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# ELEMENTAL QUALIFICATION OF WELDED STAINLESS STEELS BY XRF POSITIVE MATERIAL IDENTIFICATION

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***Abstract***

*Tests for determining the elemental composition of stainless steel (SS) in the weld metal and Heat Affected Zone (HAZ) were carried out using the Non-Destructive Evaluation (NDE) Positive Material Identification (PMI) method with X-ray Fluorescence (XRF) technology. This study aimed to identify the chemical composition of metals using the PMI method with XRF technology as a determinant of the feasibility of the stainless-steel materials tested, namely SS 316 and SS 2205. The results of the tests were then matched with the applicable standards, namely ASME Section II Part A for pipe materials and ASME Section II Part C for welding electrodes. The measurement results show that SS 316 with welding electrode grade ER 316 all parts of the object of inspection fall within the standard range used except for material 4, which is the connection between the flange and elbow is declared rejected because the values for Cr, Ni, and Mo do not fall within the standard range. Meanwhile, SS 2205 with a welding electrode grade of ER 2594 shows that all parts of the object being measured meet the requirements of the standard range used.*

***Keywords: Stainless Steel, Elemental Composition, Positive Material Identification, X-Ray Fluorescence***

**Abstrak**

Pengujian penentuan komposisi kimia logam *stainless steel* (SS) pada area *welding* dan *Heat Affected Zone* (HAZ) dilakukan dengan metode *Non-Destructive Evaluation* (*NDE) Positive Material Identification* (PMI) dengan teknologi *X-ray Fluorescence* (XRF). Tujuan penelitian ini adalah untuk mengidentifikasi komposisi kimia logam menggunakan metode PMI dengan teknologi XRF sebagai penentu kelayakan pada material *stainless steel* yang diuji yaitu SS 316 dan SS 2205. Hasil dari pengujian kemudian disesuaikan dengan standar yang berlaku yaitu *ASME Section II Part A* untuk material pipa dan *ASME Section II Part C* untuk *electrode* las. Hasil pengukuran menunjukkan bahwa SS 316 dengan *welding electrode grade ER 316* semua bagian objek pemeriksaan masuk dalam rentang standar yang digunakan kecuali untuk material 4, yang berupa sambungan antara *flange* dan *elbow* dinyatakan *reject* karena nilai untuk Cr, Ni, dan Mo tidak masuk dalam rentang standar. Sedangkan untuk SS 2205 dengan *welding electrode grade ER 2594* menunjukkan bahwa semua bagian objek pemeriksaan yang diukur, nilainya memenuhi persyaratan rentang standar yang digunakan.

**Kata Kunci:** ***Stainless Steel*, Komposisi Unsur, *Positive Material Identification*, *X-Ray Fluorescence***

## 1.0 INTRODUCTION

The analytical procedures for the chemical composition of metals and alloys have been widely developed to date. In addition, a wide variety of specialized equipment for the analysis of the chemical composition of these metals has also been widely distributed and produced industrially. Therefore, there are various choices of methods to determine the chemical composition of metals, such as Inductively Coupled Plasma Mass Spectrometry (ICP-MS), Optical Emission Spectroscopy (OES), Atomic Absorption Spectroscopy (AAS), X-Ray Fluorescence (XRF), and others [1].

The chemical characteristics of metal material are critical to be maintained because they will affect the quality and durability of the equipment used and prevent problems during operation both in terms of production quality and safety. Objects or works that require strict control over their composition due to being used for long periods are boilers operating under high pressure, auxiliary equipment such as tanks for storing fuel, lubricants, combustible materials, lifting or transporting mechanisms, cranes, and so on. Identification of Positive Materials Non-Destructive Evaluation (NDE) by the X-Ray Fluorescence (XRF) technique can be an excellent alternative for determining the chemical composition of metals and preventing problems that can arise related to material characteristics[2]–[4].

Positive Material Identification Method is a metal alloy analysis method to determine composition by reading the quantity with the percentage of the constituent elements. This analytical method uses X-Ray Fluorescence technology because it is non-destructive and provides accurate on-site test results. In addition, with the advancement of PMI testing technology, previous testing practices that could only test destructively or partially have been replaced by comprehensive material testing using PMI with XRF technology [5].

This study aims to identify the chemical composition of metals using X-Ray Fluorescence (XRF) as a determinant of the feasibility of the stainless-steel materials tested, namely SS316 and SS2205. Those pipes are used to manufacture offshore platforms to extract oil and natural gas installed in the skid module and other components.

