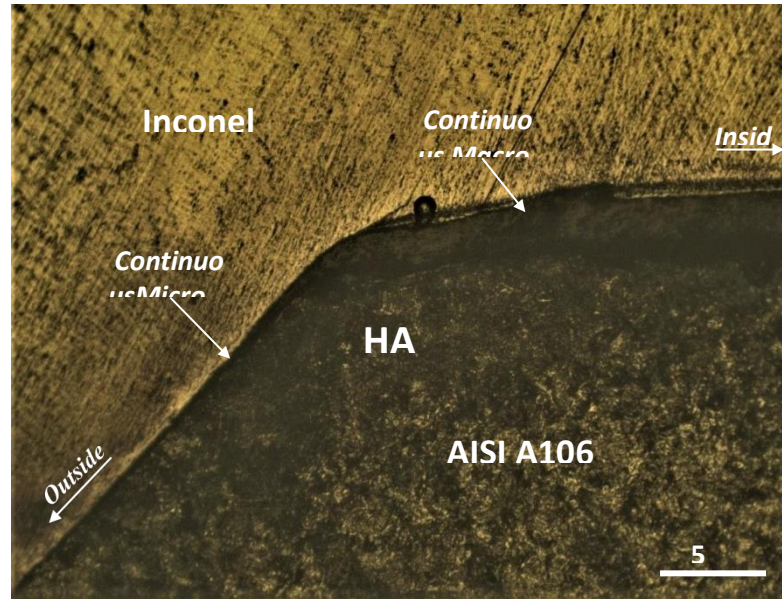


**Figure 2.** Penetrant Test Results

#### 3.2 Metallography Test

Metallographic testing using a metallurgical microscope with 200x magnification and Etchant 61 with 40 ml of HCl and 60 ml of HNO<sub>3</sub>. This test is focused on the crack area with 200x magnification. Figure 3 shows continuous microcracks and continuous macrocracks so that crack propagation starts from inside to outside. Silicon has low wear resistance and is centered in the welding's crack tip area, causing failure to occur at the welding joint. This causes a difference in expansion in the border area of Inconel 82 with ASTM A106 grade B so that the

riser tube is unable to withstand temperatures of 748°C



**Figure 3.** Metallographic results

### 3.3 Microhardness Test

The results of the hardness test on the primary reformer riser tube using a microhardness tool with a diamond indenter at a load of 0.3 kgf and a dwell time of 10 seconds against ASTM A106 grade B and Inconel 82 showed a difference in hardness values where ASTM A106 grade B has a lower hardness value than Inconel 82. . From both materials, 3 areas were tested, namely the inside, middle, and outside in the area around the crack and the area without cracks (normal area).

**Table 1.** Microhardness test results on ASTM A106 grade B and Inconel 82

Specimen	Area	Average Hardness test Results			
		inside	middle	outside	average
ASTM A106 Grade B	Area around crack	240.405	244.3	189.17	224.625
	Normal area	242.18	289.745	271.225	267.716
Inconel 82	Area around crack	250.4	242.985	226.89	240.091
	Normal area		378.75	350.16	364.455

This is proven in [Table 1](#) where A106 grade B has an average hardness value of 267,716 HV in the normal area, while Inconel 82 has a hardness of 364,455 HV in the normal area. Each area has a different hardness value, namely in the area around the crack ASTM A106 grade B the inside part has a hardness value of 240,405 HV, the middle part is 244.3 HV and the outside part is 189.17 HV. While in the area around the crack Inconel 82 the inside part has a hardness value of 250.4 HV, the middle part is 242,985 HV, and the outside part is 226.89 HV. In addition, the hardness in the normal area of both materials exceeds 250 HV, exceeding the standard hardness limit in the petrochemical industries. Carbon steel must be reheated after welding (post weld heat treatment) so that the hardness value is below 250 HV

Based on the results of the microhardness test on ASTM A106 grade B and Inconel 82, it is known that the border between 2 materials or the area around the crack has a lower hardness value than the area far from the crack so that the disbonds phenomenon increases in areas close to the crack. Disbonds is a phenomenon of releasing a bond between one material and another. The impact of disbonds causes the mechanical properties of the material to decrease

#### 4. Conclusion

Based on the research results, the results of the visual test and penetrant test showed cracks in the meeting area between the Inconel 82 weld and ASTM A106 grade B. The results of the metallography test in the meeting area between Inconel 82 and ASTM A106 grade B showed continuous microcracks and continuous macrocracks. The microhardness test results in the area around the crack had a lower hardness value than the area far from the crack. The cause of the failure of the joint in the welding of ASTM A106 grade B with Inconel 82 is due to the silicon content of 0.5% in Inconel 82, which at a temperature of 748oC there was a difference in solidification between ASTM A106 grade B and Inconel 82.

