RESEARCH OF THE NATURE OF DESTRUCTION OF 20GL STEEL SAMPLES FROM A WEDGE AND A SIDE FRAME AFTER VOLUMETRIC SURFACE HARDENING

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Annotation. This work is devoted to the topic " Research of the nature of destruction of 20GL steel samples from a wedge and a side frame after volumetric surface hardening ".

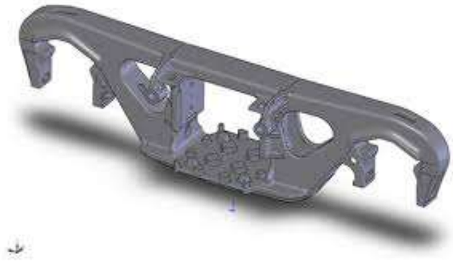
Keywords: volume-surface hardening (VSH), internal casting defects.

Recently, more than two dozen fractures of the side frames of bogies of freight cars have been occurring on the railways of Russia annually. Each case is a potential source of an accident or a crash. In addition, when carrying out scheduled repairs of freight cars, about a thousand side frames and spring beams are rejected. At this time, it is believed that the main reason for the fractures of the side frames of the trolleys is poor-quality casting of these parts. In almost every broken side frame, one or another casting defect is found.
Research material. In this work, studies of the microstructure and mechanical properties of samples of fragments of side frames made of 20GL steel after normalization (950 °C, air cooling) and VSH (945 ° C, 3 min cooling) were carried out. The chemical composition of the steel fragments of the side frames is shown in Table 1.

Table 1 – The chemical composition of the studied steel fragments of the side frames.

Stamp of steel	Content of elements, % by weight							
	C	Si	Mn	V	Al	S	P	Other ingredients
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 GOST 32400	0,17–0,25	0,3 – 0,5	0,9 – 1,4	0,04–0,16	0,02–0,06	No more 0,04	No more 0,04	Cr≤0,03 Ni≤0,3 Cu≤0,06

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



a) б)

Figure 1 – Side frame (a) and technological sample (wedge) (b) of 20GL steel

The analysis of fragments of the side frame after normalization and after thermal hardening by volumetric surface hardening 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.

The cutting of samples with a size of no more than 10x10 mm and a thickness of 3 mm was carried out on an Isomet 4000 precision water-cooled cutting machine. Cutting was performed at a disk rotation speed of 2500 rpm and a milling cutter feed rate of no more than 2 mm / min, samples in the machine are fixed with a special clamp. Figure 2 – Automatic grinding machine BuehlerVectorHead/Beta

Pressed samples were extracted from the working chamber of the press and processed manually on a Buehler Vector Phoenix Beta grinding and polishing machine (Figure 2) by sequential grinding, starting with 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 applied to it and polished for 3 to 5 minutes, as a result of which a mirror surface of the slot was achieved.

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

Metallographic analysis. The slots were examined by optical scopy on an Axio Lab A1 Carl Zeiss microscope (Figure 3) in the reflected nt mode. The sample was placed on a slide table so that the surface of the sl was on top. Figure 3 – Photo of the Axio Lab A1 Carl Zeiss microscope. T sections of each fragment were examined. The analysis of the cuts was carried out at magnification ×200, ×500 and ×1000. Using a camera connected to a computer, images of the cuts were photographed from an optical microscope.

Methods of impact strength testing. Impact strength tests are dynamic types of tests. To determine the impact strength, standard samples with a U or V-shaped incision are used, which serves as a stress concentrator. Depending on the shape of the incision, the impact strength is designated KCU or KCV. Impact strength tests were carried out on samples of type 20GL (V and U-shaped concentrator).

One of the most important indicators of strength is toughness. Impact strength is the ability of materials to absorb the energy of a shock load. It is most often determined by the impact bending of a rectangular material sample. The work that is spent during the destruction or destruction of a particular sample is an indicator of impact strength. The experiment is carried out on a special device – the Instron SI-1M pendulum copra (Figure 4).

