Characterization of a welded joint in steel API.5L.X70 having undergone successive repairs

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Abstract

The object of this paper is to study the effect of the successive repairs on the weldment quality, knowing that these repairs constitute a main problem in the hydrocarbons transportation industry. We study the effect of several thermal cycles welding on the microstructural welding joints evolution, particularly the heat affected zones and its extend. We weld and repair many times a steel sample used in the hydrocarbons transportation. The metallographic analysis and mechanical tests results show the harmful effect of repairs that cause a prejudice on the life of weldment.

Key words: *Welding, Repair*, *Thermal cycle, Heat affected zone*

1. Introduction

In metal construction, assembly techniques are constantly evolving; metallurgists and physicists discover and develop every day, methods and more effective ways to combine technology and the economy. Welding operations are expensive. Weld quality is unfortunately not always what we expect, the standards define the criteria for acceptability of defects in a weld.

However, technical and economic parameters require the prime contractor at eliminating defects to avoid cutting or total rejection of the joint.

2. Experimental procedure

The assembly material is high strength low-alloy (HSLA) steel grade API5L X70, using in crude oil and gas transport with 14.2 mm of thickness and diameter of 16 inch, obtained by SMAW process.

Several tubes were used for each repair with multiple passes for each one.

Mechanical tests such as tensile, bending and resilience are done at room temperature according to API5L Standard. Thus, microstructural evolutions are carried out for all samples of each repair using optical microscopy.

3. Results and Discussion

Figure 1 shows a typical microstructure of HSLA base metal (BM), HAZ and WM zone

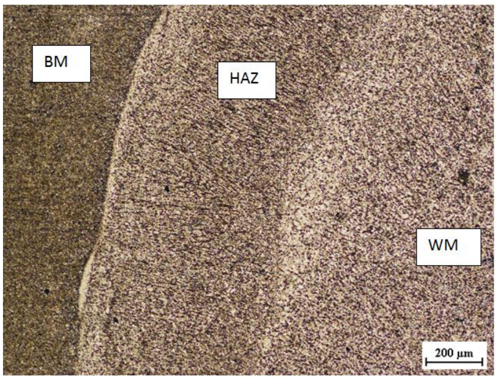


*Fig.1 M*icrostructure of BM, HAZ and WM

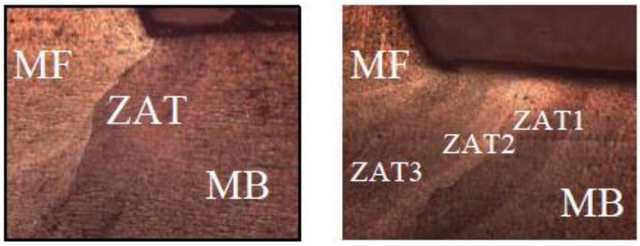
The high values of yield strength and tensile strength in all repairs are due to the existence of microalloyed elements that prevent the coarsening of austenite grain size by the formation of barriers at the grain boundary [1].

The variation of the tensile strength (Rm) and yield strength (Re) as a function of the number of repairs is resumed in table 1. We deduce that the number of repairs has no influence on tensile and yield strength for these two values, which depend on the microstructure of the weld and it does not change with the number of repairs. The repeated thermal cycles lead to the same previous transformations when the welding parameters are unchanged (Table.1).

Table.1 Results of tensile tests for different states of repair

Number of repair	yield Re (MPa)	Tensile strength Rm (MPa)	Strain at break (%)
0	539	609.58	42.85
1	590	623	42.16
2	539.32	575	38.03
3	530.33	609	27.30

The results of the toughness test for different samples, show that the energy absorbed by the base metal is higher (299.8 J), which can be attributed to the microstructure consisting of acicular ferrite produced by the received state of our material that underwent deformation during its shaping. Low values of energy absorbed is recorded in the weld metal (66.9 J), which may be related to its microstructure that contains bainite; hard phases and weld defects. This microstructure provides a low resistance to crack propagation. The heat affected zone of steel API 5L X70 shows excellent resilience and good yield strengh.



Initial weld *3rd repair*

Fig.2 Macrographies show the extent of the HAZ after each repair.

The higher the welding energy, the larger the extent of HAZ; so, repairs have a small influence on the width of the HAZ, because the measured values of the latter are closer after repair (Fig.1)

Table.2 Results of charpy test at 0°c

	Energy absorbed by the rupture KV (J)	Resilience (J/cm2)	Type of failure
MB	299.8	374.75	Ductile
MF	66.9	83.625	Semi fragile
ZAT S1	273.4	341.75	Ductile
ZAT R1	299.2	374	Ductile
ZAT R2	195.9	244.875	Ductile
ZAT R3	249.7	312.125	Ductile

4. Grain size

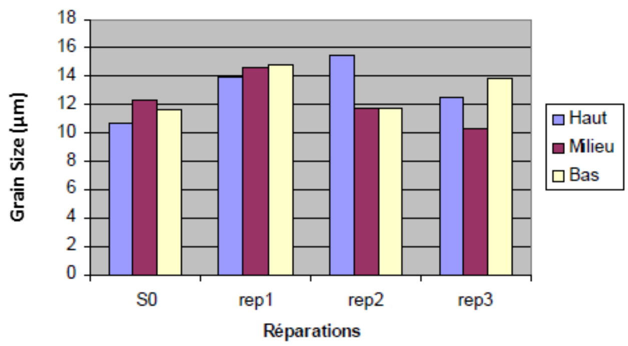


Fig3. Variation of the grain size by the number of repairs.

The number of successive repairs has a small influence on the grain size (Fig. 3). However, O.vega et al, found that the higher the number of repair the larger the grain size [2], same result found by Mc Gaughyand [3]. The factors that affect the grain size in this case are: the maximum temperature, holding time and microalloying elements. We note that the grain size in the three areas of CGHAZ (top, middle, and bottom) is small. The fine precipitation microalloyed elements prevent the coarsening of austenite grains until complete dissolution increasing with increasing temperature [1].

The temperature peak up to 1200°C allows the dissolution of the niobium precipitates.The changes recorded in the grain size after repairs are due to the variations of the maximum temperature reached between Ac3 and 1200°C.

CONCLUSION

Different mechanical and microstructural investigations lead us to conclude that:
- The number of repairs on a welded joint has small influence on the microstructure of heat affected zone (HAZ); that the repeated thermal cycles lead to the same previous transformations.
- The higher the welding energy, the larger the extent of HAZ; so, repairs have a small influence on the width of the HAZ, when the factors that affect the grain size are: the maximum temperature, holding time and microalloying elements.

- The number of repairs has no influence on the tensile and yield strength which depend on the microstructure of the weld and but it is effected by last thermal cycle that removes previous ones.

According to results, the mechanical properties agree well to API, ASME and OFFSHORE stantards, which means, the possibility of increasing the number of repair.

This study requires more investigations by further tests (tests of mechanical fatigue and thermo-mechanical).

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