Conference Paper

Material for Radiation Protection. Stretching-reducing of the Powder Composition "Al-B"

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Abstract

The fiber composite material (FCM) aluminum-boron is used in rocket-space, aviation technique. The scheme is proposed for utilization of elements from this material by crushing, grinding in a disintegrator to production of powders with particle sizes of 100-150 μm. The obtained powder composition is filled inside of a metal workpiece, pressed and subjected to stretching and pulse-magnetic reducing for compaction. The quality of the obtained material after sintering with maximal density of 95% was evaluated. The obtained material can be used for producing of grinding-polishing tool and in devices of radiation protection.

Keywords: Hybrid technology, Drawing, Pulse-magnetic reduction, Powder composition

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1. FORMULATION OF THE PROBLEM

Composite materials are increasingly used in engineering products [1-3]. Among them, fiber composite materials (FCM) are a special group, for example, "aluminum-tungsten-boron" (Al-W-B) with high specific strength. The fibers were obtained by deposition of vapors of boron trichloride on substrate from tungsten fibers. Next, aluminum is sprayed on the surface of the boron-tungsten fiber. Thus, the prepregs are obtained which are stacked in layers and then subjected to hot pressing. In so doing, the final material FCM is produced as a result of diffusion welding. Pressing is carried out at a temperature T = 500 ÷ 580 °C, pressure of 30 MPa and the holding time of 120 s in molds, or autoclaves. This technology is described in works [4-7]. An example of the microstructure of the starting FCM is shown in Fig.1.

Power elements of aerospace engineering, building constructions are made from such material. A problem of utilization of these materials arises. And it occurs already

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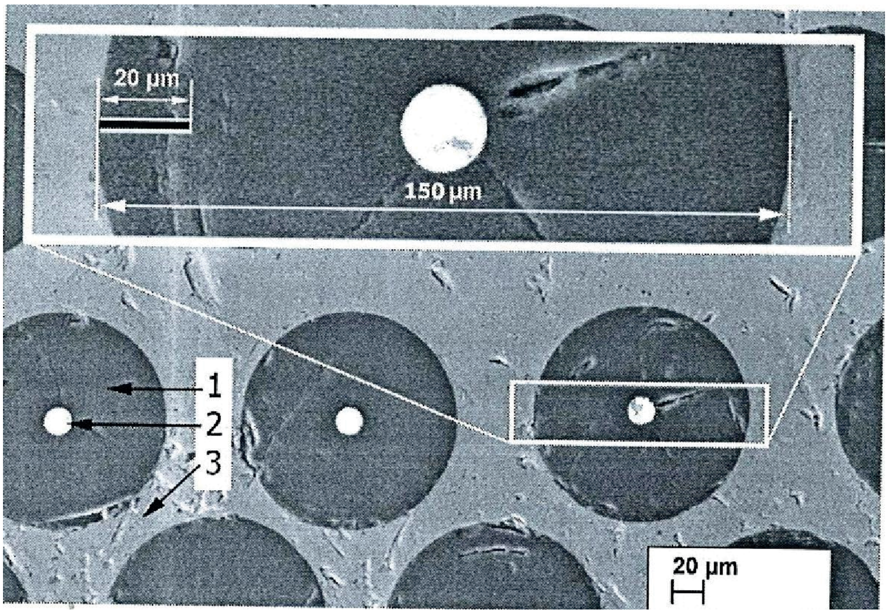


Figure 1: Microstructure of hot-pressed composite material Al-W-B: 1 – layer of boron, outer diameter of 150 μm; 2 – tungsten wire 20 μm thick; 3- aluminum die.

at the stage of production of articles during fabrication of the prepregs, utilization of rejects.

One of solutions to the problem of utilization of products from FCM “Al-W-B” is cutting of products into fragments, crushing them on rotary or jaw crushers, grinding in a disintegrator to the powder composition, compaction, sintering of the powder, obtaining of new products (Fig.2).

