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Evaluation of Electrochemical Hydrogen Absorption in Welded Pipe

J. Capelle[a,*], I. Dmytrakh[b], Z. Azari[a], G. Pluvinage[a]

1 LaBPS - École Nationale d'Ingénieurs de Metz, 1 route d'Ars Laquenexy, CS 65820, 57078 Metz, France
2 Karpenko Physico-Mechanical Institute of National Academy of Sciences of Ukraine,
5 Naukova Street, 79060, Lviv, Ukraine

Abstract

The assessment of ability to absorb hydrogen by welds components of API grade pipeline steel X52 has been done. The factors of cathodic hydrogen charging, time of exposure on hydrogen concentration in base metal, heat affected zone and metal of weld were taken into account. It has been shown that all components of weld demonstrate the sensitivity to hydrogenating in deoxygenated, near-neutral pH NS4 solution under relatively “soft” cathodic polarisation, although the efficiency of hydrogen permeation in metal is relatively low and depends on time of exposure. The ability to absorb hydrogen decreases in the following sequence: heat affected zone – base metal – weld. The sensitivity to hydrogenation is higher for heat affected zone in comparison with base metal and weld.

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Keywords: welded pipe, hydrogen concentration;

1. Introduction

Process of free corrosion promotes the hydrogenating of steel, because hydrogen can evaluate on metal surface as result of cathodic counterpart of the anodic dissolution reaction, Cheng and Niu (2007) and Cheng (2007) Moreover, the hydrogen charging of steel is also possible when a cathodic protection system of pipeline works irregular, Shipilov and May (2006). Engineering practice of pipelines operation shows, according to Somerday et al. (2009) that the welds of pipelines are highly sensitive to the hydrogen influences from the reasons of their microstructural heterogeneity and difference of chemical composition of weld components (base metal, heat affected zone and metal of weld). A number of recent issues dedicated to different aspects of hydrogenating and hydrogen entry into welded joints of pipeline steels can be found in literature, Olden et al. (2012), Koenig et al. (2010), and

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Briottet et al. (2012). In the work of Olden et al. (2012) the API X70 pipeline steel has been investigated with respect to hydrogen diffusion and fracture mechanics properties. Here it has been found that base metal and weld metal have marginal susceptibility to hydrogen embrittlement and the heat affected zone is clearly embrittled by hydrogen. Another aspect of considered problem is presented in the work of Koenig et al. (2010) where the non-destructive low-frequency impedance has been developed to determine hydrogen content in operating pipeline steel and weldment through a structural coating. The problems of the quantifying the hydrogen embrittlement of pipeline steels for safety considerations are pointed out in the papers of Briottet et al. (2012). Therefore, above-mentioned problem is real and the knowledge about hydrogenating ability of the weld components is required for reliable assessment of pipelines for transportation of hydrogen and natural gas mixtures. In presented paper the weldment of steel API X52 was studied, as it is the most used in existing European gas pipelines network, Capelle et al. (2008).

2. Experimental procedure

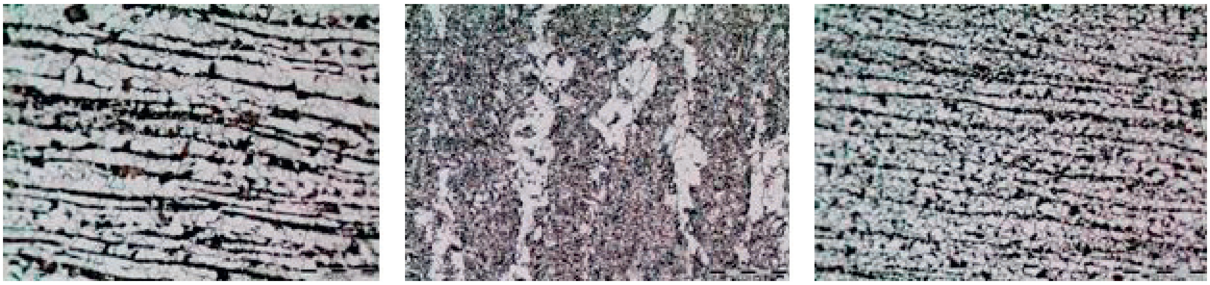
The material used for the study is API X52 that is the most usable in existed gas pipelines. The specimens were cut from a buried in-service pipeline. This pipeline with the outer diameter D=610mm and wall thickness t=11mm, was in service approximately 50 years till it was cut for testing. The chemical composition of steel and its mechanical properties in air are given in Table 1 and 2 respectively. The structural specificity of the components of welded pipe can be seen in Fig 2. The base metal consists of grains of ferrite-pearlite, typical in all carbon steels (Fig. 1a). The weld metal showed the acicular ferrite columnar grains (Fig. 1b). The HAZ is composed of refined grains of ferrite-pearlite (Fig. 1c), product of the transformation of base metal with the heat provided by the welding process.

Table 1. Chemical compositions of steel API X52 (wt %).

C	Mn	Si	Cr	Ni	Mo	S	Cu	Ti	Nb	Al
0.206	1.257	0.293	0.014	0.017	0.006	0.009	0.011	0.001	<0.03	0.034

Table 2. Mechanical properties of steels API X52 in air.

Steel grade	σ_U, MPa	σ_Y, MPa	Elongation, %
X52	528	410	30.2



a) b) c)

Fig. 1. Structural specificity of the components of welded pipe (x 200): a – base material; b – weld; c – heat affected zone.

The hydrogenation of specimens was made by electrochemical method. For this aim a special deoxygenated, near-neutral pH NS4 solution was chosen, Capelle et al. (2010). At these conditions hydrogen atoms are generated on the steel surface by the electrochemical reduction of water molecules according to known reactions, Cheng (2007). Before testing, the specimens were coated by special dielectric insulation and after the circular "windows" (d=5mm) with open surface of metal were made. This open surface of metal served as work electrode for electrochemical charging of hydrogen. The location of the "windows" with open surface of metal depends on the subject of test: base metal, weld metal or heat affected zone, Capelle et al. (2013). The electrolytic hydrogenation of specimens was made with application of the standard three-electrode electrochemical cell (open surface of metal (working electrode), auxiliary counter electrode and reference calomel electrode) where the Potentiostat VMP has been used. For modelling the hydrogen entry conditions in real operating pipelines, where there is the situation of