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CHARACTERIZATION OF IRON AND LOW ALLOY STEEL POWDERS OBTAIN BY WATER ATOMIZATION

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ABSTRACT

Three types of iron and low ally steel powders were investigated to determinate their physical properties and surface morphology by SEM analysis. The powders were obtained by water atomization. The first type of powder is an iron powder (P_1) and low alloy steel powders. Frequently, the alloying elements are copper, nickel and molybdenum (powders P_2 and P_3).

KEYWORDS: powder metallurgy, iron powder, low alloy steel, water atomization, flow rate, apparent density, particle size distribution.

1. Introduction

In recent years, there has been an increasing trend to consolidate ferrous and nonferrous alloys through powder metallurgical (P/M) processing. As compared to conventional casting techniques, P/M offers advantages such as relatively lower processing temperature, near-net shaping, greater material utilization (>95%) and a more homogenous microstructure. The properties of a P/M - processed component depend on proper optimization of the sintering cycle [1]. Iron powder is the most common form of powder in manufacturing-especially in the auto industry. Iron and alloy powder accounts for around 90% of the total world powder production [2]. A powder having good compaction behaviour gives a high-density green compact and, more importantly, a fine and homogenous porosity. [3]

This work aims at characterizing of three iron and alloying powders obtained by water atomization. The atomization operation is a highly productive process that ensures the production of a quality product and makes it possible to broadly vary the main physical and technological characteristics of the powders in relation to their ultimate use and the requirements that they must meet. The method most commonly employed at present is the atomization of melts of refined metal by high-pressure water. Iron powders atomized by water are characterized by good compactibility and form unsintered compacts of adequate strength. They are used to make a wide range of sintered structural-grade products with a density in the range of 6.5–7.1 g/cm^3. [4]

The analyzed powders have been studied by determining the following physical properties: flow rate powder using a standardized cone, apparent density and size distribution. The chemical composition of as-received iron powder (P_1) and alloyed with Cu, Mo and Ni with different percent (P_2, P_3) is illustrated in table 1.

Table 1. *The chemical composition of experimental powders*

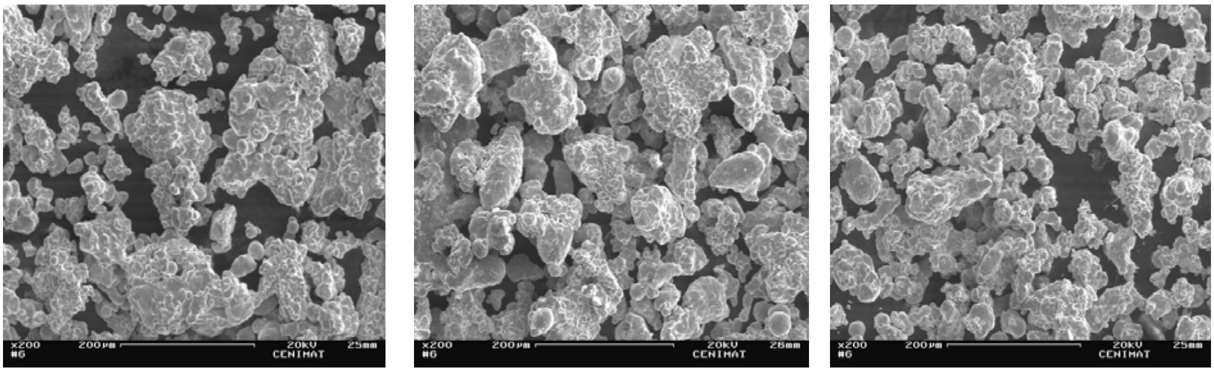
Powder type	Cu	Mo	Ni	C
P_1	0.096	0.008	0.046	<0.01
P_2	1.50	0.50	1.75	<0.01
P_3	1.50	0.50	4.00	<0.01

Alloying elements are added to improve product properties of powder. Usually, they are alloyed with Cu or Ni for enhanced sinterability and the mechanical properties [3]. The two alloying elements play very different roles during the sintering process, particularly because Cu has a much lower melting point than Ni. Thus, at the typical temperatures used to sinter ferrous alloys, Cu forms a liquid phase while Ni remains in the solid state. Since Ni remains in the solid state during sintering, partial diffusion of Ni into Fe contributes to a heterogeneous microstructure, consisting of nickel-rich ferrite as well as nickel-rich areas predominantly at the periphery of the pores [5]. Molybdenum affects almost all physical, mechanical and technological properties of steels, positively. Thus, it favors the obtaining of fine structures, increases fatigue and mechanical strength, increases resilience, hardness and corrosion resistance.

