TECHNOLOGY DEVELPOPMENT FOR AL-RARE-EARTH METALS COMPOSITE BILLETS PRODUCTION

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Abstract

The process of aluminum powders mechanical alloying was researched and powders with reference size and shape were obtained. The influence of the mechanical alloying process parameters on the powder compositions structure and properties is shown. The analysis of the possibility of compacting for mechanically alloyed aluminum-based compositions was carried out by methods of mathematical and physical modeling. The temperature range in which sealing is possible and subsequent treatment of plastic blanks, which structure corresponds to the structure of the material powder particles obtained by mechanical alloying, was defined. The processes of equal channel angular pressing, which was performed to compact the material, and subsequent rolling, which allows to carry out the deformation of layered material and to keep the integrity of the less plastic composite core were simulated and practically realized. Practical recommendations for the implementation of the process to obtain the blanks from composite material based on mechanically alloyed powders of aluminum – rare-earth metals system with special radiation-protective properties.

Keywords: mechanical alloying, rare-earth materials, compaction

Powder metallurgy techniques are widely used in the manufacture of products with special properties for a variety of industries, including nuclear power, for which light and durable materials with a high level of absorption of neutron radiation are particularly required .

These materials based on mixtures of aluminum with additions of rare earth elements (REE) have been used. They can be obtained by mechanical alloying, which allows to obtain dispersion-strengthened and composite materials. This can also be achieved by increasing the solubility of alloying elements in the matrix material and to synthesize and equilibrium metastable crystalline and amorphous phases [1].

Whatever the composition of the alloy, and especially for dispersion-strengthened materials, the advantages of mechanical alloying are fully appear only in the case where the subsequent compaction technology and heat treatment carefully investigated and well established. It should be noted that the static compaction of powders containing intermetallic compounds of high hardness, is related to certain difficulties and problems. Severe plastic deformation methods are considered to be promising to seal such materials [2].

The development of practical recommendations for production of workpieces made of composite material with special radiation-protective properties on the basis of mechanically alloyed powders of aluminum-rare earth metals using the methods of severe plastic deformation – is the purpose of this work.

Mechanical alloying materials were powdered in a ball mill. Obtaining a homogeneous microstructure defined particle size distribution and a relatively low level of microhardness in the complex creates favorable conditions for the compaction of the material the criteria for assessing the completeness of the process were.

The size and shape of the particles of mechanically alloyed composition of aluminum - rare earth elements in analyzed. Composition with different content of alloying elements is studied.

Fig. 1 Shape of powder particles Al + 15% (wt.) After the mechanical alloying REE

Fig. 1 shows the shape of the powder particles of Al + 15% (wt.) Oxysulfides. There were modes in which the particles are formed of equiaxed shape, their size is in the range 70 - 450 microns.

The powder particles are a complex composite material (Fig. 2), which occurs during the preparation of particulate and deformation hardening, the formation of new intermetallic phases and oxides. Strength characteristics of the material, uniformity of particle size distribution, shape and distribution of structural components depend not only on the ratio of the initial components, but also on the power parameters of the grinding equipment.

