Elastic hysteresis of 40X steel with surface nanostructure

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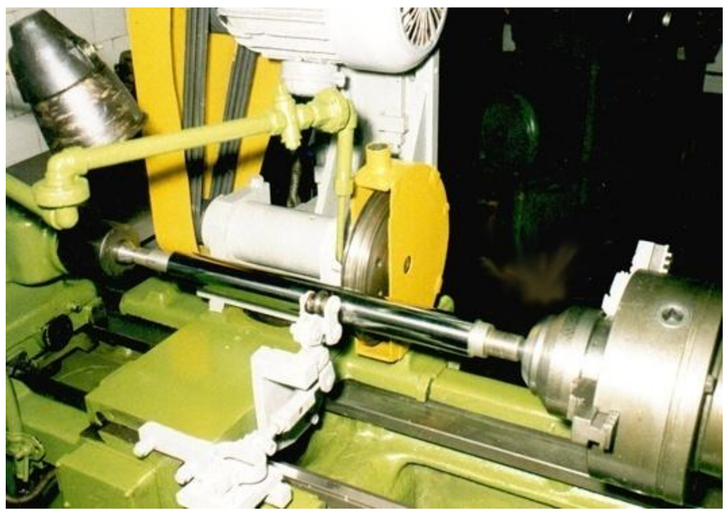
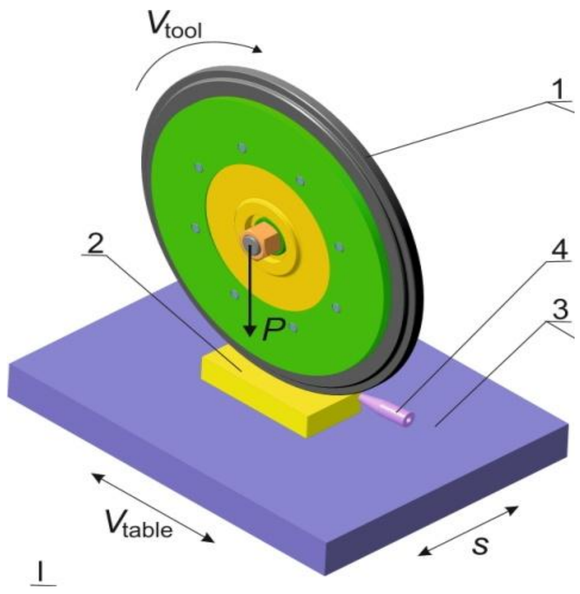
Introduction. The development of the modern technologies requires the design of novel structural materials with increasingly higher requirements for their physical and mechanical properties. Therefore, it is important to develop surface modification methods to obtain some required properties and structural stress state. Alongside with the improvement of heat treatment methods, progress in the protective and restorative coatings, the methods of formation of surface nanocrystalline structures (NCS) are being developed as well. The mechanical-pulse treatment (MPT) is among them. It forms surface strengthened layer with NCS by severe plastic deformation of the treated surface, providing the change in the structural-phase state, as well as in its chemical composition due to alloying from technological liquids during MPT. As a result of MPT of medium-carbon structural steels, their surface microhardness, resistance to wear, fatigue, corrosion-fatigue and contact fatigue are increased.



