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MICROHARDNESS AMENDMENT PROVIDED BY UTILITY MODEL MU8303487-0 OVER STEEL PLATES ASTM-36

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Abstract. *The main objective of this work is to study the effects caused by the utility model MU8303487-0 developed and patented by the Laboratory of Robotics, Welding and Simulation- LRSS of the Federal University of Minas Gerais. Many underwater welding studies indicates the difficulties of opening and stabilizing the welding electrical arc, especially in the wet underwater welding. In order to solve this problem, it was added the MU8303487-0 between the tip of three different types of electrodes and a metal plate. The MU8303487-0, due to its physic chemical characteristics, it is necessary to facilitate the process of dissociation and ionization, allowing the opening and establishment of the electrical arc. It was sought to know how and if this element interferes on the micro hardness of the metal plates. For this, weld seams with three different types of electrodes, 6013, 7018 and WW70 (Wet Welding) were performed, all submerged in water depth and hyperbaric tank at a pressure of 1 atm, simulating 10m depth to the bottom of the sea. The weld seams were made on plates ASTM A36 steel and subsequently subjected to micro hardness analysis. It was observed that due to the diffusion process, the regions of the opening arc, exactly where MU8303487-0 were placed had an increase of the steel hardness, mainly associated with interstitial effects caused by manganese and other elements present in the composition of the MU8303487-0.*

Keywords: *underwater, micro hardness, welding, utility model MU8303487-0.*

1. INTRODUCTION

The history has always been marked by the development of the knowledge. Scientific, natural and technological discoveries were, and still are, able to transform both the ecological, as the social structures. These facts have become even more relevant in the last three centuries, since the intense technological transformation period known as the "Industrial Revolution". Since then, the improvement of manufacturing methods associated with increasing demands for goods, durable or not, has intensified the research for natural resources globally.

One of these features, vitally important for today's society, is the petroeum. Despite the global effort to find cleaner and renewable energy sources able to replace it, petroleum is still indispensable in virtually all industries, either directly or indirectly.

In this sense and because it is a finite resource, countries around the world have intensified the search for new sources of this resource, especially after the occurred "oil shock" in 1973, where due to a lack of supply, prices skyrocketed, affecting the entire global economy. However, these new search for petroleum reserves has not been a simple task, specially because it is generally located in the seas platforms. The marine environment is a very severe place for the metal structures of drilling platforms, in particular due to the movements of the waves and ocean currents and also due to micro pitting provided by contact with the seawater. Other important factor is that the exploitation is increasingly happing in deep waters, where there are many reserves still untouched, however, in which the environmental severities are even more pronounced. All this represents a major technological challenge, as in the case of Brazil, where recently abundant oil reserves were discovered in the pre-salt.

According to the Brazilian oil company, Petrobras, only in Brazil by 2017, the pre-salt reserves will be producing more than one million oil barrels daily. This quantities can only be achieved with substantial investments of US $ 236.7 billion dollars. Added to this, it still has the technological challenge involved in this exploration process in a depth of more than five thousand meters deep.

A very important part of this challenging scenario is the welding. It is an essential part to ensure this type of exploitation, because it is impossible to manufacture very long oil pipelines without a welded joint. These welded joints constitute a critical point of the structure, because in them there are discontinuities zones due to structural changes generated by micro welding process. Often, these structures need repairs, and usually It is done during operation submerged in water. These repairs are made by the process known as underwater welding.

The underwater welding was born mainly from the need for maintenance of the structures underwater. Today, this process is widely used, mainly by the shipping industry, and is growing its applications in the petrochemical industry, to repair platforms or oil and gas pipelines. In freshwater, underwater welding is generally used in the recovery of hydropower stations.

The fact is that in this area, there is still too much space to be improved and developed, specially the knowledge and techniques used. It is known in this field, for example, about the difficulty to open and establish the electrical arc. In order, to improve this aspect, was developed and patented by the Laboratory of Robotics, Welding and Simulation-LRSS of the Federal University of Minas Gerais - UFMG an element added in the tip of coated electrodes. These elements contains titanium dioxide that due to its physicochemical characteristics are ionized and dissociated enabling the opening and the establishment of the electrical arc. The main objective of this work is to study how this element interferes in the micro hardness of the welded materials.

