CAE of Sensors and Actuators
Assignment 3

Tutorial: December 1st and December 2nd, 2014
Assignment due: December 8th, 2014, 6 pm

Magnetic Field Problem

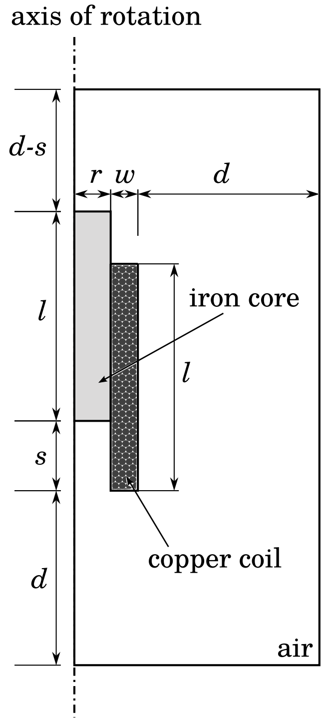

Figure 1: Inductive sensor

The **axis-symmetric** setup as displayed in Fig. 1 shows an inductive positioning sensor, which consists of a copper coil and a movable iron core. The sensor operates in air. The working principle of such kind of sensors is to measure the inductance $L(s)$ of the coil which depends on the offset s between coil and iron core. If the relation $s \Rightarrow L(s)$ is known, the quantity of interest s can be calculated from the measureable value of $L(s)$.
The sensor is specified by the following parameter

- l = height coil = height core = 60 mm,
- r = radius core = 10 mm,
- w = thickness of coil = 2 mm,
- N = number of coil turns = 50,

and should have the capability to measure s in the range from **5 mm** to **55 mm**.
Your task is to find out the relation $s \Rightarrow L(s)$ by terms of numerical simulations.

Task 1: Verify problem setup (3.5 points)

Simulation Tasks

1. Setup the geometry as shown in Fig. 1. For the yet undetermined distance d between sensor and outer boundary choose **6** different values between 50 mm and 150 mm. As meshsize choose 1 mm.
2. For each of the **6** meshes perform a **static** simulation to calculate the inductance of the **air-filled** coil for a current of 1 mA.
   Hint: Create your model with iron core for $s = 0$ and set the material of the core to air.
3. Create two Gid screenshot of the **magnetic vector potential** for $d = 50$ mm and for $d = 150$ mm. Thereby display the vector potential with **contour lines**.

Calculations

1. Calculate the inductance of the **air-filled** coil with help of the analytic formula
$$L = \frac{\mu_0 N^2 A}{l} \quad , \tag{1}$$
   where N is the number of turns, A the cross-section of the air-filled cylindric coil, l the length of the coil and μ_0 the permeablity of air/vacuum.

Plots

1. Create a linear plot showing the inductance L in dependency of the distance d between coil and outer boundary.
   Hint: Do not forget to add a legend to the graphs!

Questions

1. What material do you have to set for the coil to avoid eddy currents in its interior?
2. Which boundary conditions do you have to set in Nacs at the axis of rotation and along the outer boundary? What is/are the corresponding boundary condition(s) for the magnetic potential?
   Hint: Write your answer in the form:
   `xyz-condition in NACS <=> rst-condition for the magnetic potential`
3. How does the inductance of the setup change if you increase the distance d to the boundary? Does the value converge?
4. Compare the simulated inductance with the analytically calculated one and explain the differences. Is the model appropriate for further investigations?
5. Compare the screenshots of the **magnetic vector potential** for $d = 50$ mm and $d = 150$ mm. What do you observe, especially at the boundary?

Files to submit / Grading

- Ansys mesh script, created meshfiles and Nacs simulation script(s) (`.py`) used for the static analysis (0.5 points)
- Plot file showing the dependency of the inductance L on the distance d between coil and outer boundary **and** Gid screenshots of the **magnetic vector potential** (1 point)
- `Results.txt` file containing the analytically calculated and the simulated values of the inductance L (including the intermediate steps of the analytic computation) (0.5 points)
- `Results.txt` file answering the questions (1.5 points)

Task 2: Determination of the $s \Rightarrow L(s)$ relation (2.5 points)

Simulation Tasks

1. Set the material of the iron core to iron now. Create **11** meshes for s in the range from **5 mm** to **55 mm**. For d choose 150 mm.
2. For each of the **11** meshes perform a static simulation to calculate the inductance of the setup for a current of 1 mA.
3. Create a Gid screenshot of the **magnetic flux density** for $s = 5$ mm and $s = 30$ mm. Use **contour fill** to display the flux.

Plots

1. Create a linear plot showing the inductance L in dependency of the offset s between coil and core.
   Hint: Do not forget to add a legend to the graphs!

Questions

1. Compare the Gid screenshots with the iron core at $s = 5$ mm and $s = 30$ mm. How does the **magnetic flux density** change?
2. Describe the plot showing L in dependency of s and try to formulate the relation $s \Rightarrow L(s)$. You do **not** have to derive formulas! Just describe some basic properties like slope, type of relation (linear, quadratic, ...) etc.

Files to submit / Grading

- Ansys mesh script, created meshfiles and Nacs simulation script(s) (`.py`) used for the static analysis (0.5 points)
- Plot file showing the dependency of the inductance L on the offset s between coil and core **and** Gid screenshot of the **magnetic flux density** (1 point)
- `Results.txt` file answering the questions (1 point)

General hints and remarks

- As reference for the `Results.txt` file take a look at the sample file `Results_sample.txt`
- Submit all your files until the due date by copying your results (`Results.txt`, scripts, screenshots, ...) to
  `/home/userHome/stud/CAESAR/group<Group#>/assignment<Assign#>/`
- Points are only given if submitted data contain correct results, answers are comprehensible and plots are labeled correctly!