Universidade do Estado do Rio de Janeiro
PPG-EM – Programa de Pós-Graduação em Engenharia Mecânica

Characterization of joint welded by TIG autogenous steel process UNS S32707 simulating a heat exchanger for oil heating.

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Agenda

- Introduction
- Metodology
- Results
- Conclusion
- Refrences

Introduction

- The UNS S32707 hyper duplex steels have a biphasic structure, in the same proportion of austenite and ferrite, and are therefore very used because they have excellent mechanical properties and a great resistance to corrosion in aggressive environments such as deep waters.

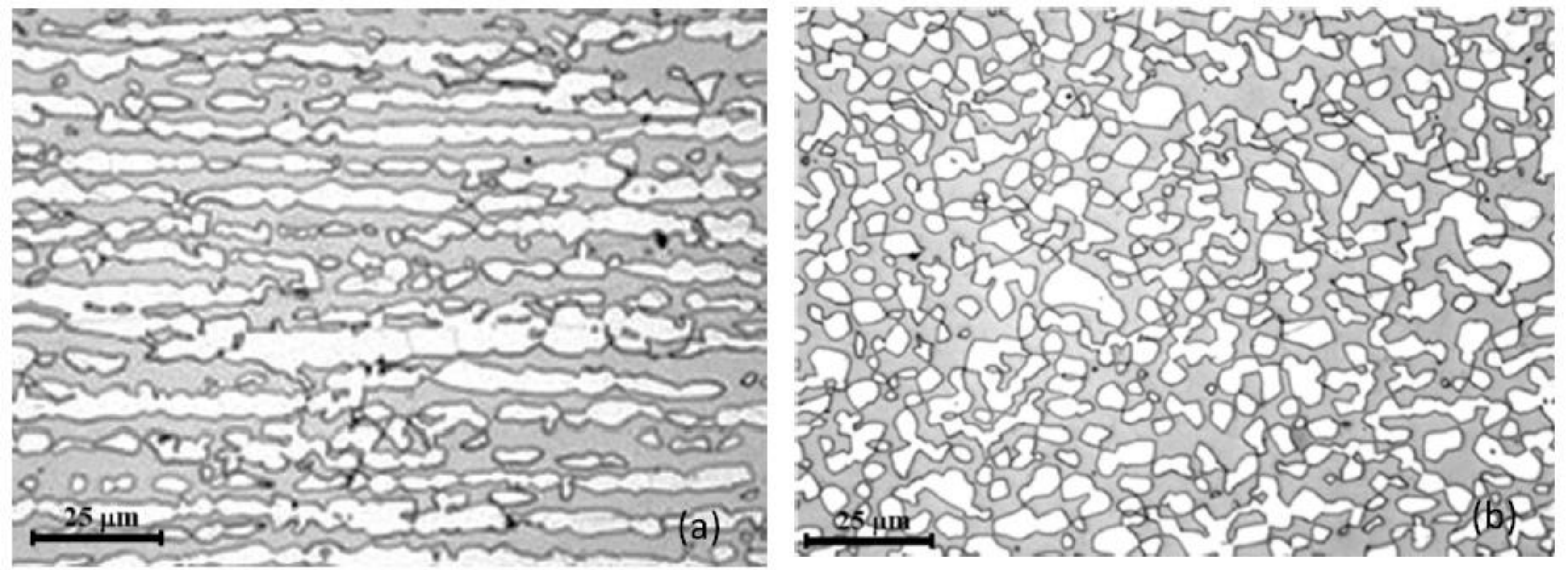


Figure 1: Microstructure of the UNS S32707 hyper duplex steel in scanning electron microscopy (SEM). (a) longitudinal section. (b) cross-section. [Chai, et al., 2016]

Introduction

- In order for the phase balance of the hyper duplex steel to be maintained, stabilizing elements of each present phase must be included. Nitrogen stabilize the austenitic phase. The ferrite is stabilizing by chromium.
- In the autogenous TIG welding, which is the focus of this work, the major problems occur with the increase of the presence of ferrite and the formation of chromium nitride.
- The austenite not to be lost as in the formation of the base metal with the addiction of nitrogen to the shielding gas plus with the argon gas. The higher the imbalance between the ferrite and austenite phases, the corrosion resistance worse.

