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INVESTIGATION OF THE MICROSTRUCTURE AND HARDNESS OF 20GL STEEL SAMPLES CUT FROM A WEDGE-SHAPED AND A SIDE FRAME AFTER VOLUME-SURFACE QUENCHING

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Abstract:

This work is devoted to the topic" Investigation of the microstructure and hardness of 20GL steel samples cut from a wedge-shaped and a side frame after volume-surface quenching ".
Recently, the railways of Asia and the Russian Federation are more than two dozen fractures of the side frames of trucks of freight cars every year. Each case is a potential source of an accident or crash. In addition, when carrying out scheduled repairs of freight cars, about a thousand side frames and truck bolsters are rejected.

Keywords: Volume-surface quenching (VSQ), quenching, wedge-shaped, truck bolster (or bolster).

INTRODUCTION

The material on this topic is huge and can serve as the basis for more than one article. Anyone can find on the Internet statistics of accidents that occurred due to fractures of the side frames of freight cars, collected since 2001. The analysis of these statistics allows us to draw two disappointing conclusions:

a) the cases of side frame fractures, which were isolated until 2006, sharply increased and reached a maximum in 2010 (more than two dozen). The current year's statistics are also disappointing. From the analysis of the press, it follows that the accident that occurred on May 11, 2012 on the stage between the stations Ledyanaya and Ust-Pera, was the 18th case of a broken frame, and the last publication on this topic was published on August 16, 2012;
b) almost all manufacturers of side frames in one or another quantity produce defective products, which are checked and put into operation. And here we are not talking about one or two dozen frames that burst during the movement of the train and caused the accident.

You can read about the reasons for the frame break in any technical report of the commission investigating the causes of the accident. For example, in the conclusion on the accident that occurred on the Trans-Baikal railway on January 30, 2012, it is reported: "The destruction of the side frame occurred due to the formation and development of a fatigue crack," which, in turn, is directly related to the presence of " internal casting defects in the lower section of the axle box opening of the side frame (R55) in an area invisible to car inspectors, which led to stress concentration and its further fracture." "Internal casting defects "are the same every time: internal shrinkable shells and poorly brewed" hot cracks", and in fact — the same shrinkage defects that come to the surface. Thus, the causes of accidents should be found in the manufacturers of these critical parts.

RESEARCH MATERIAL

In this work, the microstructure and mechanical properties of samples of fragments of side frames made of 20GL steel after normalization (950 ° C, air cooling) and VSQ (945 ° C, 3 min cooling) were studied. The chemical composition of the steel fragments of the side frames is shown in Table 1.

Table 1-Chemical composition of the studied steel fragments of side frames

Steel Grade	Element content, % weight							
	C	Si	Mn	V	Al	S	P	Other impurities
20GL	0,22	0,45	1,2	0,04	0,03	0,010	0,012	Cr=0,10 Ni=0,08 Cu=0,10
Requirements of GOST 32400	0,17–0,25	0,3 – 0,5	0,9 – 1,4	0,04–0,16	0,02–0,06	no more than		Cr≤0,03 Ni≤0,3 Cu≤0,06
						0,04	0,04	

The study of the structure was carried out at various scale levels: macro, micro. For the research, samples were made, cut from a wedge and a side frame (figure 1).