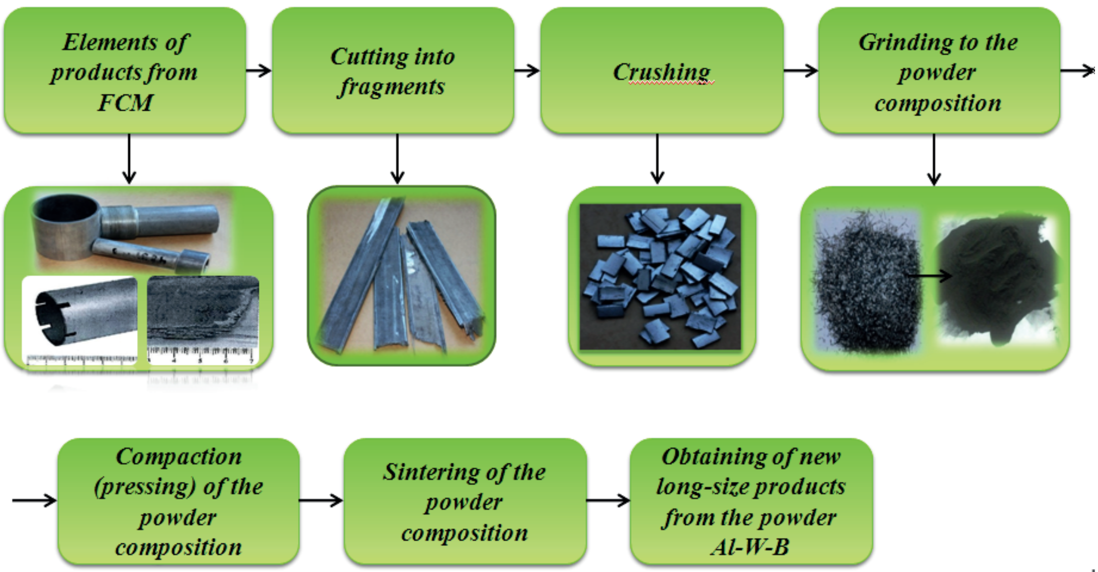


Figure 2: Sequence of operations “from utilization to new products”.

2. OBTAINING OF THE POWDER COMPOSITION

was carried out in the following sequence.

Pre-crushing of the starting material was performed using a jaw crushing to particle size not more than 200*45*4.0 mm. This stage is characterized by preserving the integrity of the connection of fibers with the die.

Intermediate grinding of crushed plates was carried out in a disintegrator DS-A3 with a four-row rotor in the mode of multiple direct grinding. In so doing, the average particle size was ~130 μk. At this stage the boron fiber separates from the aluminum die, longitudinal fracture of the fiber and separation of the boron shell from tungsten yarns occur.

Final fine grinding was carried out on the laboratory disintegrator-separator DSL-175 in the mode of inertial “JS” and centrifugal “CC” separation to the particle size of 1-35 μk. The components are crushed, separated from each other and continued to decrease in size.

Microstructures of the material at each stage of grinding are shown in Fig. 3.

