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FEMTOSECOND LASER PROCESSING OF TUNGSTEN MONOCARBIDE ALLOY CUTTING TOOLS

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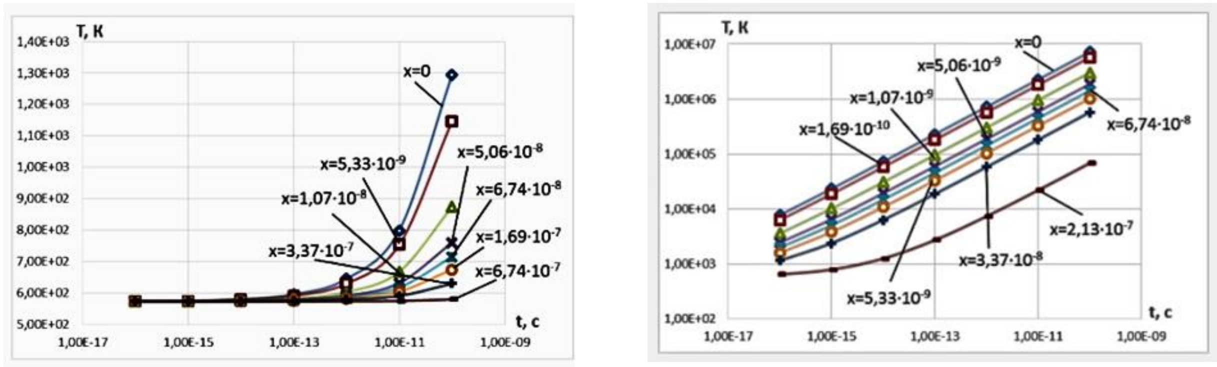
Introductions: Nanostructured materials with extremely fine grain sizes are known to have unusually high strength and toughness, higher diffusivity, beneficial sintering properties, and other characteristics that enhance the performance and reliability of tungsten monocarbide alloy part designs. This article presents the mechanism of formation of nano and subnanolayers and the influence of nanostructure on grain growth within the nanometric range have been revealed. The possibility of processing an alloy of tungsten monocarbide with a femtosecond laser beam has been demonstrated in order to form a nanostructured layer with fairly small grain sizes (about 10 nm), which can radically improve the properties of this alloy and ensure high performance and efficiency of its operation.

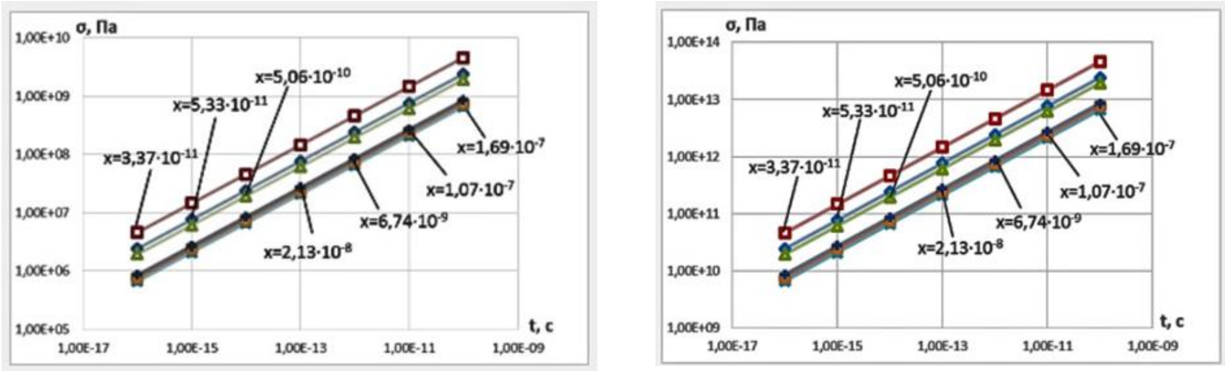
Results and discussion: By that day a lot of works were made at nanostructure (NS) research, lots of works dedicate to experimental research [1, 2] Over the past decade, the study of nanotechnology in materials science and engineering has advanced significantly. NANO is the science discipline there at heart of developing technologies with a nanomaterial size of 1–100 nm with variety of shapes and morphologies [3, 4]. The conducted research into the possibility of forming nanostructures using laser processing in the femtosecond range of a hard alloy made of tungsten monocarbide will significantly improve the performance and efficiency of cutting tools. It is often easier to adjust the pulse time in laser installations than the heat flux density. Therefore, the dependences of the maximum temperature, temperature change rate and temperature stresses in the laser radiation zone on the instrumental tungsten monocarbide alloy material from the time of action of the heat flux at different depths were constructed (fig. 4 – 6). So, in pic. 4 shows dependences of the maximum temperature in the LR action zone from the time of action of the heat flow (a - q=10^{12} W/m^2, b - q=10^{16} W/m^2). It can be seen that with increasing of operating time the temperature rises, especially rapidly for the heat flux density q = 10^{12} W/m^2 (fig. 1 a), moreover the formation zone of the nanostructures is concentrated at relatively large times 10^{-12} – 10^{-14} s, at shorter times the temperatures exceed the required. For bigger heat flux densities of 10^{16} W/m^2, zones for the criterion of the required temperature range are shifted to an almost minimum time of 10^{-16} s (fig. 1 b).



