UDC 621.7.044

TECHNOLOGICAL DEVELOPMENT OF FURNACE COIL PIPES REPAIRING MADE OF STEEL 15Cr5Mo WITH APPLICATION OF VIBRATING PROCESSING DURING WELDING

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Abstract. *This work is devoted to technological development of furnace coil pipe repairing. Technological process of furnace coil pipe repairing made of steel 15Cr5Mo with application of vibrating processing during welding is developed. It based on results of complex, theoretical and experimental researches. Researches of mechanical properties of received welding joints are carried out.*

Keywords: *heat treatment, martensite steel, welding construction, cold cracks, vibro-mechanical treatment, mechanical properties, microstructure, welding seam*

Nowadays working conditions of oil refining equipment become complicated and the nomenclature of applied materials extends as the result of growing requirements to quality of production and safety of processes and also taking into account variety of technological processes and their intensification. A considerable part of the equipment especially used for realization of high-temperature processes of oil refining in hydrosulphuric and oxidizing sulphurous environments is made of creep-resistant chromium molybdenum steel 15Cr5Mo. Chromium molybdenum steel 15Cr5Mo is commonly used for coil pipes of furnaces that are the most heat stressed and that are the responsible designs working in very severe conditions. It is affected to corrosion and erosion wear on the internal and external surface of coil pipes. In an industrial practice the cases of a deviation from a technological mode of furnace operation happen quite often. It results to a considerable overheat of the coil pipes that inevitably causes emergency stops because of change of a structural condition, mechanical properties of the coil pipes made of a steel 15Cr5Mo, and its destruction.

This steel compares favorably with austenitic stainless steel. It's cheaper, has better cutting characteristics (highly machineable), better deformability in hot condition, a higher thermal conductivity and a lower thermal expansion, also it has higher relaxation ability and changeable mechanical properties in a wide range produced by a heat-treatment process [1].

The welding process of martensitic steel is complex because of its brittleness when it becomes tempered. If martensitic steel contains more than 0.1% carbon it becomes prone to formation of cold cracks during welding because of high degree of orthorhombic lattice of martensite. In welding joints made of martensitic steel cracks can appear during continuous cooling at a temperature below the temperature of martensite transformations beginning Mn (for high-chromium steel not more than

360 °C), and also during retention interval at normal temperature (slow destruction). Points Mn and Mk go down with increase of carbon content (end temperature of martensite transformation usually 240 °C) that results to the increase of hardness and brittleness of martensite. Considering the above and to give high ductility and impact strength to the welding joint, the carbon content is limited to 0.20 % in martensitic steel. To prevent the formation of cold cracks during welding of martensitic steel preliminary and accompanying heating to 200... 450 °C is used. The temperature of heating is as high as high the ability of steel to tempering.

At the same time the heating temperature should not be excessively high because it can result to tempering brittleness because the speed of cooling of metal in heat-affected zone slows down in the temperature interval of carbide forming. Additionally the high heating, as well as high energy welding results to a long overheat heat-affected zone metal which causes grain growth, accumulation of impurities on grain borders and, as consequence, decrease in ductility and impact strength of welding joints.

From a position of technological and operational strength the weakest part of such designs are zones of the high hardness various by origin.

Feature of the repair-welding works that are carried out on the equipment, made of steel 15Cr5Mo, is the need of preliminary and accompanying heating of welding joints that is done to decrease the probability of cold cracks formation and to increase the technological strength of welding joint. But this operation considerably reduces productivity of works, increases power and labor cost and it is not always possible in assembly conditions.

In the production it is very important to carry out repair works quickly and qualitatively in accordance to standards and quite often it results to replacement of sections of coils that leads to great material costs.

Thus, it is necessary to work out scientifically based saving technologies of repair, that are aimed at increasing of technological strength of welding joints, at an exception of labor-consuming heating operation and at increase of working efficiency.

