Influence of Micro Gaps on the Magnetic Characteristics of FI-Relay

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INTRODUCTION:

FI-relays are built in protective residual current devices (RCD). They tripp at appearance of residual currents (i.e. earthleakage current) and consequently break main contacts of RCD. FI-relays must act reliably at very low tripping electrical power (µVA). They are made of softmagnetic parts called anchor and yokes, permanent magnet, coil, spring and some plastic parts.

This research is about partial reconstruction of ETI's existing FI-relay. We would like to achieve higher output mechanical forces (work) on FI-relay's striking pin, but its electrical tripping power P[VA] and impedance Z[Ω] must remain the same. Therefor we redesigned anchor positioning and replaced existing spring with torsion spring. To decrease mechanical deformation on anchor contact surface that limits required lifecycle test, we used additional thin non-ferromagnetic coating with high hardness properties on bottom anchor side. Coating presents new added micro air gaps between anchor and yokes and influences changes of relay's magnetic characteristics. We used AC/DC module to examine magnetic effects of coating with different thickness.

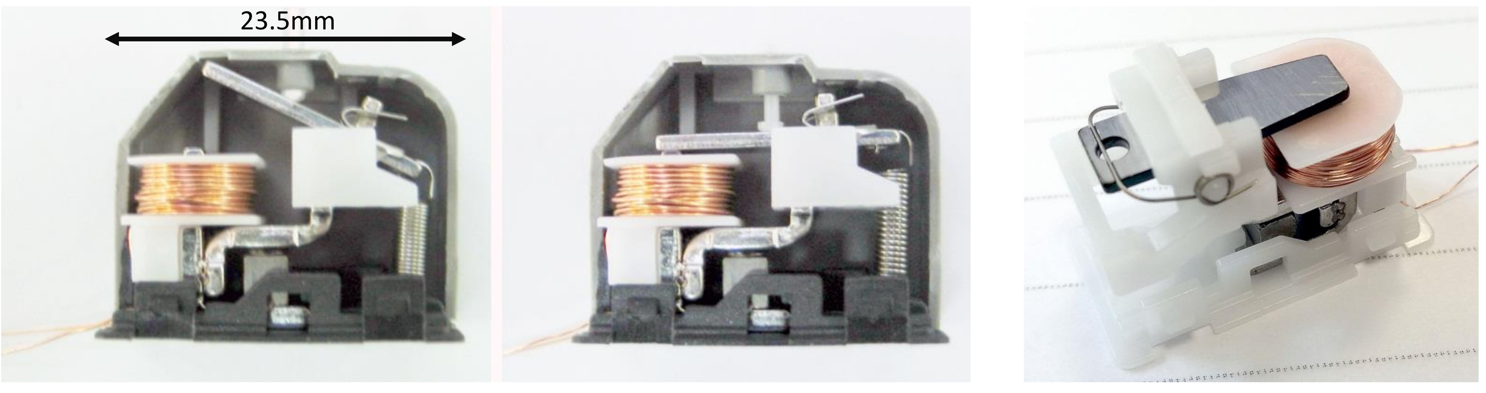

Figure 1. Existing and a prototype of new ETI's FI relay with coated anchor

COMPUTATIONAL METHODS:

- AC/DC module with *Magnetic Fields Stationary Study* was applied for calculations
- *Thin Low Permeability Gap* feature was used to model coating layer on anchor's bottom surface and to model functional gap between S-yoke and L-yoke
- Given BH-curve for softmagnetic parts was used
- Relay impedance for demagnetized relay was calculated at referenced input coil current I_{coil}=4.24mA
- Magnetic flux in magnetized relay was calculated

