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STUDY OF THE WELDING REGION OF THE STEELS HIGH STRENGTH LOW ALLOY WELDED BY THE HELICAL SUBMERGED ARC WELDING PROCESS

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ABSTRACT

The steel of API class are high strength low alloy materials (HSLA), which have both good mechanical properties such as high strength and good toughness. Although they are special steels, the region near the weld bead that always happen, is thermo-mechanically affected as it is a zone named region Affected by Heat (HAZ) modified grain and mechanical properties, and dealing with critical part in material due to changes in general. Therefore this study investigated this area (HAZ), the molten metal (weld metal) and base metal. The analysis was strictly macro and microscopically, always observing the microstructure and microhardness variances throughout the bead filler according to the processes GW-Circumferential and SAWH-Helical. The results showed that the process of helical weld by being constituted multipass causes the weld root region is strongly influenced by the energy of the previous pass, causing similar to tempering, making the acicular ferrite in the base metal with smaller grains in larger grains of primary ferrite and thereby decreasing the hardness of 225 HV in the (FZ) to 200 HV in the Heat Affect Zone (HAZ).

KEYWORDS: pipelines; girth welds; multistep; helical welding; weld root

Introdution

The increasing demand in the use of tubes to build fluid handling pipelines and major interconnections lead the studies to better themselves around the low production cost, operational efficiency and quality of material with lower technical risks to the pipelines.

For these market requirements, the steel should be designed for high strength, good toughness and weldability of the best performance. The high mechanical strength of the HSLA steels used to manufacture pipes depends on its microstructure [1].

In this way have become an important alternative pipeline facilities in the HSLA steels, they besides possessing constituents micro alloying, have lower weight and cost compared to the heat treated materials, since their characteristics were obtained by a thermo mechanical treatment lamination.

The elements common that act as micro alloying are Nb, Ti, V, Zr, Al and B, which are able to exert a significant influence on the properties and microstructure of the steel, including less than 0.1%.

Therefore its use as pipelines and the union of metal welded pipes form, because with it you can make some repairs in the material without impeding the continuous flow of fluid.

One of the weld definitions for this is to be an operation that aims to get the union of two or more parts, ensuring the joint continuity of the all the material properties.

Despite the attempt to seek the same characteristics, the base material (BM), the fused zone (FZ) and the heat affected zone (HAZ) invariably present microstructural changes due to high temperatures imposed by the welding process fusion and the cooling as shown in Figure 1.

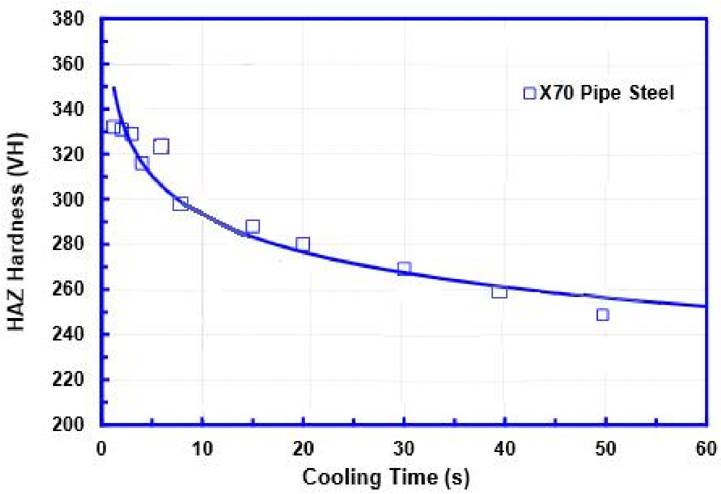

Figure 1 – Micro hardness of the ZAF for cooling function

Welded joints of high strength steels are well characterized, and failure mechanisms well known [2].

In manufacturing process of pipeline steels, chemical composition and thermo mechanical control process scheduling are two important decision-making areas that influence their final microstructure and mechanical properties [3].

Welds are critical regions with the rest of the material, so it requires a detailed study on all its length. The viable range of welding parameters for the microstructure with balanced strength and toughness (weld metal and HAZ) is narrower than those for lower grade steel X70.

Is worth noting that the steels API 5L X70 have Grade X70 witch mean 70000 psi minimum yield strength and 82000 psi minimum ultimate tensile strength, which conferred on them the same characteristics also after welding [4].

