GEW soft strip DOI 10.5281/zenodo.10372576

Compute guided elastic waves (GEWs) in a soft strip.

This code computes dispersion curves of an anisotropic waveguide with rectangular cross-section. It uses the spectral collocation method (SCM) and is an extension to "GEW dispersion script".

Three cases are included:

1. `strip_elastic_SCM.m`: linear-elastic (possibly anisotropic) strip with free boundaries.
2. `strip_elastic_clamped_SCM.m`: same but with the lateral boundaries clamped.
3. `strip_elastic_SA_SCM.m`: free strip with symmetry conditions (SS, SA, AA, AS).
4. `strip_soft_viscoAE_SCM.m`: includes **acoustoelasticity** and **viscosity** for a soft, nearly-incompressible strip.

Acoustoelasticity and viscosity are inherently present in common soft matter, such as biological tissues. Acoustoelasticity describes the effect of pre-stress on the wave propagation, which we account for using a compressible Mooney-Rivlin hyperelastic material model. Viscoelastic losses are included with a fractional Kelvin-Voigt model. The difficulty relies in the interdependence of both effects.

The methods have been presented in:

> A. Delory, D. A. Kiefer, M. Lanoy, A. Eddi, C. Prada, and F. Lemoult, “Viscoelastic dynamics of a soft strip subject to a large deformation,” *Soft Matter*, Jan. 2024, doi: 10.1039/D3SM01485A.

Code repository: https://github.com/dakiefer/gew_soft_strip

How to use

1. Change into the `GEW_soft_strip` folder or add it to the Matlab path.
2. Execute the desired script, i.e., `strip_elastic_SCM.m`, `strip_elastic_SA_SCM.m`, `strip_elastic_clamped_SCM.m` or `strip_soft_viscoAE_SCM`.
3. If you want to implement a different hyperviscoelastic material model, you can create it by adapting `initiateTensor.nb` and `createTensorForMatlab.nb` and running the latter in Mathematica. Copy the output of the last command as *plain text* and replace the marked block in `customTensor.m` with the code you copied.

Limitations

Mixed boundary conditions (Dirichlet and Neumann) as used in `strip_elastic_clamped_SCM.m` lead to instabilities at the corners. Depending on the parity of the number of collocation points, either the in-plane or the out-of-plane waves are, nonetheless, well represented. Switch to another discretization method, e.g., Finite Elements, if this is still an issue.

Mathematical background

The SCM discretizes boundary-value problems based on the strong form. The two-dimensional implementation that we use is explained in

> J. A. Weideman and S. C. Reddy, “A MATLAB Differentiation Matrix Suite,” ACM Trans. Math. Softw., vol. 26, no. 4, pp. 465–519, 2000, doi: 10.1145/365723.365727.

Dependencies

`chebdif.m` from DMSUITE is bundled and can be found at

J.A.C Weideman (2022). DMSUITE (https://www.mathworks.com/matlabcentral/fileexchange/29-dmsuite), MATLAB Central File Exchange. Retrieved August 18, 2022.

`ToMatlab.m` is bundled from

Harri Ojanen (1999). Mathematica Expression to Matlab m-file Converter (https://library.wolfram.com/infocenter/MathSource/577/), Wolfram Library Archive. Retrieved June 23rd, 2022.

Citing this software

If this code is useful to you, please cite it as (always including the DOI):

> D. A. Kiefer, A. Delory, and F. Lemoult. GEW soft strip (2023), doi 10.5281/zenodo.10372576. https://github.com/dakiefer/GEW_soft_strip

together with the related publication:

> A. Delory, D. A. Kiefer, M. Lanoy, A. Eddi, C. Prada, and F. Lemoult, "Viscoelastic dynamics of a soft strip subject to a large deformation," *Soft Matter*, Jan. 2024, doi: 10.1039/D3SM01485A.

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