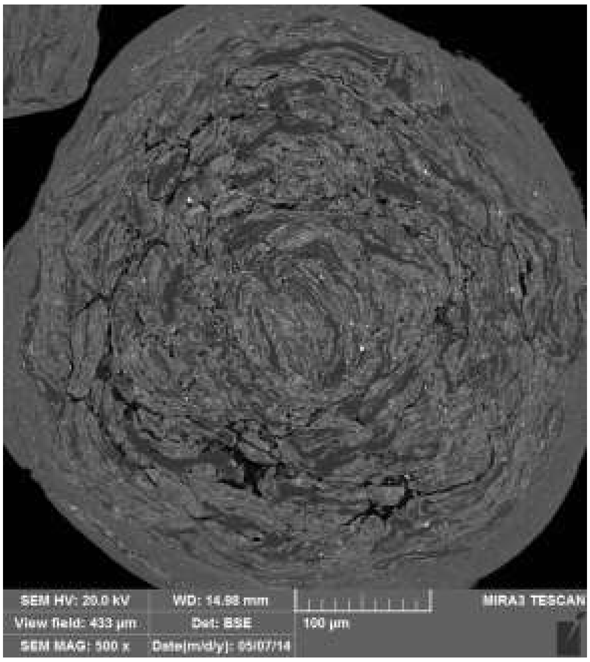
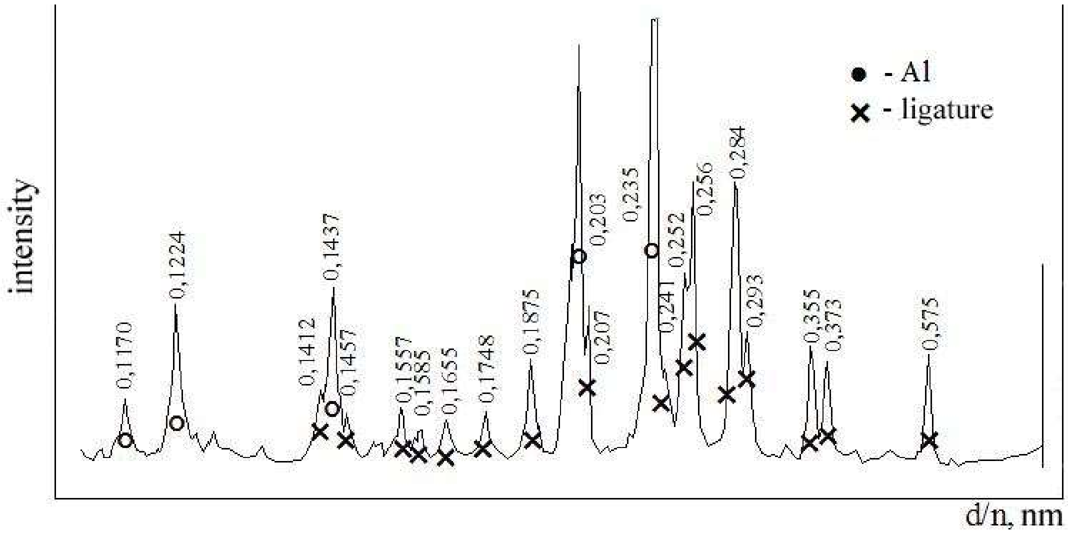
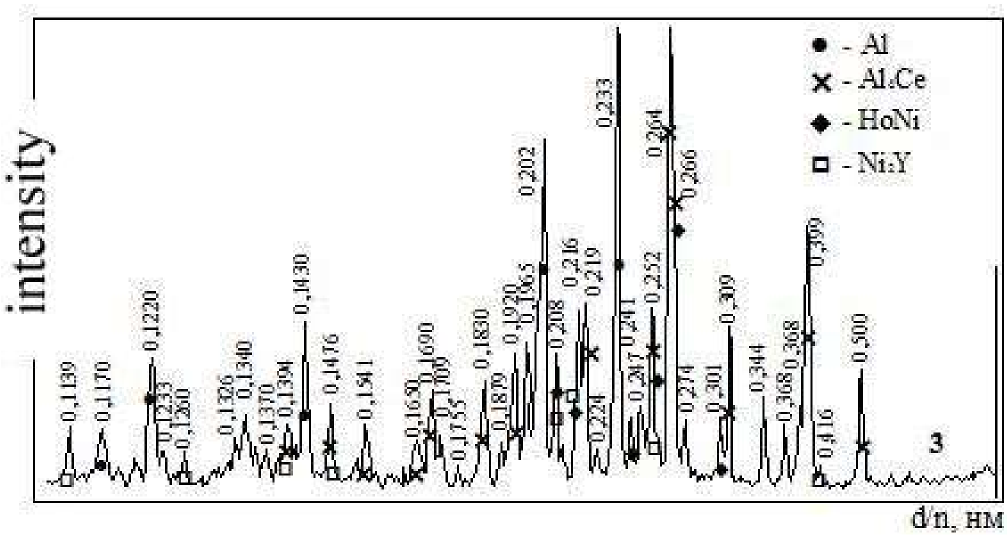