Introduction - Objective

- Analysis of welding joints of UNS S32707 type stainless steel with different amounts of nitrogen, with the highest value being 5.5% compared to the amount considered standard in the industry of 2.5% in the shielding gas in the autogenous TIG welding process through the measurement of hardness profiles, MEV, EDS and EBSD.
- Study of the corrosion resistance of the different welded joints through corrosion test by mass loss, according to ASTM G48 standard simulating conditions close to working heat exchangers in oil refineries, where the crude oil is used.

Methodology

- Base Metal
  - hyper duplex steel UNS S32707 - biphasic austenitic-ferritic microstructure.

Figure 4: Analyzed sample of hyper duplex steel type UNS S32707.

Methodology

- Autogenous TIG welding
  - Its purpose is to simulate pipe sealing conditions in heat exchangers.
  - It has no addition metal.
  - Seamless pipes, annealed.

Figure 6: The welded sample.

Methodology

- Vickers (HV) microhardness measurements on welded joints tested:
  - Together with the thesis of André Pimenta
  - Performed to determine if there was any variation in the mechanical properties of the samples between the critical regions - base metal (BM) and fusion zone(FZ).
- Corrosion Testing with Working Fluid - Crude Oil
  - Performed according to ASTM G48 - 99 method A - Mass loss corrosion test.

Methodology

- MEV (Scanning Electron Microscope)
  - Together with the thesis of André Pimenta
  - Performed to determine the phases present in the microstructure and for the possible encounter of precipitates.
  - They occurred in two stages: one with low increase (up to 1000X) and large increase, respectively.
- EDS (X-Ray Energy Dispersive Spectroscopy)
  - Semiquantitative analysis of the chemical elements present in the samples.

Methodology

- EBSD (Electron Backscatter Diffraction)
  - It allows the determination of orientations and phase compositions of any plane or crystallographic direction.

Figure 8: Images by the SEM used for the analysis of microscopy in EBSD mode

Methodology

- Corrosion Testing with Working Fluid - Crude Oil
  - Average working temperature: 220 ° C

