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PRODUCTION OF Fe-C-Cu POWDER COATINGS BY PULSE MAGNETIC PRESSING AND INFILTRATION

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ABSTRACT
The present paper describes an application magnetic pulsed compaction of powders (MPCP) for laying coatings made of Fe-C-Cu powder. It is shown that MPCP process can be used for joining metallic parts with coatings made of Fe-C-Cu powder, where powder coating may act as an antifriction material on the surface of solid metallic part. Some perspective applications of MPCP process have been reported.
Keywords: magnetic, pulsed, compaction, coating, joining, powder, fe-c-cu

1. INTRODUCTION
A method of magnetic pulsed compaction of powders (MPCP) came from powder metallurgy and was reviewed in many papers, including [1-3]. 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. In our opinion, there could be several reasons for that:

- 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.

Nevertheless, research activity and search for practical applications of MPCP is continuing. In the past, the studies of MPCP process were conducted in the U.S. [4,5], Russia [6], Israel [7], Latvia [8,10] and other countries. The main aim of research is in finding ways for improving technological MPCP equipment, and research of feasible applications of MPCP process. One of possible application of MPCP process is laying and processing of antifriction coatings.

We can distinguish two methods for producing coatings by MPCP process: a method of powder compaction through a conductive element by pulsed electromagnetic field (or shell) [3] and the method of magnetic-pulse treatment of pre-layed and then sintered powder layer [9].

Papers [1,2,3,11] describe a methodology and reveal certain recommendations on use of MPCP process in shells for antifriction part manufacturing. These recommendations are based on the possibility of obtaining high antifriction properties of the parts by use of Fe-C-Cu materials. Beside that, special features of MPCP process and the overall economic feasibility of its application are reviewed.

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2. MATERIALS AND EXPERIMENTAL PROCEDURE

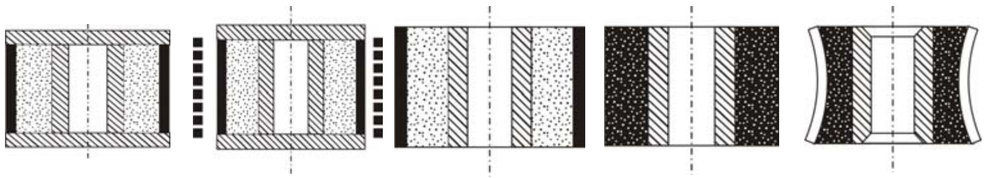
2.1. Materials

We have selected the material Fe-C-Cu with high copper content (15-20%). A high copper content was needed for impregnation of obtained coating during compaction process [10]. A percentage of copper content in the final product must be within 10-18%. The addition of copper gives the highest corrosion resistance, good antifriction and mechanical properties [11]. For experiment, powders of iron, steel, copper, and alloys [12] were used.

2.2. Experimental procedure

Experimental studies were carried out on the equipment described in [10]. In conducting the experiments we set up the following sequence of operations:

- preparation of powders and mixtures,
- annealed copper shell of diameter 20, length 40 and a wall thickness of 0,8-1,2 mm
- filling of powder into the gap between the shell and a steel mandrel with a diameter of 12 mm (Figure 1a)
- MPCP processing of powder on a mandrel (Figure 1b)
- pre-sintering temperature in range of 0,5-0,6 of powder melting point (Figure 1c)
- shell removal
- final sintering (Figure 1d)
- final machining of obtained product (Figure 1e)

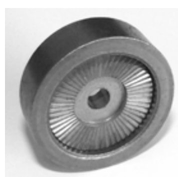


(a) (b) (c) (d) (e)

Figure 1. Schematic of technological operations for manufacturing of Fe-C-Cu coating by MPCP process.

Pressed powder parts also may be used as a mandrel. It allows to evaluate the possibility of production of multilayered parts (Figure 1b).

a) bushing made of iron powder on a steel mandrel



b) ring (bush) on the shaft (both parts made of powder Fe-C)

Figure 2. Samples of blanks before MPCP processing

The multiturn spiral inductors were used as working tools. Electrical discharge parameters (discharge current, magnetic field intensity) controlled by the shunt circuit through the Rogowski coil and magnetometric transducers. Electromagnetic pressure is calculated using the results of measurements of electrical parameters by methodology described in [2]. Study of basic physical and mechanical

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properties of the coatings (hardness, density, adhesion, wear resistance) was performed according to known methods using a standard equipment.

3. RESULTS AND DISCUSSION

The main parameter of MPCP process is the pressure of the electromagnetic field to the surface of shell. A pressure of electromagnetic field is determined by amplitude and duration of action. The increase of amplitude of the electromagnetic pressure to 350-400 MPa followed by increase of coverage density to a certain value, and depends on material. Further increase of pressure amplitude does not affect to the density (Figure 3).

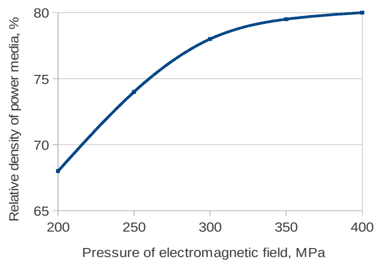

Figure 3. Relationship between pressure of electromagnetic field and relative density of powder material compact.

We can tune a pressure amplitude by changing the operating voltage in the inductor and the frequency of discharge current, or by changing an inductance of the coil. It was found that the decrease of discharge frequency may cause a rupture of shell. This phenomenon may be explained by occurrence of back pressure from metal mandrel to the shell. A significant increase in the frequency of the discharge current can lead to cracking of coating, especially for low-plastic powders. The maximum compaction degree occurs in the frequency range, calculated for conditions when the shell thickness is equal to thickness of skin layer of shell and coating. The dimensions of cavity for powder filling have a significant influence on the coating density, and thus the adhesion. For example, increasing its thickness from 0,5 to 5,0 mm leads to a decrease in density of iron powder layer up to 20%. Application of lubricant on the inner surface of the shell enhances the coating density. it can be explained by reduction of external friction. The suitability of different lubricants (motor oil, suspension of graphite, zinc stearate, paraffin wax) and polyethylene film were evaluated.

The implementation of radial-sequential pressing of powder coating is related to the problem of ensuring the coating properties uniformity. It was established experimentally that the performance of the inductor with a cone (of 20 degrees) at the entrance improves uniformity of coating density.

Adhesion strength of coating is largely determined by conditions of mandrel surface, powder material, and by discharge parameters. It was found that, comparing to a static pressing of iron powder on a steel substrate, the MPCP process reduces the activation energy of sintering process by 15-20%. In general, increasing the pressure amplitude effectively up to 450 MPa further increase has no effect to the adhesive strength (Figure 4).

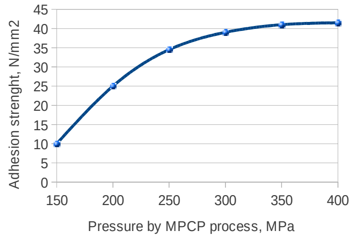

Figure 4. Relationship between adhesion strength and pressure created by MPCP process.

4. CONCLUSIONS

A development of magnetic pulsed compaction of powders (MPCP) process for production of coating made of metallic powders, in particular Fe-C-Cu has demonstrated a positive features, especially in combination with impregnation, which occurs thanks to higher copper content in the Fe-C-Cu powder mixture. MPCP process can be applied for joining parts made of metallic powders. A possible application of MPCP process can be extended to the laying of hard metal coating for reconditioning operations.

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