Fig. 2. Microstructure Powder Al + 15% (wt.) After alloying

The influence of heat treatment on the change in the technological properties of mechanically alloyed powder materials is researched. XRD analysis shows the change in the phase composition of the material after heat treatment: specific for the matrix material and the dopand for the composition (Fig. 3a) peaks were clearly separated an the radiograph before the process of heat treatment. This indicates that only dispersion strengthening and hardening occurred in the process of mechanical alloying. Upon annealing, along with the process of stress relief, the process of formation of new intermetallic phases such as: Al5Ni2Ce and Al5Ni2Pr, Al4Ce, HoNi and Ni2Y occures (Fig. 3b).



a



b

Fig. 3. Powder Diffraction Al + 15% (wt.) REE
a - before heat treatment; b - after annealing at 550 ° C

Physical modeling process changes compaction under the influence of temperature in a closed matrix was studied on the complex physical modeling GLEEBLE SYSTEM 3800. With increasing temperature an increase in the plasticity of the powder material and under the influence of the applied load it begins to thicken. The dependence of the density of the sample temperature pressing at a pressure of 68 MPa compression. Found that under these conditions at temperatures of 340 ^{0}C and 420 ^{0}C are formed intermetallic phases. Based on this fact plastic deformation temperature 300^{0}C has been recommended, at which the original phase composition of the material still keeps. Based on the physical modeling of rheological properties were obtained that provided the raw data for mathematical modeling and calibrate on of the mathematical model (Fig. 4).