Quite huge amount of works on the problems have recently appeared. It is offered to apply energy of the ultrasonic and vibrating oscillations, accompanying cooling, energy of explosion, laser irradiation and other methods to decrease the propensity to formation of cold cracks.

Considering specificity of the industry, in our opinion, vibrating processing of welding joint during welding is most applicable, it results to reduction of level of residual stress, to improvement of mechanical properties of the welded seam and working efficiency, while it excludes the heating operation.

Research of vibrating processing effects on properties of metal of welding joint has been performed to work out the technology of repair with application of vibrating processing to the parts of welding joint during welding.

Natural samples (parts of coil pipes) made of creep-resistant martensitic steel 15Cr5Mo have been researched using the various kinds of processing that is specified in Table 1.

Table 1. Types of experimental samples

Type of the sample	Kind of accompanying processing during welding
1	Welding with preliminary heating up to 300 … 350 ºC
2	Vibrating processing at frequency 90-100 Hz, amplitude up to 0,2 mm
3	Vibrating processing at frequency 130-140 Hz, amplitude up to 0,2 mm
4	Vibrating processing at frequency 160-165 Hz, amplitude up to 0,2 mm

Arc welding was done on the following modes: force of welding current: 95-115 A and voltage: 25 V, on a direct current of reverse polarity. The power supplier was rectifier VDU-506. The type of applied electrodes was CL-17 with diameter 3-4 mm.

Vibrating processing was made with application of the compressor and ВШ-10 brand pneumatic vibrating device that is able to create vibration of various frequencies, depending on pressure of supplied air. The measurement of vibrating oscillations parameters was carried out by CSI 1900 brand vibration analyzer.

The tests were carried out on parts of coil pipes of diameter 219 mm, thickness 10 mm that was cut out from a coil pipe of furnace and were working for more than 10 years. The cracks were simulated on the samples according to existing technology of repair of cracks.

The photo of part of pipe with crack model is shown in Fig. 1.

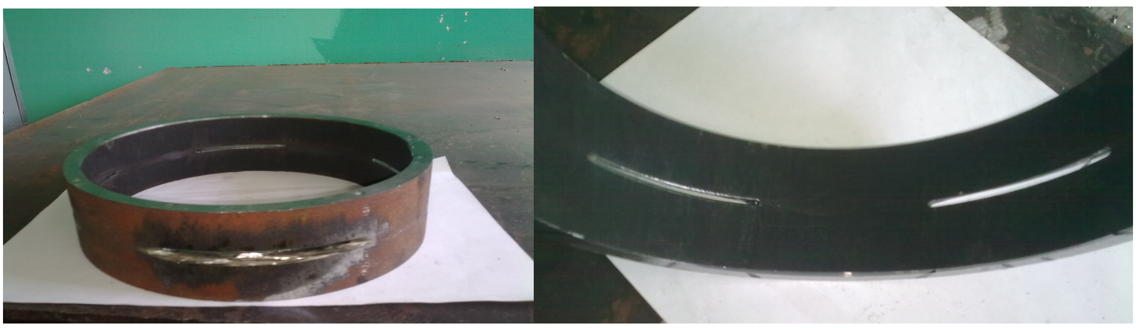


Fig. 1. Photos of samples

Further cracks were welded with application of various ways of the processing specified in Table 1. The following was carried out after the welding: visual control and color detection of welded seams, and also research of impact strength of metal welded seam according to GOST 6996, measurements of hardness and micrographic research of metal of welding joint.

Impact strength of metal was defined for the seam and heat-affected zone. To define the impact strength in heat-affected zone an U-shaped cut was made on the border of the base metal and seam metal (the distance from the middle of welded seam t = 4 mm was accepted same for all samples). The temperature of tests was equal to 20 °C, width of samples – 8 mm, height of working area – 6mm.

Results of tests of the impact strength of the samples received at various kinds of accompanying processing during welding are shown in Fig. 2.

