GEOMETRICAL MODEL FOR IMPROVING THE HOMOGENEITY OF POWDER MIXTURES AND COMPACTS OBTAINED FROM TWO COMPONENTS WITH DIFFERENT PLASTICITY

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ABSTRACT: The homogeneity degree of a binary powder mixture has an important influence on the mechanical properties of the compacts and consequently of the sintered parts. The powder obtained contains particles of the both components of a binary mixture of powders with a different plasticity and may lead to the homogeneity improvement of the mixture as well as to a accurate control of the volumetric ratio of the material components. For this study, a software modeling was made in order to determine the optimal ratio D/d of the particle size and the isostatic pressure used to obtain the homogeneous powder mixture.

KEYWORDS: homogeneity, isostatic compacting, computer simulation, composite material

1 INTRODUCTION

The hardening produced by imprinting of some hard particles into a metallic matrix is a modern method used to obtain some composite materials with superior mechanical properties required by aeronautical industry, spatial, automotive industries, etc.

The target of this work is to improve the homogeneity degree of some composite materials built from a metallic matrix (with good plasticity) and a metallic or hard ceramics reinforcement. Another objective of the research is to avoid the formation of hard particle agglomerations that has a negative influence on the mechanical characteristics of the material. For each value of the volumetric participation (values D/d) there is an interval of concentration of the mixture for which, in theory, there are not formed particles agglomerations [1, 2]. The paper also analyses the influence of the ratio D/d on the isostatic pressure needed for imprinting the reinforcement particles into the metallic matrix.

2 GEOMETRICAL MODEL

We consider a mixture of two components, both with spherical particles and with very different plasticity. If the mixture is subjected to an isostatic compacting, when reaching the pressure that causes the yelding of the metallic matrix, the hard particles are imprinted into the particles of the soft component having a much larger diameter (D) than the imprinted one (d). A penetration of the soft material through the pores of the hard material is produced. We can evaluate the pressure that should act upon the hard particles uniformly distributed around the larger and softer particle (D). The calculation is based on the hypothesis that the soft material is extruded through the pores of the hard material. Depending on the value of the isostatic pressure, the imprinting of the hard particles may be more or less profound, thus obtaining a composite material with an improved homogeneity and superior mechanical properties.

The authors also propose the following experimental methodology to be used for the validation of the model:

a) establishing such a ratio of the two-component mixture, that the imprinting particles be in excess with respect to the regular concentration of the material;
b) homogenizing the mixture;
c) isostatic compacting of the mixture;
d) breaking up the mixture;
e) pneumatically separation of the particles that have not been imprinted;
f) weighing the separate fractions and establishing the volumetric participation for possible corrections.

3 EVALUATION OF THE NUMBER OF IMPRINTING PARTICLES

In order to evaluate the volumetric fraction of imprinting particles in the metallic matrix, the following simplified hypothesis have been assumed:

- the imprinting powder as well as the soft metallic powder consist in spherical particles;
- the two sorts of powder are monodispersoide;
- the diameter of the soft metallic particle (D) is much larger than the diameter of the imprinting particle (d);
- the hardness of the imprinting powder is much greater than the hardness of the basis metallic powder (thus the hard particles do not change their shape during imprinting);
- the depth of the imprinting obtained by isostatic compacting (a) is uniform;
- the hard particles are tangent to each other when achieving the necessary imprinting depth.

The number of imprinted hard particles N, it was calculated by a computer program based on the following relationships (see also Fig.1) :

