**STUDY OF THE INFLUENCE OF EXTERNAL PRESSURE
AND SINTERING TEMPERATURE ON THE STRUCTURE
AND PROPERTIES OF THE SYSTEM ND-FE-C,B**

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Abstract. Modern industrial production of precision machinery, micro-electronics, Aeronautics, rocket science puts high demands on the materials. The main criteria which should characterize the material, high quality, low production cost, minimum material consumption while maintaining the best physical and mechanical properties of products in a production environment. In the global and domestic literature little attention is paid to using one of the thermodynamic parameters of pressure to control the crystallization and sintering of the permanent magnets. Therefore, in this paper applied an integrated approach during the study of the dependence of the coercive force from alloying and heat treatment of hard magnetic alloy Nd-Fe-C, received high-speed cooling, sintering the compact under pressure up to 1 GPa. In this formulation, the problem of obtaining high coercitive magnets is relevant and timely.

As is known, with increasing temperature, there is thermal expansion of telephone that is, due to the difference of linear expansion coefficients of the materials of the films, molds and bolts you can get more “heat” pressure. For calculations was created analysis model in the program ANSYS. In the design model include: mold, bolts and tapes. The material of the mold and bolts were selected so that the difference in coefficients of linear expansion to create additional pressure on the composite material caused by temperature change.

For modeling were used: the dependence of young's modulus for materials design models, the coefficient of linear expansion α for phase Nd₂Fe₁₄C. The dependence of the tensile strength, the yield strength of the bolt and the mold temperature. The calculations showed that after temperature of

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673K, the values of tensile strength and yield strength for the material of the screws and molds are plummeting. That is, after this temperature begins the process of plastic deformation. In order to account for this phenomenon, you need to build curves of deformation for each calculated temperature.

The greatest elongation, according to the calculations obtained for the film material. The smallest elongation for material of the bolts. For temperatures of 1023K and 1173K they differ by 4 times. It is due to this it is possible to obtain additional external pressure on the sample in a compressed state in the range of 850...900 MPa.

For research we used film, that quickly cooled, (scales) alloy composition $\text{Nd}_{20}\text{Fe}_{70}\text{C}_{9,5}\text{B}_{0,5}$. The films obtained by quenching from the liquid state in the initial state had amorphous or amorphous-crystalline structure. The resulting films (flakes) were placed into the mold and compressed under the press before sintering at a pressure of 0.5 MPa. The mold was bolted and placed in a vacuum sintering furnace in a compressed state. Due to the difference in the coefficients of linear expansion of bolts and molds, additional pressure was created on the sample when heated to 0.9GPa. Sintering was conducted at temperatures of 1023...1223K for 1800 seconds.

The reliability of the obtained scientific results confirmed by the use of modern research equipment (optical microscope OLIMPYS IX-70, x-ray diffractometer Dron-3, a scanning electron microscope JEOL JSM-6360LA, magnetometer vicious circle); the error in the reproduction of results is 3% and 10%.

With the rapid cooling of the melt phase $\text{Nd}_2\text{Fe}_{14}(\text{B,C})$ kristallizuet-sya directly from bypassing liquid equilibrium peritectoid transformation. In the films (scales) alloys $\text{Nd}_{20}\text{Fe}_{70}\text{C}_{9,5}\text{B}_{0,5}$ in sintering at temperatures of 1123...1223K of amorphous component kristallizuet-sya metastable phase with reduced metastability $\text{Nd}_2\text{Fe}_{14}\text{C}$. The external pressure helps to seal the sample and sintering on the limits of the scales. The increase in the sintering temperature in the interval 1023...1223K increases the coercive force, residual induction and specific magnetic energy of the compact ($H_c = 12...32\text{kA/m}$, $B_r = 0.15...0.23\text{T}$, $W = 0.135...0.91\text{kJ/m}^3$, respectively).

1. Introduction

The basis for the production of high coercitivity permanent magnets are alloys of transition metals (T) with rare earth (R), in which the necessary level of magnetic properties is provided by the formation of intermetal-

lic compounds of type RT_5 , and R_2T_{17} , $R_2T_{14}B$. Although SmCo magnets satisfied the demands of modern electrical engineering, but the expensive technology of obtaining of cobalt and the high price limits their practical application. The emergence of materials with high magnetic properties and low cost compared to the SmCo-based alloy system Nd-Fe-B stimulated further research and development in several industrialized countries [1]. To date, developed the technology of fabrication of high performance permanent magnets based on $Nd_2Fe_{14}C$ compound, installed precision schematics of heat treatment and methods of alloying the base alloy to achieve the maximum hysteresis properties [2; 3].

