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HYDROGEN BEHAVIOUR IN REPAIR WELDING OF THE MAIN PIPELINES UNDER PRESSURE

V.I. MAKHNENKO, O.I. OLEJNIK and A.P. PALTSEVICH

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Possibility of diffusion hydrogen penetration from hydrocarbon gas transported through the gas pipeline during repair welding performance on an operating pipeline has been analyzed. It is shown that at partial pressure of diffusion hydrogen on the inner surface of steel pipe in the range of 0.10–0.75 MPa at residual wall thickness in the defect zone of more than 5 mm increase of the parameter of hydrogen (cold) cracking risk is not higher than 5–11 %. Values of experimental measurements of diffusion hydrogen flow through the pipe wall in operating pipelines are given.

Keywords: repair arc welding, operating gas pipelines, diffusion hydrogen, gas pipeline wall, hydrogen cracks, risk of formation

A typical problem in repair welding of the main gas pipelines in stringent modes (low heat input) is the risk of appearance of cold (hydrogen) cracks, the formation of which is essentially affected by diffusion hydrogen in the welded joint metal. Application of consumables with a low hydrogen content in combination with reliable protection of the weld pool from the environment allows an essential lowering of the content of diffusion hydrogen in the HAZ. However, there still remains one more source of diffusion hydrogen — natural gas transported through the pipeline, which contains hydrogen in the form of chemical compounds (methane, propane, ethane, butane), or in the molecular form H_2 which does not diffuse into the pipeline wall metal. However, depending on pressure and temperature, natural gas can be in the two-phase state, i.e. the liquid phase also exists alongside

the gas phase. Figure 1 gives the two-phase state diagram of natural gas, from which it follows that at working pressures of about 7.5 MPa and temperatures of 40–50 °C the liquid phase is equal to approximately 20 % of the mixture volume. In the liquid phase free hydrogen can dissolve in the atomic form. Considering the high degree of gas turbulization in the main gas pipeline, higher density of the liquid phase and lower temperature in the pipe section at its walls, it can be assumed that the liquid phase concentrates at the pipe walls and from the liquid phase the dissolved atomic hydrogen diffuses into the pipe wall metal, respectively. Under the stationary conditions of natural gas transportation, hydrogen flow J through the wall can be presented in the following form [1]:

$$J = -D \frac{\partial C}{\partial r} \text{ (ml/(cm}^2\cdot\text{s))}, \quad (1)$$

where D is the average coefficient of hydrogen diffusion through the pipe wall metal; $C(r)$ is the concentration of diffusion hydrogen across the pipe wall thickness (coordinate r).

At the stationary flow and small wall thicknesses

$$J \approx \frac{C(R_{\text{out}}) - C(R_{\text{in}})}{\delta} D, \quad (2)$$

where $C(R_{\text{out}})$ is the hydrogen concentration on the outer surface $r = R_{\text{out}}$; $C(R_{\text{in}})$ is the same on the pipe inner surface $r = R_{\text{in}}$.

Assuming that $C(R_{\text{out}}) \approx 0$, and $C(R_{\text{in}}) \approx \sqrt{P_{H_2}} K(T)$ according to Sievert's law, where P_{H_2} is the partial pressure of hydrogen on the surface $r = R_{\text{in}}$, ata; $K(T)$ is the diffusivity of hydrogen in the pipe wall metal at temperature T (Figure 2), $\text{cm}^3/(100 \text{ g}\cdot\text{ata}^{1/2})$, we obtain

$$C(R_{\text{in}}) = J \frac{\delta}{D(T)} \text{ (ml/100 g)} \quad (3)$$

or in the most often used dimension

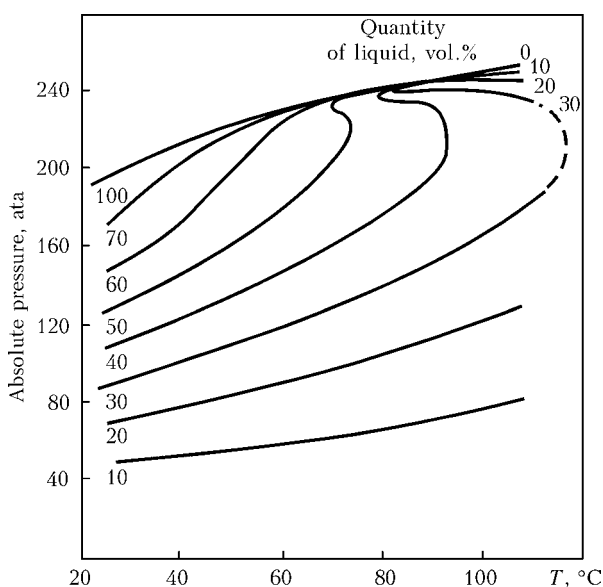


Figure 1. Phase diagram characteristic for natural hydrocarbon mixture