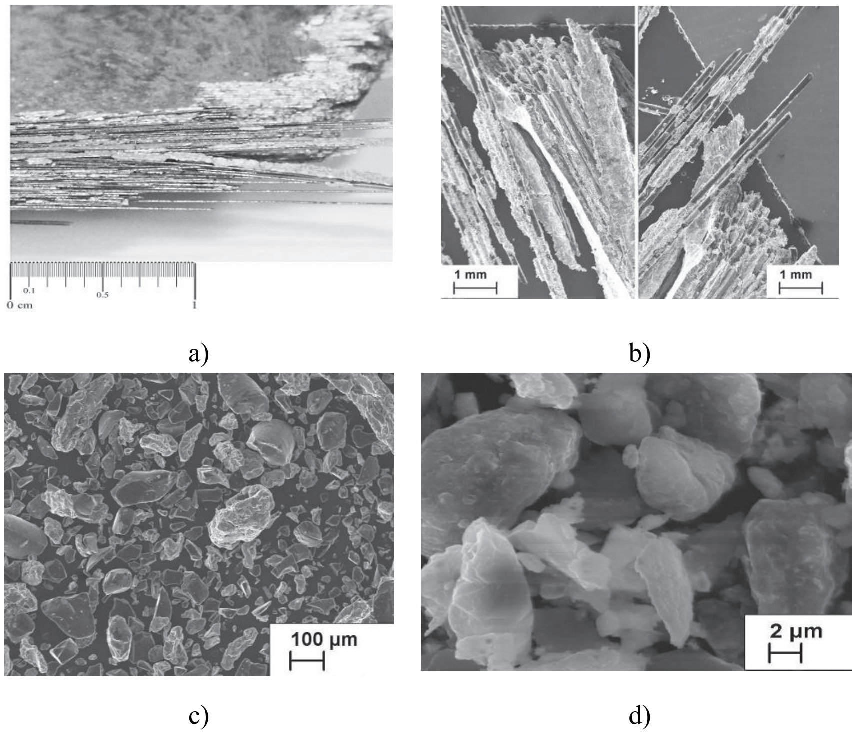
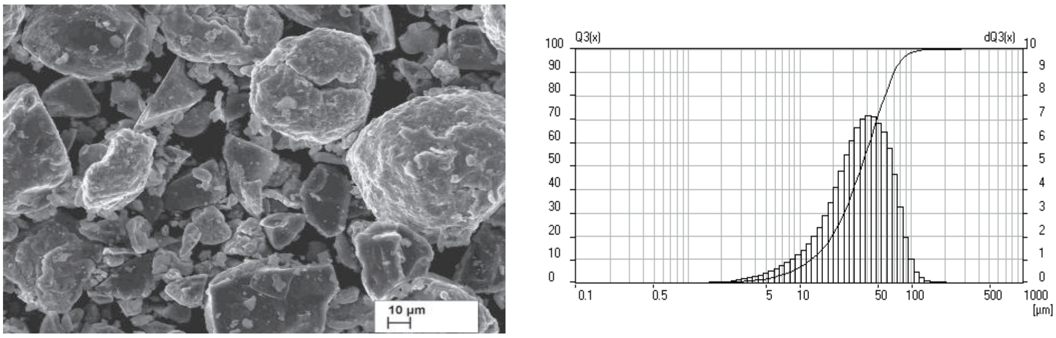


Figure 3: Fragments of the composite material Al-W-B: a,b) starting material; c) intermediate grinding of crushed plates; d) final fine grinding.

In so doing, the dependence of the particle size from the specific energy of grinding was obtained. As a result, a homogenous mixture of grinded boron fibers, tungsten and the aluminum die was created. Aluminum particles have a rounded shape, B and W particles – crystal-like one (Fig.4).



a) b)

Figure 4: Particle shape (a) and histogram of particle sizes (b) of the fiber composite material after separation grinding with energy E_S = 352kWh/T with the use of inertial classification “IC”.

The granulometric composition of the obtained powder is presented in Table 1.

Table 1: Granulometric composition depending on the degree of grinding of the composite material Al-W-H and power consumption.

Multiplicity of grinding	E_S, kWh/T	Mesh size, mm												d_{50}
		25	11,2	5,6	2,8	1,4	0,71	0,355	0,18	0,09	0,045	0,02	<0,02	
		Granulometric composition, %												
1*	4,9	0	15,2	34	20	8	4,5	4,5	4,4	6,3	3,2	0	0	0,73
2*	9,8	0	2,6	28	25	11	6,2	6,4	6,5	9,4	3	1,2	0,6	0,37
4*	19,6	0	0	12	26	12	8,2	8,9	9,7	15,2	5,2	2,3	0,8	0,24
8*	39,2	0	0	4,6	18	11	8,9	11,6	13	20	7,5	4,1	1,1	0,17
16*	78,4	0	0	1,5	6	3,8	11,9	15,5	17,4	26,8	10,1	5,5	1,5	0,13
Separation grinding “IC”	352						0	2,8	9,8	25,1	25,9	19,6	16,8	0,04
Separation grinding “ICF”	1150								0	0,9	11,2	44,9	43	0,02
Separation grinding “CC”	~2400										0	~8	~92	~0,01

When grinding, a mechanism “crush and impact” (while obtaining large particles) and “abrasion and impact” (during fine grinding) acts.

