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Investigation of nanomaterial for cryogenic application

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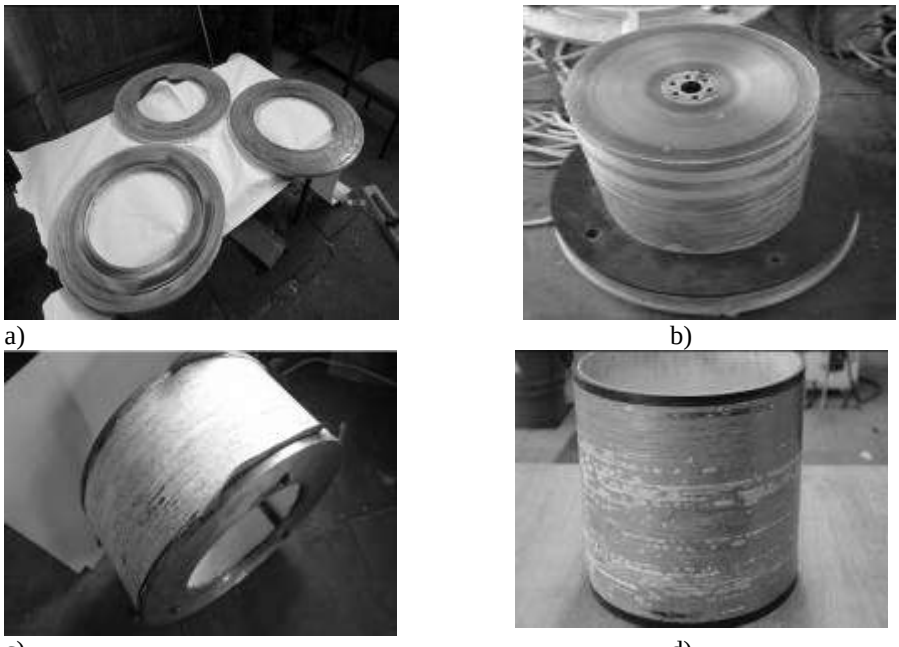
Abstract:- There are presented the results of investigation of magnetic and thermal characteristics of magnetic cores and permanent magnets intended for HTSC electrical machines and there were produce and tested experimental circular coils, intended for operation under AC. The HTSC wire 2G was manufactured by Sumitomo Electric (Japan). Main task of the work was to develop the technological process and to evaluate the parameters of the coils and possibility of their application in AC windings.

Keywords:- Superconductivity, nanomaterial, permanent magnets, amorphous alloy, cryogenic electrical machines.

I. INTRODUCTION

Nowadays magnetic cores manufactured of amorphous alloy tapes present interest for the development of HTSC electrical machines (generators, motors, transformers). There were developed and tested cylindrical magnetic cores intended for the HTSC and cryogenic (high-purity aluminum) electrical machines, manufactured of two types of amorphous alloy tapes 5BDSR и 2NSR (Russian abbreviations for the amorphous alloys). The investigated cores are presented in Fig.1.



a) b)

c) d)

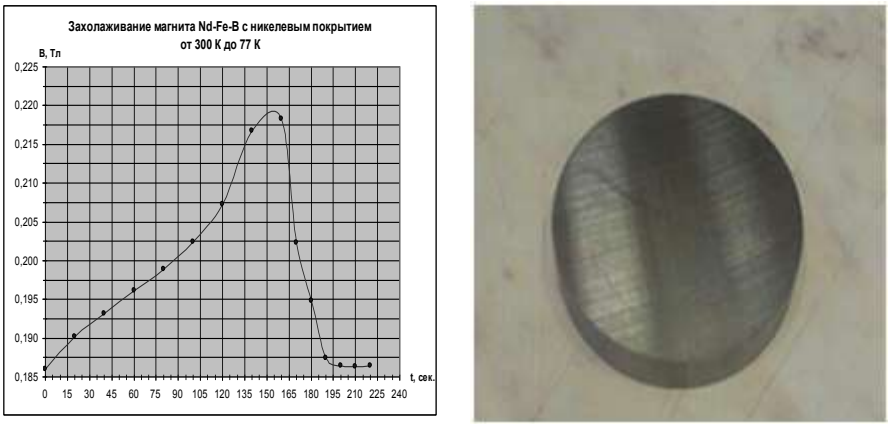
Fig.1 Samples of magnetic cores, manufactured of amorphous alloy: for HTSC motor (a), for HTSC transformer (b), for HTSC generator (c), for the cryogenic generator (d)

Solinoidal flat coils may represent the elements of both the field and armature windings and are mainly intended for the disc alternators with axial magnetic flux [1]. In case they operate in AC windings attention should be paid to several factors: proper insulation strength, adequate cooling, maximum possible operating current under external magnetic fields. Presented below are results of technology development and experimental investigations of the coils.