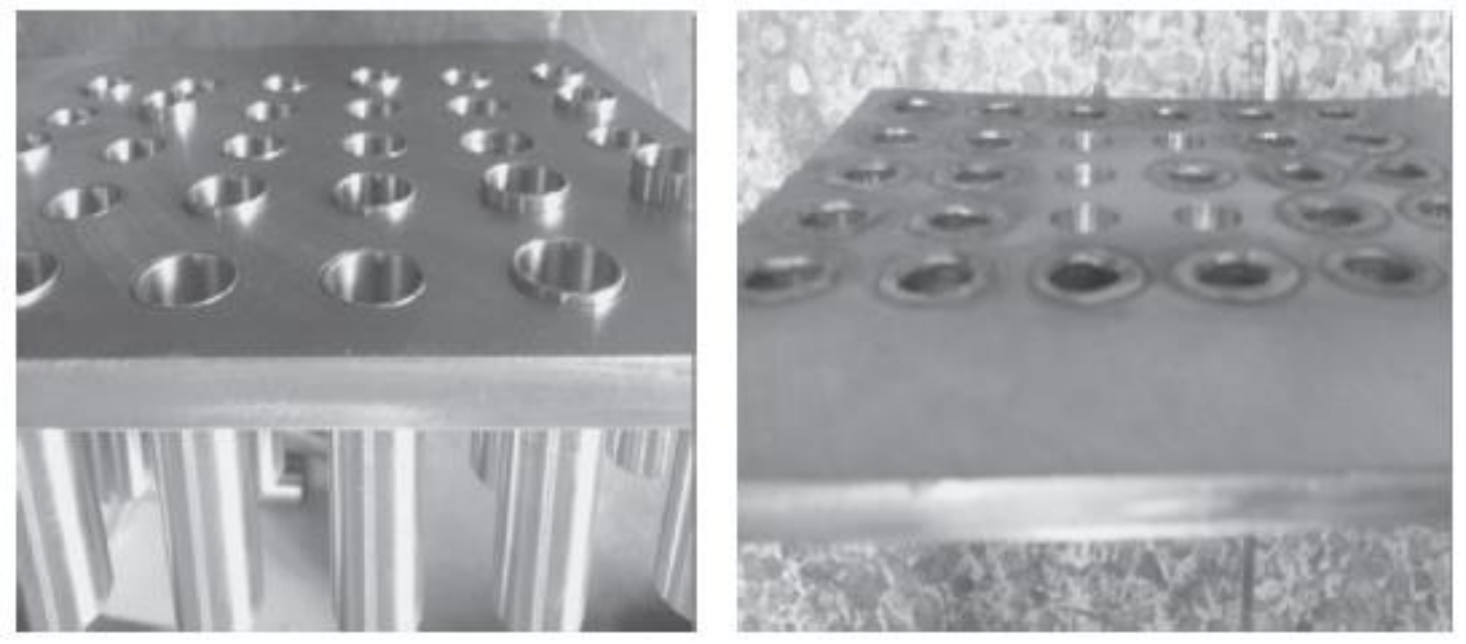


Figure 10: Mirror welding of heat exchanger in hyper duplex steel [Kim, et al., 2012]

Methodology

- Heat Exchanger studied:

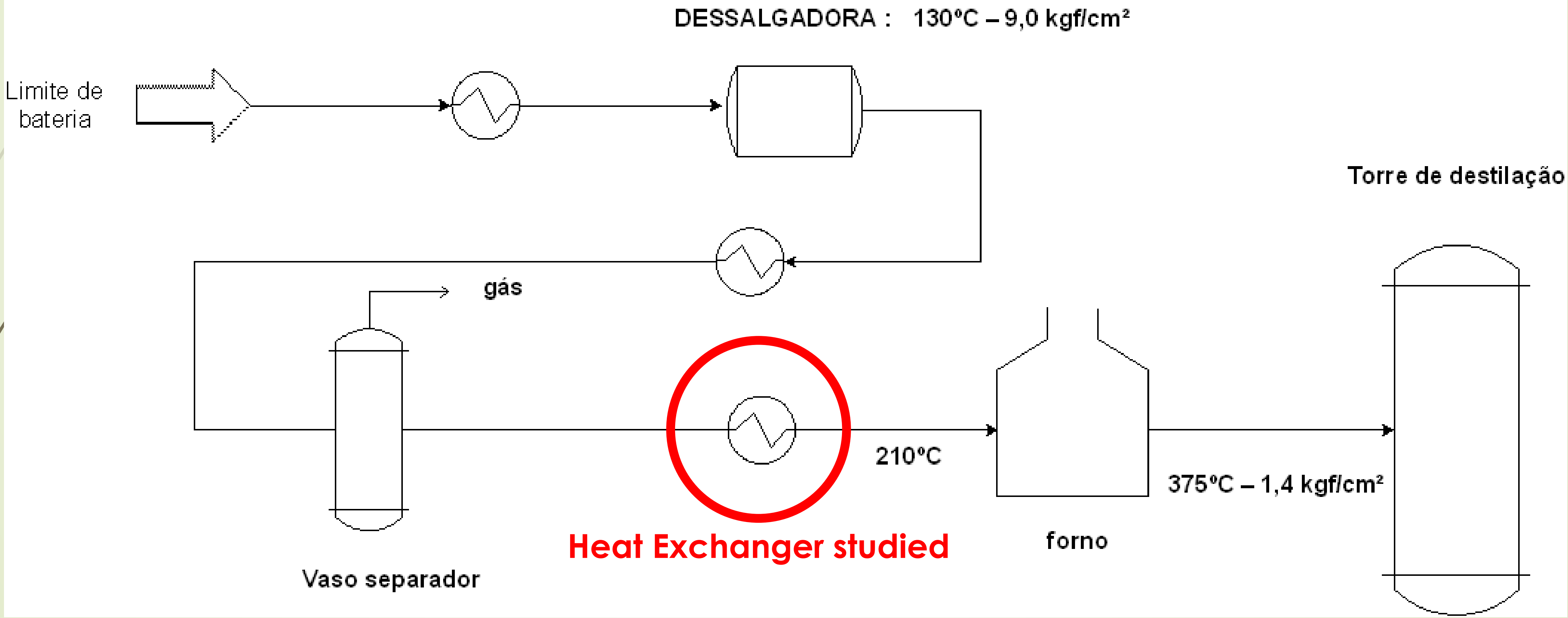


Figure 9: Schematic of the petroleum distillation line. The heat exchanger is located in the indicated area. Working temperature 210 ° C.