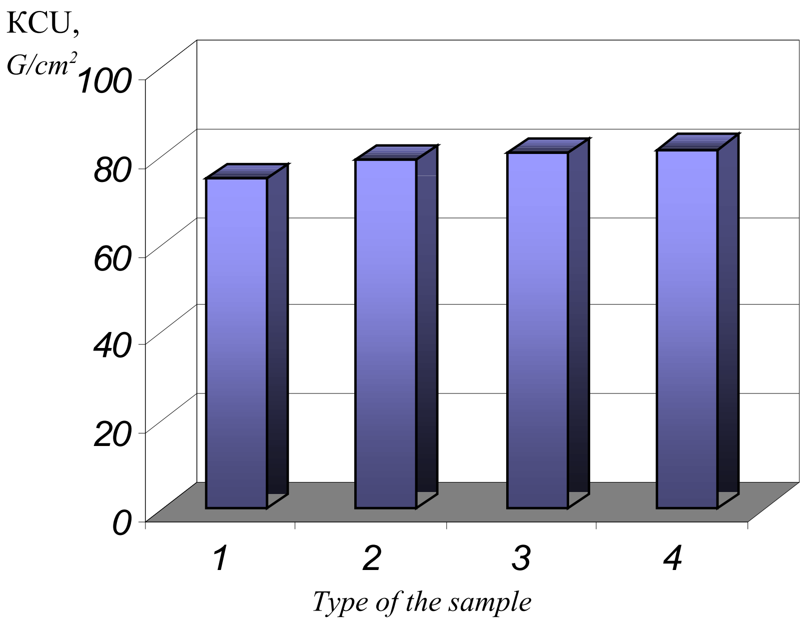


Fig. 2. The histogram of impact strength value of metal in welded seam

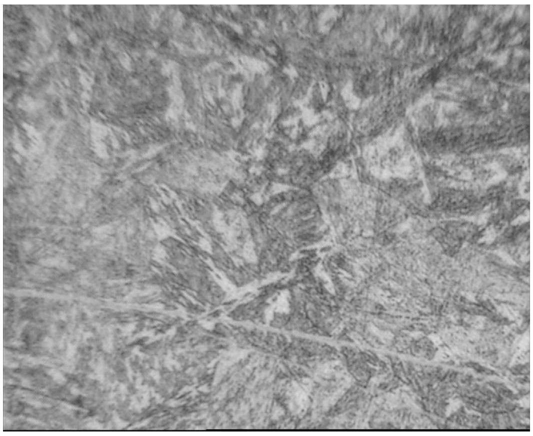
As can be seen from the results of the tests, the impact strength of the samples welded with application of vibrating processing has a greater value, than at welding with preliminary heating. Impact strength of metal of the welded seam received with vibrating processing has increased by an average of 8 %.

The hardness of metal of welding joint was determined by the portable ultrasonic hardness testing instrument MET-У. Results of researches show that the hardness of metal in welded seam almost unchanged with increasing frequency of oscillations, and decreased by 15-18 % in a heat-affected zone that indirectly shows the decrease of residual stress level in welded seam.

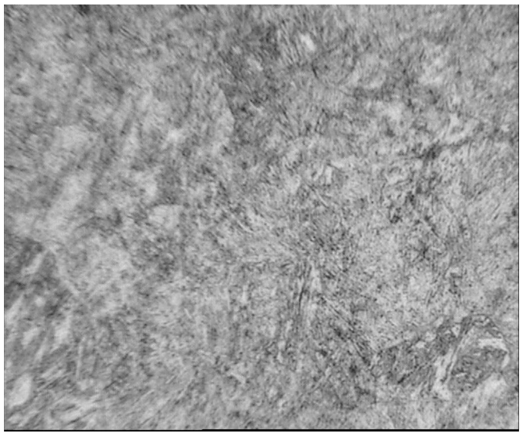
Metal-graphic research of samples was carried out to study the change of structure of metal in a welded seam and heat-affected zone depending on a kind of processing during welding.

