IOP Conf. Series: Materials Science and Engineering **218** (2017) 012005 doi:10.1088/1757-899X/218/1/012005

Static-dynamic methods of compression of «Al-B» powder composition «Al-B» in the deformable tubular casing

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Abstract. A new scheme of hybrid technology of compacting powders is proposed, which simultaneously use two sources of loading: static and dynamic. Compaction of «Al-B» powder compound is carried out in a metal casing by its longtitudal drawing and radial magnetic pulse crimping. The results of the search experiment are presented, confirming feasibility and efficiency of proposed technical solution. Developing technology of compacting powders will allow producing long-length products.

1. Problem statement

Technical progress of modern engineering requires development and use of new materials for construction of sensitive products for special purposes. An example of such material is the aluminum-boron composite. After the use of the products made of such materials there is a question of the disposal.

One solution to this problem is to crush fragments of products, grind them further into powder with a particle size of up to 100 nm, press them and sinter to obtain products of new application. E.g., the use of the powder composition «Al-B» is suggested for producing grinding tools, elements of radiation protection and other purposes.

The main technological process in the described processing chain of manufacturing new products is the process of powder pressing. Various methods [1÷4] can be used for pressing powders, including use of pulsed magnetic field (PMF) during deformation of the tubular casing filled with powder. However, existing compression methods are not perfect and have certain disadvantages relating primarily to the quality of densification, technology and equipment. That is why the task of developing new compression methods remains relevant.

2. Proposed technical solution

Hybrid technology is proposed that combines static and pulse magnetic loading. Figure 1 shows developed technological schemes of implementation of this technology. The essence of the proposed method is to combine the operations of drawing thin-walled tube filled with powder (static loading) and radial magnetic pulse compression of it (dynamic loading). The following variants of sequence of these operations are possible:

a) magnetic pulse crimping followed by drawing;
b) drawing followed by magnetic pulse crimping;
c) simultaneous drawing and magnetic pulse crimping