2. Experimental procedure

The iron powders as-received were first characterized by scanning electron microscope (SEM). Figure 1 (a, b, c) shows the particle morphology of iron powder (P_1) and the alloyed powders (P_2 and P_3). Iron powder (P_1) is sponge and looks like an agglomerate of fine particles, and is very porous. The low alloy powders (P_2 and P_3) are less porous, smoother in outline and approximate closely to a sphere shape. The surface morphology is an important factor that affects the compresibility of the powder. Flow rate of powder (flowability -it is the speed at which powder flows through openings due to gravity) is determined by using a standardized funnels; the analysis sample must be dry, without agglomeration and large enough (min.150g), in order to make it possible to maintain an amount for verification of data.

The analysis was performed using the device called Hall – Flowmetter (figure 2).



a b c

Fig. 1. *Surface morphology of powders SEM images:*
a) iron powder P_1; b) powder P_2; c) powder P_3.

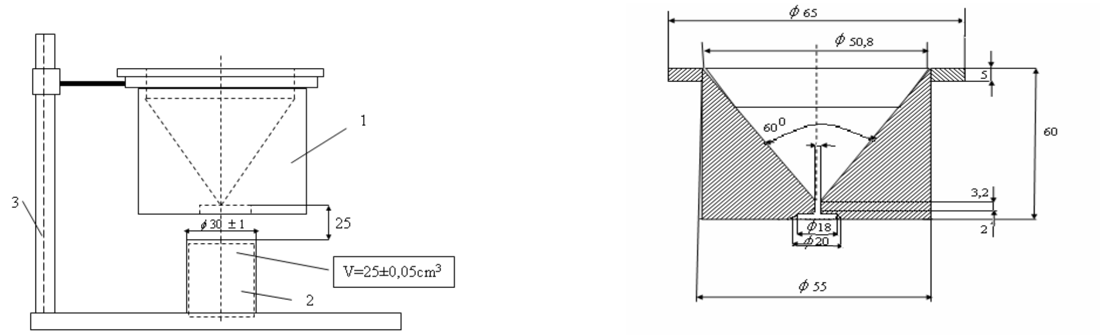


Fig. 2. *Hall - Flowmeter device: 1-funnel, 2-stand, 3-cylindrical container.*

A minimum of three such determinations is usually performed to the same test sample and the averaged results are calculated.

Flow rate is calculated as:

$v = t \times F$, [s]

where: v - flow rate of the powder, [s];

t - arithmetic mean of at least three determinations, [s].

F - correction factor of the standardized cone

The results of the flow rate for the three types of powders are presented in figure 3.

For bulk density determination, testing sample must be large enough to be able to make the necessary determinations, there are recommended at least 100 cm^3, to allow three determinations.

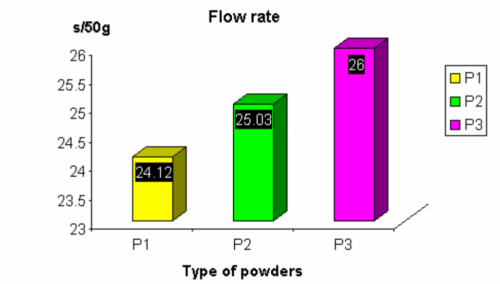


***Fig. 3**. Flow rate of analysed powders.*

The principle method is to measure the mass of a certain quantity of powder, which paid in free fill up a container of known volume. Measurement is made with the Hall - Flowmeter device.

Apparent density of powder is calculated as:

$\rho_a = m / V$, [g/cm^3]

where: ρ_a - apparent density of powder, [g/cm^3]; m -arithmetic value of the masses of powder, [g]; V- volume of standard container, [25cm^3].

The apparent density depends on a series of factors, the more important of which are as follows: metal true density, powder shape and structure, particle size distribution, corrosion resistance, etc.) [6].

The results obtained for bulk density for the analyzed powders are presented in figure 4.