It is known that to obtain high-quality permanent magnets are promising alloy system Nd-Fe-C, because the connection that is formed in the system $Nd_2Fe_{14}C$ has a high anisotropy field ($H_A=7,6$ MA/m). It should be noted that the phase $Nd_2Fe_{14}C$ in the system is formed by peritectoid reaction in the temperature range of 1123...1173K, and the time of complete conversion is more than 20 days [4].

To accelerate the transformation perfectooo resort to the following methods: 1) alloying a small amount of boron (0.5 at. %) [5]; 2) quenching from the liquid state, which is formed metastable phase $Nd_2Fe_{14}C$ along with the Nd_2Fe_{17} phase. The use of these methods reduces the conversion process to a few tens of minutes [6].

In addition to the search methods of complex alloying, and development of new compounds such as $Nd_2Fe_{14}C$, in world and domestic literature little attention is given to the development of new methods of manufacture of permanent magnets, namely using one of the thermodynamic parameters of pressure to control the crystallization and sintering of the permanent magnets. Therefore, in this paper applied an integrated approach during the study of the dependence of the coercive force from alloying and heat treatment of hard magnetic alloy Nd-Fe-C, received high-speed cooling, sintering the compact under pressure up to 1 GPA. In this formulation, the problem of obtaining high coercitive magnets is relevant and timely.

2. Calculation of additional “thermal” pressure

As is known, with increasing temperature, there is thermal expansion of the bodies. If you take a mold, put inside a bulk material, to seal it and start to heat, when thermal expansion of the material of the mold of bulk material inside it will start to spresovuyetsya. In order to calculate the additional

“thermal” pressure, it is necessary to simulate the process. This additional “thermal” pressure is due to the difference of coefficients of linear expansion of the materials of the films, molds and bolts. For calculations was created analysis model in the program ANSIS [7]. In the design model include: mold, bolts and tapes. In Fig. 1 presents a computational model is created.

**Fig. 1. Design model: a diagram of the mold;
b, the geometric model; c – finite element model**

Applied modeling of bolts of a certain force F depending on the torque M tightening bolts (forms. 1):

$$F = 0,8M \quad (1)$$

The films were studied, perceived pressure from parts of the mold together. The interaction of the powder and of the surrounding parts is modeled by contact elements. The result of the calculation is the contact pressure, which depends on the temperature of the installation.

The material of the mold and bolts were selected so that the difference in coefficients of linear expansion to create additional pressure on the material of the compact caused by the change of temperature. In Fig. 2 shows the dependence of temperature coefficient of linear expansion of the $\text{Nd}_2\text{Fe}_{14}\text{B}$ phase for parameters a and C .

In table. 1 presents values of the young's modulus and linear expansion coefficient were used for calculations.

For calculations were used the data graphs (see Fig. 3, 4). In the calculations it was considered that for the material of the CD young's modulus remains almost unchanged, while for the materials of the mold and bolts changes [9-12]. From Fig. 4 shows that after the temperature of 673K, the values of tensile strength and yield strength for the material of the screws

Fig. 2. A graph of the linear expansion coefficient α of the temperature of the $\text{Nd}_2\text{Fe}_{14}\text{B}$ phase: 1 – a; 2 – c [8]

Table 1

The Values of young's modulus and coefficient of linear expansion for materials that are used for calculations at $T = 293 \text{ K}$ (20°C)

The model element	Material	The Young's Modulus, GPa	The coefficient of linear expansion $\alpha \cdot 10^{-6}, \text{K}^{-1}$
Pres-form	12X18H10T	40,9	16,4
Bolts	30XГCA	20	11,5
Powder	Nd-Fe-B	150	1,66

and molds are plummeting. That is, after this temperature begins the process of plastic deformation. In order to account for this phenomenon, you need to build curves of deformation for each calculated temperature. The total deformation curves shown in Fig. 5.

