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PROSPECTS FOR THE USE OF ACOUSTIC FIELDS IN SHS TECHNOLOGIES

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Some regularities of the effect of acoustic fields on the macrokinetics of processes of self-propagating high-temperature synthesis (SHS) are described. The fundamental effects of the ultrasound on processes of structure formation in SHS compacting and SHS building-up are presented. The characteristic features of ultrasonic enhancement of SHS of high-temperature superconductors are shown. Comprehensive studies on the use of acoustic fields for nondestructive quality control of SHS products are made.

In solving problems on improving the operating characteristics of hard-alloy materials and products, coatings and buildups, and powders and sintered products from high-temperature superconductors, special attention is paid to manufacturing processes that allow the structure and the properties of alloys to be modified efficiently. The action of ultrasonic oscillations on an object to be synthesized is one such process.

In [1], the influence of powerful ultrasonic fields on the combustion temperature and rate and the structure and phase composition of the synthesis products in the titanium-carbon-nickel (molybdenum) system is studied. A sample sintered from a mixture of titanium, carbon, and nickel (molybdenum) was put into contact with the ultrasonic radiator coupled with a magnetostriction transducer with a frequency of 18 kHz. Synthesis was performed in argon.

It is found that the combustion rate of a three-component mixture decreases with increasing input acoustic power.

The rate and the completeness of interaction of the components in a mixture with a relatively inert diluent is determined by the ratio of the rates of capillary spreading (wetting) of titanium and nickel over the surface of carbon. The inert metal prevents macrotransfer of titanium, thereby blocking a portion of the reactive surface of carbon.

Ultrasound changes the properties of the melt, namely, it reduces the viscosity [2] and surface tension at the solid-liquid interface [3]. The data of [2, 4] show that the change in the wetting angle (θ) in an ultrasonic field is larger, the greater the initial angle θ. Thus, the influence of a reduction in θ in an ultrasonic field will be more significant for nickel. The latter causes intense spreading of nickel over soot and blocking of a large surface of the refractory reagent.

The influence of the decrease of the combustion rate is greater, the worse the wettability in the system of inert easily melted component-refractory reagent and the coarser the particles of the inert component. This conclusion was checked on a number of systems.

Studies of the structure of the synthesized samples showed that the applied ultrasonic field reduced the porosity and rearranged the open system of pores into a system of isolated ones.

As the intensity of the ultrasound grows, the structural homogeneity of the products is enhanced. The ultrasonic action suggests that all carbide grains are surrounded by a nickel (molybdenum) interlayer. The size of the carbide grains decreases. When the ultrasound in imposed on the combustion process, the lattice constant of titanium carbide increases, which points to saturation of the carbide by carbon. These patterns are caused by enhancement of heat and mass transfer processes in the ultrasonic field and suggest that it is advantageous to

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perform SHS compacting in the ultrasonic field. For the latter to be realized an installation is designed that allows compact blanks and products 50 mm in diameter to be manufactured. The ultrasound is turned on simultaneously with the initiation of SHS reaction and acts on all production stages of the SHS compacting.

The studies of the Ti-C-Ni system as an example showed that the density and the hardness of the hard alloys synthesized in the ultrasonic field are higher than in control samples. The residual porosity is more uniformly distributed over the volume of the products. A considerable refinement of the carbide grains is seen.

The 1.5-2-fold refinement of the grains of the double carbide (Ti, Cr)C is also seen in the structure of alloys containing a fourth ingredient (STIM-3B).

It is interesting that the ultrasonic field moves the concentration limit of combustion in the direction of increase in the nickel content in the mixture. Moreover, the conversion degree of the carbides increases. For example, when the ultrasonic field is absent, carbide $TiC_{0.75}$ is formed from the Ti-C-Ni system at 60 wt. % nickel; when the ultrasonic field is applied, the combustion limit is shifted to 75 wt. % nickel, with formation of $TiC_{0.82}$. These effects are obviously caused by the enhancement of reactive diffusion and self-heating under interparticle friction and ultrasonic energy absorption by the melt.

To quantitatively evaluate the influence of the ultrasonic field on the physicomechanical and operating characteristics of the alloys the bending strength was measured, and the cutting properties of plates fabricated from the synthesized blanks were studied. It was found that as the hardness grew, in the ultrasonic field the bending strength increased from 110 to 130 kg/mm^2 for the alloy in the Ti-C-Ni system and from 88 to 110 kg/mm^2 for the alloy in the Ti-Cr-Ni-C system. The cutting properties of the plates fabricated from the Ti-Cr-Ni-C alloy synthesized in the ultrasonic field were improved 1.5-3.0 times.

At present, following the technology of SHS compacting in the ultrasonic field, hard-alloy matrices and draw plates 50 mm in diameter have been fabricated from different high-temperature and scale-resisting materials.

