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**COMPARATIVE ANALYSIS OF METALLOGRAPHICAL
CHARACTERISTICS OF A SOLDERED ASTM A131 NAVAL STEEL
BOARD BY THE E7018 COATED ELECTRODE WITH VARIATION OF
THE CABLE DISTANCE OF THE ELECTRODE**

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Abstract. *Steel, is an iron-carbon alloy, is widely used in the shipbuilding industry, has been replacing wood because it has advantages such as corrosion resistance, ductility and toughness. The process of union of steel more popular is the welding, since it is the most economical, practical and common process and to which it was used in this work COLPAERT (2008). Often welders can not move the rectifier sources to be welded and then to a solution, only change the length of the electrode holder for larger, to reach the destination without the regular welding amperage, as a result there is a deposition of variation In Fusion Zone (ZF) and, consequently, the behavior of HAZ microstructure, and where the study was made. Analysis of HAZ was made by metallographic tests in both welded joints and the results of the micrographs, was made a comparison between the welded joints with three meters and a hundred meters. Comparing the pieces, the Gasket A (cable 3 meters) is similar to Gasket B (cable 100 meters) in the refining of the grains. Differing from each other in the possible structure of bainite that appeared in Plate A, due to the fact that it had greater contribution of heat.*

Keywords: *Welding; Electrode; coated; HAZ; microstructure; Metallography.*

1. INTRODUCTION

Maritime transport has been used since the earliest times for the transportation of goods and people. However, its improvement took place effectively after World War I, as a result of improving the cargo capacity to be transported as well as the creation of specific vessels to transport certain products.

According to WORLD EDUCATION (2011), about 70% of the goods that circulate in the world are made by means of maritime transport. This is due to the fact that the huge capacity of ships to carry cargoes and the great part of the earth's surface is formed by seas. Due to the importance of maritime transport, in order to make it safer and more agile, the technology of the materials and processes of construction of the vessels is driven by great innovations. One of the innovations was the replacement of the wood by the steel in the structures of the hull of the boats, which made them more resistant and durable. Steel, which is an iron-carbon alloy, is widely used in the shipbuilding industry, has been replacing wood because it has advantages such as corrosion resistance, ductility, and toughness, according to COLPAERT (2008).

The most popular process of joining steel sheets is the welding technique, since it is the most economical, practical and common process used in this work ESAB, (2000).

Welding is the process of joining two or more parts through high energy, assuring the continuity of the physical, chemical and metallurgical properties used in the vessel construction process in the region of contact between these parts MODENESI, MARQUES e Santos (2012).

The heat produced in the welding process transforms the microstructure of the steel, giving characteristics in the thermally affected zone (ZTA) and in the molten zone (ZF) with reference to the base metal (MB) and to evaluate the effects of welding on the steel microstructure a process known as metallography, which according to COLPAERTE (2008), "is the study of the morphology and structure of the metals identifying the changes in macro and micrograms of the grains".

Metallographic evaluation of a welded joint throughout the design is critical to determine control measures and thus save time and resources on welded joints maintenance.

2. MATERIALS AND METHODS

2.1 Steel

Steels are iron-carbon alloys generally containing 0.008% to about 2.11% carbon, in addition to certain residual elements. One of the most important characteristics that distinguishes steels from cast irons is the ability of steels to be deformed plastically COLPAERT (2008).

As with CHIAVERINI (1986), the basic constituents of the steels are austenite, ferrite, cementite and perlite, which influence the mechanical characteristics of steels:

- Austenite: in common carbon steels, it is only stable above 727 ° C; consists of a solid carbon solution in the gamma iron and presents a structure of irregular polygonal grains; has good mechanical strength and appreciable toughness; is non-magnetic.

- Ferrite: it is iron in the alpha allotropic state, containing carbon traces in solution; also presents a structure of irregular polygonal grains; has low hardness and low tensile strength, about 270Mpa, but has excellent shock resistance and high elongation.

- Cementite: it is the iron carbide containing 6.67% of carbon, very hard and brittle, it is responsible for the high hardness and resistance of the high carbon steels, as well as for their lower ductility. It has orthorhombic crystal structure.