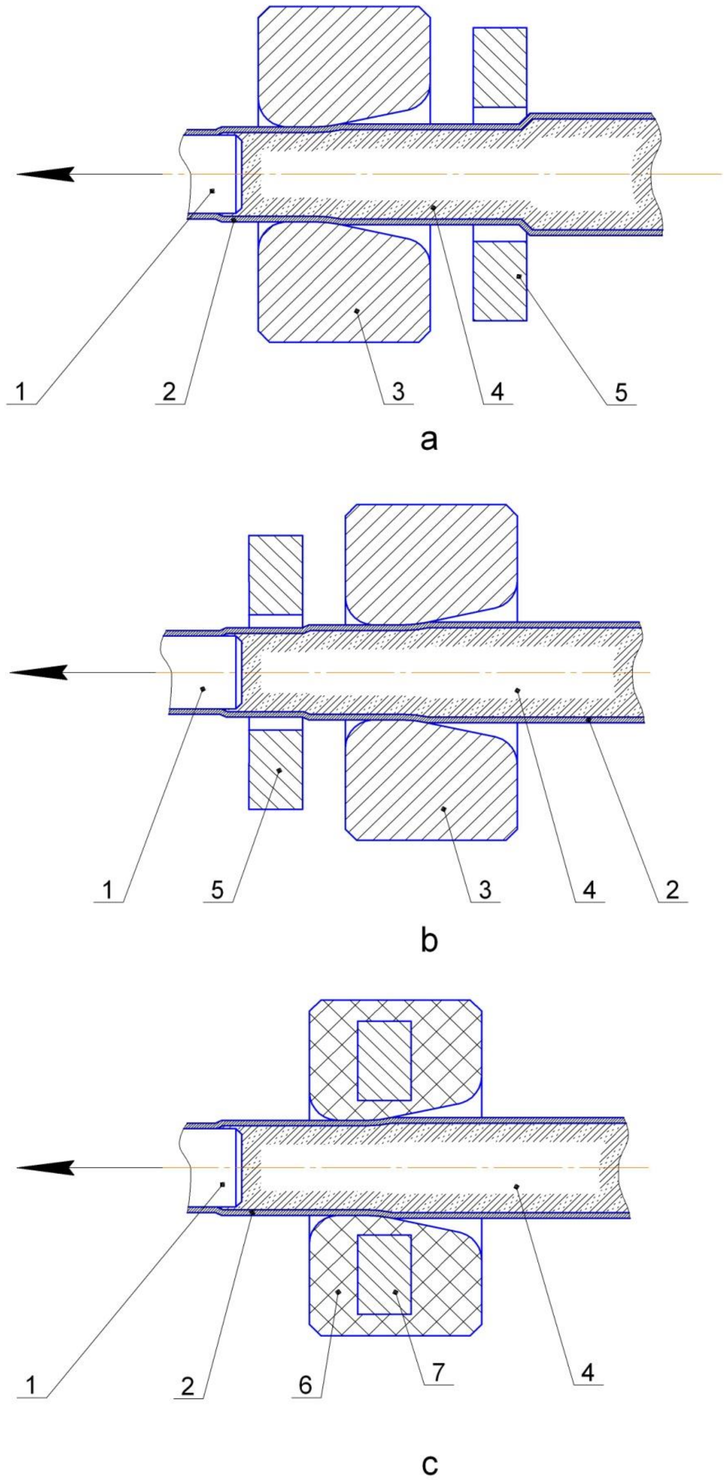

Figure 1. Hybrid schemes of powder pressing, combining static and pulsed magnetic loading: (a) magnetic pulse crimping performed before drawing; (b) magnetic pulse crimping performed after drawing; (c) magnetic pulse crimping and drawing performed simultaneously.

The implementation of these schemes is determined by the placement of the inductor (5) - in front of, behind or inserted directly into the draw die. Inductors are connected with the magnetic pulse in-

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stallation (6). Varying the location of the inductor allows changing the deformation zone, the stress-strain state of the tube and the powder in and scheme of densification.

The on-off ratio of magnetic pulse impact must be linked to a drawing speed so that the deformation zones overlap. This is particularly important for technological schemes a) and b).

3. Search experiment method

A search experiment was conducted to test the feasibility of the proposed technical solutions and evaluate the levels of factors that determine the process.

In the experiment, a powder composition was used with the percentage composition presented in Table 1. For the For the tubular casing a copper (MO) ∅ 18 mm tube was selected with the wall thickness of 1.9 mm and the working length $l_0 = 50$ mm. On one end of the tube, a plug was fixed, used at the same time as swaged before the drawing end of the tube.

Table 1. Chemical elements and their weight percent in the used powder composition.

Spectrum of chemical elements	B	O	M_g	Al	T_i	Mn	Fe	Co	W
Mean value (%)	83.35	5.49	0.53	7.12	0.04	0.08	0.45	0.21	2.71
Standard deviation	0.40	0.04	0.01	0.09	0.02	0.01	0.05	0.03	0.28

The tube was filled with powder and plugged on the other end. Assembling the tube with the plugs was carried out using magnetic pulse crimping on the facility at the magnetic-pulse installation MIU-10VCh with energy discharge value W = 2.6 kJ. The appearance of the sample is shown in Figure 2.

Figure 2. A sample prepared for the experiment.

Steel draw dies used in the experiment had the diameter ∅ 16 mm and 17 mm. The drawing process was carried out on the hydraulic testing machine TsDMU-30. Magnetic pulse crimping was carried out on the magnetic pulse installation MIU-50 at the following main parameters: C_i = 253,3 μF; L_i = 110 mH; f_0 = 30 kHz.

Sintering of the sample was conducted at the temperature T = 600^{0}C and thermal exposure of 60 min. after the furnace reached the specified mode.

Metallography studies were carried out with an electron microscope TESCAN, VEGA series, modification SB.

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4. Search experiment results

The dimensions of the samples after drawing and magnetic pulse crimping are presented in table 2.

Table 2. The dimensions of the samples after drawing and magnetic pulse crimping.

№	Before the drawing		After the drawing		The volume of the powder in the control portion, % to the original volume	After the magnetic pulse crimping	
	D_0 (mm)	L_0 (mm)	D_1 (mm)	L_1 (mm)		W (6 kJ)	$D_{fin.}$ (mm)
Draw die Ø 17mm							
1				52.4		3.8	16
2	17.9	50	17	52.3	93.1	5.3	15.7
3				52.3		7.1	15.4
Draw die Ø 16mm							
4				57.7		3.8	15.7
5	17.9	50	16.2	57.7	91	5.3	15.4
6				57.7		7.1	15.0

The volume of the powder was controlled during the process of pressing. The metallography analysis results are shown in Figures 3 and 4.

