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**Deadline 1 (present first results):** February 2nd, 2021  
**Deadline 2 (submission):** February 9th, 2021  
**Presentation:** February 11th, 2021 during lecture class.

## Project 4: Magnetics – Rotation Rate Sensor

To determine the performance of an engine, for example in automobiles, it is important to measure the number of revolutions per specific time interval. This value is utilized to operate at an optimal working point and in order to avoid engine overload. Thereby, the rotation speed measurement needs not only be able to capture high rotation frequencies but should furthermore be contactless to avoid overheating due to friction. One class of sensors fulfilling these requirements are magnetic rotation speed sensors.

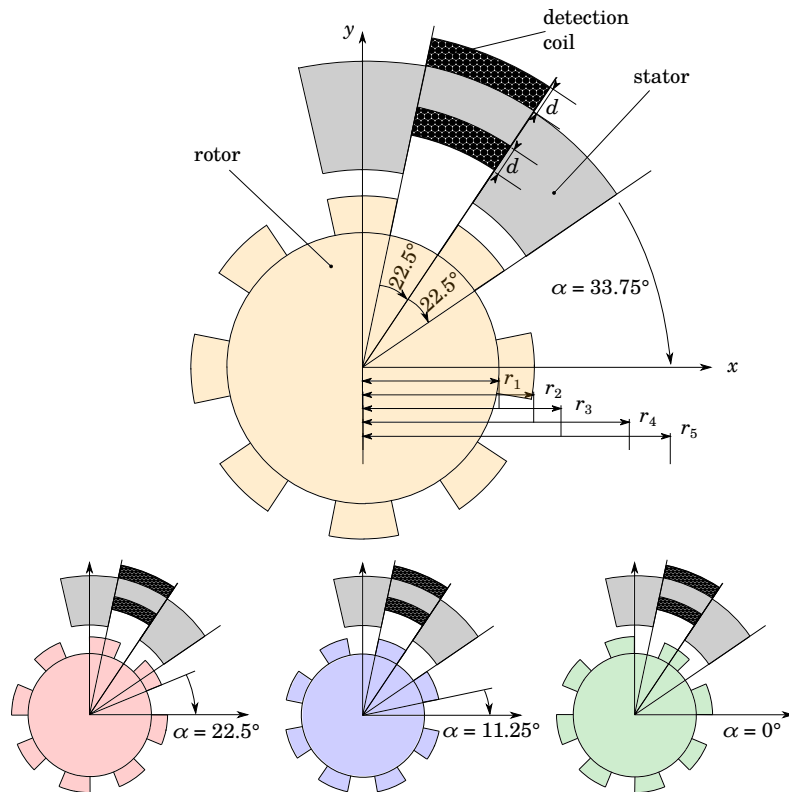


Figure 1: Plane setup of the rotation speed sensor consisting of rotor, stator and measurement coil.

Figure 1 shows the plane setup of a magnetic rotation speed sensor. It consists of a gear-wheel rotor with radii  $r_1$  and  $r_2$  and of a stator ring with radii  $r_3$ ,  $r_4$  and  $r_5$ . Rotor and stator have two and eight teeth, respectively. Their overlap depends on the angle  $\alpha$ . For  $\alpha = k \cdot 45^\circ + 33.75^\circ$ , with  $k$  being a natural number, rotor and stator teeth fully overlap and for  $\alpha = k \cdot 45^\circ + 11.25^\circ$ , the overlapping area is zero. The current overlap and therewith the angle  $\alpha$  can be determined by measuring the magnetic inductance of the measurement coil of thickness  $d$  that is attached to the stator. Note that due to the different teeth positions, the setup is **not** symmetric to the  $x$ - and  $y$ -axis, so that one has to model the whole geometry.

The main objective of this project is to derive the relation between the static coil inductance  $L$  (no dynamic effects) and the rotation angle  $\alpha$ . In this context, it shall furthermore be examined, how slight modifications of the rotor and stator geometry influence the results.

# 1 Modeling

1.1. For your investigations consider the following parameters:

- material of coil: copper
- material of stator: iron
- material of rotor: iron
- surrounding medium: air
- number of coil windings: 100
- dimensions:
  - $r_1 = 16$  mm
  - $r_2 =$  between 20 and 22 mm
  - $r_3 = 23$  mm
  - $r_4 = 27$  mm
  - $r_5 =$  between 37 and 40 mm
  - $d = 2$  mm
  - $\alpha \in [0^\circ, 45^\circ] \subset \mathbb{R}$

1.2. Model the geometry such that the dimensions/positions can easily be adapted. The whole assembly operates in air, so remember to add an additional surrounding domain.

# 2 Analysis

- 2.1. Pick out any combination of  $r_2$  and  $r_5$  and perform a static, magnetic simulation with a parametric sweep on  $\alpha$  using an increment of  $\Delta\alpha = 2.5^\circ$ . Drive these simulations by loading the detection coil with a current of 1 mA and determine the inductance  $L$  of the setup. From your results, derive a relation between  $L$  and  $\alpha$ .
- 2.2. Repeat the previous task for different combinations of  $r_2$  and  $r_5$ . Try to find the optimal combination, i.e., the one where  $L$  gets either maximized and/or shows the biggest difference between maximal and minimal overlap. Also take a look on the magnetic flux density between stator and rotor and its dependency on  $r_2$  and  $r_5$ . Create an animation of the field of the rotating machinery.

# 3 Presentation

Prepare for a **ten minutes** presentation followed by a **five minutes** discussion. Your presentation should consist of the following blocks:

- 3.1. Introduce yourselves (names, fields of studies).
- 3.2. Motivate and introduce the topic, i.e., what is this project about, how does the shown sensor/actor/assembly work in practice, what is it used for, what are the main objectives.
- 3.3. Present the major aspects of your modeling and analysis, i.e., what quantities were analyzed, are there any analytic estimates, what major difficulties had to be solved, how did you overcome these difficulties, etc.
- 3.4. Show and discuss your results in a descriptive way using graphs, screenshots, videos, etc.
- 3.5. Give a short conclusion.

## Some remarks

- Brainstorm a concept on how to proceed and think about the desired goals and how you can achieve them. Focus on the relevant aspects of the project.
- Start early with your project and meet regularly to work together and/or exchange ideas. You might be able to distribute some tasks inside your group.
- The task description is rather vague on purpose and has room for your own interpretations. If you face uncertainties, e.g., regarding the choice of some parameter, discuss in the group first and think about reasonable choices. Only if this does not help, contact your supervisor.
- Present your project milestones to your supervisor **twice or thrice** during the course of the project. Discuss your “almost” final slides with your supervisor **before the first** deadline. Keep in mind, that you might need to make substantial changes and/or more simulations after this discussion.
- You can/should use Matlab where you deem it useful.
- When making animations, make sure to fix the color range of surface plots.

## Submitting your project

Hand in your

- .mph file (clear all meshes and results beforehand, see the COMSOL Tutorial),
- Presentation in PowerPoint or PDF format

before the final due date (second deadline) by uploading to the project section on StudOn.