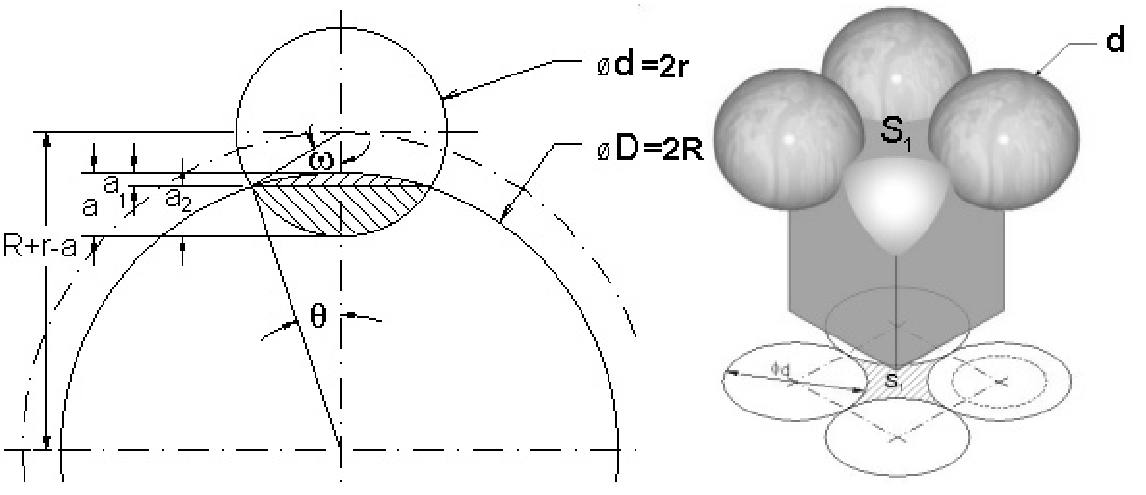

Fig. 1 Evaluating of the number of imprinting particles (d).

$$a_1 = r\cdot\cos\omega-(r-a) \qquad (\mu m) \qquad (1)$$

$$a_2 = R\cdot\cos\theta-(R-a) \qquad (\mu m) \qquad (2)$$

$$r\cdot\sin\omega = R\cdot\sin\theta \qquad (\mu m) \qquad (3)$$

$$a = a_1 + a_2 \qquad \text{(imprinting depth)} \qquad (\mu m) \qquad (4)$$

$$\theta = a\cos\left(\sqrt{1-\left(\frac{r}{R}\cdot\sin\omega\right)^2}\right) \qquad (rad) \qquad (5)$$

Equation (5) has been obtained by replacing equation (3) in the identity : $\sin^2\theta + \cos^2\theta = 1$. Using equation (4) and taking into account equation (1), (2) and (5) we get and thus arrive at the following solution for ω, equation (7) :

$$a = r \cdot (1 - \cos\omega) + R \cdot \left(1 - \sqrt{1 - \frac{r^2}{R^2} \cdot \sin^2\omega}\right) \qquad (\mu m) \qquad (6)$$

$$\omega = a\cos\left[\frac{(R + r - a)^2 + r^2 - R^2}{2r \cdot (R + r - a)}\right] \qquad (rad) \qquad (7)$$

4 EVALUATING OF THE EXTRUSION PRESSURE

The powder mixture is issostically compacted using the wet jacket method, the pressure of the liquid being equal to the pressure needed for extruding the basis material through the pores of the hard material to the imprinting depth (a). The effect of the friction force between the powder particles is neglected, considering a constant pressure in the volume of the isostatic compacting jacket. The extruding force F_{ex} is calculated using equation (8) and the isostatic pressure p_{ex} with equation (9), accordingly [3]:

$$F_{ex} = 2 \cdot k \cdot c \cdot \left[\left(\frac{1}{2\alpha} + \frac{1}{\sqrt{3}}\right) \cdot \ln\frac{S_0}{S_1}\right] \cdot S_0 \qquad (daN) \qquad (8)$$

$$p_{ex} = 2 \cdot k \cdot c \cdot \left[\left(\frac{1}{2\alpha} + \frac{1}{\sqrt{3}}\right) \cdot \ln\frac{S_0}{S_1}\right] \qquad (daN/mm^2) \qquad (9)$$

$$0.47\, R_c < k < 0.58\, R_c \qquad (daN/mm^2) \qquad (10)$$

$$c = \frac{P}{\pi \cdot 1.13 \cdot \sqrt{S_1}} \qquad - \qquad (11)$$

$$S_0 = \frac{\pi \cdot D^2}{N} \qquad (\mu m^2) \qquad (12)$$

where :
k = yield stree in pure shearing, (daN/mm^2);
a = imprinting depth, (µm);
c = correction multiplier for non-circular extrusion section;
P = perimeter of the extrusion section, (µm);
R_c= tensile yield stress of the basis material, (daN/mm^2);
α = extrusion angle, (rad);
S_0 = initial section, (μm^2);
S_1 = extrusion section associated to a pore between the particles of the hard powder, (μm^2).

