Effect of Surface Ultrasonic Shock Treatment on Micristructure and Fatigue Resistance of High-Strength Steel Weldments

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Abstract – The high efficiency of ultrasonic shock treatment (UST) to reinforce the surface of weldments of structural high-strength steel is shown. UST leads to microstructure refinement at subsurface layer at ~ 0.2 mm. It is discovered that the surface hardening causes increase of the fatigue strength of weldments in more than 1.5 times.

The ultrasonic shock surface treatment of weldments is an effective and highly productive method to increase the fatigue fracture resistance of constructions. The strengthening effect of such a treatment was attained due to shock interaction of vibrated chock-needles at ultrasonic frequency and the material is deformed in weld zone [1, 3–4]. Residual compressed stresses, deformation hardening of subsurface layer, and decrease of stress gradient in the weld are a result of surface plastic deformation. It defines an efficiency of the UST regarding to increase of the fatigue life of weldments [5].

In the paper the influence of ultrasonic shock treatment on the fatigue strength of the weldments of high-strength steel is studied. The influence of UST on the microstructure and mechanical properties for the weldments of these structural steel is investigated. Strength tests were carried out by means of the Schenk Sinus 100.40 machine.

The microstructure of the base metal and weld of high-strength steel consist of high-disperse martensite plates less than 1 μm (Fig. 1). This martensite has tetragonal lattice with the following parameters: $a = 0.28762$ nm, $b = 0.28942$ nm, and $c = 0.29636$ nm.

The depth microhardness measurements shown that the strength is rapidly decreased in the weld and HAZ. The areas of microstructure investigation are shown in Fig. 2. For HAZ it is related to the growth of grains up to 50 μm. Decrease of strength of the root weld is more than the one of face weld (Figs. 3, 4) that is referred to the difference in their structure states. The face weld consists of dendrite, but the root weld has a tempering polyhedron structure. The base metal microhardness is 5400 MPa, the root weld microhardness is 4660 MPa, and the microhardness of the face weld is 5220 MPa. The indentor load was 200 g.

The width of treated material was admitted to be up to 20 mm for weld width 8–10 mm, and HAZ width 4–5 mm on the basis of metallographycal analysis, and there was taken into account that the fatigue crack usually initiates and develops at the "HAZ–weld" interface.

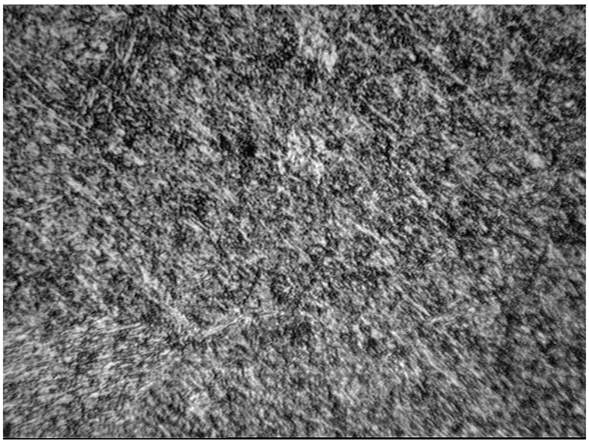

Fig. 1. Microstructure of high-strength steel (×1000)

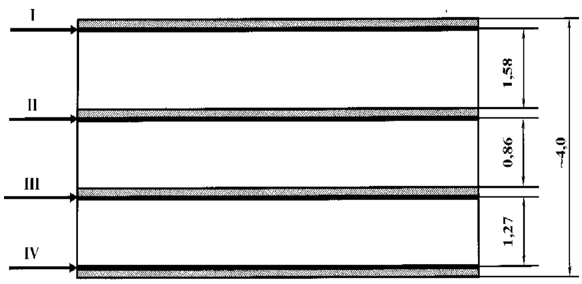

Fig. 2. The scheme of areas of investigation of the microstructure and micro-hardness of weldment

Metallographical explorations of welded joints proved that there was great grinding in the surface layers of face, root welds and in HAZ. It should be noted about significant increase of the microhardness (more than by 10–12%) for all UST exposured areas (Fig. 5). The experimental data analysis proves that the depth of hardened surface layers on the both sides of weldment is approximately 200 μm.

