Foil Coil

2D Application Note Summary

Introduction

This chapter discusses the creation of a coil conductor region with losses and detailed geometrical description to represent a foil coil.

The following topics are covered in this documentation:

- Device description
- How to create a coil conductor region describing a foil coil in a Flux project
- Limitations
- Example of application

Keywords

Applications	Flux main functions	Post-processed quantities
• Steady State AC Magnetic	• Create project • Create Foil Coil region • 2D Curves	• Magnetic flux density • Current density

Device description

A foil coil is a winding obtained from a thin, rectangular, metallic sheet folded in a spiral-like shape, as shown in Figure 1. The sheet is covered by an insulating coating (varnish). This kind of coil design is common in electromagnetic devices such as power transformers and actuators.

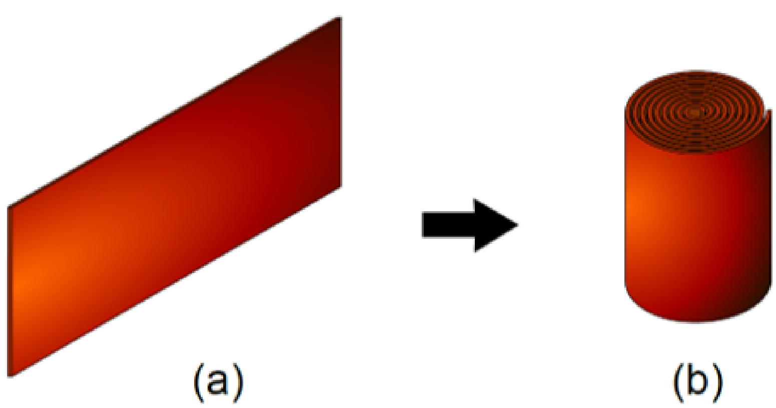


Figure 1: A thin metallic sheet (a) folded in the shape of a foil coil (b)

The current density distribution in a foil-wound coil fed by a time-varying source depends on skin and proximity effects. Since the foil is usually very thin and made from a material with a high electrical conductivity, the skin effect along its thickness is negligible (i.e., the current density in each turn results practically uniform along a radial direction). On the other hand, the current density in each foil turn may greatly vary along the axial direction of the coil as a function of both position and frequency.

This anisotropic behavior is specific to foil coils and influences the Joule losses developed in the bulk of the coil material. Thus, Flux implements a special homogenization technique to efficiently represent it in its 2D Steady State AC Magnetic application. This technique is exclusive to foil coils and differs from the approach used in the other subtypes of coil conductor regions with losses and detailed geometric description representing stranded coils.

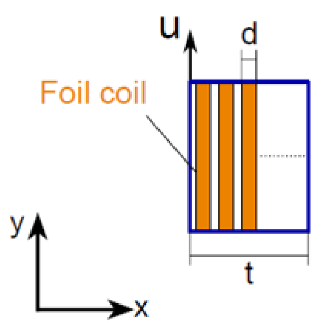
How to create it in a Flux project

The foil-wound coil is a subtype of coil conductor region with losses and detailed geometrical description that is only available in Flux 2D. The availability of these regions in Flux FEM applications is discussed in the following documentation topic: Coil models and their availability in Flux projects.

This region may be created as follows:

- While creating a new region, select **Coil conductor region** in the drop-down menu **Type of region**.
- In the **Basic Definition** tab, proceed in the same manner as in the case of a coil conductor region without losses.
- In the **Coil Loss Models** tab, proceed now in the same manner as in the case of a coil conductor region with losses and simplified description, but select **Detailed description (considers proximity and skin effects)** in the drop-down menu instead of **Simplified description (neglects proximity and skin effects)**. This action will display the **Strand or unit cell definition** drop-down menu.
- In the **Strand or unit cell definition** drop-down menu, select the type: **Foil-wound coil**. The template is displayed in Table 1.
- Provide the geometrical parameters required for characterizing the foil coil, in accordance with Table 1.