Section S_1 is not constant for a given imprinting depth, so we'll calculate an average of the extrusion section. The current area of the soft particles is the sum of the areas of the spherical domes obtained by intersecting the surface of the imprinted particles with the surface of the soft particle as well as the sum of the extruding areas associated to the pores (see equations 13 and 14) :

$$\pi \cdot D^2 = N \cdot \pi \cdot D \cdot a_1 + N \cdot S_1 \qquad (\mu m^2) \qquad (13)$$

$$S_1 = \frac{\pi \cdot D \cdot (D - N \cdot a_1)}{N} \qquad (\mu m^2) \qquad (14)$$

$$\pi \cdot D \cdot h_e = \frac{\pi \cdot D \cdot (D - N \cdot a_1)}{N} \qquad (\mu m^2) \qquad (15)$$

The perimeter of the extrusion section (equation 19), needed for obtaining the correction factor c, is calculated as an average value equal to the perimeter of a spherical dome having the area equal to the average extrusion area. Equation (15) is used to evaluate the height of the spherical dome *h_e* :

$$h_e = \frac{(D - N \cdot a_1)}{N} \qquad (\mu m) \qquad (16)$$

$$r_e = R \cdot \sin \gamma \qquad (\mu m) \qquad (17)$$

$$\gamma = a\cos\left(1 - \frac{h_e}{R}\right) \qquad (rad) \qquad (18)$$

$$P = 2 \cdot \pi \cdot R \cdot \sin\left[a\cos\left(1 - \frac{D - N \cdot a_1}{R \cdot N}\right)\right] \qquad (\mu m) \qquad (19)$$

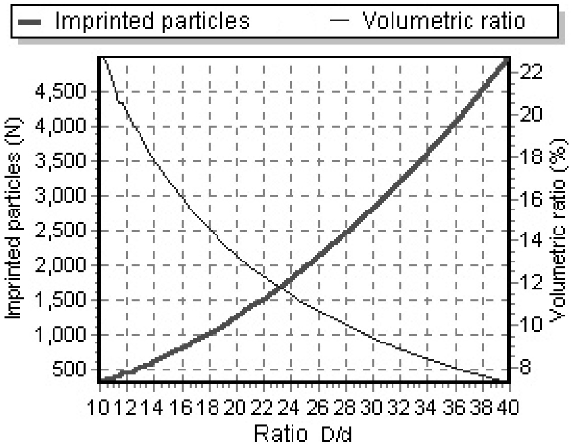

Fig. 2 The number of imprinted particles (N) and its volumetric participation versus ratio D/d (Aluminium, D=400 μm, R_c=10 daN/mm^2).

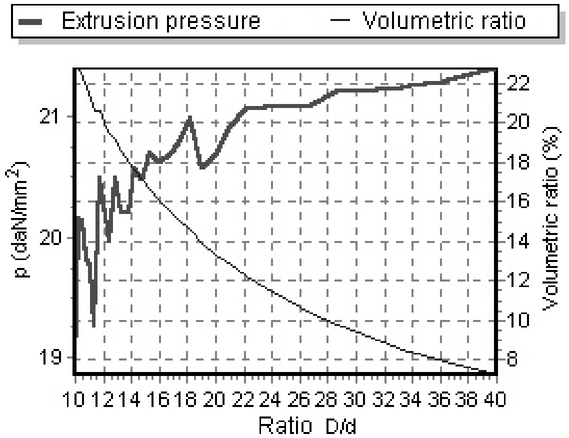

Fig. 3 The extrusion pressure and volumetric participation of imprinted particles versus ratio D/d (Aluminium, D=400 μm, R_c=10 daN/mm^2).

5 CONCLUSIONS

- The number of imprinted particles decrease as shown in Fig. 2, accordingly with the increasing of ratio D/d. For a given value of volumetric participation the pressure for isostatic compacting is calculated with the computer program and shown in Fig. 3 (the soft material was Al, R_c=10 daN/mm).
- It is possible to obtain the same volumetric participation, varying the hard particles size (D, d) and consequently the isostatic compacting pressure.
- The optimum value for the ratio D/d can be established if we take in consideration the minimum value for isostatic compacting pressure.
- Also the homogeneity of the structure obtained is improved due to the uniformly distribution of hard particles into the metallic matrix.

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