The samples were subjected to etching in a saturated alcoholic solution of nitric acid. The optical microscope of METAM PB-22 with optical zoom ×300 was used for microstructure research. The photos received on the microscope were processed in a program SIAMS 600 on a PC.

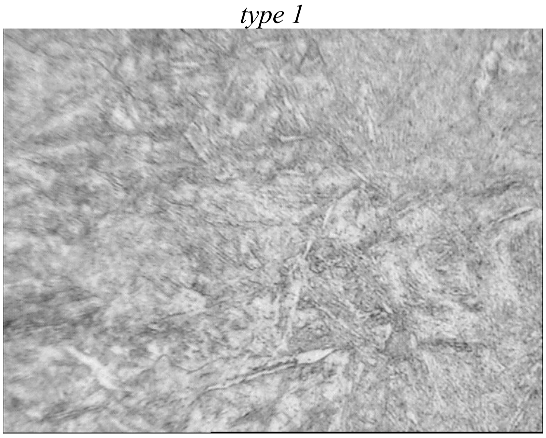
Photos of microstructure of the welded seam metal in a cross-section for various types of samples are shown in Fig. 3.



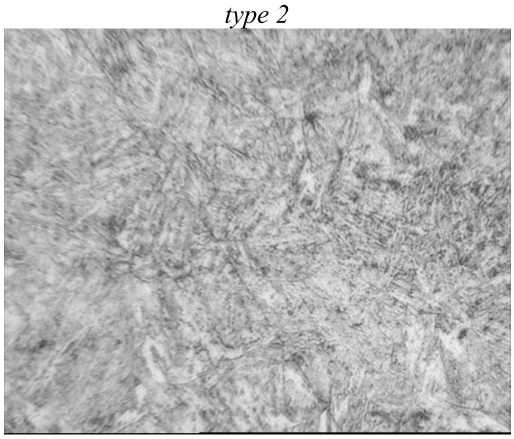
type 1



type 2



type 3

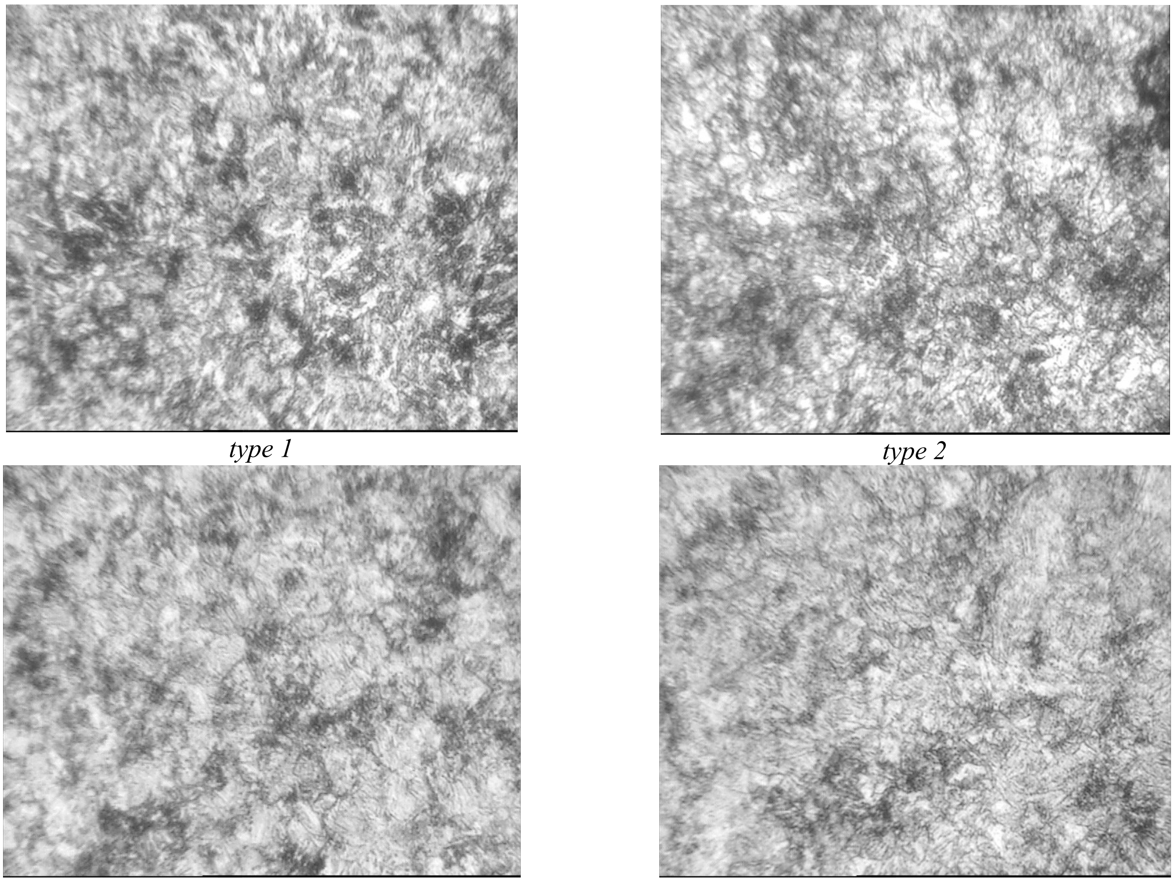


type 4

Fig. 3. Photos of a microstructure of the welded seam metal for various types of samples

As can be seen from the microstructure of the welded seam in Fig. 4 the vibrating processing decreases the heterogeneity of the structure and in this connection causes possible decrease in level of residual stress.

Photos of a microstructure of metal in heat-affected zone for various types of samples are resulted in Fig. 4.



type 1 *type 2*

type 3 *type 4*

Fig. 4. Photos of a microstructure of metal in heat-affected zone
for various types of samples

As can be seen from the microstructure of metal in heat-affected zone in Fig. 5 micro defects are not formed on the above methods of welding.

