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Use of Pulsed Electromagnetic Fields for Materials Processing in Powder Metallurgy

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ABSTRACT

In current article, applications of electromagnetic pulsed fields for processing of powder materials are presented. The main attention is paid to the following applications of pulse electromagnetic fields in powder metallurgy and allied industries: pressing of powders, manufacturing of powder coatings, and conveying of ferromagnetic powders by means of pulsed electromagnetic field. Feasibility for conveyance of ferromagnetic powders by means of electromagnetic elevator is shown.

Keywords: electromagnetic compaction, powder materials, coil, impulse currents, transportation, conveying.

1. INTRODUCTION

Practical usage of pulsed electromagnetic fields in powder metallurgy is rather slight, yet it can be applied to variety of technological processes such as, pressing of powders, processing of powder coatings, conveying of powders etc. A majority of research activities in this area was conducted in the USA, Germany, Russia, and Latvia. D. Sandstrom is pioneered the research of pulsed electromagnetic fields for consolidation of powder materials [1]. V. Mironov has investigated a method of magnetic-pulse pressing of powders on the basis of iron and hard alloys [2] [3]. N. Dorozhkin, A.Kot, etc. have studied influence and practical use of a method of magnetic-pulse processing of materials on powder metal coatings [4]. A comprehensive research in the field of consolidation of iron powders and hard alloys were carried out in Germany by H. Wolf and V. Mironovs [5]. The intensification of processes of the expiration of powder materials from bunker devices under the influence of electromagnetic impulses was studied in work [6]. Application of pulse electromagnetic fields for joining of metallic materials obtaining a single-piece connections was investigated in works [7] [8]. Recently, applications of pulsed electromagnetic fields for conveying of ferromagnetic particles and metal powders have been studied [9] [10]. Current paper is a short overview of the research activities of the Laboratory of Powder Materials of Riga Technical University (Riga, Latvia).

2. MAGNETIC PULSED COMPACTION OF POWDERS (MPCP)

A method of magnetic pulsed compaction of powders (MPCP) came from powder metallurgy and was reviewed in many papers, including [2] [3] [11]. Great technological capabilities of MPCP for manufacturing of complex configuration, multi-layered and high-density part were discovered. However, the MPCP method did not receive a welcome from the industry, due to the following reasons:

- Lack of comprehensive studies of the process,
- A short lifespan of equipment,
- Low-precision product that requires subsequent machining,
- Need of liners (conductive plates) or shells used for pressing powders.

In the past, the studies of MPCP process were conducted in the U.S. [12] [13], Russia [14], Israel [15], Latvia [16] and other countries. The main aim of current research is in finding the ways for improving technological MPCP equipment, as well as a research of feasible applications for MPCP process. Preceding research [17] shows that MPCP process could be used for laying and processing of antifriction coatings.

Magnetic pulsed compaction of powders is a process which occurs under the action of electromagnetic pulsed loads. A principle of MPCP process is illustrated in Figure 1. An example of cylindrical coil used in experiments with radial MPCP process is shown in Figure 2. By means of MPCP process it is possible to achieve up to 75-85% of theoretical density for green PM parts. The MPCP is a very complex process with many influencing factors on the compaction results:

- work piece dimensions,
- properties of the powder,
- electrical parameters (current frequency),
- wall thickness,
- electromagnetic pressure,
- work-piece pre-treatments,
- form of particles,
- discharge energy (capacity, voltage),
- gap between coil and work piece,
- coil properties.

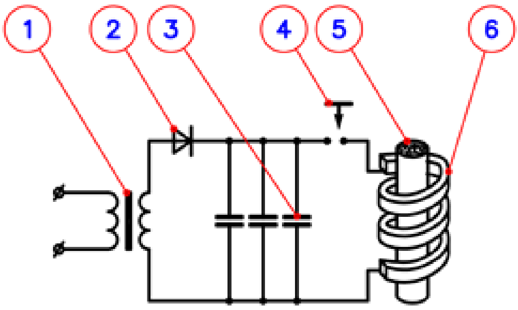


Figure 1: Schematics of magnetic pulsed compaction of powders (MPCP).

