Fatigue Analysis of Nitinol Stent Used in Endovascular Aneurysm Repair (EVAR) Considering Anisotropic Aortic Walls

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In this work, a fatigue/failure analysis of Nitinol stents such as those employed in endovascular aneurysm repair (EVAR) is presented. The study is conducted for one billion hemodynamic cycles, that is more than 15 years of service life. The strain-stress curves are obtained using the fluid-structure interaction (FSI) analysis in Abaqus/Simulia and the high-cycle loading fatigue analysis is done on Ansys.

The stent we use for the study is a honeycomb closed-cell structure. It our own design. The geometry of the aorta is a cylindrical shell with three concentric layers. The aorta is modelled with the Holzapfel–Gasser–Ogden (HGO) hyperelastic equations which account for the anisotropy of the aorta. We use Nitinol superelastic property to study the stent structural fatigue. This is done with the Smith-Watson-Topper (SWT) model which takes into account the mean stress on the structure. The fatigue behaviour is obtained from fatigue life, fatigue damage, fatigue safety factor and a biaxiality indication contour plots.

Results indicate that the stent can withstand 10 years of pulsatile hemodynamic load, as recommended by the US. Federal Food & Drug Administration (FDA). The fatigue safety factor (FSF) decreases as the number of cycle increases. Increasing the load by 25% decreases the stent life by approximately half (down to 5.61e8 cycles) and doubling the load results in the stent failing. Areas of the stent struts subjected to pure uniaxial load are shown to be most prone to failure.

This study can give insights into the optimal design of self-expanding stents in addition to new directions to improve their functionality.