Peculiarities of the technological process in the preparation of metal powders

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Abstract: *This publication traces the peculiarities of metal powder production for powder metallurgy. Of the variety of methods, particular attention is paid to those that are most widely used in practice - reduction and powdering methods. Metallurgical photo of iron powders obtained by different technological processes are presented, as well as tables with the basic technological properties of iron powders obtained by reduction and powdering.*

***Keywords**: POWDER MATERIALS, IRON POWDERS, POWDERING, REDUCTION, TECHNOLOGICAL PROPERTIES*

1. Introduction

Since the beginning of the industrial application of metal powders in powder metallurgy, that is, since about 1930, a number of methods for their production have emerged. For various technical or economic reasons, some of these methods have not been industrialized at all and others have been used for a short time. Among the relatively short-lived methods used, however, which are an important step in the development of these processes, the Hametag method and the electrolysis method should be mentioned. The Hametag process is the grinding of soft metal wire to powder. It was used during the Second World War in Germany. The metal powder electrolysis process was developed in the mid-1940s in Sweden and England and has been applied for about 20 years. The iron powder obtained is characterized by high purity and very good compressibility.[3,5]

In this study, we traced the peculiarities of the technological processes for the production of iron powders by powdering and reduction, and also identified the main technological characteristics of the most common brands of powders.

2. Exposition

Of the many iron powder production methods, only two have lasted their technical and economic benefits: [3]

- the method of reduction;
- the powdering method.

The two methods have different modifications. In the reduction method, the modifications relate to the raw material used and to the completion of the reduction process. The raw material used is iron ore or slag, and the reduction process is carried out in one or two steps.

In a one-step process, the iron oxide is usually reduced with hydrogen in a belt furnace.

In the two-step process, also known as the Hoganes method, the iron ore (or slag) is first reduced by hard carbon in tunnel furnaces to sponge iron, which is then crushed and milled, and the resulting powder is thermally treated in a reducing medium and this leads to the final product.

The Hoganes method has been widely used in industry, using iron ore as a feedstock.

The method of producing iron powder by smelting melt was developed in World War II as the cheapest alternative to the Hammetag method. Initially, the jet of liquid metal was dispersed from a rotating water-cooled disc.

Subsequently, the use of kinetic energy of air, steam or water to convert the liquid metal to powder began - powdering. Today, the following modifications to this process are being applied in industry:[1,2]

- Air sputtering of molten cast iron - C> 4%, followed by thermal treatment to decarbonise the material and reduce oxygen to the surface of the particles - the process is known as the RZ process;
- Granulation or powdering of high-purity cast iron melt to relatively coarse particles which, after milling in ball mills, are subjected to reduction-heat treatment to remove carbon and oxygen;
- Direct water spray melt of steel to powder with desired particle size, subjected to temperature treatment in furnaces with reducing medium. The production of iron and steel powders by this state-of-the-art method began in 1965 year in USA. Shortly thereafter, the same method began to be used at Hoganes (Sweden), Manesman-Pulvermetal (FRG) and Kobe Style (Japan). A variant of this method is the process developed by Sumitomo (Japan) to powdering with oil melt.

Of the elements of the first group, carbon is of greatest importance. High quality iron powders typically contain less than 0.02% carbon. The content of the other elements is also very low and depends on the type and quality of the starting materials used in the production of the iron powder. All iron powders contain certain non-metallic inclusions, but their amount is significantly lower in the powders obtained by powdering.

Table 1 shows the experimental results of the study of impurities in two of the most characteristic iron powders obtained by reduction and powdering.

***Table 1:** Experimental results for impurities in iron powders*

Compounds, %	Iron powder type	
	NC100.24	ASC100.29
C	0,008	0,005
Mn	0,030	0,200
Si	-	0,020
Cr	0,002	0,080
Ni	0,020	0,040
Mo	0,0001	0,005
Cu	0,003	0,060
Sn	0,0003	0,006
SiO_2	0,140	0,010
AL_2O_3	0,190	0,010
TiO_2	0,140	0,002
MgO	0,240	0,006
CaO	0,030	0,003

Several decades ago, there were only a few brands of iron powder for use in powder metallurgy. Today, more than 50 special types are available. This requires that the properties of the powders are very well known in order to select the most appropriate type for each case.

