Evaluation of efficiency of rotary friction welding in obtaining joints from corrosion and heat resistant steel

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Abstract. The efficiency of using rotary friction welding in obtaining joints from 20Cr13 steel has been evaluated. For this purpose, test samples with welded joint and from the base metal were made, and then microstructure studies and tensile tests were carried out. As part of the microstructure study, the structure of the welded joint metal and base metal was determined. As a result of tensile tests, the tensile strength, relative elongation after rupture, and fracture area were determined for the base metal and welded joint specimens. These tests have shown that friction welding can produce joints without the use of heating during welding.

1 Introduction

Heat exchangers are widely used at enterprises of various industries, including mining, oil and gas, energy and many others, reaching in some cases half of the total amount of equipment used at the enterprise [1].

The resource and reliability of this equipment, thus, has a significant impact on production as a whole. In the case of shell-and-tube heat exchangers, these parameters largely depend on one of the most complex and most frequently encountered nodes, namely the tube-to-tube sheet joint, of which there can be up to several thousand in one unit [2-4].

Many processes take place at elevated pressures and temperatures. For operation in these conditions heat-exchange equipment is often made of heat-resistant stainless steels, such as steel 20Cr13 and analogs (version B1 according to Russian National Standard 55601-2013 "Heat-exchange apparatus and air-cooling apparatus. Fastening of tubes in tube sheets"). Steel 20Cr13 is used as a heat-resistant material at temperatures up to 550 degrees Celsius and as heat-resistant up to 700 degrees Celsius, respectively. This steel is also resistant to corrosion during operation in oxidizing environments [5].

For such working conditions, tube to tube sheet joints are rolled and welded, i.e. made by welding and reaming operations [6].

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20Cr13 steel is a limited weldable steel [7]. To prevent the formation of cold cracks, it is necessary to use the accompanying or preheating to a temperature of 400 degrees Celsius inclusive. After welding operations, high tempering is carried out, most often it is done at a temperature of about 700 degrees Celsius. Heat treatment operations are not only difficult to realize, but also energy consuming, which affects a significant increase in the costs of heat exchange equipment manufacturing enterprises.

There are studies [8-10] showing the effectiveness of friction welding for obtaining rolled and welded tube to tube sheet joints. Application of this technology makes it possible to obtain welded joints with the required operational properties without the need for heat treatment operations. However, the study of the effectiveness of the application of this technology in relation to heat-resistant corrosion-resistant steels such as 20Cr13 has not been carried out so far.

2 Purpose and objectives

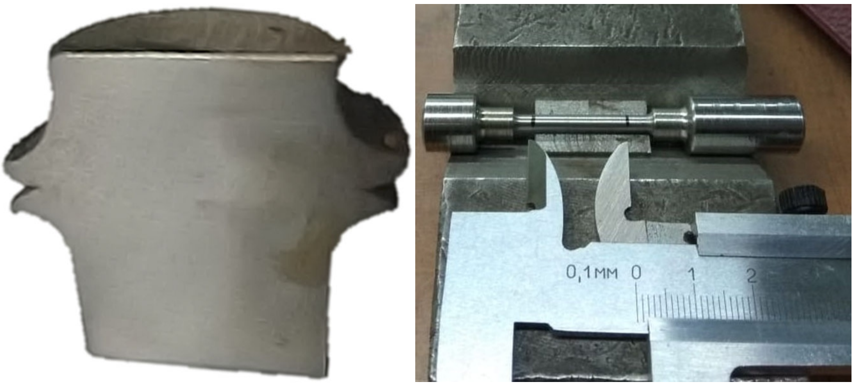
The purpose of the study is to assess the effectiveness of rotary friction welding in obtaining joints from 20Cr13 steel.

To achieve this goal the following tasks were solved:

1. Joining cylindrical samples of 20Cr13 steel by friction welding, making test samples from them for research.
2. Study of microstructure of welded joints of test samples.
3. Tensile testing of test samples.

3 Methods of research

For research were made cylindrical samples with a diameter of 20 mm from steel 20Cr13 in an amount of 11 pieces: 6 welded samples obtained by rotary friction welding without heat treatment, and 5 samples from the base metal. Further, test samples of appropriate shape and size were cut from these samples depending on the research being conducted (Figure 1).



a b

Fig. 1. Test samples for research (a - sample for microstructure study; b - sample for tensile tests).

Friction welding was carried out on a friction welding machine KUKA RS 12 on the mode presented in Table 1.

Table 1. Mode of friction welding of cylindrical samples.

