RECOLO: A Python package for the reconstruction of surface pressure loads from kinematic fields using the virtual fields method

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Summary

In experimental mechanics, conducting non-intrusive measurements of surface pressure distributions acting on blast-loaded structures remains a challenge even in controlled, laboratory environments (see e.g., (Pannel et al., 2021)). Still, for the design of tomorrow's sustainable and material-efficient structures, detailed knowledge of how pressure loads from extreme loading events interact with deformable structures is essential. When pressure loads are imposed on a deformable structure, fluid-structure interaction (FSI) effects are known to cause non-trivial loading scenarios which are difficult to quantify (see e.g., (Aune et al., 2021)). This project aims at reconstructing the full-field surface pressure loads acting on a deforming structure employing the virtual fields method (VFM) on full-field kinematic measurements (Kaufmann et al., 2019). Even though the current framework is limited to reconstructions of full-field pressure information from deformation data of thin plates in pure bending, it also allows for future extensions to other loading and deformation scenarios. Provided that the properties of the structure are known, the transient pressure distribution on the plate can be reconstructed. To understand the capabilities and accuracy associated with the pressure reconstruction methodology, the package provides tools for performing virtual experiments based on analytical data or data from finite element simulations. The current implementation is based on the deflectometry technique, using the grid method to obtain the deformation measurements and corresponding kinematics of the structure.

This Python package is made for RECOnstructing surface pressure LOads, RECOLO, acting on plated structures based on deformation measurements using the VFM (Pierron & Grédiac, 2012). The current implementation determines the surface pressure acting on a thin plate undergoing small deformations, assuming linear, elastic material behaviour. However, the framework will be extended to large plastic deformations, allowing the two-way interaction between the pressure loading and the deformation of the plate to be studied. Other VFM toolkits such as PeriPyVFM are readily available but typically aimed at determining material properties from deformation and load measurements. Hence, as opposed to other VFM toolkits, RECOLO assumes that the material properties are known and use the full-field deformation measurements to reconstruct the pressure loading.

RECOLO contains a collection of tools enabling the user to perform virtual experiments on synthetically generated data as well as performing pressure reconstruction on experimental datasets. The pressure reconstruction algorithm is based on the work by (Kaufmann et al., 2019). The implementation is based on numerical operations provided by NumPy (Oliphant, 2015) and SciPy (Jones et al., n.d.) as well as visualization by Matplotlib (Hunter, 2007).

Statement of need

RECOLO was established to quantify the blast loading acting on plated structures in a purpose-built shock tube apparatus at SIMLab, NTNU (Aune et al., 2016). To the authors' best knowledge there a no open-source software providing the functionality necessary to perform pressure load reconstruction based on the kinematics of plated structures during fast transient dynamics, motivating the RECOLO project.

The methodology developed in this project is directly applicable to obtain new, unique insight into surface pressure distributions on plated structures subjected to blast loading. This project is part of the ongoing research within the SIMLab research group at NTNU.

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