MICROSTRUCTURE AND MICROHARDNESS HOMOGENEITY OF THE LOW-CARBON STEEL Fe-Mo-Nb-V-C PROCESSED BY HIGH-PRESSURE TORSION

Maier G.G[1], Astafurova E.G.[1], Koshovkina V.S.[2], Melnikov E.V.[1], Naydenkin E.V.[1], Odessky P.D.[3], Dobatkin S.V.[4]

[1]*Institute of Strength Physics and Materials Science, SB RAS, Tomsk, Russia*
[2]*National Research Tomsk Polytechnic University, Tomsk, Russia*
[3]*Central Research Institute of Building Structures, Moscow, Russia*
[4]*A.A. Baikov Institute of Metallurgy and Materials Science, RAS, Moscow, Russia*
galinazg@yandex.ru

The influence of high-pressure torsion (HPT) on the microstructure and microhardness of low-carbon Fe-Mo-Nb-V-C steel was investigated using electron microscopy, X-ray researches and microhardness testing. Three initial states of steel, i.e. normalization at 920 °C for 0.5 h and cooling with a furnace (state I); quenching after 920 °C for 0.5 h into the cold water (state II); and quenching after 920 °C for 0.5 h following by tempering at 670 °C for 1 h (state III), were used. The unconstrained HPT was conducted under a pressure of P = 6 GPa (states I, II), P = 4 GPa (state III) for 5 revolutions at room temperature.

After HPT, steel specimens were highly deformed, and their structures were fragmented into small (sub)grains with the mean sizes of 91±57 nm for state I, 98±72 nm for state II, and 100±73 nm for state III as measured using TEM dark-field images. Selected area electron diffraction (SAED) patterns indicate that formed structures are ultrafine-grained ones, as these patterns are shaped close to a circle independently on initial states. The character and distribution of reflections on SAED patterns imply the presence of both low- and high-angle boundaries between structural elements. According to X-ray analysis the sizes of coherent-scattering regions for HPTed speciments decrease down to 45 nm (state I), to 25 nm (state II), and to 80 nm (state III). Independently on initial treatment, the values of a microstrain of a crystal lattice change from ~ 10^{-4} in initial states to ~ 10^{-3} after HPT, which indicates the presence of the large internal microstresses σ^{II} ≈700 MPa in structure of steel after HPT. The values of dislocation density after HPT calculated from the broadening of X-ray lines are of ~ 10^{11} cm^{-2}, which are much higher than that for the initial states.

The increase of microhardness up to 700 HV (state I) and 770 HV (state II) and 600 HV (state III) was observed after HPT compared to initial states (160 HV for state I, 320 HV for state II and 200 HV for state III). The distribution of microhardness is more homogeneous in the case of deformation of the samples in states I and II (HV (edge) / HV (center) = 1.4 and HV (edge) / HV (center) = 1.2) in comparison with the state III (HV (edge) / HV (center) = 1.7). That is a result of both differences in the applied pressures (6 GPa for states I and II, 4 GPa for state III) and initial state of steel prior to HPT. Between two states (I and II) deformed at the same conditions, and HPTed state II demonstrates more homogenous distribution of microhardness along the disk radius due to high initial (before HPT) dispersion of the structure. These differences are caused by high initial dispersion of the structure due to phase hardening in the quenched state compared to the states after normalization and after quenching following by tempering.

This research was partially supported by the Fundamental Research Program of RAS on 2013-2016 (III.23.2.2.) and a grant of President of Russian Federation (project No. SP-4682.2013.1).