The effect of heat treatment on the mechanical behavior of an ASTM-F2063 nitinol stent intended for venous application

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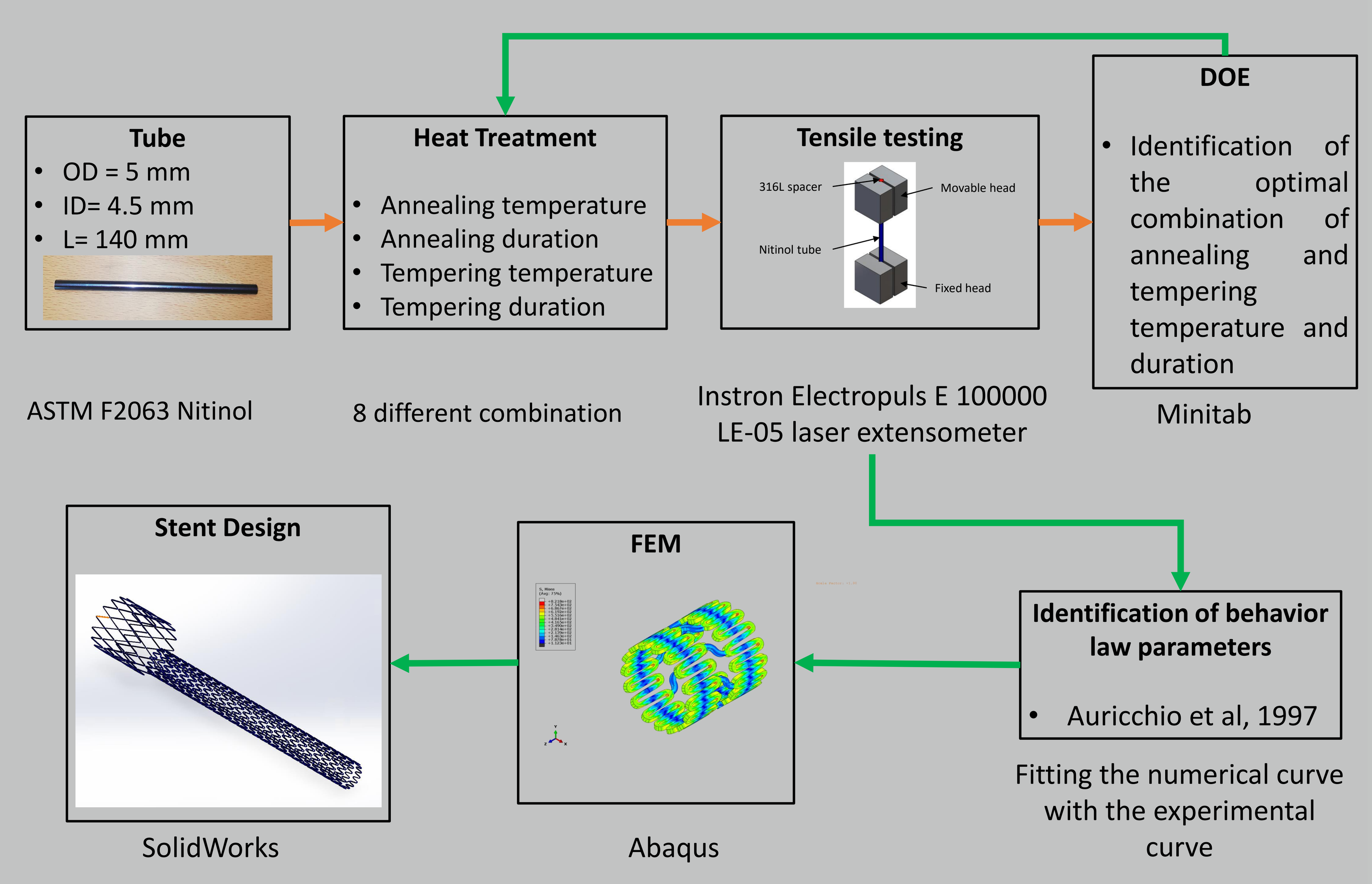
Objectives

1. Discuss the effect of heat treatment on the behavior of an ASTM-F2063 biomedical nitinol.
2. Maximizing the superelastic capacity of the stent in order to avoid irreversible plastic slippage and minimize the stiffness of the stent to limit the pressure on the diseased venous system.
3. Identifying the parameters of the material's constitutive law in order to simulate the behavior of the stent under mechanical loading.

