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DEFORMATION, MICROSTRUCTURE EVOLUTION AND PROPERTIES OF GRANULATED AND AGGREGATED CERAMIC POWDERS UNDER COLD ISOSTATIC PRESSING

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The work is devoted to an important problem of forming green compacts with homogeneous microstructure that ensures sintering of high-performance structural ceramics from granulated and aggregated ultrafine powders [1].

Possible mechanisms of granulated or aggregated powders densification under cold isostatic pressing (CIP) have been discussed with a special emphasis on zirconia ceramics (ZrO_2 + 3mol. % Y_2O_3) at pressures up to 0.8 GPa. A model of multistage densification of aggregated powders was applied to describe the pressure effect [2].

Compaction of nanopowder materials by isostatic pressure effect occurs due to deformation granules, aggregates, particles in consecutive order and due to their sliding relative to each other. Therefore, according to the work [3] the plasticity condition of the powder body can be introduced as

$$\frac{P^2}{\psi(\rho)} + \frac{\tau^2}{\varphi(\rho)} = \rho k^2, \quad (1)$$

where p is macroscopic hydrostatic pressure; τ is intensity of the macroscopic stress deviator; ρ is relative density; $\psi(\rho)$, $\varphi(\rho)$ are functions of porosity equal to

$$\psi(\rho) = \frac{2}{3}\frac{\rho^3}{1-\rho}, \ \varphi(\rho)=\rho^2.$$

k is the yield strength of the powder material in shear.

When powder materials compacted by slipping

$$k = K + \alpha P, \quad (2)$$

where K is the shear binding coefficient (Pa); α is the internal friction coefficient.

During isostatic compression τ=0 and equation of the powder densification derived from the model (equations 1, 2) is as follows:

$$\sqrt{\frac{2}{3}}\frac{\sqrt{1-\rho}}{\rho^2} = \alpha + \frac{K}{P},$$

Above equation can be used to identify densification stages (see Table 1) and to determine properties of granules, aggregates and particles, namely, shear binding coefficient K characterizing the granule or aggregate strength and internal friction coefficient α characterizing the mechanism of densification [4]. In the case of granules (aggregates) fragmentation coefficient α is close to zero.

The advantage of using this equation is that the coefficients K and α are the characteristics of powder materials. The shear binding coefficient K characterizes strength of bonds between granules at first densification stage, between aggregates at second stage and between particles of powders at third one. The value of this coefficient depends on the material and manufacturing technology of powder. The value of the internal friction coefficient depends on the mechanism of deformation of powder.

Also, since the properties of the granules, aggregates and particles are different, the values of the coefficients K and α at different densification stages will vary.

The coefficients K and α are determined by plotting relation $\rho(P)$ in the coordinates:

$$x=\frac{1}{P}, \quad y=\sqrt{\frac{3}{2}}\frac{\sqrt{1-\rho}}{\rho^2}$$

The calculation of the coefficients K and α for the Tosoh TZ-3Y zirconia powder is shown in Figure and Table 2. The calculated value of the coefficient K characterizing the strength of granules is equal to 5 MPa and the strength of aggregates is equal to 68 MPa.

Obtained results enable to find optimal CIP pressure providing the homogeneous microstructure of compacts. Subsequent sintering at various temperatures had confirmed validity of the proposed approach. Also, these results allow us to determine the effect of process conditions on the powder properties and regulate the process correctly.

Table 1. Densification stages for aggregated powders.

Stage	Mechanism of densification	Structure of compacts
1	displacement of granules	granules
2	deformation and fragmentation of granules, displacement of aggregates	aggregates
3	deformation and fragmentation of aggregates, displacement of particles	separate particles

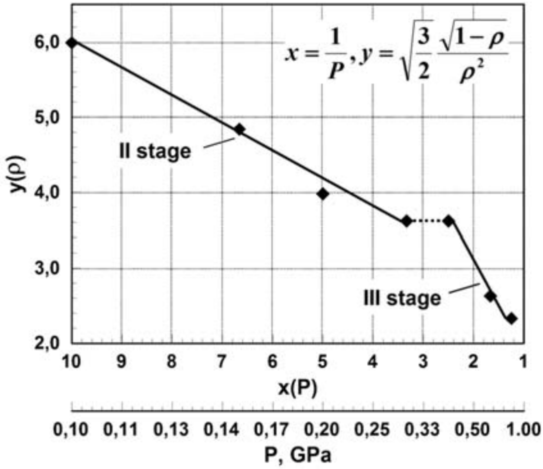

Figure. Fitting of densification stages in the case of the aggregated powder.

Table 2. Values of the coefficients *K* and α calculated on the basis of density values of granules aggregates and powder particles.

Stage	CIP pressure *P*, MPa	Density	Coefficients		Mechanism of densification
			K, MPa	α	
1	0.1–8	$\rho_{granule}$=0.36	0.05	1.56	-
2	8–50	$\rho_{aggregate}$=0.58	7.5	1.28	deformation and fragmentation of granules, $\alpha(\rho_{granule})=0$
		$\rho_{granule}$=0.36	5	0	
3	60–400	$\rho_{particle}$=1	194	2.47	deformation and fragmentation of aggregates, $\alpha(\rho_{aggregate})\approx 0$
		$\rho_{aggregate}$=0.58	68	0.25	

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