APPLICATIONS OF PULSED ELECTROMAGNETIC FIELDS IN POWDER MATERIALS HIGH SPEED FORMING

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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.

Keywords

Electromagnetic compaction, pressing, powder materials, coil, impulse currents, coatings, multilayer parts.

1. INTRODUCTION

Practical applications of pulsed electromagnetic fields in powder metallurgy are rather limited, yet it can be applied to a 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] .

A method of magnetic pulsed compaction of powders (MPCP) came from powder metallurgy and was reviewed in many papers, including [2] [3] [5] . Great technological capabilities of MPCP for manufacturing of complex configuration, multi-layered and high-density part were discovered. The current article overviews engineering and research activities of the Scientific Laboratory of Powder Materials of Riga Technical University (Riga, Latvia).

2. MAGNETIC PULSED COMPACTION OF POWDERS (MPCP)

In the past, the studies of MPCP process were conducted in the U.S. [11] [12] , Russia [13] , Israel [14] , Latvia [15] 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 [16] shows that MPCP process can be applied for laying and processing of anti-friction 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.

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.

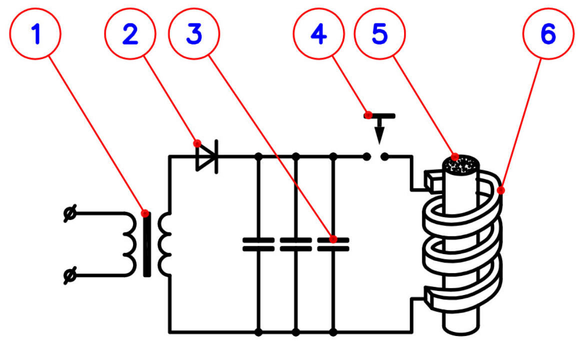

Figure 1: *Schematics of magnetic pulsed compaction of powders (MPCP).*

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

In this case the electromagnetic pressure can be determined by the following expression (1) [3] :

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

where, H_m - 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 2.

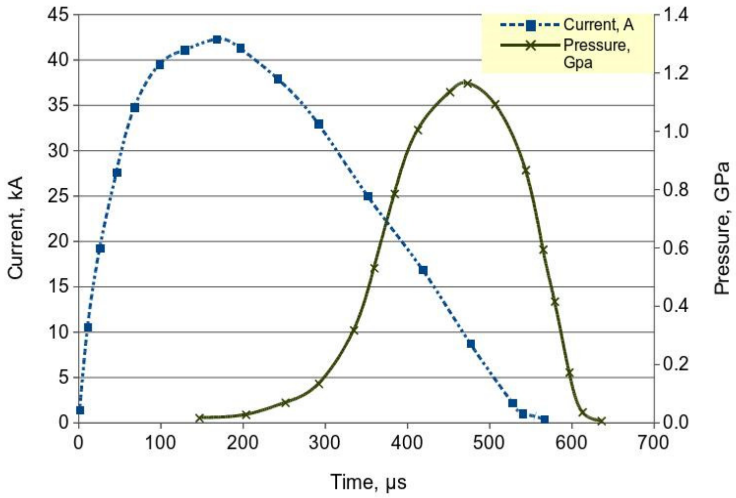

Figure 2: *Change of pulse current and produced electromagnetic pressure.*

Main advantages and disadvantages of MPCP process are outlined in Table 1.

Advantages of the MPCP process	Disadvantages of the MPCP process
✓ Obtaining PM parts made of different powder materials, including ferromagnetic, ceramic and amorphous powders. ✓ By means of MPCP process it is possible to achieve up to 75-85% of theoretical density for green PM parts. ✓ Manufacturing of multilayer parts.	× Need of liners (conductive plates) or shells used for pressing powders, × Low-precision product that requires subsequent machining, × A short lifespan of equipment.

Table 1: *Advantages and disadvantages of MPCP process.*

Another MPCP technique is a stepped radial compression of rod-shaped or tubular parts [15] with a length to diameter ratio greater than 2.5 Figure 3. This technique can be applied either along a whole length of tubular part or in certain points of a tubular shell.

