Various types of anisotropic permanent magnets with nonhomogeneous convergent texture of the axes of easy magnetization were prepared and investigated. These magnets make possible to substantially increase the value of external flux density in comparison with conventional homogeneously textured magnets. They can be manufactured from most of the modern hard magnetic materials possessing high coercivity and magnetocrystalline anisotropy.

Results obtained on rare-earth based hard magnetic materials are presented. The external flux densities of convergently and homogeneously textured magnets are compared.

1. INTRODUCTION

Performance of many devices using permanent magnets depends heavily on the value of magnetic induction in the air gap. With a view to enhance the air-gap flux density we worked on magnets having a special magnetic texture where the orientation of the axes of easy magnetization of elementary regions (e.g., crystal grains) is convergent. The convergent texture can be linear, curvilinear, continuous or discrete and has two or three-dimensional symmetry. Magnets of this type make possible to substantially increase the value of flux density in the vicinity of the pole in comparison with conventional homogeneously textured (oriented) magnets [1]. The increased flux density supplied to the exterior, however, is reached in a smaller cross section than the cross section of the magnet where the convergent orientation concentrates the magnetic flux.

The increased flux density could be also supplied to pole pieces made of a soft magnetic material.

2. THEORY

The effect of convergent magnetic texture on the external flux density was studied by means of a theoretical model. For calculations of the flux density produced by continuously convergent magnets the polarization vector \( \mathbf{j} \) was determined by a continuous vector function of position which is constant in magnitude and varies only in direction. The flux density was calculated from magnetic scalar potential [2]. Calculations of the flux density produced by some special continuously convergent magnets were published elsewhere [1, 3].

*) Dedicated to Dr. Svatopluk Krupička on the occasion of his 65th birthday.

In case of discretely convergent magnets the assumption $J = \text{const.}$ was used for calculation. The flux density was found by linear superposition of the terms arising from each particular segment of the convergent magnet. These simplifying assumptions are often made when calculating the flux density produced by permanent magnets which possess high coercivity and high value of the ratio $K/J^2$. High uni-axial anisotropy depresses fluctuations of the polarization vector $J$ caused by non-uniform demagnetization fields. Calculation of the magnetic field produced by rectangular planes with uniform magnetic charge density was presented elsewhere [4]. In this way we calculated the flux density produced by discretely convergent magnets which were assembled of homogeneously textured parts.

3. EXPERIMENTAL RESULTS

Various types of convergent magnets having texture with two or three-dimensional symmetry were produced in laboratory for theoretical study and practical applications. One of the first developments was to determine suitable hard magnetic materials. Both ceramic ferrite and rare-earth based permanent magnet materials were found to be very well suited to this types of magnets. Whereas ceramic magnets were manufactured from commercially available strontium and barium ferrites, the rare-earth permanent magnets were made mostly from materials prepared in the National Research Institute for Materials (SVÚM).

Since 1973 we have conducted an extensive research on rare-earth permanent magnet materials. Various composition types based on rare-earth – cobalt and recently rare-earth – iron – boron alloys have been developed. Powder metallurgy techniques are employed. The basic process consists of preparing alloy by melting, producing powder by crushing cast ingots and milling, pressing the powder in a magnetic field followed by further compacting the field-oriented pellet by die pressing, sintering the compact and heat-treating the sintered product. Figure 1 shows demagnetization curves achieved on several homogeneously oriented magnets produced in laboratory.

![Fig. 1. Demagnetizing curves of some rare-earth permanent magnet materials developed at SVÚM. 1 -- (Sm$_{0.2}$MM$_{0.8}$)Co$_5$, 2 -- (Sm$_{0.5}$,MM$_{0.5}$)Co$_5$, 3 -- SmCo$_5$, 4 -- Nd–Fe–B.](Image)