ESTABILISHMENT OF OPTIMUM METHOD FOR POWDER ATOMIZATION USING VALUE METHOD

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ABSTRACT

At the moment is important to obtain metallic powder with a high quality to meet the increasing demand for manufacturing advanced materials. The present paper presents some studies about metallic powder for engineering and bioengineering applications. Because this powder, obtained in special installation, offers big advantages, this technical paper presents some non-traditional methods to obtain spherical metallic powder and proposes Value Method to compare these methods and to determine which method can be used in different circumstances.

KEYWORDS: metallic powder, atomization, plasma, injection moulding, gas atomization, melt, spraying.

1. INTRODUCTION

A number of standard and non-traditional powder production techniques have been developed to meet the increasing demand for high-purity metal powders. Techniques like gas atomization, water atomization, centrifugal atomization, plasma atomization, mechanical attrition and alloying; melt spinning, rotating electrode process (REP), and a variety of chemical processes are used to produce metal powders.

The metal powders are characterized by their morphology which can be described as irregular, blocky or spherical, and powder size. Physical properties such as hardness and ductility, chemical properties such as reactivity and impurities, and bulk properties such as flow properties, apparent density, tap density, compressibility, and green strength are among the properties by which the metal powders are characterized. [2]

The powder metallurgical route is often more convenient regarding cost, precision, and productivity than other processes like casting and forging. Using non-traditional methods atomization is a two-step process.

First, shearing of liquid metal and, second, freezing of liquid droplets. In the first step, a relatively large volume of liquid is sheared into smaller liquid particles.

The energy needed for shearing is supplied by such sources as high-velocity gas jets, water jets, centrifugal action, and by plasma jets. The non-traditional processes of atomization are divided into: gas atomization, water atomization, centrifugal atomization, and plasma atomization.

In the second step, the molten droplets formed during shearing try to minimize their surface energy by forming spheres and then solidify.

The speed and efficiency of the process depends on the surface tension of molten metal and the temperature of super-heated molten droplets.[1]

Usually metal powder atomization technology is used for thermal spray coatings, metal injection moulding powders, brazing metals and nickel based super alloys. These powders are used in a wide variety of applications, including aerospace, industrial gas turbines, fuel cell and pharmaceutical area.

For the first time metallic powder technology was used after 1900 year to obtain wolfram filament of incandescent lamp. At the moment, in the world, powder producers are adding production capacity and are refining their processes to produce higher yields.

2. NON-TRADITIONAL ATOMIZATION TECHNIQUES

Few unconventional processes of atomization are: gas atomization, water atomization, centrifugal and plasma atomization. Metallic particles can be obtained, also, using mechanical or chemical methods.

Gas atomization method uses air, steam, or an inert gas to produce powders from molten metal. Air, nitrogen and argon are commonly used gases, and water is the liquid most widely used, but can be used and paraffin.

The molten metal prepared in an induction, arc or other type of furnace is transferred to the ladle and then to the tundish to make a molten metal stream. It is disintegrated to powder by the impact of gas jets from the nozzles (Fig. 1).

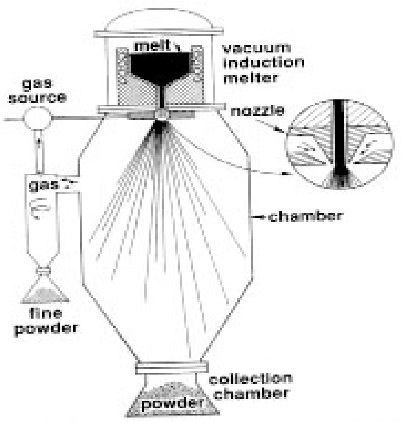

Fig. 1. Gas atomization [1]

Plasma atomization is a two fluid atomization process and the metal can be a molten stream, a wire or other feeds (Fig.2).
Plasma Atomization (PA), process can produce perfectly spherical metallic particles of extremely high purity. The plasma is generated through the inductive coupling of the energy into the plasma.

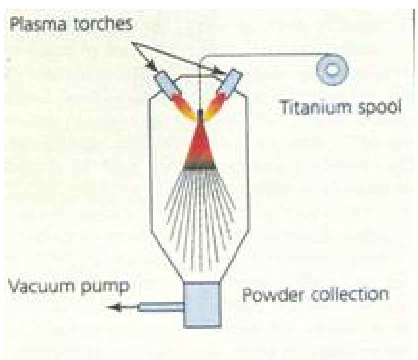

Fig. 2. Plasma atomization process [4]

Alternatively, centrifugal force can be used to break up the liquid as it is removed from the periphery of a rotating electrode or spinning disk (Fig. 3).

There are two types of centrifugal atomization processes: in one, a cup of molten metal is rotated on a vertical axis at a speed sufficient to throw off droplets of molten metal, or a stream of metal is allowed to fall on a rotating disc; in the other a bar of the metal is rotated at high speed and the free end is melted by an electron beam or plasma arc. The bar can be rotated on a vertical or on a horizontal axis

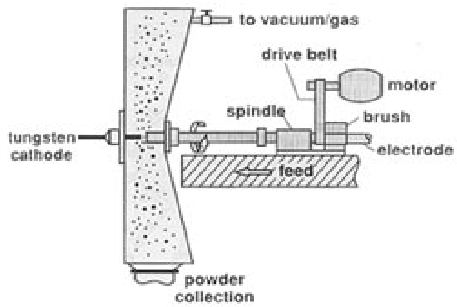

Fig. 3. Centrifugal atomization process [4]

In water atomization process the material is melted and the liquid metal is broken into individual particles by a high velocity stream of the water. The metal is disintegrated into fine droplets which solidify during their fall trough the atomizing chamber.

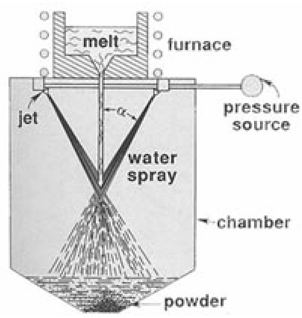

Fig. 4. Water atomization process [4]

Considering process parameters, atomization can be looked as a system (Fig. 5). Particle's parameters can be controlled by varying few from input parameters.

The particle size can be controlled varying configuration of the used jets, pressure and volume of the atomizing fluid.

Particle shape, usually, is determined by the rate of solidification and can be all most spherical, when is used a low heat capacity of gas. When is used water atomization, particle shape is highly irregular.

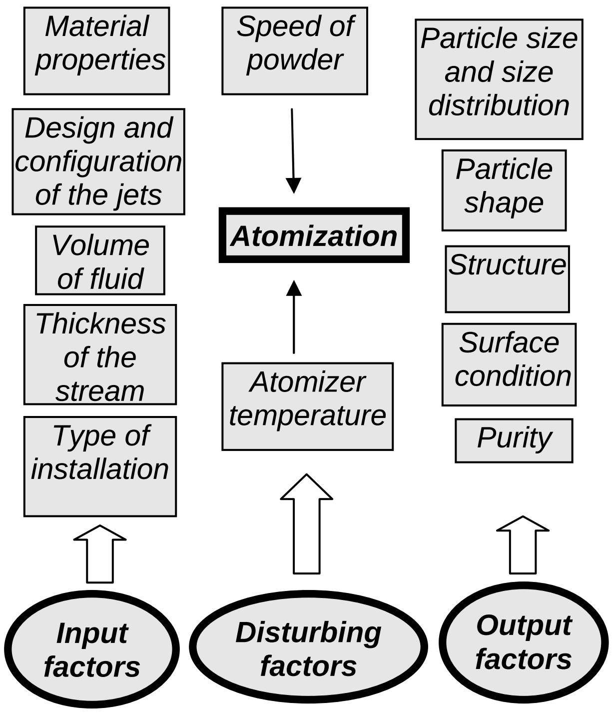

Fig. 5. Atomization process as a system

Usually, these techniques are applicable to all metals which can be melted like: iron, copper, steel, alloy steel, bronze, aluminium, zinc, titanium etc. For readily oxidable metals is used as atomization fluid an inert gas, usually argon.

3. VALUE METHOD

Metallic powder, obtained using non-traditional methods, is analyzed according with few estimation criteria. Finally, using value method, can be decided which method is applicable for different circumstances. The non-traditional methods can be noted with *a*, *b*, *c* and *d* (*a* - gas atomization, *b* - water atomization, *c* - centrifugal atomization, *d* - plasma atomization).

As value method proposes, principal stages which have to be completed to take a decision can be:

1. Establishment of the proposed estimation criteria:
   - Particle's size, form, purity and distribution, C_1;
   - Productivity, C_2;
   - Production costs, C_3;
   - The degree of universality of the device, C_4;
   - The technological simplicity, C_5;
2. Preponderance and reordering of appreciation criteria. Will be successive compared two by two the criteria C_1 to C_6, assigning values, 0 and 1 for criteria with different importance and for criteria with the same importance 0,5 (table 1). For our case, the number of decision, regarding estimation criteria, can be calculated with relation 1.

$$D_C = C_n^{\ 2} = \frac{n(n-1)}{2} = \frac{5 \cdot 4}{2} = 10 \quad (1)$$

Where n represent the number of criteria.

