Anisotropic Heat Transfer in Orthocyclically Wound Coils

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Introduction: It is important to understand heat transport through an orthocyclically wound coil (Ref. 1, figure 1) for demanding motor applications in a high-tech setting, but it is difficult to model purely based on the geometry. This poster shows how to apply anisotropic heat transfer as a computa-tionally efficient solution.

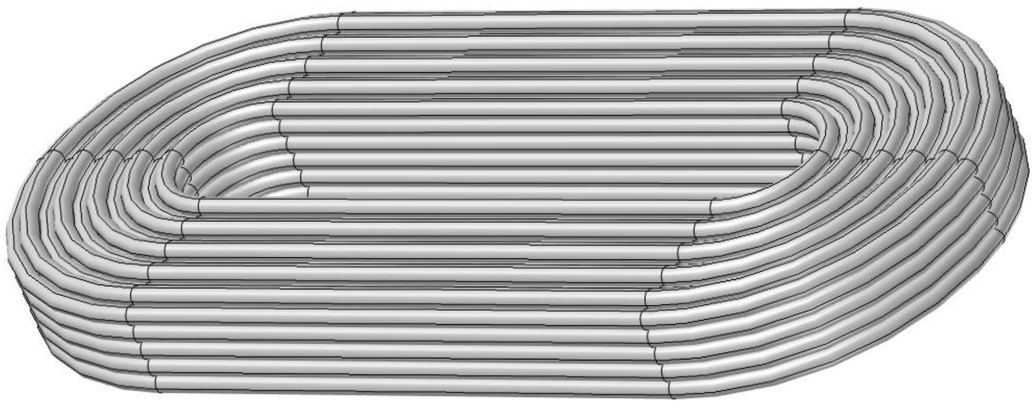

Figure 1. Geometric approximation of an orthocyclic coil

Computational Methods: There are two ways of finding the heat transfer:

- Geometrical: start from a geometry similar to figure 1. However, because the insulating mantle is typically two orders of magnitude smaller than the wire diameter, the resulting number of mesh elements is impractically large.
- Anisotropy: treat the coil as a “meta-material” with anisotropic thermal con-ductivity k.

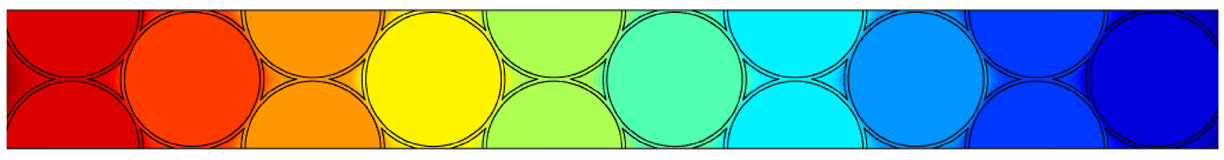

Figure 2. 2D simulation to find the effective conductivity

Using this approach we can effectively model heat transfer through the coil volume. However, a real linear motor has more parts, see figure 3:

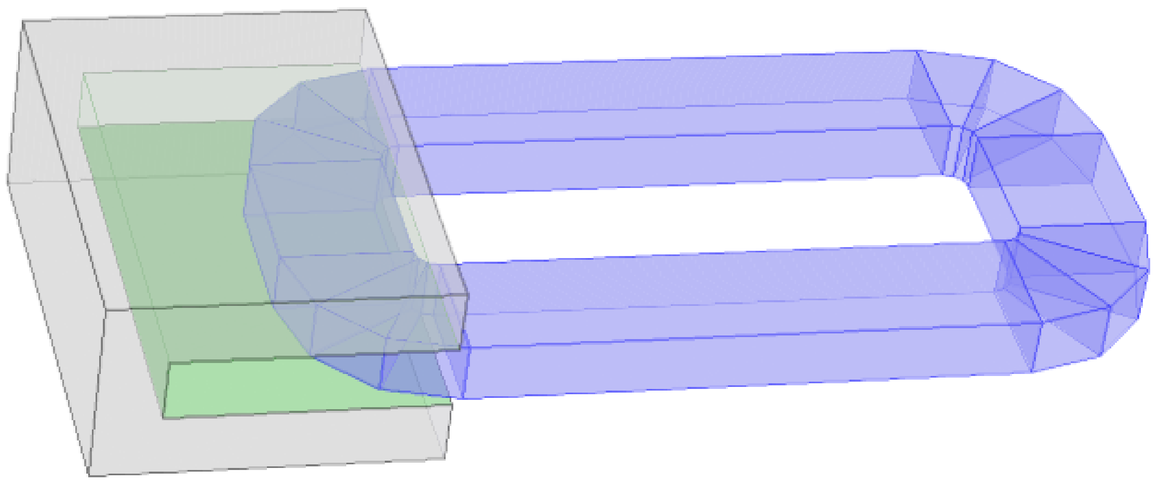

Figure 3. Coil geometry in purple, linear motor housing in grey, thermally conductive resin in green.

Results: Heat transport through coil and motor housing can be visualized. The results can also be checked against heat transfer measurements of both motor and coil.