a **b**

Fig. 1. Dependence of the maximum temperature in the zone of action of laser radiation on tungsten monocarbide material from the time of action of the heat flux at different depths with the density of the heat flux: a - q=10^{12} W/m^2; b - q=10^{16} W/m^2.

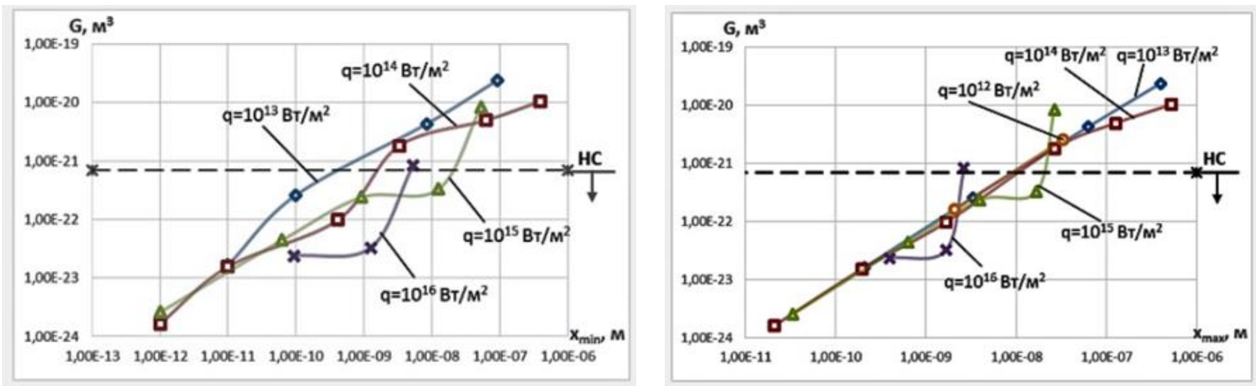
The effect of temperature stresses leads to an acceleration of the formation of NS at tension 10^7 – 10^9 Pa, and at tensions exceeding 10^{10} Pa, there is a real possibility of the formation of NS directly due to the action of temperature stresses. The results of the research of the dependence of the temperature stresses in the LI action zone on time at different depths are shown in the fig. 6. With a heat flow density of q=10^{16} W/m^2 at times of 10^{-10} – 10^{-15} s, there is almost always a probability of NS formation due to thermal stresses. Only at times 10^{-16} s at large depths, temperature stresses can only accelerate the process of formation of NS. In the other cases, the acceleration of the formation of the NS with the action of temperature stresses can almost always be realized.



a **b**

Fig. 2. Dependence of temperature stresses in the zone of action of laser radiation on tungsten monocarbide material from the time of action of the heat flow at different depths with the density of the heat flux: a - $q=10^{12}$ W/m^2; b - $q=10^{16}$ W/m^2.

