Nanostructured surfaces

Mechanical nanostructuring the surface layers of metallic materials using ultrasonic impact treatment

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In recent years, great progress has been made in the study of ultrafine-grained (UFG) and nanocrystalline (NC) materials having equiaxed microstructures with a large fraction of high-angle boundaries [1]. The ultrasonic impact treatment (UIT) shows good efficiency regarding the strain induced grain refinement and providing the overall superior functional properties for different metallic materials [2, 3].

This work presents examples and mechanisms of mechanical nanostructuring of the surface layers of metallic materials with different crystalline lattice, stacking fault energy, propensity to shear banding, twinning and phase transformations. Under consideration are also construction materials, such as aluminium alloys (5056, 2024), carbon steels, austenite stainless steel (AISI 321), titanium alloys (c.p.Ti, Ti6Al4V, Timetal-LCB), Zr-Nb alloys, AlCuCrCoNiFe high entropy alloy.

The determinative effects of several UIT parameters on the nanostructurization efficiency are shown to be as follows: high strain extent ($e \approx 4$), high strain rate ($\sim 10^3$), successive multidirectional impact loads containing the shear component of load (sliding impacts), and strain induced temperature rise enough to initiate the dynamic recovery/recrystallization or phase transformations.

The UFG/NC microstructure (grain size of 20-150 nm) and compressive stresses formed by UIT in the surface layers (~30-150 μm thick), and diminished surface roughness provide exceptional physical and mechanical properties of metallic materials. Thus, UIT can be used for producing modern construction and functional materials with enhanced fatigue durability, improved wear and corrosion resistance, starting from the raw materials of different initial strengths, phase compositions, and structures.

1. *Estrin Y., Vinogradov A.* Extreme grain refinement by severe plastic deformation: A wealth of challenging science // Acta Mater.-2013, **61**, 782-817.
2. *Mordyuk B. N., Prokopenko G. I.* Ultrasonic impact peening for the surface properties' management // J. Sound Vib.- 2007.-**308**.- P. 855-866.
3. *Mordyuk B. N., Prokopenko G. I.* Ultrasonic impact treatment – an effective method for nanostructuring the surface layers of metallic materials // in: Handbook of Mechanical Nanostructuring, Wiley-VCH.- 2015.- P. 417-434.