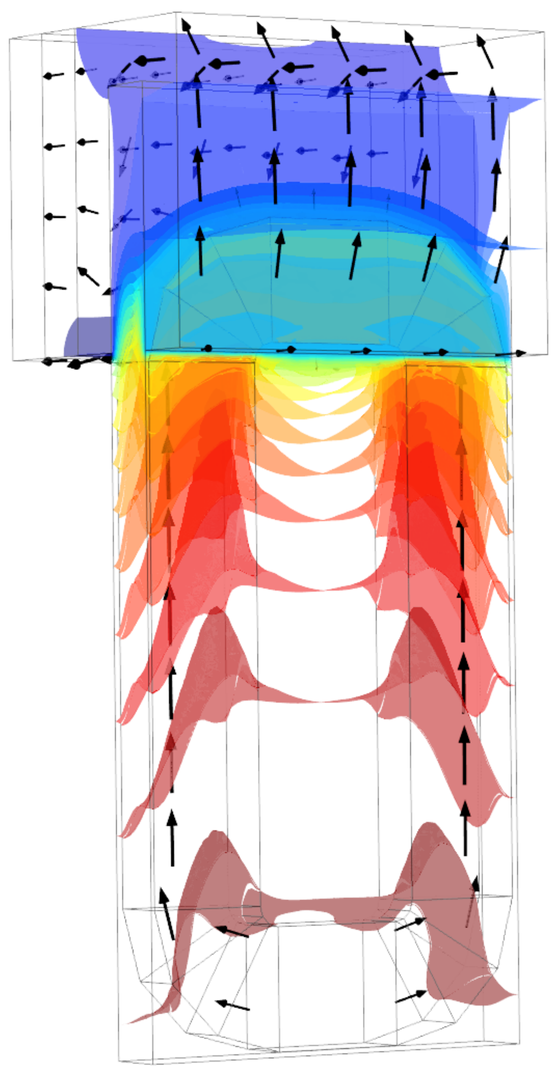

Figure 3. Temp isosurfaces and arrows for heat flow

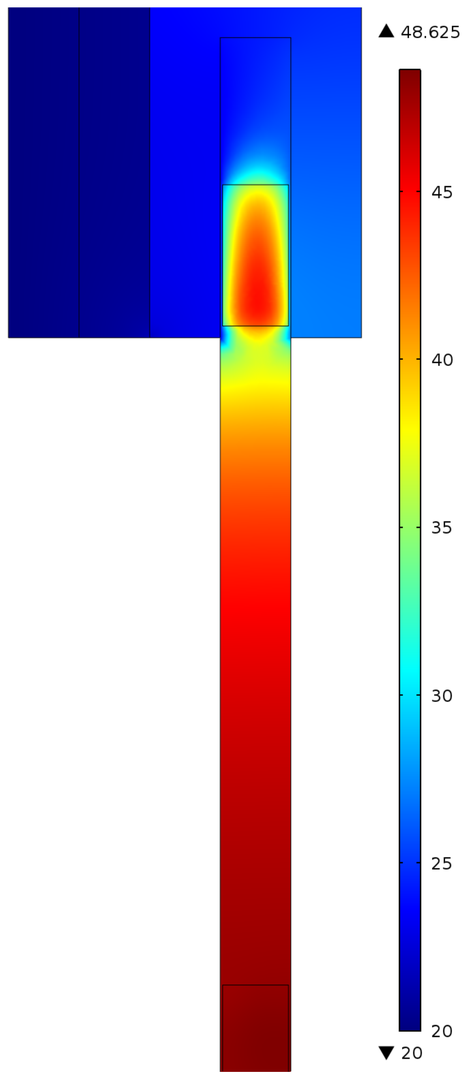

Figure 4. Cross section of temperature distribution

Conclusions: New insight was gained in the relative importance of “in-depth” vs. “in-length” thermal resistances.
In absolute terms, the calculated thermal resistance for motors matches the measurements to within 25%.
To improve on this, we want to perform better measurements of our coils, which will require optimized equipment.

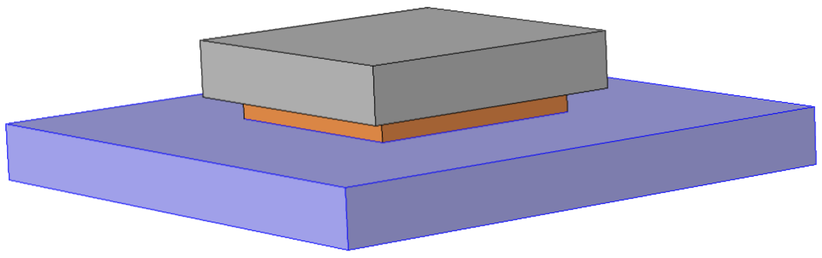

Figure 5. Classical approach to thermal conductance measurement. (Grey is the hot contact, purple cold.) To be replaced with a symmetric setup: cold on both sides, to reduce heat leaks. This requires two identical samples.

References:

1. W. van der Hoek (Philips), Polygonal Electric Coil, US Patent No. US2930014, (1960)

Excerpt from the Proceedings of the 2013 COMSOL Conference in Rotterdam