3. METHODS OF COMPACTION OF POWDERS WITH THE USE OF PULSED MAGNETIC FIELDS

For compaction of the powder composition, various methods of pressing with the use of pulsed magnetic fields (PMF) (Fig.5) are used: one-sided pressing in a closed rigid die (a), pulse-magnetic reducing of the metal shell with the powder (b), two-sided pressing (c). These and other methods are discussed in works [8-11]. It should be noted that the known methods do not always provide a predetermined density as well as do not allow obtaining of long-size products with uniform density along length.

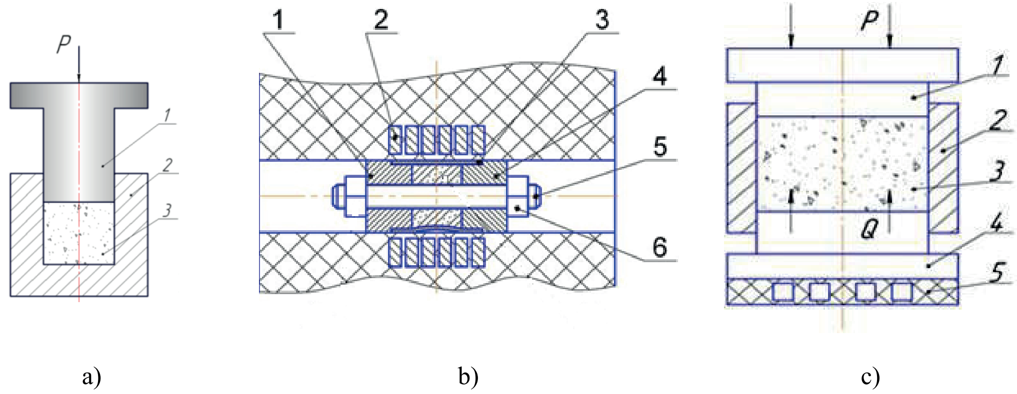


Figure 5: Schemes of existing methods of pressing of powders with the use of PMF 1 – punch; 2 – mould; 3 – powder; 4 – inductor; 5 – shell; 6 - mandrel.

4. HYBRID TECHNOLOGIES "DRAWING-PULSE-MAGNETIC REDUCING"

To obtain long-size products, so-called hybrid technology of pressing of powders was proposed which combines static longitudinal (drawing) and dynamic radial (pulse-magnetic reducing) loads (Fig.6). The action of dynamic load is carried out periodically with the pulsed frequency of 1-2 s.

The powder composition is filled inside the thin-walled metal pipe and is pressed with the effort not causing deformation (expansion) of the pipe. The plugs are fixed on both sides of the pipe with the powder (Fig.7).

The schemes, shown in Fig.7, differ in the location of the inductor [12]: upstream, downstream or in the draw plate. A different location of the inductor changes the scheme of stress-strain state in the deformation zone in drawing. Longitudinal and radial deformation changes the mechanism of compaction of the powder.

