INVESTIGATION AND MEASUREMENT OF THE PARTICLE SHAPE FACTOR FOR BULK MATERIALS

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A new method of measuring the shape factor of the particles composing bulk materials and its theoretical basis are described.

The shape of particles of bulk materials can be characterized in two ways: by the ratio of the particle dimensions in three mutually perpendicular directions and by the angularity of the particle contour (i. e., the degree of nonuniformity of the surface curvature).

With respect to the first of these characteristics particles can be divided into three types: compact (all three dimensions similar), rod-like, and lamellar.

The idea of a shape factor is primarily of interest in connection with compact particles since, firstly, in this case it is much less definite and, secondly, compact particles are the most widespread.

With respect to the second characteristic compact particles can be divided into three groups:

1) particles with maximum angularity—tetrahedra and cubes (Fig. 1a);

2) particles with minimum angularity—spherical particles (Fig. 1b);

3) intermediate particles, i. e., particles bounded by planes and with rounded edges and corners (Fig. 1c).

The averaged shape of the particles of a specific natural bulk material is characteristic and may be regarded as a property of the material.

The idealized particle of characteristic shape can be represented in the form of a body whose surface is formed by planes and rounded edges and corners.

Of course, each specific particle of an actual batch differs from the idealized particle. In the mass (statistically) these particles display properties (shape-dependent) similar to those of a mass of fictitious idealized particles of characteristic shape.

The method proposed by the author will serve for the the direct objective measurement of the shape factor of particles of granular material over a broad range of variation of dimensions and properties.

The method consists in the experimental determination of the function $a = \Phi(b)$, which uniquely characterizes the particle shape (Fig. 1).

For particles of intermediate shape (Fig. 1c) this function must be found as the statistical solution of the problem of measuring the dimensions a and b in one section of each of the particles forming the entire mass.

In accordance with the method proposed, the dimensions a and b of all the particles are measured by means of a special sieve analysis.

This original sieve analysis employs a set of sieves, some of which have square and some round mesh opening.

Sieving through the sieves with square openings gives a sieve characteristic $\varphi(A)$; the corresponding characteristic for the sieves with round openings is $f(D)$.

A bulk material with cubical particles has sieve characteristics (Fig. 2a) the maximum distance apart along the A-D axis (axis of abscissas).

In this case equal total residues R_i on the sieves with round and the sieves with square openings are obtained at mesh size ratios

$$\frac{D_i}{A_i} = \frac{b_c}{a_c} = 1.41.$$

This property is retained over the entire range of mesh sizes $A_{min}-A_{max}$.

For cubical particles, the shape factor, which can be characterized, for example, by the ratio $K = D_i/A_i$, has a constant and limiting (maximum) value $K = 1.41$ over the entire range of particle sizes (Fig. 2a).

A bulk material with spherical particles has sieve characteristics (Fig. 3) that coincide over the entire range of mesh sizes, since the residue of spherical particles is the same for sieves with round and square openings of the same size (A = D):

$$\frac{D_i}{A_i} = \frac{a_{sp}}{a_{sp}} = 1.00.$$

For spherical particles, the K factor has a constant and limiting (minimum) value K = 1.00 over the entire range of particle sizes (Fig. 2b).

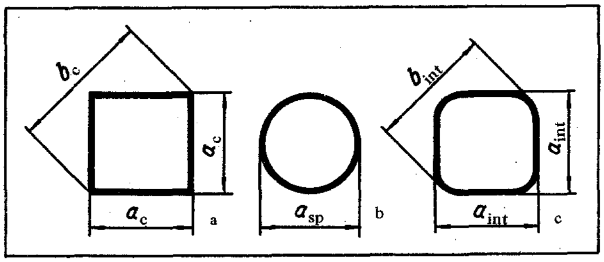

Fig. 1. Shape and dimensions of particle cross sections.

