CHARACTERISATION OF MORPHOLOGY OF POWDER PARTICLES

Kohútek I.[1], Käerdi H.[2], Besterci M.[3], Kulu P.[4], Mikli V.[4], Velgosová O.[5]

[1] U. S. Steel Košice, s.r.o,, Research and Testing Institute, 04454 Košice, Slovak Republic

[2] Tallinn Technical University, Ehitajate tee 5, 19086 Tallinn, Estonia

[3] IMR SAS, Watsonová 47, 04353 Košice, Slovak Republic

[4] Estonian Public Service Academy, Kase 61, 12012 Tallinn, Estonia

[5] Faculty of Metallurgy TU, Letná 9, 04001 Košice, Slovak Republic

CHARAKTERIZÁCIA MORFOLÓGIE PRÁŠKOVÝCH ČASTÍC

Kohútek I.[1], Käerdi H.[2], Besterci M.[3], Kulu P.[4], Mikli V.[4], Velgosová O.[5]

[1] U. S. Steel Košice, s.r.o., Výskumný a skušobný ústav, 04454 Košice, Slovensko

[2] Tallinn Technical University, Ehitajate tee 5, 19086 Tallinn, Estonia

[3] ÚMV SAV, Watsonová 47, 04353 Košice, Slovensko

[4] Estonian Public Service Academy, Kase 61, 12012 Tallinn, Estonia

[5] Hutnícka fakulta TU, Letná 9, 04001 Košice, Slovensko

Abstrakt

V práci bola charakterizovaná morfológia práškových častíc analýzou vplyvu rôznych tvarových faktorov mletých WC-Co práškových častíc pripravených viacnásobnou dezintegráciou.

Veľmi dôležitým parametrom práškov vyrobených mechanickým mletím je ich hranatosť, ktorá môže byť charakterizovaná viacerými tvarovými faktormi. V tejto práci boli použité "hrotový faktor" *SPQ* a tvarové faktory (guľatosť *RN*, koeficient guľatosti *RNF*, parameter nepravidelnosti *IP*, predĺženie *EL*, disperzia *DP*). Na základe vyhodnotenia WC-Co práškov boli vyvodené následovné závery:

parameter nepravidelnosti a *SPQ* parameter adekvátne charakterizujú morfológiu častíc a preto môžu byť použité pre charakterizáciu práškov pripravených mechanickým drvením. S rastom hranatosti regulárnych tvarov (z kruhového na trojhranný) hodnoty parametrov *IP* a *SPQ* stúpajú v rozmedzí 1.0-2.0 resp. 0-0.866.

faktor *SPQ* je v porovnaní s parametrom nepravidelnosť citlivejší na hranatosť. Pre drvené prášky hodnota *SPQ* je v rozmedzí 0.652-0.258 zatiaľ čo priemerná hodnota parametra nepravidelnosti je v intervale 1.89-1.76.

Z uvedeného vyplýva, že najoptimálnejšou charakteristikou pre hodnotenie morfológie práškov je "hrotový faktor" *SPQ*.

Abstract

In this paper were characterised the morphology of powder particles by analyse of the influence of different shape descriptors on disintegrated WC-Co hardmetal powder particles produced by multiple disintegrator milling.

A very important parameter of powder particles produced by mechanical methods is their angularity that can be characterized by numerous shape factors. In this work were used the "spike parameter" *SPQ* and shape factors (roundness *RN*, roundness factor *RNF*, irregularity parameter *IP*, elongation *EL* and dispersion *DP*). On the basis of evaluation of WC-Co hardmetal powder particles were determined the following:

the irregularity parameter *(IP)* and spike parameter - quadratic fit *(SPQ)*, the numerical descriptors for shape factor that adequately characterize the particle morphology, may be used to characterize powders produced by mechanical methods. With an increase in the angularity of regular configuration (from circular to triangular), the values of parameters *IP* and *SPQ* are in the range of 1.0-2.0 and 0--0.866, respectively.

the shape factor parameter *SPQ* studied for characterizing WC-Co hardmetal powders is a more sensitive factor for angularity than irregularity parameter *IP*. For disintegrator ground powders, the values of *SPQ* parameters are in the range of 0.652-0.258. At the same time the average values of the irregularity parameter *IP*, what takes into account of ellipticity and irregularity of particles were in the range of 1.89 to 1.76.