Results

- Vickers microhardness (VH):

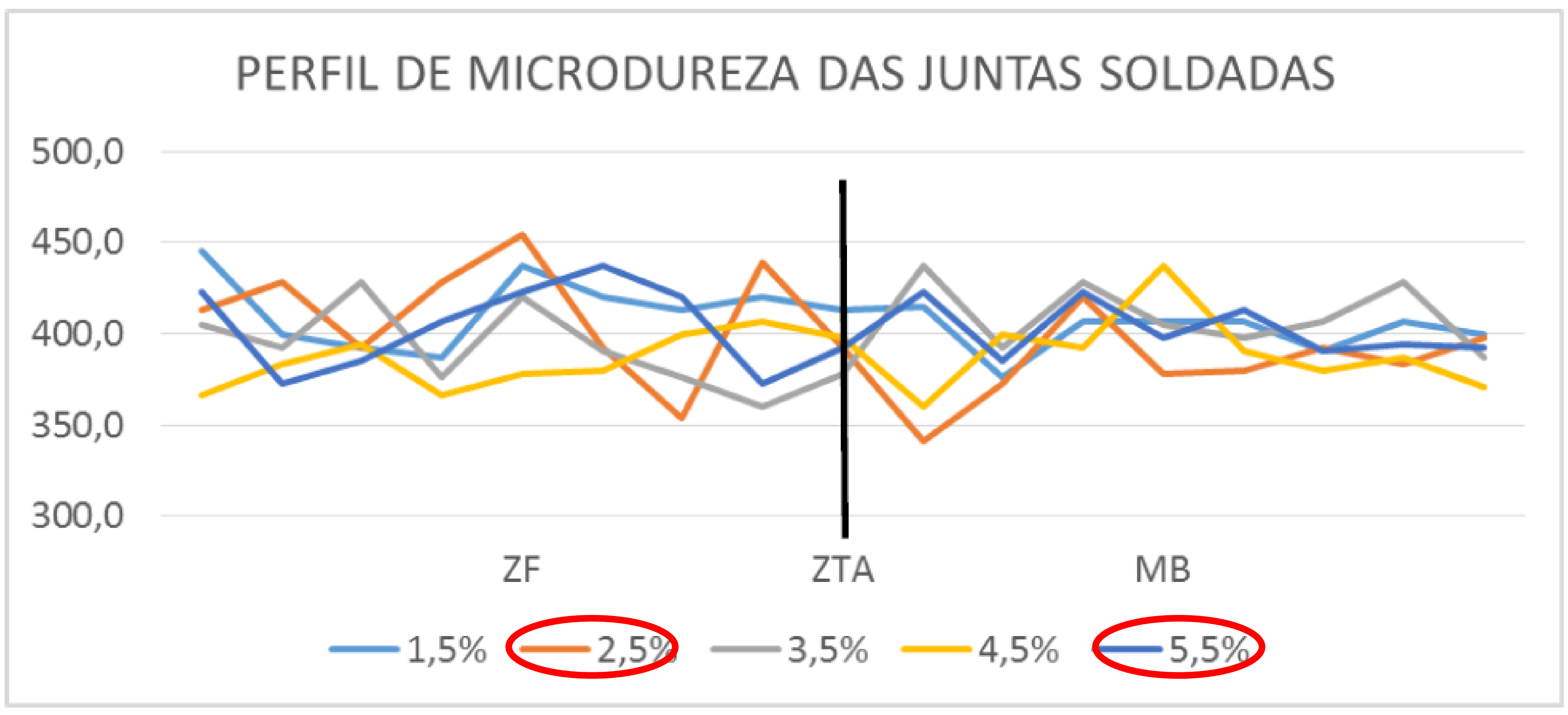


Figure 17: Vickers microhardness profile of welded joints.
[Extracted from Pimenta, A. R. - PhD thesis PPG-EM]