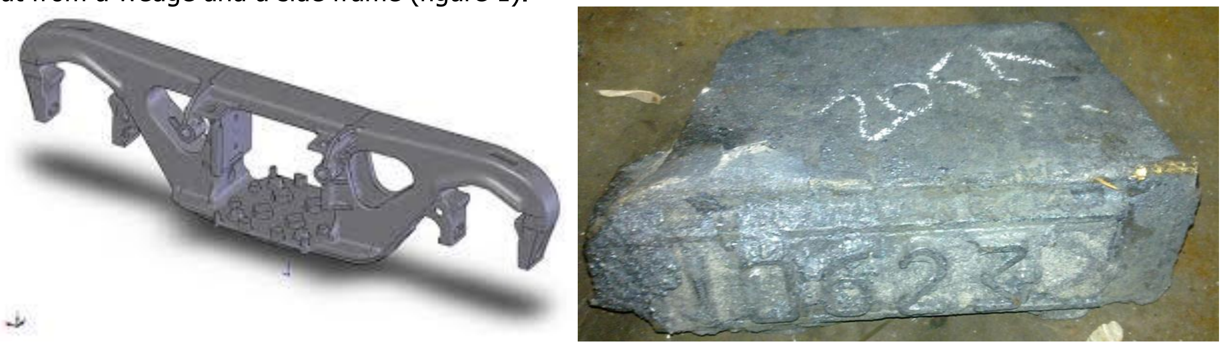


Figure 1-Side frame (a) and process sample (wedge-shaped) (b) of 20GL steel

The analysis of fragments of the side frame after normalization and after thermal hardening by volume-surface quenching was carried out on samples that were cut from the side frame of 20GL steel.

SAMPLE PREPARATION

For the preparation of all types of samples, cutting, pressing, grinding and polishing operations were carried out.

Cutting of samples with a size of no more than 10x10 mm and a thickness of 3 mm was carried out on a precision water-cooled Isomet 4000 cutting machine. Cutting was performed at a disk rotation speed of 2500 rpm and a milling cutter feed speed of no more than 2 mm / min, the samples in the machine are fixed with a special clip. The dimensions of the samples after cutting were measured with an electronic vernier caliper.

For the preparation of metallographic grinds, the samples were hot pressed into a special mixture of epoxy resin. Hot pressing was carried out in an automatic Buehler Simplimet 1000 press with a working chamber diameter of 25 mm at a temperature of 150 °C and a pressure of 2×10^7 Pa. The sample was placed on a special press table and filled with a powder mixture of PhenoCure epoxy resin (a phenolic compound with a filler in the form of wood powder, which has an average hardness). After that, the table with the sample and the mixture was lowered into a special chamber by an electric drive, where the epoxy resin was pressed and solidified.

The pressed samples were removed from the working chamber of the press and processed manually on a Buehler Vector Head / Beta sanding and polishing machine (Figure 2) by successive sanding, starting with the less dispersed sanding paper (P 400) and ending with the most dispersed sanding paper (P 2500). The processing time at each stage was from 1 to 5 minutes. Before proceeding to each subsequent stage, the samples were washed with water. At the final stage, when polishing, a cloth (or velvet) was used with a Masterprep suspension with a $SiO2$ particle size of 0.05 microns and polished for 3 to 5 minutes, as a result of which a mirror surface of the cut was achieved.

Figure 2 - Automatic Grinding Machine Buehler Vector Head/Beta

After polishing, the grinding surfaces were cleaned from the remnants of the polishing suspension with a cotton swab moistened with ethyl alcohol or water and dried with hot air.

METALLOGRAPHIC ANALYSIS

The sections were examined by optical microscopy using an Axio Lab A1 Carl Zeiss microscope (Figure 3) in the reflected light mode. The sample was placed on a slide table, so that the surface of the slot was on top.

Figure 3 - Photo of the Axio Lab A1 Carl Zeiss microscope

Two sections of each fragment were examined. The analysis of the sections was carried out at magnification ×200, ×500 and ×1000. Using a camera connected to a computer, images of the sections were photographed with an optical microscope. Obtaining austenitic grains in samples after normalization.

Preparation of the etchant: distilled water 100 ml, 3 drops of surfactant, 5 mg of picric acid. The etching holding time is 5 seconds. After applying the etchant on the surface of the sample, we wash it with water and dry it quickly so that the steel does not oxidize.

To measure the proportion of excess ferrite in the samples after the OPP, we use the Paint program, find the characteristic areas and paint the ferrite inside the grain in yellow, and along the grain boundaries-in red. After the selection using the Image Expert program, we calculate the percentage of ferrite and perlite.

HARDNESS MEASUREMENT

Rockwell hardness measurement

Using the Macromet 5101T equipment (Figure 4), the hardness values of 20GL steel samples were measured. The measurements were carried out on the surface of the samples from one edge to the other with a step of 1.3 mm according to the scheme shown in Figure 5. The measuring point should be at a distance of 1.75 mm from the edge of the sample.

