Designing Materials for Mechanical Invisibility Cloaks

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Introduction: In solid mechanics there is a considerable interest in achieving ”invisibility”. The applications in mechanics include protection of structures and parts of structures from potentially harmful transient waves and steady state vibrations, see Figure 1.

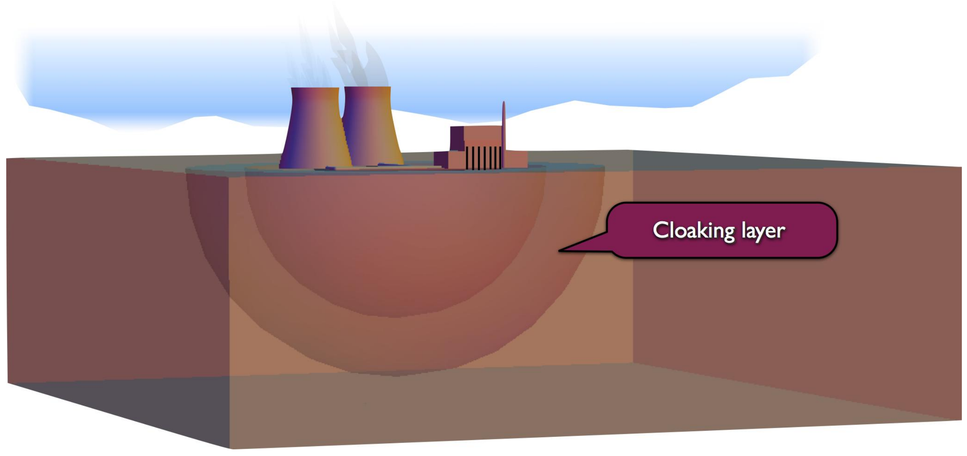

Figure 1. A potential mechanical cloaking protecting from seismic waves.

Computational Methods: In order to cloak a structure we seek to find a suitable transformation which allows us to mimic a homogeneous material response while using an anisotropic micropolar material. Under the assumptions of high stiffness w.r.t. curvature the governing equations are

$$\boldsymbol{\sigma} = \mathbf{C} : (\nabla \otimes \mathbf{u})$$

$$\nabla \cdot \boldsymbol{\sigma}^{\mathsf{T}} + \rho\omega^2 \mathbf{u} = 0 \quad \text{in } \Omega,$$

Where **C** is the non-standard elastic stiffness lacking minor symmetry.
The geometry used for this work is illustrated in Figure 2.

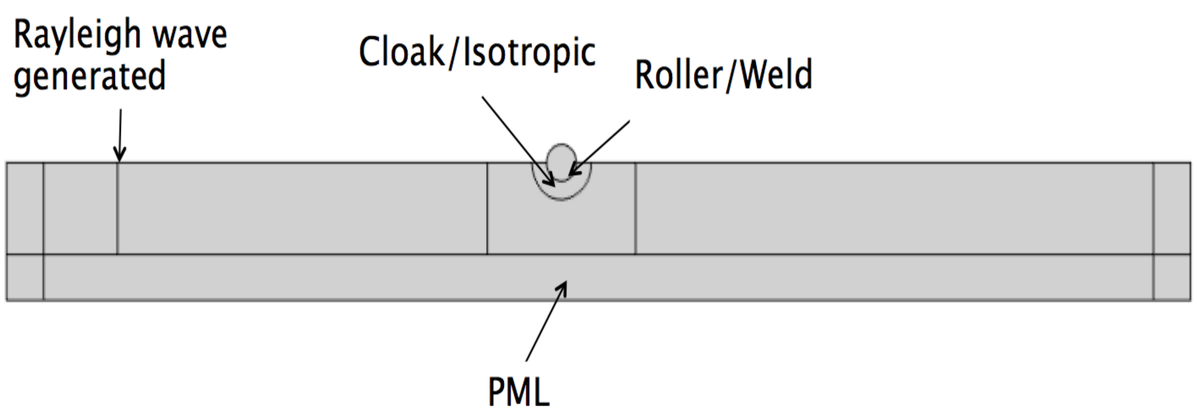

Figure 2. The geometry

Results: We have found that elastodynamic cloaking from Rayleigh waves is theoretically possible, using a certain limiting type of such materials. The movement of the pipeline reduces with at least 5 orders magnitude.