## 2.0 METHOD

This research follows the steps shown in the following flow chart in the following Figure 1.

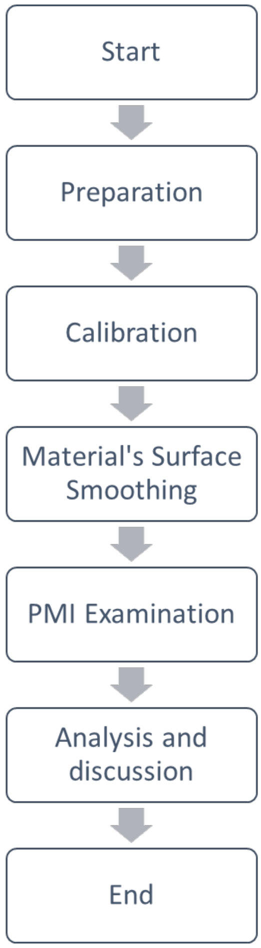


Figure 1. Methodology Flow Chart

### 2.1 Samples

Materials used as samples in this study are stainless steel SS316 and SS2205. These materials have high corrosion resistance and are commonly used for offshore oil and gas refinery installations in injection pipes. The samples are welded with the parameters shown in Table 1.

Table 1: Welding Parameter

| Material | Welding Parameter | | | | | | Dimension |
|---|---|---|---|---|---|---|---|
| | Electrode Class | Process | Electrode Diameter | Polarity | Current | Voltage | |
| SS316 | ER316 | GTAW | 2.4 mm | DCEN | 109.1 A | 11.1 V | 2" × 3.91" |
| SS2205 | ER2594 | GTAW | 2.4 mm | DCEN | 111.3 A | 11.7 V | 2" × 5.54" |

The chemical composition in the weld metal and HAZ needs to be examined because its properties are susceptible to change due to the heat treatment process. Therefore, the inspection results were compared with ASME Section II Part A for pipe materials [6] and ASME Section II Part C for welding electrodes [7].

There are five samples for each material. A representative of each piece is shown by the following Figure 2 and Figure 3.

Figure 2. An SS316 Sample Welded with ER316

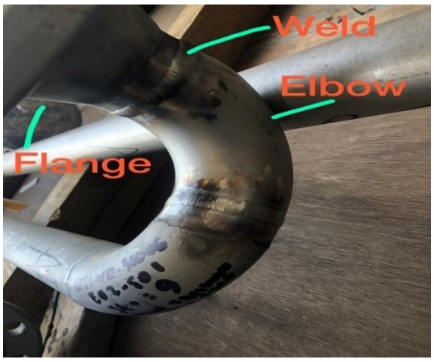

Figure 3. An SS2205 Sample Welded with ER2594

## 2.2 Calibration

This study used Thermo Scientific Niton XL2 Analyzer X-Ray Fluorescence. The examination begins with preparing the required instrument and materials. Then the instrument was calibrated with designated coin grade AISI 321 UNS S32100. The sample then cleaned and finally be tested. The device is shown by the following Figure 4.

Figure 4: Thermo Scientific Niton XL2 Analyzer X-Ray Fluorescence.

The calibration step is essential, which aims to ensure the correct value of the measuring instrument indication. The measuring standard used is a calibration block of a designated coin with the AISI 321 / UNS S32100 grade.

Calibration starts by turning on the device, then selecting the setting time menu to set the length of the tool for the testing process. The reading duration was set to 5 seconds/spot for each test. Then, the material type was set to be stainless steel.

The next step was to touch the device's sensor towards the calibration block. Then, the button was pressed while the space touched a flat test spot surface and held for 5 seconds. The results will appear on the XRF screen. Finally, the test results were matched with the calibration block certificate in Table 3. The chemical composition reading of the metal should be the same as those stated in the certificate. Then the device has been appropriately calibrated and suitable for use.

Table 2: Chemical Composition of AISI 321 UNS S32100 Calibration Block [8]

| Element (% weight) | | | |
|---|---|---|---|
| Cr | Mn | Ni | Mo |
| 17.13 | 1.38 | 9.15 | 0.331 |

## 2.3 Material Surface's Smoothing

The material's surface needs to be smoothed to facilitate the examination. The treatment was crucial because the surface's profile could influence the accuracy and precision of the device's reading. Thus, the surface was smoothed with a grinder until a spot area approximately 1 $cm^2$ wide was smoothed. The room was then cleaned with a cloth.