- Perlite: is the mechanical mixture of 88.5% ferrite and 11.5% cementite, in the form of thin sheets (thickness rarely exceeding one thousandth of a millimeter) arranged alternately. The mechanical properties of perlite, therefore, are intermediate between those of ferrite and cementite, however, dependent on the size of cementite particles.

2.2 Base Metal

In order to carry out this work, ASTM A131 steel was used as base metal (MB) and its use in marine engineering represents about 90% of the materials used in marine applications.

According to MOTA (2013), "ASTM A 131 A is a structural steel of the low carbon and low alloy steel grade used in the shipbuilding industry", its mechanical properties and chemical composition are expressed in Tables 1 and 2 below. They are applied on medium and large vessels and on offshore oil extraction platforms. In order to ensure the uniformity and quality of the services performed, naval steel is specified according to the technical standards of the international classification bodies.

2.3 Welding Consumables

The consumable used was the AWS E7018, as it is the latest version of the low hydrogen electrode presenting considerable amounts of iron powder to the coating in a smoother arc with less spatter which contributes to a great improvement in the stability of the arc, in the direction of the arch and ease of handling in all positions, according to ESAB (2000).

2.4 Power Supply

The source used in this work was the type of rectifier, direct current of the brand MARKLE BALMER BR 425.

2.5 Welding Procedure

Three welding passes were performed for each plate and the welds were made with two distinct characteristics, the first was done near the rectifier source with a cable of the electrode holder the source of three meters in length, the second was made with a distance of hundred of electrode holder cable away from the source.

For the process of welding plate A, a total time of approximately 12 minutes was spent and five (5) electrodes were consumed at a distance of 3 meters from the source of the rectifier and with a cable area of 30mm².

Table 1. Welding Process Sheet A

SHEET A welded 3 meters from the rectifier source

Pass	Current (A)	Tension (V)	Weld Cord Thickness (mm)
Root Pass	100	24 -25	12.3
Pass 1 (Filling / Finishing)	110	24-25	19.1
Pass 2 (Filling / Finishing)	110	24-25	12.5
TOTAL	3 Pass		

For plate B, a time of approximately 22 minutes was spent and 07 (seven) electrodes with 30mm² cable area were consumed. This plate was welded at a distance of 100 meters from the rectifier source, without adjustments being made for such a change.

Table 2. Welding Process Sheet B.

SHEET B welded 100 meters from the rectifier source			
Pass	Current (A)	Tension (V)	Weld Cord Thickness (mm)
Root Pass	87 – 90	21 – 23	6.3
Pass 1 (Filling / Finishing)	98 – 102	21 – 23	10.2
Pass 2 (Filling / Finishing)	98 – 102	21 – 23	9.6
TOTAL	3 Pass		

2.6 Metallography

To perform the metallographic assay the plates were cut with a Bosch Disk Saw, GDC 14-40, 127V ~ 50 / 60Hz 12A 1450W. A lot of water was used in the cutting process to minimize the temperature in the cutting region, avoiding the possible change in the microstructure. The plates were cut in four parts each, measuring approximately 80 mm in length, according to fig. 1. The preparation of the samples was done at the Federal Institute of Amazonas - IFAM



Figure.1 Longitudinally cut sheets A and B.



Figure.2 Area to be analyzed micrographically.



Figure.3 Samples to be analyzed.

2.7 INLAY

The inlay consists of surrounding the sample with a suitable material, forming a single body. In this work, the hot inlay was utilized using the equipment called embutidor. In this way, the hot embossing happens when the sample is embedded in thermoplastic materials by means of presses, using pressure and heating to effect the polymerization. The method consists of placing the specimen with the face to be analyzed in contact with the lower plunger of the embossing machine.

In this case the following procedures were performed:

1. The plunger was positioned so that the face is completely visible;
2. The sample was placed with the face to be analyzed downwards (in contact with the plunger);
3. The plunger has been lowered slowly;
4. The resin (bakelite) was a measurement of 30 grams
5. The release agent was used on the upper plunger;
6. The upper plunger has been closed;
7. The pressure was maintained during the process between 120 and 150 (KgF / mm²);
8. It was waited about eight minutes for the inlay to be completed;
9. The pressure valve has been opened and the cap of the press has been removed;
10. The plunger has been raised until it is possible to pick up the specimen;
11. The specimen was removed from the embossing press.



