5th Zhengzhou International Superhard Materials and Related Products Conference

Counting particles per carat by means of two-dimensional image analysis

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Abstract

The number of particles per carat is a useful parameter which depends on the particle size distribution of a diamond batch. It is shown, that a two-dimensional image analysis can be used as an alternative method to the physical counting and weighing process for determining the particles per carat value. Theoretical reasons for measuring errors are discussed along with experimental results. In case of blocky saw grit diamond a factor of 1.2 can be applied to the image processing results in order to meet the physically counted values.

Introduction

The proper size distribution of the abrasive particles in a cutting or grinding tool is crucial for the tool performance. The officially approved method for checking the grit size is given by the ISO standard 6106 [1]. As it uses a sieving process with precision sieves for the size check it is basically a limit check. It gives no information about the size distribution of the main fraction between the upper and lower limit sieve.
A few years ago the PPC (particles per carat) value for saw grit products was introduced by e6 [2]. As a single number value it constitutes an elegant approach to get hold on the stability of the size distribution of a diamond batch. The original direct measuring method for PPC consists of weighing and counting procedures. Especially the counting process requires dedicated hardware, which is not appropriate for end user of the powder. The given paper discusses, how two-dimensional digital image processing as an indirect method can be used for the measurement of the PPC value.

Measuring principle

The basic equation for all approaches to the PPC measurement is

$$PPC = n \times \frac{0.2}{m} \qquad (1)$$

n = number of particles
m = mass in g of these n particles

The original direct measuring procedure determines the mass m by putting n particles on the scales. The contact-free indirect method must calculate the mass from the material density and the sum of the volumes of the individual particles:

$$m = \rho \sum_{i=1}^{n} V_i \qquad (2)$$

ρ = density of the material
V_i = volume of particle i

The volume V_i must be derived from some of the parameters of the two-dimensional projection of the particle into the image plane, as there are area, perimeter, diameters etc. In case of known and well defined geometries an exact solution can be given, as for perfect spheres and cubes. In these cases all possible 2D-projections are identical and have a definite relation to the 3D shape and volume. The area A of the 2D projection can be used for the calculation of the volume V.

$$V_C = A^{3/2} \qquad (3)$$

$$V_S = \frac{4}{3\sqrt{\pi}} A^{3/2} \approx 0.75 A^{3/2} \qquad (4)$$

Vc = volume of a cube
Vs = volume of a sphere
A = projection area

For diamonds there are two possible orientations of the crystal towards the base. The crystal may rest on a 100 or a 111 face. The statistical probability of each state depends on the area of this face. The projected view of the whole crystal is shown in Fig.1 for a perfect cubooctahedral diamond.

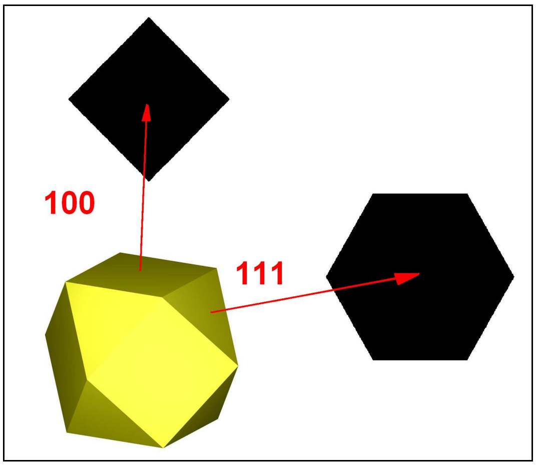

Figure 1: Projections of the cubooctahedron

Three-dimensional models for all possible morphologies of the diamond between cube and octahedron where formed by means of a 3D CAD program. The area of the projections of the 100 and 111 orientations of these models were measured along with the volume of the models. Using equation (2) the volume V_s of the corresponding sphere models was calculated. The ratio f between the sphere model volume and the true volume was calculated as

$$f = \frac{V_S}{V_t} \qquad (3)$$

and is shown in Fig. 2.

