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Crack Resistance Tests of Samples from Polyethylene Pipes

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Abstract. The article presents the test results of samples of welded joints of polyethylene pipes for crack resistance at various temperatures. It is shown that in the weld zone a decrease in the stress intensity factor to 27% is observed in comparison with the main material.

1. Introduction

The use of products from polymer materials is very promising for regions with a cold climate [1-2]. Currently, polymer pipes are widely used in gas and water supply systems. However, the problem of crack resistance of polymers becomes more acute at low temperatures. Studies show that crack stops due to the brittle fracture resistance that the material possesses. Thus, it is important to learn how to evaluate various materials for their ability to arrest cracks [3]. The fracture toughness of polymer materials is investigated in many works [4-6].

The most critical element of the pipeline is the welded joint. According to the experience in using thermoplastics pipes, about 54% of accidents occur at the joint failure [7]. A more detailed study of the physical-mechanical properties of welded joints of polymer materials will improve their strength and make some adjustments to the welding process. Earlier tests were conducted on the crack resistance of samples of polypropylene pipes used in water supply [8].

The present work is aimed to study the crack resistance of the butt-weld joints of polyethylene pipes in various weld areas.

Fracture mechanics methods, in contrast to standard cracking test methods, allow evaluating the resistance to crack growth. These methods make it possible to determine the dependence of the crack propagation velocity on the loading parameters, which also sets the threshold for initiating the development of a stable crack. A characteristic parameter here is the critical value of the stress intensity factor corresponding to failure under conditions of plane deformation — K_{Ic} [9].

2. Research objects and methods

In this work, PE100 SDR 11 pipes with a diameter of 110 mm and a wall thickness of 10 mm, designed for gas pipelines, were tested. The experiments were performed according to the method described in [10]; the value K_{Ic} was taken as the test result.

Compact rectangular samples with dimensions of 35 × 35 mm with an edge crack were manufactured from the welded joints for eccentric tensile testing (type 3 according to GOST 25.506). Figure 1 demonstrates the scheme of the sample. Incisions 17.5 mm deep were applied with a hacksaw blade and sharpened with a razor.

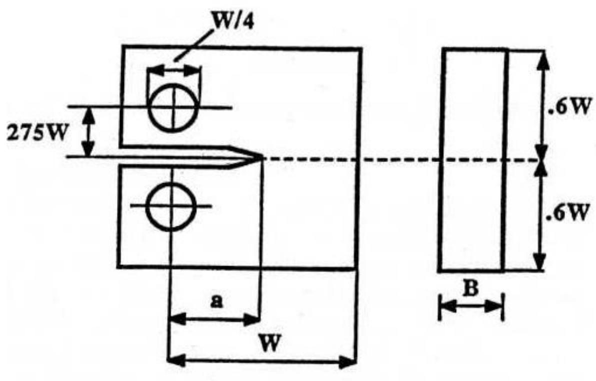

Figure 1. Scheme of the test sample.

As is known, the researchers divide the area of a butt-weld joint of polymer pipes into several areas depending on the structure of the polymer formed as a result of thermal deformation during welding [11, 12]. Thus, 5 main zones are distinguished in [11]: weld junction, spherulitic zone, zone near the weld line, heat-affected zone, and weld ridge. In this work, the area of the butt-joint was divided into 5 zones of the welded joint: weld junction, weld-adjacent zone, a zone under the weld ridge, heat-affected zone, and base material (Fig. 2).

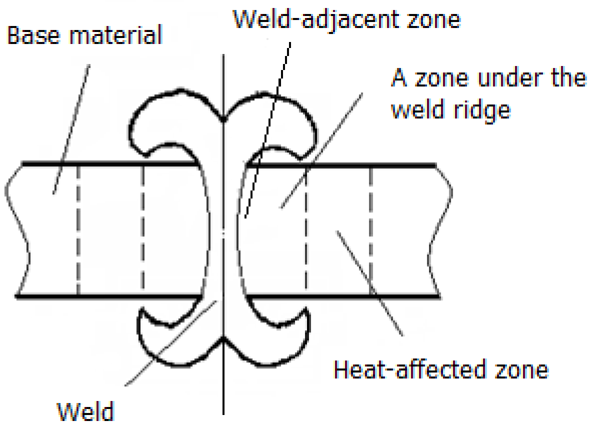

Figure 2. Separation scheme of the zones of butt-weld joint.

3. Discussion of research results

Crack resistance tests were performed at different temperatures to detect a negative temperature, at which the results would be most reliable.

Weld junction is the most critical area of the welded joint. Its microstructure primarily determines the quality of the welded joint. Weld-adjacent zone is located near the weld line, i.e. between the solid polymer and the melt. The material has a spherulite structure characteristic of the main material in the zone under the weld ridge. Here, the average size of spherulites is usually smaller than in the main material. As for the heat-affected zone, it is the area of the main material adjacent to the zone under the weld ridge. At room temperature of 23 ± 3°C, the area at a distance of ± 5 mm from the middle of the weld of a pipe with a diameter of 63 mm is subjected to heating above 80 °C. Area, where the physical-mechanical properties of PE begin to change, serves as a distinction between the heat-affected zone and the main pipe material.

Figure 3 presents the stress intensity factors obtained during the tests of welded joint samples in zones at a testing temperature of -15 °C.

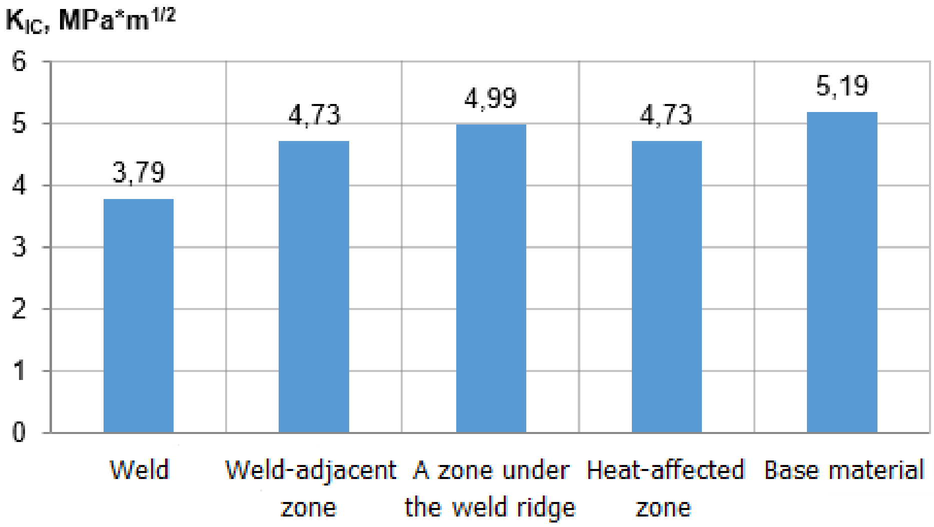

Figure 3. Stress intensity factor of the welded joint samples by zones.

4. Conclusion
Test results have revealed an increase in crack resistance of the base material. A decrease in the value of the stress intensity factor is observed in the weld zone. A slight change in the welding parameters, such as the temperature of the heated tool, heating time, and pressure during heating and upsetting, depending on the ambient temperature, will be promising for improving the strength properties precisely in this zone.

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