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Characterization of the Hydrogen Damage in an API 5L X52 Steel by Scanning Electron Microscopy

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Nowadays, the use of carbon steel pipes is the most efficient alternative to transport gas and crude oil in large volumes and long distances. However, these steels could fail prematurely due to their exposition to aqueous phases containing CO_2 y H_2S, which create a very aggressive sour solution that remains in contact with the internal surface of steel pipes [1-3]. The failure occurs as general and localized corrosion and hydrogen induced damage (blistering and cracking).

The aim of the present investigation was to characterize, the hydrogen damage in an API 5L X52 steel, which is widely used in the oil industry, using Scanning Electron Microscopy. The employed steel had four different conditions: as-received and heat treated (normalized, annealed and water quenched), while the test solution was 0.1M Na_2SO_4 (pH =2) + 5 mM of Na_2S. Metallografic and tensile samples were cathodically charged at a constant potential (-900 mV vs SCE) in the test solution.

Microstructural characterization and a fractographic study were carried out in the as-received and heat treated samples, previous and after the exposition to the test solution. The samples in the as received, normalized and annealed conditions have the same type of microstructure, comprised mainly by ferrite grains and pearlite, as expected. They only differ in the ferrite grain size and the pearlite amount. The water quenched sample showed a martensite-type of structure. All the tested samples were susceptible to hydrogen damage after 3 hours of exposition in the above mentioned condition. The severity of the hydrogen damage was greater in the quenched and complete annealed samples, followed by the as-received condition and normalized ones. The damage was present in the form of blisters with diameters between 5 and 350 μm related to the presence of aluminum inclusions - fig. 1(a-d). The fracture mode in the samples no subjected to the hydrogen environment, was microvoid coalescence, while for the complete annealed and quenched samples after 3 hours of exposition, the fracture appearance was a mixture of faceted dimples and quasi cleavage – fig 2(a-b). Some inclusions were associated to the dimples as has been shown in the fig. 2c for a water quenched sample. According to the chemical composition reported in the EDS microanalysis, the inclusions are rich in aluminum (fig. 2d).

References

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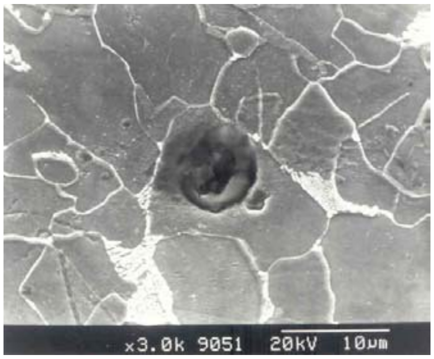
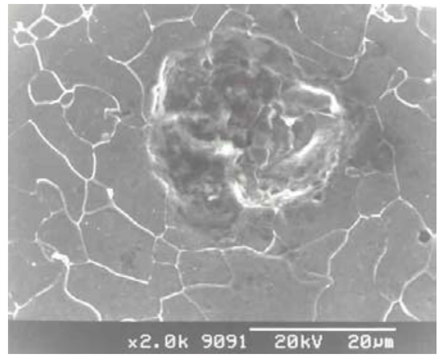
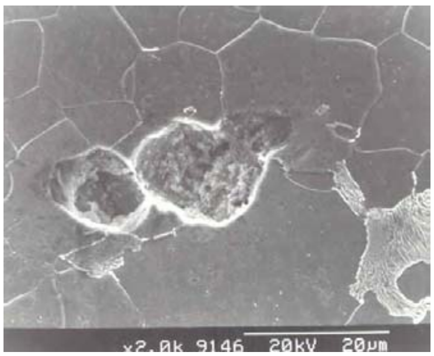


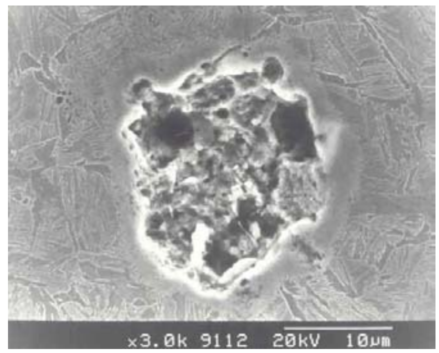
a) As received



b) Normalized



c) Annealed

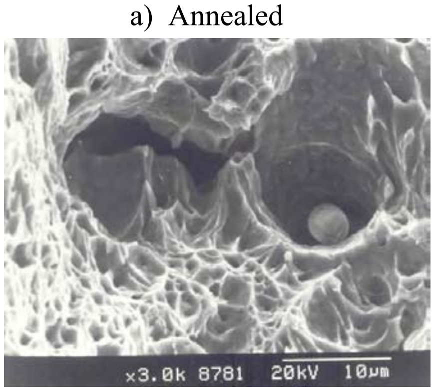


d) Water quenched

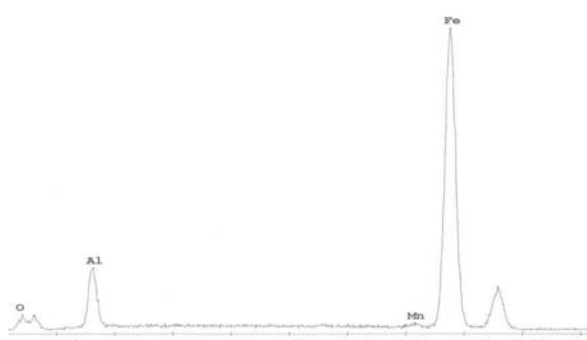
FIG. 1. SEM micrographs showing the blisters present in charged samples.

a) Annealed

b) Water quenched



c) Water quenched



d) EDX microanalysis

FIG. 2. SEM fractographs showing cracks, faceted dimples, quasi cleavage and aluminum inclusion associated to the dimple in charged samples.

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