From analysis of table 1 the order become: C_1, C_3, C_2, C_5, C_4.

3. The non-traditional considered methods are compared and can be determinate the value numbers for these methods.

This stage permits to reorder proposed methods according with value numbers. Non-traditional methods will be compared appealing to used criteria; the resulting dates are mentioned in table 2.

The positive decisions number, in this case, regarding supposed methods, can be calculated with relation 1: $D_S = 4 \cdot 3/2 = 6$. The value number N_{VI} for each of supposed non-traditional methods can be calculated with relation 2.

$$N_{VI} = \sum_{l=1}^{N} K_{il} \cdot K_l \quad (2)$$

Where K_{il} are importance coefficients of one from unconventional methods a, b,c d. These coefficients are founded for each of criteria C_1 to C_5, K_l are importance coefficients for each criterion l (K_{C1} to K_{C5}). In this case, for every solution, the value number will be:

N_{va} = 0,33+0,33+0,33+0,5+0,33 = 1,82
N_{vb} = 0+0,33+0,5+0,33+0,5 = 1,66
N_{vc} = 0,16+0,16+0,16+0,16+0 = 0,64
N_{vd} = 0,5+0,16+0+0+0,16 = 0,82

4. Solutions reorder according to value number.

In concordance with value number, in decreasing order, disposal of solutions will be: a, b, d, c.

This order relieves which method can be used, in different circumstances, regarding estimation considered criteria.

Table 1 Determination of importance coefficient for each estimation criterion

Criterion	Decision number										Decision sum	Importance coefficient
	1	2	3	4	5	6	7	8	9	10	N_I	$K_i=N_I/D$
C_1	1	0,5	1	1							3,5	0,35
C_2	0				0	1	1				2	0,20
C_3		0,5			1			1	0,5		3	0,30
C_4			0			0		0		0,5	0,5	0,05
C_5				0			0		0,5	0,5	1	0,10

Table 2 Elements for value numbers determination of supposed non-traditional methods

Solution	Criterion C_1								Criterion C_2								Criterion C_3							
	Decision						N_i	$K_I=N_I/D_S$	Decision						N_i	$K_I=N_I/D_S$	Decision						N_i	$K_I=N_I/D_S$
	1	2	3	4	5	6			1	2	3	4	5	6			1	2	3	4	5	6		
a	1	1	0				2	0,33	1	0	1				2	0,33	0	1	1				2	0,33
b	0			0	0		0	0	0			1	1		2	0,33	1			1	1		3	0,5
c		0		1		0	1	0,16		1		0		0	1	0,16		0		0		1	1	0,16
d			1		1	1	3	0,5			0		0	1	1	0,16			0		0	0	0	0

Solution	Criterion C_4								Criterion C_5							
	Decision						N_i	$K_I=N_I/D_S$	Decision						N_i	$K_I=N_I/D_S$
	1	2	3	4	5	6			1	2	3	4	5	6		
a	1	1	1				3	0,5	0	1	1				2	0,33
b	0			1	1		2	0,33	1			1	1		3	0,5
c		0		0		1	1	0,16		0		0		0	0	0
d			0		0	0	0	0			0		0	1	1	0,16

4. CONCLUSION

In the table 3 are presented non-traditional methods used to obtain metallic powder ordered after their importance and according with estimation considered criteria.

Table 3 The new order of the solutions

Place	1	2	3	4
Solution	a	b	d	c
Value number	1,82	1,66	0,82	0,64

Considering the criteria C_1 to C_5, the optimal solution for powder atomization is solution a – gas atomization. Of course, when has to be obtained perfectly spherical particles, with high level of purity, the optimal solution is plasma atomization. Centrifugal atomization (rotating electrode process) has some limits regarding melt superheat that can be afforded making difficult atomization of alloys with wide freezing ranges. To atomize alloys with this method, alloy has to be made into a high quality bar. This restriction means that centrifugal processes are often not suitable for the production of alloys powder. Centrifugal atomization, which involves liquid metal feeding, is suitable for production of metallic and alloys powder.

Water atomization method can produce powder with small costs and good productivity, amorphous, nano and quasicrystalline structures. Can be obtained powder with superior mechanical properties with low density.

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