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INFLUENCE OF THE HYDROGEN IN THE FRACTURE TOUGHNESS IN THE STEEL AISI 8630M

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Abstract. *The growth in the use of structural steel has been studied by researchers and companies in underwater applications with the use of materials increasingly resistant to this type of environment. Of this materials, we can highlight the steel AISI 8630M, considered a low-alloy steel. In applications in aggressive environment, makes use of cathodic protection systems for the structures, which promotes the release of hydrogen ions and favors the appearance of unexpected fractures of these materials. In the proposed study, the influence of hydrogen on the fracture toughness was evaluated through the CTOD parameter, in application of the steel 8630M. The results indicated that the presence of hydrogen in the material decreased the fracture toughness of about 25% compared with the material without hydrogen. The fractográficas analysis showed that, despite the influence of hydrogen in steel 8630M, the micromechanics of the fractures were presented, in general, ductile, however, some areas of brittle fracture were observed, showing the drop in material toughness.*

Keywords: *8630M, welding, hydrogen, GMAW*

1. INTRODUCTION

The fracture mechanics study has been outstanding in preventing fractures in materials, enabling the project closer to reality the most reliable parts and components in many applications. Whereas the presence of cracks in the material is inevitably difficult or deleting, the study of the fracture behavior, based on the concepts of fracture mechanics, it is important in the application of engineering materials. The application in underwater environments of high strength steels require a good balance between mechanical strength and toughness, especially when there is the possibility of hydrogen embrittlement of these materials. Whereas the application of low alloy steels has AISI 8630M steel, as a material used in manufacturing structural components. The AISI 8630M is a medium carbon steel and low alloy, and is typically used in hardened and tempered condition, in compliance with the requirements for underwater applications and with the possibility of hydrogen embrittlement as the standard NACE MR0175. With the application of steel 8630M in cathodically protected environments, the H + ions diffuse into the metal and are trapped in regions of lower diffusivity and good solubility and may result in material fracture. In light of the foregoing, there is a need to evaluate the influence of hydrogen on the steel toughness 8630M fracture.

2. FRACTURE MECHANICS

The fracture mechanics study has stood out for its contribution in the understanding of unexpected fractures in materials which enables more reliable design components for the desired applications in engineering. Whereas the presence of cracks in the material is inevitably difficult or exclusion, fracture mechanics study is important in understanding the prevention of breakdown of the material. The fracture toughness of a material should be considered when there is a possibility of the emergence and propagation of cracks with possible rupture of the material during the applied requests. This condition from the imperfection of the material can be compounded with the use of certain structures in environments that use cathodic protection, such as in underwater conditions. Considering the application of low alloy steels, steel AISI 8630M, as a material used in the manufacture of structural components and being a medium carbon steel and low alloy, and is typically used in hardened and tempered condition, in compliance with the requirements for applications underwater and with the possibility of hydrogen embrittlement as the standard NACE MR0175. With the application of this material in cathodically protected environments, the H + ions diffuse into the metal and are trapped in the material may result in embrittlement of the material and hence in failure. Thus, the steel

AISI 8630M was evaluated its fracture toughness before and after receiving cathodic protection, checking the influence of this protection in the fracture toughness of the material studied.

3. THE HYDROGEN

The hydrogen embrittlement is an injury that occurs in metals due to the presence of atomic hydrogen accumulated inside the material, reducing the deformation capacity and may cause failure in loading levels below the supported when there is the presence of hydrogen, which may result in unexpected fracture of the material. Some studies (CARRASCO, 2013; DEMORI, 2011) are related to the effect of hydrogen, from the cathodic protection, in steels, as evaluation of the influence of the use of condition in material properties, defining a better condition of use of the materials. The hydrogen embrittlement can result in brittle fracture, with voltages well below the strength of the applied material, so it is important their understanding for the necessary control. The hydrogen embrittlement is heavily dependent on the strength of the material and the higher this property, the greater the possibility of embrittlement, and for many steel products, among these the low alloy medium carbon steels a relationship exists between the material and the critical concentration of hydrogen, which occurs above the crack propagation in the material, depending on usage conditions such as temperature, chemical composition, cathodic potential and crystalline structure of the material.

4 – METHODOLOGY

The methodology is illustrated in Figure 4.1, in achieving the expected results in the research.

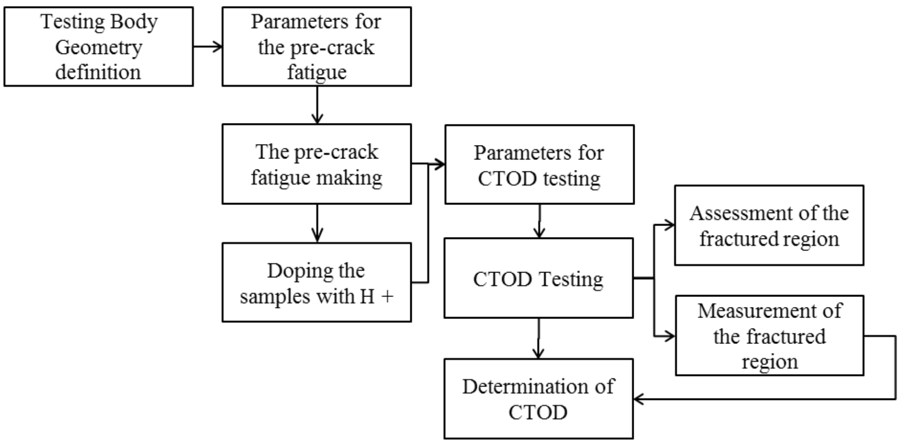

Figure 4.1 - Methodology

4.1 - Materials used

The base material used was AISI 8630 steel as the chemical composition of Table 3.1. This steel is medium carbon low alloy being originated from forged bars.

Table 3.1 – Chemical composition of base metal

Material	C	Si	Mn	P	Cr	Mo	Ni	Al	Cu	V
AISI 8630	0,33	0,26	0,84	0,007	0,92	0,38	0,81	0,006	0,09	0,015

4.2 – METHODS

4.2.1 – CTOD Test

The fracture toughness test to determine the CTOD parameter was based on ISO 12135 (2002) with the preparation of the samples, carried out with the machining of welded plate, setting the required geometry, as detailed and fashioned to fatigue cracking at the root of the notch in the equipment itself of carrying out the test, servo machine pulse of Shimadzu manufacturing. In the preparation of specimens, initially, the welded plate was planned with a milling machine, leaving the entire flat plate, and then used the electro erosion process to machine the profile of the specimens. After this stage, the blocks were rectified to ensure a better surface finish machining was performed by electro erosion using a wire with a diameter of 0,18 mm, which allowed the machining shape slot needs and meeting ISO 12135 (2002). Definition of specimen geometry: depending on the thickness of the specimen (B = 20 mm) and width (W = 20 mm).

The opening of the fatigue crack was held in the sample with machined notch, with an applying cyclic loads of 15 Hz and a relation (R) of 0.1. In the CTOD test, we used a scroll rate of 1 mm / min. Figure 4.2, are determined all other dimensions, both the test specimen and the devices involved in equipment, always following the criteria of ISO 12135 (2002).

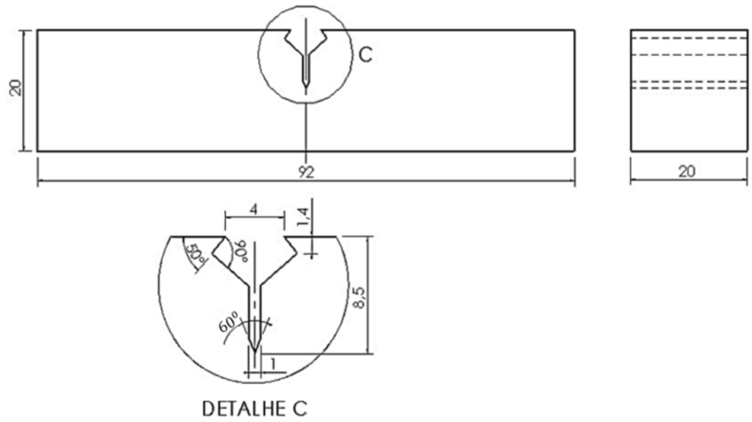

Figure 4.2 – CTOD sample

For the hydrogenation of the specimens, followed by recommendations DNV-RP-B401 standard (Cathodic Protection Design), simulating a cathodic protection system adopted for metal protection in harsh environments. The samples were placed in a medium with synthetic sea water, according to ASTM D 1141 (2008) and subjected to a potential of -650mV, to evaluate the influence of the parameter, with monitoring of the pH in 7.0. The soaking time of the specimens, it was a period of 7 (seven) days the 0^0C. All samples was painted with paint epoxy, keeping the cutout region without the presence of paint.

4.2.2 - Thermal treatment of coated material

The plates were conditioned in a metal box and covered with iron filings then set the parameters of the oven using a heating rate of 20 °C per minute, two temperature ranges for each condition studied. A maximum temperature to be reached 620 °C and 720 °C both with a time duration at the maximum temperature set 2 hour followed by cooling in air.

5 – RESULTS

5.1 – Base Metal CTOD without H+

The following Table 5.1 shows the values maximum load CTOD without hydrogen to the base metal, which can be seen a variation parameter from 0.168 mm to 0.212 mm. It is observed that the maximum charge for the tasting glasses that condition, had similar values.