2. METHODOLOGY

2.1 Matherials and Equipaments

To do the weld seams it was used: electrodes 6013, 7018 and the WW70, 3 ASTM-A36. To open and stablish the arc, were used the utility model MU8303487-0 developed by Laboratório de Robótica, Simulação e Soldagem - LRSS of the Universidade Federal de Minas Gerais -UFMG. Also, It was necessary an specific underwater welding machine, 1 aquarium for welding, 1 hyperbaric tank, auxiliary equipment, specific tools, such as wrenches, keys besides, etc.

2.2 Procediments

The Wet Underwater Welding process done in the LRSS are totally mechanized. The seams are made in an hyperbaric tank, or in the welding aquarium. Since the procedures were done, there are an specific mechanism that conduces the electrode by the action of gravity doing the welding seams. As the process doesn´t has human interference after mounted, it is very complicated to open and stablish the electrical arc. So, to solve this problem the LRSS developed the utility model MU8303487-0. This element, is added at the tip of the electrode. Then, the first step in the experiment was to create this utility model. It were done in the laboratory of metallographic tests of the LRSS. The MU8303487-0 compositions is the following:

1) Ferro-Manganese; in a percentage ranging from 70 to 80% approximately of the total mass;
2) Potassium silicate; in a percentage ranging from 10 to 20% of the total mass;
3) Rutile (titanium dioxide); percentage ranging from 5 to 10% of the total mass.

In order to enable proper correlation with use of the utility model and the changes caused by it, each element had 0.6 cm square, 0.1cm thickness, measured with a caliper and contained approximately 170 mg. The figure below shows the element used in the experiments, the ruler servant just to give scale to the Figure 1:

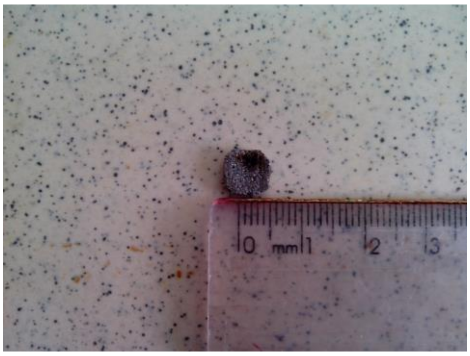


Figure 1 – A sample of the padronized utility model MU8303487-0

After that, the welding process were continued. The experiment was conducted within the aquarium and later in hyperbaric tank, where the electrodes were positioned at an angle of approximately 60 °. Figure 2 shows an example of WW-70 electrode mounted under water depth. Note the presence of MU8303487-0 utility model at the electrode tip.

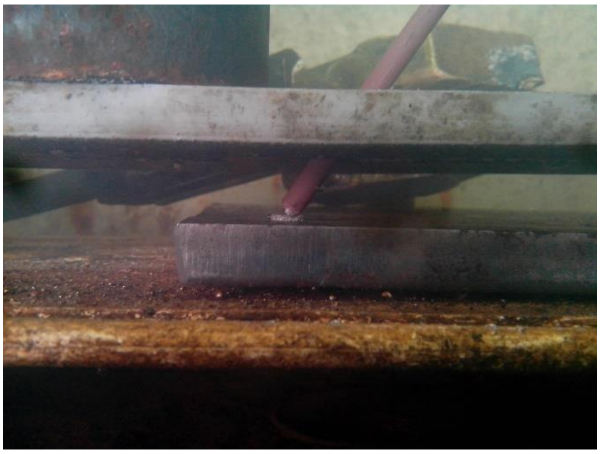
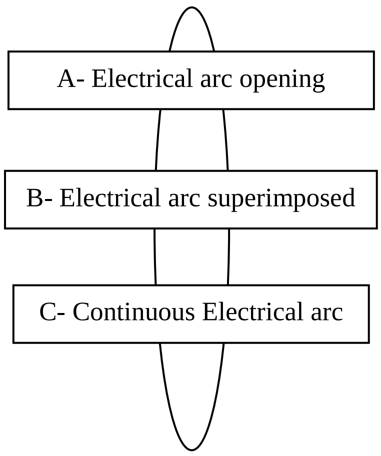


Figure 2 – Welding procedure using the utility model MU8303487-0 and the WW70 Electrode

Following this methodology, six welding seams were done. One for each electrode in the aquarium and one for each in the hyperbaric tank. The electrodes used were the WW-70, 7018 and 6013.