Determination of particle size distribution requires sufficiently large samples (minimum 250g) in order to make the necessary determinations and consists to determine the mass proportions of different particle size classes.

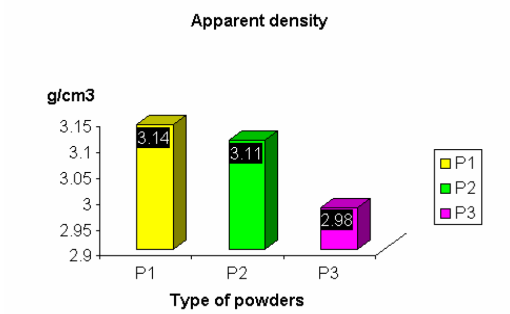


Fig.4. *Apparent density of analysed powders.*

The analysis was performed using a screening machine, which consists of a set of standard wire mesh sieves between 25 and 1000 micrometers. The results obtained for the analysis powders are presented in table 2 and figure 5.

Table 2. *Granulate size distribution of examinated powders*

Sieve size	Granulate size distribution					
	P1		P2		P3	
	m	Xp	m	Xp	m	Xp
	[g]	[%]	[g]	[%]	[g]	[%]
> 150 μm	2.78	3	3.72	4	3.31	3.3
> 100 μm	17.73	18	20.98	21	20.33	20
> 63 μm	25.01	25	30.65	31	29.92	30
> 45 μm	20.19	21	20.99	21	21.11	21.2
plate	32.22	33	23.90	23	25.14	25.2
mt (g)	99.93	100	99.64	100	99.81	100

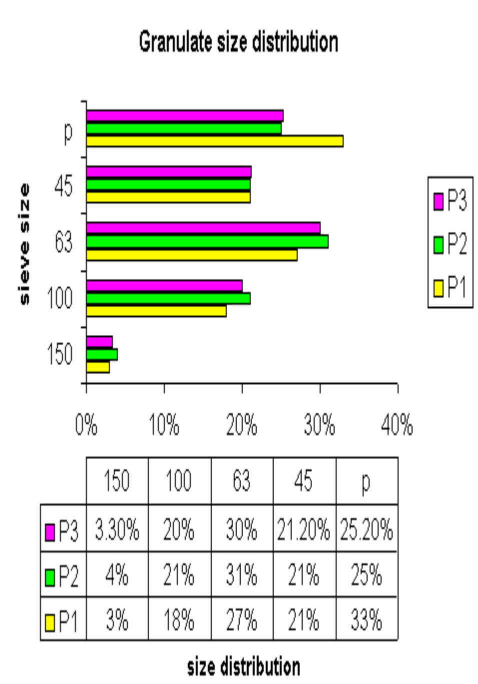


Fig. 5. *Granulate size distribution of examinated powders.*

3. Results and discussion

The properties of the powders depend on the shape and the morphology of the particles forming the powder. For example, the difference in apparent density can be explained by an analysis of the structure of the powder particles. [7]

Alloying elements are added to improve product properties of powder. Frequently, they are alloyed with Cu or Ni for enhanced sinterability and mechanical properties. Molybdenum is an alfagen element, is dissolving into iron and can form stable hard carbides. Molybdenum affects almost all physical, mechanical and technological properties of steels, positively. Thus, it favors the obtaining of fine structures, increases fatigue and mechanical strength, increases resilience, hardness and corrosion resistance.[8]. The flowability of a metal powder depends on the interparticle friction, which is dominated by the surface area and surface roughness of the particles. As the surface area and surface roughness increase, the amount of friction in the powder mass increases and the powder exhibits less efficient flow. The same appears with the shape of particle. The more irregular the particles shape is, the less efficient is the powder flow. The effect of particle size distribution on the powder flowability is also important. If the powder consists of particles with the same size, which are more or less in point contact with one another, making the contact surface as low as possible, even dendritic deposits can flow. If the powder consists of particles with different sizes, the interstitial voids of the larger particles can be filled by the smaller ones, the contact surface area increases, and the flow of the powder is less efficient. As a result of this, a non- sieved powder often does not flow, while the fractions of the same powder flow. Hence, the best conditions for the free flow of the powder are fulfilled if the powder consists of particles with the same size, with spherical shape, and with a surface structure approaching the structure of a smooth metal surface. [9].

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