Although these tubes were made for a long time by Girth Welds (GW) process butt weld with half notch V, currently Submerged Arc Welding Helical (SAWH) which requires double notch in V and produced by automated machines under controlled conditions, which has been gaining good progress in welding processes for these purposes [5].

Submerged arc welding helical is generally the preferred method for joining the seam edges of large diameter spiral pipes but causing moderate tensile residual stress caused by the welding process [6].

Materials and Methods

Commercial API X70 grade pipeline steels with Nb and a yield strength between 70 ksi and 80 ksi, were used in this study, and their chemical compositions are shown in Table 1and 2.The samples were obtained for parts of the pipelines, one containing the top weld and the other helical, but both machined and ground surface until reaching a width of 36 mm and height equal to the thickness of pipe 15 mm.

Samples for the revelation of macrographs were removed from the weld region, prepared and attack with Nital solution 4%, as ASTM E 340, in order to observe the occurrences in the fused zones (FZ), heat affected zones (HAZ) and base metal (BM), or possible micro cracks.

Micro hardness Vickers measurements were carried out in the welding region, both the Girth Welds (GW) and Submerged Arc Welding Helical (SAWH) processes with a pyramidal diamond penetrator according to ASTM E 384-73 (ASTM, 1999), to analyze the variations of microstructural hardness along the entire length of the weld, especially in the heat affected zone (HAZ), this region more critical with respect to changes.

The metallographic analyzes were performed in digital optical microscope DINO-LITE-AM-413T PRO where according to ASTM 1647 (ASTM, 2009), for each sample was observed grain structure formed in the regions of interest, their micro constituents.

Table 1- Chemical composition of the API 5L X70 steel-Girth Welds process (GW)

	C_{max}	Mn_{max}	P_{max}	S_{max}	Nb+V+Ti
Sample 1	0.26	1.65	0.03	0.03	<0.15

Table 2 - Chemical composition of the API 5L X70 steel-Submerged Arc Welding Helical process (SAWH)

	C_{max}	Mn_{max}	P_{max}	S_{max}	Nb+V+Ti
Sample 2	0.22	1.85	0.025	0.015	<0.15

Welding processes used were: GW (Girth Welds) process - Weld Circumferential for butt weld with half notched V and SAWH (Helical Submerged Arc Welding) process - Helical Submerged Arc Welding with double notched V. Each specimen was carefully prepared surface, degreased in digital ultrasonic washer for 15 minutes to remove impurities and make it suitable for the study.

The measures of Vickers hardness were performed with load of 300g and 0.25mm of distance between indentations and with load of 500g and 0.50 mm of distance between each indentation, always in the three regions of BM, HAZ and FZ as shown in Figure 2.

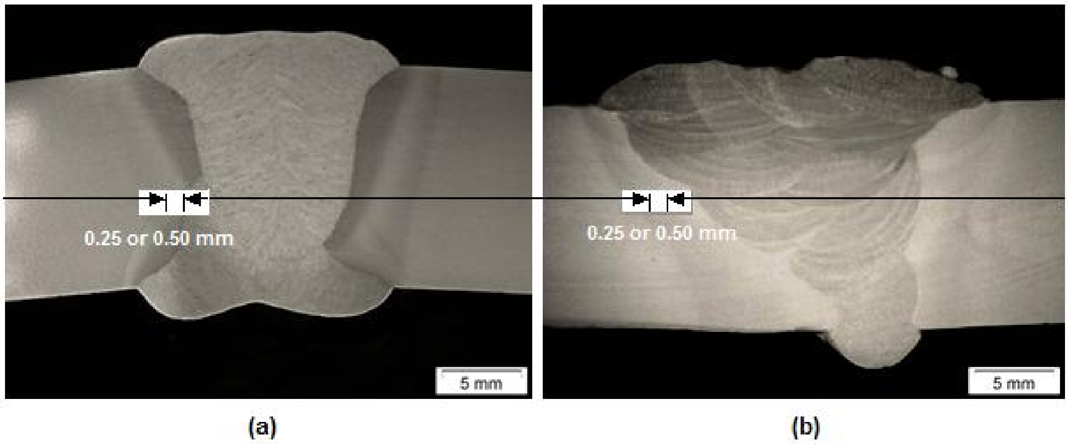

Figure 2 - Schematic profile adopted for micro hardness measurements of 0.25 or 0.50 mm of distances between indentations.