Figure. 4 Test body removed from the stuffing press

2.8 Sanding

For the sanding, the standard was used (ABNT NBR 13284: 1995), where its orientations were applied in this work.

The polishing is done after the sanding of the sample and is aimed at a polished surface finish, without marks, the chemical etching of the surfaces of the samples was done with the reagent Nital 2%, which was already prepared in the Laboratory.

After the chemical attack the photos of the test bodies were carried in the laboratory of the Technological Center of the Industrial Pole of Manaus (CT-PIM) located in the Center of Biotechnology of Amazonas (CBA)

3. RESULTS OBTAINED BY MICROGRAPHIC ANALYSIS

The following images are for plate A.

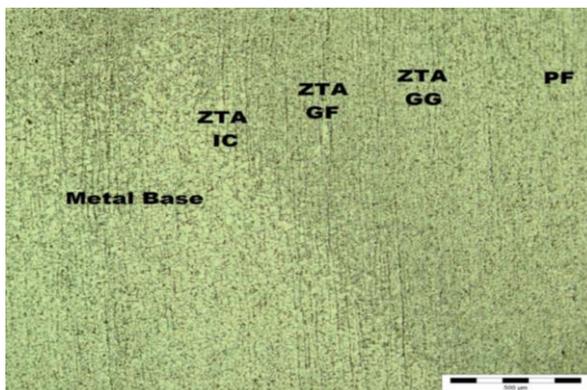


Figure. 5 Microstructure increased by 5x.

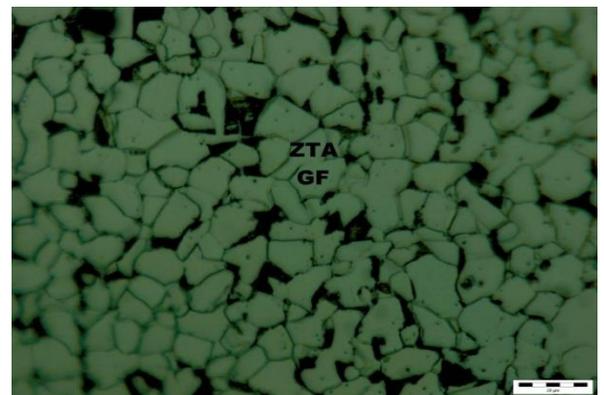


Figure. 6 Microstructure increased by 100x.

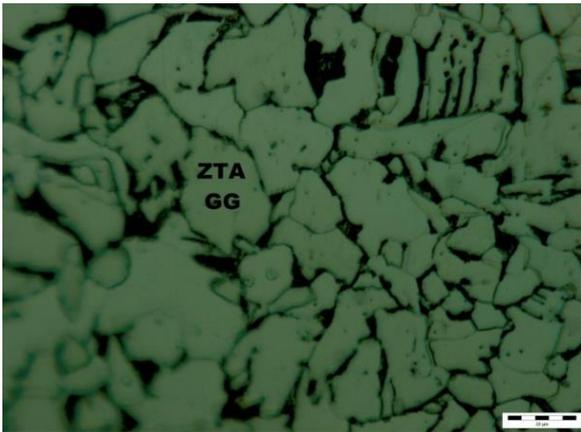


Figure. 7 Microstructure increased by 100x.

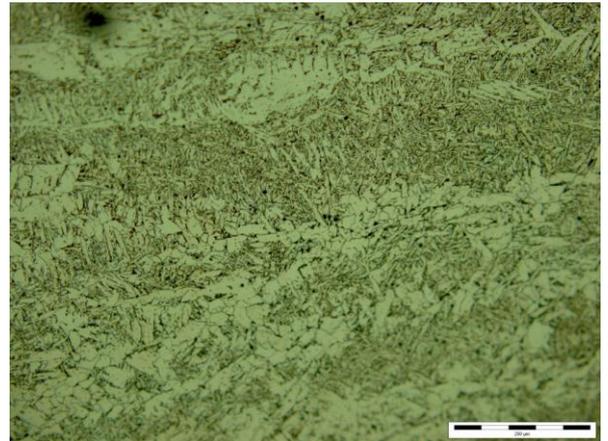


Figure. 8 Microstructure increased PF by 20x.

