Multibody & Mechatronic Systems Laboratory
Department of Aerospace & Mechanical Engineering
www.ltas-mms.ulg.ac.be

Marie Skłodowska-Curie Actions

Job announcement

"Nonlinear rod models for system-level braiding process simulation"
(THREAD ESR 2)

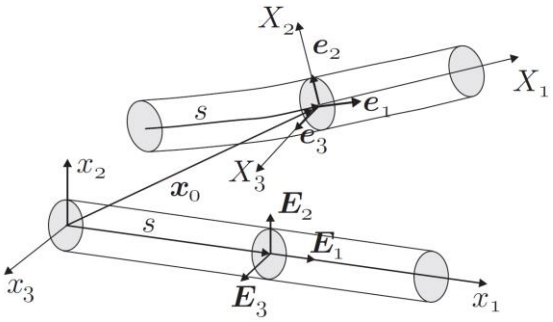

Fig. 1 Geometrically exact rod model [1]

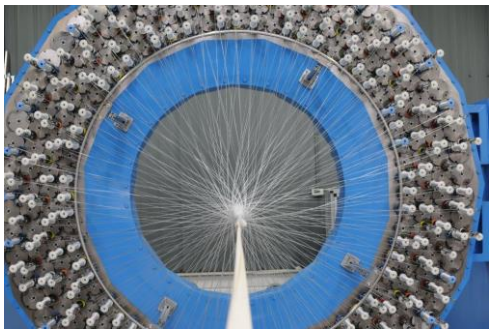

Fig. 2 Braiding process (Copyright: Centexbel)

Practical aspects

- **Laboratory**: Multibody and Mechatronic Systems Laboratory of the University of Liège, Belgium (www.ltas-mms.ulg.ac.be).
- **Supervisor**: Prof. Olivier Brüls (o.bruls@uliege.be).
- **Duration**: full-time PhD position starting from October 15, 2020 (or later), and limited for 36 months.
- **Project**: this "early stage researcher" 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]*".
- **Salary**: the salary follows the regulations set by the European Commission. It includes social security and is composed of living, mobility and family allowances, where applicable, as outlined in the Grant Agreement and Horizon 2020 Marie-Skłodowska-Curie Actions Work Programme, please see here:
  http://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-msca_en.pdf

Background

THREAD 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 simulation software development. It establishes an innovative modelling chain starting from detailed 3D modelling and experimental work to build validated 1D nonlinear rod models, which are then brought to a system-level simulation thanks to the outstanding numerical properties of the developed algorithms. This holistic approach combines advanced concepts in experimental and theoretical structural mechanics, nonsmooth dynamics, computational geometry, discretisation methods and geometric numerical integration and will enable the next generation of virtual prototyping.

Research

The research project targets the development of novel nonlinear rod formulations for the system-level simulation of complex machines. As a representative problem, the braiding manufacturing process (see Fig. 2 and Ref. [2]) is considered, in which hundreds of yarns interact through frictional contact conditions and are driven by a machine with a sophisticated kinematics. The aim of a system-level simulation in this context is to predict the influence of some key control parameters of the machine on the final layout of the textile product.

The project will cover the mathematical modelling of continuous 1D yarn structures as geometrically nonlinear rods, the representation of contact conditions, the spatial and temporal discretisation and the solution algorithms. It will capitalize upon previous and ongoing work in the team on geometrically exact rod and beam models [3], contact formulations [4,5], beam-to-beam contact models (under development by another PhD student), and numerical solvers for nonlinear and nonsmooth dynamic systems [6-9].

Specific open questions and scientific challenges are related with

- the determination of the constitutive law in order to represent the yarn global behaviour in the rod model,
- the development of novel contact models and formulations able to capture efficiently spatial and temporal transitions between open and closed contact states between the yarns,
- the geometric description of the yarn cross-section and the modelling of the section flattening effect,
- the reduced-order modelling of the yarns in order to speed-up the overall simulation,
- the integrated simulation of the yarns and the machine kinematics and dynamics,
- the investigation of robust and efficient numerical solvers.

Besides the theoretical investigations and the development of simulation code prototypes, we foresee the implementation of some algorithms in the finite element simulation code Oofelie (www.open-engineering.com) that is jointly developed by the company GDTech and the University of Liège.

Secondments

During the project, the researcher will participate in four secondments:

- a 3-months internship at the industrial partner GDTech in Liège (Belgium) supervised by Dr. Michael Bruyneel in order to receive training on simulation techniques in the industry, develop numerical methods in Oofelie, and validate the software implementation;
- a 3-months internship at the textile research center Centexbel in Liège (Belgium) for the study of the braiding process and the definition of the numerical test case;
- a 1-month internship to Prof. Sigrid Leyendecker at the Friedrich-Alexander-Universät Erlangen-Nürnberg (Germany) to learn about the discrete mechanics of beams;
- a 2-months internship to Prof. Martin Arnold at the Martin-Luther-University Halle-Wittenberg (Germany) to study mathematical and numerical methods in non-smooth contact dynamics.

Requirements

- MSc in Mechanical Engineering, Aerospace Engineering, Computational Engineering, Computational Physics or related fields is preferred (all backgrounds are welcome to apply).
- Experience in numerical software development is highly desirable.
- Experience in modelling methods in mechanics and dynamics is desirable.
- High standard of spoken and written English.
- Qualification as an "Early Stage Researcher", i.e. at the time of appointment no PhD and less than 4 years of research experience (full-time equivalent) after obtaining a degree that formally allows you to embark for a PhD.
- Mobility requirement: at the time of appointment an "Early Stage Researcher" must not have resided or carried out their main activity in Belgium for more than 12 months in the 3 years immediately prior to their appointment.
- For more details please see here: https://thread-etn.eu

Advisory and work environment

The researcher will be supervised by Prof. Olivier Brüls, who is an expert in flexible multibody dynamics, mechatronics, numerical simulation, control and optimisation methods. He will also benefit from close interactions with other PhD students and post-doc researchers of the group for the development of the modelling and simulation tool.

Applications

Please submit your application in English until **September 30, 2020** on the website https://thread-etn.eu. Applications must include a motivation letter, the curriculum vitae (in Europass format), the digital copy of the highest academic degree (e.g. master) and the recommendation letters or names of two scientific references. The recruitment procedure will guarantee a fair and equal treatment of all applications. Please contact Prof. Olivier Brüls by email (o.bruls@uliege.be) for any further information.

References

1. M. Géradin and A. Cardona. *Flexible multibody dynamics – A finite element approach*. John Wiley & Sons, 2001.
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4. J. Galvez, F.J. Cavalieri, A. Cosimo, O. Brüls, and A. Cardona. A nonsmooth frictional contact formulation for multibody system dynamics. *International Journal for Numerical Methods in Engineering*, published online in April 2020.
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7. O. Brüls, A. Cardona, and M. Arnold. Lie group generalized-α time integration of constrained flexible multibody systems. *Mechanism and Machine Theory*, **48**:121-137, 2012.
8. O. Brüls, V. Acary, and A. Cardona. Simultaneous enforcement of constraints at position and velocity levels in the nonsmooth generalized-α scheme. *Computer Methods in Applied Mechanics and Engineering*, **281**:131-161, 2014.
9. A. Cosimo, J. Galvez, F.J. Cavalieri, A. Cardona, and O. Brüls. A robust nonsmooth generalized-α scheme for flexible systems with impacts. *Multibody System Dynamics*, **48**(2):127-149, 2020.