2.3 Microhardnees tests

Since the seams were performed, they were removed from the metal plates under the sawing process using cutting fluid, low feeds and high speed, in order to preserve mechanical characteristics of the metal samples. Three specific regions of the weld seams were object of study for evaluation of micro hardness, in the following way:



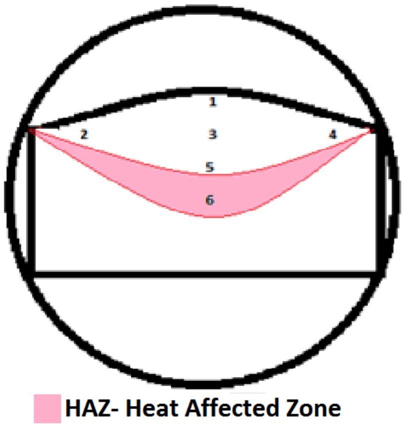
- **A- Electrical arc opening**; this region is initially where the electrical arc is opened using the MU8303487-0 utility model. The seams is performed for approximately 15s until the region B.

- **B- Electrical arc superimposed;** in this region another utility model is placed so as to overlap the weld seam. Here the two Heat Affected Zone - HAZ be will evaluated, top and bottom. The cord is again open for over 15s.

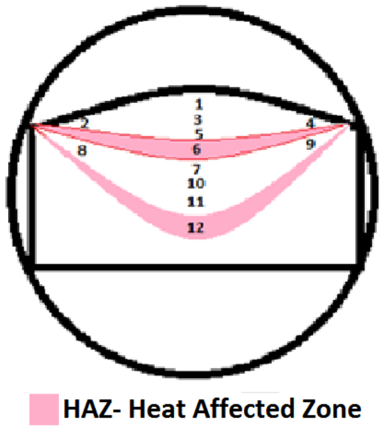
- **C- Continuous Electrical arc;** in this region the welding procedure is finalized. In it, a specimen is taken for comparison with other regions where the utility model were placed.

The metal plates were sectioned withdrawing the regions of interest to analyze the micro hardness as described above. The samples were subjected to micro hardness tests. Each region has received several tests. The regions A and C received six each one and region B, twelve. Each test received three different readings of the measurements in order to avoid mistakes. The points were chosen in order to do a scan of various parts of the weld seam, including the HAZ. The scheme below is how the tests were performed on each region:

A- Regions A e C; each one received six micro hardness tests:



B- Region B; in this Electrical arc superimposed region it was realized twelve tests:



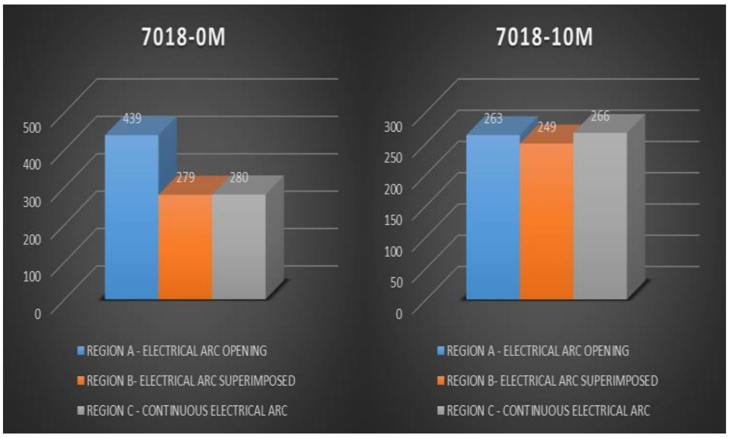
3. RESULTS AND DISCUSSIONS

For the WW70 electrode, the weld seam obtained in the aquarium, or 0m water depth, presents a better appearance compared with the same under water at 10m. This difference aspects, although it may be associated with other phenomenas, especially regarding the opening and stabilization of the arc, can also be associated with different pressure levels exerted when done in hyperbaric tank under 1 atm. Using data obtained with the hardness measurements, comparisons graphs were plotted of the regions A, B and C:

The coated electrode, Wet Welding - WW70, resulted from a pioneer research in the LRSS is an oxy-rutile electrode with oxidizing components that seek to inhibit hydrogen formation in the weld seams. It has in its composition the titanium dioxide (TiO2) whose objective is to promote the opening of the electric arc welding by dissociation and ionization.

The results performed in 0m and 10m water depth for the WW70 electrode indicate a relative hardness increasement of 29% and 17%, respectively. It is noticed that in areas A and B has a considerable increasement of the hardness relative to the region C. It is not possible to obtain any conclusion that can establish some standard for comparison between the regions A and B. For this, it would necessary to replicate the total number of tests and increase the amount of spacemens to establish a criterion for statistical repeatability.