Figure 4-Macromet 5101T Macrohardness Meter

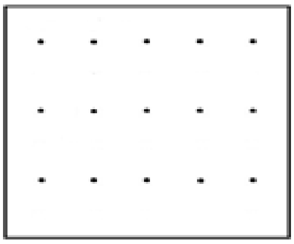
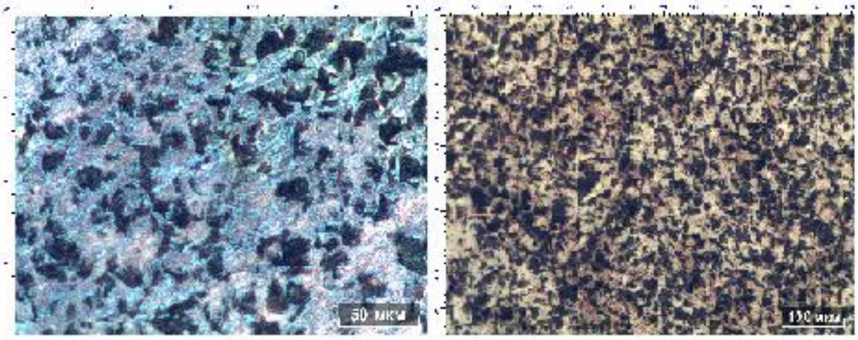


Figure 5-Hardness measurement diagram

RESULTS OF THE RESEARCH

Results of metallographic analysis

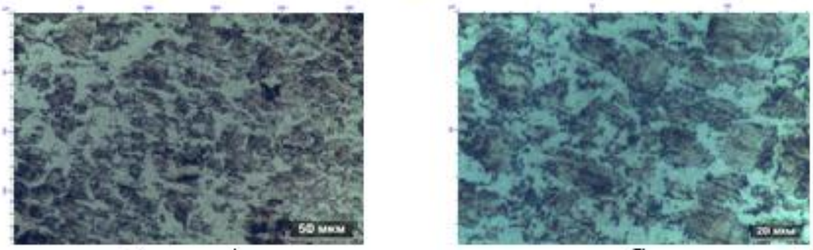
Figure 6 shows the structure of the side frame after normalization. The microstructure is ferrite-pearlite, fine-grained, with a uniform distribution of structural components



a) б)

Figure 6 - Microstructure of the side frame after normalization at x500 (a) and x200 (b)

Figure 7 shows the microstructures of the samples cut from the wedge after normalization. The results of the quantitative metallographic analysis are presented in table 2.



a) б)

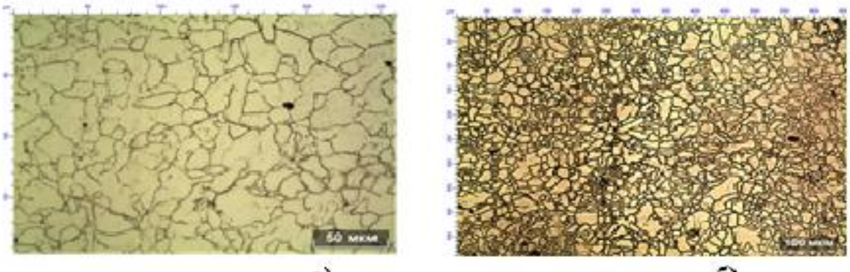
Figure 7-Microstructure of samples cut from a wedge-shaped after normalization at x500 (a) and x1000 (b)

Table 2-Microstructure parameters in samples

Sample	Ferrite grain size, mkm	Perlite grain size, mkm
Frame, normalization	**25,73 ±6,8**	**14,73 ±8,5**
Wedge-shaped, normalization	**22,52 ±5,3**	**15,56±8,4**

Table 2 shows that the average grain size of ferrite and perlite in the samples from the frame and wedge after normalization coincide within the error range.

Figure 8 shows the microstructure of a sample cut from a wedge after etching on austenite (after normalization).



a) б)

Figure 8-Microstructure of samples cut from a wedge-shaped sample after etching on austenite (after normalization, at x500 and x200)

The average size of large austenitic grains in the wedge samples was 35.39 microns, and the average size of small austenitic grains in the wedge samples was 9.1 microns.