High-frequency ultrasonic oscillations are successfully used for rapid diagnostics of SHS alloys of the group STIM-5 [5]. It is shown that the dispersion of the sonic velocity is the measure of homogeneity of the alloys. Correlations among the structure and the acoustic, physicomechanical, and operating properties of the alloys are constructed. The operating characteristics of an alloy are improved when the sonic velocity increases. Dependences of the sonic velocity C on the porosity of SHS alloys Π of the type $\ln C = A - B\Pi$, where A, B are constants for a particular alloy, are constructed.

The present article deals with comprehensive studies of the influence of the ultrasonic field on the formation of coatings under SHS building-up of a complex titanium-chrominum carbide on a steel substrate. During the combustion of the CrO_3-TiO_2-Al-C system the ultrasonic field action causes the velocity of the propagation of the SHS wave to grow, which is caused by acceleration of capillary mass transfer of aluminum in the heating zone and enhancement of processes of dissolution of carbon in the melt of reduced metals and semifinished products.

When high-intensity ultrasonic oscillations propagate in the melt, cavitation and acoustic micro- and macroflows should be considered to be the fundamental effects.

When the build-up is formed in the ultrasonic field, cavitation and acoustic flows exert an substantial influence on the size of the carbide grains of the coating, the width of the transition zone between the interlayer and the coating, the melting depth of the substrate, the completeness of spreading of the melt of SHS products over the substrate surface, the completeness of phase separation, and, finally, the physicomechanical and operating properties of built-up products.

The dependences of the melting depth of the substrate on the amplitude of the oscillations are increasing in nature. When the oscillations are input from the side of the substrate the heat flux from the combustion products to the substrate increases. Powerful acoustic flows and viscous friction at the boundary of growing crystal-melt promote growth of the number of crystallization centers and change in the structure of the build-up. The size of the carbide grains may decrease 2-3 times over the entire height of the build-up. The shape of crystals changes, too.

The dependence of the mean size of the chromium carbide grains near the transition zone on the amplitude of the oscillations is described by a curve with a minimum, and the amplitudes of the oscillations equal to the cavitation threshold correspond to this minimum.

Above the cavitation threshold when the oscillation velocities are high, coarse carbide crystals are entrained from the volume of the build-up to the substrate surface. When acted on by the micro- and macroflows, the material of the substrate is also transferred from the transition zone to the volume of the build-up. In this case, the width of the transition zone decreases to the point of complete disappearance. The hardness of the built-up layer falls, and the shock viscosity and strength grow.

Thus, the ultrasonic field allows control of the structure and properties of the build-up. Under subcavitation conditions (small amplitudes of oscillations) the transition zone width and the adhesion strength grow, while the high hardness and the wear resistance of the surface of the build-up are retained. In the case of high oscillation velocities the transition zone and the hardness decrease, and the strength of the built-up composition, on the contrary, grows.

Enhancement of the heat transfer processes leads to growth of the viscosity of the melts and decrease of the characteristic times of crystallization, which reduces the completeness of phase separation. So, when the combustion stage is acted on by the ultrasound a large number of spherical Al_2O_3 particles are concentrated near the substrate. The cermet composition of Cr_7C_3-Al_2O_3-TiC-metal is a product.

There exist optimal parameters of the action on the process of forming the build-up that provide better spreading of the melt of the combustion products over the substrate.

By productivity the technology of the SHS of powders of high-temperature superconductors, for example, $YBa_2Cu_3O_2$, is unique. The quality of the synthesized powder Y_{123} is determined by the properties of the initial reagents BaO_2, Cu, Y_2O_3 (size and shape of the particles, chemical purity, presence of defects of the crystals, etc.) as well as the ability of this powder to be sintered when products are manufactured in the form of targets, screens, etc.

The present article is concerned with the influence of ultrasonic cavitation treatment of reagents on their reactivity, the combustion parameters, and the structure and the properties of the synthesis products. The effects of ultrasonic treatment of Y_{123} powders are studied, too.

Treatment was performed in organic nonaqueous liquids at field intensities of 2-10 W/cm^2. The frequency of the action was varied over the range 17-44 kHz.

It is found that the greatest effect is manifested when the powder of BaO_2 is subjected to ultrasonic action. The mean size of the particles decreases 3-4 times. The defactiveness of the BaO_2 crystals grows. This reduced its decomposition temperature and the desorption rate of oxygen. The combustion rate in this case increased from 0.65 to 0.85 mm/sec; the oxygen content z in end products increased from 6.80 to 6.95, and the content of impurities (barium cuprates, Y_{211}) decreased from 5 to 2-3% [6].

When the Y_{123} powder is subjected to cavitation treatment, the mean size of the particles decreases 2.5 times. Besides the dispersion, the ultrasound causes growth of oxygen mobility in the lattice and the surface layers of crystals of Y_{123}. The latter causes the sintering rate of the powder to grow considerably, the initial temperature of the main sintering stage to decrease from 860 to 780°C, and the isothermal holding time to decrease 2-3 times [7].

Integrated studies on the use of ultrasonic fields of different frequency ranges in SHS technologies made it possible to reveal some regularities in the ultrasonic field action. As a result ultrasound was recommended as a means to control the process and the properties of SHS products.

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