In order to build these facilitation curves (Fig. 6) you must use the data graph shown in Fig. 43. The angle α is found from the following relationship:

$$\text{tg} \alpha = \frac{\sigma_m}{\varepsilon_1} \quad (2)$$

The angle β is as follows:

$$\text{tg} \beta = \frac{\sigma_m - \sigma_m}{\varepsilon_2 - \varepsilon_1} \quad (3)$$

Fig. 3. Graph of relative length (a) and young modulus (b) against temperature for the materials of the bolts and mould:
1 – material films Nd-Fe-B; 2 – bolt material 30KHGSA;
3 – material mold 12KH18N10T

Fig. 4. The dependence of the tensile strength, yield strength on temperature: 1 – tensile strength for bolts; 2 – yield strength for bolts;
3 – tensile strength for the mold; 4 – yield strength for the mold

Thus, in the simulation we used the following simplified deformation curves (Fig. 7).

Fig. 5. The General form of curves of deformation at different temperatures: $T_3 > T_2 > T_1$

Fig. 6. A simplified theoretical curve deformation

Mechanical stress depends on the deformation in the following way:

$$\{\sigma\} = [E]\{\epsilon^{el}\}, \quad (4)$$

where $\{\sigma\} = \{\sigma_x \sigma_y \sigma_z \sigma_{xy} \sigma_{yz} \sigma_{xz}\}^T$ – vector mehanna in voltage,
 $[E]$ – the young's modulus, or elastic stiffness matrix (or stress-strain matrix).

The vector of elastic strain:

$$\{\epsilon^{el}\} = \{\epsilon\} - \{\epsilon^{th}\}, \quad (5)$$

Fig. 7. Deformation curves at different temperatures for the material of the bolts 30KHGSA (a) and for the material of the mold 12KH18N10T (b): 1 – 673K; 2 – 723K; 3 – 773K; 4 – 823K; 5 – 873K; 6 – 923K; 7 – 973K; 8 – 1023K; 9 – 1173K

where $\{\epsilon\} = [\epsilon_x \ \epsilon_y \ \epsilon_z \ \epsilon_{xy} \ \epsilon_{yz} \ \epsilon_{xz}]^T$ – the total strain vector,
 $\{\epsilon^{th}\}$ – thermal strain vector.

Sign vector for direct strains and stresses can be represented as follows: the rule of signs for the normal stresses and strains that are used in the program ANSYS, such a tensor is positive, and compression negative, to offset: positive if imposed two additional.

$$\{\epsilon\} = \{\epsilon^{th}\} + [E]^{-1}\{\sigma\} \quad (6)$$

For three-dimensional vector thermal strain:

$$\{\epsilon^{th}\} = \Delta T [\alpha_x^{se} \ \alpha_y^{se} \ \alpha_z^{se} \ 0 \ 0 \ 0]^T, \quad (7)$$

where α_x^{se} – Jan the coefficient of thermal expansion along the X axis;

$$\Delta T = T - T_{ref};$$

T – current temperature;

T_{ref} – reference (stress-free) temperature.

Elastic matrix is:

$$[E]^{-1} = \begin{bmatrix} 1/E_x & -\nu_{xy}/E_x & -\nu_{xz}/E_x & 0 & 0 & 0 \\ -\nu_{yx}/E_y & 1/E_y & -\nu_{yz}/E_y & 0 & 0 & 0 \\ -\nu_{zx}/E_z & -\nu_{zy}/E_z & 1/E_z & 0 & 0 & 0 \\ 0 & 0 & 0 & 1/G_{xy} & 0 & 0 \\ 0 & 0 & 0 & 0 & 1/G_{yz} & 0 \\ 0 & 0 & 0 & 0 & 0 & 1/G_{xz} \end{bmatrix}, \quad (8)$$

where E_x – the young's modulus along the X axis, G is the shear modulus,

μ_{xy} – the basic Poisson's ratio,

μ_{yx} – the minor Poisson's ratio,

σ_{xy} – the module of the tangential mechanical stress in the XY-plane.

