3. Steels used in parts of percussive equipment were investigated. It was shown that, regardless of their good damping properties, specimens of steel ITs-1A have the lowest endurance.

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EFFECT OF SURFACE PLASTIC DEFORMATION ON THE INELASTIC CHARACTERISTICS AND FATIGUE LIMIT OF STEELS 20 AND 14Kh17N2 WITH CYCLIC TORSION

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In order to predict the endurance of specimens made of metals and alloys with cyclic loading there is extensive use of strain and energy methods based on measuring the dynamic hysteresis loop [1]. As a rule inelastic properties are studied in mechanically or electrochemically polished specimens when work hardening and residual stresses are at a minimum in the surface layer. There are no data in the literature on experimental verification of the use of the dynamic hysteresis loop for metals and alloys whose surface has been subjected to treatment by special methods. For example these methods relate to surface plastic deformation (SPD) carried out by burnishing with rolls, shot blasting, etc. After SPD favorable residual compressive stresses arise in the surface layer increasing the property of resistance to fatigue failure for materials [2].

In the present work an experimental study has been made of the effect of SPD on inelastic characteristics and the fatigue limit of steels 20 after annealing at 1153-1163°K for 0.5 h ($\sigma_{0.2}$ = 352 MPa; σ_f = 477 MPa; δ = 25.8%; ψ = 58.8%) and 14Kh17N2 in the as-supplied condition ($\sigma_{0.2}$ = 640 MPa; σ_f = 830 MPa; δ = 22%; ψ = 46%).

Solid cylindrical specimens (gage length diameter 14 mm) were prepared by two techniques with differing finishing treatment. In one of them the final operation was grinding of the gage length by abrasive cloths of different grain size and final polishing with pastes to a surface finish R_a = 0.1 μm. Since the material condition of the surface layer after mechanical polishing depends on previous treatment [3], during turning metal layers were removed in several passes with a decreasing cutting depth. The thickness of the last layers did not exceed 0.1 mm, which provided the minimum depth of work hardening. In accordance with the second technique after mechanical polishing there was burnishing of the specimen gage length with a roll (D = 30 mm, profile radius R_{pr} = 12 mm) in a lathe by means of a special attachment.

Burnishing was carried out by the following regime [4]: load on the roll p = 500 N for steel 20 and 1500 N for steel 14Kh17N2, linear feed S_f = 0.1 mm/rev, two passes, and burnishing rate not more than 6 m/min.

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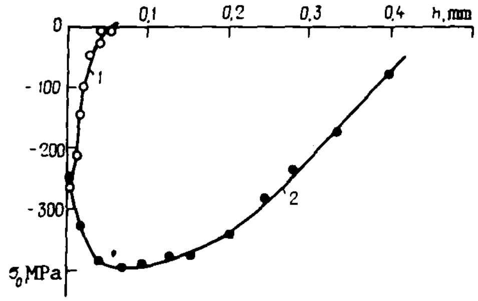

Fig. 1. Curves for axial residual macrostresses in cylindrical specimens of steel 20 after mechanical polishing (1) and SPD (2).

After treatment residual stresses were determined in the gage length of cylindrical specimens by layer-by-layer etching [2]. The technology of their treatment is the same for specimens intended for fatigue tests.

The distribution of residual macrostresses through the depth of the surface layer for cylindrical specimens of steel 20 is presented in Fig. 1. The data provided point to presence of significant residual compressive stresses (their depth overall is 0.05 mm) at the surface of specimens even after mechanical polishing. In specimens given SPD the maximum of the curve shifts into the depth of the material, and the extent of the zone of active compressive stresses was 0.4-0.5 mm.

The surface finish of the specimen gage length was checked with a N218 profilograph–profilometer. After mechanical polishing the roughness was R_a = 0.08 μm, and after SPD it was 0.2 μm, which satisfied the requirements of the operating standards [5].

Fatigue testing in torsion of solid cylindrical specimens was carried out by a symmetrical cycle for the change in stress with a frequency of 22-25 Hz in a soft loading regime at room temperature in a unit described previously [6-8]. Inelastic strain per cycle was measured by the method of the dynamic hysteresis loop [6, 8].

