THE PLASTIC DEFORMATION IN THE MECHANICAL ALLOYING OF THE AMORPHOUS ALLOYS

DRAGOI D. D., BESLEAGA Cr., DRAGOI A.

University of Bacău, SC IMF SA Bucharest, SAM Bacau

Abstract: The plastic deformation in the cold state generates an increase of the density , of the dislocation and this intensifies the diffusion process in the powder volume and substantially modifies the interfacial characteristics of these by creating some big concentrations of crystalline flows of the type of interstitial allows and vacancies. Knowing the fact that the mobility of the interstitial atoms is bigger than that of the vacancies, these areas can be at a certain moment suprasaturated in vacancies, which could strongly affect the diffusion process.

Keywords: plastic deformation, interfacial characteristics, interstitiall,atoms

1.GENERAL CONSIDERATION

The basic mechanism that governs the mechanical alloying is that of the diffusion in a solid state. In their work [1] Bhattacharya and Orzt issued the hypothesis , according to which , the diffusion reaction in solid state is strongly influenced by the plastic deformation in a cold state of the powder mixture, a process characteristic to the mechanical alloying .

So, the plastic deformation in the cold state generates an increase of the density , of the dislocation and this intensifies the diffusion process in the powder volume and substantially modifies the interfacial characteristics of these by creating some big concentrations of crystalline flows of the type of interstitial allows and vacancies. Knowing the fact that the mobility of the interstitial atoms is bigger than that of the vacancies, these areas can be at a certain moment suprasaturated in vacancies, which could strongly affect the diffusion process.Recently, Bhattacharya and Arzt [2] succeeded in elaborating a mathematical model on which can be analyzed the diffusion process according to which the mechanical alloying takes place. In elaborating this mathematical model they started from the speed relation of the deformations determined by Carroll and Holt [1] , which allows a quantitative evaluation of the plastic deformation and of the density of the dislocations following this process.

2.THE ELABORATION OF THE MODEL AND ITS ANALYSIS

In the beginning of the mechanical allowing , a great number of particles enter a typical process of concussion a result of a collision between the pairs of the grinding balls , creating an agglomeration of particles called “ compacted powder “ by the authors. In the figure 1.a, there is an illustration of the initial stage of the process of mechanical alloying.

During the later concussion, the powder particles that form the compact powder flatten (fig.1.b.). The authors approximated the state of the compacted powder as a homogeneous medium in which there are uniformly distributed pores (fig.1c).

Owing to the process of the plastic deformation of the compacted powder , that takes place as a result of the concussions with the grinding balls , the size of the pores changes continually , and the porosity of the compact undergoes essential changes.
The model elaborated by Bhattacharya and Orzt has at its base the following simplifying hypotheses:

a) the distribution of the pores from the statistics viewpoint in homogenous and isotropic;
b) the pores are spatially isolated , that is the interactions between these are neglected
c) the initial porosity is known for a limited number of particles.

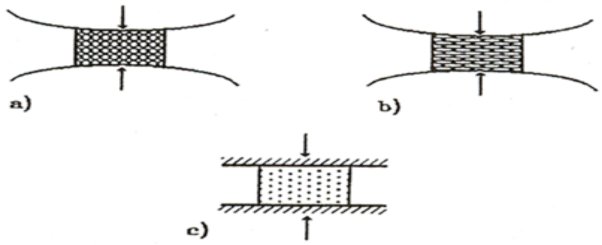

Fig. 1. The schematic representation of the compact powder in three stages: a) before the plastic deformation (the initial stage); b) after some concussion ; c)the homogeneous mid stage [2].

For a certain arrangements of the particles (considering as being of a spherical shape), that form of the compacted powder, it was admitted, by convention that the radius of the pore, marked a_0, is 0, 46 d (d being an average diameter of the particle) and the global porosity of 0,46.

These values were reached considering that the initial state of the compacted powder was according to the arrangement presented in fig.2. So, in this case the global porosity of the compacted powder can be expressed by the relation:

$$\Phi = \frac{V_g}{V_t} \tag{1}$$

where v_g is the volume occupied by vacancies and v_t is the total volume of the compacted powder (in which the pores are included too).

$$\text{As} \quad V_t = n \cdot m \cdot d^3 \tag{2}$$

where n and m express the number of the powder particles from two perpendicular directions , from the fig. 2 V_g can be determined by the relation:

$$V_g = V_t - V_s \tag{3}$$

where V_s represents the total volume occupied by the spheres .