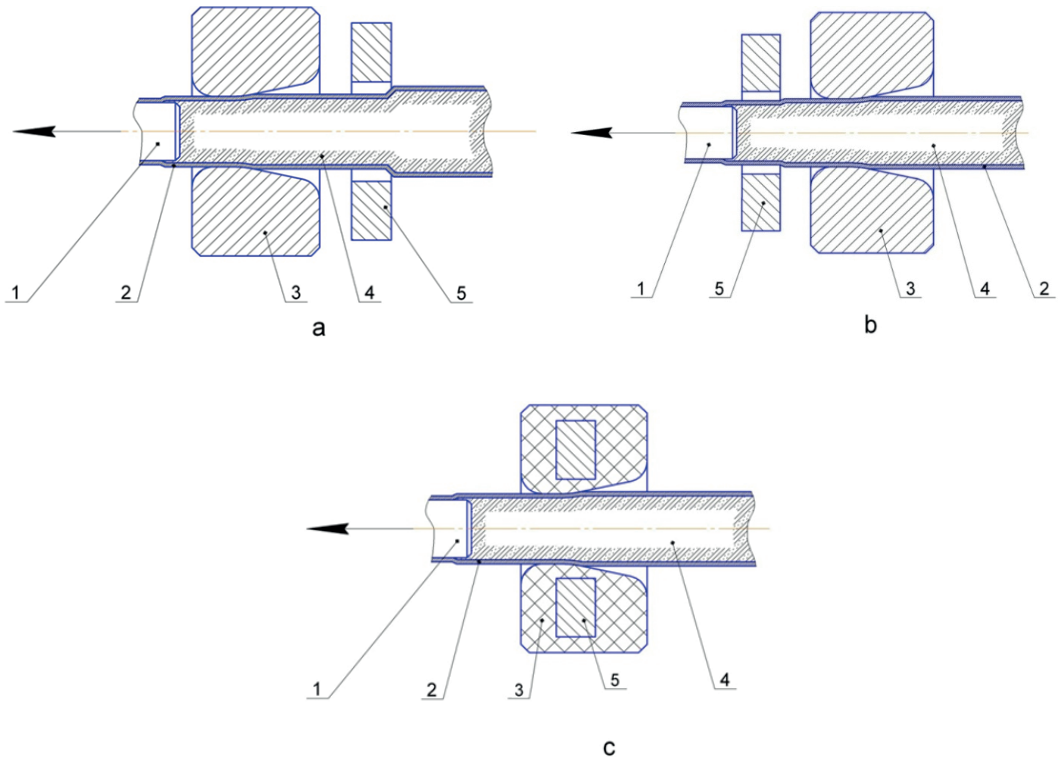


Figure 6: Schemes of the hybrid technologies of pressing of powders 1 – plug; 2 – pipe; 3 –draw plate; 4 – powder; 5 – inductor.

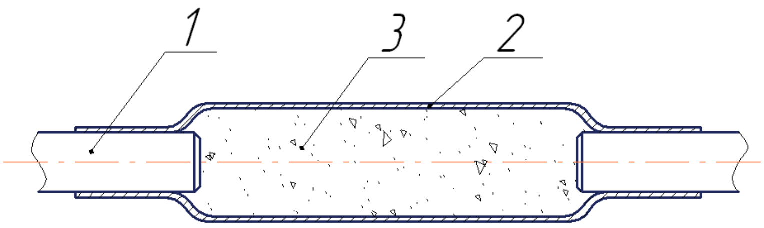


Figure 7: Sample before drawing 1 – plug; 2 – metal shell; 3 – powder Al-B.

5. EXPERIMENTAL PROCEDURE

For the experiment a copper pipe 18 mm in diameter with wall thickness of 1 mm, 110 mm in length was used. Steel draw plates with the inner diameter of 17 mm and 16.2 mm were used (Fig.8). Drawing was conducted on the stretching test machine, pulse-magnetic reducing was performed on the installation PMI-10 (Fig.9) with the parameters given in Table 2 [13]. Previously, graduation lines were applied on the workpiece to measure the sample's length changing in the course of the drawing process.

Measuring of the diameter and length of the sample made it possible to calculate the volume of material before and after drawing and pulse-magnetic reducing, to define

Figure 8: Exterior view of the sample and draw plate.

the degree of compaction of the powder. Pulse-magnetic reducing was conducted at three values of energy: W = 3.8; 5.3; 7.1 kJ. Sintering of the compacted powder together with the shell was carried out in a protective atmosphere of endogas at T = 800°C.

