STATIC-DYNAMIC POWDER MATERIAL COMPACTION METHODS

Victor Mironov[1], Pavel Stankevich[1], Irina Beljaeva[2], Vladimir Glushenkov[2]
[1]Riga Technical University, Latvia; [2]Samara State Aerospace University, NIL-41, Russia
viktors.mironovs@gmail.com, mail020580@gmail.com, belyaeva-ommr@yandex.ru, vgl@ssau.ru

Abstract. The paper discusses the basic methods of combined static-dynamic compaction of powder materials. According to the authors, one of the important directions is a method that combines axial compaction of powder, carried out with the help of a hydraulic press, and pulse-magnetic compaction (MPC). Experimental studies were carried out on metal powder materials based on Fe-C-Cu. Particular attention is paid to the production of long length products using step-type compaction; the effect of specific pressing energy on a compressibility of materials is shown. It has allowed giving advice on the choice of compaction modes and on designing of inductor devices.

Keywords: static-dynamic compaction, powder materials, electromagnetic pulse.

1. Introduction

Methods of compaction of ceramic powders in hydraulic and high-performance mechanical presses, vibratory compacting, rolling and other methods are widely known. Dynamic methods of powder material compaction using hydraulic and electromagnetic pulses are not less known. The development of new ceramic and composite materials as well as products from them is closely linked to improvement of compaction methods, which allow obtaining a higher density of materials, increasing the size of products, diversifying their possible form. In recent years, there has been increased interest in hybrid and combined technologies of compaction, which combine static and dynamic loads. In hybrid technologies a material is acted on by two or more sources of loading simultaneously throughout the production cycle. For the combined technologies, it is characteristic that while one source acts the second source operates once at a given (usually at the start or end) moment of the production cycle (Fig. 1).

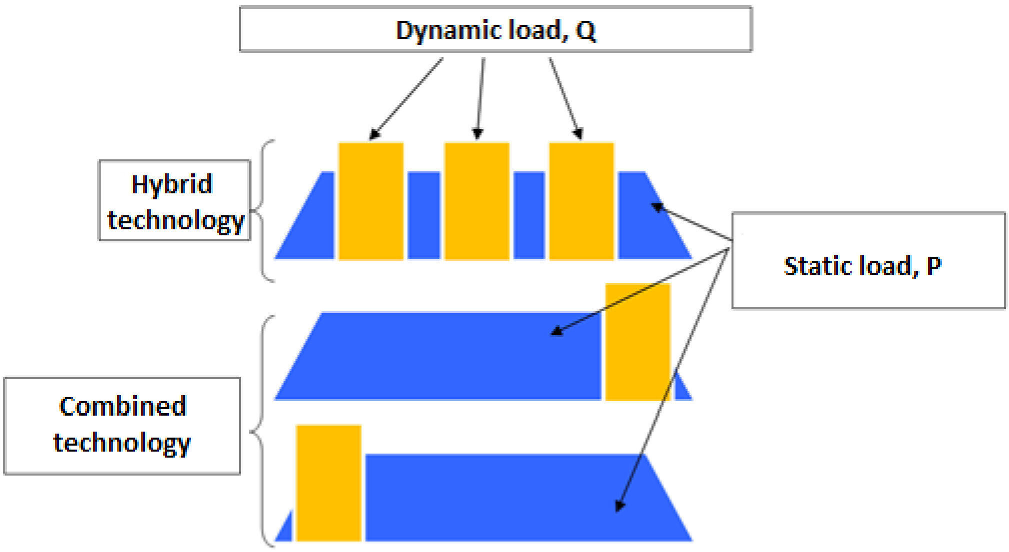

Fig. 1. **Cycloramas of hybrid and combined technologies**

To combined technologies may be assigned the combination of vibration shaking down and pulse compaction [1], radial dynamic compaction of long-length products with their step-type moving [2], static compaction on a hydraulic press and pulse compaction [3].

The combined technologies are of considerable interest for treatment of suspensions and solutions in a pulsed electromagnetic field [4].