Table 1: Template for coil conductor region with losses and detailed geometrical description modeling a foil coil winding

Type	2D Foil Coil representation	Parameters
Foil-wound coil		d: sheet thickness

Limitations

For a given frequency f, the homogenization approach assumes that the foil thickness d is always smaller than the skin depth δ. In practice, this hypothesis restrains the validity of the model with an upper frequency limit. Thus, the model yields good results in a frequency range not exceeding a maximum frequency f_{max} given by

$$f_{max} = \frac{\rho}{\pi\mu}\left(\frac{N}{\lambda t}\right)^2$$

In the previous expression:

- ρ is the electrical resistivity of the foil material
- μ is the magnetic permeability of the foil material
- N is the number of turns of the coil
- λ is the coil fill factor
- t is the thickness of the winding

As for any other Coil Conductor region with losses and simplified geometrical description, the user may postprocess quantities related to the material resistivity in the surface (2D) representing the coil (e.g., the power loss density in the winding or the total dissipated power).

Example 1: Current density through foil coil

In this case, the different magnetic quantities represented are:

- Plot magnetic flux density isovalues on the domain
- Plot 2D curves of the current density on different paths along the width of the foil coil equivalent region

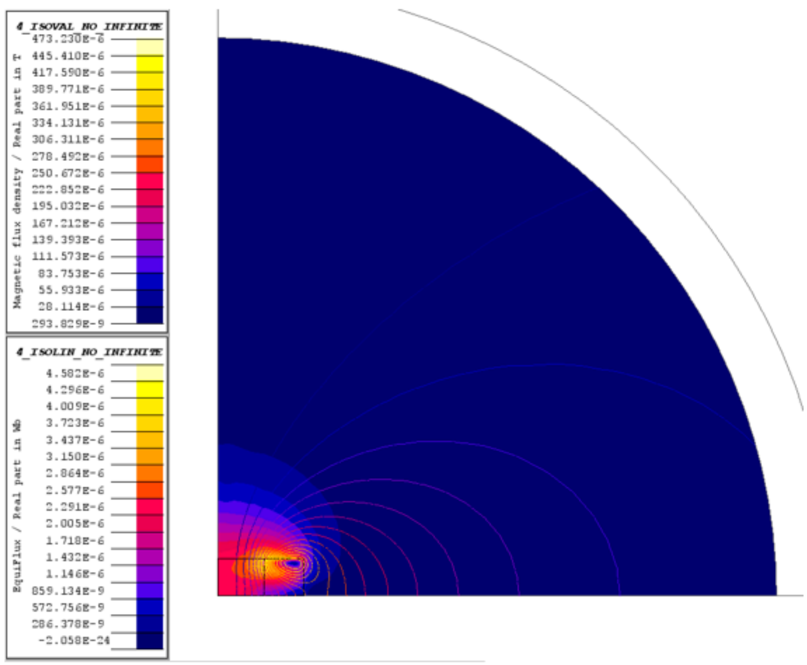


Figure 2: Magnetic flux density isovalues and isolines in domain

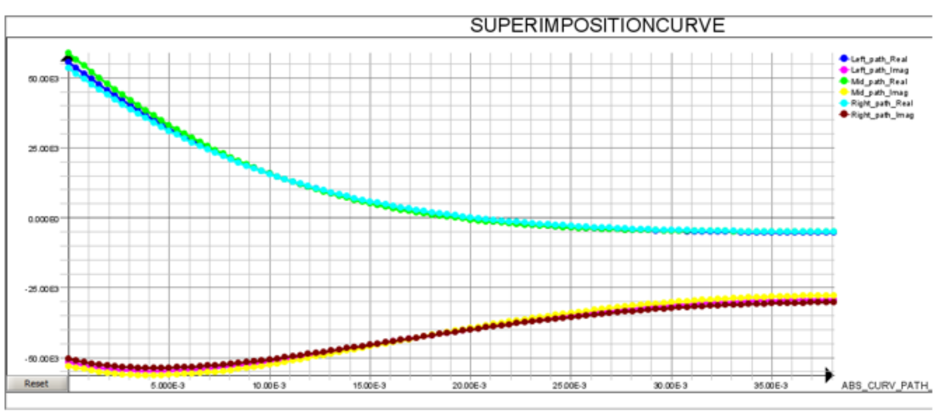


Figure 3: Current density plotted on different paths along the foil coil region width