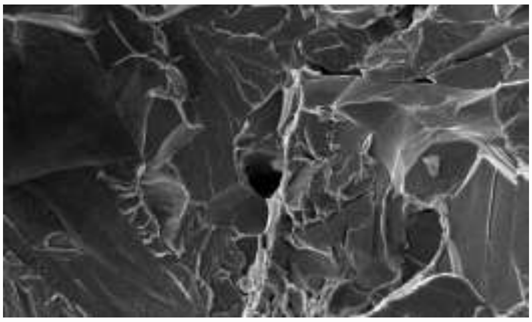
Figure 4 – Instron SI-1M pendulum coper.

Samples with an incision in the middle are tested by hitting them with a pendulum knife. Depending on the metal and the purpose of the test, the experiment can be carried out at temperatures from minus 100 ° C to 1200 ° C. The toughness shows the ability of a metal to resist destruction caused by the

tensile stress between atoms. A decrease in the impact strength of metals with a large drop in temperature is considered an indicator of their cold breaking. Low-alloy steels and some metals, such as chromium, molybdenum, tantalum, and tungsten, which consist of a volume-centered cubic lattice of metal atoms, are subject to such a phenomenon as cold-breaking. Impact strength, first of all, depends on temperature.
GOST sets its own temperature for each type of steel, at which the impact strength is determined, and also the temperature that is optimal for testing with a particular type of steel. The impact strength depends on the presence of alloying elements, on various impurities, as well as on the composition of the steel itself. The appearance of quenching structures in steel products significantly reduces the impact strength.
Fractographic analysis. The study of the microstructure of the fracture surface makes it possible to determine the structural trajectory of the crack – the path of least resistance to its propagation. However, in practice, it is usually necessary to meet with the complex nature of the fracture relief, containing morphological elements of both brittle and viscous fracture.
After the impact bending test, 10 photos were taken for each sample. To measure the proportion of components in the fractures of samples, we will use the Paint program. With the help of the Paint program, each component was highlighted in different colors for all the pictures (chip – red, quasi–chip – blue, pits - yellow, etc.). After painting with the help of the Image Expert 3 program, the proportions of the components for each color in the pictures are considered, and the average values are calculated and presented in the form of a table.
Impact strength test results. As a result of the impact strength tests, the data presented in Table 2 were obtained.
Table 2 – Results of determining the impact strength of samples from the wedge and frame.

	Impact strength KSV -60 °C, J/cm2			
№ Sample	Samples from the frame		Samples from the wedge	
	Normalization	VSH	Normalization	VSH
1	12,5	17	8,2	20,0
2	7,5	17	8,4	19,0
3	7,5	18	11,0	18,0
4	8,0	17	8,6	17,0
5	7,4	18	8,7	16,0

The values of impact strength according to GOST 32400-2013 must correspond to KCV-60 at least 17 J/ cm2 (20 J/ cm2 from 01.01.16). Within the error, the values obtained by us for samples after VSH comply with the requirements of GOST 32400-2013. Also, GOST 32400-2013 requires testing for impact strength on samples cut precisely from a technological sample (wedge). In the case of cutting samples from frames, the results may be less by 20%.
The data obtained show that the impact strength after normalization in both cases does not correspond to GOST 32400-2013, as it has values below 20 J/sm2.
The values of impact strength for hardened samples are within the permissible limits of GOST, which indicates the suitability of hardened products for operation even in the conditions of the North.
It should be noted that the normalization carried out using standard technology allows to achieve an average value of impact strength two times lower than with VSH. This confirms the fact that the standard technology of normalization of cast steel 20GL with air cooling in the workshop atmosphere cannot provide stability in obtaining an equilibrium microstructure, the required dispersion and uniformity.
An important role in obtaining high values of impact strength is played by internal residual stresses, which are realized in the hardened wedge as a result of creating a gradient of mechanical properties and hardness. Samples for impact bending tests made by cold cutting methods from a hardened VSH wedge inherit a plot of internal residual compressive stresses, despite the reduced size of the sample and relaxation of part of the stresses during manufacture. This is confirmed by the results of the tests carried out.
It can be seen that in the case of VSH, the discrepancy between the samples cut from the wedge and the frame is small and is within 20%.