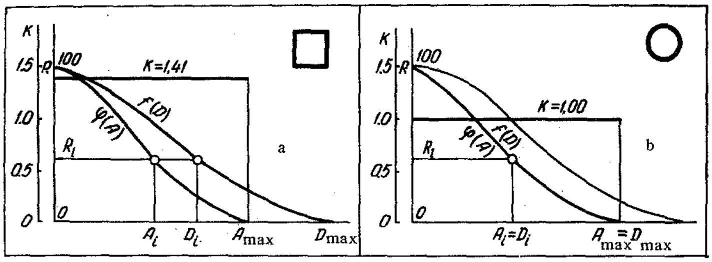

Fig. 2. Complex sieve characteristic of bulk materials with cubical (a) and spherical (b) particles.

A bulk material with particles of intermediate shape has sieve characteristics (Fig. 3), such that the relative distance between them along the A-D axis is determined by the particle shape, i. e.,

$$\frac{D_i}{A_i} = F(K) = \frac{b_{\text{int}}}{a_{\text{int}}} = 1.41 - 1.00.$$

In this case the relative distance between the φ(A) and f(D) curves along the A-D axis is less than the distance between the analogous characteristics for a bulk material with cubical particles having the same f(D) characteristic as the bulk material in question.

The K factor for intermediate particles has the value

$$1.00 < K < 1.41,$$

determined by the shape of the particles. In this case the graph of the function K = α(A) is inscribed in the hatched region of Fig. 3.

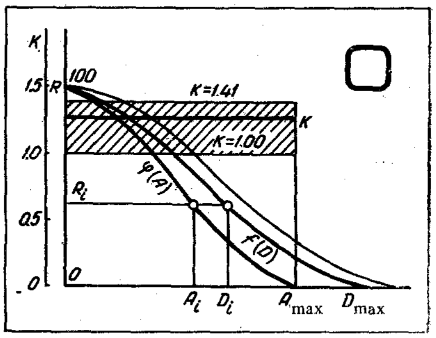

Fig. 3. Complex sieve characteristic of bulk material with particles intermediate in shape between a cube and a sphere.

Thus, by means of the proposed method, for any size fraction, for example, for particles corresponding to a residue R_i (Fig. 3), we can measure the characteristic dimensions a and b. In other words, we can make a direct study (probe) of the entire mass of particles and on the basis of the statistical data obtained directly determine the shape factor of particles of any of the fractions of a polyfractional material.

For a polyfractional material with particles of the same shape over the entire range of particle sizes we have

$$\frac{D_i}{A_i} = \frac{D_i}{A_j} = \ldots = \frac{D}{A} = \text{const.}$$

For a natural polyfractional material with particles of different shape (on passing from one fraction to another) we have

$$\frac{D_i}{A_i} = \theta(A).$$

For such a material we obtain the averaged value of the shape factor

$$K_{\text{av}} = \frac{\int_0^{A_{\max}} K dA}{A_{\max}}.$$

The theoretical and applied significance of the method described consists in that, having used it to obtain the function

$$K = \vartheta\left(\frac{D}{A}\right)$$

for the material in question and having established by a special investigation the relation

$$N = \tau(K),$$

we can finally obtain a functional relation of the form

$$N = \tau(K) = \tau\left[\vartheta\left(\frac{D}{A}\right)\right] = \Omega\left(\frac{D}{A}\right).$$

If we possess data on this unique relation between the technological properties and the shape factor of the particles, we can reliably control the properties by varying the particle shape (by rolling, for example) or predict the properties from shape factor measurements, etc.

NOTATION

a, a_c, a_{sp}, and a_{int} denote the side dimensions of the cross sections in particles of arbitrary, cubic, spherical, and intermediate shape; b, b_c, b_{sp}, and b_{int} denote the diagonal dimensions of the particles cross sections; A is the size of the square mesh opening; D is the size (diameter) of the round mesh opening; K is the particle shape factor; R is the total residue on the sieve, %; N is any investigated technical characteristic of the bulk material.

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