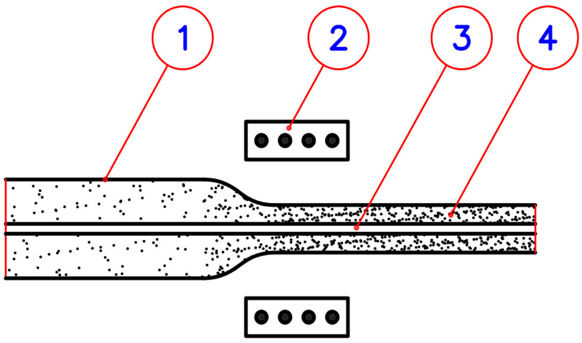

Figure 3: *Schematics of stepped radial compression of rod-shaped or tubular parts.*
1 – shell filled with powder; 2 – coil; 3 – mandrel (made of solid of powder material); 4 – compacted powder;

However, a stepped radial compression in shell technique is characterised by advantages and disadvantages shown in Table 2.

Advantages of stepped radial compression	**Disadvantages of stepped radial compression**
✓ Compaction of ceramic or granular materials, obtaining porous structures with variable porosity. ✓ Tight crimp of powder materials in shell. ✓ Obtaining compacted powder parts with variable density.	× 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.

Table 2: *Advantages and disadvantages of stepped radial compression technique.*

The MPCP process opens an opportunity to manufacturing of metallic coatings, where material of coating have solid or porous structure. Here, a method of powder compaction in a conductive deformable shell (outer layer) by pulsed electromagnetic field [5] and the method of magnetic-pulse treatment of pre-stowed and then sintered powder layer [17] can be applied. Methodology and recommendations on use of MPCP process in shells for anti-friction part manufacturing are described in [4] . 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 [18] . In conducting the experiments the following sequence of operations was developed Figure 4.

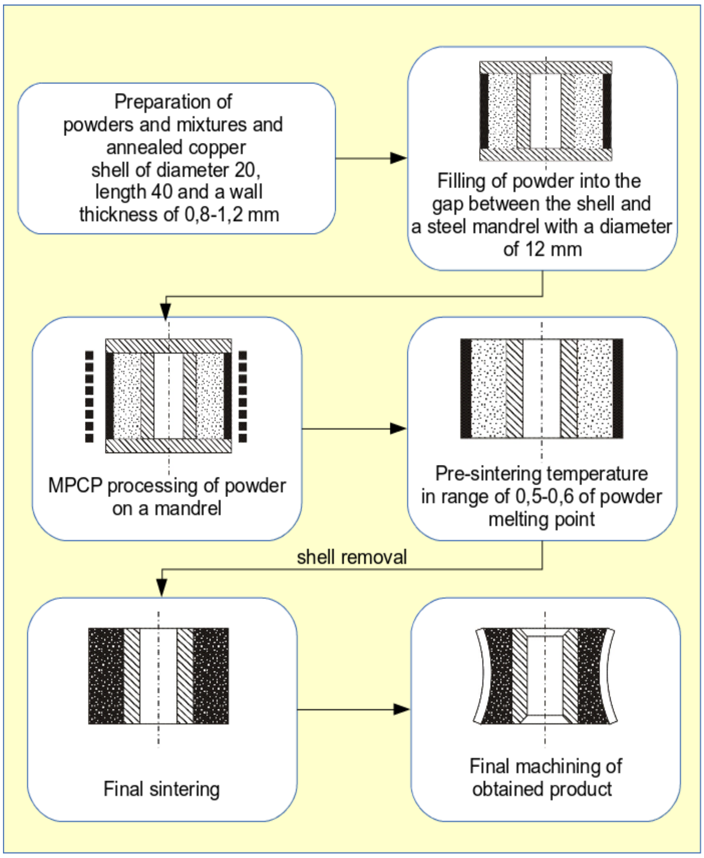

Figure 4: *A sequence of operations for powder coating manufacturing by means MPCP process.*

Advantages and disadvantages of powder coating manufacturing process are listed in Table 4.

Advantages of powder coating manufacturing	Disadvantages of powder coating manufacturing
✓ Obtaining compacted porous powder coating which can be impregnated by lubricants. ✓ Manufacturing of multilayer elements with variable properties for each layered material.	× The implementation of radial pressing of powder coating is related to the problem of ensuring the coating properties uniformity. × Adhesion strength of coating is determined by conditions of mandrel surface, powder material, and by discharge parameters.