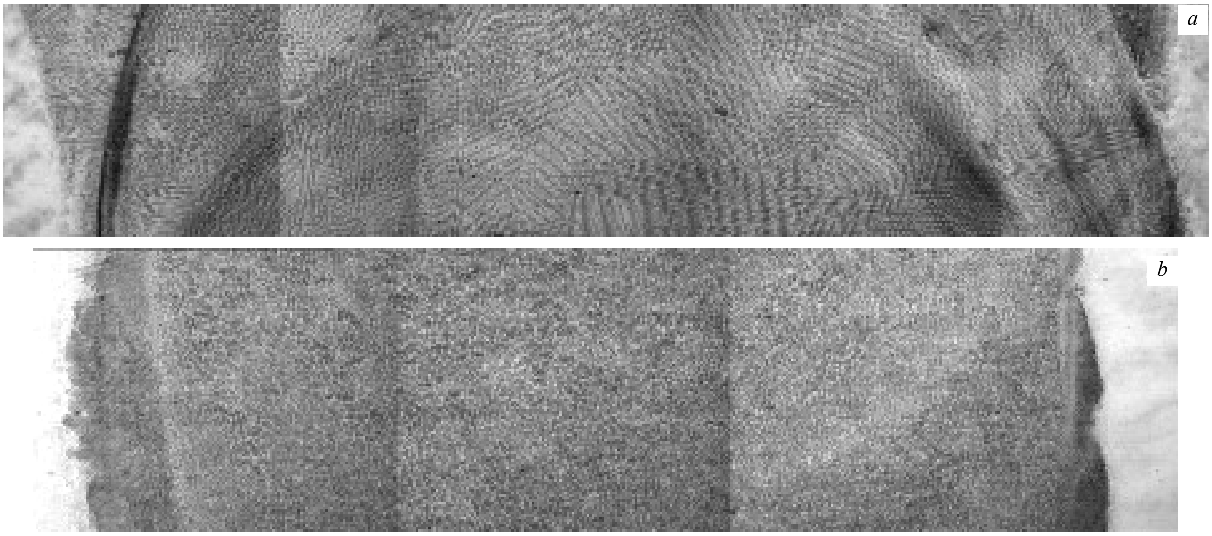

Fig. 3. Microstructure of weld of high-strength steel. *a* – face weld, *b* – root weld (×100)

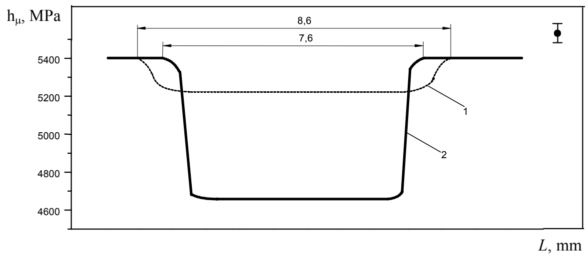

Fig. 4. Microhardness distribution for high-strength steel weldment before UST

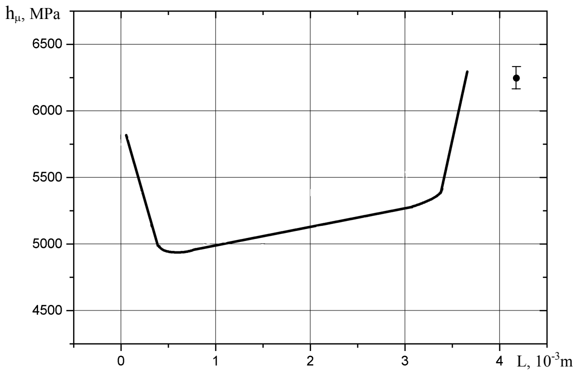

Fig. 5. Microhardness distribution for high-strength steel weldment after UST (metallographic cross-section)

The treatment of high-strength steel welded joints by UST provides higher high-cyclic fatigue life in comparison with initial ones more than by 50%. It is important that the fracture of specimens with exposured weldment occurs in the vicinity of fillet but not about HAZ. It means that real growth of fatigue life for weld and HAZ material is higher after UST.

There is a great grinding of metallographical structure and increasing of hardness in subsurface layers of high-strength steel due to ultrasound shock surface treatment. The depth of hardened layers is about 200 μm. The surface hardening allows to arrest the deformation processes at the surface that reduce fatigue failure accumulation in the bulk of the materials and leads to increase of the fatigue life of high-strength steels more than by 50%.

So, ultrasonic shock treatment is a high-effective method to increase the fatigue strength of welded joints of structural steel, heat-resistant steel and high-strength steel.

References

[1] O.V. Abramov, V.V. Artemiev, E.V. Kisterev, Materialovedenie **7**, 44 (2001).
[2] P.P. Mikheev, A.Ja. Nedoseka, I.V. Parkhomenko, Avtomaticheskaya Svarka **3**, 4 (1984).
[3] U.F. Kudrjavtcev, V.F. Korshun, Avtomaticheskaya Svarka **12**, 3 (1995).
[4] U.F. Kudrjavtcev, V.F. Korshun, A.Z. Kuzmenko, Avtomaticheskaya Svarka **7**, 24 (1989).
[5] V.G. Stepanov, M.I. Statnikov, Tehnologia Sudostroenia **7**, 32 (1974).