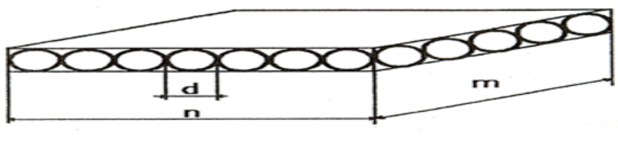

Fig. 2 The initial configuration of the powder particles that form the compacted powder.

In accordance with the arrangement from fig.2 we have n = 7 and m = 5 so that the ϕ porosity will be:

$$\phi = 1 - \frac{V_s}{V_t} = 1 - \frac{\pi}{6} = 0.476 \tag{4}$$

By a similar calculation to that above, the radius of a pore can also be determined. Starting from the same arrangement of the powder particles, shown in fig. 4.13 in which we have a member of 34 vacancies (pores) , we can write the equality :

$$34\frac{4\pi a_0^3}{3} = 35 \cdot d^3 \cdot \phi \tag{5}$$

$$34\frac{4\pi a_0^3}{3} = 35 \cdot d^3 \cdot (1 - \frac{\pi}{6}) \tag{6}$$

From which it results that

$$a_0 = \sqrt[3]{0 \cdot 1 \cdot d} = 0.46 \cdot d \tag{7}$$

Here we mention the observation, that this arrangements of the powder particles is perpendicular, being adopted by conversation by the authors of the model and this means that this can be replaced by another anytime.
Bhattacharya and Orzt applied in this case the model of the empty sphere proposed by Carroll and Holt, considering that the system of the compacted powder is the equivalent of one formed by an empty sphere(fig.3)

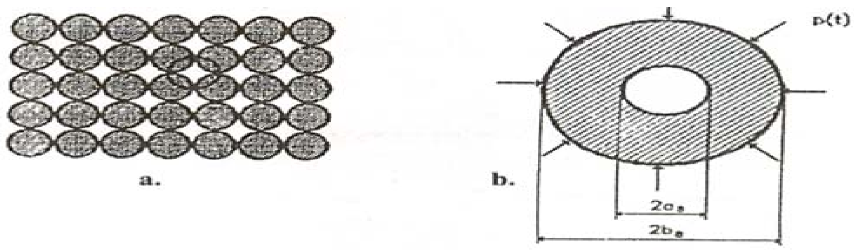

Fig. 3 The way in which Bhattacharya and Orzt approximated the system of compacted sphere with that of an empty sphere.

Such a sphere has the interior diameter equal to that of a pore, and the global porosity is considered aqual to that of the compacted powder presented in fig.2c [1].

Neglecting any change of the porosity of the plastic phase, Carroll and Holt put in equation the variation speed of the kinetic energy of the empty sphere with the difference between the variation speeds of the mechanical work of plastic deformation. This, the energy on the mass unit (W_p) necessary to reduce the porosity from ϕ_0 to ϕ is given by the relation [1] :

$$W_p = \frac{2\sigma(1-\Phi)}{3\rho_s}\left[\ln\left(\frac{\alpha_0^{\alpha_0}(\alpha-1)^{(\alpha-1)}}{\alpha^{\alpha}(\alpha_0-1)^{(\alpha-1)}}\right)\right] \tag{8}$$

where : $\alpha_0 = \dfrac{1}{(1-\phi_0)}$ and $\alpha = \dfrac{1}{(1-\phi)}$; ϕ – is a porosity defined as the volume fraction of the pore from the volume of the sphere; p_s is the average density of the powder material, and o represents the tension of the plastic formation of the material of the spheres.

The factor a_0 can be determined depending on the initial dimension of the empty sphere (fig.3 b) where :

$$\phi = \frac{V_p}{V} \tag{9}$$

In which V_p represents the volume of the pore, and V the total volume of the sphere. It follows from fig.3 b that: $V_p = \frac{\pi}{4} a_0^3$ and $V_p = \frac{\pi}{4} b_0^3$ and replacing ϕ_0 in the relation of α_0 it follows :

$$\alpha_0 = \frac{b_0^3}{b_0^3 - a_0^3} \tag{10}$$

In this case, the energy of plastic deformation, after each concussion is a small fraction of the kinetic energy resulting after the impact between the balls. The approximate calculations of Maurice and Courtney [1] showed that this fraction, for various metals, is in the region of 0.1 , but they did not take into consideration , too , the compacted powder that is between the balls that collide. As Bhattacharya and Orzt affirm, a rigorous evaluation of the total energy, divided on the one hand between the elastic energy balls – compacted powder, and on the other hand between the energy of plastic deformation of the compact is difficult to realize, a reason for which they used the same approximation of 0.1 .