Results

- MEV Results :

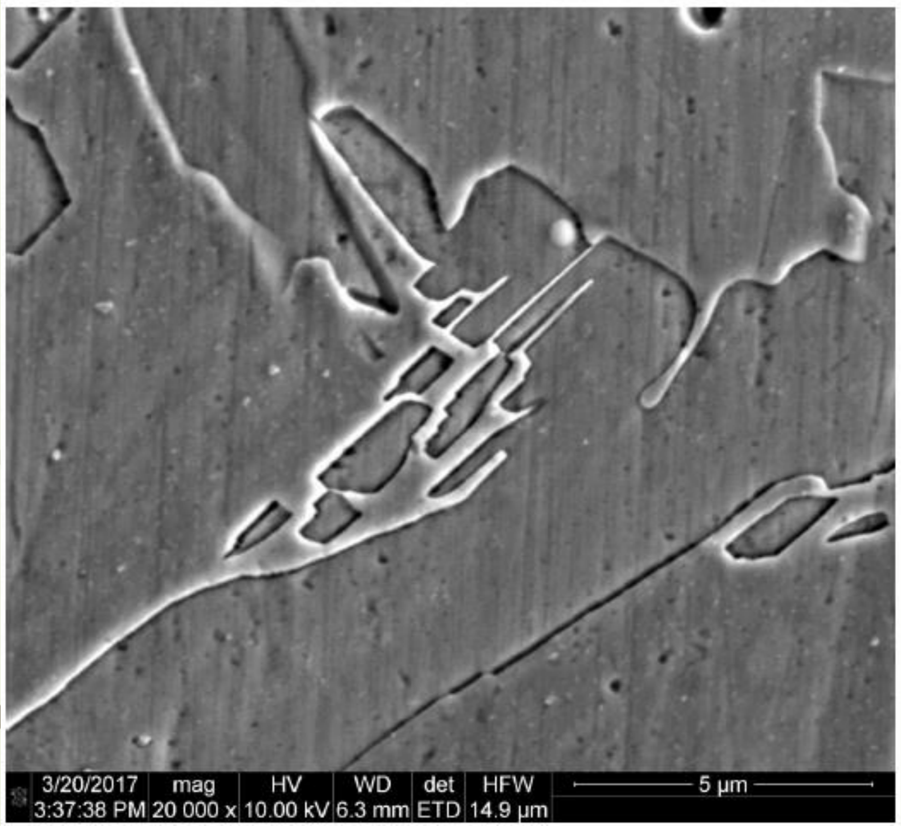


Figure 11: SEM in the thermally affected zone with 2.5% N2. MEV EGF in SE mode with an increase of 20,000X. Well delimited ferrite and austenite phases.
[Extracted from Pimenta, A. R. - PhD thesis PPG-EM]