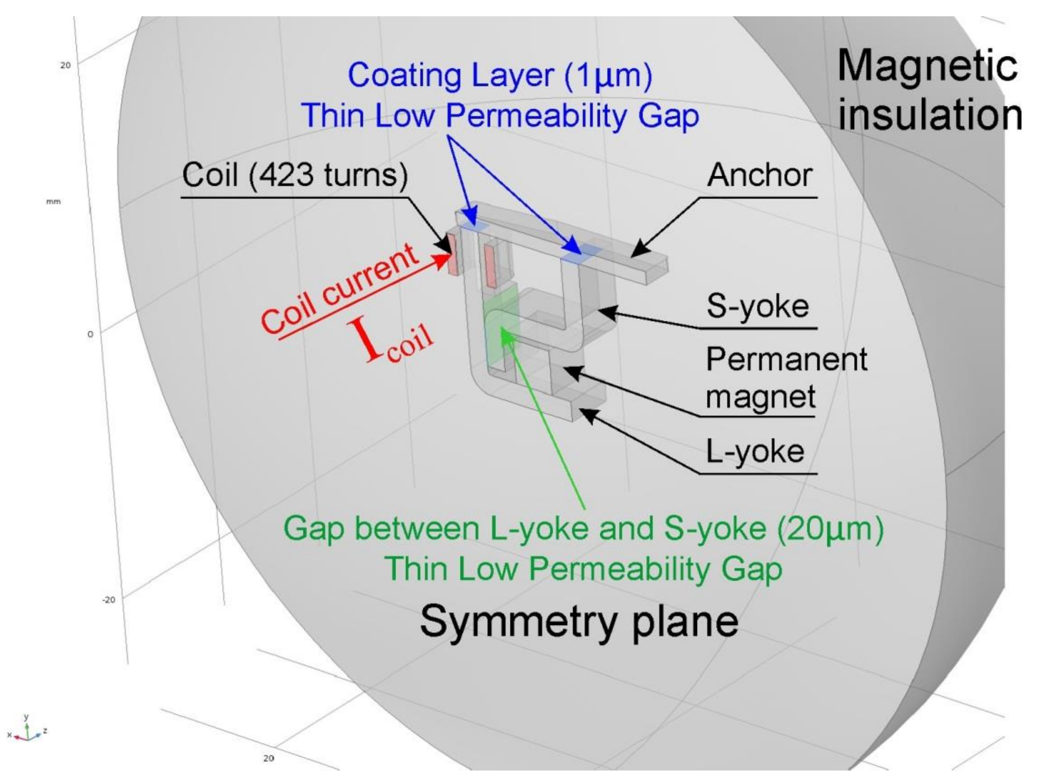

Figure 2. Presentation of FI-relay model for AC/DC Analysis

RESULTS:

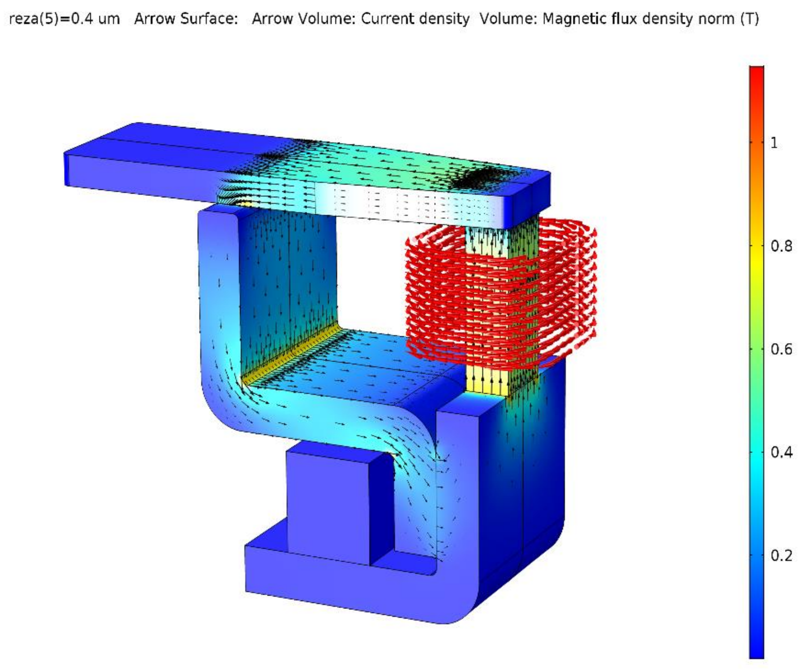

Figure 3. Magnetic flux density at I_{coil}=4.24mA and N=423 turns

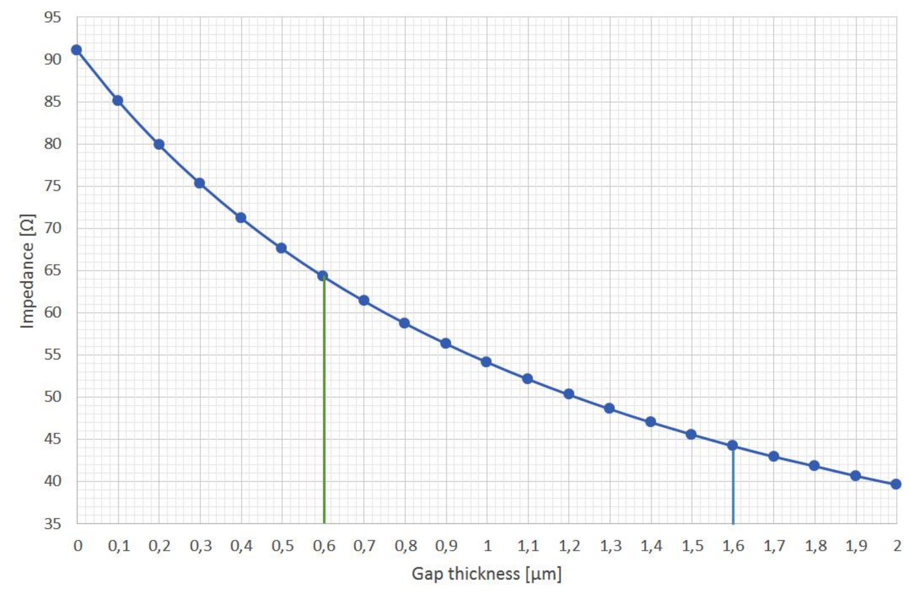

Figure 4. Calculated impedance as a function of gap thickness at I_{coil}=4.24mA and N=423 turns

