

# Applying the principle of superposition to the design of the magnetic circuit

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## 1 Description of the TeslaMax model

The TeslaMax model is the model for a novel magnetic circuit under development. Its name derive from the goal of maximizing the magnetic flux delivered to the air gap. The first quadrant of the design can be described by Figure 1.

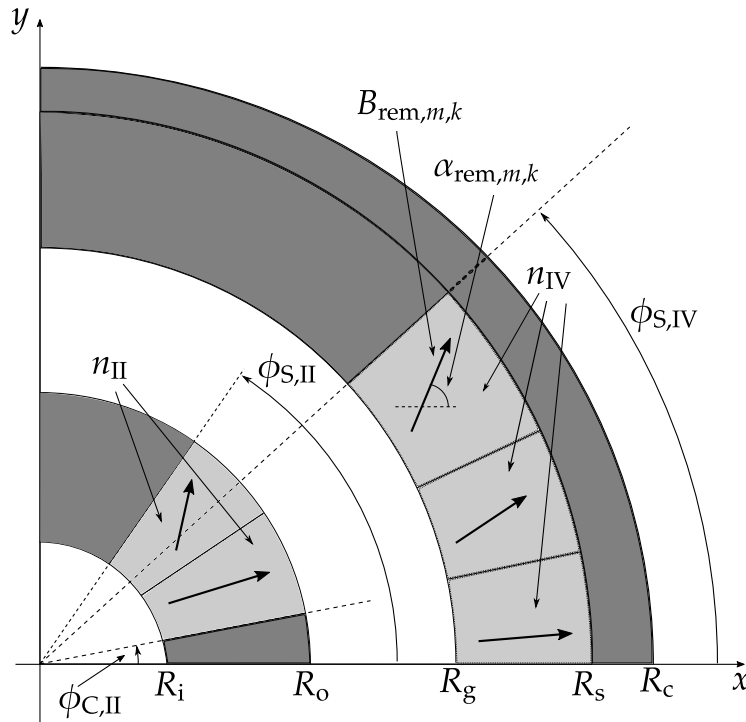


Figure 1 – Geometry for the TeslaMax model. Dark gray areas represent iron, light gray represent permanent magnet, white represent air.

A fundamental feature of TeslaMax is that it is composed of an inner and an outer cylinder, denoted by II and IV, respectively. Each cylinder has magnet blocks of equal size (but they may be different across cylinders); there are  $n_{II}$  blocks in the inner cylinder

and  $n_{IV}$  in the outer one. The segment numbering starts at 1 at the bottom-most unit (lowest value of the  $y$ -coordinate of the block's center).

All magnet segments are characterized by a relative permeability  $\mu_{r,m}$ , uniform for magnet  $m$ ; for instance, all blocks in magnet II have permeability  $\mu_{r,II}$ . Each block is uniformly magnetized in a direction:

$$\mathbf{B}_{\text{rem},m,k} = B_{\text{rem},m,k} \left( \cos(\alpha_{\text{rem},m,k}) \hat{\mathbf{e}}_x + \sin(\alpha_{\text{rem},m,k}) \hat{\mathbf{e}}_y \right) \quad (1)$$

where  $m$  represents the magnet and  $k$  the segment in that magnet.

Iron blocks fill the remainder of the cylinders, and there is an iron ring outside the outer cylinder. The iron regions are characterized by a relative permeability  $\mu_{r,\text{iron}}$  and have the purpose of guiding the flux lines.

The whole TeslaMax system is linear, as will be discussed later.

Only the first quadrant is represented for simplicity; it can be shown that, to maintain a two-pole symmetry, the following conditions must be applied:

1. The orientation of the remanence vectors in the second quadrant is opposed to the first quadrant:

$$(\alpha_{\text{rem},m,k})_{1Q} = -(\alpha_{\text{rem},m,k})_{2Q} \quad (2)$$

2. The top half-circle (first and second quadrant) has mirror symmetry with the bottom one; this *magnetic insulation* condition is equivalent to specifying:

$$\mathbf{B} \cdot \hat{\mathbf{n}} = 0 \quad (y = 0) \quad (3)$$

## 2 Linearity of the TeslaMax model

Each region (the air gap, each magnet segment, each iron block) is governed by the following equations:

$$\nabla \cdot \mathbf{B} = 0 \quad (4)$$

$$\nabla \times \mathbf{H} = 0 \quad (5)$$

and the materials follow the constitutive relation

$$\mathbf{B} = \mu_r \mu_0 \mathbf{H} + \mathbf{B}_{\text{rem}} \quad (6)$$

It can be seen that, assuming the permeability is constant, all equations are linear. This is fundamental because it allows the application of the Principle of Superposition.

## Bibliography