Figures 9 and 10 show the microstructure of the samples cut from the side frame and the wedge-shaped after the VSQ.

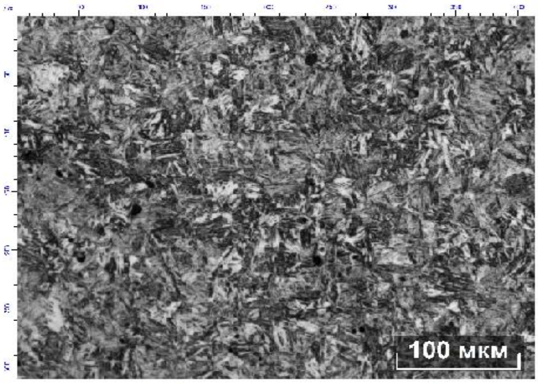


Figure 9-Microstructure of the sample cut from the side frame (after the VSQ).

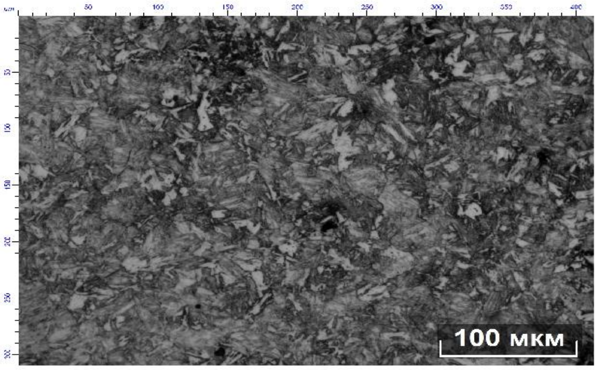


Figure 10-Microstructure of the sample cut from the wedge-shaped (after the VSQ).

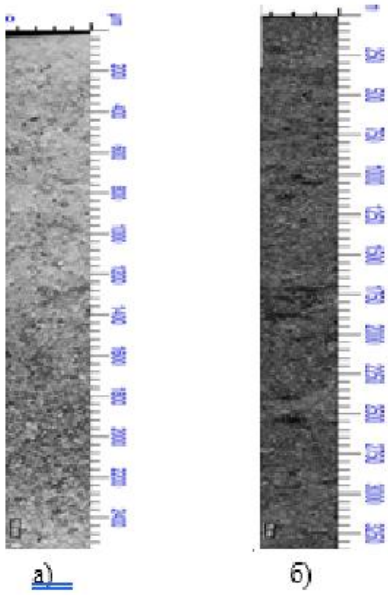
The results of the excess ferrite fraction are presented in Table 3.

Table 3 -The proportion of excess ferrite in the samples

Sample	The proportion of ferrite inside the grain (%)	The proportion of ferrite at the grain boundaries (%)
Side frame (VSQ)	**11,1±3,4**	**7,6 ±2,6**
Wedge-shaped (VSQ)	**13,7±2,5**	**8,5+2,1**

Table 3 shows the results of measuring the proportion of excess ferrite in the samples from the wedge and frame after the VSQ. It can be seen that the percentage of excess ferrite inside the grains is greater than at the grain boundaries. The proportion of excess ferrite inside the grains in the samples from the side frame (11.1 %) and from the wedge (13.7 %) after the VSQ is the same.

Panoramas 11 show that a decarburized layer is present in the sample cut from the side frame, and no decarburized layer is observed in the sample cut from the wedge. The cross-sectional structure varies from the surface to the center from troostomartensite to sorbitol.



a) from side frame b) wedge-shaped

Figure 11- Panoramas of the samples after VSQ

HARDNESS MEASUREMENT RESULTS

Figures 12-13-14-15 show the hardness diagrams of the samples after normalization and after volume-surface quenching.

