A review of Developments in Powder Metallurgy Technique for Metal Powder Production and Processing

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Abstract— this chapter is a review of recent developments in powder metallurgy technique for generation of metal powders and their processing, and aims to provide the reader with an introduction to a range of conventional techniques developed in the last decade, in order to understand the latest developments.

Key words: Metal Powder Production, Powder Metallurgy Technique

I. Introduction

Any fusible material can be atomized by anyone of the powder production technique. Several techniques have been developed so far which permit large production rates of powdered particles, often with considerable control over the size ranges of the final grains of powders[2]. Powders may be prepared by crushing, grinding, chemical reactions, or electrolytic deposition and so on.

Powders of the elements titanium, vanadium, thorium, niobium, tantalum, calcium, and uranium have been produced by high temperature reduction of their corresponding nitrides and carbides. Sub micrometer powders of iron, nickel, uranium, and beryllium are obtained by reducing metallic oxalates and formats[3]. Exceedingly fine particles also have been prepared by directing a stream of molten metal through a high temperature plasma jet or flame[1], atomizing the material. Various chemical and flame associated powdering processes are adopted in part to prevent serious degradation of particle surfaces by atmospheric oxygen.

In tonnage terms, the production of iron powders for PM structural part production dwarfs the production of all of the nonferrous metal powders combined[1]. Virtually all iron powders are produced by one of two processes: the sponge iron process or water atomization.

II. Conventional methods of powder production

A. *Sponge iron process:*

In the process, selected magnetite (Fe_3O_4) ore is mixed with coke and lime and placed in a silicon carbide retort. The filled retort is then passed through a long kiln, where the reduction process leaves an iron “cake” and a slag. In subsequent steps, the retort is emptied; the reduced iron sponge is separated from the slag and is crushed and annealed.

B. *Atomization:*

Metal powders are produced by disrupting a molten metal stream with high-pressure water or gas jets. The relative volumes of the metal stream and the impinging fluid together with the pressure of the atomizing medium, amongst other variables, are critical in determining the particle size distribution of the atomized powder.

1) *Inert Gas atomization:*

For non-ferrous metal powders this method is suitably employed. In inert gas atomization, the particle shape produced is dependent on the time available for surface tension to take effect on the molten droplets prior to solidification and, if a low heat capacity gas is used (nitrogen and argon are most common), this time is extended and spherical powder shapes result.

2) *Water atomization:*

Atomization involves the disintegration of a thin stream of molten metal through the impingement of high energy jets of a fluid. Water is the most commonly used liquid in atomization. Water atomized iron powders have irregular particle shape and therefore good green strength.

C. *Electrolytic Production:*

Electro-deposition conditions can be arranged so that the metal is not plated out as a solid electrode layer, but as a powdery deposit, which does not adhere to the cathode and can be removed from the electrolyte bath as a fine sludge. The most common product is pure copper powder

III. Recent advances in powder production methods

A. *Mechano-Chemical synthesis:*

Mechano-chemical processing (MCP) is the term applied to the powder process in which chemical reactions, structural changes and phase transformations are activated by the application of mechanical energy[3]. It was shown that the halides of gold, silver, platinum and mercury decomposed to halogen and the metal during fine grinding in a mortar. This study clearly established that chemical changes could be brought about, not only by heating but also by mechanical action. MCP technique embraces three different processes, mechanical alloying, mechanical milling, and reaction milling. All these three processes involve cold welding, fracturing and re-welding of powder particles during repeated collisions with grinding balls in a high energy milling device. But depending on the actual process, other features may be present.