## 2.4 PMI Examination

The examination was carried out on ten samples. Five samples of SS316 pipes welded by ER316 were assigned with A code, and the remaining samples of SS2205 pipes welded by SS2205 welded by ER2594 were marked with B code.

The standards used for this test are ASME Section II Part A for pipe materials and ASME Section II Part C for welding electrodes, which are shown in Table 4 and Table 5.

Table 3. ASME Standard Section II Part A [6]

| Material | Element (% weight) | | | |
|---|---|---|---|---|
| | Cr | Mn | Ni | Mo |
| Pipe SS316 | 16.00 – 18.00 | 0 – 2.00 | 10.00 – 14.00 | 2.00 – 3.00 |
| Pipe SS2205 | 21.00 – 23.00 | 0 – 2.00 | 4.50 – 6.50 | 2.50 – 3.50 |

Table 4: ASME Standard Section II Part C [7]

| Electrode | Element (% weight) | | | |
|---|---|---|---|---|
| | Cr | Mn | Ni | Mo |
| ER316 | 18.00 – 20.00 | 1.00 – 2.50 | 11.00 – 14.00 | 2.00 – 3.00 |
| ER2594 | 24.00 – 27.00 | 0 – 2.50 | 8.00 – 10.50 | 2.50 – 4.50 |

## 3.0 RESULTS AND DISCUSSION

### 3.1 PMI Examination of SS316 Pipes

The examination was carried out in three locations of each sample. Two spots at the heat-affected zone (HAZ), and one spot at the weld metal. Measured elemental compositions of SS316 Pipes are shown in Figure 5 and Figure 6.

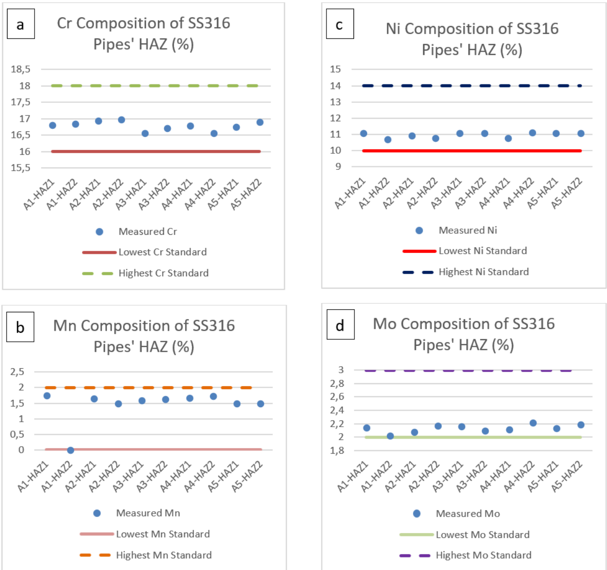


Figure 5. Elemental Compositions in the Heat Affected Zone of SS315 Pipes

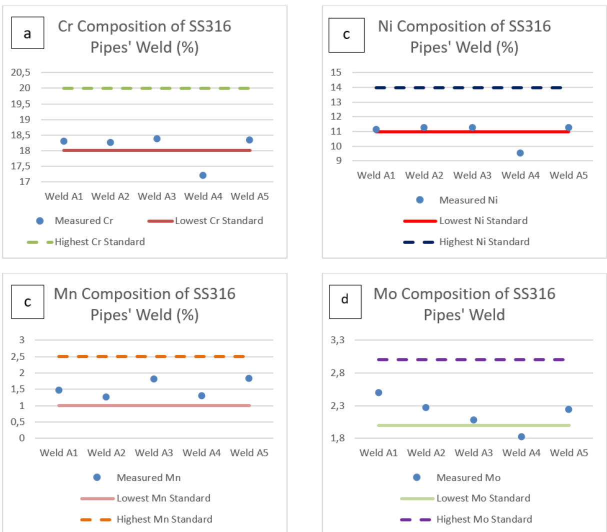


Figure 6. Elemental Compositions in the Weld Metal of SS315 Pipes

The data indicated that one sample named A4 did not comply with the standard ASME Standard Section II Part C, as shown in Table 4. The decrease is presumably due to the diffusion of those elements to other areas like HAZ. Therefore, that sample was rejected and must be repaired with new welding.

### 3.2 PMI Examination of SS2205 Pipes

The SS2205 Pipes were also examined at three locations, i.e. two at the HAZ and one at the weld metal. Elemental data of the five samples are shown in the following Figure 7 and Figure 8.