Abstract

Super elastic nitinol is an adaptive material belonging to the shape memory alloys (SMA) family. This material can reach a higher level of deformation and has the ability to return to its initial configuration by a simple discharge. This specific behavior and its biocompatibility favor the use of this material in the medical field with numerous applications. Among the best known medical applications of superelastic nitinol are self-expanding stents. In this work, the effect of heat treatment on the behavior of an ASTM-F2063 biomedical nitinol is studied. The main objectives of this work are, on the one hand, to maximize the superelastic capacity of the stent in order to avoid irreversible plastic slippage and to minimize the stiffness of the stent in order to limit the pressure on the diseased venous system and, on the other hand, to identify the parameters of the material's constitutive law in order to simulate the behavior of the stent under mechanical loading.

Methodology



Heat Treatment Effects on the Mechanical Behavior of nitinol

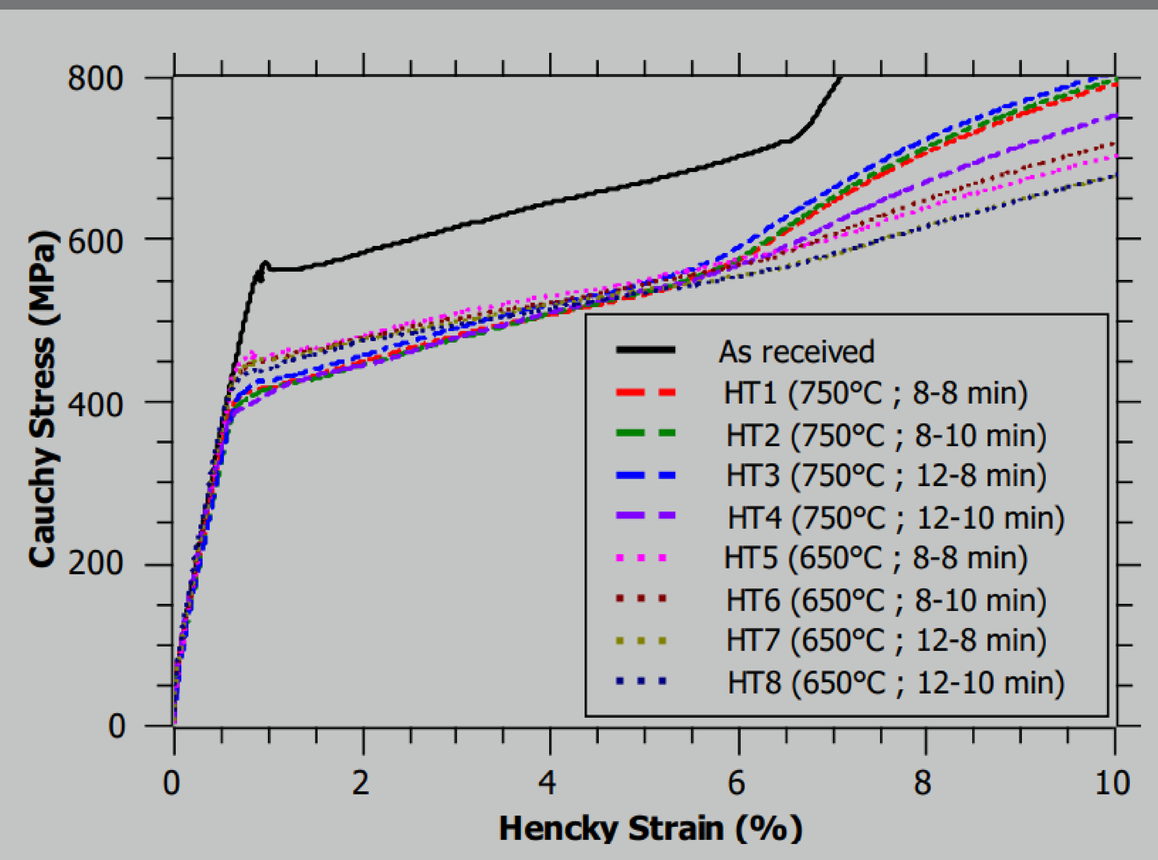


Figure 1: Comparative Tensile Test Curves of nitinol Samples with Varied Heat Treatments