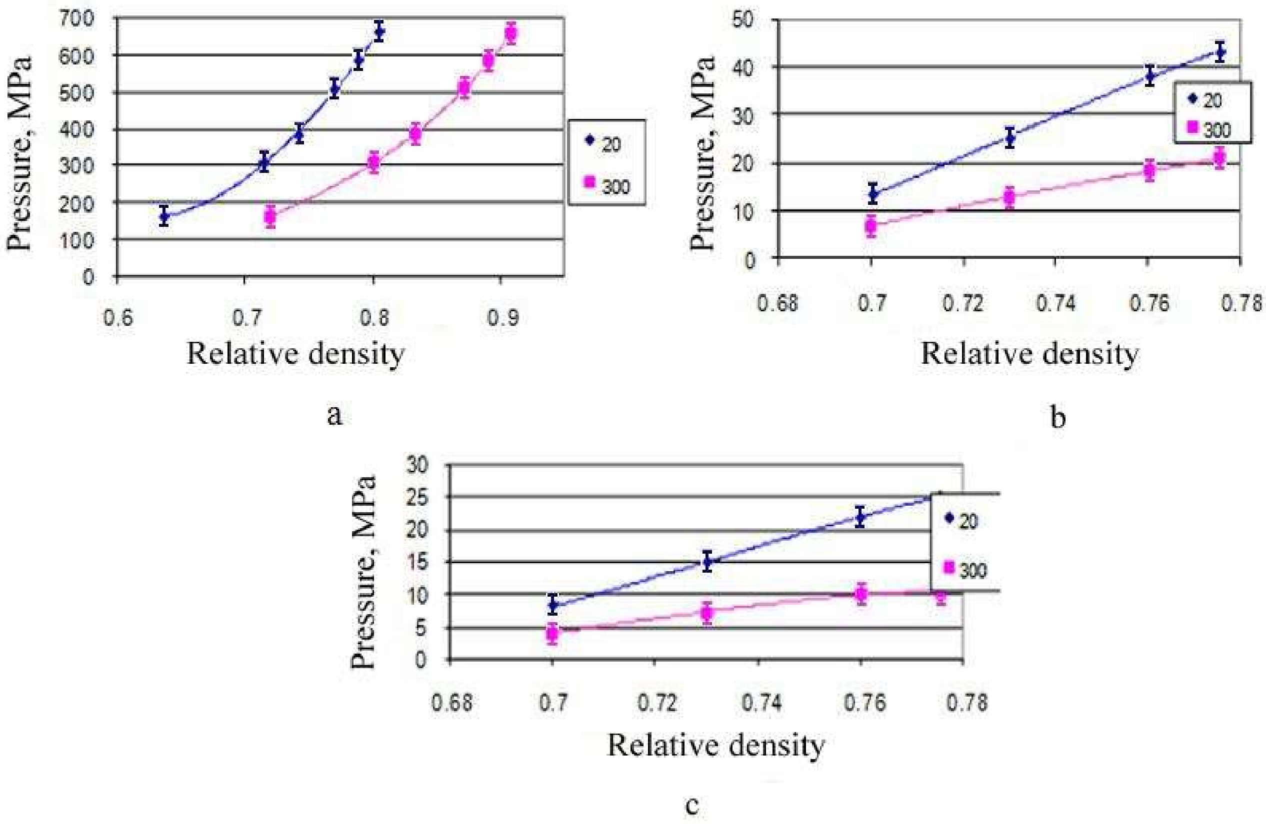
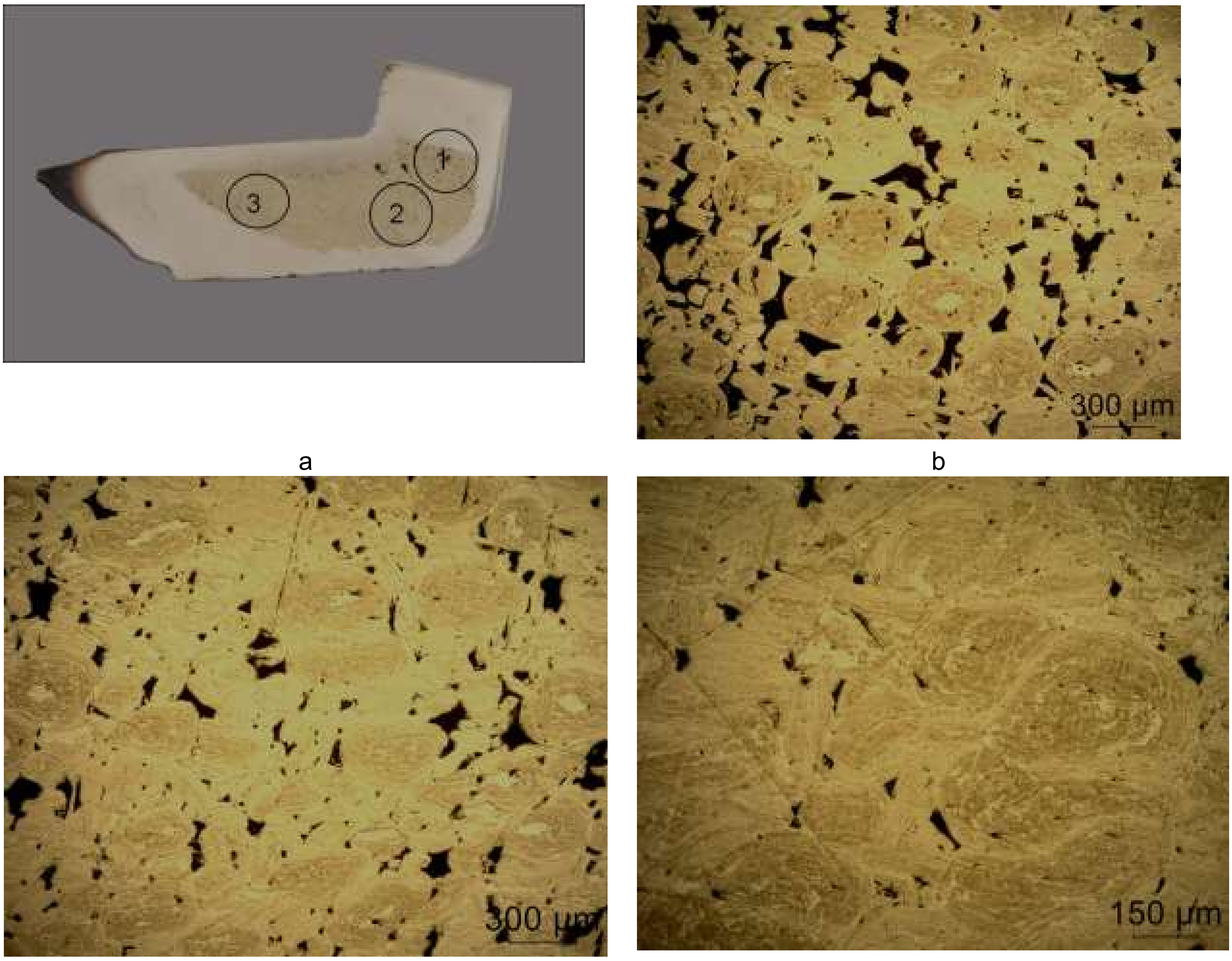