Figure 7. Elemental Compositions in the Heat Affected Zone of SS2205 Pipes

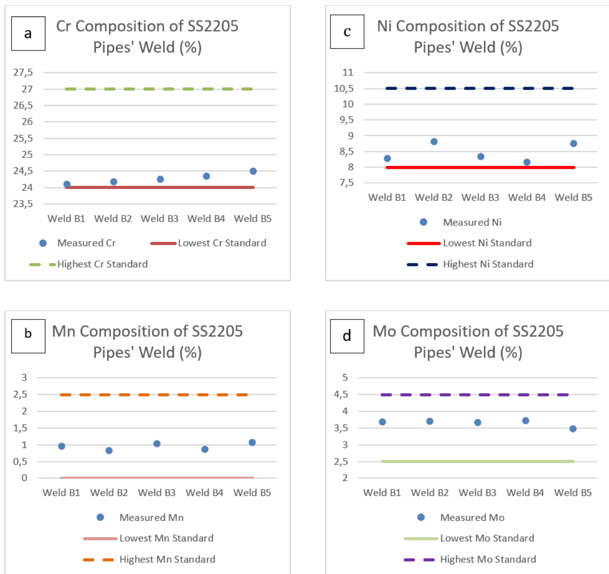


Figure 8. Elemental Compositions in the Weld Metal of SS2205 Pipes

The data show that their chemical composition qualifies for both ASME Standards. Therefore, it could be concluded that the welding of SS2205 pipes met the standards of materials. Therefore, all samples of SS2205 lines apply to their desired usage.

These facts show that both welding parameters apply to the material for standard usage requirements. However, we suggest that the SS316 welding by ER316 needs to be evaluated. Then, we could have 100% suitable material; hence, the practical application would be safer and better.

## 4.0 CONCLUSION

The chemical composition of SS316 welded by ER316 indicates that all parts of the inspection object qualify the ASME Standard Section II Part A for pipe materials. However, one sample does not meet ASME Standard Section II Part C for welding electrodes. The sample was then declared rejected and should be repaired. Examining SS2205 pipes by ER 2594 shows that all parts of the pieces qualify for either ASME Section II Part A or ASME Section II Part C.

## REFERENCES


[1] K. P. S. Gunasekaran P. Kuppuraj, "Determine the Chemistry of Selected Steel by NDE Technique of Positive Material Identification (PMI)," *Int. J. Sci. Res.*, vol. 3, no. 9, p. —, 2014.

[2] J. Brocchieri and C. Sabbarese, "Thickness determination of the gilding on brass materials by XRF technique," *Nucl. Instruments Methods Phys. Res. Sect. B Beam Interact. with Mater. Atoms*, vol. 496, no. March, pp. 29–36, 2021, DOI: 10.1016/j.nimb.2021.03.018.

[3] A. Bolewski, M. Matosz, W. Pohorecki, and J. M. del Hoyo-Meléndez, "Comparison of neutron activation analysis (NAA) and energy dispersive X-ray fluorescence (XRF) spectrometry for the non-destructive analysis of coins minted under the early Piast dynasty," *Radiat. Phys. Chem.*, vol. 171, no. October 2019, p. 108699, 2020, DOI: 10.1016/j.radphyschem.2020.108699.

[4] S. Martinuzzi *et al.*, "A robust and cost-effective protocol to fabricate calibration standards for the thickness determination of metal coatings by XRF," *Spectrochim. Acta - Part B At. Spectrosc.*, vol. 182, no. May, p. 106255, 2021, DOI: 10.1016/j.sab.2021.106255.

[5] A. Thurston, "Recent Advances in Handheld X-Ray Fluorescence-Based Alloy PMI/Material Testing," in *19th World Conference on Non-Destructive Testing*, 2016, pp. 1–8.

[6] ASME, "ASME Boiler and Pressure Vessel Code, Section II Part A - Ferrous Material Specifications," in *ASME Boiler and Pressure Vessel Code*, 2010, p. 247.

[7] ASME, "ASME Boiler and Pressure Vessel Code, Section II Part C - Specifications for Welding Rods, Electrodes, and Filler Metals, "Specification for titanium and titanium-alloy welding electrodes and rods," in *ASME Boiler and Pressure Vessel Code*, 2010, pp. 377–390.

[8] Analytical Reference Materials International, "Certificate of Analysis Certified Reference Material Grade AISI 321 / UNS S32100," 2009.