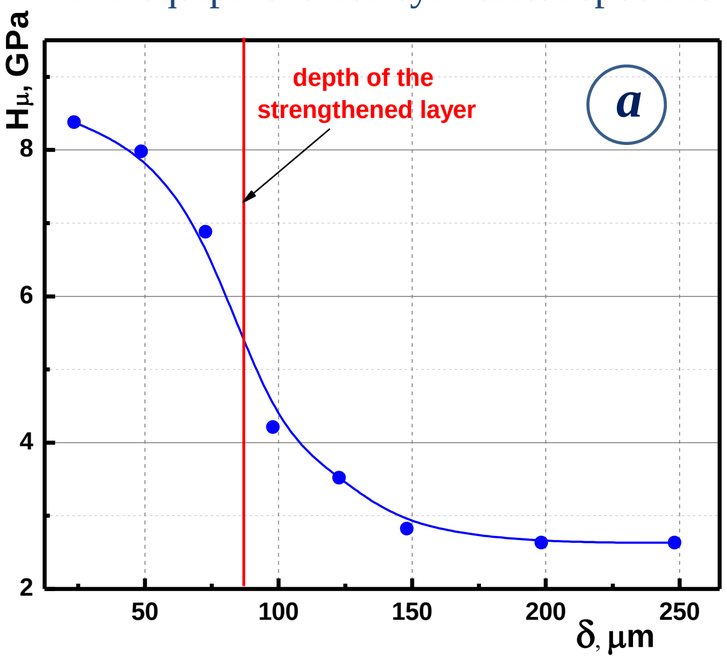
MPT equipment for cylindrical specimens

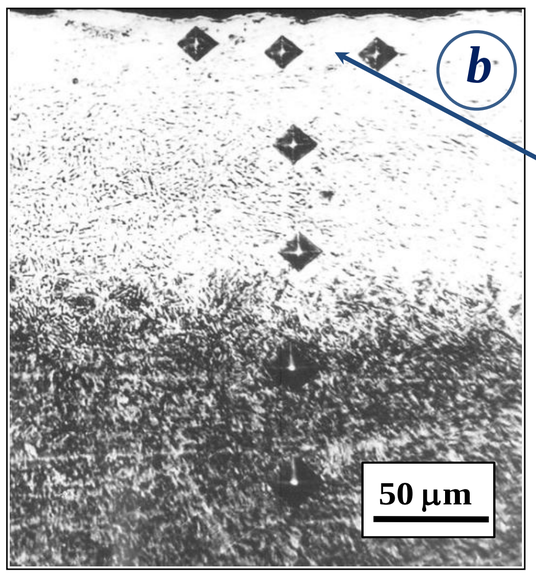


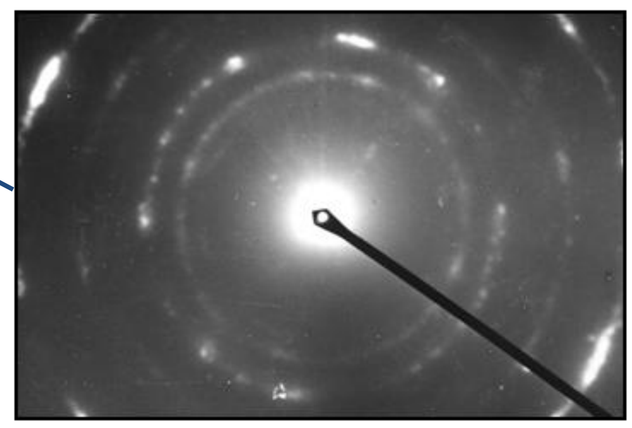
Aim. For the purpose of improvement of physical and mechanical properties, as well as serviceability of the machinery components, elastic properties of the surface NCS formed on 40X steel by MPT were studied and compared with untreated 40X steel and steel 20.

The scheme of MPT of flat specimens:

1 – strengthening tool; 2 – specimen;
3 – lathe's table; 4 – supply of the technological medium (TM); P - pressure in the friction contact zone; V_{tool} and V_{table} – the speed of strengthening tool and table (specimen); S - longitudinal feed.