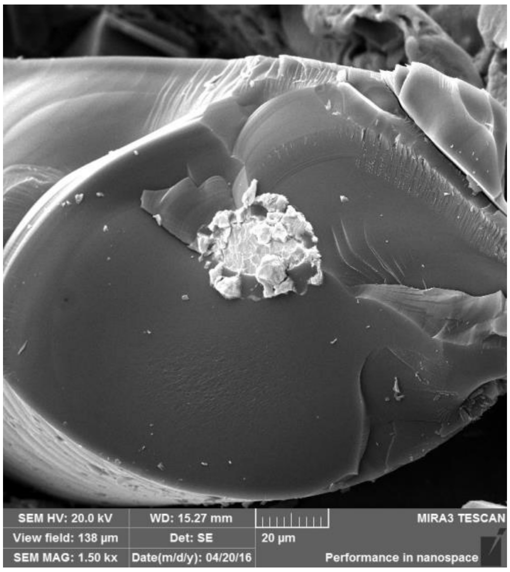
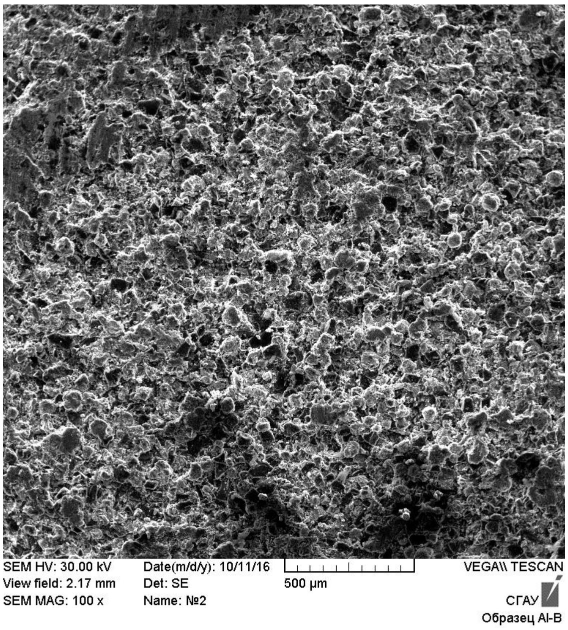
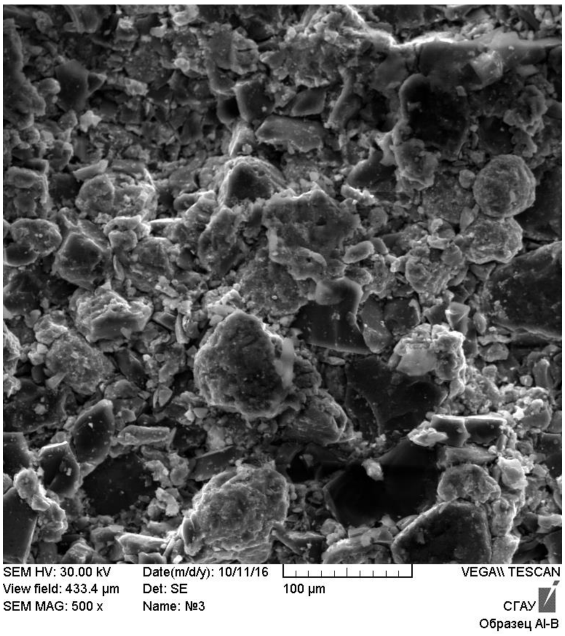


Figure 3. Structure of boron fiber.
Tungsten is in the center.





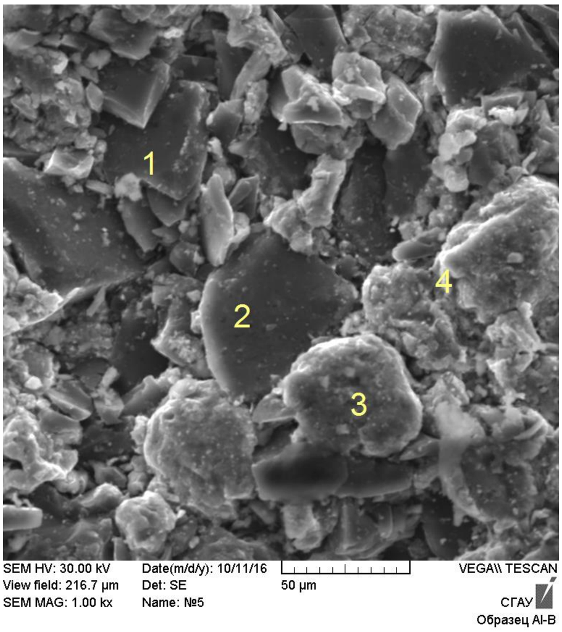


Figure 4. Structure of the powder after the implementation of hybrid technology at different magnification ratio. Dark particles – B, light particles - Al

5. Analysis of results

In the drawing process the powder composition is milling to the size of 50÷20 nm. Moreover, the density of the powder is not uniform across the section. Higher density was observed at the external surface, i.e., at the side of powder exposure to the metal casing.

It was established that both loadings contribute to the densification of the powder. Presumably, the mechanism of densification differs for longitudinal and radial deformation. The density of the powder after the hybrid treatment amounts to 91÷93%.

6. Conclusion

1. A new method of compacting powder compositions in a metal casing – the hybrid technology combining static and pulsed magnetic loading allows simultaneously performing simultaneously two operations: longitudinal drawing and radial magnetic pulse crimping.
2. Several schemes of implementation of this technologies are proposed, one of which has been tested in the laboratory and has confirmed its feasibility and efficiency.
3. The longitudinal-radial deformation of the powder changes the compression mechanism, providing high density of powder composition up to 91 - 93%
4. The proposed technologies offer a possibility of producing long-length products, as one of the areas of utilization of «Al – B» composite materials.

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