Existing FI-relay has an effective micro gaps about 0.6um between each polished magnetic pole. Initial impedance is 64.3Ω. When it's added non-ferromagnetic coating with required thicknes 1µm, impedance drops to 44.2Ω (Figure 3.).

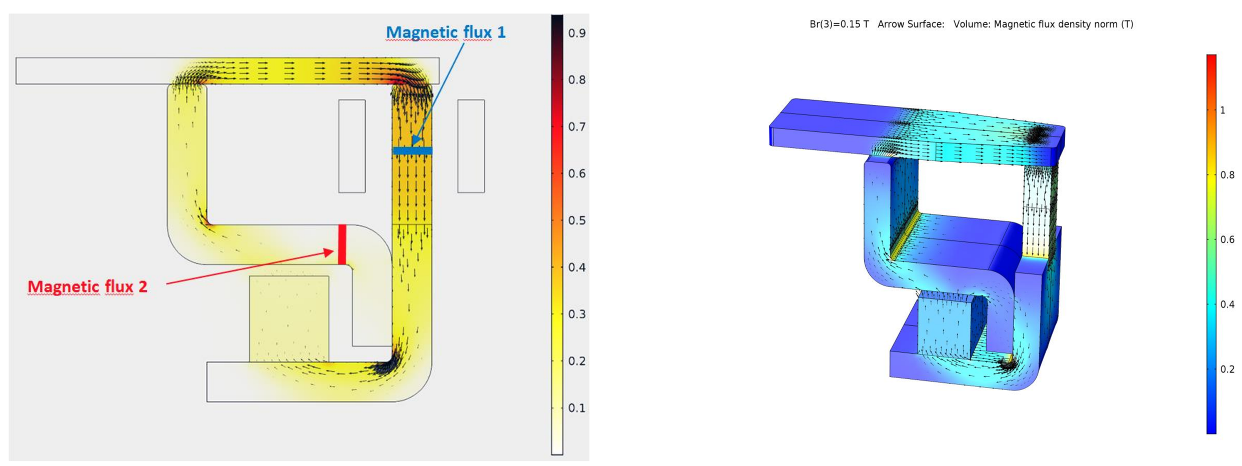

Figure 5. Magnetic flux density in relay generated by permanent magnent for B_r=0.15T

Magnetic flux generated by permanent magnet is divided in magnetic flux 1, which holds anchor in position over poles, and magnetic flux 2. Their values depend on how high is magnet's remanent flux density and also on level of saturation in magnetic flux conducting softmagnetic parts.

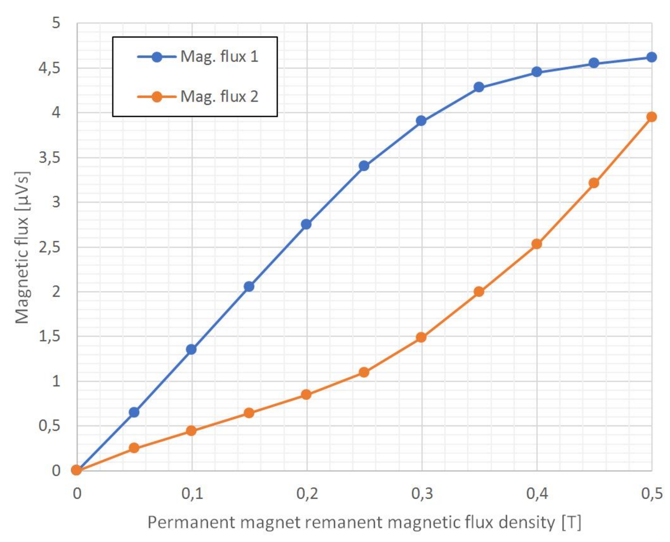

Figure 6. Existing relay - calculated values of magnetic flux 1 and 2 [µWb] as a function of magnet's remanent magnetic flux density B_r[T]

CONCLUSIONS:

Magnetic flux over anchor drops significantly, if anchor is coated with 1µm of non-ferromagnetic layer. We can use higher magnetization of magnet to compensate that drop, but FI-relay's impedance is lower than required.

The solution is to change the coil and increase number of its turns. COMSOL® results were found useful and positively validated on prototypes.

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