Pressability is undoubtedly one of the most important properties to consider when selecting the type of iron powder, as it determines the density that can be obtained when pressed, and hence the physical and mechanical properties of the product.[4] When we talk about pressability, we have in mind both sides - compactability and moldability. Tables 2 show the experimental results for the moldability of iron powders by pulverizing and reducing.

It is determined by the crude strength of specimens with a density of $6{,}5.10^3 kg/m^3$.

Table 2: *Experimental results for the moldability of iron powders with a density of* $6{,}5.10^3 kg/m^3$

№	Brand of powder	Method of preparation	Rm, MN/m^3
1.	MH 65.17	reduction	36
2.	MH 80.23	reduction	20
3.	NC 100.24	reduction	12
4.	EC 100.24	reduction	10
5.	SC 100.26	reduction	8
6.	AHC 100.29	powdering	6
7.	ASC 100.29	powdering	5

The crude strength depends on the particle structure and the compression pressure. This is primarily a technological feature related to the pressing operation. Pressed articles must be able to withstand the forces that they exert upon release from the pressing tools and must not be dipped when transported to the kiln. For all powders intended for the manufacture of low density products, the crude strength is a basic characteristic. Therefore, the ratio between the crude strength (the formability of the powder) and the compactness must be selected on a case-by-case basis.

It is known that the physic-mechanical properties of powder metallurgical products depend to a great extent on their porosity. It can also be assumed that impurities have the same effect on mechanical properties as pores. Spongy powders typically contain about 0,8% (by weight) impurities, which roughly corresponds to 1,5% (by volume). High quality powdered material generally have less impurities. This means that in the manufacture of structural products by conventional methods, ie. with single and double pressing, the impurities have a negligible effect on the mechanical properties and the reducing and dusting powders can be used equally. However, where the aim is to obtain products with a very low porosity, or example below 3%, as in the hot forging method, the influence of impurities is harmful and dusts with a minimum of such content should be selected. Impurities are also undesirable when the products must have special physical properties - for example, magnetic materials. Then, high quality powders obtained by the water spray method are worked.

In tables 3 and 4 we have defined the main technological properties of the most used brands of iron powders.

Powder brands offered by different companies are in many cases comparable in their qualities, but very rarely could be completely replaced. This applies in particular to powders obtained by the melt powdering method. The production of quality powders by the reduction method is the exclusive monopoly of the Swedish company Hoganes, which uses high quality ore from a large field in northern Sweden as raw material. Reducing powders produced in the USA and Canada are also based on Swedish ore.

There is no generally accepted classification of iron powder brands. Each company uses its own designations. The letters of the Hoganes company indicate the method of manufacture (M, N and S - reduction, A - powdering).

Table 3: *Experimental results for technological properties of reducing iron powders*

Powder mark	Max. particle size, µm	Bulk density, $.10^3 kg/m^3$	Max. flowability, s	Max. compaction at 420MPa, $.10^3 kg/m^3$	Max. O_2, %	Max. C, %
MH 40.24	420	2,40	35	6,20	0,45	0,04
MH 40.28	420	2,80	33	6,35	0,35	0,04
MH 65.17	210	1,70	-	-	0,45	0,03
MH 80.23	180	2,30	35	6,19	0,55	0,10
NC100.24	155	2,45	32	6,40	0,30	0,02
SC100.26	150	2,65	30	6,63	0,15	0,01
MH 100.28	150	2,80	30	6,45	0,30	0,02
MH 300.25	50	2,80	-	-	0,35	0,02

Table 4: *Experimental results for technological properties of powdering iron powders*