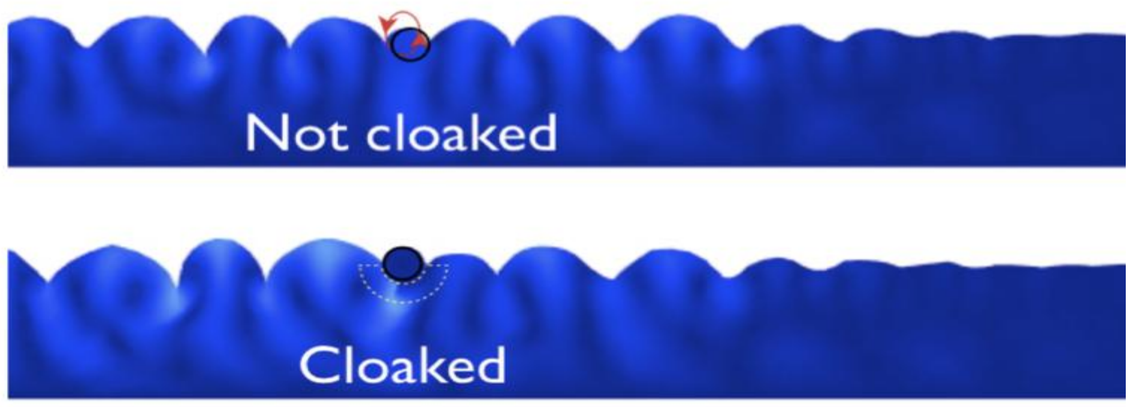

Figure 3. The obtained results

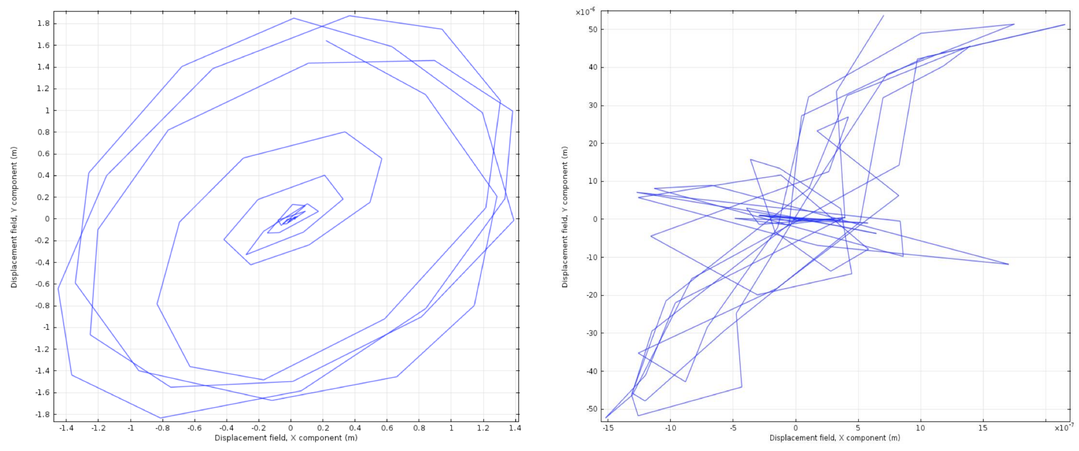

Figure 4. Results: a) Homogeneous (Welded).
b) Anisotropic (Roller).

Conclusions: Our findings support the hypothesis that it is possible to protect structures against seismic waves using mechanical cloaks. This type of protection can also be used to e.g. control noise and vibrations. Future work includes homogenization analysis for meta-material and also studying different material configurations.

References:

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