EXPERIMENTAL STUDY OF THE GRADING COMPOSITION
OF ALUMINIUM OXIDE FINELY DISPERSED POWDER,
SYNTHESIZED IN A THREE-JET PLASMA CHEMICAL REACTOR

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ABSTRACT

The influence of reactor operating conditions on the grading composition of Al₂O₃ finely dispersed powder (FDP) was investigated. It was found that the mass flow rates of the plasma gas and raw material are the main factors for mean particles size control.

1. INTRODUCTION

Grading composition of FDP is important characteristic for its practical application. The problem to control grading composition is of practical importance. The results of previous works /1/ have shown, that the formation of FDP consists of follow stages, particulary crossing in time: a) formation of condensed phase nuclei, b) nuclei growth by vapour condensation, c) particle's coalescence, d) particle's aggregation by adhesive force. Gas temperature and velocity distributions in reactor can significantly influence on the rate and duration of every stage. The changing of raw material and plasma jets mixing conditions allows to control the said distributions. Also it can be done by changing plasma jet enthalphy and velocity.

2. EXPERIMENTAL

Aluminium oxide powder was synthesized from aluminium powder (mean diameter 10⁻⁵m) in nitrogen-oxygen plasma flow. Aluminium was injected by oxygen transport jet in the collision zone of three air plasma jets. The schematic of reactor and mixing chamber is shown in Fig. 1. The morphology and size of produced powder were studied by the electron microscope JEM-100CX, and phase composition was studied by X-ray diffractometer DROM-2.0. Synthesized powder consists of spherical particles. The range of particle's size is 2-80 μm. There were observed three phases in the Al₂O₃ FDP: δ, θ and γ' (identification by ASTM X-ray diffraction data cards). The main phase is the δ-phase. Quantitative phase analysis was not done because of absence of chemically pure single phase patterns. Al₂O₃ FDP size distribution is shown in Fig. 2.
Fig. 1. Schematic of mixing chamber and reactor
1-3 D.C. arc plasmatrones, situated on the chamber under
the angle $120^\circ$ between each other, 2 - mixing chamber,
3 - reactor

Fig. 2. $\text{Al}_2\text{O}_3$ FDP size distribution $\alpha = 60^\circ$
1 - $K = 2.72 \times 10^{-2}$, 2 - $K = 4.42 \times 10^{-2}$
This distribution is close to log-normal distribution. The deviation from straight line in region of large size points on the broadening of distribution. That broadening is caused by the character of gas flow in reactor. The evaluations carried out have shown, that at experiment conditions coalescence is a limite stage of synthesis. The gas temperature and velocity distributions in reactor during coalescence stage, and the duration of the stage can greatly influence on the particles size. The measurements of temperature and velocity fields in the reactor were carried out by enthalphy probe. It was found, that two zones exist in reactor: zone of jet flow near reactor axis and recirculation zone near its wall. The schematic of flow field is shown in Fig. 4. AI\textsubscript{2}O\textsubscript{3} particles coalescence in the zone 1, which is bounded by isothermal line \( T = T_c \) (under the temperature below \( T_c \) no coalescence takes place). While the gas flow moves in zone 1 at the segment \( x - x^* \), the mass flow rate of the gas, entrained from recirculation zone 2 to zone 1 is increased and achieves maximum at \( x = x^* \). The temperature at the reactor's axis at \( x = x_{\text{max}} \) is equal \( T_c \). Frequent "active" zone (see Fig. 4) results in the broadening of size distribution. We studied the influence of mean enthalpy and velocity of plasma jet, and also two-phase parameter \( K = G_p(G_t + G_g) \) on the mean size of the product particles. Mean volume-surface diameter \( d_{32} \) was taken as mean size. It was calculated from specific surface area \( S \) measurements (BET method) by formulae (1):

\[
d_{32} = \frac{6}{\rho \cdot S}
\]  

(1)

It was accepted, that the FDP density is equal the density of AI\textsubscript{2}O\textsubscript{3} phase - 2400 kg/m\textsuperscript{3}. The calculation of \( d_{32} \) by particles size measurements from electron microscope photgraphs have shown, that the value of \( d_{32} \), calculated from formulae (2) is 1.5-1.7 times less than \( d_{32} \) value calculated from (1).

\[
d_{32} = \frac{\sum N_i d_i^3}{\sum N_i d_i^2}
\]  

(2)

Perhaps, this disagreement is because of small quantity of measured particles (700-900) or because of arbitrary chosen value of AI\textsubscript{2}O\textsubscript{3} FDP density. Fig. 3 shows the value of \( d_{32} \) calculated from (1) as a function of parameter \( K \) under condition, that the angle between jet and reactor axes \( \alpha \) is 60°. It is obvious, that the change of mean mass enthalpy and velocity in the range 8-12 MJ/kg and 100-200 m/s respectively weakly influenced on the mean particle size.

3. RESULTS

The two-phase parameter \( K \) is the main factor, which controls FDP particles mean size. The size distribution of FDP is close to log-normal distribution.
Fig. 3. Mean particle size $d_{32}$ as function of two-phase parameter $K$

- $H = 8$ MJ/kg, $u = 100$ m/s; 0 - $H = 12$ MJ/kg, $u = 200$ m/s

Fig. 4. Schematic of the gas flow field in the reactor

1-"active" reaction zone ($T > T_c$), 2-recirculation zone, 3-"passive" zone of jet stream (there is no coalescence taking place in it)
NOMENCLATURE

$G_p$, $G_{t_g}$, $G_G$ - mass flow rate of raw material, transport gas and plasma gas, $N_i$ - a number of FDP particles with diameter $d_i$, $i = 1,...,i_{\text{max}}$ - a number of particle's fraction, $\phi$ - density.

REFERENCES