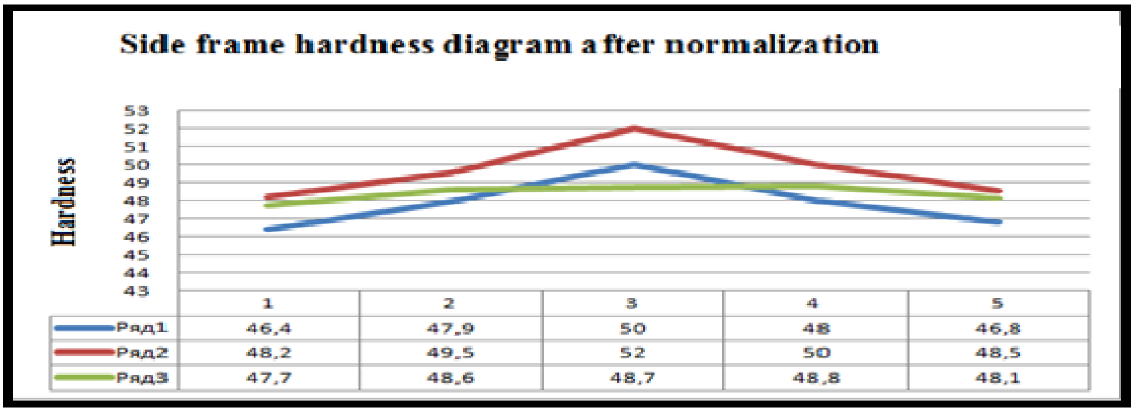


Figure 12-Side frame hardness distribution after normalization (HRA)

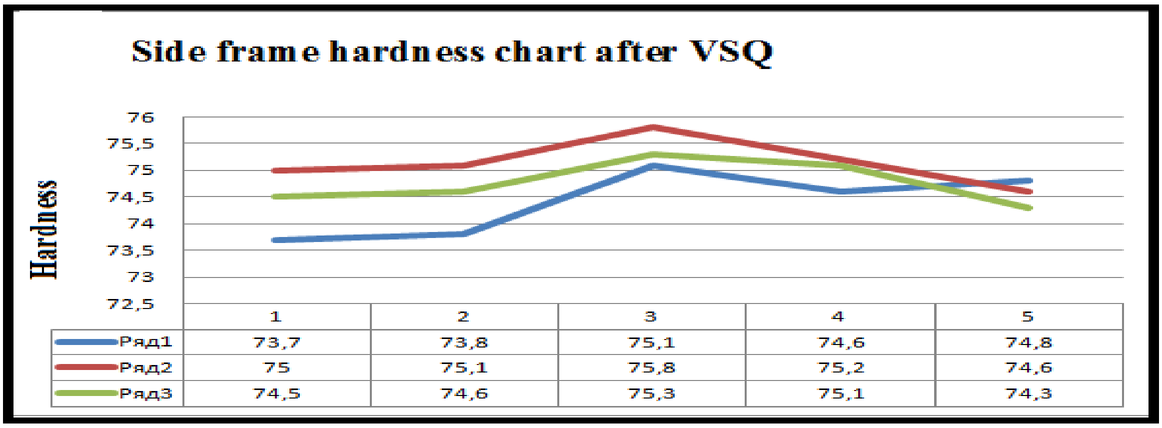


Figure 13-Side frame hardness distribution after VSQ (HRA)

