HYDROGEN DISTRIBUTION IN FLASH-BUTT WELDED JOINTS ON STEEL 10G2FB

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Peculiarities of hydrogen distribution in flash-butt welding of steel 10G2FB were studied. It was found that the nature of hydrogen distribution in contact zone is defined by the upsetting value.

Keywords: *flash-butt welding, low-alloy steel, upsetting value, friction welding, hydrogen, abnormal mass transfer, deformation*

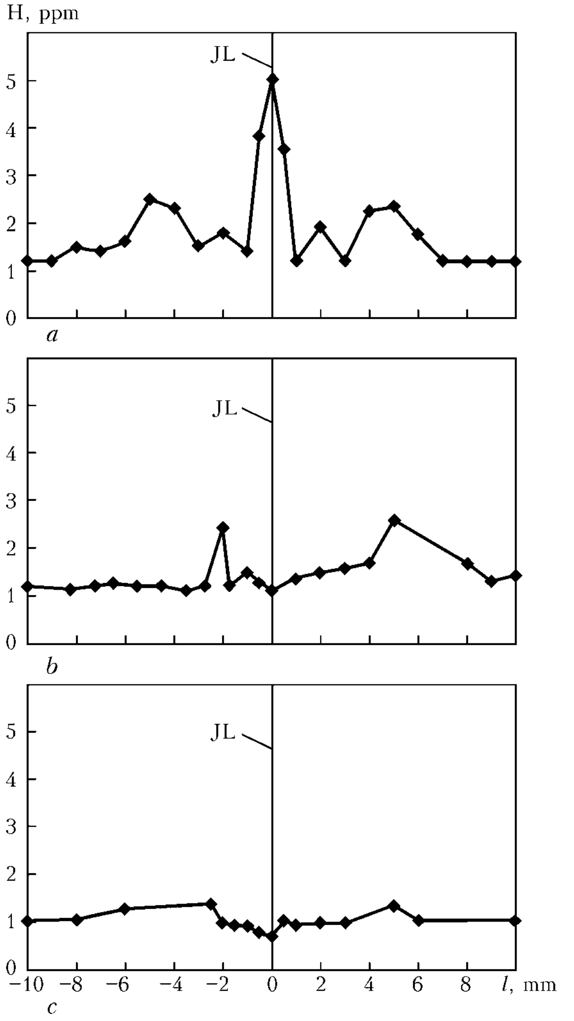
Distribution of gas-forming interstitial impurities (hydrogen, oxygen and carbon) in joints made by different pressure welding methods was shown earlier in studies [1–4]. Evaluation of the hydrogen content in joints on steel 10G2FB [1] and nickel alloy EI-698VD [2], made by friction welding (FW), was carried out by employing the local mass spectrum analysis techniques and equipment using the laser beam. It was shown that a 2 time reduction of hydrogen is observed in a 4 mm wide area in the joining zone in conventional FW of steel 10G2FB [1]. General reduction of the hydrogen content takes place in an area around 8 mm wide, which corresponds to the width of the plastic deformation zone. It was found that inertia FW provides approximately a 6 time reduction of the hydrogen content across the joining line (JL), in comparison with that in the base metal. The temperature of metal and rate of its plastic deformation have an influence on the character of distribution and local content of hydrogen in the joining zone.

In addition, as determined in studies [1, 2], not only the content of hydrogen, but also the content of carbon in a joint reduces during FW. The same picture is observed in carbon distribution in flash-butt welding (FBW) of steel 10G2FB [4]. However, there are no publications considering peculiarities of hydrogen distribution in zones of the FBW joints on low-alloy steel, in particular 10G2FB. A gas environment containing fumes of metal and alloying elements of steels forms in a spark gap in FBW, in contrast to FW. Hydrogen in the atomic form can be present in the gas environment of the spark gap, reacting with its other components. In FW, there is almost no gaseous environment of a similar content in the contact zone. Comparative investigations of hydrogen distribution in the joints on the same steels, made by different pressure welding methods under optimal conditions, allow obtaining information on the dominating factors affecting the hydrogen distribution in the joints produced by pressure welding.