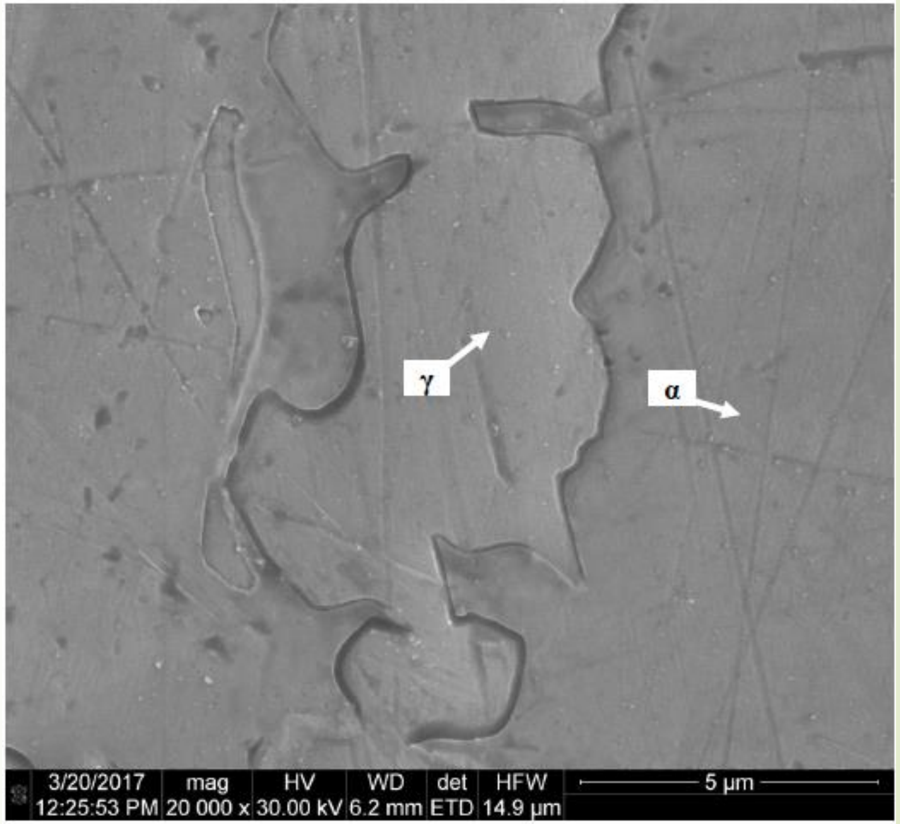


Figure 12: SEM in the thermally affected zone with 5.5% of N2. MEV EGF in SE mode with an increase of 20,000X. Ferrite and austenite phases present.
[Extracted from Pimenta, A. R. - PhD thesis PPG-EM]

Results

- EDS Results :