Fig. 4. Dependence of rheological characteristics of the material density at 20 and 300 ° C: a - yield under hydrostatic pressure (ps); b - yield under plastic shear (τs); c - limit seal (c)

According to the results of mathematical modeling «Multidef» package developed at the University, found a positive effect of the application of capsules for hard-compaction of powder materials. Just mathematical modeling, allowed to determine the nature of the flow of the powder material in the capsules during equal channel angular pressing. [3]

After defining the basic technological parameters full-scale experiment was carried out. The capsule of aluminum powder brand A7 material with a relative density of 0.72 was heated in an electric furnace to a temperature of 300 ° C and held for 1 hour. After this, the capsule was placed in a special heated tooling for equal channel angular pressing and subjected to deformation.

Fig. 5a shows the distribution of porosity in the powder preform, the resulting experimental study of equal channel angular extrusion billets powder in capsules. Fig. 5b shows the microstructure of the powder in the vertical channel, due to the compressive stress is sealed with a sample density from 0.72 to 0.91 relative density. Figure 5c corresponds to the deformation zone, where sample due to large shear deformation and manifestations of dilatancy sample is compacted to a relative density of 0.94, while the appearance of surfaces "setting" of the individual particles of the powder material clearly shows. Further compaction of the material takes place in a horizontal channel due to back pressure (Fig. 5d). The results of experimental studies well agree both qualitatively and quantitatively with the results of the simulation process.