II. INVESTIGATION OF NANOMATERIALS

The cores presented in Fig.1 (a-c) were annealed and cooled down in the transverse magnetic field. The core in Fig. 1 (d) was not annealed.

The obtained magnetization curves and specific loss curves permit to compare the influence of annealing process and of cryogenic temperatures on the properties of amorphous alloy tapes. The cool down processes of magnetic cores intended for different devices were evaluated, accounting for the anisotropy of specific thermal conductivity of cylindrical cores, manufactured of amorphous alloy tapes in axial and tangential directions. The investigation of the magnetic properties of rare-earth magnets of Nd-Fe-B was carried out during their cooling down to 77 K. The variation of the magnetic inductance with the temperature displayed an obvious maximum in the temperature range of 300 to 77 K (Fig.3,a) corresponds to the lower Curie point for this type of



a) b)

Fig.2. Variation of magnetic inductance of Nd-Fe-B rare-earth magnets at 77 K (a) and disk-(b) permanent magnets of rotor of synchronous machine

magnets it shows that it is preferable to apply them not at liquid N_2 but at gaseous N_2 temperatures, providing a corresponding cooling system. The tests refer to alternator with a combination of permanent magnets on the rotor and HTSC tape winding on the armature for the wind-power installation (Fig.2,b).

The main task of experimental HTSC coils manufacturing was the development of technological process of the coil winding, insulating and impregnating. The coils represent a double layer flat circular unit, wound up from the middle. The HTSC tape of 4.7 by 0.38 mm^2 was manufactured by Sumitomo Electric. The support structure was manufactured of fiber-glass laminate. To ensure the dielectric strength of HTSC tape electrical insulation it was strengthened by the glass cloth tape. Main insulation of the coils was provided by the glass cloth, impregnated with epoxy. Some examples of HTSC coil manufacturing are presented in Fig. 3.

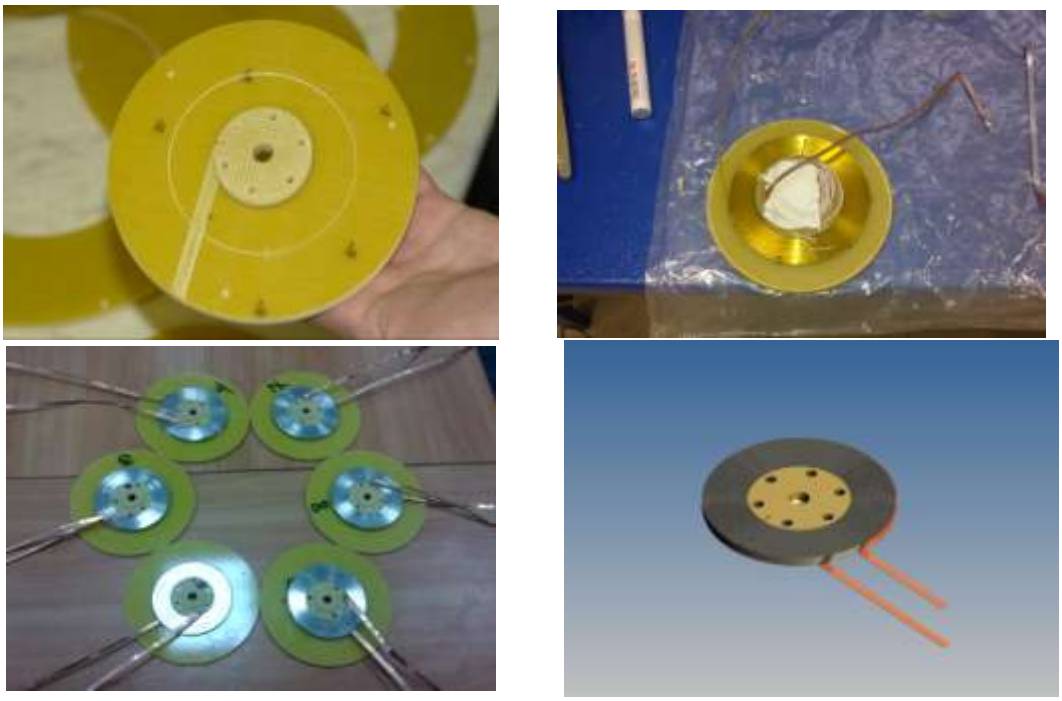


Fig.3. Different stages of HTSC coil manufacturing The coils were tested at ambient and LN_2 temperatures. Results of experiments are presented below.