Heating pressure, MPa	**Heating pressure, MPa**	**Heating pressure, MPa**	**Heating pressure, MPa**	**Heating pressure, MPa**
100	200	5	1,5	3000

The study of microstructure was carried out in accordance with paragraph 7 of Russian National Standard 57180-2016 "Welded joints. Methods of determination of mechanical properties, macrostructure and microstructure".

Tensile tests were performed at room temperature on Type II specimens (Russian National Standard 1497-84 "Metals. Tensile test methods"). The speed of movement of the traverse of the tensile tester was 5 mm/min. Five specimens each of base metal and welded joint samples were tested.

4 Results and discussion

The sample obtained by friction welding for microstructure study is free of flaws, inclusions, cracks and other defects (Figure 1, a).

Figure 2 shows the microstructure of the weld metal. This metal has a two-phase pearlite-ferrite structure, which is characteristic of unannealed metal.

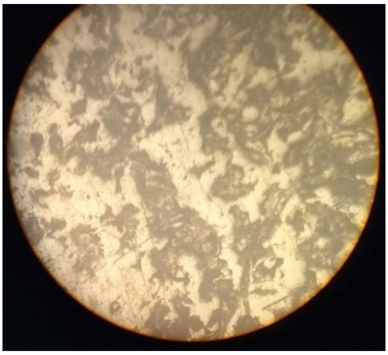


Fig. 2. Microstructure of the weld metal.

Figure 3 shows the microstructure of the base metal, which is a granular pearlite, characteristic of annealed metal in the delivery state.

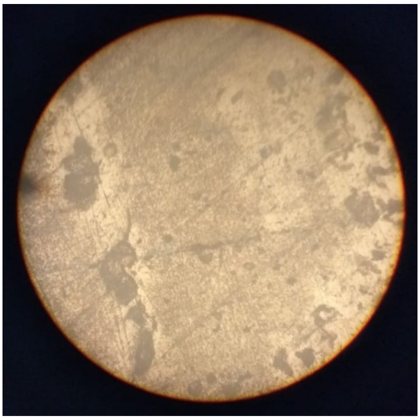


Fig. 3. Microstructure of the base metal.

As a result of tensile tests, all welded samples failed along the base metal (Figure 4).

Fig. 4. Welded samples after fracture.

The average values of tensile strength and relative elongation after rupture for the base metal and welded samples are shown in Figure 5.

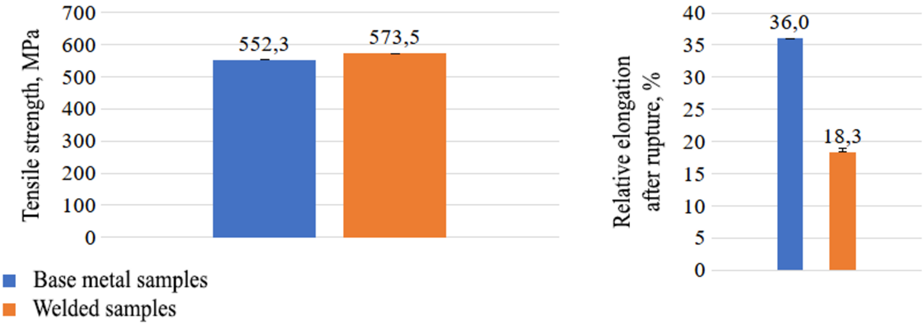


Fig. 5. Tensile test results of test samples.

These tests showed that the welded joints in the samples obtained by friction welding have higher strength than the base metal. However, the relative elongation after fracture of the welded samples is almost 2 times lower than that of the base metal samples.

5 Conclusion

The study of macrostructure of welded samples showed the absence of defects, such as flaws, inclusions, cracks and others.

The study of weld microstructure showed that thermomechanical influence during friction welding leads to the formation of two-phase pearlite-ferrite structure. This structure is characteristic of unannealed metal and as a rule has higher strength and hardness.

Tensile tests have shown that the friction welded seam has higher strength than the base metal. The tensile strength of the welded samples was 3.8% higher than that of the base metal samples. At the same time, the relative elongation after rupture of welded samples was almost 2 times less than the base metal samples. This indicates a lower plasticity of the welded joint zone compared to the base metal.

Thus, the conducted studies have shown that friction welding allows to obtain high-quality joints from steel 20Cr13 without the use of heat treatment operations. However, the low plasticity of the obtained joints may be a factor that in some conditions will require the application of heat treatment. In the future it is planned to investigate other mechanical properties for more specific conclusions.

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