Symbology where Metal Base MB is the metal used for welding, ZTA GF is the Thermally Affected Zone with fine granulation and ZTA GG is the coarse granulation and PF is the fusion pool.

The following images are for plate B.

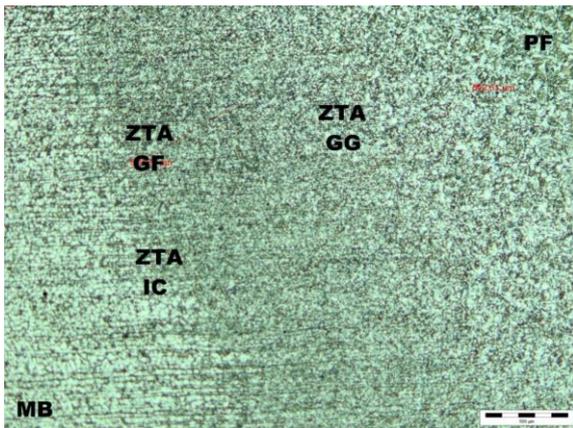


Figure. 9 Microstructure increased by 5x

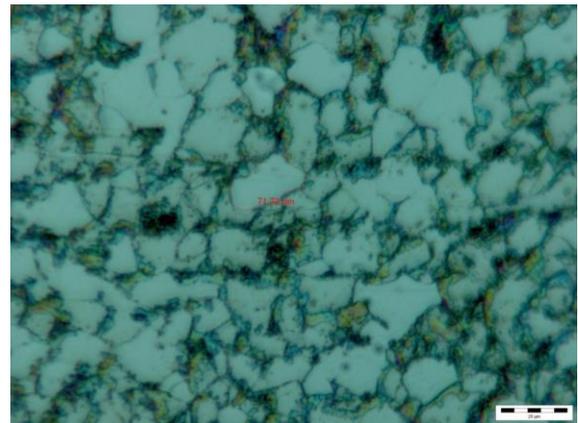


Figure. 10 Microstructure ZTA GF increased by 100x

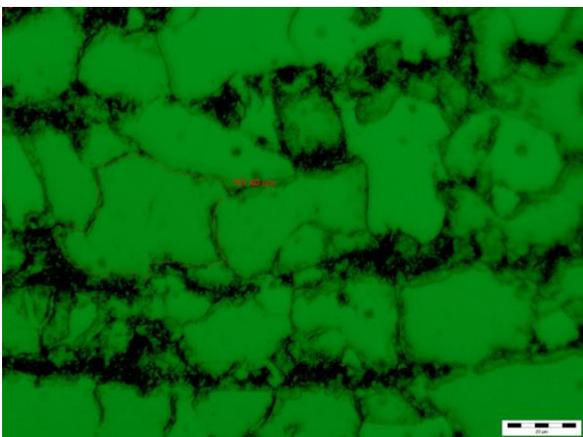


Figure.11 Microstructure ZTA GG increased by 100x

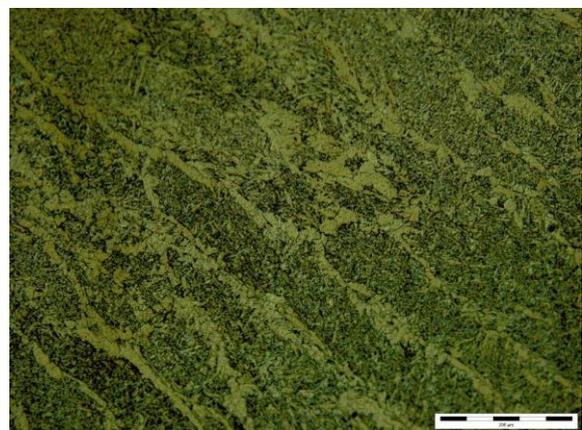


Figure. 12 Microstructure PF increased by 100x

The microscopies of the samples of Fig. 6, 7, 10 and 11 present phases of ferrite and perlite, except for Fig. 8 that show the formation of bainite.