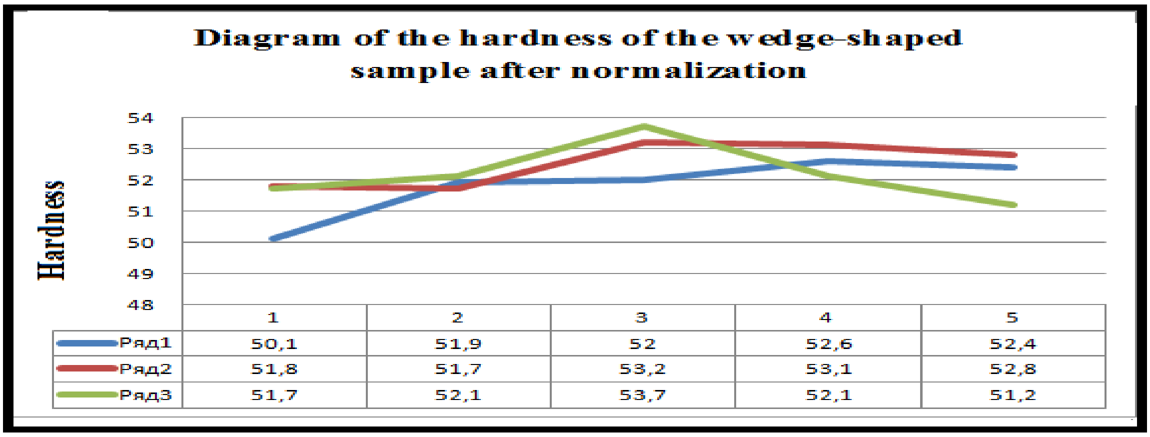


Figure 14-Wedge-shaped hardness distribution after normalization (HRA)

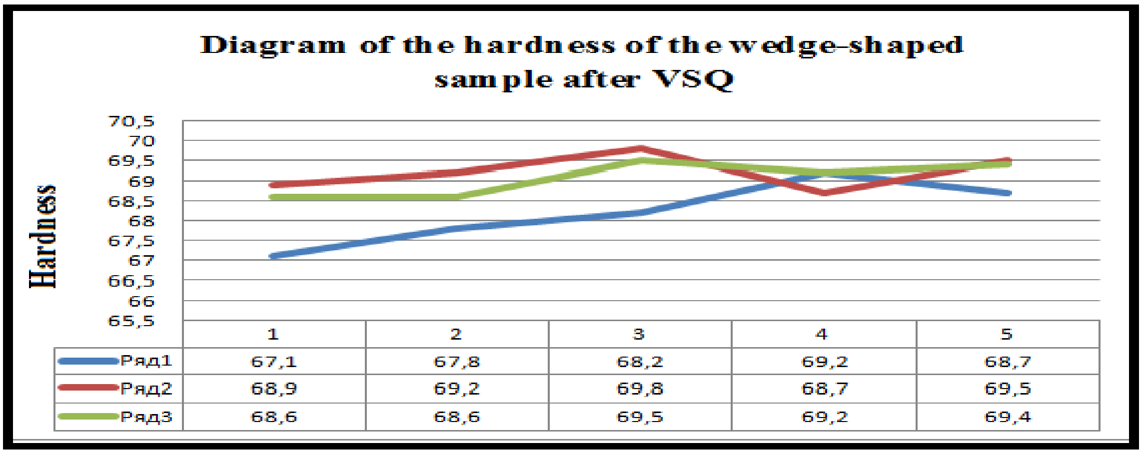


Figure 15-Wedge-shaped hardness distribution after VSQ (HRA)

Figures 16 and 17 show a comparison of the hardness of the 20GL steel samples under study (before and after VSQ)