The aim of this paper consisted in studying the distribution of hydrogen in the FBW joints. Investigations were carried out on samples of pipe steel 10G2FB with the δ = 8 mm thickness. The samples were cut out from the 200 mm wide plate and welded under the conditions recommended for this grade of steel [5]. The hydrogen content in the base metal was 1.2 ppm on the average. The rate of deformation of the HAZ metal of the joints was varied during the welding process by changing the upsetting value in a range of (0.1–2.0)δ.

The character of hydrogen distribution in a joint on plates welded was investigated by the method of local mass spectrum analysis using the laser beam according to the procedure described in studies [1, 2]. It should be explained what the «joining line» term means for the authors of the present study. For them it is a reference point in assessment of the hydrogen content on both sides of this line. The so-called light band 0.4–1.2 mm wide, the content of carbon in which is up to 50 % of its content in the base metal [4], can be visually observed within the joining zone on microsections of the FBW steel joints. The ferritic band with JL situated in its middle [6] is revealed at the central part of the microsections after corresponding heat treatments and etching.

The Figure shows the hydrogen distribution at different upsetting values. The hydrogen content in JL exceeds that in the base metal 4–5 times at a small upsetting value comparable with the spark gap of 0.1δ. As the upsetting value and, accordingly, the deformation degree in all the areas of the heated HAZ metal are increased, the hydrogen content along JL decreases down to the level of that in the base metal. At the same time, increase in the hydrogen concentration is observed at a distance of 3–6 mm to both sides of the welding line. The near-contact volumes having the increased hydrogen content go to the flash with increase in the upsetting value to more than 0.8δ. The metal region along JL becomes depleted in hydrogen. For example, in the welded joint made at an upsetting of 1.2δ, the most noticeable reduction of the hydrogen content is observed on both sides of JL



Hydrogen distribution in the zone of FBW joints on steel 10G2FB at upsetting of 0.1δ (*a*), 0.3δ (*b*) and 1.2δ (*c*)

in a region with a total width of around 8 mm. The hydrogen content across JL reduces approximately 2 times in comparison with that in the base metal. The peak values at a level of the hydrogen content in the base metal are observed at a distance of up to 6 mm from JL. Non-uniformity of the distribution of hydrogen on both sides of JL is observed in FBW. Experimental results indicate that hydrogen escapes most intensively from the area situated on the side of action of compressive force. It should be noted by comparing the distribution of hydrogen in the HAZ metal, shown in the diagram, with that FW of the same steel that they are identical in many respects. Reduction of the hydrogen content across JL, as well as increase in it on its both sides is observed in both cases.

It can be supposed that transfer of hydrogen from the joint occurs by the following mechanism. Hydrogen transfers most intensively from the center to flash in the process of deformation of the melt. This process is accompanied by a simultaneous displacement of hydrogen in a direction normal to the contact plane, i.e. into the near-contact metal volumes. The character of the distribution of hydrogen in a volume interaction area can be explained by appearance of the effect of abnormal mass transfer [7] and formation of the compression and tension zones in FBW, which are situated in sequence one after another and in parallel to JL. The main compression region is situated across the JL. Therefore, hydrogen transfers from the compression zone to the tension one adjoining this material. The obtained experimental data are in full agreement with the Gorsky effect [8] on transfer of interstitial impurities into the tension zones in plastic deformation of metal. Along with the regularities of hydrogen distribution common for FW and FBW, there are also differences that are non-specific for FBW. In steel joints welded under the optimal conditions of FBW the hydrogen content reduces 1.5–1.7 times, and in FW it reduces 4–5 times, compared with the base metal.

Therefore, in the FBW joints on steel 10G2FB the hydrogen content in the joining zone depends on the upsetting value. As it increases, the hydrogen content in the joint decreases, but to a lesser degree than in FW.

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