

The industrial braiding process: modelling & simulation

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Kaiserslautern, Germany



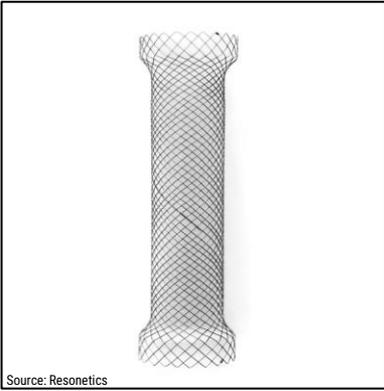
Joint Training on Numerical Modelling of Highly Flexible Structures for Industrial Applications
This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 860124.



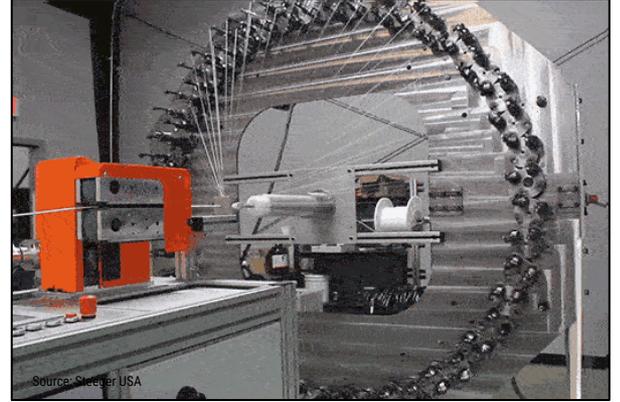
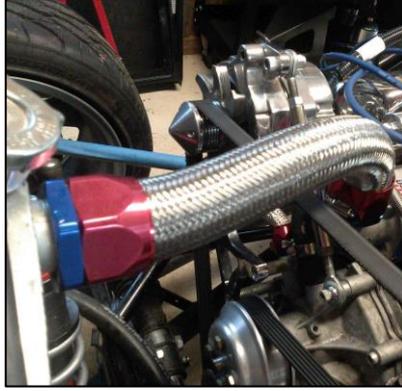
Motivation



Source: Kratos Defense & Security



Source: Resonetics

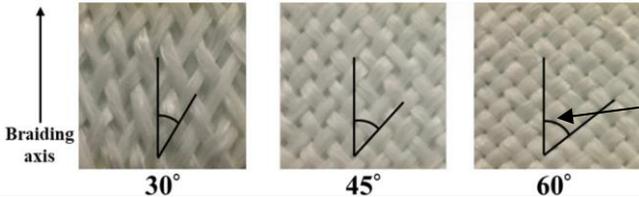


Source: Steeger USA

Mechanized braiding → Preform shape → RTM/Vacuum Infusion → Composite product

Such a *process-level simulation* is highly crucial because:

Process parameters ↔ Topological & constitutive properties of composite product



Braid angle

- High braid angle = high thickness of composite [4]
- Uniaxial tension test: [6]
 - < 30° – linear elastic response
 - > 50° – nonlinear response (progressive necking)