Powder mark	Max. particle size, µm	Bulk density, $.10^3 kg/m^3$	Max. flowability, s	Max. compaction at 420MPa, $.10^3 kg/m^3$	Max. O_2, %	Max. C, %
AHC100.29	169	2,95	25	6,69	0,10÷0,20	0,01÷0,02
ASC100.29	170	2,95	25	6,82	0,10÷0,15	0,01÷0,02
WP150	200	2,80÷3,10	26	6,65	0,20	0,02
WP150HD	210	2,90÷3,20	30	6,81	0,15	0,01
WP400	400	3,00÷3,30	30	6,65	0,20	0,02
WPL200	200	2,50÷2,70	33	6,61	0,21	0,02
KIP260A	250	2,55÷2,75	35	6,60	0,20	0,02
KIP280A	200	2,70÷2,90	30	6,62	0,19	0,02
KIP300A	205	2,80÷3,10	30	6,70	0,20	0,02
KIP300AS	200	2,80÷3,10	30	6,78	0,20	0,02
300M	220	2,852÷3,10	30	6,64	0,25	0,02
500M	250	2,85÷3,10	30	6,65	0,25	0,02

The first group of digits is the particle size of the dust particles and the second group of digits is the bulk density. The letters of the company Manesman (Germany) also give information about the method of producing the powder (WP - water powdering), and the figures determine only the largest particle size in µm.

Of the reducing sponge iron powders manufactured by Hoganes (Sweden), the most widely used powder brand is NC 100.24. The powder compaction is very good. Due to its spongy structure, its formability is particularly high. Iron powder SC 100.26 has a very high density after single pressing and sintering. It is recommended to produce parts that will undergo chemical-thermal treatment. Unlike NC 100.24, the iron powder MH 100.28 has a high density. Thanks to it - $2{,}8{,}10^3 kg/m^3$, it is preferable for the production of long and thin details in order to obtain a smaller bulk height. To adjust the bulk density of mixtures, MH 100.28 is often added to other grades of iron powder. At equal pressure, MH 100.28 gives a slightly higher product density than NC100.24. MH 80.23 is a specially created brand for the production of self-lubricating bearings. It has excellent formability. The crude strength of the pressed powder is 50% better than that of NC100.24. MH40.24 and MH40.28 are more coarse-grained than NC 100.24 and MH 100.28 and can be used when high requirements for the smoothness of the surfaces of the pressed products are not met. However, their crude strength is not as high as that of NC100.24. MH300.25 iron powder is often used as an aditive to NC100.24 in the manufacture of structural parts when particularly demanding surface smoothness requirements are imposed. Such an additive is also useful when dust specimens are required. MH65.17 has very high formability - the crude strength of the pressed specimens is almost twice that of NC 100.24. It is mainly used in the production of friction materials.

The most common brand of iron powder obtained by the spray method is ASC 100.29. It is the highest quality iron powder brand. With its very high purity, it has excellent compaction, which allows a density of $7{,}2 \div 7{,}3.10^3$ kg/m^3 to be reached with a single pressing. It is especially suitable for the manufacture of high-density structural products, as well as for products with certain magnetic characteristics. Its use has a beneficial effect on the durability of the press tools. The AHS 100.29 iron powder has a very good seal. Its use is similar to SC100.26. WPL 200 is a high quality iron powder. It is characterized by high purity, very good sealability (at a pressure of 600 MPa a density of $7{,}0.10^3 kg/m^3$ is reached) and formability. WP150 and WP150HD are powders with very good sealability and purity. In terms of these characteristics, they are similar to the AHC100.29 and ASC 100.29 respectively. Their formability is worse than the WPL 200. The WP 400 iron powder has a larger particle size and is suitable for large parts. The KIP 260A iron powder has good formability and sealability. Its properties are similar to those of the WPL 200. The KIP 280A and KIP 300A powders are highly compacted. They are comparable to the WP150 brand. The KIP 300AS iron powder has high compaction and purity. It is particularly suitable for magnetic materials, is comparable to the WP 150HD and is close to the ASC100.29.

3.Conclution

From the researches made about the dependence of the technological properties of iron powders on the way of their production, the following generalizations can be made for the choice of the type of iron powder in the manufacture of structural parts:

- Reducing spongy and iron powders are particularly applicable where particularly high density (eg anti-friction products) is required. Their use is obligatory when the product has to have high raw strength, as with some friction materials, with long and thin details, etc.;
- Medium-density products can be made with either sponge or powder. The choice for each case is made by technical and economic considerations;
- In the manufacture of high density articles, powdered iron powder with high compaction and purity is used. Powdered iron powder is also used in the manufacture of magneto-mechanical and hot-rolled products, since it contains less impurities.

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