Results and Discussion

Macrographs:

The macrographs were carried on properly prepared and revealed specimens, in order to define the macro-structures with appropriate boundaries of base metal (MB), heat affected zone (HAZ) and the fused zone (ZF) as shown in Figure 3 and 4.

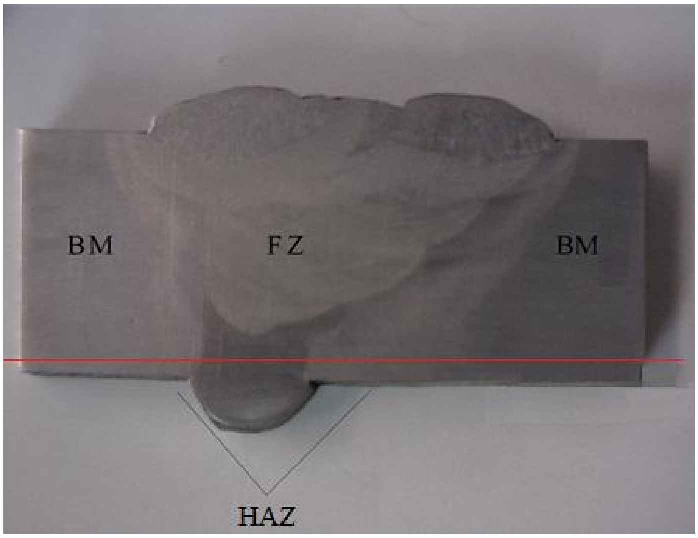

Figure 3 - Macrostructure the butt weld region half notched V. Magnification: 20 X

The red line shows the area which was called bottom line, it marks the root of the top circumferential weld, however near the heat affected zone - HAZ you can see the darker cast zone than the other regions, which is due to the material welding the root pass of being different from others, because there is a fusion of different cooling to the base metal.

We also observed contours of filling passes and their respective HAZ, noticeably larger at the root, because there was a greater influence of welding energy by the upper layer.

The size of the HAZ depends on the temperature of the plate, welding energy, thickness, geometry of the notched, which explains why for helical weld, the HAZ is essentially uniform throughout around its cord and it is possible to observe a columnar dendritic zone produced in cast region, usual process in castings.

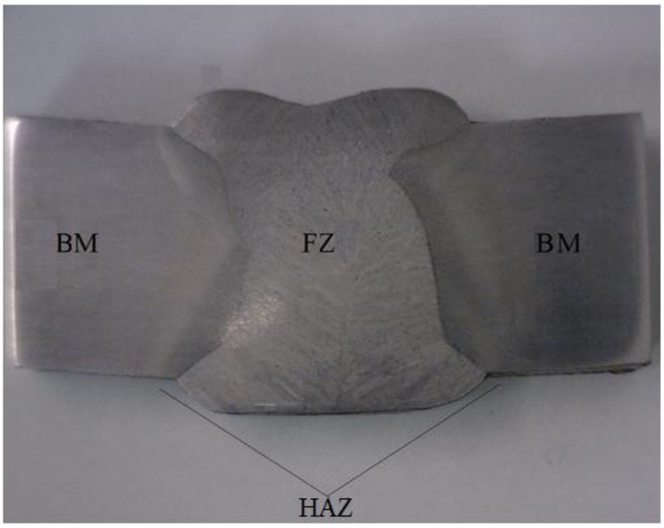

Figure 4 - Macrostructure the butt weld region double notched V. Magnification: 20 X

Micrographs:

Specimens GW (Girth Welds) (WEI, et al., 2011) process and SAWH (Helical Submerged Arc Welding) process were attacked and seen with magnification of 1000 times obeying the terminology: Perlita (P); Martensite (M); Austenite dendritic (AD); Acicular ferrite (AF); Primary ferrite with coarse grain boundaries (PF(G)) polygonal ferrite intragranular (PF(I)).

The Figure 5 and 6 show the microstructures revealed in both cases and the relevant regions of the weld.