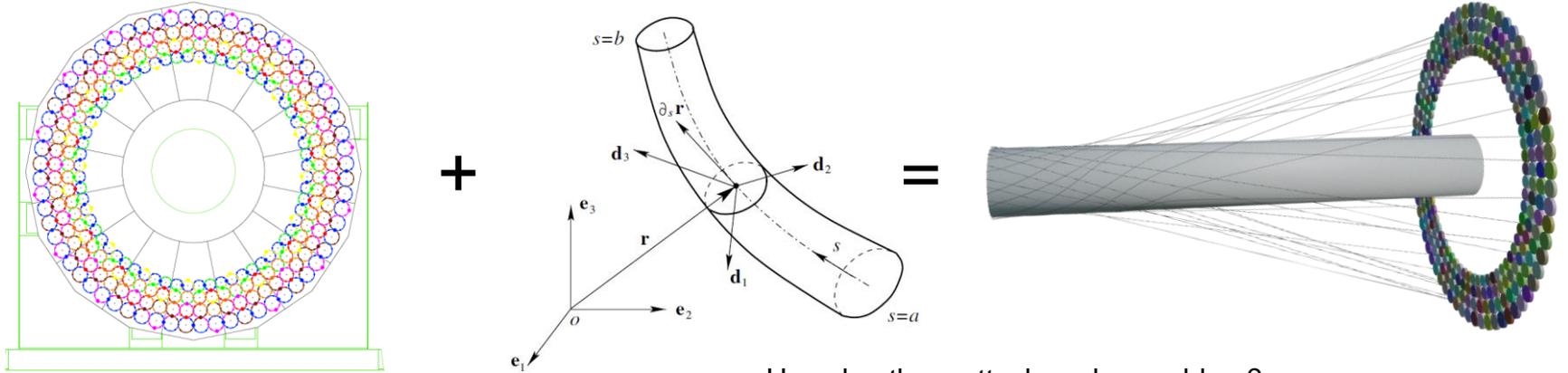


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Research objective

Develop a *machine-to-process* simulation as a *constrained dynamical system* !



- Machine model
- Process model
 - Deformable yarn dynamics: beam model
 - Yarn-to-mandrel contact interactions
 - Yarn-to-yarn contacts interactions

How do others attack such a problem?

Collab with **ViBra** [7] Project: Virtual Braiding
 Explicit FE: LS-Dyna [5] – Face several challenges!

Alternatively, we propose a multibody system framework

Odin [3] is a C++ based research code developed at ULiege for the *simulation of flexible multibody systems with contacts/impacts*.



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Challenge 1: The machine

How can we model these motions ??

Approach 1: Use fundamental geometry (analytical expressions)

It will do the job, but:

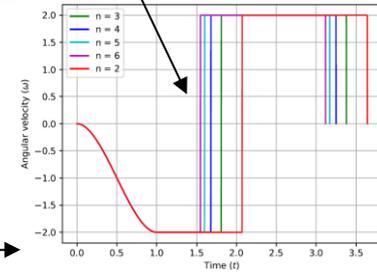
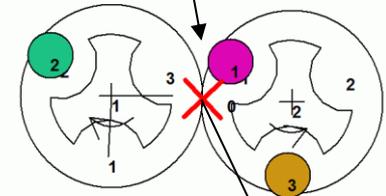
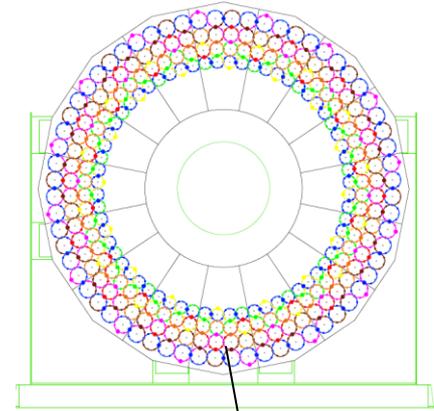
- Highly **laborious and cumbersome**.
- **Machine components ignored**: only trajectory is computed. This **loses access to internal forces** (dissipation due to friction, stiffness in the gears etc.)
- Non-generic!

Approach 2: Constraint-based (implicit) ! *→ (Developed in this research)*

- **Unified and natural**: avoids any explicit efforts – **Odin** directly solves the machine and process together!!
- **Machine component interactions** precisely modelled: access to constraint forces estimate **driving torque**, etc.
- Highly modular and generic

Uses a **constraint switching mechanism** for transfers between gears

Nonsmooth problem!!



Challenge 2: yarn-mandrel contact

The deformable slender yarns:

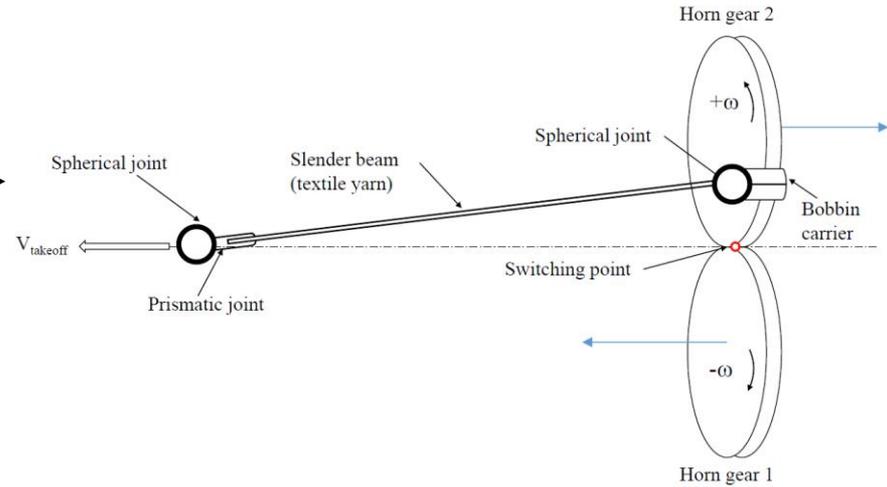
The yarns are modelled using geometrically exact beams [2].

Now attach the **machine-to-yarn** !

Yarn-to-mandrel contact interactions

What do we have in **Odin**?

- Beam model
- Machine model
- **Contacts between flexible beams**
- **Contacts between rigid bodies**



- **Approach 1:** exploiting the beam-to-beam contact – mandrel modelled as a stocky (fixed) beam
- **Approach 2:** exploiting the beam-to-rigid body contact – mandrel modelled as a rigid body



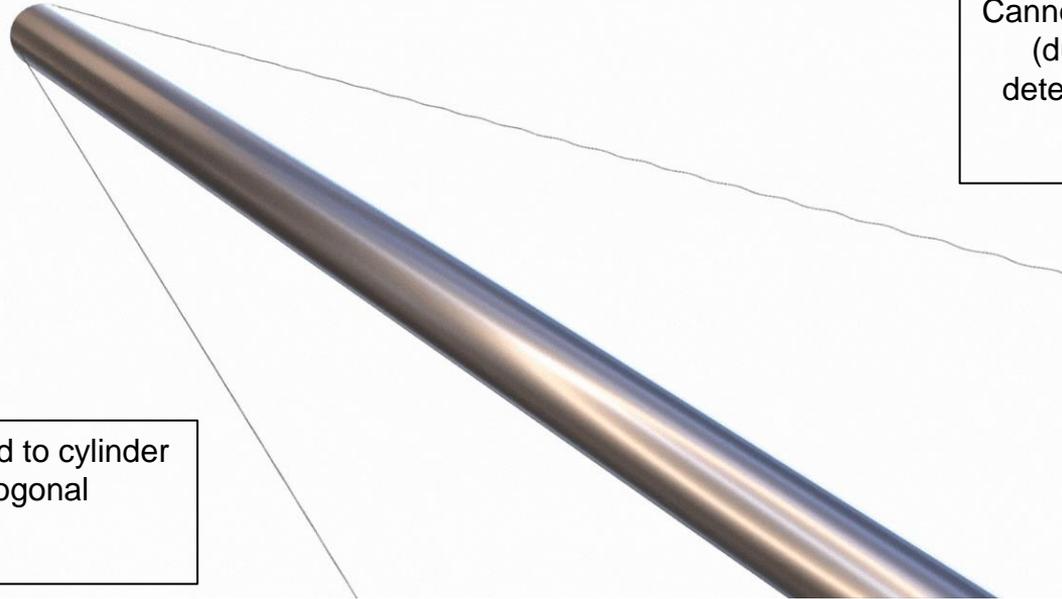
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THREAD
EUROPEAN TRAINING NETWORK

Yarn-mandrel: beam-to-beam

Beam-to-beam contact [1]: Mandrel is modelled as a (stocky) beam !!