III. RESULTS OF EXPERIMENTAL INVESTIGATIONS

One of the main experiments at ambient temperature was checking of the inductance of several coils and comparison with the calculated data. The difference was around 0.3-0.4 %. Experimental investigation of the influence of magnetic screen on one side of the coil showed the inductance increase by 60 %. The presence of magnetic screen influences the operating current value as well due to more favorable distribution of magnetic field against the HTSC tape cross-section. The installation for measurements is presented in Fig. 4.

Fig.4. Experimental investigation of HTSC coil inductance with magnetic screen below the coil

The Volt-Ampere curves obtained in experimental coils under AC at LN_2 temperature is given in fig.8 they show substantial decrease under AC in the self field of the coil.

There was tested the amorphous alloy saturation of the core and there was determined the value of specific losses at 77K, room temperature and frequency of 50Hz. The results of the tests are shown on fig. 5,6,7.

$$H = \frac{Iw}{l},$$

$$B = \frac{U_2}{w_2 4{,}44 S k_s f_1},$$

$$P_{sp} = \frac{P_c w_1}{w_2 G_c}.$$

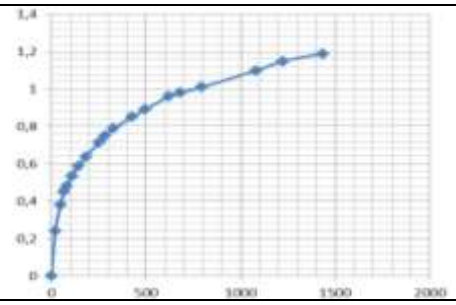


Fig.5. The magnetic curve of amorphous core at room temperature.

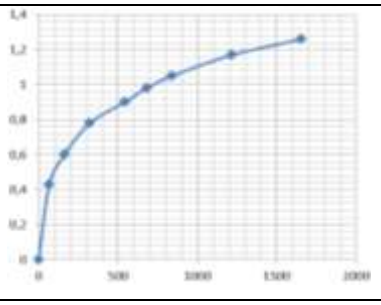


Fig.6. The magnetic curve of amorphous core at 77K.

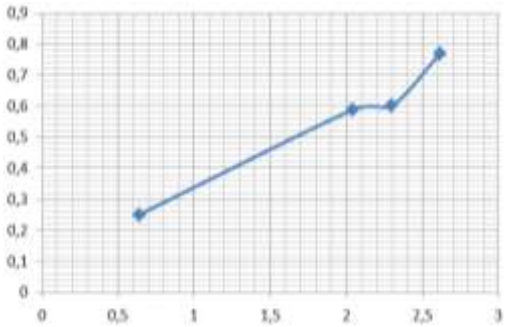


Fig.7. The specific losses of amorphous alloy at 77K.

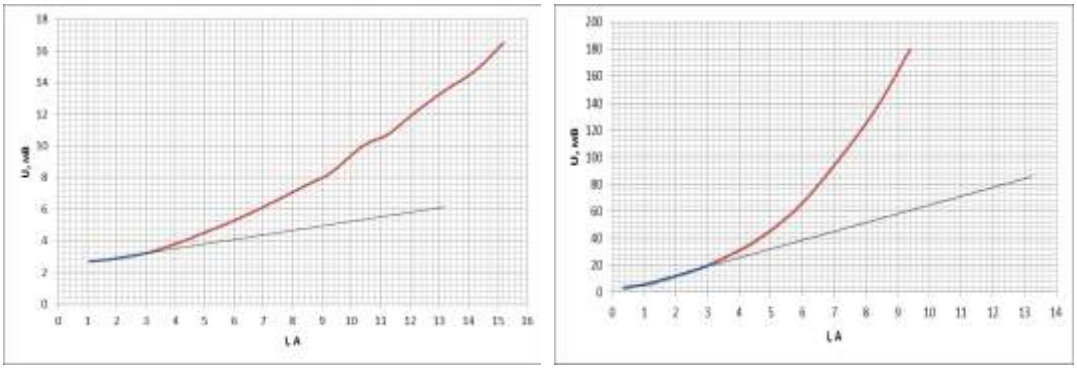


Fig.8. Volt-Ampere characteristics of model coils under AC

IV. CONCLUSION

Though the operating current in HTSC tape 2G under AC is not very high, nevertheless on the present stage of HTSC wire technology it is possible to apply the tape for the armature windings of the alternators of medium ratings. There exist several possibilities to exclude the circulating currents between the tapes and to provide relatively high armature currents: multi-disc and multi-phase designs, application of tape transposing along the length of the phase, etc. The value of magnetic saturation of amorphous alloy is about 1,2 – 1,3T so these cores are available to use as a magnetic circuit for axial slotless synchronous machines. The parameters of rera-earth permanent magnets are increased at 77K for 25% so it leads to decrease the active volume of electric machine and to increase the specific power.

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