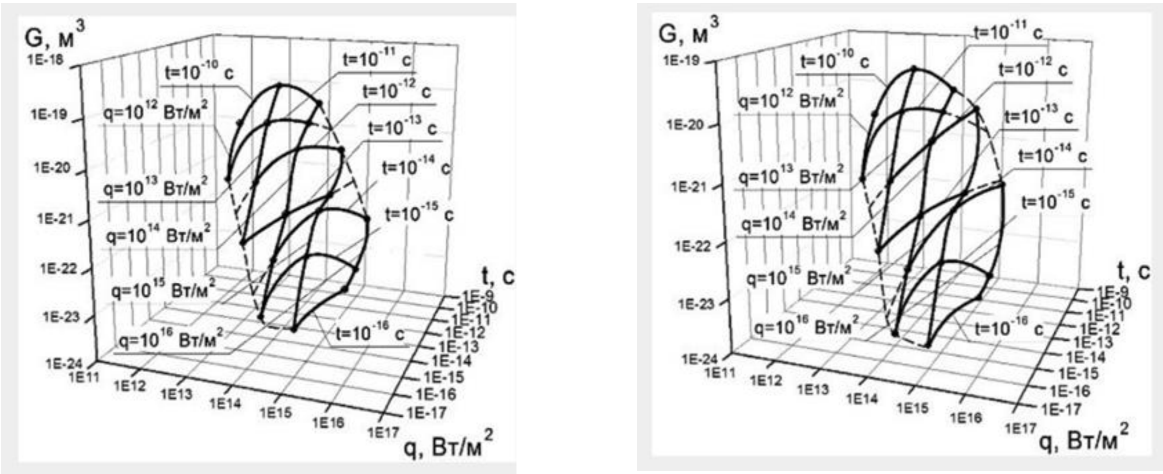
The grain size determines the possibility of realization nanostructures in the material, and the technological parameters that provide them are an important result of the research. In addition, the depth of occurrence of this grain is also important for constructing the surface of parts from nanostructures. Therefore, was made the research of the dependence of the nanocluster volume on the minimum and maximum depth of occurrence of the NS (the dashed line indicated the volume corresponding to the NS emergence boundary). Such dependences are presented for the radius of the LR spot on the detail $R=5\cdot10^{-7}$ m (fig. 3).



a **b**

Fig. 3. Dependence of the nanocluster volume $R=5\cdot10^{-7}$ m from the minimum (a) and maximum depth (b) under the laser radiation acting with different heat flux density q.

For the express-evaluation of technological parameters for the implementation of the NS, volume patterns of the dependence of the nanocluster volume on the density of the heat flux and the time of its action (fig. 4).



a **b**

Fig. 4. Dependence of the nanocluster volume on the density of the heat flux of laser radiation - q and the time of its action t in the zone where nanostructures are produced: a - R=10^{-6} m; b - R=$5·10^{-7}$ m.

Conclusions: Constructed dependencies allow us to select pre-technological parameters, at which the implementation of NS is possible, which have a great practical importance. The conducted researches showed the real possibility of obtaining nanostructures with the help of laser processing in the femtosecond range of the tungsten monocarbide hard alloy moreover we can choose, with the expert review assessment, the pre-technological parameters and laser settings (spot size) in order to obtain nanostructures at a certain depth, and by changing the technological parameters to fill completely with nanostructures a rather significant surface layer of the part (about 10-5 m). All of it will significantly improve the efficiency and effectiveness of the cutting tool from the tungsten monocarbide hard alloy.

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