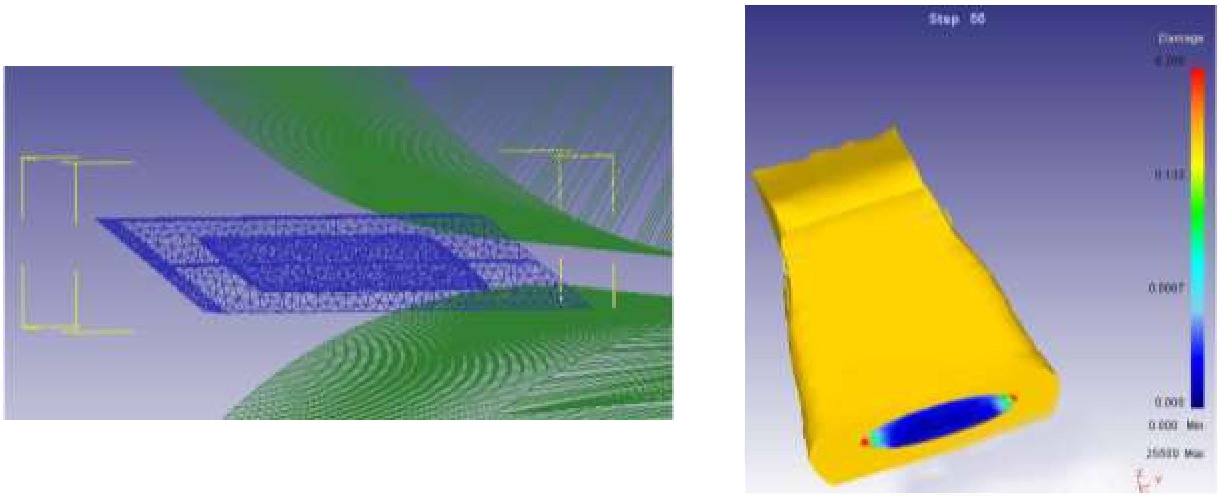
a b
c d

Fig. 5. The microstructure of the sample after equal channel angular pressing

Analysis of the stress-strain state and the plastic flow of the composite preform obtained by equal-channel angular pressing, hot rolling was performed using mathematical modeling package Deform-3D.

Based on extrapolation of the experimental dependences of the yield in plastic shear (τ_S) the relative density is chosen non-porous material model with similar rheological characteristics. Model deforming tool is based on the geometric parameters of the laboratory rolling mill 210 (Figure 6).

Further hot plastic deformation by rolling was carried out at a temperature of 300 ° C with a total strain of 0.9. Rolling the resulting material compacts until substantially nonporous state (Figure 7). In contrast to hot rolling in the capsule without ECAP much more stable distribution of powder material over the section of the workpiece and greater broadening of the sample is seen. (Fig. 8)



a b

Fig 6. Finite element mesh (a) and the results of calculations (b) the mathematical modeling of rolling in the package Deform 3D

Fig. 7. Macrostructure sample after equal channel angular pressing and hot rolling

Fig. 8. The macrostructure of the sample after hot rolling without equal channel angular pressing

According to the results of an experimental rolling limit reduction (60%) set, at which the destruction of the central (composite) of the laminar blank. This allowed us to estimate the marginal value of fracture criterion Cockcroft-Latham for the deformation of the laminate, mathematically simulate and test non-destructive modes of multi-pass hot deformation of the composite material with complex geometry of the container, as well as to establish the nature of flow of the laminate at different compression.

Analysis of the microstructure of the composite material indicates the preservation of its initial homogeneous structure. (Fig. 9)

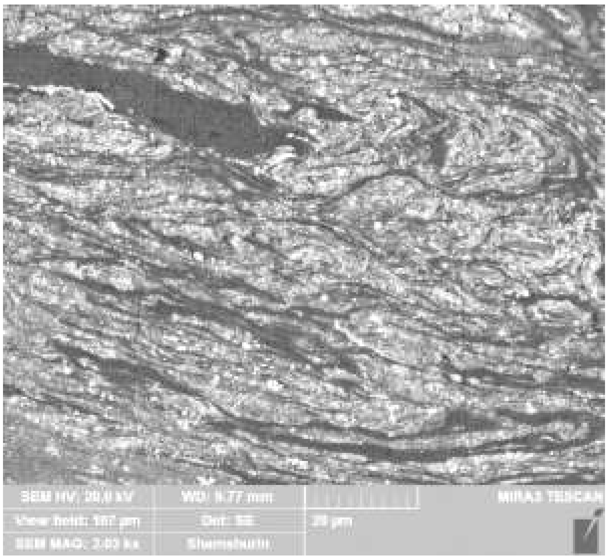


Fig. 9. The structure of the core material is compacted after plastic deformation

Thus, we have developed practical recommendations for the implementation of the technological process of workpieces made of composite material with special radiation-protective properties on the basis of mechanically alloyed powders of aluminum-rare earth elements.

The temperature range in which the possible compaction and subsequent processing plastic blanks is determined; rolling process parameters determined allowing for a deformation of the laminate material witu preserving the integrity of less plastic composite core.

By comparison of numerical and physical experiments the maximum value of the fracture criterion Cockcroft-Latham at joint deformation of materials and hard-shell composite core is determined. Non-destructive modes of multi-pass hot deformation of the layered composite material established were establishing.

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