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

Sindre Nordmark Olufsen[1,2], **Rene Kaufmann**[1], **Egil Fagerholt**[1], **and Vegard Aune**[1,2]

1 Structural Impact Laboratory (SIMLab), Department of Structural Engineering, NTNU - Norwegian University of Science and Technology, Trondheim, Norway **2** Centre for Advanced Structural Analysis (CASA), Department of Structural Engineering, NTNU - Norwegian University of Science and Technology, Trondheim, Norway

Summary

In experimental mechanics, it is well known that it is very challenging to conduct non-intrusive measurements of surface pressures on blast-loaded structures, even in controlled, laboratory environments (see e.g., (Pannel et al., 2021)). Still, it is of utmost importance to provide structural engineers with a detailed knowledge of loads, understand the underlying physics and predict how structures respond during extreme loading events. 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 pressure loading can be reconstructed both temporally and spatially. To understand the capabilities and accuracy associated with the reconstruction methodology, the package provides the scientific 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.

Recolo is a Python package that allows for the reconstruction of surface pressure loads acting on plated structures by using the VFM (Pierron & Grédiac, 2012). Other VFM toolkits such as PeriPyVFM are readily available but are focused on different applications.

Recolo contains a collection of science-driven functions which enables 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). No open-source software

---

41 known to the authors provided the functionality neccessary to perform pressure load recon-
42 struction based on the kinematics of the specimen subjected to the load, motivating the
43 'Recolo project.

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

Acknowledgements

References

53 Aune, V., Fagerholt, E., Langseth, M., & Børvik, T. (2016). A shock tube facility to generate
54   blast loading on structures. *International Journal of Protective Structures*, *7*(3), 340–366.
55   https://doi.org/10.1177/2041419616666236

56 Aune, V., Valsamos, G., Casadei, F., Langseth, M., & Børvik, T. (2021). Fluid-structure
57   interaction effects during the dynamic response of clamped thin steel plates exposed to
58   blast loading. *International Journal of Mechanical Sciences*, *195*, 106263. https://doi.
59   org/10.1016/j.ijmecsci.2020.106263

60 Hunter, J. D. (2007). Matplotlib: A 2D graphics environment. *Computing In Science &
61   Engineering*, *9*(3), 90–95. https://doi.org/10.1109/MCSE.2007.55

62 Jones, E., Oliphant, T., Peterson, P., & Others. (n.d.). *SciPy: Open source scientific tools
63   for Python*. http://www.scipy.org/

64 Kaufmann, R., Ganapathisubramani, B., & Pierron, F. (2019). Full-Field Surface Pressure
65   Reconstruction Using the Virtual Fields Method. *Experimental Mechanics*, *59*(8), 1203–
66   1221. https://doi.org/10.1007/s11340-019-00530-2

67 Oliphant, T. E. (2015). *Guide to NumPy* (2nd ed.). CreateSpace Independent Publishing
68   Platform. ISBN: 151730007X, 9781517300074

69 Pannel, J. J., Panoutsos, G., Cooke, S. B., Pope, D. J., & Rigby, S. E. (2021). Predicting
70   specific impulse distributions for spherical explosives in the extreme near-field using a
71   Gaussian function. *International Journal of Protective Structures*. https://doi.org/10.
72   1177/2041419621993492

73 Pierron, F., & Grédiac, M. (2012). *The virtual fields method. Extracting constitutive mechan-
74   ical parameters from full-field deformation measurements*. (1st ed.). New-York: Springer.
75   ISBN: 978-1-4614-1824-5, 978-1-4614-1823-8