For an isotropic material ($E_x = E_y = E_z$) and ($\nu_{xy} = \nu_{yx} = \nu_{xz}$) there is no difference between the data that is entered. Write down 6 explicit equations:

$$\varepsilon_x = \alpha_x \Delta T + \frac{\sigma_x}{E_x} - \frac{\mu_{xy} \sigma_y}{E_x} - \frac{\mu_{xz} \sigma_z}{E_x} \quad (9)$$

$$\varepsilon_y = \alpha_y \Delta T - \frac{\mu_{xy} \sigma_x}{E_x} + \frac{\sigma_y}{E_y} - \frac{\mu_{yz} \sigma_z}{E_y} \quad (10)$$

$$\varepsilon_z = \alpha_z \Delta T - \frac{\mu_{xz} \sigma_x}{E_x} - \frac{\mu_{yz} \sigma_y}{E_y} + \frac{\sigma_z}{E_z} \quad (11)$$

$$\varepsilon_{xy} = \frac{\sigma_{xy}}{G_{xy}} \quad (12)$$

$$\varepsilon_{yz} = \frac{\sigma_{yz}}{G_{yz}} \quad (13)$$

$$\varepsilon_{xz} = \frac{\sigma_{xz}}{G_{xz}} \quad (14)$$

where ε_x –direct deformation along the X axis;

σ_x –direct mechanical stress along the X-axis;

ε_{xy} –shear strain along XY plane;

σ_{xy} –shear stress along XY plane.

Study of the influence of external pressure and sintering temperature...

If the shear modulus G_{xy} , G_{yx} and G_{xz} not introduced for isotropic materials, then they are equal

$$G_{xy} = G_{yz} = G_{xz} = \frac{E_x}{2(1 + \mu_{xy})} \quad (15)$$

When solving the above equations we can obtain the following two levels for the main mechanical stress and strain. The equation for determining the main stress:

$$\sigma_e = \frac{1}{2} \sqrt{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2} \quad (16)$$

Equations for deformation:

$$\varepsilon_e = \frac{1}{2 \cdot (1 + \mu)} \cdot \sqrt{(\varepsilon_2 - \varepsilon_1)^2 + (\varepsilon_2 - \varepsilon_3)^2 + (\varepsilon_3 - \varepsilon_1)^2} \quad (17)$$

where μ is the Poisson's ratio for elastic and thermal deformations of the material.

The results of calculations by the formulas 16,17 shown in Fig. 8: distribution of elongation Δl in mm in the cross section of the mold, bolts and pattern as well as the distribution of the contact load on the sample for temperatures from 293...1073K.

It is seen that with increasing temperature an additional “thermal” pressure initially increases and then gradually decreases and remains almost unchanged. In Fig. 9 shows the dependence of tensile strength, yield stress and “thermal” pressure, temperature, and Fig. 10 – dependence of elongation on temperature.

From Fig. 9 shows that the yield stress for the material of the mold at room temperature lower than the thermal pressure at the same temperature. The maximum thermal pressure 895,8 MPa was obtained for the temperature 673K. With further increase in temperature the value of thermal pressure decreases slightly and remains at about 850...860 MPa. This can be explained by the fact that, as for the material of bolts and the material of the mold with the increase of temperature begins the phenomenon of plastic deformation.

From Fig. 10 shows that the greatest elongation, according to the calculations obtained for the film material. The smallest elongation for material of the bolts. For temperatures of 1023 K and 1173 K they differ by 4 times. It is due to this it is possible to obtain additional external pressure on the sample in a compressed state in the range of 850...900 MPa.

Fig. 8. Distribution diagram widower and contact pressure:
1 – distribution vidaurri in the mold, the bolts, the material
of the compact; 2 – distribution of contact pressure at the contact
between the punch mold and the material of the CD; a – 293K
(20 °C); b – 1023 K (750 °C); c – 1173 K (900 °C)

Fig. 9. The dependence of the tensile strength, yield strength and thermal pressure from temperature: 1 – extra pressure; 2 – tensile strength for bolts; 3 – yield strength for bolts; 4 – tensile strength for the mold; 5 – yield strength for the mold

Fig. 10. The dependence of elongation on temperature: 1 – the material of the compact; 2 – material molds; 3 – bolt material; 4 – seredni value

3. The influence of external load and sintering temperature on structure, phase composition and magnetic properties of the alloy $\text{Nd}_{20}\text{Fe}_{70}\text{C}_{9,5}\text{B}_{0,5}$

To verify the results of mathematical simulation was verified based on phase composition, microstructure and magnetic properties on sintering temperature and external loads. Sintering was carried out for the base alloy composition $\text{Nd}_{20}\text{Fe}_{70}\text{C}_{9,5}\text{B}_{0,5}$ in the temperature range of 1073...1223K every 50K, the initial pressure of 0.5 MPa, a sintering time of 1800 sec. Annealing occurred at a temperature of 1113K, the annealing time of 1800 sec. The study of structural phase transformations and measurements of magnetic properties were carried out by standard methods.