Fractographic analysis. Photos of the fractures of the samples are shown in Figures 5-8. They show the fractures taken at magnification x1000, and pictures of the central part of the fractures.

Figure 5 – Fracture of the sample cut from the side frame after normalization (x1000). In the fracture of the frame, there are mainly large facets with a smooth surface and a small number of pits, which suggests the fragile nature of the fracture. The facets themselves have clear edges and secondary cracks are present on the fracture.

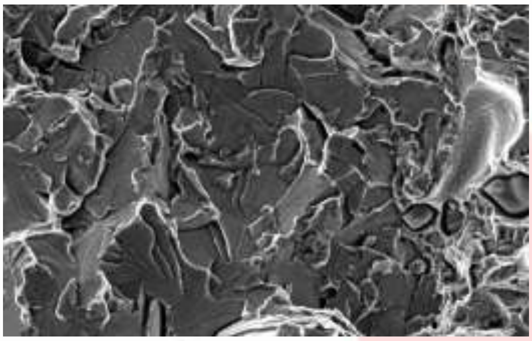


Figure 6 – Fracture of the sample cut from the wedge after normalization (x1000)

The wedge fracture is visco-brittle, there are inclusions in the recesses that differ in color and have clear edges, which characterizes them as fragile, their average size is about 15 microns.

Figure 7 – Fracture of the sample cut out of the frame after the VSH (x1000). Fracture is visco-brittle. There are inclusions in the fracture that differ in color and have clear faces of inclusions with dimensions of 7-25 microns.

The fracture is visco-brittle, there are facets with a smooth surface and pits with an average size of 5 microns. The results of the facet measurement are shown in Table 3.

Sample	Facet Size , mkm
Frame, normalization	10,9 ± 4,1
Fame, OPZ	8,84 ± 2,8
Wedge , normalization	11,1 ± 3,9
Wedge , VSH	8,5 ± 3,1

Fractures of samples after normalization are brittle. After volume-surface hardening in the fractures of the samples, both the wedge and the side frame facets become smaller.

Table 4 shows data on the quantitative analysis of the fractures of all images.

Table 4– Proportions of components in the fractures of 20GL steel samples

Components of the fracture	Side frame (%)		Wedge (%)	
	After normalization	After VSH	After normalization	After VSH
Scol	88,8 ± 4,3	23,5 ± 2,8	87,95 ± 5,8	10,4 ± 6,3
Quasiscol	8,73 ± 2,6	73,27 ± 6,9	7,43 ± 3,1	83,48 ± 3,4
Hole	0,35 ± 0,01	1,43 ± 0,19	0,28 ± 0,03	4,3 ± 0,04

It can be seen from Table 4 that the proportions of the chip, quasi-chip and pits in the fractures of the samples of the side frame and wedge coincide within the error (after normalization). The fraction of cleavage on the surface of the samples of the side frame and wedge after the VSH is much less than after normalization. The shares of the quasi-dome on the surface of the samples of the side frame and wedge after the VSH are much larger than after normalization. In the fractures of the samples there is a small amount of non–metallic inclusions, about 0.5 - 1.5%.

Conclusions. 1. The results of the impact strength measurement showed low values for the samples after normalization – 8.58 J/sm2 for the frame and 8.98 J/sm2 for the wedge. VSH led to a twofold increase in the impact strength – up to 18 J / sm2.

2. The fractures of the samples after normalization are brittle. After volume-surface hardening in the fractures of the samples, both the wedge and the side frame facets become smaller, the proportion of the quasi-disc grows by an order of magnitude.

3. The work carried out allows us to conclude that it is possible to evaluate the structure and mechanical properties after the VSH of the entire frame based on the test results of samples from the technological sample (wedge).

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