Table 5.1 – Result of the test base metal CTOD without H+ (CBS)

Sample	Force [kN]	K [MPa.m^{0,5}]	V_P [mm]	CTOD [mm]	Status
CBS1	27,978	111,28	0.62	0,212	δ_m
CBS2	26,908	101,61	0,51	0,185	δ_m
CBS3	26,437	101,14	0,46	0,168	δ_m

The curve relating force to the opening of the crack (V) as the clip gage during the test for steel AISI 8630M without hydrogen, showing no pop-in tested no proof glass and it is classified as the type of curve 5, according to the classification of ISO 12135 (2002). At the time, the curves are shown with good similarity in the behavior of test specimens and showed no outliers and keeping certain standard behavior. There has been a greater similarity to the specimen CBS2 and CBS3. To the specimen 1 (CBS1), there is a curve behavior with a higher level of plasticity, compared with the other, which influenced the result with CTOD higher value compared to obtained by CBS2 and CBS3, as can be seen in Figure 5.1.

The Figure 5.2 observes a surface characterized by ductile fracture, with good plastic deformation capacity and the presence of wells (dimples). Generally, the assessment of the CTOD fracture in the base metal (AISI 8630M) without hydrogen doping, had completely ductile fracture.

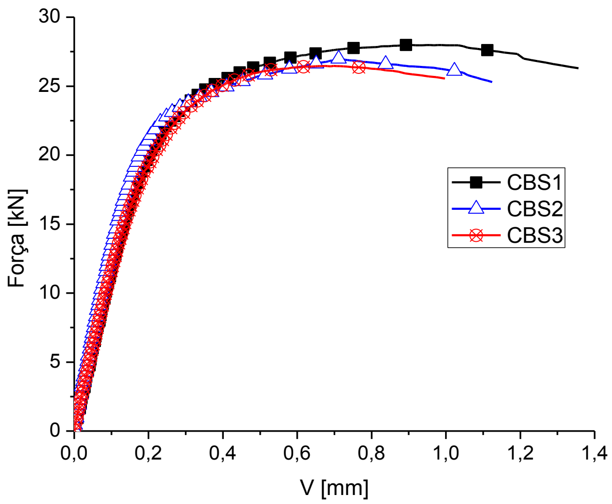

Figure 5.1 – CTOD without H+ (CBS)

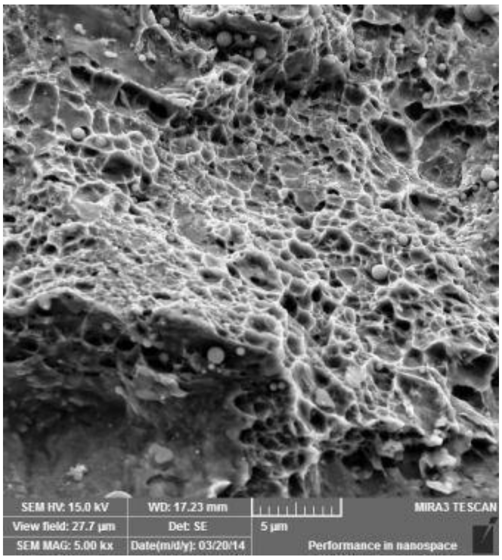

Figure 5.2 – Fracture CTOD without H+ (CBS)

5.2 – Base Metal CTOD with H+

With samples already doped, there was the test CTOD air at room temperature 20 ^{0}C. Table 5.2 summarizes the results obtained for the base metal provided with H +.

Table 5.2 – Result of the test base metal CTOD with H+ (CBH)

CP	Force [kN]	K [MPa.m^{0,5}]	V_P [mm]	CTOD [mm]	Status
CBH1	24,602	108,70	0,39	0,150	δ_m
CBH2	25,134	110,42	0,41	0,159	δ_m
CBH3	24,407	107,19	0,37	0,145	δ_m

In Figure 5.3, they observe the behavior of three base metal specimens (AISI 8630M) with the doping of hydrogen, defined as CBH. From the results, you can see a difference in race 3 of the body results (CBH3) than the other.

This behavior is reflected in the results, Table 5.2, with a smaller amount of the plastic portion (Vp), which contributed to a lower CTOD. Physically evaluating the result with the curve behavior, we can say that the hydrogenated base metal showed some regularity in behavior to the test specimens.

The behavior observed in the curves of the specimens, CBH1 and CBH2, showed similar results, which was reflected in the CTOD. Despite the divergence presented, it is perfectly justified by the conditions that are submitted each specimen, which involves unwieldy variables during rehearsals, as the very doping sample, which may have influenced, on a larger scale, the specimen CBH3. In a way, the results were considered valid, the criteria adopted as ISO 12135 (2002), being acceptable to the presence of differences between sampled.

The base metal fractures (AISI 8630M) can be hydrogenated in Figures 5.4 developed. In the evaluation, it is clear that the fractured region, presented a ductile fracture, with deformation of the material before the final break.