In Fig.11 shows images of the microstructure of the compacts of base composition after sintering at different temperatures (see Fig. 1 a,c,f,h,m) and after annealing(see Fig. 1 d,b,g,k,n).

As can be seen from the results of metallographic studies of alloys in the structure of the compacts have a multiphase structure. After etching of the sintered alloys were observed components of three types: light grass, dark grass and areas, which after etching have a greenish tinge.

After sintering at a temperature of 1023K and 1073 K (see Fig. 11 a, C) it can be seen that the grain is not formed and the structure is fine. After annealing (see Fig. 11 b,d) the structure is virtually unchanged, grain boundaries are not expressed. Further pawsan sintering temperature of the alloy and the growth of the grains of the main magnetic phase. In the process of growth of grains of the main magnetic phase $\text{Nd}_2\text{Fe}_{14}\text{C}$ acquire a regular geometric shape (see Fig. 11 f,h,m). With increasing sintering temperature up to 1223 K (see Fig. 11 m) of grain ϕ -phase is the main volume and acquire a rounded shape. Annealing helps to optimize the structure (see Fig. 11 g,k,n), the main volume is uniform in grain size ϕ -phase ($\text{Nd}_2\text{Fe}_{14}\text{C}$) with a thin clear boundaries, the number of pores and misereor space is minimal. The structure of the CD as a whole is dispersed, some areas consist of areas of directional solidification grains of the ϕ -phase.

Analysis of phase equilibrium diagrams of the system Nd-Fe-C (see Fig. 12) has shown that in the alloys studied composition possible for the next phase: the main phase of magnetic $\text{Nd}_2\text{Fe}_{14}\text{C}$, a solid solution of carbon in phase $\text{Nd}_2\text{Fe}_{17} \rightarrow \text{Nd}_2\text{Fe}_{17}\text{C}_{0,4}$ and enriched in neodymium and carbon carbides.

Fig. 11. The microstructure of the compacts sintered from the base alloy Nd20Fe70C9,5B0,5: a – 1023 K; b – 1073 K – 1123 K; g – 1173 K, q – 1223 K.

X-ray structural analysis of alloys of Nd-Fe-C is complicated by the fact that the angles of diffraction of the main phases $\text{Nd}_2\text{Fe}_{14}\text{C}$, $\text{Nd}_2\text{Fe}_{17}\text{C}_{0,4}$, $\text{Nd}_2\text{Fe}_{17}$ match. Other phases present in the sintered compacts, due to the low symmetry of its crystal lattices, the large values of their periods, in their majority, have low intensity and overlap. All this complicates the phase analysis, calculation of periods of lattices

Fig. 12. Projection of the liquidus surface on the plane of the concentration triangle in the system Nd-Fe-C [13, 14]

of the phases present in the compact, and determine their quantitative relationships.

Analysis and calculation of diffraction patterns showed that the main phase components in the alloy after sintering is tetragonally carbide $\text{Nd}_2\text{Fe}_{14}\text{C}$ (φ -phase) and a solid solution of carbon in the phase of $\text{Nd}_2\text{Fe}_{17} \rightarrow \text{Nd}_2\text{Fe}_{17}\text{C}_x$. In addition to these phases in the alloys are double and triple carbides of neodymium. Also, the sintering process changes the phase composition of the alloys. With increasing sintering temperature there is a redistribution of the intensities of diffraction peaks, which is obviously related to the elastic stresses (see Fig. 13).

Data precision measurements of the lattice parameters of the main magnetic phase showed that with increasing sintering temperature there is a growth tetragonality (c/a) φ -phase in the interval 1,358...1,394. Because the composition of the alloys does not match the stoichiometry of the phase $\text{Nd}_2\text{Fe}_{14}\text{C}$ and offset in the direction of greater carbon content and neodym-

Fig. 13. Diffraction of compacts, sintered from the base alloy
 $\text{Nd}_{20}\text{Fe}_{70}\text{C}_{9.5}\text{B}_{0.5}$: 1 – 1023 K; 2 – 1073 K; 3 – 1123 K;
 4 – 1173 K, 5 – 1223 K

ium, when cooling after sintering, the formation of a supersaturated solid solution of neodymium and carbon in the σ -phase. Also in terms of external pressure and in the presence of dramatically increasing the rate of diffusion of alloying elements. Furthermore, the increase tetragonality phase $\text{Nd}_2\text{Fe}_{14}\text{C}$ may indicate the allocation of the excess of the neodymium and carbon from the lattice of the main phase, as this is a compression of the lattice along the C axis and the associated extension along the axis and, due to the “desire” of the structure to balance the change of volume of an elementary lattice.