Factors of pulse-magnetic action (induced pulsed currents, stress waves, acceleration of the material) change the structure, mechanical and technological properties of materials. This technology is particularly interesting for processing of suspensions containing metal ferromagnetic particles [5].

Pulse-magnetic processing can be used in preparation of suspensions or directly in implementation of processes of slip casting in devices where inductors are mounted in the mold.

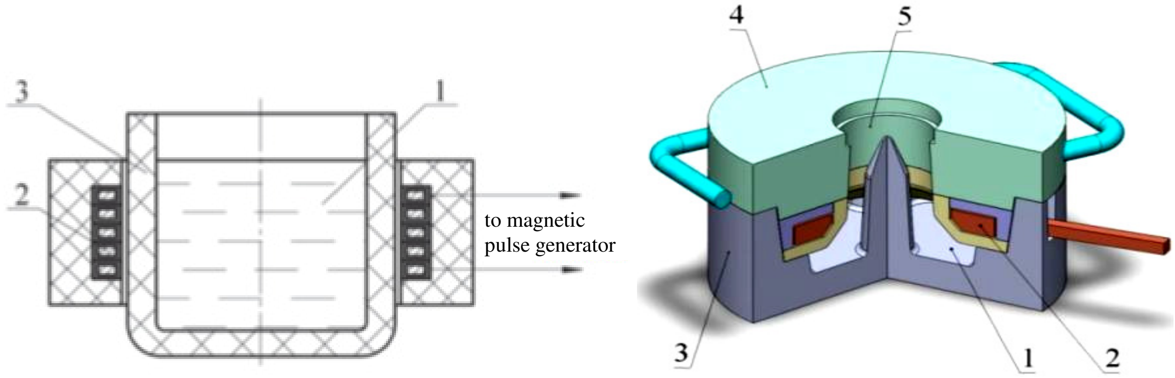

Fig. 2. **Technological scheme of pulse-magnetic processing of solutions and suspensions:** 1 – material; 2 – inductor; 3 – heating device; 4 – mold; 5 – location of the cover

This paper considers the methods of pulse-magnetic compaction (PMC) of powder materials in which a pulsed electromagnetic field (PEMF) is used to move a punch or shell. Advantages of these methods are: a micro or millisecond range of application of additional dynamic load, the possibility of obtaining long-length products, the ability to integrate a pulse-magnetic installation into a processing line. The implementation of such technology is made possible by the use of resistant inductors, connected with the pulse-magnetic installation, and devices for continuous feeding of the powder material. Features of the design and application of effective re-usable inductors are considered in the work [6]. This experience was used also in experimental research.

2. Materials and methods

2.1. Combined compaction of a powder material in a rigid die.

The studies were carried out on powders Hoganas AB [8]. The data for the materials are given in Table 1. When mixing, 0.6 % lubricant Cennlube was added.

Table 1

Powder materials based on Fe-C and Fe-C-Cu

No.	Iron powder brand	Production method	Additional components
1	NC 100.24	reduced	4 % Cu + 0.6 % C
2	ASC 100.29	atomized	1.5 % Cu +0.15 % C
3	SC 100.26	reduced	2.0 % Cu +0.15 % C
4	Distaloy AB	pre-alloyed Cu (1.5 %), Ni (1.75%), Mo (0.5%)	0.15 % C
5	MH 80.23	reduced	2.0 % Cu +0.5 % C

For compaction a hydraulic press with a maximal force 100 kN was used. A steel mold 10 mm in diameter was placed on the frame of the press. Depth of the filling chamber was 20 mm. The lower punch, provided with a conductive plate, is mounted on the plane inductor connected to a generator of pulse currents MT-1 with maximal energy of 2.5 kJ (Fig. 3, 4).

Previously the powder is acted on by the static pressure of the hydraulic press with the force of 50 kN with subsequent single or multiple pulse action through the use of the inductor connected to the generator of pulse currents. A plane inductor 5 from copper wire 6 mm^2 in section, with a number of turns 12 was used. Mass of the punch was 98 g, mass of the copper plate – 25 g.

