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# Mechanics of Laser Cut Stent Grafts

Štěpán Major[1,a], Vladimír Kocour[1,b], Štěpán Hubálovský[2,c]

[1] Institute of Theoretical and Applied Mechanics/Academy of Sciences, Prosecká 809/76, 190 00 Prague 9, Czech Republic

[2] Department of Informatics, Faculty of Science, University Hradec Králové, Rokitanského 62,500 03 Hradec Králové, Czech Republic

[a] major@itam.cas.cz, [b] kocour@itam.cas.cz, [c] stepan.hubalovsky@uhk.cz

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**Abstract:** This article is dedicated to a finite element analysis of tubular, laser cut stent grafts with peak-to peak bridge geometry under representative cyclic loading conditions for abdominal aortic aneurysm repair. Cardiovascular diseases are the principal cause of death in the developed world. For computational analysis, ANSYS software was employed to study the mechanical behavior of stents. Contrary to conventional engineering materials, nitinol stent fracture is not stress based but strain based. The effects of crimpling and cyclic pressure loading on stent–graft fatigue life were simulated and analyzed.

## Introduction

Stent-grafts are tubes made out of wire or by cutting laser meshes that are inserted into arteries to help keep them open so blood can flow properly. The stent is mounted on a balloon catheter and delivered to the site of blockage. Endovascular aneurysm repair has clear benefits when compared with conventional open surgery in terms of less trauma, earlier return to daily activities, reduced mortality, and lower morbidity. However, stent–graft failure, i.e., implant migration, device fatigue, and endoleaks resulting potentially in abdominal aortic aneurysms rupture, remains a major concern [1,2,3].

## Stent graft geometry and material

**Peak-to peak bridge geometry of stents.** Virtually all previously published analyzes, however, dedicated stents with a diamond shape geometry [1,3]. This study is dedicated to stents with peak-to peak bridge geometry, see Fig. 1.

**Material.** Nitinol alloys exhibit two closely related and unique properties: and shape memory. Shape memory is the ability of nitinol to undergo deformation at one temperature, then recover its original, undeformed shape upon heating above its "transformation temperature". Superelasticity occurs at a narrow temperature range just above its transformation temperature; in this case, no heating is necessary to cause the undeformed shape to recover, and the material exhibits enormous elasticity, some 10-30 times that of ordinary metal. A self-expandable nitinol stent-grafts repair utilizes these characteristics rather well. Cooled to less than 5 C, it fully transforms into martensite and hence becomes very deformable and easily compressed into a small catheter. Contrary to conventional engineering materials, nitinol fracture is not stress based but strain based.

## Modeling

**Geometry modeling.** Nitinol stent model with a total of 16 bridges or cells and 5 rings built into the tubular stent. Because stent and graft are sutured together, a tight, rigid contact is assumed to simulate the interaction between stent and graft interaction between stent and graft. Fully expanded stents has a length L of 20 mm, an outer diameter D of 5 mm, a thickness s of 0.1 mm.

**Material modeling.** The two materials of the artery wall, arterial tissue and stenotic plaque, were modelled using a 5-parameter third-order Mooney–Rivlin hyperelastic constitutive equation. This has been found to adequately describe the non-linear stress-strain relationship of elastic arterial tissue. The general polynomial form of the strain energy density function in terms of the strain invariants, given by [1,3] for an isotropic hyperelastic material is

$$W(I_1, I_2, I_3) = \sum_{i,j,k=0}^{\infty} a_{ijk}\,(I_1 - 3)^m (I_2 - 3)^n (I_3 - 3)^o$$

$$a_{000} = 0 \qquad (1)$$

where $W$ is the strain-energy density function of the hyperelastic material, $I_1$, $I_2$ and $I_3$ are the strain invariants and $a_{ijk}$ are the hyperelastic constants.

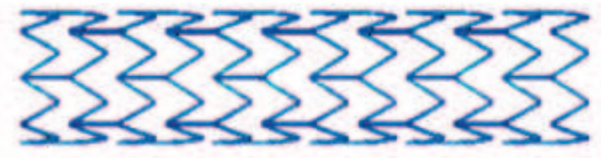

Fig. 1: Peak-to-peak bridge geometry of stent-graft.

## Simulation

The ANSYS Finite Element Analysis package, in combination with user-defined material subroutines for the nitinol material properties, was employed to calculate the stress and strain fields. The governing equation for the structure(s) was the condition for static equilibrium, where zero body loads were applied:

Stent is loaded by: 1) Crimping is used to compress an expanded stent graft into a delivery system; 2) In the sealing section, the arterial wall prevents the stent graft from completely expanding, which implies the stent is under compression and the graft material may not encounter significant tensile stress. 3) When the stent graft is deployed in the artery main body of stent-graft is under cyclic loading as a result of pulsatile blood flow.

## Results

It was found that the maximum strain is located at the strut's internal side, bridge connection. The maximum crimping strain for NITI is 7.8%, which is lower than in the case of diamond shape stents. Thus, in terms of crimping performance, the peak-to-peak bridge geometry of stents is preferable to diamond shape geometry. Under representative cyclic pressure loading, sealing stents are located in the safe zone of the fatigue life zone.

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