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## THE APPLICATION OF MULTI – POLE BONDED MAGNETS IN ELECTRIC MOTORS

### ZASTOSOWANIE WIELOBIEGUNOWYCH DIELEKTROMAGNESÓW W SILNIKACH ELEKTRYCZNYCH

**Abstract:** Dielectromagnets, also called bonded magnets, are permanent magnets produced by combining hard magnetic powder with dielectric. They have many advantages. One of these for isotropic dielectromagnets is the possibility of multi - pole magnetization in all directions. Dielectromagnets from Nd-Fe-B melt-spun ribbon have good magnetic properties, better than sintered ferrite magnets. Dielectromagnets open new possibilities for the construction of electric machines. The paper presents the advantages of multi - pole dielectromagnets, allowing to replace the multi - pole glued constructions of bipolar permanent magnets. The paper presents the known methods of multi – pole magnetization of permanent magnets, and new solutions for simplification of electric motor designs. Also presented are examples of application of multi - pole Nd-Fe-B dielectromagnets.

#### 1. Introduction

Permanent magnets are used in electric motors as the excitation source. There are different types of permanent magnets according to their composition: ferrite magnets, alnico magnets, magnets from rare earth alloy. According to technology sintered magnets, cast magnets, and bonded magnets also called dielectromagnets.

Dielectromagnets from melt-spun ribbon of Nd-Fe-B alloy are manufactured by bonding the hard magnetic powder with bonding agent. Dielectromagnets of isotropic nature, can be magnetized in various directions, with configuration of magnetic poles adjusted to the design of the electric motor.

This types of permanent magnets have many advantages such as: good magnetic characteristics, simple production technology (much less sophisticated than the production technology of sintered magnets), or the possibility to adjust the physical properties to the requirements of designers of electric machines. The production technology makes it possible to manufacture dielectromagnets in complex shapes and precise dimensions without further machining. They are also recycling - friendly.

Designers of electric machines with excitation from permanent magnets require magnetic materials with specific physical properties such as magnetic, mechanical, thermal or electrical.

One multi-pole permanent magnet can replace several bipolar permanent magnets glued together. This helps to reduce time needed to manufacture a device which causes economic benefits. In the case of bipolar permanent mag-

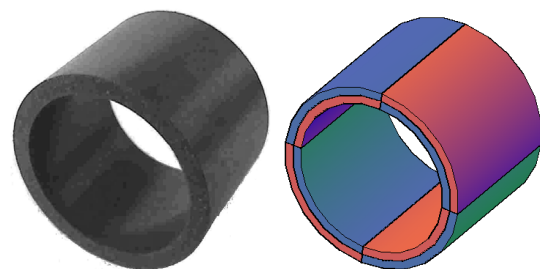
nets glued to the motor components there is a danger of tearing off magnets during operation of the device. In the case of multipolar magnets that risk is minimized.

In Tele & Radio Research Institute research is conducted to improve the physical properties of bonded magnets. The Institute is looking for new opportunities for their application in the construction of electric motors [1 -3].

#### 2. Multi - pole permanent magnets

##### 2.1. Multi - pole ring permanent magnet radially magnetized

This kind of permanent magnet (Fig.1) can be applied in brushless DC Motor. Multi - pole cylindrical permanent magnet instead of several single-glued magnets allows to eliminate problems with tearing off of permanent magnets from the rotor at high rotational speed [5]. Figure 2 shows distribution of radial component of magnetic induction on the surface of four - pole cylindrical permanent magnet in half of its length.



*Fig. 1 Four poles cylindrical permanent magnet. Outer diameter 38 mm, inner diameter 31 mm, height 30 mm*

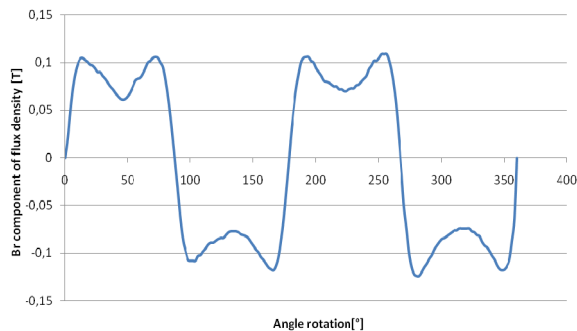


Fig. 2 Distribution of radial component of magnetic induction on the surface of four - pole cylindrical permanent magnet in half of its length. Resolution is 2