The density of pressing δ was estimated by measuring the degree of settlement of the punch into the die. The results of the experiments are shown in Fig. 6-7. The experiments were performed on powder compositions 1-4 (Table 1) under the same parameters of compaction.

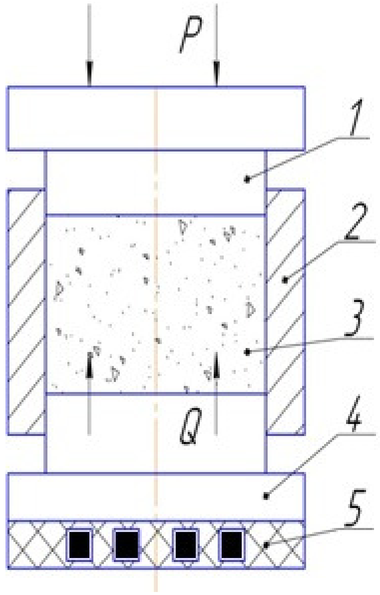

Fig. 3. **Scheme of the hybrid technology of PMC of powders in a rigid die:** 1 – upper punch; 2 – container; 3 – powder; 4 – lower punch; 5 – inductor

Fig. 4. **Experimental device for PMC of powders**

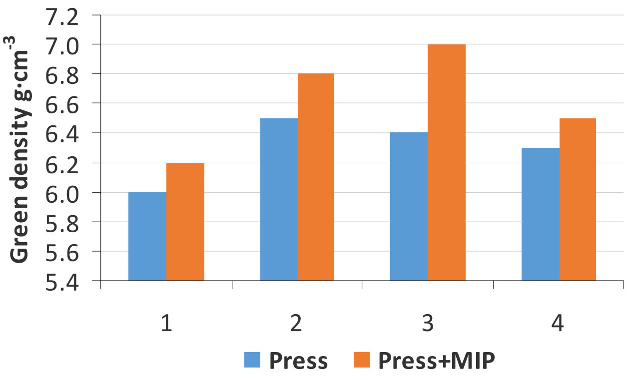

Fig. 5. **Change in the density of different powder compositions under static and static-dynamic compaction**

The results show (Fig. 5) that imposition of a shock pulse adds the density of pressing for all powder compositions in the range of 4.5 to 9.5 %. In this case the biggest increase of pressing density is observed at higher levels of energy of discharging of the generator (Fig. 6). The studies were conducted on the powder composition 2 based on the powder ASC 100.29.

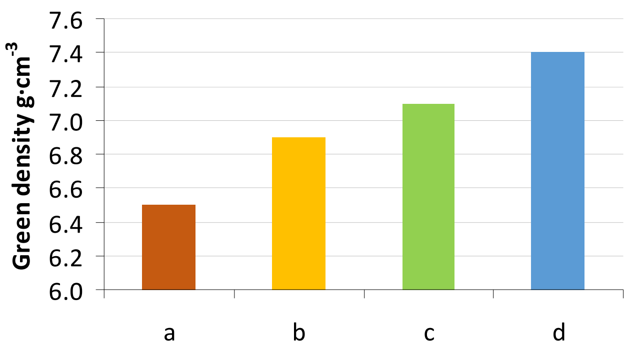

Fig. 6. **Change in the pressing density depending on the specific energy of discharge 0.8; 0.9; 1.0 and 1.2 kJ·cm^{-3}**

The influence of the number of discharge pulses is especially noticeable when the number of them is small. As the number of pulses increases over 10 this effect becomes less noticeable (Fig. 7). Studies were performed on the powder compositions 2 and 4 based on the powder ASC 100.29.

