



HAL
open science

Investigating the compaction of open ring stacks through real and numerical experiments

Emile Hohnadel, Tomohiko G Sano, Toshiyuki Kawata, Thibaut Métivet,
Florence Bertails-Descoubes

► **To cite this version:**

Emile Hohnadel, Tomohiko G Sano, Toshiyuki Kawata, Thibaut Métivet, Florence Bertails-Descoubes.
Investigating the compaction of open ring stacks through real and numerical experiments. European
Solid Mechanics Conference ESMC 2022, Jul 2022, Galway, Ireland. hal-03962464

HAL Id: hal-03962464

<https://hal.science/hal-03962464v1>

Submitted on 30 Jan 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License

Investigating the compaction of open ring stacks through real and numerical experiments

Emile Hohnadel^{1*}, Tomohiko G. Sano^{2*}, Toshiyuki Kawata², Thibaut Metivet¹, Florence Bertails-Descoubes¹

¹ Univ. Grenoble Alpes, Inria, CNRS, Grenoble INP, LJK, Grenoble, France

² Department of Mechanical Engineering, Keio University, Yokohama, Japan

* These authors contributed equally to this work

E-mail: emile.hohnadel@inria.fr

E-mail: sano@mech.keio.ac.jp

Keywords: Thin elastic rods, frictional contact, simulation, mechanical metamaterials, snap-fits

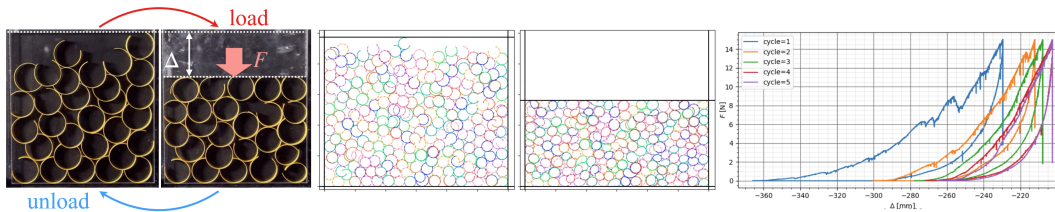


Fig. 1: Left: Our experimental set-up with 30 open rings. Center: Simulation of our set-up scaled up to 300 open rings. Right: Stress-strain plot from our simulation, for 5 consecutive compression cycles.

We investigate the mechanical response of a stack of bidimensional flexible open rings subject to compression cycles, by the means of experiments and simulations. To perform reliable and scalable simulations, we build a numerical model based on an unclamped version of the 2D super-helix [1] for open thin elastic rods, coupled to frictional contact constraints [2]. We carefully validate this numerical model, first against theoretical predictions given by the analysis of a single ring snap fit [3], second by comparing numerical and experimental results for an assembly of rings of moderate size (30 rings). Our excellent prediction results allow us to rely on the simulator for investigating the mechanical behaviour of a large collection of (300) randomly stacked rings, depending on their opening angle and their friction coefficient. In particular, we find that such a system, which acts as a disordered mechanical metamaterial, can absorb and store mechanical energy upon compression in a controlled fashion, exploiting large displacement and rearrangement of rings, snap-fits, and friction.

References

- [1] F. Bertails, B. Audoly, M.-P. Cani, B. Querleux, F. Leroy, J.-L. L ev eque, "Super-Helices for Predicting the Dynamics of Natural Hair", *ACM Transactions on Graphics*, 25:3: 1180-1187, 2006.
- [2] G. Daviet, F. Bertails-Descoubes, L. Boissieux, "A hybrid iterative solver for robustly capturing Coulomb friction in hair dynamics", *ACM Transactions on Graphics*, 30, Article 139: 1-12, 2011.
- [3] K. Yoshida, H. Wada, "Mechanics of a Snap Fit", *Physical Review Letters*, 125, 194301, 2020.