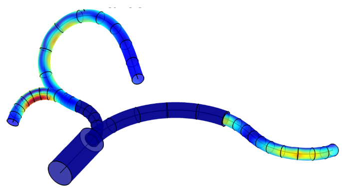
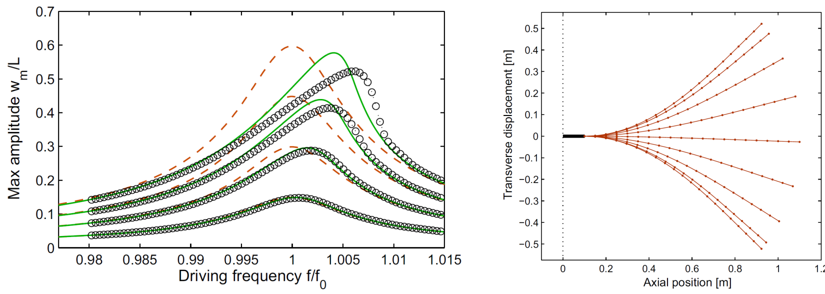
Marie Skłodowska-Curie Actions

Open PhD position

Nonlinear dynamics of highly flexible slender structures: frequency domain numerical strategies and reduced order modelling



Static simulation of 3D beams [1]



Resonance simulation of a cantilever beam [2]

Practical aspects

Laboratory and university:
Arts et Métiers institute of technology
Laboratoire d'ingénierie des systèmes physiques et numériques (LISPEN)
8 boulevard Louis XIV 59000 Lille, France

Advisory: Pr. Olivier THOMAS, Dr. Aurélien GROLET

Salary: it follows the regulations set by the European Commission and will include social security and will be composed of living, mobility and family allowances, where applicable.

Dates: Three years starting after 1st. April 2020 and before 30 sept. 2020

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http://artsetmetiers.fr/en, http://www.lsis.org/thomaso

Background

The present PhD position is offered within the EU Marie-Skłodowska-Curie Innovative Training Networks in the project "Joint Training on Numerical Modelling of Highly Flexible Structures for Industrial Applications [THREAD]". It addresses the mechanical modelling, mathematical formulations and numerical methods for highly flexible slender structures like yarns, cables, hoses or ropes that are essential parts of high-performance engineering systems. The complex response of such structures in real operational conditions is far beyond the capabilities of current virtual prototyping tools. With 14 new PhD positions at 12 universities and research institutions in Austria, Belgium, Croatia, France, Germany, Norway, Slovenia and Spain, the project brings mechanical engineers and mathematicians together around major challenges in industrial applications and open-source simulation software development. It establishes an innovative modelling chain starting from detailed 3D modelling and experimental work to build validated one dimensional (1D) nonlinear rod models, to built the next generation of virtual prototyping strategies. For more informations, see *http://thread-etn.eu*

Research

Slender one dimensional structures like beams and cables are highly flexible in bending and can thus be the subject of very large amplitude vibrations for moderate input forces, in particular if resonant responses are under concern. As a consequence, suitable models must include so-called geometrical nonlinearities, which are the source of various complex dynamical phenomena such as resonance frequency dependance upon the amplitude of the motion, coexisting possibly stable and unstable solutions, bifurcations, strong exchanges of energy between vibration modes, chaotic responses etc. At the moment, only analytical models, restricted to moderate amplitude vibrations, have been used to reproduce such phenomena. The purpose of this PhD work is to produce efficient fully numerical strategies, validated by dedicated experiments, applicable to the nonlinear dynamics of slender 1D structures.

In this context, this thesis will investigate the dynamics of slender beams in large rotation nonlinear dynamics with numerical efficient models. We will target the simulation of periodic solutions of those systems, since it is an efficient tool to explore the complex dynamics observed. Several aspects will be investigated.

- New modelling strategies will be proposed and investigated, based on an original coupling of quaternions (for rotation parametrisation) / finite elements (for discretisation) / asymptotic numerical method (for continuation) and the harmonic balance method (to get periodic solutions). This work will be an extension to dynamics of the work proposed in [1].
- Reduced order modelling strategies will be investigated. The computation of nonlinear modes and normal forms will be the basis [3, 4]. Then, the convergence of basic modal expansions will be tested [4]. Other strategies, such as Proper Orthogonal Decomposition [5, 6] or technics from flexible multibody dynamics will be tested [7].
- Dedicated experiments will be performed, to exhibate particular nonlinear coupling between modes and constitute reference solutions, such as the primary resonances of a cantilever beam [2], 1:1 internal resonances in cantilever beams with a symmetric cross section [8], particular coupling between bending and torsion motions [9] and vibrations around a prestressed curved state [10].
- A targeted industrial application, in partnership with the french automotive supplier VALEO, will be the design of a nonlinear torsional vibration absorbers based on prestressed beams [11].

During this PhD, the student will develop the following skills:

- master the modelling and the simulation of the behaviour of **structures with strong nonlinear behaviours**;
- design and lead experimental **vibration tests**;
- Have a unique **industrial research and development** experience at VALEO (see next section).

Industrial secondment

During this PhD, a secondment of three months in the design department of the french company and automotive supplier VALEO is planned, for the design of a novel torsional vibration absorber for automotive drivelines.

Requirements

- A master of science level or an engineering degree in structural mechanics and dynamics, with a good appetite for numerical methods. Programing skills with the software Matlab will be appreciated.
- High standard of spoken and written English.
- At the time of appointment, no doctoral degree and less than 4 years of research experience (full-time equivalent) after obtaining a degree that formally allows to embark for a doctorate.
- Mobility requirement: at the time of appointment, the candidate must not have resided or carried out their main activity in France for more than 12 months in the 3 years immediately prior to their appointment.
- For more details please see here: *https://thread-etn.eu/apply/*

Advisory

This thesis will be co-advised by Pr. Olivier THOMAS, full professor, and Dr. Aurélien GROLET, associate professor. O. Thomas and A. Grolet are experts in structural dynamics and vibrations, passive control, elastic/piezoelectric coupled structures, nonlinear dynamics and geometrical nonlinearities [3, 12, 2, 1, 13, 11, 4, 8, 5, 14].

Application

Applications must be submitted on the website https://thread-etn.eu. Applications must include a motivation letter tailored to the research project, the curriculum vitae (in Europass format), the digital copy of the highest academic degree (e.g. master) and the contact details of 1 to 3 scientific references. A preliminary contact with Pr. O. Thomas (*olivier.thomas@ensam.eu*) is strongly suggested.

References

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[5] A. Grolet and F. Thouverez. On the use of the proper generalised decomposition for solving nonlinear vibration problems. In *Proc. of the ASME 2012 International Mechanical Engineering Congress and Exposition*, Houston, USA, 2012.

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[12] A. Lazarus, O. Thomas, and J.-F. Deü. Finite elements reduced order models for nonlinear vibrations of piezoelectric layered beams with applications to NEMS. *Finite Elements in Analysis and Design*, 49(1):35–51, 2012.

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