Comparison between optimized topologies of permanent magnet thrust bearings with induced pole

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Magnetic bearings present the advantage to be contactless guiding devices. Most of current magnetic bearings are actively controlled. They reach high stiffness and are stable alone but need complex control system. In opposition, permanent magnet (PM) bearings are simple but in accordance with Earnshaw theorem, levitation with only PM is impossible. As a result, at least one degree of freedom has to be stabilized i.g. mechanical bearing.

Classically, the main characteristic of bearings is stiffness which have guiding function. Combination of PM bearings with mechanical bearings may lead to a solution where a PM thrust bearing (PMTB) is used only to carry the load of the system, but not to ensure the guiding function. This allows a high increase in life time of the mechanical bearings and a decrease of the mechanical losses.

Different kind of PM bearings can be found in the literature. This paper will address topologies including induced poles (ferromagnetic material). The topologies are made of PM rings axially or radially polarized and axially or radially stacked (some example are shown in Fig. 1). To evaluate the axial force, a 2D plane finite element model (FEM) is used with COMSOL Multiphysics. This model profit of the anti-periodicity of the stacked structure and consider an infinity of rings as shown in Fig. 2. The axial force per unit length $f_z = \frac{F_z}{L} = \frac{F_z}{2\pi R}$ is evaluated by the Maxwell stress tensor.

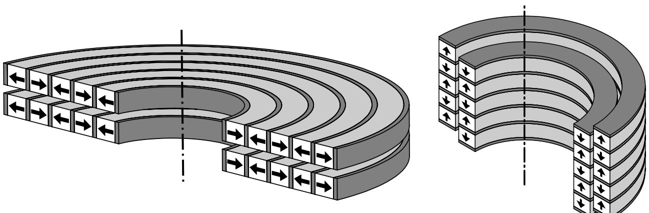

Figure 1: Thrust bearing with radially (a) or axially (b) stacked permanent magnet rings, and with induced pole (in dark grey).

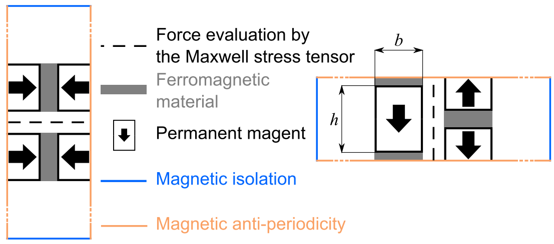

Figure 2: Description of the finite element model for the radial (a) and axial (b) stacked structure.

Each topology is optimized separately for minimizing the ratio of the PM volume on the axial load: $\frac{V_{PM}}{F_z} = \frac{2hbL}{f_z L} = \frac{2hb}{f_z}$. As demonstrated in a previous work [1], this result can be generalized: $\alpha = \frac{V_{PM}}{F_z \times g \times 1/B_r^2}$ where α is independent of the load F_z, the air gap g and the remanent flux density B_r. This coefficient allows to compare easily the topologies. As shown in Table 1, the induced pole (IP) decreases the performance of the radially stacked PMTB. In opposition, the induced pole increases the performance of axially stacked PMTB.

	Radial stack (a)		Axial stack (b)	
	without IP	with IP	without IP	with IP
$\alpha = \frac{V_{PM}}{F_z \times g \times 1/B_r^2}$ $[\times 10^{-5}\ \frac{m^2T^2}{N}]$	3.65	2.78	3.62	3.72

Table 1: Comparison of PMTB without and with iduced pole (IP) for radial (a) and axial (b) stack.

[1] Van Beneden, Maxence ; Kluyskens, Virginie ; Dehez, Bruno. *Optimal sizing and comparison of permanent magnet thrust bearings.* In: *IEEE Transactions on Magnetics*, Vol. 53, no. 2, p. 8300110 (2017)