**2.2. Multi - pole ring permanent magnet, radial magnetization, skewed location of magnetic poles**

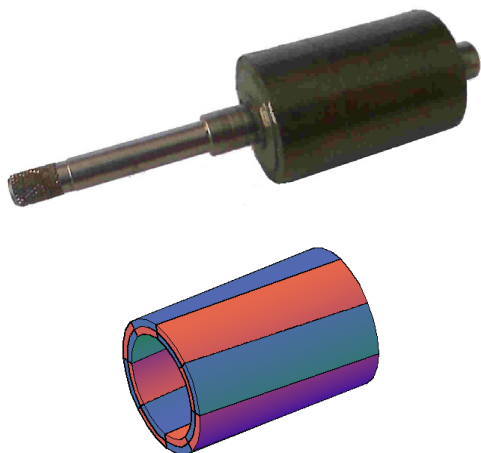


Fig. 3. Eight - pole rotor with skewed location of magnetic poles for brushless electric motor. Outer diameter 26 mm, inner diameter 20 mm, height 39 mm

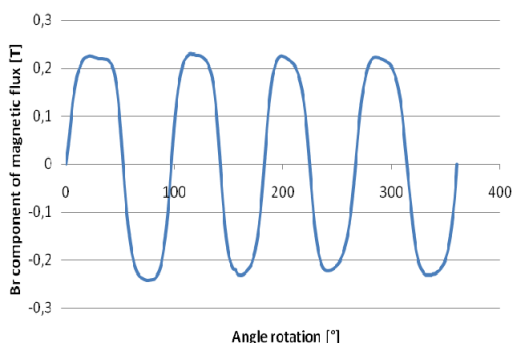


Fig. 4. Distribution of radial component of magnetic induction on the surface of eight - pole cylindrical permanent magnet with skewed location of magnetic poles in half of its length. Skew is 8° and resolution is 2°

Multi – pole Permanent magnet with skewed location of magnetic poles (Fig.3) can be applied in brushless high-speed synchronous electric motor. Pulsation of motor torque can be minimized by usage of permanent magnets which was skew magnetized. In case of using permanent magnet magnetized in such a way, the skewed slots in the magnetic core are not needed. It means that magnetic core may have straight grooves, which allows to manufacture it using powder composite. The result is that the technological process is significantly simplified and the fabrication costs are reduced.

Figure 4 shows distribution of radial component of magnetic induction on the surface of eight - pole cylindrical permanent magnet with skewed location of magnetic poles in half of its length. The Nd-Fe-B dielectromagnets have an important technological advantage. Mounting of multi – pole permanent magnets on the rotor instead of gluing bipolar permanent magnets is easy and time-saving. Skewed multi-pole Nd-Fe-B dielectromagnets allows the simplification of fabrication of stators. Production of stators with straight slots is much easier and cheaper than stators with a skew. It is also easier to wind coils in a stator with straight slots. This is particularly beneficial for motors with small diameters and extensive length of magnetic cores [4].

**2.3. Multi - pole flat magnet, magnetic poles in two-dimensional array configuration**

Flat magnet with magnetic poles in two-dimensional array configuration can be applied in planar motors.

Movement in several degrees of freedom could be executed in devices with several motors that coordinate management in every direction. Generally, to achieve motion in several degrees of freedom a separate actuator is used per each degree. However, there is a group of motors which allows movement in several degrees of freedom.

The requirements for advanced motion control are increasing in applications, such as robotics, tooling machines, pick-and-place systems.

Surface motors, are also called planar motors, are able to move the mover in x and y direction as well as rotate around its axis. They may be used in various precision positioning systems. Precision high-speed positioning can be achieved even in open-loop mode.

In known solutions (Fig.6) the stator consists of a large number of permanent magnets arranged according to one of the various examples, forming a regular chessboard grid (Fig.5) [6].

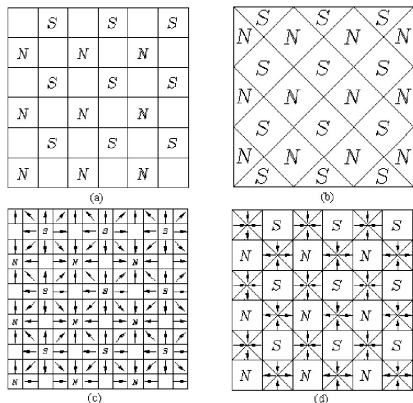


Fig. 5. Magnetization patterns for planar motors [6]

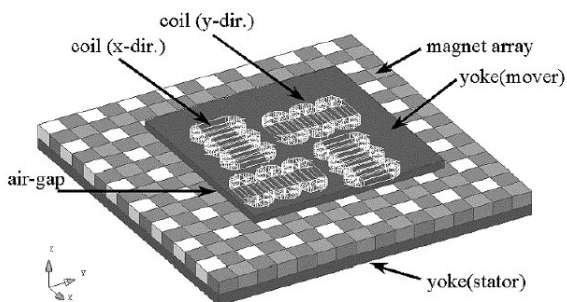


Fig. 6. Brushless planar motor [6]