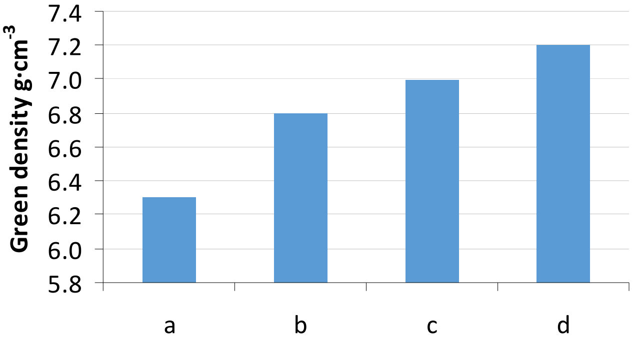

Fig. 7. **Change in the pressing density depending on a number of pulses:** a – 0; b – 5; c – 10; d –15 at the specific energy of discharge 0.9 kJ·cm^{-3}

2.2. Combined technology of step-type static-dynamic compaction of powders

This technology appears to be promising for production of long-length products. The scheme of the process is shown in Fig. 8, the experimental device – in Fig. 9. Compaction was conducted in a tubular shell from copper. Previously the tube 1 was compressed on the mandrel 4 with the help of the inductor 1. Further, by means of the actuator 5 the tube with the powder moved through the draw die 3 (Fig. 8).

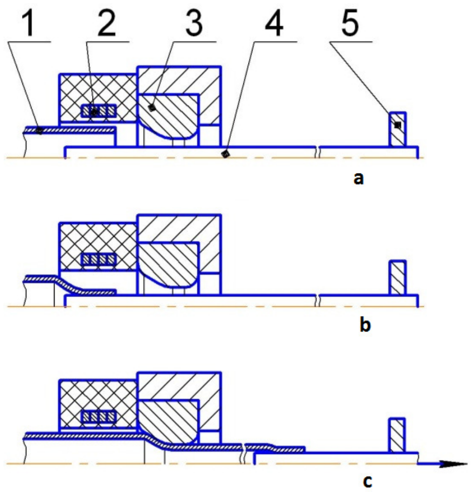

Fig. 8. **Scheme of compaction (a – starting state; b – stage of press-forging; c – stage of drawing):** 1 – billet; 2 – inductor; 3 – drawing die; 4 – mandrel; 5 – puller

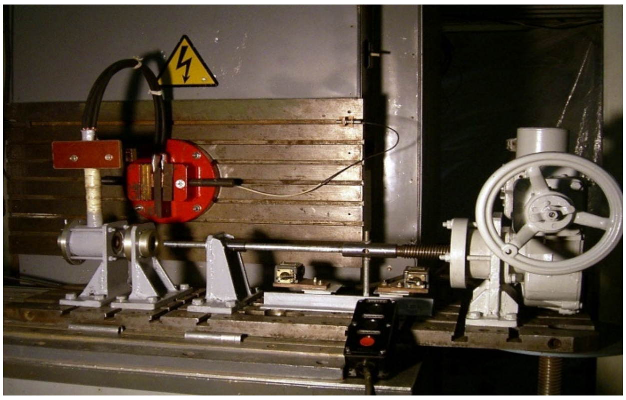

Fig. 9. **Device with the inductor on the table**

3. Results and discussion

As the experiments showed, the use of combined methods of static-dynamic compaction helps to increase the density of a powder material. For products of small height the method of compaction of powder in a rigid die with imposition of electromagnetic pulses is most convenient. With step-type compaction the quality of the obtained product depends on many factors: density of prior filling of the powder into the tube, magnitude of the angle of the draw die, plasticity of the material and the properties of the powder. With the simultaneous turning on of the drawing mill, both operations (pulse-magnetic press-forging of an end of the tube and pulling the tube through the draw die) are performed at a single site and by a single operator. Productivity increases, total energy consumption decreases.

4. Conclusions

We can assume that in the near future, interest to the static and dynamic methods of compaction of powder materials, especially ceramic powder, will increase. This can be explained by the development of a new generation of pulse current generators in recent years: with a higher specific capacity, small-sized and with the increased frequency of bit pulse repetition. However, for successful development of the technology, it is necessary to create sustainable development of inductor systems and improve the safety of the equipment.

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