Acknowledgements

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DOE results

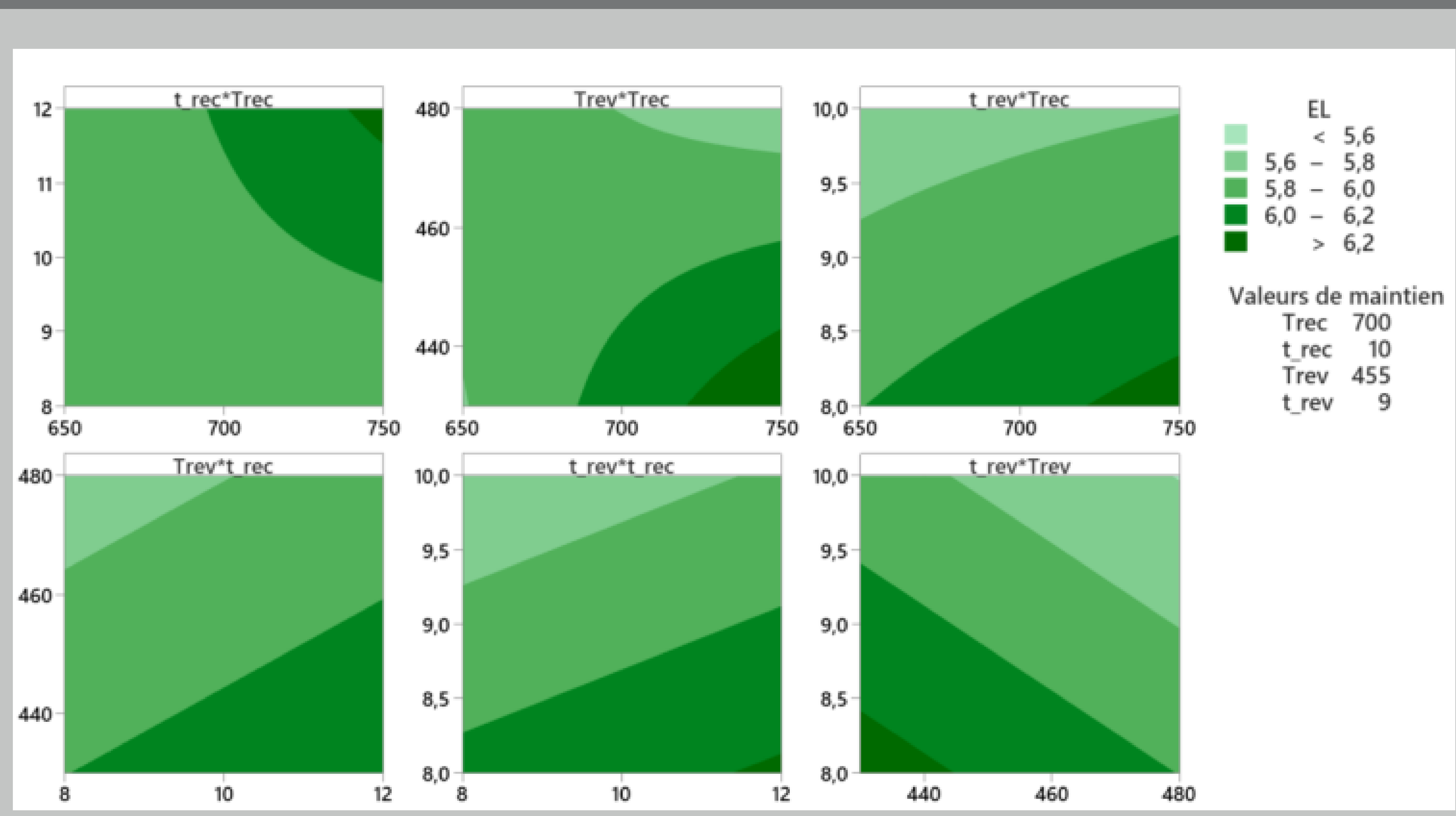

Figure 2: Contour plots of ε_L

Table 1: Optimized values of annealing temperature and duration, as well as tempering temperature and duration.

$T_{annealing}$=700℃; $t_{annealing}$=10 min; $T_{tempering}$=455℃; $t_{tempering}$=9 min