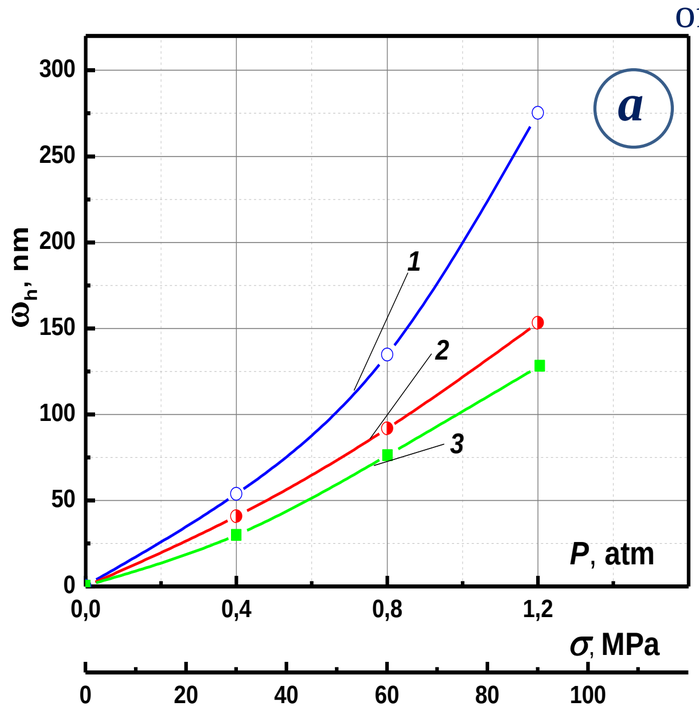


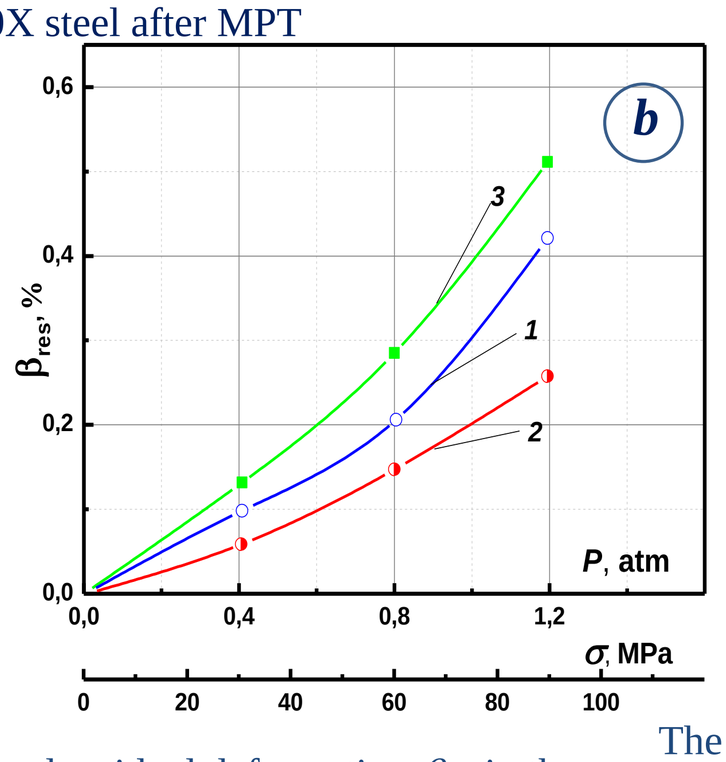




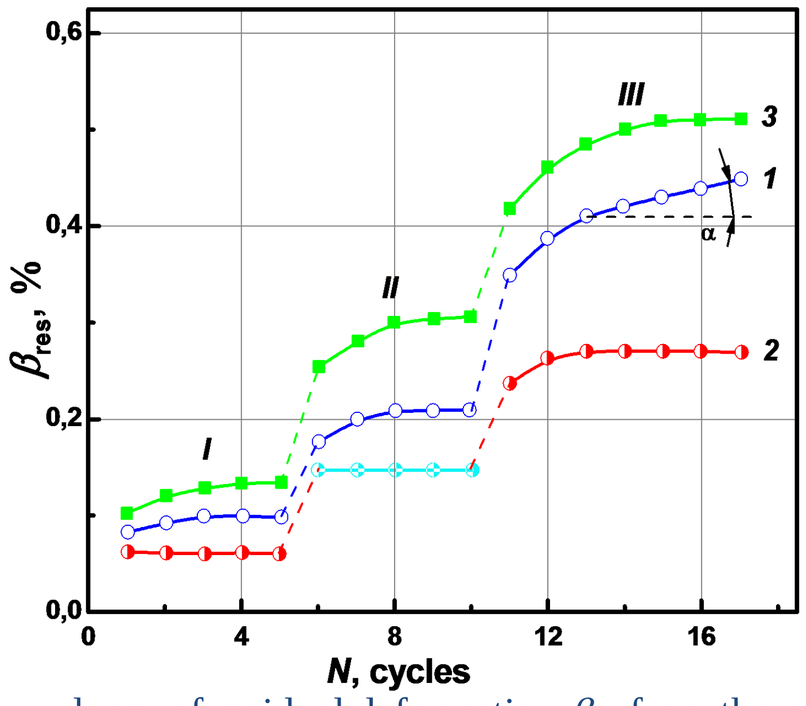
The diffraction pattern of the steel 40X with NCS made on the depth of 10 μm from the surface.

Microhardness distribution in the depth from surface (*a*) and microstructure (*b*) of 40X steel after MPT





The dependence of elastic hysteresis ω_h (*a*) and residual deformation β_{res} in the saturation range (*b*) from applied loads σ for untreated 40X (*1*), strengthened 40X steel with surface NCS (*2*), and for untreated steel 20 (*3*).



The dependence of residual deformation β_{res} from the number of cycles *N* of applied loads σ for untreated 40X (*1*), strengthened 40X steel with surface NCS (*2*), and for untreated steel 20 (*3*): *I*, *II*, *III* received at the applied loads σ = 30, 60 and 90 MPa.

Results. The elastic hysteresis of 40X steel was investigated by determining deflection and residual deformation of specimens depending on the applied loads. It was found that 40X steel with the surface NCS behaves like an elastic body after 1-2 cycles of loading compared to 5-7 cycles for untreated 40X steel. Residual deformation β_{res} was 30-40% less for 40X steel with the surface NCS. The elastic limit for 40X steel with surface NCS is σ ≥60 MPa, and for untreated steel it is 2 times lower, σ ~ 30 MPa. Increasing in elastic limit for the treated steel occurred due to high dislocation density of the surface refined structure.

Conclusions. The surface NCS formed on 40X steel due to significantly lower elastic hysteresis ωh and especially low residual deformation β_{res} is expected to possess higher values of fatigue and service life than the untreated one, since these characteristics are inversely proportional to ω_h and β_{res}.