For the coated electrode 7018, In the case of the electrode 7018, once again the weld seam performed under water film had a favorable performance in relation to that performed at 10m depth. This result was expected because the basic formulation of the 7018 coated electrode has better results when performed without pressure.



The composition of the 7018 is showed in the Table 4 below:

Table 4 - Electrode Composition - 7018

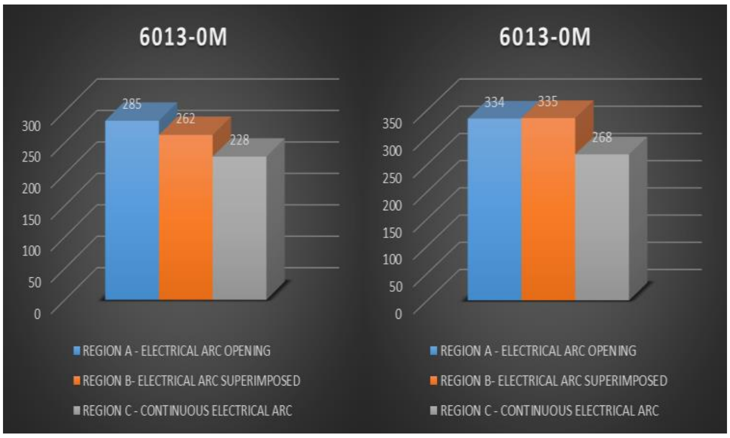
SPECIFICATION		**CHEMICAL COMPOSITION**								
		% C	**% Si**	**% Mn**	**%P**	**%Ni**	**%Cr**	**%Mo**	**%V**	**%Cu**
E-7018	**% MIN**	*****	*****	*****	*****	*****	*****	*****	*****	*****
	% MAX	0,150	0,750	0,160	0,035	0,300	0,200	0,300	0,080	-

The addition of considerable quantities of iron powder to the coating of such electrodes results in a smooth arc and less spatter. The coating ingredients balance results in a large improvement in stability of the arc toward the arc and the ease of handling in all positions.

The addition of considerable quantities of iron powder to the coating of such electrodes results in an electrical smooth arc with less spatters. The coating ingredients balance results in a large improvement in stability of the arc and the ease of handling in all positions.

For the electrode 7018, it had a non expected result, since the specimen hardness of the region C, made under 10m depth, had higher relative hardness compared with the other regions A and B. This result contradicts the assumption that the clay causes hardening effects. However, it is believed that this point outside of the curve is related to inherent errors of the analysis procedures, as the cut section in the sawing process, the cut before the embedding of the sample and the polishing. All this steps could make some changes in the micro structure of the specimen. Therefore and because it was an specific case, the repetition of hardness tests would be needed in other specimens in order to depart the error hypothesis.

The weld seams obtained with the coated electrode 6013 showed an opposite behavior compared to the others. In the aquarium It had a poor performance compared with the seam performed in the hyperbaric tank. This difference may be associated with the strong presence of the rutile (TiO2) which promotes the opening and establishment of the electrical arc.



The electrode 6013 has a rutile characteristic of coating composition. It contains a large percentage of titanium dioxide (rutile - TiO_2). They are designed to have an arc of low penetration, allowing the welding of thin metals without sticking the piece. The coating contains sufficient potassium compounds to stabilize the arc in the welding using alternating current (AC) .Its composition is presented below:

Table 5 - Electrode Composition - 6013

SPECIFICATION		CHEMICAL COMPOSITION								
		% C	% Si	% Mn	%P	%Ni	%Cr	%Mo	%V	%Cu
E-6013	% MIN	*****	*****	*****	*****	*****	*****	*****	*****	*****
	% MAX	0,200	1,000	1,200	-	0,300	0,200	0,300	0,080	-

Finally, using the electrode 6013, the hardness tests showed results within normal limits. In the two depths, at 0 and 10m, an increase of average hardness obtained was approximately 25% of the regions A and B in relation to C. Again it was not possible to draw any conclusion about the effects of clay over the regions A and B.

The results obtained with the use of electrodes WW70, 7018 and 6013 demonstrate that the use of clay in fact experiments directly influence the hardness of the material. The average hardness increase observed in all cases was 25%.