By cooling the austenite to the temperature range between 200 and 540 ° C, the cementite will grow in the form of extremely thin needles, rather than layers. The needle-shaped structure is called bainite. The ferrite phase in the bainite is generally highly deformed. The deformation results from the volumetric changes caused by the transformation and the excess carbon trapped in the atomic interstices due to the rapid cooling to low temperatures. At temperatures between about 300 and 540 ° C, the bainite forms as a series of parallel strips or ferrite needles, separated by elongated particles of the cementite phase. This structure is denominated like superior bainite. Between 200 and 300 ° C, the ferrite phase forms thin plates with thin particles of cementite, forming inside these ferrite plates. This structure is called the lower bainite.

Ferrite is iron in the alpha allotropic state, containing carbon traces; also presents a structure of irregular polygonal grains; has low hardness and low tensile strength, but excellent shock resistance and high elongation. Perlite is the mechanical blend of 88.5% ferrite and 11.5% cementite. In low carbon steels it is generally found in the contours of the ferrite. In relation to the mechanical properties, the perlite has intermediate properties between the (ductile) phase and Fe₃C (hard and brittle). Coarse perlite has higher ductility, while fine perlite is harder and more resistant.

The transformations in the perlite and bainite phases are concurrent, that is, if a fraction of the alloy turns into perlite or bainite, the transformation into the other micro-constituent (perlite or bainite) is only possible if a reheating is made in the austenitic temperature range.

In order for the bainite transformation to take place, it is necessary to have a control of the cooling temperature that the steel, as the temperature has not been measured, remains as a suggestion of study to be made in future works.

It was found that a weld made with cable from the electrode holder increased the process time. In plate B (100 meters of cable) was spent approximately 22 minutes and 07 (seven) electrodes were consumed in the process while in plate A (03 meters of cable) was spent 12 minutes and so consumed 5 (five) electrodes, which means that plate A was spent almost double the time and a higher electrode expense.

Copper cables use a circular area of 30mm² and their specific resistivity of 1,7. 10^{-8} Ω.m, since there is no amperage regulation, it is applied in Equation 1. Page 26, where there is a resistivity of the cable of 3 meters is 1,7. 10^{-9} Ω.m of the 100 meter cable and is 5,6. 10^{-8} Ω.m demonstrating that the 100 meter cable has a higher resistivity.

Comparing like two joints, that a joint of Plate A resembles Plate B without refining criterion of the grains, differing from one another in a visible way in the Fusion Potion, where Plate A has a larger series than in Plate B and in the probable structure bainite that appeared in Plate A, to which I like as a suggestion for later works.

4. CONCLUSION

Figures and tables should be placed in the text as close as possible to the point they are first mentioned and must be numbered consecutively in Arabic numerals. Figures must be referred to as, "Fig. 1" either in the middle of a phrase or as "Figure 1" in the beginning of a sentence. The figures themselves as well as their captions must be centered in the breadth-wise direction. The captions comparing the two joints, the Gasket A (cable 3 meters) is similar to the Gasket B (cable 100 meters) in the refining of the grains. Differing from each other in the possible structure of bainite that appeared in Plate A, due to the fact that it had greater contribution of heat.

It was also found that the working time in the weld bead of Sheet A was smaller compared to that of Sheet B due to the fact that Sheet A had a higher amperage, facilitated the deposition in the fusion well, Plate B had some difficulties at the time of melting where no sufficient arc was deposited for deposition and the electrode was adhered (glued) to the plate without being diluted, visibly characterizing a larger volume of the melt pool and a larger extent in (ZTA) of Sheet A.

The greater the length of the cable of the electrode holder, the lower the final current to be worked, if there is no adjustment in the source due to the resistivity generated, because as the cable is an electric conductor, a greater resistivity is generated when compared to a cable, where it would be necessary to have a study of a power loss pattern by resistivity, remaining as a suggestion of studies for future work.

5. ACKNOWLEDGEMENTS

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