1 – transformer; 2 – rectifier; 3 – battery of capacitors; 4 – discharger; 5 – ferromagnetic powder in shell; 6 – coil

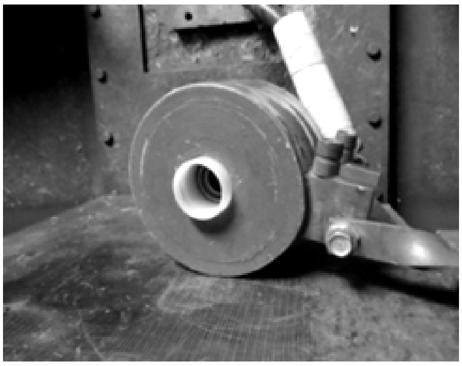


Figure 2: Coil used for radial compaction of powder materials (University of applied sciences of Zwickau, Germany)

In this case the electromagnetic pressure can be determined by the following expression [3]:

$$p(t) = \frac{1}{2} H_m^2 \mu e^{-2\beta t} \sin^2 \omega t$$

where, Hm - magnetic field strength in the gap between coil and details, μ - magnetic constant, β – damping of discharge current, ω – current angular frequency, t – time. Technical parameters of electrical current and pulse pressure obtained on equipment designed at Riga Technical University are shown in Figure 3.

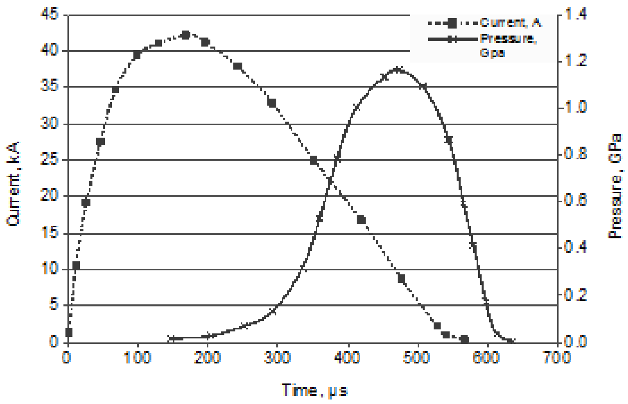


Figure 3: Change of pulse current of I and electromagnetic pressure P at flat pressing on the electromagnetic equipment at Riga Technical University.

Great interest has the stepped radial compression of rod-shaped or tubular parts [16] with a length to diameter ratio greater than 2.5 Figure 4. This technique can be applied either along a whole length of tubular part or in certain points of the tubular shell (stepped pressing).

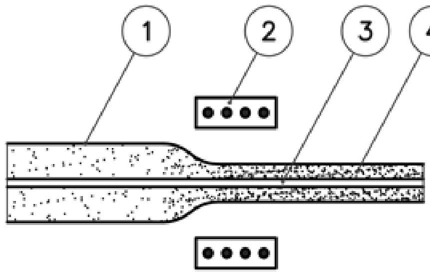


Figure 4:
Schematics of stepped radial compression of rod-shaped or tubular parts.1 – shell filled with powder; 2 – coil; 3 – mandrel (made of solid of powder material); 4 – compacted powder;

The production of rod-shaped parts encounters the following drawbacks:

• Transverse cracking by axially acting tensile stresses during the compression process

• Density drop in the radial direction, inhomogeneity of the density and strength.

• Tubular parts can be manufactured with wall thickness up to 8 mm with sufficient density distribution in the radial direction by magnetic force compaction using a driver.

3. MANUFACTURING OF MULTI-LAYERED PM PARTS AND COATINGS

There are two methods of production of coatings by MPCP process: a method of powder compaction through a conductive element (shell) by pulsed electromagnetic field [11] and the method of magnetic-pulse treatment of pre-stowed and then sintered powder layer [18]. The book [4] describes a methodology and reveals certain recommendations on use of MPCP process in shells for anti-friction part manufacturing. Besides that, special features of MPCP process and the overall economic feasibility of its application are given. These recommendations are based on the possibility of obtaining high anti-friction properties of parts by means of Fe-C-Cu materials. Experimental studies were carried out on the equipment described in [7]. In conducting the experiments the following sequence of operations was developed Figure 5. (Next Page)