#### References

- [1] T. B. Santoso, S. Solichin, and P. Trihutomo, "Pengaruh kuat arus listrik pengelasan terhadap kekuatan tarik dan struktur mikro las SMAW dengan elektroda E7016," *J. Tek. Mesin Univ. Negeri Malang*, vol. 23, no. 1, p. 141149, 2015.
- [2] I. B. J. . Beumer, *Ilmu Bahan Logam.*, 3rd ed. Jakarta: Bhatara, 1994.
- [3] Wiryosumarto, Harsono, and T. Okumura., *Teknologi Pengelasan Logam*. Jakarta: PT. Pradnya Paramita, 1994.
- [4] N. Supornpaibul, J. Duff, M. G. Burke, Y. Wang, and F. Scenini, "Stress corrosion crack initiation in filler metal 82 in oxygenated high-temperature water," *Corros. Sci.*, vol. 214, no. 111008, 2023.

- [5] Z. F. Musthofa, B. Prasojo, and D. Wardani, "Pengaruh Variasi Suhu Preheat dan Jarak Pengelasan Terhadap Kekerasan, Struktur Mikro dan Lebar HAZ Pada Material ASTM A 106 B," *Proc. Natl. Conf. Pip. Eng. Its Appl.*, vol. 9, no. 1, pp. 109–113, 2024.
- [6] S. Genculu, *Structural Steel Welding*. Dakota: PDH Center, 2007.
- [7] Y. Zhang *et al.*, "Effect of nickel-based filler metal types on creep properties of dissimilar metal welds between Inconel 617B and 10% Cr martensitic steel," *J. Mater. Res. Technol.*, vol. 14, pp. 2289–2301, 2021.
- [8] H. Timothy, K. Refining, and M. Pine Bend, "National Petroleum Refiners Association Plant Maintenance," in *Journal "Heater Tube Life Management*, 2000, pp. 22–25.
- [9] D. Dewi and S. Sriyana, "Spesifikasi, Kode dan Standar Baja Nasional dan Potensinya untuk Mendukung Program PLTN Tipe LWR di Indonesia.," *J. Pengemb. Energi Nukl.*, vol. 20, no. 2, pp. 111–119, 2019.
- [10] M. A. Fitrah, Mardin, M. Balfas, H. H. Utami, M. T. Thahir, and H. H. Hafid, "Karakterisasi Inklusi Terak Pada Pengelasan Pipa SA 106 Grade B Menggunakan Mikroskop Elektron Pemindai," *J. Chem. Process Eng.*, vol. 9, no. 1, pp. 52–59, 2024.
- [11] A. Rahman and H. Sholih, "Pengendalian Kualitas Proses Fabrikasi Sand Filter," *Teknosains J. Sains, Teknol. Dan Inform.*, vol. 8, no. 2, pp. 86–99, 2021.
- [12] S. Nugroho and W. Sudiarso, "Pengaruh PWHT dan Preheat pada Kualitas Pengelasan Dissimilar Metal antara Baja Karbon (A-106) dan Baja Tahan Karat (A312 TP-304H) dengan Filler Metal Inconel 82," *ROTASI*, vol. 14, no. 1, pp. 16–20, 2022.
- [13] B. Yuniyanto and P. Wicaksana, "Analisis Cacat Hasil Pengelasan Pada Pipa ASTM A106 Grade B Menggunakan Magnetic Particle Test Dan Liquid Penetrant Test Di Workshop Las Dan Inspeksi PPSDM Migas Cepu," *ROTASI*, vol. 25, no. 2, pp. 54–60, 2023.