With each concussion that takes place, the energy necessary to the plastic deformation of the compacted powder increases owing to the increase of the elasticity of this. But the module of elasticity increases as a result of the decrease of the porosity of the compacted powder. So , the available energy for the plastic deformation of the compacted powder decreases with each concussion. The elastic energy (We) of two spheres (balls) that collide was calculated by Maurice and Courtney using the Hertz Ian analysis. They found that this is proportionate to $E_s^{0.2}$ where E_s is the module of the spheres .Considering a module of elasticity equivalent E_{ech} , between the material of the spheres E_s and the material of the porous compact (of the compacted powder) E_c , given by the relation :

$$E_{ech} = \frac{E_c \cdot E_S}{E_c + E_S} \tag{11}$$

the elastic energy will be now proportionate to E_{ech} 0.2.In the equation (11) E_c is expressed in the terms of Springs' equation :

$$E_c = E_{c_0} \exp(-p\phi) \tag{12}$$

where E_{c_0} is the elasticity module of the compacted material with zero porosity , and p represents a constant of material.Bhattacharya and Orzt considered the tension of plastic deformation of the matrix of the material of the empty sphere, after a certain concussion, as being given by the relation:

$$\sigma = \sigma_0 + H(\frac{\varepsilon}{2}) \tag{13}$$

in which σ_0 represents the plastic deformation tension of the matrix of the empty sphere material at the beginning of the concussion; H is the linear speed of the cold hammering of the material; ε signifies the average equivalent deformation that appears during a concussion.
Writing down:

$$\frac{b^3}{a^3} = \frac{a}{a-1}; \frac{a_0^3}{a^3} = \frac{(a_0 - 1)}{a-1} \tag{14}$$

and neglecting any elastic deformation , they formed for the average equivalent deformation in the considered sphere the following relation:

$$\bar{\varepsilon} = \frac{1}{3} 1n[\frac{a(a-1)}{(a_0 - 1)^2}] \tag{15}$$

Replacing the equations (13) and (15) in the equation (8), they obtained the average equivalent deformation ε , in the compacted powder , caused by a certain concussion.

Once the value of ε determined, the new porosity level and the plastic deformation tension after a certain concussion are obtained from the equation (15) and (13), respectively. These values will be used as initial values (α_0 and σ_0) for the next concussion, considering that the pore does not change its size during the elastic discharge at the end of the concussion.

The plastic deformation of the compacted powder that results after repeated concussions of this with the milling balls creates an increase of the density of dislocations inside the powder material.The effective diffusibility D of the reaction of the mechanical alloying can be strongly influenced by the total density of dislocations p_t , being expressed by a relation like: $D_s \exp(-\frac{Q_S}{RT}) + \beta b^2 p_t D_v \exp(-\frac{Q_v}{RT})$ (16)

where D_s , D_v and s ,v are diffusion coefficients , respectively the activating energies of the diffusion at the limits of the contact surfaces and in volume, respectively; b is the Burgers vector and B represents the factor of diffusibility in volume.

Considering only the static storing of the dislocations and neglecting any loss of these by dynamic recurrence, one can determine the diffusion coefficient D. The neglecting of any dynamic recurrence of the dislocations is valid when the duration of a concussion is very short (of the order of 10^{-5} s).

The variation speed of the dislocation density with the deformation ε is given by the relation [1]:

$$\frac{d_p}{d_\varepsilon} = \frac{1}{100 \cdot b} \sqrt{p_t} \tag{17}$$

REFERENCES:

[1].A.K.Bhattacharya si E. Arzt, *Plastic Deformation and Influence on Diffusion Process During Mechanical Alloying*, Scripta Metallurgica et Materialia,27,5(1992), P.635.
[2].**A**.K.Bhattacharya si E. Arzt, *Influence on Diffusion Process During Mechanical Alloying*,Scripta Metallurgica et Materialia,28(1993), P.395-400.