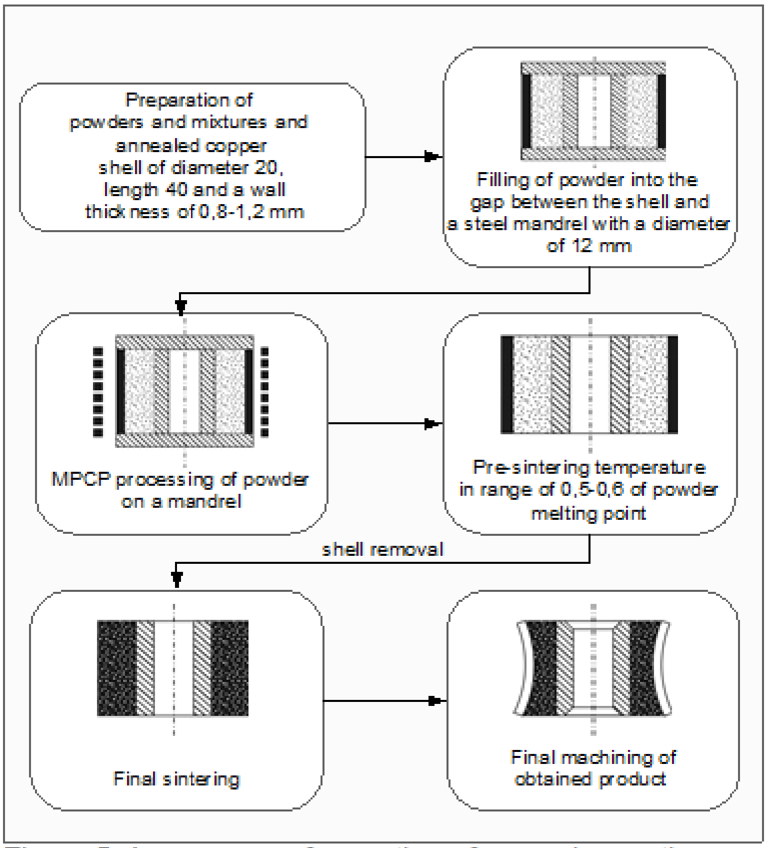
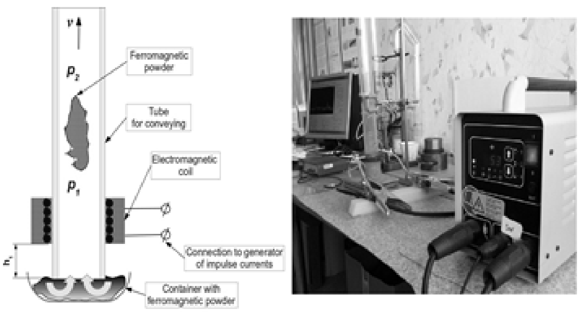


Figure 5: A sequence of operations for powder coating manufacturing by means of pulsed electromagnetic fields.

4. CONVEYING OF FERROMAGNETIC MATERIALS BY MEANS OF PULSED ELECTROMAGNETIC FIELD

Conveying of ferromagnetic powder materials is another application of pulsed electromagnetic field [19]. The most common operations where conveying of powdered materials is taking place are: vertical, horizontal and inclined transportation, dosage, loading to and unloading from containers [20] [21]. In the Scientific Laboratory of Powder Materials at Riga Technical University a laboratory-scale single-stage electromagnetic system for powder conveying on short distances (up to 4-5 meters) in pipes has been designed [22]. Schematics of the laboratory-scale installation and technical parameters are shown in Figure 6.



Parameter	Value
Generator of impulse currents	
Capacitance, μF (F)	66000 (0.066)
Energy, J	1600
Impulse duration, ms	1.0-5.0
Conveying tract (tube)	
External diameter, mm	50
Length, mm	2000

Figure 6: A sequence of operations for powder coating manufacturing by means of electromagnetic pulsed fields.

Experimental data on ferromagnetic powders conveying (weight of conveyed material (per shot) vs discharge energy) for different iron powders [23] and steel nuts are shown in Figure 7.

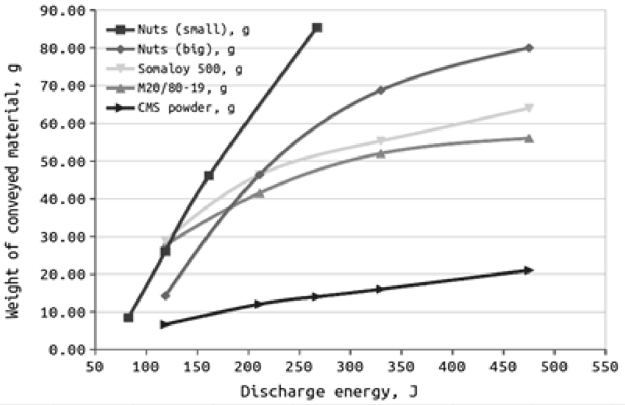


Figure 7: Laboratory experiments on conveying of powder materials and solid iron parts.

5. CONCLUSIONS

Applications of pulsed electromagnetic fields have a number of positive features opening great prospects for improvement of technological processes in powder metallurgy:

- flexible opportunity for generation of pulsed pressure with variable amplitude and duration,
- concentration of pressure in certain locations of PM part,
- Directed action of pulsed electromagnetic fields on a material with the aim of changing its properties.

At the same time a number of technical constraints are limiting the use of pulsed electromagnetic fields for mass production of PM parts. For example, a need for reliable and affordable high-performance equipment for industrial applications and related manufacturing procedures in order to ensure a constant and high-quality final production of PM products.

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