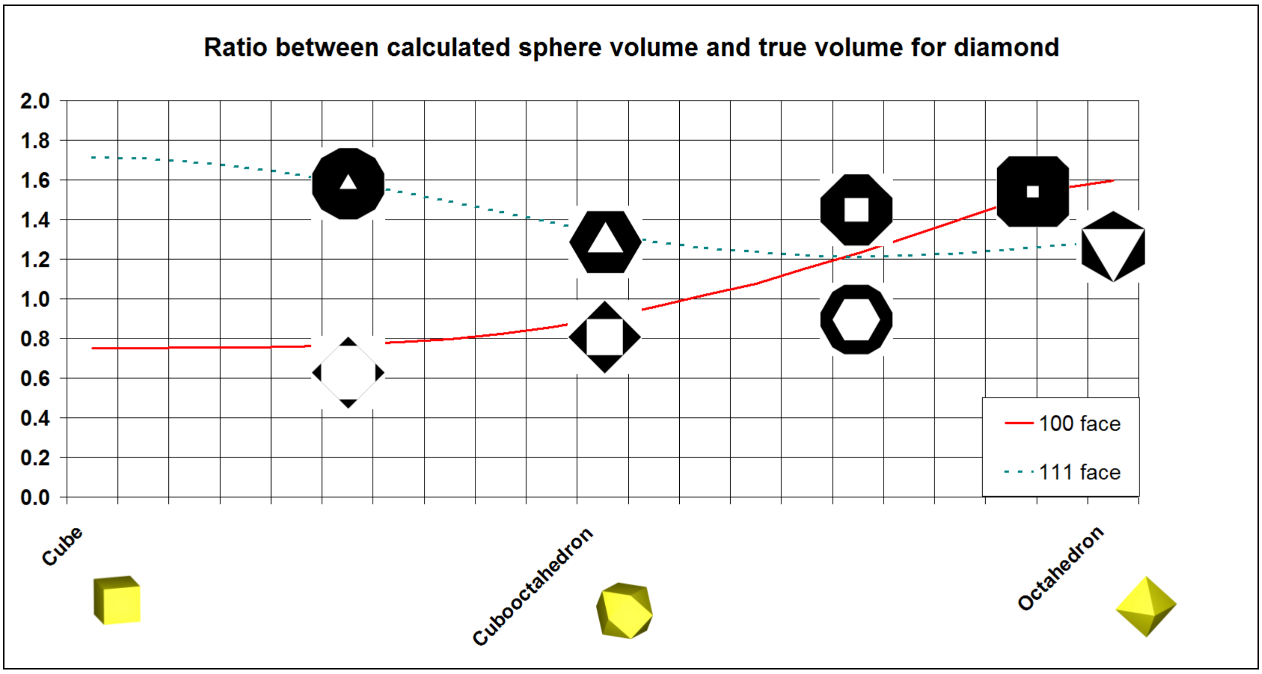

Figure 2: Ratio between sphere model volume and true volume for both views of the diamond at different morphologies

The ratio f can be found in the wide range from ~0.8 for the 100 face of the cube up to ~1.7 for the view on to the 111 face of the almost perfect cube. If only the probable positions of particles on sufficiently large faces are taken into consideration the range of f is narrowed to the range of 0.8 … 1.35. For an exact calculation of the volume one must classify the morphology and the face of the projection must be classified in order to choose the proper correction factor. This is possible for perfectly grown and sorted synthetic diamonds of high quality. Asymmetrically grown diamonds or particles with heavy defects will make it very difficult to determine the true volume from the 2D projection. The various shapes in Figure 3 illustrate this fact.

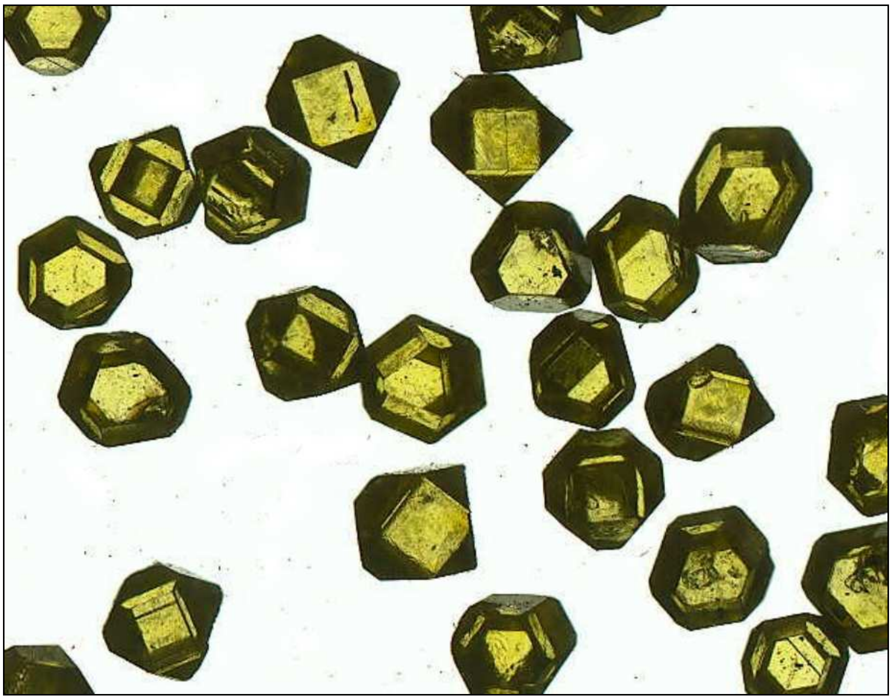

Figure 3: Part of a picture from saw grit, captured on a 4000 dpi slide scanner

Practical experiments were carried out to prove, if the straightforward application of the sphere volume model (2) leads to satisfying results.

