Influence of surface active agent on the size of metal powder particles during their ball milling in a planetary mill

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Abstract. The paper presents the results of a study of the influence of surface active agent during the ball milling of metal powders in a planetary mill. It is shown that the mass fraction of the surface active agent in the powder mixture under study affects the size of the particles being treated, depending on the time of processing. The particle size distribution, the specific surface area were determined, and the surface morphology of the initial and ball milled particles was studied.

1. Introduction

One of the main tasks of solid state physics, powder metallurgy and mechanochemistry is the grinding of solids to powder with the smallest possible particle size, for example, by ball milling materials in a planetary mill. The degree of grinding depends on the properties of the material, which determine its internal structure (porosity), physical and mechanical properties, such as elasticity, ductility, and strength [1]. Depending on the properties of the material, their grinding mechanisms are realized. As shown in [2], plastic materials (Ti, Al, Ni, Cu, NiCr, Nb) require milder grinding conditions at lower temperatures and lower collision energy, while the initial particles are actively dispersed at the initial time of machining. Further, ball milling of the powder particles becomes similar to the granulation process by the rolling method, which leads to a multiple increase in the average particle size. It is possible to stop the increase in particle size and continue their grinding during mechanical processing using surfactants [3,4]. Surfactants can be liquids or solids that do not chemically interact with the mechanically processed material. The role of surfactants is associated with a modification in the mechanical properties of the material. The mechanical treatment of particles is accompanied by continuous volumetric deformation, which leads to a change in the internal structure, nucleation and the appearance of microcracks and cracks. The adsorption of surfactants on a newly formed particle surface prevents their recovery. In this case, the resulting value of the force arising during stress relaxation is directed through the volume of the material, as a result of which the particle volume is divided along the formed crack.

The purpose of the work is to experimentally study the effect of surface active agents during the ball milling of metal powders.
2. Experimental procedure
In this work, the influence of a surfactant (carbon black P803) during the mechanical treatment of powders of titanium (PTOM-2), cobalt (PK-1U) and nickel-chromium alloy (PH80N20), the fraction is less than 40 microns was studied. The histograms of volumetric and counting particle distributions were determined on particle size analyzer LS 13 320 (Beckman Coulter). The specific surface of the samples was determined by the BET method by thermal desorption of argon with an internal standard. Before the measurements, all samples were heated in a gas flow of Ar and He at temperature of 120 °C for 0.5 h. Particle morphology was determined using Evo MA15 electron microscope (Carl Zeiss). The planetary mill "Activator-2SL" has two cylinders with volume of 250 ml each with inner radius of 42.5 mm, the mass of loaded balls is 160 g for each cylinder, the acceleration of grinding bodies is 117 g, the mass of the processed material is 30 g. Maximum rotation speed of the central axis is 1045 rpm, that of the cylinders is 1550 rpm. As grinding bodies, steel balls with diameter of 5 mm were used.

3. Results and discussion
To study the effect of a surfactant on the initial particles of metal powders, powder mixtures were prepared, the compositions of which are presented in table 1.

| Powder mixture designation | The mass fraction of components |
|---------------------------|--------------------------------|
| 1-1                       | Ti                             |
| 1-2                       | Ti – 5%C                       |
| 1-3                       | Ti – 10%C                      |
| 1-4                       | Ti – 20%C                      |
| 2-1                       | NiCr                           |
| 2-2                       | NiCr – 5%C                     |
| 2-3                       | NiCr – 10%C                    |
| 2-4                       | NiCr – 20%C                    |
| 3-1                       | Co                             |
| 3-2                       | Co – 5%C                       |
| 3-3                       | Co – 10%C                      |
| 3-4                       | Co – 20%C                      |

Control samples of metal powders, as well as their mixtures (table 1) were taken after ball milling for 15, 30, 45, 60, and 90 seconds. Figure 1 shows the experimental dependences characterizing the change in the average volumetric size depending on the time of machining. From the presented data, it can be seen that an increase in the percentage of surfactant in powder mixtures from 5 to 20% during their mechanical processing, ceteris paribus, leads to a significant decrease (dispersion) of particles of metal powders and with increasing time of high-energy exposure remains approximately constant. This is due to the fact that ultrafine carbon black particles, adsorbed on a new surface formed during the bulk deformation of a metal particle, create a protective shell that prevents their further agglomeration.
Figure 1. Change in average volumetric size depending on the time of mechanical processing of the powders: (a) titanium, (b) nickel-chromium alloy, (c) cobalt and their compositions with different mass fraction of surfactant.

Figure 2 shows the change in the values of the specific surface of metal powders and their mixtures depending on the time of machining. The ball milling of powder mixtures (table 1) is accompanied by an increase in the specific surface area (figure 2), which indicates an increase in the number of particles with sizes of one micron or less. Figure 3 shows the morphology of titanium particles, which is also typical for other materials studied, isolated from a mixture mechanically processed for 90 seconds.

Figure 2. The specific surface values depending on the time of mechanical processing of the powders: (a) titanium, (b) nickel-chromium alloy, (c) cobalt and their compositions with different mass fraction of surfactant.
Figure 3. The morphology of particles of ball milled titanium within 90 seconds of the composition: (a) 1 - 1; (b) 1 - 2; (c) 1 - 3; (d) 1 – 4.

4. Conclusion
It is shown in the paper that the mass fraction of the surface active agent in the studied powder mixture affects the size of the ball milled particles, depending on the time of the processing. An increase in the content of the mass fraction of the surfactant in the powder mixture from 5 to 20% leads to a significant decrease in the volumetric average size of the metal particles, while plating them with carbon black. Thus, above mentioned features, it makes it possible to stimulate reactions of interfacial interaction of dissimilar elements, in particular, it increases the reaction rate of self-propagating high-temperature synthesis of chemical compounds, and also makes an additional contribution to the formation of a nonequilibrium structural-phase state of a cermet alloy during its synthesis.

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