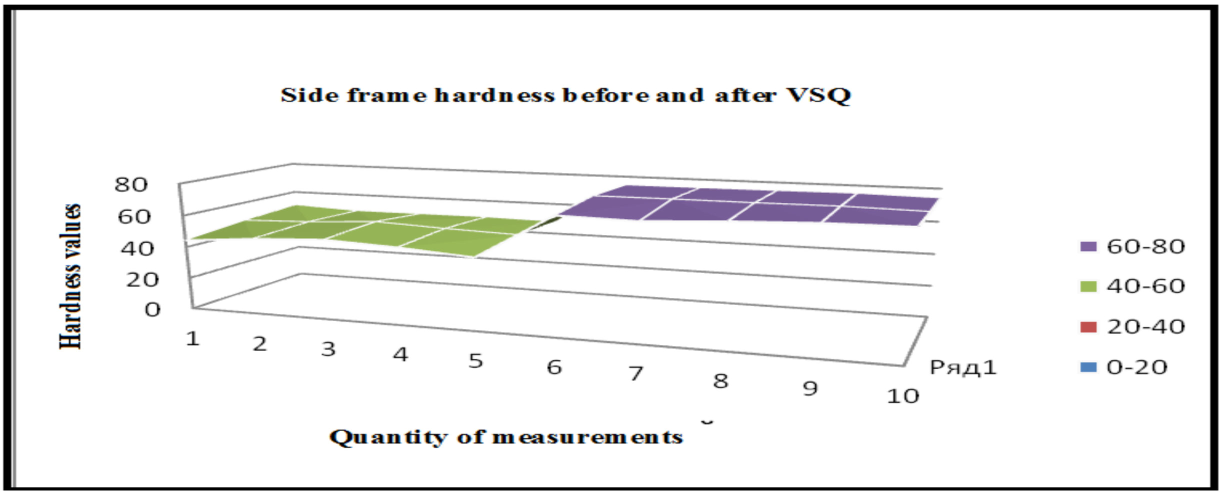


Figure 16-Side frame hardness diagram before and after VSQ (HRA)

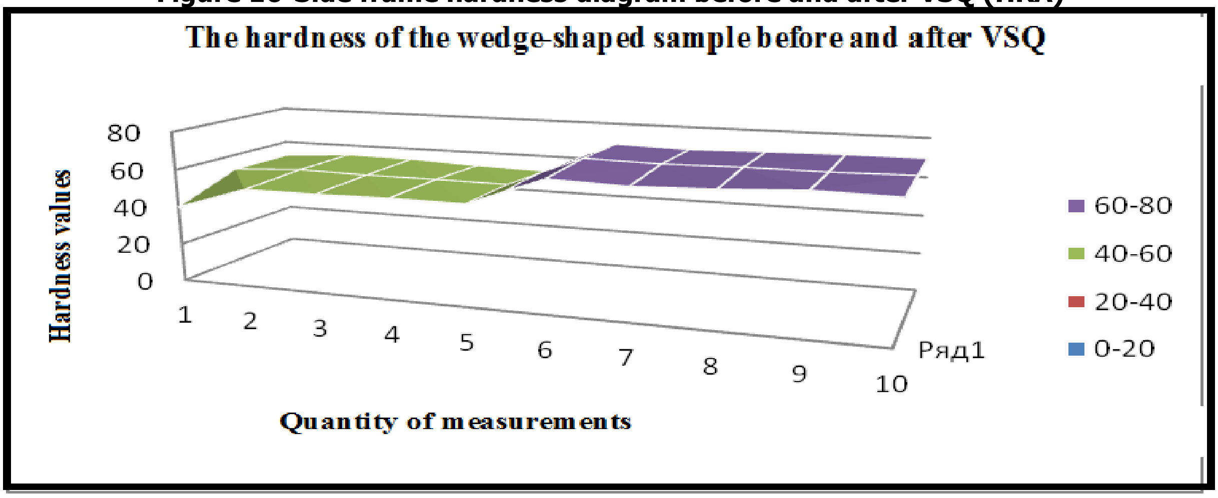


Figure 17- The hardness of the wedge-shaped sample before and after VSQ (HRA)

The diagrams showed that the hardness of the samples of the side frame and the wedge-shaped sample increases after volume-surface quenching. The values of the hardness of the side frame and the wedge after the VSQ coincide and are in the range of 55-65 HRA.

CONCLUSIONS

1. The microstructure of the side frame and the wedge-shaped after normalization is a ferrite-perlite mixture. The average ferrite grain sizes in the sample from the wedge-shaped and side frame after normalization coincide and are (22.5±5.3) and (25.7±6.8) microns, respectively. The average values of the grain size of perlite in the sample from the wedge and the side frame after normalization coincide and are (15.5±8.4) and (14.7±8.5) microns, respectively.

2. VSQ leads to a change in the structure of the cross-section: from the surface to the center from troostomartensite to sorbitol. In the case of samples from the frame, a decarburized layer is present on the surface. The proportion of excess ferrite inside the grains is greater than at the grain boundaries. The proportion of excess ferrite at the grain boundaries in the samples from the side frame is 7.6±2.6 % and from the wedge-shaped 8.5±2.1 %.
3. The hardness of the samples of the side frame and the wedge-shaped sample increases after volume-surface quenching. The values of the hardness of the side frame and the wedge-shaped sample increase. coincide and are in the range of 55-65 HRA.

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