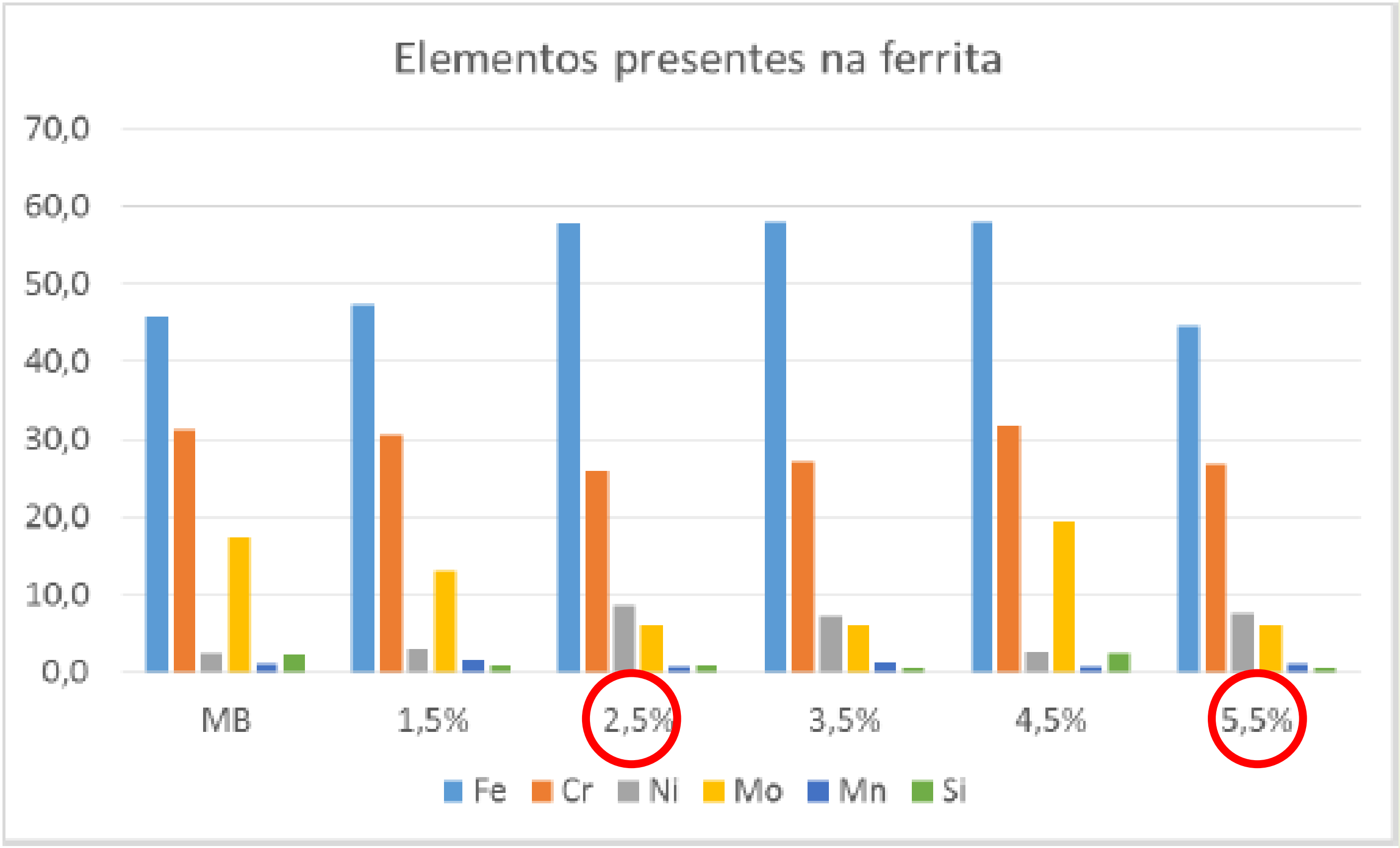


Figure 14: Analysis of EDS in ferrite phase regions, with protection gas ranging from 1.5% to 5.5% N_2. Highlight the percentages studied. [Extracted from Pimenta, A. R. - PhD thesis PPG-EM]

Results

- EDS Results :