Fig. 7. Flat multipole permanent magnet width 44mm, length 44mm, thickness 5mm

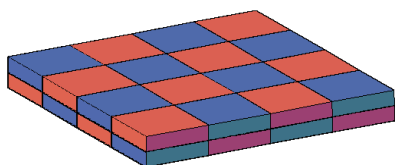


Fig. 8. Distribution of magnetic poles in two dimensional array system 4x4 poles. Magnetized through the thickness

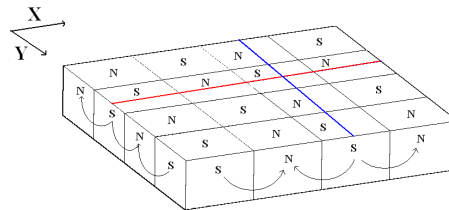


Fig. 9. Theoretical distribution of magnetic poles in two dimensional array system. 4x4 poles. Surface magnetized

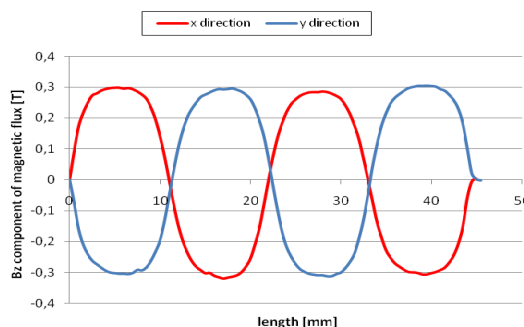


Fig. 10. Distribution of  $B_z$  component of magnetic induction on the surface of sixteen - pole flat permanent magnet in x and y direction. Only one surface of magnet was magnetized. Resolution is 0.5 mm.

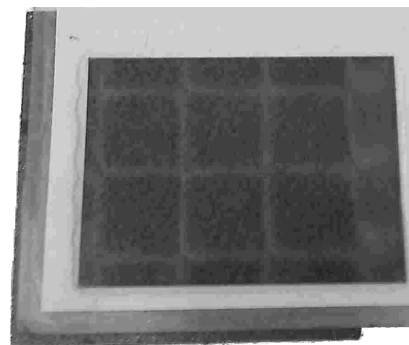


Fig. 11. Configuration of magnetic flux on the surface of sixteen - pole flat permanent magnet

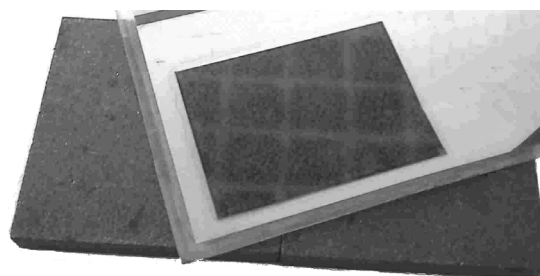


Fig. 12. Configuration of magnetic flux on the surface of two combined sixteen - pole flat permanent magnet

Special magnetization head was designed and constructed to magnetized flat permanent magnet where distribution of magnetic poles is in two dimensional array system. At the current stage of research, performed magnetization head consists of only one magnetizing part. Therefore flat permanent magnet can be magnetized on only one surface (Fig.9). For magnetization through the thickness of flat permanent magnet (Fig.8) the magnetization head should have two identical magnetization parts.

The flat permanent magnet which was produced in Tele & Radio Research Institute (Fig.7) has distribution of magnetic poles in the system of two dimensional array  $[i,j]$  on the  $xy$  plane (Fig.9), where  $i$  means the number of poles in the  $x$  direction and  $j$  means the number of poles in the  $y$  direction. The distribution of magnetic poles in the system of two-dimensional matrix " $ij$ " is typically obtained by combining two-pole permanent magnets. The advantage of flat multipolar magnets is distribution of the magnetic poles in two-dimensional array system resulting in one magnetization process (Figs.11,12). In practice, smaller number of items contained within the device means faster and easier process of its production. One multipole permanent magnet usually has greater mechanical strength than glued component with a single pole permanent magnets.

### 3. Conclusions

One of advantages for isotropic dielectromagnets is the possibility of multi - pole magnetization in all directions. Multi – pole permanent magnet allow to replace the multi - pole glued constructions of bipolar permanent magnets. This helps to reduce time needed to manufacture a device which causes economic benefits.

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