In order to understand the physical and chemical mechanisms that cause part of the clay to mix the weld bead and generate an increase in the hardness of the material, there were unseen footage with high precision cameras in order to film the initial moments of opening arc. These mechanisms have been observed and are discussed in the following section.

4. CONCLUSIONS

In the results obtained by the experiments, there is an evidence that the use of clay to initiate the electric arc induces an incensement of the hardness of the weld seam in the regions where it was placed.

This hardness increase may be associated to physical and chemical phenomena, such as the melting and the molecular diffusion. As reported, the utility model MU8303487-0 has in its composition the presence of iron-manganese, and other components aimed to opening and stabilize the electric arc. It is known that manganese in the ferossas alloys, because its element has a atomic radius which is much less than the iron atom, exerts a distortion in the crystal lattice, leading to an increase of tensiles and thus hardening the alloy.

Thus, there are indications that the hardness increases observed in the electrical arc initiation regions are related to the presence of manganese from the clay. In this case, in order to better visualize these effects and to understand the mechanisms that lead to this hardening, cameras of higth precision shooting was used. The Figure 3 below represents several moments of the opening of the electric arc in water depth of WW70 electrode:

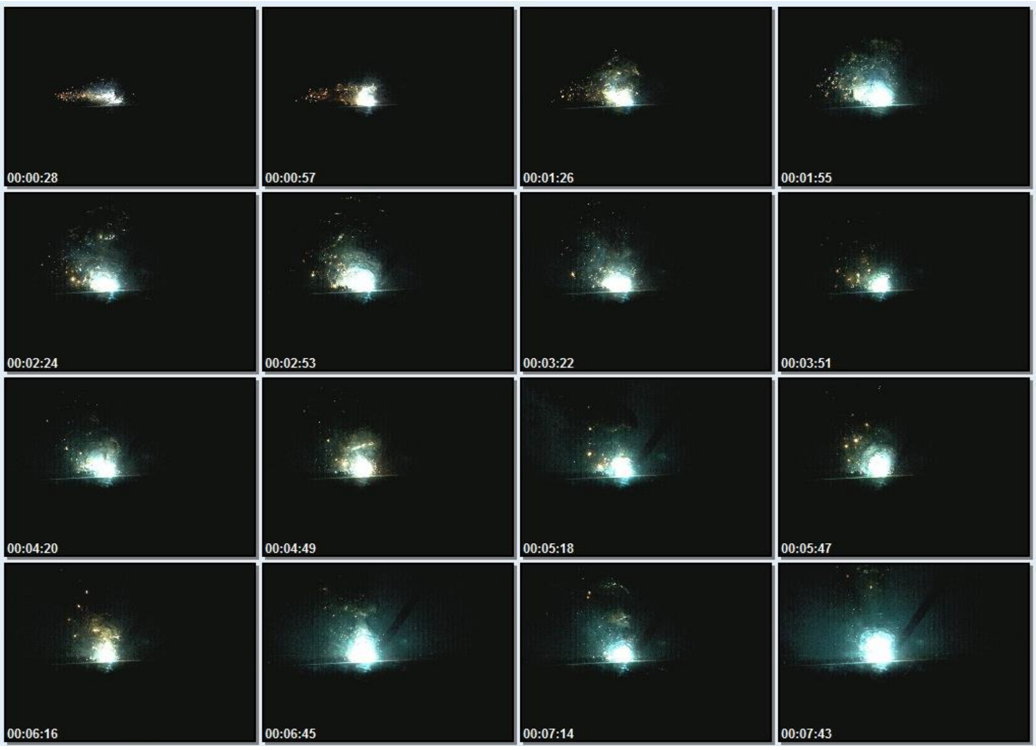


Figure 3- Some moments of the opening of the electric arc in water depth of WW70 electrode

Despite the video have a whole 7min 43s and in fact the actual elapsed time of the opening at the end of the video was about 1.5s. This time lag is due to the amount of frames able to be viewed by the shooting.

Analyzing the footage, we can see that from ionization time until the stabilization of the arc, several small phenomena occurs. First, they are observed several small points of light coming from the opening region. These outbreaks are micro electrical arcs that are formed as the dielectric rigidity is broken. There is a time when the potential energy is sufficient to break completely isolating and then passes to conduce current. At this instant of time, the energy released is large enough to promote a small "explosion" of the utility model, showed as yellow dots scattered throughout arc.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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