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EXCHANGE OF EXPERIENCE

MEASUREMENT OF THE TAP DENSITY OF METAL POWDERS

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The paper deals with one of the technological properties of metal powders, such as tap density. The objective is to analyze the state standard in force for determining the density of metal powders after tapping, taking into account operational experience in the field of powder metallurgy. It is established that the methods identified in the standard for determining the density of metal powders have contradictions and discrepancies. A simple and reliable device is proposed and manufactured for mechanical tapping of powders.

Keywords: *metal powder, bulk density, shaking, tapping.*

The economical use of metals in the manufacture of machine parts has been and remains an urgent economic problem, whose solution is largely due to the powder metallurgy methods that provide waste-free processes to make products. In addition, these methods significantly reduce the complexity of metal making processes.

Parts from metal powders are produced by pressing and sintering. Other conditions being equal, the results of pressing and sintering are largely determined by the physical and technological properties of metal powders. These properties underlie to a certain extent the success of pressing and sintering, i.e., the strength of powder metallurgy articles [1]. Therefore, reliable methods for determining the physical and technological properties of metal powders, as well as the development of devices for measuring these properties, are of great applied importance.

The density of metal powders is classified into two types: (i) bulk density after the powder is freely settled [2] and (ii) tap density after the powder is consolidated [3]. They both are volume characteristics of metal powders and have the same dimension (g/cm^3).

The standard [2] clearly and unequivocally sets forth the method for measuring the bulk density of metal powders, so there are no difficulties in determining this parameter. However, in our opinion, the standard [3] is not so clear and unequivocal in describing how to measure the tap density of powders. Note that the interstate standard [3] is based on the European standard that currently exists in a more recent revision issued in 2011 [4].

The current practices of physical metallurgy suggest that a standard for determining a property of metals or conducting any tests necessarily specifies the device or machine for these activities (Table 1). This is required to ensure the unity of measurements.

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However, the standard [3] does not indicate any standardized device for powder tapping. Instead, it provides a schematic device for mechanical tapping of powders. The text of the standard [3] states that the tapping amplitude should be 3 mm and may have a tolerance of 3 ± 0.2 mm. With these precise requirements for the tapping amplitude, it would be reasonable to expect stringent requirements for the tapping frequency. However, there is a wide range for this indicator in the standard [3]: it allows from 100 to 300 taps per minute. It is also stated in [3] that "3000 taps are sufficient for all sizes of fine powders of refractory metals."

At the same time, the use of a mechanical tapping device, according to the schematic shown in the standard, is not required since the standard allows the manual tapping of powders by striking the cylinder onto a hard rubber plate. It is clear that there is no need to perform 3000 taps with an amplitude of 3 ± 0.2 mm and a frequency of 100–300 taps per minute in manual regime, regardless of whether the cylinder strikes a hard rubber plate or the plate strikes the cylinder.

According to [3], the cylinder with powder is tapped until no further reduction in its volume occurs. In other words, the criterion to be guided by to terminate the tapping of metal powder in a divided cylinder (as termed in [3]) is when its height no longer reduces. Note that the conventional term (e.g., in chemistry) is a graduated cylinder. This correction is justified especially since the cylinder must be made of a transparent material such as glass because it can be determined only visually whether the height (or volume [3]) of the powder still reduces during tapping. Since a graduated glass cylinder is intended to be used, it is also challenging to perform manual tapping, as proposed in [3], by striking the cylinder onto a hard rubber plate.

Based on the schematic shown in [3], a mechanical tapping device is to include a cam and a follower. However, any cam mechanism is known to require a strong, rigid, and complex design. This is even more evident from the requirements for tapping amplitude, frequency, and number stated in the standard. At the same time, the cam-based principle of mechanical tapping of a cylinder with powder does not seem to be the only option. As stated in [1], tapping can be performed using a vibrator.

Thus, in our opinion, the essence of the process is not in the way of tapping (mechanical or manual), and neither in its amplitude, frequency, or number. The only specific, clear, and unequivocal criterion indicated in [3] is that tapping should be terminated when it is visually determined that the powder volume (i.e., the height of the powder in a graduated cylinder) no longer reduces.

However, it is apparent that mechanical tapping is preferred since its conditions can be reproduced in each subsequent experiment, which is impossible in manual tapping. Based on these considerations and bearing in mind the recommendations of [1] on the possible use of a vibrator, we have designed and manufactured a device for mechanical tapping of metal powders (Fig. 1).

The device consists of graduated cylinder *1* and motor *2* with cam *3* fixed on its shaft, which is placed on movable plate *4* (Plexiglas). It is seen that graduated cylinder *1* is fixed on movable plate *4* with bolted joints to allow the cylinder to be removed from the plate if necessary to install there cylinders with desired capacity (25, 50, or 100 cm^3) as recommended by the standard [3]. Movable plate *4* rests on four springs *6* attached to fixed support plate *7* (Plexiglas). Electrochemical dc source (battery) *5* drives motor *2* with cam *3* on its shaft. Since plate *4* is supported by springs, the rotation of the motor shaft with the cam gives rise to vibration of plate *4* and, as a result, of graduated cylinder *1*. Hence, the metal powder in the cylinder is being tapped.

It would be useful to compare the tapping of powders using the proposed device and the method stated in [3]. However, we should note again that the standard shows a schematic of the device, but it is not commercially produced at least in the CIS, neither there are sale proposals on the market, as opposed, for example, to devices indicated in the references in Table 1. In any case, we are not aware of such information.

Nevertheless, it is quite feasible to compare the tapping with the proposed device and manual tapping, which is not only described in [3] but seems "to produce, as a rule, results comparable with" mechanical tapping [3].

The results of comparative tests are presented in Table 2. We used powders produced by electrolysis on request of one of the enterprises. The graduated cylinder was 25 cm^3 and the tapping was terminated when the powder volume no longer reduced.

According to [3], when 25 cm^3 cylinders are used, the divergence of results should be no more than 3%. Table 2 shows that the difference in tap density determined manually [3] and with the proposed device is 2.2% for