Cannot be generalized
(due to collision
detection problems)



- Mandrel geometry restricted to cylinder
- Fails when beams are orthogonal



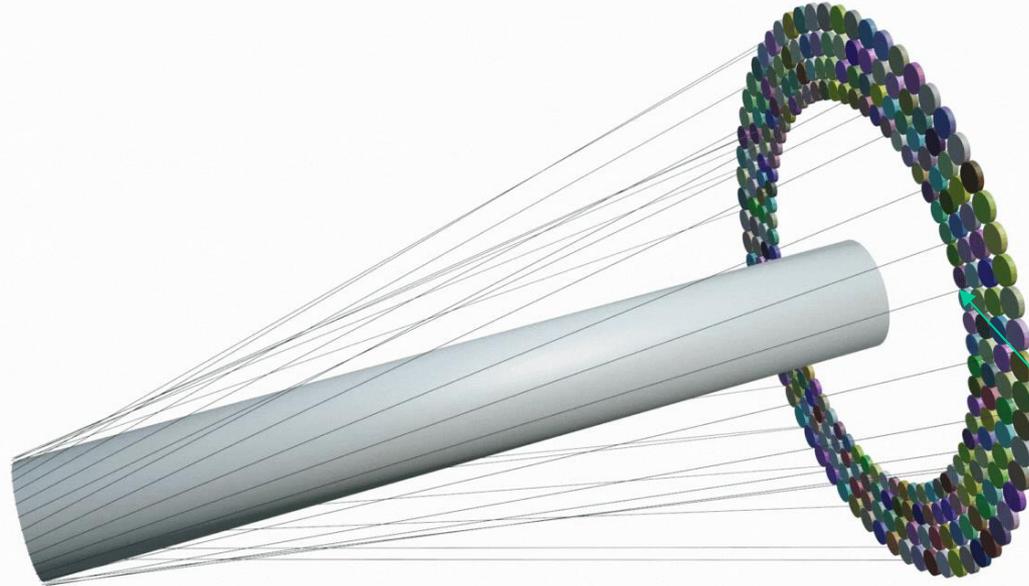
So, let us try [Approach 2](#): mandrel as a rigid-body !!



Yarn-mandrel: beam-to-rigid body

Beam-to-rigid body contact-friction with 30 yarns on industrial braiding machine (Centexbel, Belgium): dynamic simulation

Highly generic for
mandrel shapes and
several yarns !!



Bullet collision engine
is robust !!



FAILS: due to improper tension compensation in the yarns !!



Solutions: ALE approach (ambitious!)
Extra yarn with slider at machine end !!

Challenge 3: yarn-to-yarn contact interactions – work continues



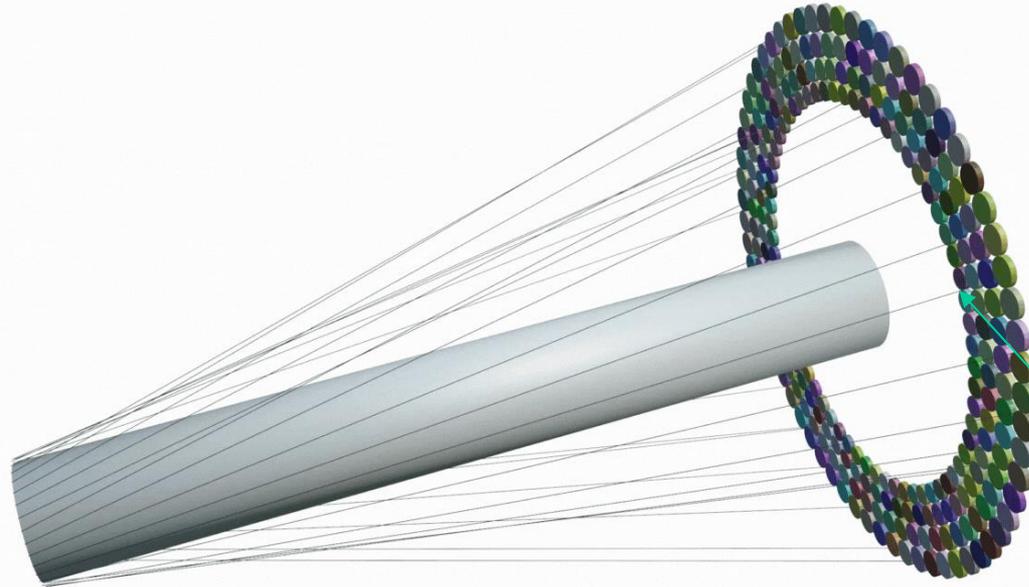
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References

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