# The effect of aluminum coil-forms on Helmholtz coils field

## Motivation

Our standard use of "U" profiles in aluminum alloy as coil-forms for our *Ferronato** Helmholtz systems have raised questions that these forms may affect the magnetic field. We try to demonstrate here that such concerns are unfounded.

## Magnetic susceptibility of the related materials

Volume susceptibility. Values in SI (unitless).

- Oxygen Free copper (C10100): **≈ -1 x $10^{-5}$** (diamagnetic). Used in special applications.
- ETP copper (C11000): **≈ +3 x 10-5** (paramagnetic). This is the used for electrical conductors, including the winding wire of our coil-sets.
- Aluminum (pure): **≈ +2 x $10^{-5}$** (paramagnetic).
- Aluminum alloy 6061, normally used in our forms: **≈ +2 x $10^{-5}$** (paramagnetic).
- Iron (pure): **≈ +2 x $10^{5}$** (ferromagnetic).
- Air: **+3.6 x $10^{-7}$**.

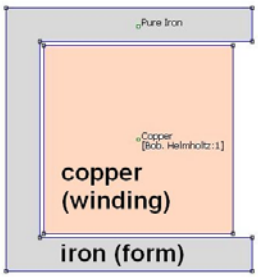


Fig. 1: Copper + form.

## Simulations by FEMM 4

The purpose is to compare the results with two materials that are very dissimilar magnetically, copper and iron, with a huge ratio of $10^{10}$ (!!) in between their susceptibilities, in order to extract conclusions for the copper/aluminum case of our interest.
The section of winding and form is depicted in Fig. 1. Copper section is 10x10 mm, while iron profile is 14x13x1.8 mm, geometry very similar to the used in the *Ferronato** BH300 and BH600 coils. The copper is insulated from the form.
The field from copper turns, without forms, is shown In Fig. 2, while in Fig. 3 is the field with the iron forms.
Each image shows half the central plane of the Helmholtz pair. Magnetic axis (z) is vertical. The White area at the center shows the volume with field homogeneity within ±0.5 and ±1 % respectively.
The one-turn coils have a mean diameter of 300 mm. Current is of 1 ADC in both cases.

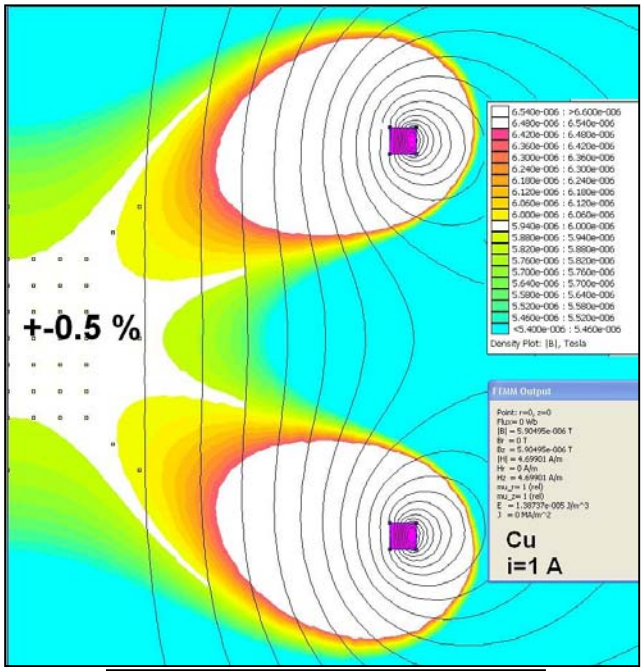


Fig. 2: Copper coils without forms.

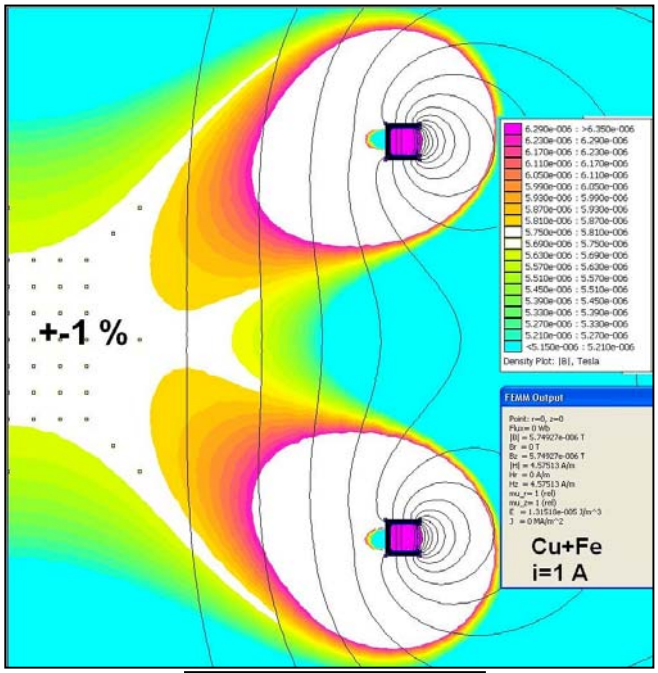


Fig. 3: With iron forms.

## Conclusions

a) The iron forms have little effect on the field intensity at the center: 5.91 x $10^{-6}$ T in Fig. 1 versus 5.75 x $10^{-6}$ T in Fig. 2. The field is a bit lower with the iron forms.

b) The iron forms worsen the field homogeneity by approximately 50% at the center. The volume within ±0.5% with only copper would be within around ±0.75% with iron forms.

c) This demonstrates that the aluminum forms as used in our coils, with susceptibility very similar to copper, have no perceptible effect on the generated field, even for the most demanding experiments.

## Note about AC operation

Due to a gap in its perimeter, our coil-forms are free of eddy currents, posing no problems with AC fields.

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