METHODS OF MECHANICAL GRINDING AND DISPERSION ANALYSIS OF SOLIDS

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Introduction

Dispersion of solids - their grinding to particles with smaller sizes. It is carried out to increase the speed of heterogeneous processes. In most practical cases, the use of solid materials in the solid phase and heterogeneous reactions without prior grinding is impossible. As almost all commercially used materials are normally in solid state, grinding is one of the basic operations of their reprocessing. There are various methods of obtaining solids in a dispersed state , of which the most simple, economical and, therefore, the most common is mechanical grinding.

Currently, the world production of powders reaches a billion tons per year. Approximately 10% of generated electricity is spent on this. Several million tons of steel is annually spent on manufacturing grinding solids. Grinding is used in such tonnage industries like mining, cement, glass, food, and in the production of sintered metal , ferrite products , solid fuels for jet engines, explosives, nuclear fuel elements, medicinal powders , poisons , etc.

Depending on the nature of the material and the nature of its use there are different requirement to grinding which are more often quite specific i.e. dispersion, purity, safety, etc. In most cases, the task of obtaining possibly finer powders is set, however, under the conditions of limitation of energy consumption and time. All this led to the need to study the laws of the grinding process and the properties of the powders, and necessitated the development of methods of dispersion analysis. The purpose of scientific papers in the field of grinding solids is to determine the conditions and the development of methods for their most rational use and dispersion.

Along with dispersing and aggregation during grinding, as in any other kind of mechanical treatment, change of crystal structure and energy state of the surface layers of particles occurs. Their study is of interest for physics of surface phenomena and is very important for understanding the mechanism of grinding. Condition of the surface layers significantly affects the interaction between the particles and the medium, and, thus, on dispersion of powders. Knowledge of chemical and physical properties of surfaces in a number of cases is necessary to determine the conditions of practical use of grinded materials.

Basic Methods of Mechanical Grinding and Dispersion Analysis of Solids

Features of a chemical reaction in the solid state under the influence of mechanical energy is generally regarded as the realization of the process in time of thermal rupture under the influence of voltage fluctuation of chemical bonds.

Two questions arise here: a) what chemical processes are initiated and thus occur in the future and b) how the preliminary mechanical treatment can alter the reactivity of solids. In a first possible case, from the analysis of the physical processes that take place during the mechanical destruction of solid substances was

found that chemical changes result in the destruction of crystals and the friction due to the formation of cracks. The model is presented in which in the point of contact with friction there are conditions conducive to impulse excitation of nonequilibrium states. Such states are most often localized on microdefects and characterized with strains many times exceeding the average value of the failure stress. Upon reaching a value corresponding to tensile strength of this compound the process of the formation and propagation of cracks is initiated.

Further course of the process of destruction of the particle kinetic regime is supported by mechanical action due to continuous updating of the contact surface. The second of these questions comes down to the main factors affecting the reactivity of the solid, i.e.: a) dispersion, b) defect formation and c) the formation of mechanolysis products in solid substance. Dispersing - fine grinding of solids and liquids in the environment, leading to the formation of homogeneous dispersion systems: powders, suspensions, emulsions, etc.

Formation of defects can be represented as the process by which matured portion of the atoms or ions leave the regular positions in the lattice and move in an intermediate position - internodes. For elementary crystal vacancy concentration is expressed by the type of state of solids characterized by the presence of non-equilibrium defects called active as opposed to the normal state, which is determined by the equilibrium disorder of the lattice. Measure of activity is a measure of the excess free energy of one mole of substance in a given state as compared to normal. This energy is equal to the affinity of the process: the active substance – thermodynamically stable substance.

Thus, when the mechanical treatment of substance as a result of mechanical influence in the contact region of a solid body, stress field is created and its subsequent relaxation occurs, which is the main ways of heat , crystal defects , the formation of new surface excitation of the chemical reaction. These processes occur in the complex, but preferred direction of relaxation depends on the properties of substance and loading conditions. Presumably, with increasing power of mechanical action there is a gradual transition from the thermal relaxation channel to the channels associated with the accumulation of lattice defects, destruction and interaction. Part of the energy remains in a solid form in excess free energy. It is associated with morphological and electronic defects and maintained for a long time, especially at low temperatures. Such " activated " state leads to the increase in the chemical reactivity of the material. The main reason for the mechanical activation is to increase the enthalpy of the solid as a result of accumulation of crystal defects - vacancies, interstitials, dislocations, grain boundaries and subgrains, as well as increasing of the surface area and degree of disorder. Increasing the number of point , one-dimensional and two-dimensional crystal defects are major contributors to the increase in enthalpy. Come to the surface , line and point defects lead to changes in the energy state of the surface layers. Atoms in the field of elastic distortions around the dislocations become active centers and have a significant impact on the chemisorption and catalysis . As noted above, when the mechanical treatment of solid bodies, the work is mainly spent not so much on a new surface or structural defects as the creation of high-energy , active short-lived excited states [2]. The occurrence of such conditions and the accumulation of power is about 10-15% of the work strain. Multiple plastic deformation of the individual particles results in a significant increase in the contact surface between the reactants. In conjunction with the presence of the particles of the areas on the surface containing microdistortions of crystal lattice and characterized by high values of density of dislocations and free energy, may be sufficient for mixing substances at the molecular level and intensification of the diffusion-

controlled reactions during mechanical treatment. Conditions to facilitate this process, are special deformation mechanism and higher temperature. In places of contacts of grinding solids significant local pressure (up to 15,000 kg/cm^2) and elevated temperatures are developed (up to 1000 ° C) , the existence of such high temperatures with area 10^{-3}-10^{-5} cm^2 is 10^{-4} . As a result, leakage of solid state reactions with the formation of intermediate, metastable compounds is possible in microvolumes.

In reality, a reflection of the complex physical and chemical processes occurring during the machining process, is the change of morphology and particle size of the processed composition. In general, their formation is described by the following scheme. When handling the powder mixtures in mechanoreaktor, processes of destruction and formation of particles by welding granular composition flow simultaneously.

At different processing stages, only one of the them prevails. In general, when plastic deformation, density of crystal defects continuously grows. When a critical value as a result of the interaction of force fields of dislocations in local volumes of crystals is achieved, submicron fractures, in which destruction of particles occurs, appears. In parallel with the destruction of the particles, resulting in adhesion processes, agglomeration and granulation occur. Adhesion of the particles is mainly due to van der Waals and electrostatic forces and receives its development, primarily in the areas of contact with fresh surfaces [3]. On impact of the grinding solids in these places agglomerated composition cold welding occurs, accompanied by diffusion processes . In practice, by means of the stage of mechanical treatment of solids, the possibility of obtaining homogeneous , finely divided , highly powder particles is realized, thereby reducing the time and temperature of the synthesis / sintering and formation of qualitative microstructure of the article and ultimately improving the structure-sensitive properties of the material as a whole.

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