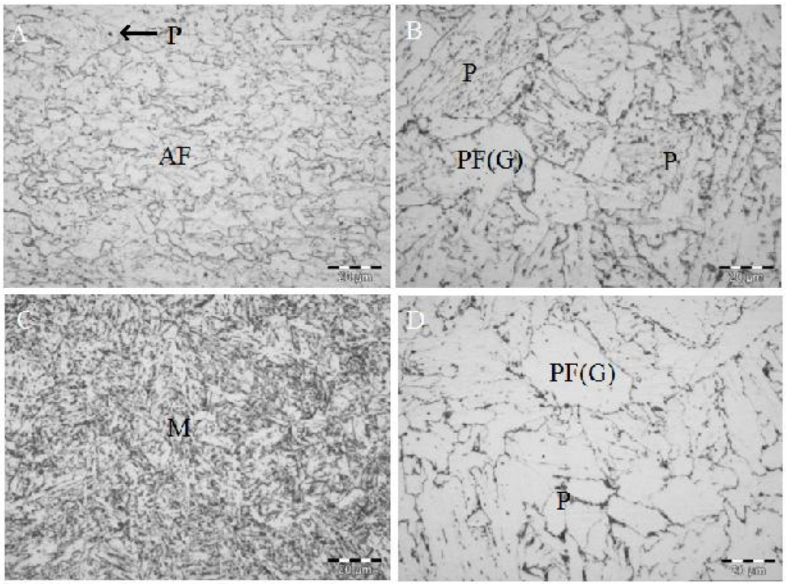

Figure 5 - Microstructures of circumferential butt weld: a) a) Basic Metal b) Thermally heat affected zone c) Filling Weld d) Root Weld. Magnification: 1000X

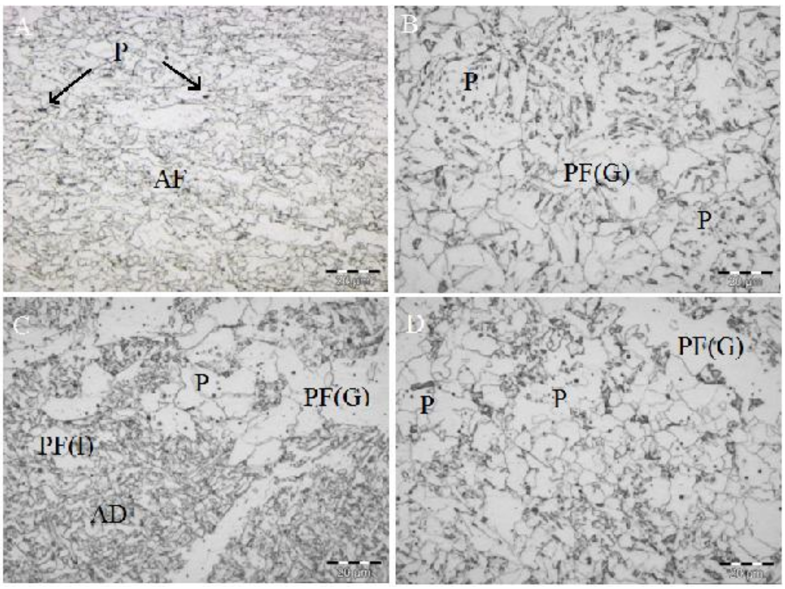

Figure 6 - Microstructure of Weld Helical Submerged Arc a) Basic Metal b) Thermally heat affected zone c) Filling Weld d) Root Weld. Magnification: 1000X

We can see that in Figure 5 pearlitic matrix has been dominated by the ferrite transformation throughout the HAZ which has fine pearlite in coarse grain boundaries. Filler metal where there martensite islands with higher bainite with perlite practically solubilized and the weld root observed predominantly perlite with coarse grain boundaries [7].

The filling weld microstructure consists of refined upper bainite islands randomly embedded in the polygonal fine-grained ferrite matrix, because the equiaxed grains in base metal was completely transformed to lath bainite with some polygonal/grain boundary ferrite.

It is well known that microstructural changes in the weld are primarily affected by heating rate, peak temperature, and subsequent cooling [8]. However in Figure 6 which refers to Helical Submerged Arc Weld process, we did not observe the appearance of martensite, but have isolated islands of lower bainite and austenite dendritic mainly in the filler metal.

Micro hardness measures:

With delimiting the regions BM, HAZ and FZ, we obtain a Vickers micro hardness profile with 500g load for each region separately and each WG and SAWH process as shows the Figures 7 and 8 with the normalization of the data.

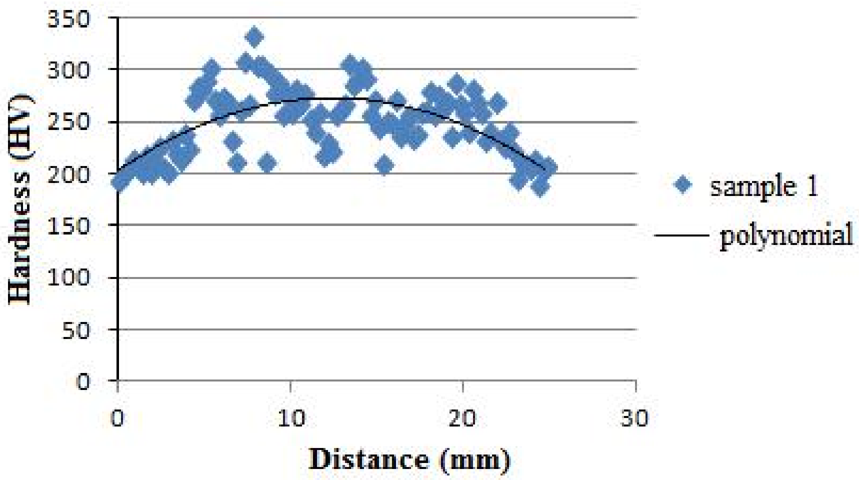

Figure 7- Micro hardness measures with 300g load along the weld profile GW

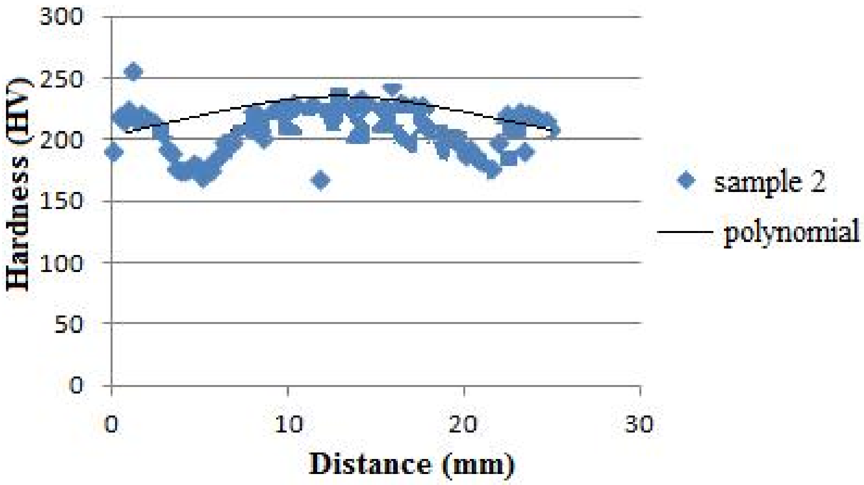

Figure 8 – Micro hardness measures with 300g load along the weld profile SAWH

However, hardness profiles measured from 0.25/0.50 to 0.25/0.50 is shown for both cases in Figures 9 and 10.

The mean values of micro hardness found both in the melting zone (FZ) and in the heat affected zone (HAZ) are due to presence of upper bainite island in the FZ and refining grains and martensite [9].

It was observed that bainite and tempered martensite can lead to the highest susceptibility to cracking in the HAZ, while acicular ferrite shows better resistance against specific fracture by hydrogen for example [10,11].

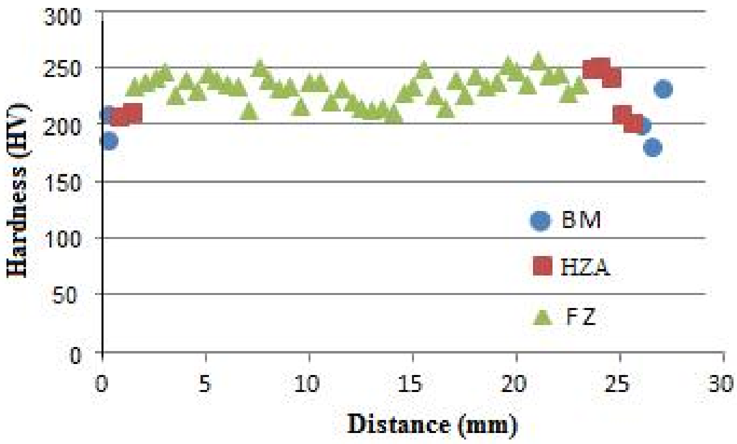

Figure 9 - Profile hardness with 500g load in the regions BM, FZ and its HAZ and respective means for the sample with half notched V GW process.

