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PRELIMINARY COMMUNICATIATION

Physical modelling of representative particles of electrodeposited copper powders

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Abstract: A method for the estimation of the size of the representative particle of a copper powder is given. Cross sections of representative particles of flowing and non-flowing powders estimated by this procedure are also presented.

Keywords: copper powder particles, copper powder flowability.

INTRODUCTION

The concept of the representative particle[1] of a copper powder was successfully used for the determination of the critical apparent density at which free flow of the copper powder becomes possible,[2] as well as for the determination of the surface and internal structure of particles of flowing and non-flowing powders.[3,4] This was done by modelling the properties of representative powder particles. The aim of this work was to initiate the physical modelling of them, which means not just behaviour, but also structure modelling. Spherical particles were used in order to avoid the influence of particle shape on flowability, *i.e.*, to emphasize the effects of the surface structure. The elementary cell of 3D-cross shape was chosen, as this shape was shown as suitable for relating powder properties with the properties of a particle. As opposed to previous paper,[1] where the particle was presented by a 3D-cross, here this shape was used for the presentation of the elementary cell. Certainly, the requirement for the representative particle to be of spherical shape is not very rigid. Actually, a particle which is required in the first approximation can be considered as roughly (nearly) spherical and which is composed of elementary cells, *i.e.*, of a 3D-cross. Contrary to a previous paper,[4] where the elementary cell was calculated, in this work the dimensions of the particle were also calculated.

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DISCUSSION

A copper powder is not composed of particles of identical size and morphology and, consequently, it is difficult to relate the properties of the powder with the properties of the particles.[1] The situation can be simplified by using the representative particle, as the particle which has the same specific surface as the powder. In this way, a powder can be considered as a set of identical particles, which, as it was shown,[2] should be spherical when considering the free flow of the copper powder. The radius r of the spherical representative particle can be calculated using:

$$r = \frac{3}{\rho' S_{\mathrm{sp}}} \tag{1}$$

where ρ' is the apparent density and S_{sp} is the specific surface of the powder. The surface of the elementary cell of such a particle can be taken as the square segment of the compact metal with edge a placed in the middle of an empty square segment with edge b.[3] As it has already been shown,[4] the corresponding internal structure can be represented by a 3D-cross. The specific surface of the 3D-cross inside the lattice of a powder particle is given by:[4]

$$S_{\mathrm{sp}} = \frac{12(1-k)}{3k-2k^2}\frac{1}{\rho b} \tag{2}$$

where ρ is the density of the bulk metal, the relation of which to the apparent density ρ' is given by:

$$\rho' = \frac{\rho}{2}(3k^2 - 2k^3) \tag{3}$$

and

$$k = a/b \tag{4}$$

On the other hand, it was also shown that:[5]

$$\rho' = \rho^0 + \frac{K^0}{S_{\mathrm{sp}}} \tag{5}$$

where $\rho^0 = 0.12$ g/cm^3 and $K^0 = 944$ cm^{-1}, or

$$S_{\mathrm{sp}} = \frac{K^0}{\rho' - \rho^0} \tag{6}$$

Substitution of S_{sp} from Eq. (6) into Eq. (1) and further rearranging gives:

$$r = \frac{3(\rho' - \rho^0)}{\rho' K^0} \tag{7}$$

which permits the calculation of the radius of a representative powder particle using the known apparent density of the powder.

Simultaneously, elimination of S_{sp} from Eqs. (2) and (6) gives:

$$b = \frac{12(1-k)}{3k-2k^2}\frac{\rho'-\rho^0}{\rho K^0} \tag{8}$$

Obviously, k can be derived from Eq. (3) if ρ' is known. Hence, radius of the representative particle and the dimensions of the elementary cell can be calculated using Eqs. (4), (7) and (8).

The diameter d of a representative particle is:

$$d = 2r \tag{9}$$

and number of elementary cells per diameter n is given by:

$$n = \frac{d}{b} \tag{10}$$

For example, for the representative particle of a powder with $\rho' = 0.528$ g/cm^3 (non-flowing powder[4]) using Eqs. (4), (8) and (10), the dimensions of the particle and elementary cell can be calculated: $d \approx 5 \cdot 10^{-3}$ cm, $b \approx 0.8 \cdot 10^{-3}$ cm, $a \approx 0.2 \cdot 10^{-3}$ cm and $n \approx 6$. For a powder with $\rho' = 2.3$ g/cm^3 (flowing powder[4]), $d \approx 6 \cdot 10^{-3}$ cm, $b \approx 1.5 \cdot 10^{-3}$ cm, $a \approx 0.75 \cdot 10^{-3}$ cm and $n \approx 4$. The corresponding cross sections of the representative particles are shown in Fig. 1.

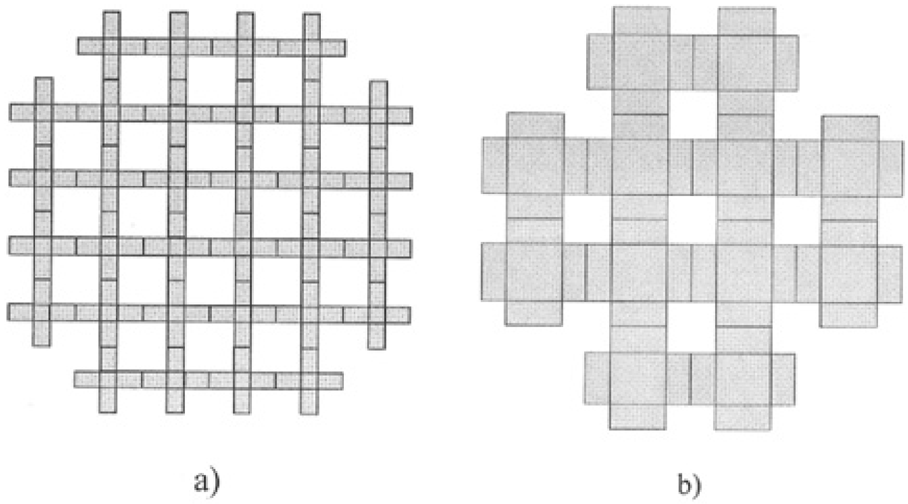

Fig. 1. Shematic presentation of the cross sections of representative particles of powders in the horizontal and vertical plane for different apparent densities: a) $\rho' = 0.528$ g/cm^3, б) $\rho' = 2.3$ g/cm^3. Magnification: × 1000.

It was shown earlier by a procedure based on the modelling of the powder properties[3,4] that a powder with an apparent density lower than a critical value can not flow, while a powder with an apparent density equal to or higher than a critical apparent density can flow. The results obtained in this work are in agreement with this and indicate that a powder of lower apparent density can jam while it is not possible for the particles of a powder of higher apparent density to jam to each other.

It can also be seen from Fig. 1 that the density of the particle decreases with decreasing apparent density of the powder, as well as with the size of it, which is in accordance with literature data.[6,7]

The aim of further work will be the formation of a 3D presentation of above representative particles, and a discussion of their mutual effects.

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ИЗВОД

ФИЗИЧКО МОДЕЛОВАЊЕ РЕПРЕЗЕНТАТИВНИХ ЧЕСТИЦА ЕЛЕКТРОХЕМИЈСКИ ИСТАЛОЖЕНОГ БАКАРНОГ ПРАХА

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У раду је дат метод за процену величине репрезентативних честица бакарног праха. Представљени су попречни пресеци репрезентативне честице течљивог и нетечљивог праха добијени коришћењем овог поступка.

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