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Phenomenological Model of Abrasive Tool Components Mixing Process

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Abstract

The article considers the peculiarities of the process of mixing the abrasive grains with the particles of ceramic binder and adhesion-neutral filler for the manufacture of abrasive tools. We determined the conditions for the uniform distribution of the binder in the molding compound and the aggregation of these components during their mixing, in which abrasive grains become structure-forming. We got the formula for the analytical determination of the mixing uniformity ratio considering the mixing mode, the volume content of the components, and the void ratio of mixture. The implemented theoretical and experimental investigations and the basis of the phenomenological model allowed substantiating the character of the processes, as well as analytically determining, using the derived dependencies, the conditions for the uniform distribution of the components of molding mixtures for the production of heavy-duty abrasive tools.

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Keywords: model; abrasive; binder; filler; tool; mixing uniformity.

1. Introduction

The moldable mixture preparation including a mixing of abrasive grain, binder, filler is considered to be an important stage of the creation of an abrasive tool. The aim of the research is to determine the conditions of the uniform distribution of all the structural elements of the abrasive tool in the molding mix.

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2. The relevance of the research

In the process of the creation of high-performance abrasive tools, there is a very important technological problem [1-23] is to provide the necessary strength of tools. In the first place this problem may be solved due to achieving of a high degree of uniformity of distribution of abrasive grains and binder particles during mixing.

3. Formulation of the problem

In connection with the foregoing, from the Physico-Chemical Mechanics point of view we consider the moldable mixture as a system consisting of a dispersed phase and the dispersion medium. A dispersion phase includes abrasive grains, particles of binder and fillers in solid form, which are distributed in a dispersion medium. This dispersion media may be air for dry mixes and various fluids and solutions for mixtures prepared for the manufacture of tools. The authors [19,20,21] gives the scheme of energy links and contact interactions in a dispersed system "moldable mixture"

It is necessary to mention that at the moment of their mixing contact interactions of a grain, binder particles and filler without humidifier flow in the dynamic conditions.

In the process of mixing abrasive grains, particles of binder and filler without humidifier under the influence of arising forces and stresses start to move relative to each other at different rates which depend on their size. As a result grains, which are larger than particles of binder and fillers, move slower while particles of binder and fillers move faster. It leads to their collisions and the formation of aggregates of two or more particles and grains. Thus, in proportion to such of interaction the aggregating of the dispersed phase is going on until the formation of the structural units in which the abrasive grains are structure-forming.

4. Theoretical part

Within the framework of this paper we determined the possibility of the calculation of the probability of contact interaction of grains and binder particles, using the term "section of collision" [1,2], according to the following functional connection:

$$S = 2\pi \int_0^{\infty} f(V,l)\, l\, dl \tag{1}$$

where V – he rate of relative movement between the grains and particles; l – distance from the center of mass of the particles to the line on which grain moved till the interaction.

The law of distribution of the distance L from any abrasive grain to the nearest particle of binder is the probability P_0 that, at least one particle of binder enters a sphere of radius L. Then:

$$P_0 = 1 - \exp\left[-n_{\text{average}} V_N(L)\right] \tag{2}$$

where $V = 4/3\ (L)^3$; $n_{\text{average}} = 3\varphi/2\pi d^3_{\text{gr}}$; φ – volume concentration of particles; d_{gr} – abrasive grain size.

For the cellular model of the structure and cubic packing of particles between the centers of the abrasive grains was determined in [11-15].

The uniform distribution of particles of binder between abrasive grains minimizes the aggregation of the particles of binder. With aggregation the size of particles increases, that as a result causes the lack or on the contrary the excess of binder in some places of the crock of a tool.

The second condition of the uniform distribution of binder particles in abrasive mixture is their critical concentration [3,16].

This aggregation of particles of binder is characterized by the inequality: