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A NON - CONVENTIONAL TYPE OF PERMANENT MAGNET BEARING

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Résumé : L'utilisation d'aimants disposés en quinconces permet d'obtenir un type particulier de palier magnétique, qui présente des propriétés très intéressantes : entrefer plan, force axiale nulle, et absence de couplage dû aux inhomogénités d'aimantation. Ces paliers sont bien adaptés aux systèmes tournant très lentement, et à ceux en levitation magnétique partielle.

Abstract: By using staggering magnets, we obtain a particular type of magnetising bearings, owning very interesting properties: plane gap, null axial force, and absence of coupling produced by magnetization non-homogeneities. These bearings are well adapted for low rotational speed systems, and for partially-magnetic suspensions.

I . INTRODUCTION

New permanent magnet materials of high coercive force allow the fabrication of very efficient bearings. The TR-Co₅ magnets are well adapted to this application, because of their high coercive force. All the bearing configurations, running by attraction or repulsion, can be built (Fig.1) /1/.

![Diagram of bearing configurations](http://dx.doi.org/10.1051/jphyscol:1985665)
The use of the new Fe Nd B magnet allows an important improvement of the bearing forces, because they depend quadratically on the magnet remanence. Most bearings are running at room temperature, and the bad temperature coefficient of this magnet has no effect. Two configurations are very often used: the coaxial type (Fig.1.A), and the facing type (Fig.1.E). Several other configurations are interesting, especially the type C bearing (Fig.1.C) which owns particular properties.

II. COMPARISON BETWEEN THE DIFFERENT TYPES OF BEARINGS

Among the different configurations of the Figure 1, only two are very often used:

* type A, built with coaxial ring magnets. Its axial force is null in centered position, but its radial displacements are limited by the gap between the two magnets.
* type E, built with two identical rings. Its radial displacements are not limited but its axial force is very important.

In addition to these two classical configurations, type C has much interest. Its gap is plane, which allows large radial displacements (Fig.2). Its axial force can be small or null; it depends on the magnet dimensions. It can be built with two ring shaped magnets (basic disposition: Fig.2), or with a double ring configuration (Fig.3 and 4).

For type C bearing, the two magnets are neither in attraction, nor in repulsion. If we consider one magnet, the field created by the other magnet is nearly perpendicular to its magnetization direction. The magnetization must be as rigid as possible.

III. FORCE AND STIFFNESS CALCULATION

Exactly as for type A, the forces and stiffnesses can be analytically calculated /4/. As an example, the radial stiffness exerted between two ring magnets (Fig.2) is given by

\[
K_r = \frac{J^2}{8\pi h_0} R_m \{ \rho(e) + \rho(e+2h) - 2 \rho(e+h) \}
\]

with

\[
\rho(z) = \ln \left[ \frac{(2l+d)^2 + z^2}{(d^2 + z^2)} \right]
\]

where \( J \) is the magnet remanence, and \( R_m \) the average radius of the bearing.

\[\text{Figure 2. Type C bearing built with two ring magnets of identical sections.}\]
IV . EXPERIMENTAL STUDY

We have measured the axial and radial forces exerted by a double ring bearing. The results are shown in the figures 3 and 4.

![Figure 3. Axial force $F_z(e)$](image)
Measured points and theoretical curve

![Figure 4. Radial force $F_r(\Delta r)$](image)
Experimental measurements

Magnet dimensions:
- Inner ring $\phi_i = 17.6$ mm $\phi_e = 22.6$ mm $h = 8.1$ mm
- Outer ring $\phi_i = 27.6$ mm $\phi_e = 32.6$ mm $h = 8.1$ mm
- Middle ring $\phi_i = 22.6$ mm $\phi_e = 27.6$ mm $h = 8.1$ mm

Magnet material: Sm Co$_5$ (J = 0.85T)

For this bearing, the axial force is null when $e = 0.5$ mm (Fig.5). For a smaller gap, the middle ring is attracted by the other part of the bearing. For a larger gap the two parts are in repulsion.

The radial force is almost linear when $\Delta r < 0.5$ mm (Fig.6), and the radial displacement must be smaller than 1.2 mm, otherwise the bearing is unstable. For a gap of 0.5 mm as an example, the radial stiffness is $K_r = 7.10^3$ Nm$^{-1}$ = 7 N/mm. This value is in the same order as the stiffness of conventional bearings (type A and E).

By modifying the magnet dimensions, it is possible to adjust the axial force for a given gap and a given radial stiffness. In addition to its axial force particularity, type C is also very interesting for the coupling between the two bearing parts.
V. COUPLING BETWEEN THE FIXED AND THE ROTATING PART

The magnets are not perfectly homogeneous. Their magnetization varies slightly along the ring perimeter. It can create settling points and circumferential forces in low speed applications (watt-hour meters). When we consider the different configurations of magnetic coupling /1/, we realize that the coupling between the two parts is maximum for types A and E, two widely-used bearings. This coupling is theoretically null for type C. It means that this bearing is not sensitive to the magnet inhomogeneities. But exactly as for other types, the inhomogeneities can produce eddy currents at high rotational speed.

VI. POTENTIAL USES OF TYPE C BEARING

The original properties of type C bearing would be well-adapted to very low rotational speed systems, and to partially-magnetic levitation.

For low speed systems, the very small coupling between the two bearing parts is very attractive. The rotor can rotate very regularly. This bearing can be used in watt-hour meters for example.

In partially-magnetic suspensions, only a few degrees of freedom are magnetically controlled. The stability is achieved by another type of bearing, mechanical for example. In such devices, large radial displacements of the bearing are necessary to cross the critical speeds. The possibility of adjusting the axial force is very interesting, because the magnetic force can balance the rotor weight, and the mechanical thrust is used only for the stabilization. This type of suspension can support heavy rotors: energy storage wheels, centrifugation systems for liquid or gas, etc...

VII. CONCLUSION

Among all the different types of magnetic bearings built only with permanent magnets, the type C configuration, with staggering magnets, owns very interesting properties. Firstly, it operates with a plane gap, and it allows large radial displacements. Secondly, its axial force can be very small or null. It is the only bearing type having simultaneously these two properties. Moreover, in this bearing type the magnetization non-uniformities do not produce any coupling.

To obtain the same stiffnesses as conventional types, it is necessary to use three ring magnets instead of two. This disadvantage is balanced by its particular properties. It is well-adapted for very low rotational speed systems, and for partially-magnetic suspension of heavy rotors.

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