Results of the microstructure analysis of the base metal that was in high temperature and vibrating load zone show that the structure of the base metal has a similar structure at various modes of processing.

The received results of the microstructure analysis were processed in a program SIAMS 600 on a PC that defined the average size of grains. The measurements are resulted in Fig. 5.

As can be seen from the microstructure in Fig. 6 the average size of grains that were received with preliminary heating is bigger than with vibrating processing.

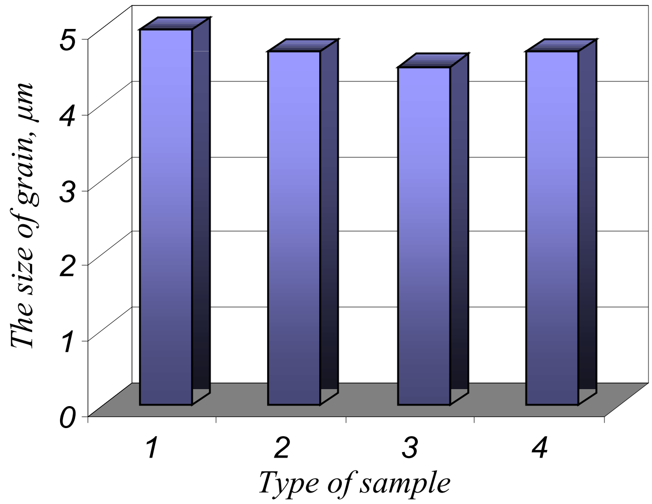


Fig. 5. The histogram of average grain size of metal in welded seam

Conclusions

1. The researches show that replacement of power-cost preliminary heating by accompanying vibrating processing does not reduce technological strength of metal of a welded seam.

2. The results of carried out tests of mechanical properties show the positive influence of accompanying vibrating processing that leads to lower hardness and the size of grain, and also to increase in impact strength of metal of a welding joint.

References

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