Model response

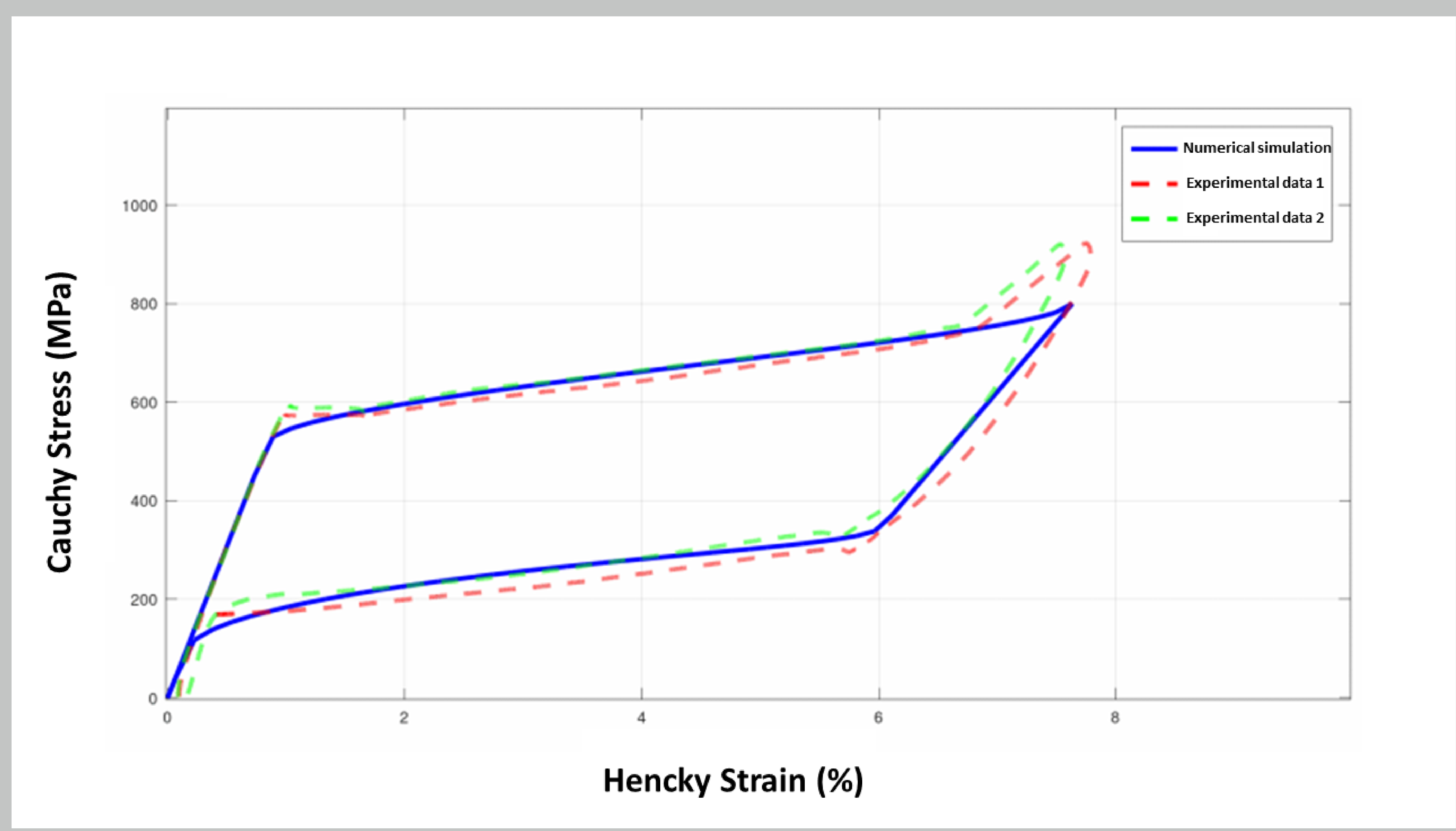

Figure 3: Experimental and Simulated Stress-Strain Behavior with Optimized Heat Treatment

Table 2: Model parameters for ASTM-F2063 nitinol [1]

Parameter	Value	Parameter	Value	Parameter	Value
E_A (MPa)	61540	E_M (MPa)	28230	ν_A	0.33
ν_M	0.33	ε_L	0.05	σ_s^{AM} (MPa)	540
σ_f^{AM} (MPa)	800	σ_s^{MA} (MPa)	350	σ_f^{MA} (MPa)	100

Conclusions

In this study, a Design of Experiments (DOE) approach was employed to optimize the behavior of medical nitinol ASTM-F2063 and identify model parameters for simulating stent response, specifically using the Aurricchio model. Through careful experimentation and analysis, the following key findings have been obtained:

- Optimization of Nitinol Behavior: By systematically varying the heat treatment parameters, we were able to optimize the mechanical behavior of nitinol ASTM-F2063. The DOE study identified the optimal combination of annealing and tempering temperature and duration that maximizes the desired properties for stent applications.
- Model Parameter Identification: By correlating the experimental data with the simulation results using the Aurricchio model [1], the model parameters that describe the behavior of nitinol has been defined.

References

[1] Ferdinando Auricchio and Robert L. Taylor.
Shape-memory alloys: modelling and numerical simulations of the finite-strain superelastic behavior.
Computer Methods in Applied Mechanics and Engineering, 143(1):175–194, 1997.

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