The dependence of nominal inelastic strain per cycle $\Delta\gamma_n$ on the number of loading cycles N was plotted from the results of studies for these materials (Fig. 2). They are cyclically softening materials, and surface hardening does not change the nature of their behavior at the test stress levels.

Analysis of the data obtained shows that SPD for specimens leading to surface layer work hardening and inducement of residual compressive stresses in it reduces the inelastic strain per cycle with the same stresses compared with that for polished specimens with any number of loading cycles in the multicycle fatigue range. For steel 20 the inelastic strain per cycle in the stabilization stage with loads of 1.06-1.11τ_{-1}^{i} was reduced by 50-60%, and for steel 14Kh17N2 with loads 1.07-1.1τ_{-1}^{i} it was reduced by 12-16% (τ_{-1}^{i} is the fatigue limit for unstrengthened specimens).

These results indicate that the effect of SPD on inelastic characteristics develops to a greater degree for steel 20 than for steel 14Kh17N2. Apparently this may be explained by the fact that the first material hardens with plastic deformation, and the deformation diagram for the second material is close to a deformation diagram for an ideally elastoplastic material for which strengthening is absent. Therefore, with SPD when there are large plastic strains the yield point of the surface layer for steel 20 increases markedly, whereas for steel 14Kh17N2 these changes are at a minimum.

It has been established [9] that cyclic inelastic strain for steels may serve as a measure for dissipated fatigue damage of the material surface layer in the stage of fatigue crack generation. A link exists between the number and sizes of microcracks observed per unit area of smooth specimen surface and inelastic strain per cycle in the stabilization stage. The higher the value of $\Delta\gamma_n$, the greater is the size and number of microcracks occurring per unit area.

The data provided indicate that with the same number of loading cycles for each stress level the surface layer of mechanically polished specimens is more damaged than those strengthened by SPD. Therefore, a main crack causing final failure of specimens in the first case develops earlier, which in turn is reflected in the overall endurance.

Fatigue curves on semilogarithmic coordinates (amplitude value of nominal tangential stresses τ_a^n versus logarithm of the number of cycles to failure for a specimen N_f) were