However, some regions presented with a less distorted appearance, compared with the base metal without hydrogen condition. While performing the analysis of fractures, using the SEM, it was found that the fracture did not appear as homogenous as in hydrogen without condition. Nevertheless, the results, in general, showed also characterized as ductile fractures with occasional regions having a tendency of brittle fracture as more planar regions observed in Figure 5.4, it may be characterized as a mixed fracture, being predominantly ductile and regions isolated fragile.

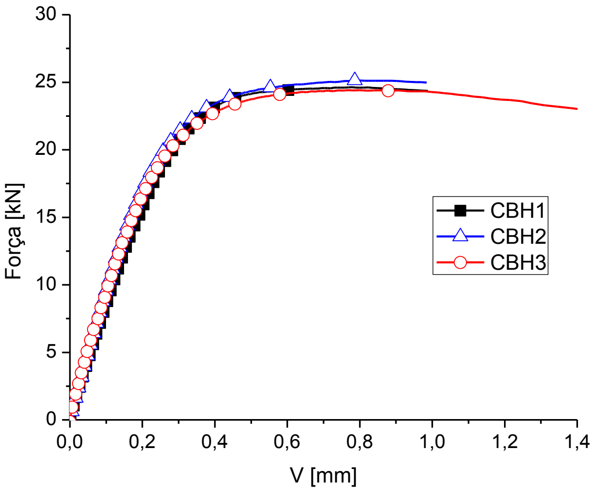

Figure 5.3 – CTOD CBH with H+ (CBH)

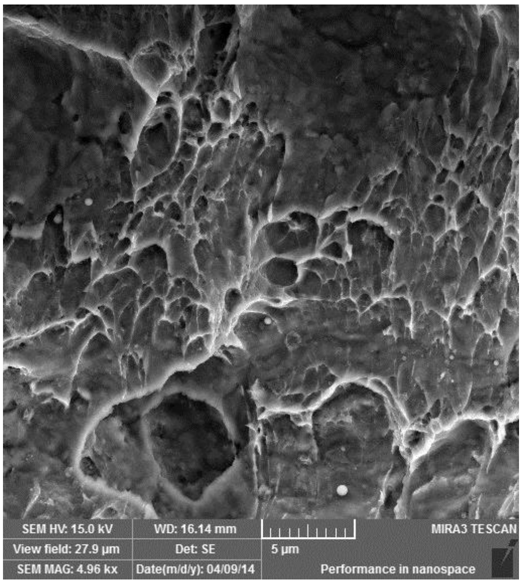

Figure 5.4 – Fracture CTOD with H+ (CBH)

For comparison purposes, we can see in Figure 5.5 CTOD's behavior to the base metal specimens with and without doping hydrogen showing for the specimens CBH, smaller CTOD values, there is a tendency to drop when compared to the average values of the CBS test specimens, with a reduction in toughness by approximately 24% when there is the presence of hydrogen in the base metal.

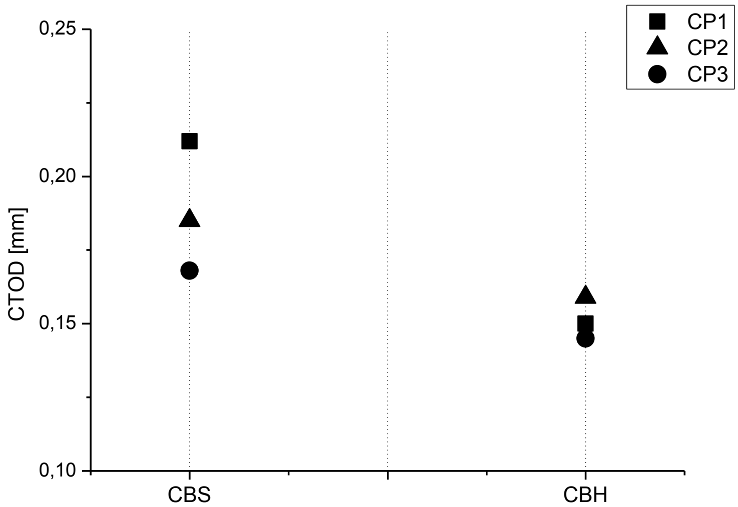

Figura 5.5 – Comparation whithout (CBS) and with (CBH) H+

6 – CONCLUSIONS

Based on the results, we can conclude that all results of CTOD tests of the base metal, steel AISI 8630M, showed values related to maximum load applied (δm). In the evaluation of the influence of hydrogen on the material, we conclude that the fracture toughness, generally, the hydrogen was affected with a fall in the toughness of approximately 24%, according to the potential use of cathodic protection. Regarding the analysis of fractografias, we conclude that the predominant type of fracture in both conditions (with and without hydrogen) were ductile fracture, however, with areas of brittle fracture when the material was doped.

7 – RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.

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