Key words: powder particles, morphology and geometrical shape parameter.

Introduction

Technological properties of powders (bulk density, flowability, surface area etc.) as well as the potential areas of their application depend on the particles size and shape. In powder used for thermal spray, their preferable particle size is spherical to have high flowability of powders and optimal conditions of particles melting and their spraying. These are preconditions for producing high density and high wear resistant sprayed or melt coatings. In hard powder used as abrasive material in abrasive tools, high abrasivity (angularity) of particles is necessary. The same problem occurs with abrasive wear, the wear caused by abrasive grits depends on their size, shape, hardness etc.

The morphology of powder particle is evaluated by a description (e.g., spherical, angular, dendritic, dish-shaped and acicular) or quasi-quantitatively, e.g., by means of a geometrical shape parameter. The shape parameter characterizes mainly the shape, without any influence on the size. Qualitative descriptions of particle visual appearance, such as "rounded", "semi-angular" or "angular", have been used to classify and differentiate among various groups of abrasive particles. Several attempts have been made to characterize particle shape using various numerical descriptors (1, 2, 3).

The goal of present study is to analyse the influence of different shape descriptors on disintegrated hardmetal powder particles.

Experimental procedure

The hardmetal powders from used (recycled) WC-Co hardmetal produced by disintegrator technology were studied. Disintegrator technology consisted of preliminary cyclic thermal treatment and mechanical size reduction - milling of pretreated particles by collision. Multistage milling was used for obtaining hardmetal powder with determined granulometry.

A very important parameter of powder particles produced by mechanical methods is their angularity. The particles angularity can be characterize by numerous shape factors (1). It was shown that shape factors - aspect, roundness (see Table 1) - could be used to sufficiently sensitive for angularity.

A modified particle angularity parameter called "spike parameter - quadratic fit" *(SPQ)* was developed in (4). The *SPQ* parameter takes into account only those spikes that are outside the circle with equal particle area centred over the particle centroid. The areas outside the circle with equal particle area centred over the particle centroid. The areas outside the circle, "spikes", are regarded as areas of interest, while those inside the circle are omitted. For each protrusion outside the circle, i.e. "spike", the local maximum radius is found and this point is treated as the spike's apex, as illustrated in (Fig.1). The sides of the "spike", which are between the points "1-2" and "3-2", (Fig.1), are represented by fitting quadratic polynomial functions. Differentiating the polynomials at the point "2" yields the apex angle Θ and the spike value "*SV*", i.e., $SV = \cos(\theta/2)$. The new *SPQ* is calculated as follows:

$$SPQ = SV_{average}$$

a) b)

Fig.1 Schematic illustration of *SPQ* calculation method based on fitting quadratic segments to protruding sections of particle boundary.

As it follows from (4), SPQ particle angularity factor is very sensitive - for different abrasives of +0.25-0.3 mm (glass, silica sand, garnet, quartz, alumina, SiC), the values of *SPQ* are in the range of 0.0231-0.6008.

Table 1 Shape factors of particles of different form

*- see Fig.2

P and A - perimeter and area of the object, d_A -diameter of the circle with equal particle area, D and d - the diameters of the minimum circumscribed and maximum inscribed circles

a and b - the axes of Legendre ellipse with the centre in the object centroid and with same geometrical moments up to the second order as the original object.

N_c - the number of angles (taking into account) in *SPQ* calculation.

Results and discussion

The analysis of different shape factors characterizing of angularity was made on the base of calculated shape factors of particles with different regular configurations.