Despite the fact that carbon is a light element sensitivity of x-ray spectral analysis using a JEOL JSM-6360LA allows it to be detected in the alloy. In Fig. 14 shows the chemical composition of the compacts made from alloy $\text{Nd}_{20}\text{Fe}_{70}\text{C}_{9.5}\text{B}_{0.5}$ at a temperature of 1173 K (a) and 1223 K (b). In the x-ray spectral studies determined that grains of light gray color correspond to the phase $\text{Nd}_2\text{Fe}_{14}\text{C}$ (see Fig. 14, points 1,4,6), and grain dark gray phase $\text{Nd}_2\text{Fe}_{17}$ (see Fig. 14, points 3,7). In addition, miserendino space there are grains enriched in neodymium (see Fig. 14, points 2,5). Also in Fig. 14a shows the distribution of elements on the surface of the

Fig. 14. The chemical composition of the compacts, sintered alloy $\text{Nd}_{20}\text{Fe}_{70}\text{C}_{9.5}\text{B}_{0.5}$ at a temperature of 1173 K (a) and 1223 K (b)

sintered compacts. More content elements correspond to a more saturated color in the pictures.

In General, increasing the sintering temperature up to 1223K leads to coarsening of grains of the main magnetic phase, its boundaries become indistinct and blurred. The amount of magnetic phase is increased, its grains are separated by thin layers of paramagnitnyi. At the joints of grains of the main phase are small inclusions of carbides. The dark areas between the grains correspond to the enriched neodymium and carbon hardened during cooling of the melt, and individual defects such as pores. The increase in vacuum at a sintering promotes the formation of a thin and clear boundary grains of the φ -phase and to reduce the number of carbides and oxides (Fig. 3.7).

Thus, the results showed that increasing sintering temperature peritectoid accelerates the reaction, improves the structure of the compacts. Nearly all compact φ -is the phase after sintering at a temperature of 1223K, the grain take the correct form, be homogeneous in size, with thin sharp edges. Although grain boundaries of space, inclusions of paramagnetic carbides and oxides (according to x-ray spectral analysis), the number of grain boundaries and space is minimal.

For rice. 15 the dependence of the specific magnetic energy on the sintering temperature for the compact sintering of base alloy $\text{Nd}_{20}\text{Fe}_{70}\text{C}_{9.5}\text{B}_{0.5}$. After annealing is presented. Anals loops heterosis for magniv showed that the maximum specific magnetic energy and coercive force of this alloy increased

Rice. 15. Dependence of specific magnetic energy on the sintering temperature for compacts sintered from the base alloy $\text{Nd}_{20}\text{Fe}_{70}\text{C}_{9,5}\text{B}_{0,5}$, after annealing: 1 – 1023K; 2 – 1073K; 3 – 1123K; 4 – 1173K, 5 – 1223K

with increasing sintering temperature in the range 0,135...0.91 kJ/m^3 and 12...32 kA/m , respectively.

Such differences can be explained by the fact that CD number 1 is not observed a clear structure, fragments of ϕ -phase is not formed, the boundaries of the fragments are blurred. Also structure compactum present fragments of soft magnetic $\text{Nd}_2\text{Fe}_{17}$ phase, which contribute to the emergence of stray fields. On the contrary, for sample No. 5 there is an optimal microstructure with small fragments of the ϕ -phase and with the least amount of Defragmenter space.

4. Discussion of results

Analyzing the obtained results, we can say that quenching from the liquid state of alloys $\text{Nd}_{20}\text{Fe}_{70}\text{C}_{9,5}\text{B}_{0,5}$ allows to obtain the main magnetic phase $\text{Nd}_2\text{Fe}_{14}\text{C}$ directly from the liquid. In addition, obtaining ϕ of the metastable phase does not preclude the crystallization phase $\text{Nd}_2\text{Fe}_{17}$ -type, which corresponds to the equilibrium state diagram, and participates in perfectnow the transformation of $(\text{Fe} + \text{Nd}_2\text{Fe}_{17} + \text{Nd}_4\text{FeC}_6 \leftrightarrow \text{Nd}_2\text{Fe}_{14}\text{C})$. In addition to the above fact it is also known that boron contributes to the acceleration of the transformation of the $\text{Nd}_2\text{Fe}_{17}$ phase in $\text{Nd}_2\text{Fe}_{14}\text{C}$ [15; 16]. In this work introduced another thermodynamic parameter, external and examines its influence on the process perfectooo conversion.

