Department of Architecture
and Civil Engineering

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WS 2024

Enriched Continua and Metamaterials

Project WS 2024

General instructions

- You will find a COMSOL file called "ProjectWork24" on Moodle in the "Evaluation" section. The model in this file represents the unit cell shown in Figure 1, and the numerical simulations must be performed in this file.
- For the project's evaluation, a personal report (one report per student) in the form of a PDF document and the COMSOL file in which the calculations were made must be submitted.
- The submission link is indicated on Moodle. Please name your files as follows: "24ECM_LastNames_FirstNames.fileExtension".
- The report must clearly explain the different steps performed to achieve a task. The results must be presented either as continuous text or in the form of bullet points and supplemented by tables and graphics (screenshots or exported figures) as required.
- The deadline for the submission is Friday, December 20, at 6 pm.
- Questions about the project can be discussed in the Moodle forum "Discussion" and appointments can be scheduled for the afternoons of Tuesday or Friday via mail.

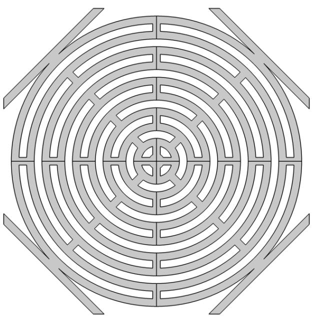

Figure 1: Unit cell.

Part A - Dispersion curves mode shapes (12 points)

The tasks in this part are to be performed for the unit cell shown in Figure 1. The unit cell has the same symmetry class as the unit cell discussed during the lecture.

Tasks:

1. Complete the model by adding the appropriate boundary conditions for the 2D unit cell in order to perform Floquet-Bloch type simulations. 2 P
2. Calculate the first 10 dispersion curves of the Irreducible Brillouin Contour (IBC) and show them in a dispersion diagram. 2 P
3. Perform a mesh convergence study until you reach a mesh size for which the frequencies of the third dispersion curve change not more than 30 Hz for the next smaller mesh size. Use the parameter "meshSize" in the model. 2 P
4. Highlight the full and the directional band gaps in the dispersion diagram which you obtain from the smallest (=converged) mesh size. 1 P

Instruction: Use the converged mesh size for the remaining tasks of Part A and Part B

5. Calculate the gap to mid-gap ratio of all band gaps that you find including complete and directional band gaps. 2 P
6. Generate two mode shape plots for the unit cell. The plots must show the norm of the displacement field ("solid.disp" in COMSOL) for the following two points of the second dispersion curve: The wavenumber in y-direction is equal to 0 and the wavenumber in x-direction corresponds to a wavelength which is 3 P
    a. 4 times the size of the unit cell.
    b. 2 times the size of the unit cell.

Part B – Optimizing the unit cell (8 points)

Your task is to optimize the given unit cell such that it reduces vibrations as good as possible under the following conditions:

- The frequency range of interest goes from 100 Hz to 3000 Hz.
- The size of the unit cell must not exceed 5 cm.
- The geometry can be modified by varying the parameter "tBeam" in a range from -0.125 mm to 0.125 mm.
- The base material of the unit cell can be chosen from Table 1 below.

Table 1: Material parameters

Material	Young's modulus E [GPa]	Poisson ratio ν [-]	Mass density ϱ [kg/m^3]
PMMA	3.0	0.4	1190
ABS	2.6	0.37	1010
PLA	2.0	0.4	1240
PP	1.8	0.41	990

Tasks:

The following tasks must be performed only for the final optimized unit cell.

1. List the changes you made with respect to the original unit cell. 2P
2. Show the dispersion diagram of your optimized unit cell and highlight the band gaps (complete and directional) that lie in the frequency range of interest. 2P
3. State the gap to mid-gap ratio of the band gaps (complete and directional) that lie in the frequency range of interest. 2P
4. Prove that a metamaterial made from the optimized unit cell absorbs vibrations better than a metamaterial based on the original unit cell. 2P