In Table 1 are given the shape factors (roundness RN, roundness factor RNF, irregularity parameter IP, elongation EL and dispersion DP) and *SPQ* values of regular configurations in order to increase their sharpness: circular, orthogonal, hexagonal, quadrangular, triangular and rhomb (with axes 1:2).

As it follows from Table 1, in this sequence shape factors *IP* and *SPQ* are more sensitive parameters and parameter *RNF* is a more insensitive one. Whereas the shape factor *IP* characterizes integrally both angularity and elongation, so from the values of *IP*, it is not possible to find separately angularity and elongation. As it follows from Fig.3 more sensitive factor for describing the angularity of different regular configurations is spike parameter *SPQ*.

∞ 8 6 4 3 2 $\mathbf{N_c}$

Fig.2 Schematic illustration of *SPQ* Calculation of 1:2 axes rhomb

Fig.3 Dependence of *DP* and *SPQ* on the N_c

Table 2 Angularity parameter *SPQ* of disintegrated WC-Co hardmetal powder

Table 2 presents changes in the parameter *SPQ*, characterizing the dependence of hardmetal powder particles angularity on the number of milling cycles- after 2, 5, 15 and 50 cycles of collision. Also the *EL* and *DP* of studied powders are given. Fig.4a shows the image of cross-section of the analysed powder particles after 2 times and Fig.4b after 50 times of milling. As it follows from Table 2, the circularity of coarse fraction increases (parameter *SPQ* decreases) with an increasing the number of milling cycles. At the same time, the angularity (parameter *SPQ*) of particles of fine fraction does not decrease essentially. It means that fine fraction is the product of direct fracture of milling by collision.

Fig.4 Powder particles cross-sections milled: a - 2x; b - 50x.

Fig.5 Dependence of *EL*, *SPQ* and *DP* on the cycles of grinding

The powder particles shape changed notably after great number (50 cycles) of milling cycles by separative milling. The angularity parameter *SPQ* for these powder particles is equal 0.258. As it follows from Fig.5 the parameter *SPQ* of particles is monotonically decreasing with increasing of milling cycles number (from 2 up to 50).

Conclusions

The irregularity parameter *(IP)* and spike parameter - quadratic fit *(SPQ)*, the numerical descriptors for shape factor that adequately characterize the particle morphology, may be used to characterize powders produced by mechanical methods. With an increase in the angularity of regular configuration (from circular to triangular), the values of parameters *IP* and *SPQ* are in the range of 1.0-2.0 and 0-0.866, respectively.

The shape factor parameter *SPQ* studied for characterizing WC-Co hardmetal powders produced by multiple disintegrator milling is a more sensitive factor for angularity than irregularity parameter *IP*. For disintegrator ground powders, the values of *SPQ* parameters are in the range of 0.652-0.258. At the same time the average values of the irregularity parameter IP, what takes into account of ellipticity and irregularity of particles were in the range of 1.89 to 1.76 [5].

Acknowledgement

This research was sported by the Slovak Grant Agency for Science VEGA (Grant No. 2/6097/99).

Literature

[1] Kulu, P., Tümanok, A., Mikli, V., Käerdi, H., Kohútek, I. and Besterci, M.: Proc. Estonia Acad. Sci. Eng., 1998, 4, pp.3-7

[2] Wojnar, L.: Image analysis, Ed. CRL Press, Washington, D.C.,1999

[3] Kohútek, I., Käerdi, H., Kulu, P., Sülleiová, K., Velgosová, O., Mikli, V., Besterci, M.: Acta Metallurgica Slovaca, 6, 2000, 3, pp.256-260

[4] Stachowiak, G. W.: Wear, 2000, 241, pp.214-219

[5] Mikli, V., Käerdi, H., Kulu, P., and Besterci, M.: Proc. Estonian Acad. Sci. Eng., 2001, 7, 1, pp.22-34