Changing the appearance of diffraction patterns before annealing (after sintering) and after annealing of the sintered compact, significantly reduced fluctuations of the background intensity increases the “sharpness” of the diffraction maxima, and also increases the intensity of peaks that correspond to the ϕ -phase. This means that after quenching from a liquid phase $\text{Nd}_2\text{Fe}_{14}\text{C}$ not fully formed. The increasing sintering temperature (external heat pressure) improves spket compacts and the formation of fragments of the ϕ -phase. Thus the external pressure helps to seal the sample and sintering on the limits of the scales, but at the same time, diffusion processes in the volume of hard scales are accelerated [17], and on the limits of sintered flakes hampered. The result perfectone reaction at such acceleration is not complete, therefore, completion perfectooo conversion and the creation of the optimal structure to obtain high magnetic properties required to perform additional annealing after sintering without any external loading.

Increasing sintering temperature in the range 1023...1223K contributes to improving the coercive force and residual induction compacts ($H_c = 12...32 \text{ kA/m}$, $B_r = 0,23...0,15\text{T}$, respectively). With increasing sintering temperature, firstly, improving the density of the compact decreases the number of pores and Defragmenter space ($\uparrow B_r$), and secondly, the displacement of the points of phase equilibrium according to the equation of Clausius-Clapeyron, and getting into the temperature range of formation of hard magnetic phase $\text{Nd}_2\text{Fe}_{14}\text{C}$. The increase in the coercive force of compacts after annealing are due to the conversion of almost the entire amount magnetomeco phase $\text{Nd}_2\text{Fe}_{17}$ phase in magnetogorsk $\text{Nd}_2\text{Fe}_{14}\text{C}$, the decrease in grain boundary areas and number of inclusions, carbides and oxides.

That is, we study the dependence of completeness peritectoid reactions from sintering temperature at a constant primary pressure of 0.5 MPa. From the data of Fig.11 shows that the increase in temperature promotes a phase transformation according to peritectoid reaction at constant time of sintering and annealing, that is, increasing the number of phase $\text{Nd}_2\text{Fe}_{14}\text{C}$. In model 5 the number of phase $\text{Nd}_2\text{Fe}_{14}\text{C}$ exceeds 80%, but is still present phase $\text{Nd}_2\text{Fe}_{17}$.

5. Conclusions

Thus, the paper studies the influence of external primary and additional heat of the pressure created due to the different coefficients of expansion of the mold and screws bonding, sintering temperature, doping on structure and magnetic properties of the permanent magnets, sintered products of quenching of liquid alloys of Nd-Fe-B. based On the above we can draw the following conclusions:

1. According to mathematical modeling, at the time of sintering of alloy $\text{Nd}_{20}\text{Fe}_{70}\text{C}_{9,5}\text{B}_0$, you can get 5 additional “thermal” pressure up to 1 GPA.

2. Alloying boron, copper and rapid cooling of alloys in Nd-Fe-C, allows to obtain the main magnetic phase $\text{Nd}_2\text{Fe}_{14}\text{C}$ directly from the liquid, including crystallization magnetomeco phase $\text{Nd}_2\text{Fe}_{17}\text{C}_x$.

3. Pressing is rapidly cooled flake under the pressure of 0.5 MPa and sintering at a temperature of perfectooo conversion 1223...1073K gives the opportunity to obtain a compacted sample with good sintering on the limits of the scales and accelerate the process perfectooo conversion under the influence of external pressure.

4. Annealing of the compacts sintered without external pressure almost completes perfectone conversion, and also contributes to the formation of the optimal structure with the contents of the main magnetic phase $\text{Nd}_2\text{Fe}_{14}\text{C}$ to 80%.

5. Vstanovleno scho laguana forest that Spinna under towns the vise may pcvisit magnet characteristics VDC after VDP AU. Magnta energy, eco can dosage in these magnets sklada of 0.91 kJ/m³.

In the future, complex studies of the influence of alloying (Cu, Ti), initial external pressure (0.5...10 MPa), time and temperature of sintering on this nd-Fe-C, b alloy are planned.

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