Optimizing Magnetic Shielding

Continuous exposure to high electro-magnetic fields (EMF) generated by sources such as busbar connections to transformers, cabinets, high voltage overhead lines, etc. can impede normal function of electronic equipment. For example, high EMF can cause broken strips, communication problems and even hardware degradation. The current densities in the copper coils of the electromagnet are as follows:

- **Coil a**: \(1.37727 \times 10^6\) Amp/m² (anti-clockwise);
- **Coil b**: \(7.15188 \times 10^6\) Amp/m² (anti-clockwise);
- **Coil c**: \(3.78390 \times 10^5\) Amp/m² (anti-clockwise); and
- **Coil d**: \(1.315905 \times 10^6\) Amp/m² (clockwise).

The simulation software used to analyze this particular electromagnet offers the option of switching to either FEM or BEM solvers, but the latter was adopted here. The space around the device was not meshed since, as discussed, the BEM approach requires only the design surface to be modeled. This relative simplicity is especially useful for this type of application.

**Magnetic Field Analysis of Electromagnets by BEM**

Figs. 2 and 3 present magnetic field results after solving the model with the BEM solver. A magnetic field of 1.5 Tesla is observed within a volume of 1 cm³ around the origin inside the electromagnet (as shown in Fig. 2).

Fig. 3 provides the plot of variation of \(z\) component of magnetic field along the \(z\)-axis. It can be observed that value of \(B\) is 1.5 Tesla up to 34 cm; thereafter the value decreases to 30 Gauss at 240 cm and remains constant for 300 cm.

The contour plot of magnetic field magnitude on a circular surface constructed around origin with radius 300 cm is presented in Fig. 4. It shows a magnetic field of circa 8.721 Tesla (red) is present around the corners of the first and last coils.
Magnetic Field Analysis of Shielded Electromagnet

A 1 cm thick, 3 x 3 x 6 m$^3$ 1010 steel shield was constructed around the electromagnet. Symmetry conditions were applied to reduce the size of the model to 1/8 of normal size. The symmetry features of the solver allow reducing model size while still providing results that apply for the full model. This reduces number of meshed elements and memory requirements. Here, 9000 elements were required to mesh 1/8 of model versus 72,000 for the full model. Moreover, only 7 GB of memory was required in contrast to 400 GB for a full model.

Fig. 5 shows the results after solving the model with the BEM solver. A reduction is observed in value of the $B_z$ component to 1.498 T compared to 1.5 T for the unshielded magnet (see Fig. 3).

Fig. 6 shows the contour plot of the full model. It is evident that magnetic field has a considerably high value (red contour) near the walls of the shield. Fig. 7 graphs values of magnitude of magnetic field along the segment of circle of radius 350 cm. These values can be reduced by increasing wall thickness but this will make the shielding structure heavy. An alternative is placing the electromagnet in a double-layered shield with air gaps between the shields.

Fig. 8 shows a two-layered shield with a 1 cm separation around the electromagnet. Again, symmetry features were applied to reduce the model to 1/8 of its original size. The graph shows magnitude of magnetic field along the segment of circle with radius 350 cm. There is reduction in field values compared to those in Fig. 7, meaning the double wall shield has reduced the values of magnetic field in comparison to a single-walled shield.

Conclusions

BEM allows for easy visualization of the element distribution in magnetic shielding, especially for 3-D designs where FEM meshes are too complex. The BEM approach therefore provides designers with a valuable alternative approach to design magnetic shields. These types of CAE tools not only enhance engineering productivity but also increase competitive advantage.