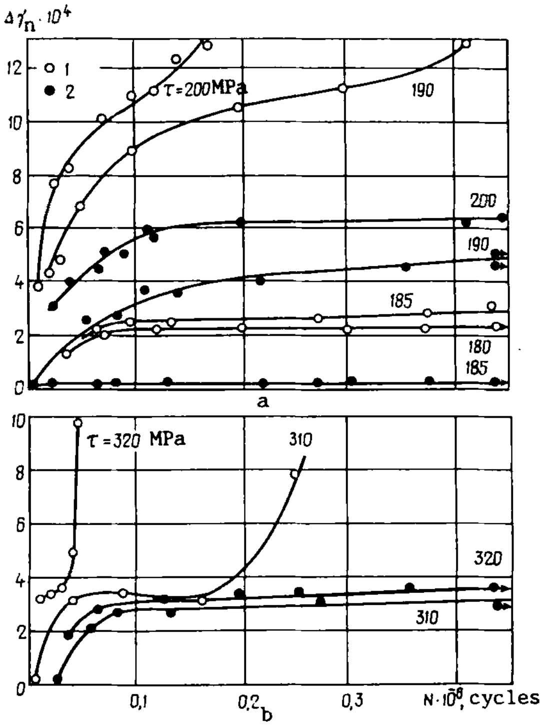

Fig. 2

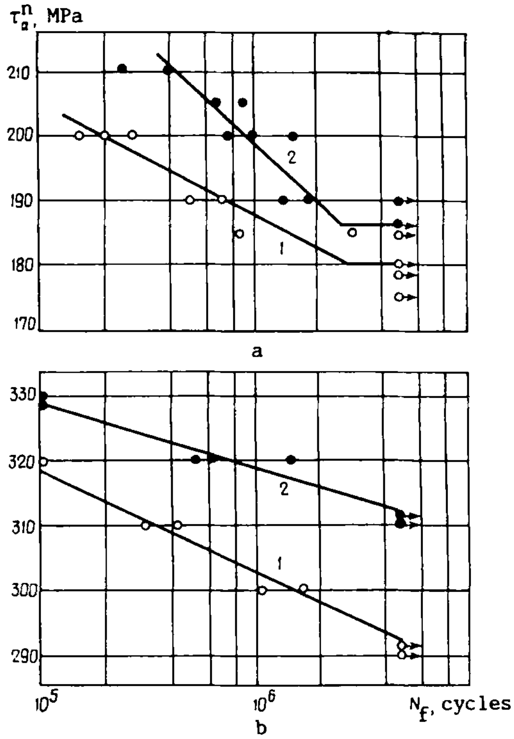

Fig. 3

Fig. 2. Change in nominal inelastic strain per cycle in relation to the number of loading cycles for steels 20 (a) and 14Kh17N2 (b) after mechanical polishing (1) and SPD (2).

Fig. 3. Fatigue curves for steels 20 (a) and 14Kh17N2 (b) after mechanical polishing (1) and SPD (2).

plotted from the results of experiments (Fig. 3). Parameters of experimental relationships $N_f = f(\tau_a^n)$ for the sloping branches of fatigue curves were estimated by the least squares method by means of the equation [10]

$$N_f = A \cdot 10^{B\tau_a^n}.$$

It can be seen from the data in Table 1 that the endurance and fatigue limit of mechanically hardened specimens is higher than for polished specimens. However, it was not possible to increase markedly the fatigue limit. The coefficient for the effect of surface hardening K_v on fatigue limit, which is the ratio of the fatigue limit for strengthened specimens to the fatigue limit for unstrengthened specimens [11], was 1.03 for steel 20 and 1.07 for steel 14Kh17N2. There was a more marked increase in the endurance of strengthened specimens. For steel 20 with stresses $1.06\text{-}1.11\tau_{-1}^{i}$ it increased by a factor of 2.5-4.8, and for steel 14Kh17N2 with stresses $1.1\tau_{-1}^{i}$ it increased by almost a factor of ten. This indicates that use of mechanical hardening is more effective for high-strength materials.

TABLE 1. Results for Fatigue Tests in Torsion

Steel	Method of finishing treatment for the specimen gage length	Fatigue curve coefficients		Correlation coefficient r	Fatigue limit τ_{-1}^{i} (MPa) on a base of $5 \cdot 10^6$ cycles	Coeff. of the effect of surface hardening K_v
		lg *A*	*B*			
20	Mechanical polishing	17,005	—0,0587	—0,9120	180	—
	SPD	12,216	—0,0314	—0,8433	185	1,03
14Kh17N2	Mechanical polishing	24,975	—0,0628	—0,9920	290	—
	SPD	39,010	—0,1035	—0,9461	310	1,07

CONCLUSIONS

1. It has been established that SPD reduces inelastic strain per cycle for the stress levels studied with any number of loading cycles.

2. As a result of mechanical strengthening the fatigue limit and endurance of steel 14Kh17N2 specimens increased to a greater extent than for steel 20.

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EFFECT OF STRUCTURE ORIENTATION OF THE INITIAL MATERIAL ON SPALL DAMAGES OF THE D16 AND AMg6 ALLOYS

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Differences in the orientation of defects in the prespall state of aluminum A95 and the alloy D16 were detected earlier during the investigation of the spall strength of these materials [1]. The prespall state is characterized by the occurrence of individual defects in the form of pores, cracks, or cavities in the spall plane. Besides, it was noted that in the alloy D16 the pore orientation is perpendicular to the spall plane, i.e., along the direction of the load wave, and in aluminum A95, parallel to this plane, i.e., perpendicular to the direction of propagation of the load wave [1]. A well-defined relationship between the pore orientation in the material relative to the direction of propagation of the load wave and the presence of velocity dispersion of the particles in the material was also established [1]. If the velocity dispersion of the particles is high, then the pores are oriented along the wave direction and vice versa. A perpendicular pore orientation is indicative of the absence of velocity dispersion of the particles in the subject material.

It is known that the initial structure of a material, which depends in particular on the method of its production (as for instance, rolling), has a significant effect on the pore orientation [2-4]. In view of this, it is quite probable that for specimens cut from the same billet but with differing angles in relation to its structure, the orientation of defects under the action of a load wave will be different. In this manner, we can conclude that even

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