B. *Plasma synthesis of metal nano powders:*

Transfer arc plasma, the anode electrode material is made from metal (e.g. Al, Cu, Fe, Co, Ni etc.) and is consumed in the synthesis of metallic nano-powders. The cathode electrode is made from tungsten and is a non-consumable electrode. The plasma heats up the anode material to above its boiling point. This leads to the evaporation of the anode material and subsequent cooling of metal vapor by collision with the background gas species. This reduces the diffusion rate and develops a supersaturated vapor, where the metal atoms diffuse around and collide with each other to form clusters of nuclei[4]. Homogenous nucleation from the supersaturated vapor results in the formation of a nucleation zone and more nuclei are formed, some of which are rapidly cooled and combine to form primary particles by Brownian coagulation and an agglomeration growth mechanism

IV. Conventional Methods of Powder Processing

A. *Mixing and Blending:*

The object of mixing is to provide a homogeneous mixture and to incorporate the lubricant. The main function of the lubricant is to reduce the friction between the powder mass and the surfaces of the tools - die walls, core rods, etc. - along which the powder must slide during compaction, thus assisting the achievement of the desired uniformity of density from top to bottom of the compact.

B. *Pressing:*

The mixed powders are pressed to shape in a rigid steel or carbide die under pressures of 150-900 MPa. At this stage, the compacts maintain their shape by virtue of cold-welding of the powder grains within the mass.

C. *Sintering:*

Sintering is the means whereby the powder particles are welded together and a strong finished part produced

V. Recent Developments in Powder Processing

A. *Microwave sintering of Metallic powders:*

Microwave sintering of powder metallurgy (PM) green bodies comprising various metals, steels and metallic alloys, in general, produces highly sintered bodies in a very short period of time. In the last decade various metal/alloy powders such as Fe, Cu, Al, Ni, Mo, Co, Ti, W, WC, WHAs, Sn, brass, have been sintered using microwave successfully by various researchers. An important distinction in the microstructures of conventional and microwave-sintered samples observed was that the pores in the microwave sintered samples (FC208 steel) had more rounded edges than the conventional sample and hence improved ductility and strength[10].

B. *Warm compaction of metallic powders:*

Similar to the traditional powder metallurgy compaction process, warm compaction utilizes traditional compaction equipment while the powder and the die assembly are heated to temperatures of about 100–150°C. At higher temperatures, lubricants begin to break down and the oxidation of iron powders occurs more rapidly; hence, the application of the warm compaction process is technically limited to temperatures <150°C however at too low temperatures (about 100°C) a sufficient compaction effect would not be achieved. temperature ranges were determined to achieve consistent apparent density and flowability, which guarantee close dimensional tolerance and weight scatter of the compacted parts[8]. Here, it is pertinent to point out that binder treatment of the powder is one of the key components in the success of the warm compaction process.

C. *Powder Extrusion:*

Powder extrusion is an alternative powder metallurgy process used to manufacture parts with high length to diameter ratios. In this manufacturing process, powders are placed in a container of thin sheet metal. This is evacuated and sealed, producing a vacuum inside. The container containing the powder is then extruded.

D. *Loose Sintering:*

Loose sintering, also known as pressure less compaction is a manufacturing method of forming a part from powders, without compacting the powders in any way[9]. Powder is poured into the die cavity and sintered in the mold. Sintering times tend to be longer with this method. Parts produced by pressure less compaction are extremely porous. This powder process is used to manufacture items such as metal filters.

E. *Spark Sintering:*

Spark sintering is a unique powder process that uses both electrical and mechanical energy to form the part. A high power electric current travels through the compact, simultaneously the work is compressed. This is possible because the punch are also electrodes. The entire part can be pressed and sintered in seconds. This current burns away surface films from powder particles and heats the work.

VI. Conclusion

Atomization breaks liquid metal into droplets, which then cool to form powder and can be processed further. Recent developments in powdered metal processes have led to demands for finer grained powders and atomisation techniques can be used to create powders up to (but not including) the nanoscale. Different techniques such as gas/air, water and centrifugal atomization have been discussed. Potential problems such as inclusions, contamination and oxide films can occur when processing metal powder and this chapter has discussed some of the ways to mitigate these problems. Finally, the economics of powder production and some of the scores of applications for atomized metal powders have been touched upon.

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