Study of Stent Deformation and Stress Developed at Different Stent Deployment Pressures

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Abstract

According to clinical reports, cardiovascular disease has become a major global health care problem in the present decade. To tackle this problem, the use of the cardiovascular stent is considered promising and effective for certain conditions. In the technical vocabulary of medicine, a stent is an artificial 'tube' inserted into a natural passage/conduit in the body to provide a mechanical support to the diseased vessel and prevent, or counteract, a disease-induced, localized flow constriction. Usually it is a small, meshed metal tube placed into an artery to compress the plaque and widen the vessel wall. Recently many polymeric braided stent structures have also undergone successful clinical trials.

While satisfactory results are being obtained with stent interventions, yet the risk of restenosis (stenosis in the vessel post stent interventions) remains high. Evidences of stent fracture have been related with deployment pressure of stent as well as fluid structure interaction. Many studies have shown high correlations between restenosis and the stresses that develop within a stent after deployment. Hence there is a dire need of simulating the different stresses that a stent needs to undergo during and post deployment procedure. The modelling of a single cell of a rectangular slotted coronary stent was developed using COMSOL Multiphysics 4.2a. The Structural Mechanics module has been used. Materials studied were 316L Stainless Steel, Nitinol (Ni-Ti alloy), Elgiloy (Co-Cr alloy) and Tantalum. Three different load values have been used for deploying the stent- 2atm, 7 atm, and clinically relevant 12 atm. Symmetry boundary planes have been used to prevent rigid body translation in Y and Z directions and rotation around all axes. A fixed point constraint in X direction has been used to fix the rigid body translation. A physics controlled fine mesh has been generated and grid sensitivity with finer grains have been compared. Stationary Parametric solver has been used for the solution. Initial studies with 316L Stainless Steel show a maximum displacement of 1.68mm (Figure 1). Von Mises Stress gives a maximum value of 850 MPa at 12 atm stent deployment pressure (Figure 2), whereas at 2 atm it attains a max value of 171 MPa. Since of UTS (Ultimate Tensile Strength) of 316L SS is 550 MPa, there is a risk of stent fracture in case of 12 atm. In case of Nitinol, Von Mises Stress is 237 Mpa at 2 atm and 633 MPa at 12 atm (Figure 3). The UTS of Ni-Ti is 1268 MPa hence expectedly stent fracture won't occur. This shows a high correlation between deployment pressure and UTS of a material. Along with the maximum value of stress developed, the stress concentration near the strut-link joint is also significant for stent fracture. Fluid Structure Interaction also contributes significantly to the stress development. Principal stress, strain energy density will also be studied. Non Newtonian pulsatile flow across stent wall needs to be analysed. Also the arterial stresses that develop due to stent deployment needs to be

accounted during stress analysis of coronary stent implantations.

Reference

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Figures used in the abstract

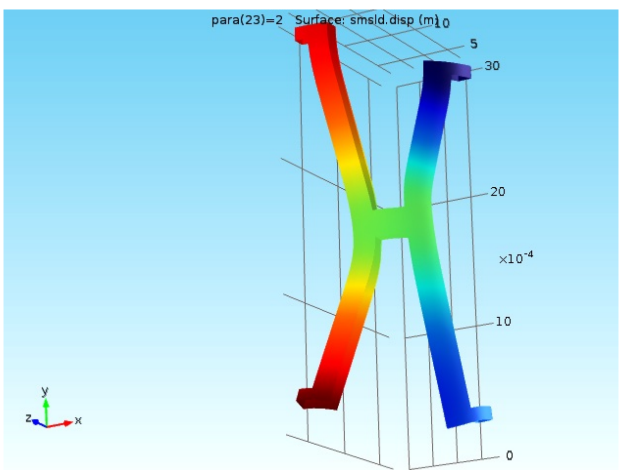

Figure 1: displacement of 316L - SS.

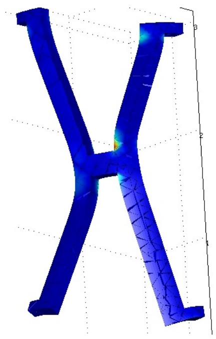

Figure 2: Von Mises Stress of 316L-SS at 12 atm.

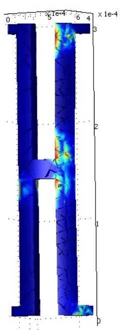

Figure 3: Von Mises Stress of Ni-Ti at 12 atm.