Table 3: *Advantages and disadvantages of stepped radial compression technique.*

3. CONCLUSIONS

This article outlines scientific and engineering developments of the Scientific Laboratory of Powder Materials of Riga Technical University (Riga, Latvia) related to magnetic pulsed compaction of powders process. 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 [19] and related manufacturing procedures in order to ensure a constant and high-quality final products.

4. BIBLIOGRAPHY

[1] D. J. Sandstrom, “Consolidating metal powders magnetically,” Met. Prog., vol. 86, no. 3, pp. 215–221, 1964.
[2] V. Mironov, “Pulververdichten mit Magnetimpulsen,” *Planseebericht fur Pulvermet.*, vol. 24, pp. 175–190, 1976.
[3] V. A. Mironov, *Magnitno-impulsnoe pressovaniye poroshkov /in Russian/*. Riga, Zinatne, 1980, p. 196.
[4] N. N. Dorozhkin, V. A. Mironov, and A. A. Kot, *Jelektrofizicheskie metody poluchenija pokrytij iz metallicheskih poroshkov*. Riga (Latvia): Zinatne, 1985, p. 131.
[5] V. Mironov and H. Wolf, “Pulververdichten durch elektromagnetische Kräfte Herstellunsmöglichkeit für Werkzeugaktivelements,” *Fertigungetechnik*, no. 9, pp. 558–590, 1980.
[6] V. Zemchenkov, V. Mironovs, and J. Viba, “Intensification of technological processes with electromagnetic impulses,” in *5th Int. DAAAM Conf*, 2006, pp. 307–310.
[7] V. Mironovs and I. Boyko, “Application of the electromagnetic impulses for joining of details and compacting of powders,” in *10th Int. Conf. TMT-2006*, 2006, pp. 205–208.
[8] M. Kolbe and V. Mironovs, “Gemeinsame Forschungsarbeiten zur Impulsstrombearbeitung mit Wissenschaftlern der TU Riga,” *IfPnews der Westsächsischen Hochschule Zwickau*, no. 12, 2011.
[9] V. Mironov and J. Viba, “Elevator for Powders,” in *EuroPM 2007 Conference (Vol. 2)*, 2007, pp. 39–44.
[10] V. Lapkovsky, V. Mironov, A. Shishkin, and V. Zemchenkov, “Conveying of Ferromagnetic Powder Materials by Pulsed Electromagnetic Field,” in *Euro PM2011 – Tools for Improving PM: Modelling & Process Control*, 2011, pp. 253–258.
[11] B. Chelluri and E. Knoth, “Powder Forming Using Dynamic Magnetic Compaction,” *4th Int. Conf. High Speed Form.*, pp. 26–34, 2010.
[12] A. G. Mamalis, D. E. Manolakos, A. G. Kladas, and A. K. Koumoutsos, “Electro-magnetic Tooling for Metal Forming and Powder Compaction : Numerical Simulation,” pp. 143–154.
[13] V. Banin and S. Paranin, “Processing of nanostructured oxide ceramics with magnetic pulsed compaction technique,” *Key Eng. …*, 2001.
[14] V. Shribman, “Take advantage of the new magnetic pulse welding process,” *Svetsaren, a Weld. Rev.*, no. 2–3, pp. 14–16, 2001.
[15] V. Mironov and V. Lapkovsky, “Tubular articles with the high permeability by uses of the MIOM technology,” in *Engineering materials and Tribology-2004*, 2004, pp. 201–205.
[16] V. Mironov, I. Boyko, and V. Lapkovsky, “Production of Fe-C-Cu powder coatings by pulse magnetic pressing and infiltration,” in *tmt.unze.ba*, 2011, pp. 137–140.
[17] I. Boyko, V. Mironov, and V. Lapkovsky, “Property and Structure Changes of Sintered Powder Materials by The Treatment in The Pulse Electromagnetic Field,” in *Proceedings of Euro PM 2007 (Vol. 3)*, 2007, pp. 439–444.
[18] V. Mironovs and I. Boyko, “Application of the electromagnetic impulses for joining of details and compacting of powders,” in *10th Int. Conf. TMT-2006*, 2010, pp. 205–208.
[19] C. Beerwald, “Anlage zur elektromagnetischen Umformung – SMU SSG 3020,” *Poynting GmbH Dortmund*, 2010.