CAE of Sensors and Actuators
Project 3
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Lehrstuhl für Sensorik
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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 3: Mechanics – Surface Acoustic Wave Sensor

Surface Acoustic Waves (SAWs) propagate along the free surface of an elastic body. The chemical sensor shown in Fig. 1 makes use of the propagation characteristics of SAWs, which vary due to different surface mass loading. The SAW is launched from four excitation fingers by applying forces normal to the surface with alternating sign on neighboring fingers. The SAW travels along the surface of the substrate to a set of receiver fingers, where they are detected. Along this traveling path, a coating material may be applied to the substrate. If the coating is sensitive to a specific substance, its physical properties, like for example the mass, will change depending on the amount of molecules of that particular substance. The change in mass of the coating influences the SAW velocity and, thus, the SAW sensor can be utilized to detect the presence and the amount/concentration of that substance.

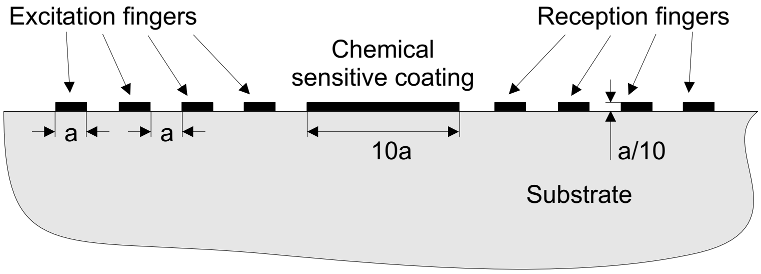

Figure 1: Surface Acoustic Wave sensor

The main objectives of this project are:

- Simulate the transient wave propagation from the excitation to the reception fingers.
- Determine the influence of the coating material onto the wave propagation and estimate the sensitivity of the sensor.
- Examine the effect of different excitation frequencies onto the wave propagation inside the substrate.

1 Modeling

1.1. Model the plane mechanical geometry as shown in Fig. 1.

1.2. The width a of a finger which is equal to the spacing between two adjacent fingers shall be set to $50\mu m$.

1.3. The material of the fingers has to be chosen as copper and the sensitive coating as steel. The substrate consists of silicon (Si).

1.4. The longitudinal wave velocity in the solid body can be calculated as $c_L = \sqrt{(c_{11}/\rho)}$ with c_{11} the (1,1) entry of the stiffness matrix and ρ the density. Take care of the mesh-size ($l_{elem} < \lambda_L/12$ with λ_L being the longitudinal wave length).

1.5. The boundaries of the assembly have to be positioned at a distance, where no disturbing reflection can be detected during the interesting time interval. At the bottom, homogeneous Dirichlet boundary conditions have to be set (on all DOFs) to hold the overall assembly.

1.6. The surrounding air may be neglected.

2 Analysis

2.1. Simulate an excitation of five wavelengths (i.e. a sine burst of five periods length), where λ_{SAW} is equal to $4a$ at a frequency $f = c_{\text{SAW}}/\lambda_{\text{SAW}}$. c_{SAW} can be calculated approximately with $c_{\text{SAW}} = 0.94c_S = 0.94\sqrt{(c_{44}/\rho)}$. The sine burst shall be applied with a force of 10 N per finger. As main result, take a look at the displacement of the midpoint of the first receiver finger on the interface between finger and substrate.

2.2. Make simulations with and without the sensitive coating.

2.3. Vary the mass m of the sensitive coating using a parametric sweep in the range of $\pm 30\%$ and investigate on the effect of this change onto the time of flight τ between sending and reception. From your results, calculate the sensitivity to deposition as a function of different masses:

$$S_m(m) = \frac{\partial \tau}{\partial m}. \tag{1}$$

2.4. Finally, take a look at the displacement in the substrate at a position of $4a$ beneath the midpoint of the sensitive coating. Increase the excitation frequency by a factor of two and compare the displacement at this special point with the results before. Thereby, make sure to use an appropriate mesh for the new frequency. For a better understanding, take screenshots at varying time steps (or even make movies) of the two wave propagation processes. If there are any differences, how can they be explained?

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 `project3` folder (name the folder **exactly** this way!).