MODELING TECHNIQUES FOR BRAIDED STENT DEVICES

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INTRODUCTION

Braided stents offer a good solution to treat **vascular diseases** through a minimally invasive intervention. They are composed of **interlaced wires,** wrapped around a cylinder or other shapes. While the use of mathematical modeling allows investigating the mechanical behavior of braided devices and could help clinicians in the best device selection, FE simulations are still too complex and computationally expensive. Since most numerical issues are related to the high number of **contacts** among the stent wires, in this work two possible solutions are compared in terms of accuracy and computational time. Both approaches are based on beam elements and use implicit or explicit solver.

MATERIALS AND METHODS

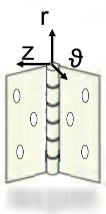
The simulations were conducted in **ABAQUS.** A **MATLAB** code was implemented able to create parametric geometries, mesh and connectors.

Contact modelling

Wires → beam elements (B31).

1. Connector

at the points of overlapping
type: Hinge
Implicit



✓ fast
☒ simplified

*View options
beam profile: scale factor 0.3

2. General contact

penalty: 0,2
Explicit

✓ more realistic interaction
☒ slow

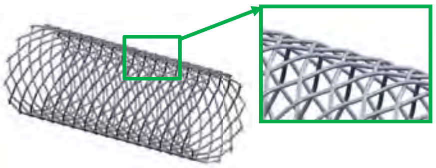
Geometry & Material properties

Resembling the **Wallstent** endoprosthesis (Boston Scientific)

$$x(t) = (Rstent + Rwire \cdot \cos(t \cdot Nwire)) \cdot \cos(t)$$

$$y(t) = (Rstent + Rwire \cdot \cos(t \cdot Nwire)) \cdot \sin(t)$$

$$z(t) = t \cdot \frac{Rstent}{\tan(\alpha)}$$



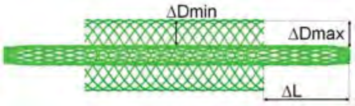
Geometrical Parameters	
Dstent	8 mm
Dwire	0,13 mm
Lstent	20 mm
Braiding angle	30°
Number of wires	2·12

Material Properties	
E	35,9 GPa
ν	0,33
σ_{yield}	489 MPa

Boundary conditions & investigated parameters

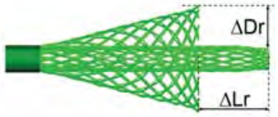
A) Crimping

A catheter is used for the in vivo stent deployment. The crimping is the diameter reduction of the device down to the catheter size.
A frictionless contact with a cylindrical surface is used.



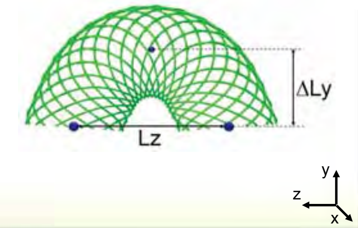
B) Release

Starting from the crimped configuration, the confining surface is axially shifted, allowing the self-expansion of the stent and mimicking the deployment process.



C) Bending

Stent flexibility is crucial since vascular tracts can be tortuous. A bending simulation of the stent in free-expanded configuration was then performed, using MPC constraints with two reference points that are rotated of 1,5 rad. One extremity is let free to translate along the z-axis.



RESULTS

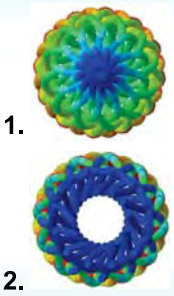
We considered the results in terms of local (von Mises stress) and global quantities (forces and displacements). In particular, the total radial force acting on the crimping surface (RF) and the reaction moment measured in the reference points (RM) are reported. Computational times were also analyzed.

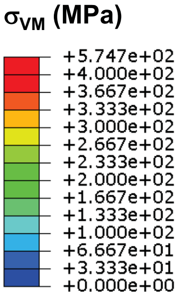
In the case of the explicit simulations, a step time of 1 and a target time increment of 10^{-6} was used so that the kinetic energy of the stent was negligible with respect to the internal energy.

CPU time (sec)	Crimping	Release	Bending
1	326	80	169
2	42537	44562	36265

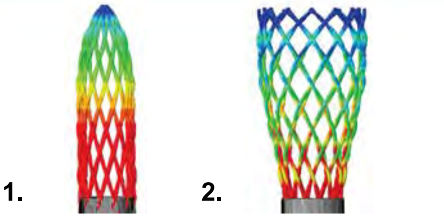
A) Crimping

	ΔDmax (mm)	ΔDmin (mm)	ΔL (mm)	RF (N)	σ_{VM} max (MPa)
1	3,849	2,918	9,358	3,38	379,044
2	3,317 - 3,345	2,917	9,359	3,51	440,566



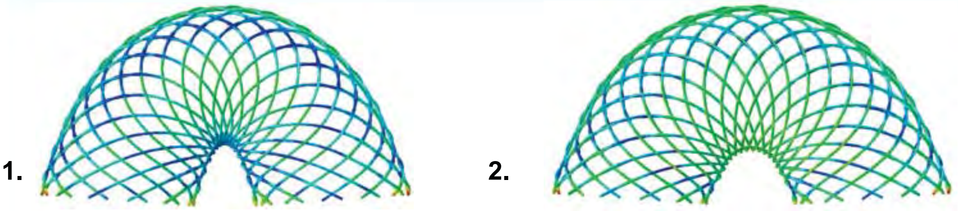


B) Release



	ΔDr (mm)	ΔLr (mm)	σ_{VM} max (MPa)
1	0,0214	0,0001	390,475
2	1,133	0,547	574,7

C) Bending



	ΔLz (mm)	ΔLy (mm)	RM (Nmm)	σ_{VM} max (MPa)
1	9,080	6,532	2,475	385,780
2	7,744	6,543	2,218	393,087

CONCLUSIONS

	COMPUTATIONAL EFFICIENCY	TEST A-C	TEST B
Model 1	Efficient	Quite similar to model 2, although some wire interpenetrations occur	Limited when considering challenging situations
Model 2	Not efficient	More realistic wire interactions	Realistic results

Contact model 1: although the more favorable timing makes it appealing for a possible **clinical use**, further improvements need to avoid very unrealistic results (e.g. case B).

Contact model 2: given the greater accuracy of the contact modeling this technique could be used during the **design stage** of new devices

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