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Density as a factor limiting the workability of P/M materials

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ABSTRACT

In this study a general scheme expressing the factors which affect a workability of powder materials is presented. It was found from laboratory experiments that workability of powder metal materials is limited by their density. Aluminium based materials with additions of Cu, Ni and Sn were used in the experiments. Workability determined in compression tests depends strongly on a sintered density, independently of the chemical composition of material. A linear dependence between workability and sintered density was found. The results are related to relatively high density values, taken from the range of 0.85–0.96 of theoretical density.

1. INTRODUCTION

In recent years, a wide variety of parts are fabricated by plastic forming of sintered preforms, prepared on the basis of powder metallurgy. Forming of powder metallurgy parts is limited by so-called workability (deformability). Workability of powder sinters or ability to shape changes without failure is not recognized fully as yet. Many years experience in workability testing of as cast metals and alloys allowed the authors to propose the scheme expressing the principal factors affecting the workability of powder sinters [1]. Porosity is a characteristic feature of powder sinters assigned to forming processes. In case of such materials the additional aim of the forming process is to obtain possibly fully dense material. In the work [1] the workability of powder sinters was investigated for the materials prepared on the basis of Al powder with additions of Cu, Ni and Sn. The workability was determined in compression, rolling and extrusion tests. The essential conclusion there was that a dependence exists between workability and porosity (density) of sintered powder metals. This becomes the basis for submitting the thesis that density is a principal factor influencing the workability of powder sinters.

2. DENSITY AND WORKABILITY OF Al-BASED POWDER SINTERS

2.1. Samples preparation technique.

The following powder mixtures were prepared for workability testing (in

Fig.1. Factors affecting the workability of P/M materials.

weight): Al, AlNi10, AlCu5Ni15, AlCu10 and AlSn10. Elemental powders of 150 μ m Al, 63 μ m Cu, 63 μ m Ni, 63 μ m Sn were mixed with 1.2% zinc stearate for 30 min., compacted under the pressure of 300MPa and sintered in vacuum furnace at 773, 823 and 853K. The samples of 20mm in diameter and 12mm in height were subjected to density determination. The results are shown in table 1.

Table 1. Materials density as a function of sintering temperature.

Material	Sintering temperature, K	Density, ρ , 10^3 kg/m^3
Al	773	2.54
	823	2.55
	853	2.55
AlNi10	773	2.47
	823	2.75
	853	2.80
AlCu5Ni15	773	2.47
	823	2.62
	853	2.76
AlCu10	773	2.47
	823	2.55
	853	2.72
AlSn10	773	2.51
	823	2.55
	853	2.55

2.2 Workability testing.

The compression test is very useful to study the workability of material assigned to various processes. It consists in compression of a sample having cylindrical shape, usually till the moment of sample failure. As a result of friction between the sample and the tool the effect of barrelling can usually be observed. On the lateral, unloaded surface of the sample there occur tensile stresses resulting in material cracking. The reduction value at the moment of cracking is assumed to be a workability measure and may be of use for the elaborating forging, rolling or extrusion processes.

The critical reduction ϵ_c in compression test is calculated from the dependence:

$$\epsilon_c = \frac{h_0 - h_1}{h_0} \quad (1)$$

where: h_0 - initial height of sample,

h_1 - height of sample at the moment of cracking.

The results of the ϵ_c determination for the materials being tested are shown in Figures 2 and 3.

Fig.2. Critical reduction dependence on sintered density for several Al-based metal powders

Fig.3. Critical reduction dependence on relative density for several Al-based materials.

3. COMMENTS ON THE RESULTS.

The data shown in figures 2 and 3 indicate that the critical reduction, ϵ_c , representing the workability of aluminium-based materials being tested, is proportional to their sintered density. Generally, the workability increases with increasing density. The linear course of the ϵ_c , expressed as a function of density or relative density occurs, independently of chemical composition of the material. It appears from the experiments that sintering temperature influences density, and in this way the critical reduction also is affected. Experimentally confirmed linear behaviour of ϵ_c with respect to density may find application in practice. Assuming the lowest critical reduction value resulting in safe leading of deformation process equal to 0.3, it becomes clear from the graph 3 that the minimum relative density should be of 0.9 at least.

It is known from the literature review that there is no direct works related to the workability-density relationship. Particularly, the question is, whether the observed here dependence is correct for different from Al with additions materials. It has been reported that elongation for sintered copper depends on the relative density; the higher density the higher elongation value [2]. The relative elongation for iron decreases rapidly with increasing porosity, especially within the range of 5-15% [3]. To be sure, the elongation is not strictly a workability measure, however, there is a certain connection between them and hence the relationship between workability and density is confirmed to some extent.

It is important to note that the observations mentioned above are satisfied for the fcc and partly bcc materials. However, it may not be true for the other metals and alloys, especially for materials of complicated phase structure, and for that containing the considerable amount of brittle phases.

4. CONCLUSIONS.

Ability to forming of sintered P/M materials is strongly limited by their density. A linear dependence of workability determined in compression test on sintered density is observed for the Al-based materials above 0.85 of theoretical density.

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