Figure 9: General view of the PMI-10.

Table 2: Parameters of the installation PMI-10.

U, kV	L, μH	C, μF	F_{es}, kH	W, kJ	Overall dimensions, m
1...18	50	50	92	10	0.6 x 0.8 x 1.5

6. RESULTS OF THE EXPERIMENT

Changes of geometrical sizes of the samples after drawing and after pulse-magnetic reducing are given in Table 3, micro-sections of the samples after sintering – in Fig.10.

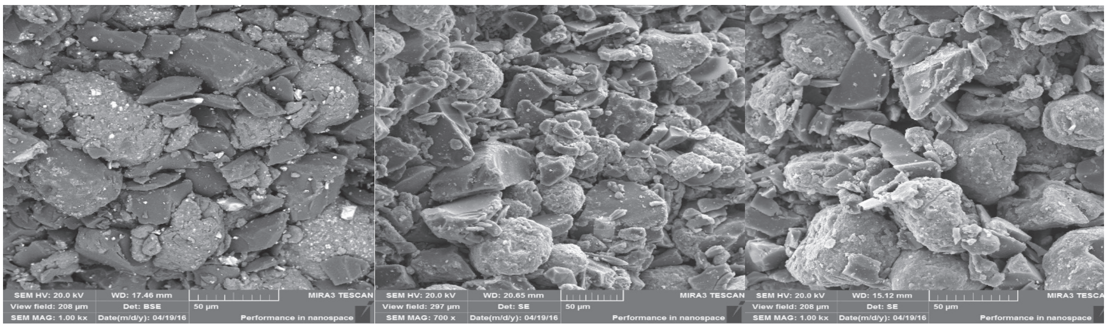


Figure 10: Microstructure of samples of the composition Al-W-B after sintering.

Table 3: Parameters of the samples after drawing and pulse-magnetic reducing.

№	Before drawing		After drawing		Volume of powder in the control part, % of the initial volume	After pulse-magnetic reducing	
пп	D_0, мм	L_0, мм	D_1, мм	L_1, мм		W, кДж	$D_{кон.}$, мм
Draw plate Ø 17мм							
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 plate Ø 16мм							
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

7. ANALYSIS OF THE RESULTS

The obtained results of the experiments allow making preliminary considerations on static-dynamic compaction of powders. When drawing, particles of the powder acquire directed longitudinal deformation, they stretch in the direction of the longitudinal force. The aluminum phase is compacted. But pores between the particles remain. To reduce the number of pores is possible by radial deformation under the action of the dynamic load. In this case nano-particles of the powder are distorted (deformed) in the direction of closing pores and even are crushed. This leads to final tight packing them. The mechanism of static-dynamic compaction calls for further experimental and theoretical investigation. The density achieved in the experiments is 94-96%.

8. POSSIBLE FIELDS OF APPLICATION OF THE OBTAINED MATERIAL

Taking into account the high hardness of boron, it is proposed to create the grinding tool from the obtained samples. A prototype of such tool was fabricated and tested in laboratory conditions. On the other hand, high ability of boron to absorb neutron radiation involves the use of the obtained material for the purposes of radiation protection.

9. CONCLUSIONS

1. One of directions of utilization of the fiber composite material “Al-W-B” has been proposed which consists in crushing and grinding of elements of constructions to the powder composition and obtaining new products by pressing of the powder in the metal shell.

2. Schemes of hybrid static-dynamic compaction of the powder composition in the metal shell: “Drawing – pulse-magnetic reducing” have been developed.

3. Experimental confirmation of efficiency and effectiveness of such technology for obtaining of long-size products with high degree of compaction has been conducted.

4. The mechanism of hybrid static-dynamic compaction (longitudinal and radial) has been proposed.

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