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Model of cup gland

Instructions for the laboratory exercise

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Jarosław Guziński, Marcin Morawiec

1. Aim of the exercise

The purpose of the exercise is to prepare the model and perform calculations and their analysis for cup gland.

2. Assumptions

The analysis concerns the distribution of the magnetic field generated in the cup choke shown in Fig. 1.

axis of symmetry
(coordinate r = 0)

Fig. 1. Cup gland

The analyzed fragment of the axially symmetrical choke is shown in Fig. 2.

1

2

air

3

winding

core

Fig. 2. The analyzed fragment of the axially symmetrical choke

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The dimensions of the gland elements correspond to the dimensions of rectangles 1, 2 and 3 marked in fig. 2. All dimensions and coordinates are given in mm.

The rectangle 1 defining the coil cross-sectional area has the coordinates: (6, 24), (24, 24), (6, -24), (24, -24).

The rectangle 2 defining the dimensions of the gland window has the coordinates: (5,25), (25, 25), (5, -25), (25, -25).

The rectangle 3 designating the external dimensions of the gland has the following coordinates: (0, 30), (30, 30), (0, -30), (30, -30).

The winding is made of copper wire with a diameter of 1 mm. Choke core is made of iron. The choke is placed in the air. Set up any number coils. Check that the assumed number of turns will fit in the cross-sectional window of the gland. Taken for the window to fill copper-k $_{Cu}$ = 0.3.

The model introduced in the FEMM program should look like shown on fig 3.

Fig. 3. The analyzed model divided into areas in which it was defined individual materials.

3. Exercise program

1. Create a new magnetic problem file.
2. Define the analysis area as in exercise 1 - (define border points, plot an arc and define the axis of symmetry).
3. Draw the gland.

4. Add materials and assign them to areas as appropriate.
5. Accept the boundary conditions as in exercise 1.
6. Generate a finite element mesh - to speed up the calculations, eg for the air surrounding the gland set the minimum length of the mesh elements to 0.6 mm.
7. Define all areas, start the grid generator and attach calculations.
8. If the calculations take too long, it should be stopped and the project modified - for example reduce the number of nodes or redefine areas.
9. Check the magnetic field distribution, determine the coil parameters.
10. Plot the basic characteristics and analyze the results obtained.
11. If the results obtained are not correct, eg the stream density is too high and the choke is saturated then the number of turns or winding current should be reduced. characteristics magnetizing the core material can be checked in the properties edition window iron.
12. Check how the current and the number of windings affect the saturation of the magnetic circuit choke.
13. Repeat the introduction of the choke analysis area and geometry using any CAD program generating the output file in DXF format, eg A9CAD, QCAD. Import the prepared DXF file into FEMM.
14. Model the actual cup gland in the laboratory and determine number of turns. The gland view is shown in fig. 4 while the drawing with dimensions in fig. 5. The coil winding is wound with copper wire 2 mm in diameter. In the laboratory

the actual winding inductance $L = 9.4$ mH was measured.
Take current density $J = 2.5$ A / mm^2. The actual choke core is made of Iron powders, however, should be taken as pure material for simplification of modeling iron (*pure iron*). When entering the model, skip the holes for the wires.
Read the winding resistance for the selected number of turns.

Fig. 4. Views of the cup gland.

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Fig. 5. Dimensions of the cup gland.

15. Calculate the number of threads of the gland based on the sample catalog data core manufacturer.
The inductance can be calculated using the core manufacturer's catalog data choke L with known number of turns N or specify how many turns N should be wound to obtain the required inductance L.
Knowledge of the A_L parameter is required for these calculations . on the card sheet. It should be noted that normally in catalogs A value of $_L$ is given in nanohenrach [nH].
The relationship between A_L , L and N determines the relationship:

$$And_{L} \quad \frac{L}{N^{2}} \tag{1}$$

Reactor core of the point 14 is made of iron powder (*Powder iron*) by HaKRon company. The core material is produced in four marked varieties PA2, PA6, PB5 and PC3. A_L coefficients for these materials are presented in Tab. 1.

Tab. 1. AL factors for HaKRon cup cores with a diameter of 100 mm [4]

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For the gland shown in Fig. 4, the type of material is unknown, ie whether it is PA2, PA6, PB5 or PC3. Therefore, the number of turns should be calculated for four material variants.

NOTE: Choke coil differences calculated on the basis of the A_L factor and obtained from the simulation in FEMM they will be different - in the simulation iron material was chosen. Simulation compliance with the calculations require the introduction to the FEMM program of the magnetizing characteristics given by material producer. This is the subject of a separate exercise

16. The reactor modeled at p. 14 made of pure iron (called. *Pure iron*) enter, one of the number of turns calculated in p. 15. In the middle of the choke column Insert a 1 mm air gap. Check how it changes inductor inductance. Then select the gap thickness so that the gland has inductance 9.4 mH.
Check the distribution of induction in the gap (Fig. 6a) and in the choke core (Fig. 6b).

and) b)

Fig. 6. Location of the coordinate axis for analysis of the induction distribution:
a) in the gap, b) in the choke core

Divide the determined air gap into 3 equal parts and distribute evenly
in the choke column. If the inductance of the choke is other than 9.4 mH, correct it
gap thickness.
Again, check the distribution of induction in the gap and in the choke core.

4. Processing of results

1. Modeled choke:
   present the gland drawn, mark the dimensions,
   show timetable B | in color or shades of gray,
   draw a schedule | B | in the cross-sectional area of the gland from the inside to the outer edge,
   give the number of turns,
   give current value
   give inductance and coil resistance,

   specify the value of the maximum induction in the core and mark where in the drawing
   Occurs.

2. Laboratory choke:
   present the gland drawn, mark the dimensions,
   show timetable B | in color or shades of gray,
   draw a schedule | B | in the cross-sectional area of the gland from the inside to the outer edge,

give the number of turns,
give current value
specify coil resistance,
specify the value of the maximum induction in the core and mark where in the drawing Occurs.

3. Calculate the number of turns according to item 15.
4. For iron throttle with air gap, draw the characteristics L = f(d),
   $B_{max\ RDZ} = f(d)$, $B_{max\ SZCZ} = f(d)$, where:
   d - air gap thickness,
   $B_{max\ RDZ}$ - maximum induction in the choke core,
   B_{max} - maximum induction in an air gap.

5. Literature

1. David Meeker: *FiniteElement Method Magnetics. User's Manual* .
2. David Meeker: *FEMM 4.0 Magnetostatic Tutorial* .
3. Konopiński T., Pac R.: *Transformers and chokes for electronic power devices* . WNT, Warsaw 1979.
4. HaKRon website: http://www.hkrweb.de/index.php?page=home.php&lang=EN