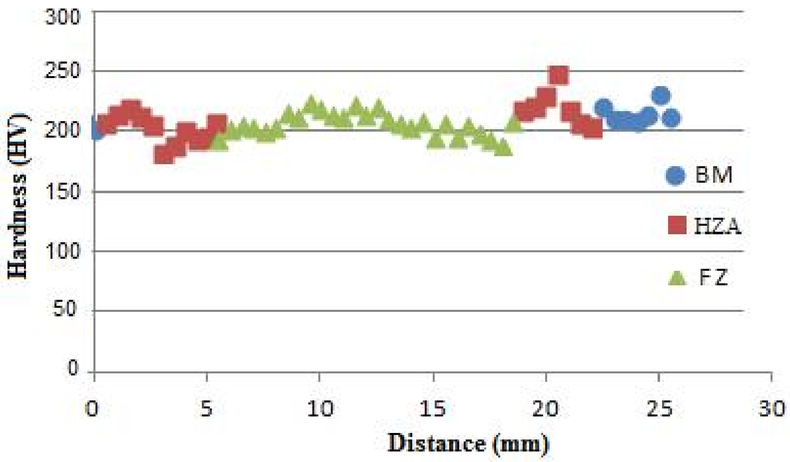

Figure 10 - Profile hardness with 500g load in the regions BM, FZ and its HAZ and respective means for the sample with a double notched V in SAWH process.

Based on figures above we can see that the circumferential weld (SAWH) introduced micro hardness profiles for the three different weld zones because the surroundings of the weld regions are modified thermo mechanical heat between weld passes.

Such changes happen mainly due to the cooling time between the HAZ and FZ. For its part, the next region of the FZ and within of the HAZ region the cools temperature increases rapidly, which generates the tempering effect, which results in increased grain size and hardness [12].

The influence of high angle grain boundary, i.e., the great distortion among neighbors grains [13].

The more removed from the bead, the faster the cooling rate and thus decrease the grains, since little beyond the grain refining region, there is another inter critical region, which is a partial transformation of the base metal where the hardness is reduced.

Analyzing the results it is clear that the HAZ has greater hardness than the base metal in the majority of your profile, as lower hardness points have been detected, which is attributed to the type of process, the amount and type of micro alloying elements.

In the Helical Submerged Arc Welding (SAWH) has a pass in the double notched V, which in the circumferential weld (GW) in the multistep half notched V is present, so that there is the appearance that influences multilayer to increase the grain size.

However, a pass may influence the other by providing more thermal energy, causing something similar to tempering and for these reasons the hardness in the weld root region with half notched V is lower in relation to all data obtained.

Thus, we observed that in the HAZ have higher hardness levels compared to the rest of the region (due to increased grain and more likely to appear martensite), noting that Petrobrás Standard (N-2163-2008) requires lower hardness to 279 HV for these products.

In HAZ may occur increased mechanical strength with the rest of the material, but sometimes a hardness fall and there is concern for these HSLA steels, whose main function is to have good strength and good toughness.

The increase in FZ hardness with an average value of 218 HV was observed, which can be attributed to the presence of lower temperature transformation products in fusion zone [14].

The variation of microstructure and hardness in various sub-zones of submerged arc welded showed a high level of hardness 225 HV in the fusion zone (FZ) decreases to 200 HV in the heat affected zone (HAZ).The high hardness characteristics of the seam weld can be attributed to its cast microstructure and the presence of grain boundary phases (such as pro eutectoid ferrite), confirmed by standard metallographic and also reported by [15].

Conclusions

The differences in hardness between the two processes, circumferential and helical were recorded.

In HAZ may occur increased mechanical strength with the rest of the material, but sometimes a hardness fall and there is concern for these HSLA steels, whose main function is to have good strength and good toughness.

Wherefore variation of microstructure and hardness in various sub-zones of Helical Submerged Arc Welding (SAWH) showed a high level of hardness 225HV in the fusion zone (FZ) decreases to 200HV in the heat affected zone (HAZ) due to transformation of acicular ferrite in the base metal with smaller grains in larger grains of primary ferrite.

The high hardness (275HV) characteristics of the Girth Welds (GW) process can be attributed to its cast microstructure and the presence of grain boundary phases (pro eutectoid ferrite).

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