Experimental results

The experiments were carried out in the following steps for 6 samples in the size range from 50/60 mesh up to 25/30 mesh:

1. taking a representative sample of a diamond batch
2. weighing a quantity of 1 carat of this batch
3. manual counting of the particles in the 1 carat quantity
4. preparation of 3 glass slides 24x36 mm with the particles from step 3
5. scanning of the slides with a 4000 dpi scanner
6. processing of the scanned pictures with the particle analysis program DiaInspect (Vollstaedt-Diamant GmbH, Germany) [4], record of the calculated PPC values from the sphere volume model (2)

The image processing options were carefully set in order to include every single particle in the picture in the calculation while excluding groups of touching particles. The amount of single evaluable particles on the slides reached from 150 for 25/30 mesh up to 500 for 50/60 mesh. The shape of the diamonds was blocky and regular. The results of the experiment are shown in Fig. 3. The average values were calculated from all slides of one size. The fluctuation margins show the extreme single results. There is no significant influence of the grain size on the ratio f, while the fluctuation margin of the calculated values increases at smaller grain sizes.

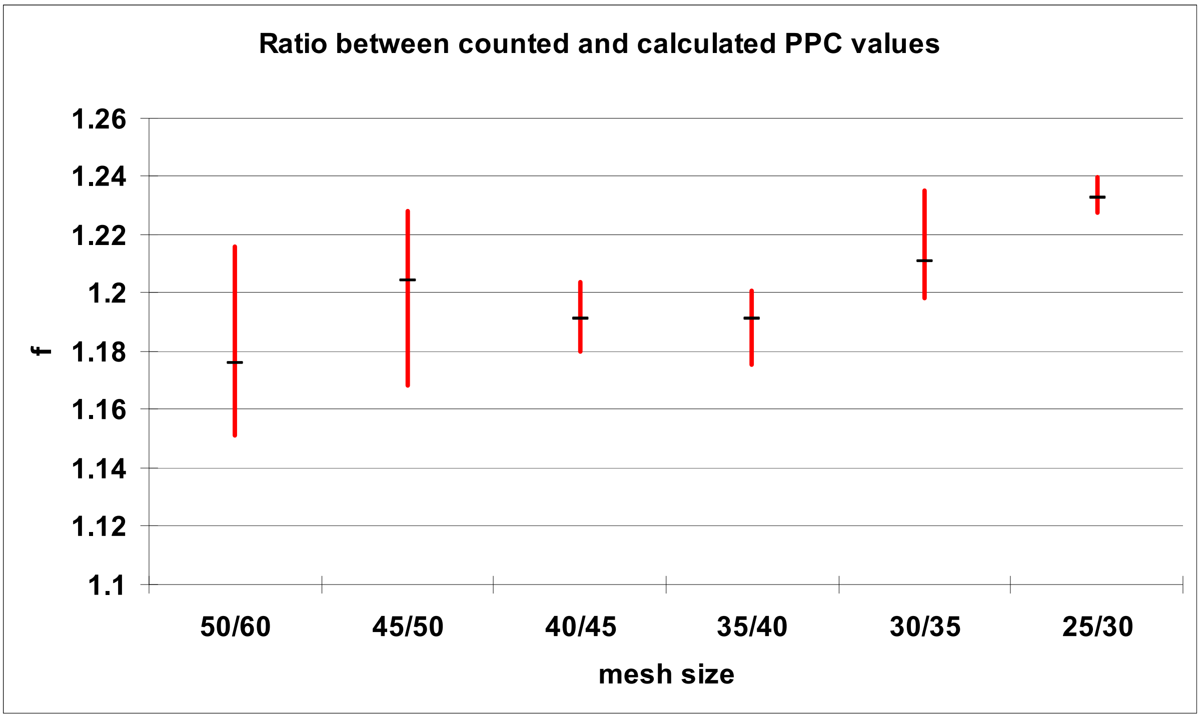

Figure 3: Ratio between counted and calculated PPC values for different sizes

The average ratio f calculated for all slides of all sizes was found as f = 1.2.

Discussion

The experimental results show calculated PPC values which are consistently smaller than the counted values by a factor of 1.15 … 1.24. The individual particle volumes calculated by the sphere volume model are bigger than the real volumes by the above factor. This correlates to the results shown in Fig.2, where the average sphere model results could be estimated inside this range.
As a thumb rule for blocky diamonds a correction factor of 1.2 can be applied to the calculated PPC values from the two-dimensional image processing. For particles of different shape the calculated PPC values will show a different relation to counted values. Nonetheless the values from the sphere model might serve very well for a quick comparison of different batches of diamonds.

Acknowledgment

The authors are thankful to the meticulous sample preparation and counting work of
□□□ Pu Fenggang
□□□ Ding Yiliang
□□□ Sheng Guangren
□□□□□□□□□□□□ HENAN HUANGHE WHIRLWIND CO.LTD.

References

[1] ‘ISO 6106:2005 Abrasive products -- Checking the grit size of superabrasives’
http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=28477

[2] ‘The role of particles per carat in diamond tool behaviour’, Engels, A.
IDR. Industrial diamond review, ISSN 0019-8145, 2(2006), 39-45

[3] DiaInspect / DiaInspect.OSM operating manual
http://www.vdiamant.de/English/download.htm