CAE of Sensors and Actuators
Project 2
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Lehrstuhl für Sensorik
Universität Erlangen-Nürnberg
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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 2: Electrostatics – Capacitive Positioning Sensor

One of the research projects at LSE deals with the development of a linear stepper motor that follows the inch-worm principle (see showcases at the LSE). To increase the possible workload of such a motor, the driving rod and the clamping device are equipped with micro-teeth. Figure 1 shows the dimensions of the micro-teeth.

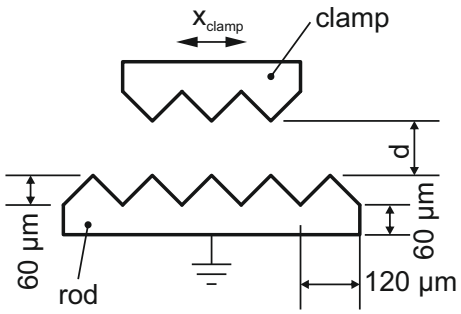

Figure 1: Capacitive sensor, principle and dimensions.

Before the two parts (clamp and rod) are pressed together by a piezoelectric actuator, the relative position of the clamping teeth to the teeth on the rod has to be detected. Pressing the tooth tips of the clamp directly onto the tooth tips of the other side might damage the structure. One possibility to detect the relative lateral position between the upper and the lower teeth is to evaluate the electric capacitance between the two surfaces at a certain vertical distance d.

The main objectives of this project are:

- Determine the influence of the vertical distance d onto the capacitance.
- Investigate on the influence of the relative lateral position onto the capacitance. For which value(s) of d can you obtain a reasonable sensitivity?
- Can the sensitivity of the sensor be optimized by varying the dimensions of the involved teeth?

1 Modeling

1.1. Model the geometry as depicted in Fig. 1 (driving rod with 5 teeth, clamping device with 3). The sensor operates in air, so make sure to model adequate air regions as well. The geometric parameters should easily be modifiable, in particular the lateral position x_{clamp} of the clamp with respect to the rod should be variable between -60μm and +60μm.

1.2. Mesh the geometry with appropriate element size.

2 Analysis

2.1. Visualize the electric field intensity for changing lateral positions x_{clamp} and make an animation.

2.2. Determine the electric capacitance of the device for different relative lateral positions x_{clamp} while keeping the vertical distance d constant. Compute the sensitivity with respect to the lateral position:

$$S_{x_{\text{clamp}}}(x_{\text{clamp}}) = \frac{\partial C}{\partial x_{\text{clamp}}}. \tag{1}$$

2.3. Visualize the charges on the teeth surfaces. How do capacitance and charge react to changing values of d? Does the sensor "see" the teeth?

2.4. Vary the distance d between 5 μm and 60 μm and calculate the change in capacitance C and the sensitivity

$$S_d(d) = \frac{\partial C}{\partial d} \tag{2}$$

w.r.t. the vertical distance d. When is the sensor most sensitive to d?

2.5. How does the sensitivity change, if the height of the teeth is changed to 40μm or 80μm?

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),
- plots (as `.png` files) and
- Presentation in PowerPoint or PDF format

before the final due date (second deadline) by copying everything into your home directory inside an `project2` folder (name the folder **exactly** this way!).