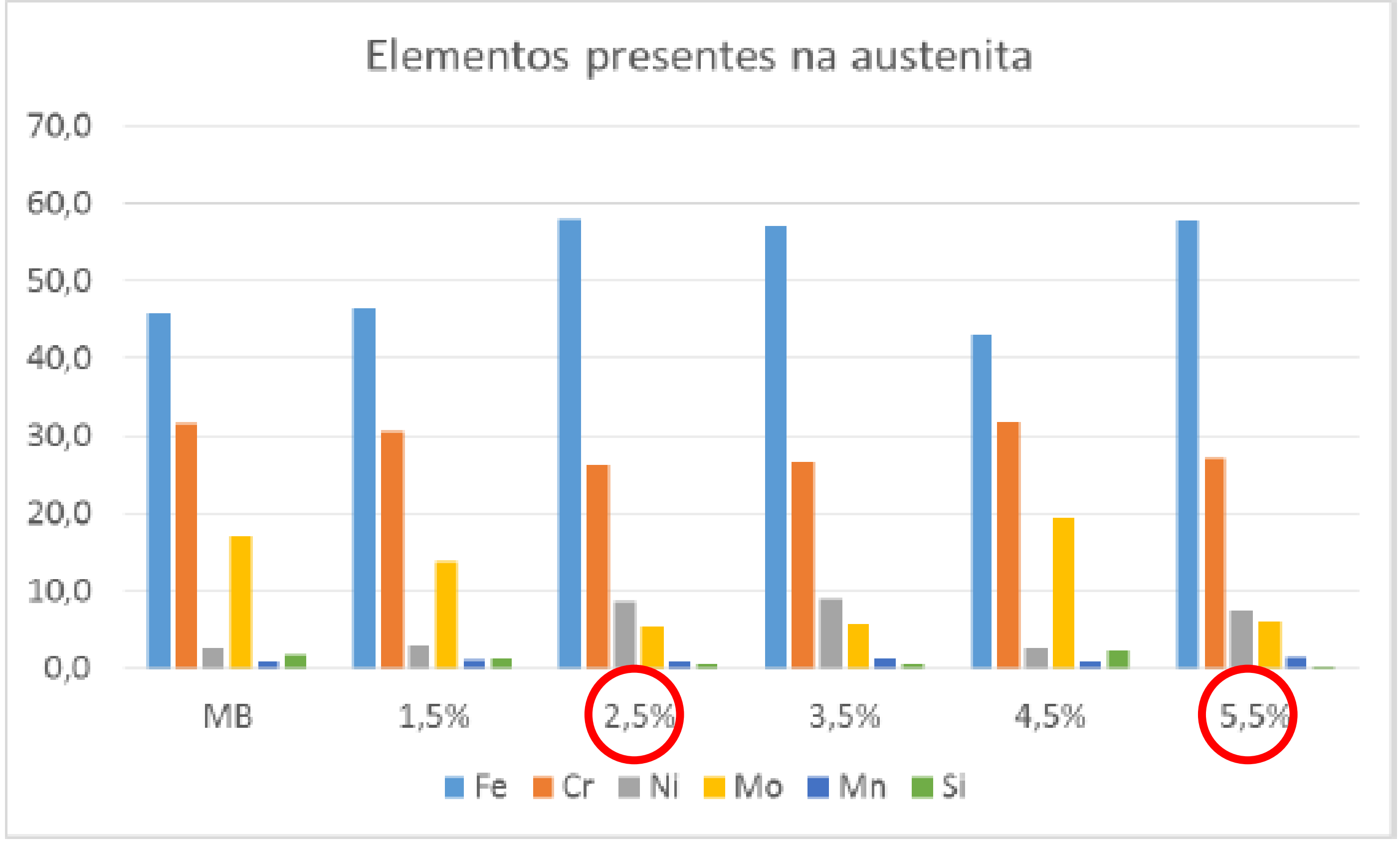


Figure 15: Analysis of EDS in regions of austenite phase, with protection gas varying between 1.5% and 5.5% of N2. Highlight the percentages studied. [Extracted from Pimenta, A. R. - PhD thesis PPG-EM]

Results

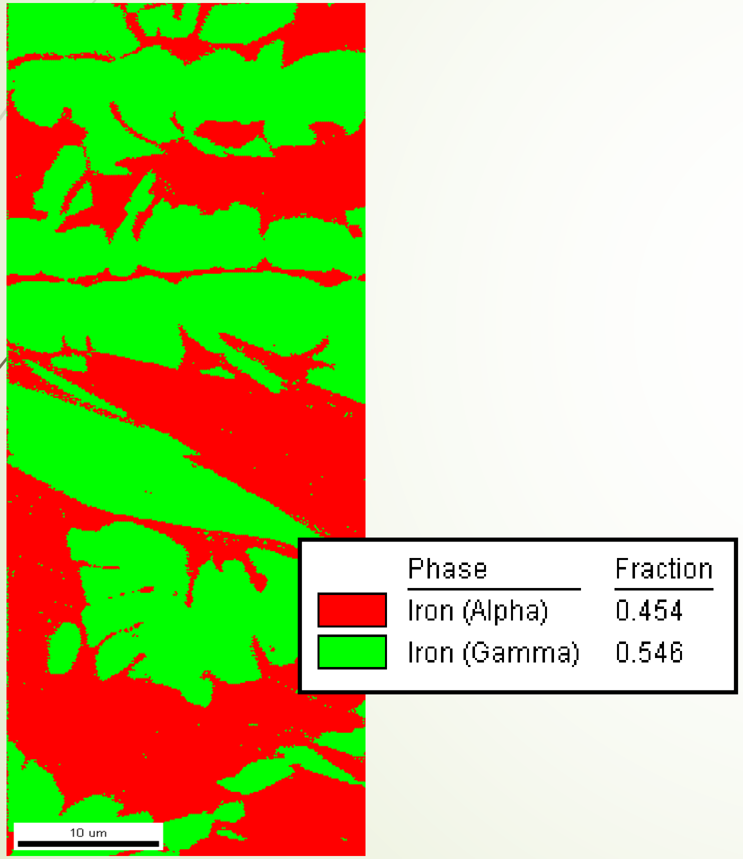
- EBSD Results – MEV Analysis:

Figure 16: Comparison of the two welded regions together with the base metal (I) standard sample composed of 1.5% N; (II) modified sample composed of 5.5% of N.

Results

- EBSD Results – Phase Composition:

(I)



(II)

Figure 17: Comparison with respect to the composition of Ferrite (Red) and Austenite (Green) phases, together with their percentages. (I) standard sample composed of 1.5% N; (II) modified sample composed of 5.5% of N.

Conclusion

- Tests have confirmed that addition of the amount of nitrogen in the shielding gas causes the amount of austenite to stabilize in the fusion zone. This makes the hyperduplex steel have a better resistance to corrosion.
- Other corrosion tests that exhibit greater sensitivity should be performed to better demonstrate the efficacy of the study.

THANK YOU!