HEMODYNAMICS AND FATIGUE ANALYSIS OF VASCULAR STENTS WITH COVERED MEMBRANE

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SUMMARY
The stents have to sustain up to a few hundred million cycles induced by the cyclic diameter change of coronary arteries. Among all side effects of vascular stents, the fracture of stents has been recognized as a common complication following stent implantation for all cardiovascular applications. Other medical devices such as heart valves are also subjected to this potentially adverse event. In this paper, we analyze the deformation, and mechanical behavior of the vascular stent when implanted into a patient-specific carotid artery. Commercial finite element software was used for the modeling and stress analysis, and Goodman method was applied to the fatigue analysis. Based on the fatigue safety factors, the highly possible fracture locations can be identified. The present work will expanded to covered stents with membranes.

INTRODUCTION
Stroke is the leading cause of disability in the United States and the third cause of death in developed countries. It’s also the fourth cause of hospitalization in Singapore. It’s estimated that 50% of ischemic stroke is related to carotid artery stenosis (Figure 1).

Though vascular stents are very successful in treating coronary artery diseases, however, it is not so successful in carotid arteries diseases. Also, compared with Carotid Endarterectomy (CEA), Carotid Artery Stenting (CAS) is less common and the cost is higher. The statistics of CAS and CEA performed in US shows a significant increase in the number of carotid stenting between 1998 to 2007 with a decrease in number on open surgery carotid endarterectomy. Though carotid stenting seems to be a perfect solution for carotid artery stenosis, however, the carotid stents used are basically modified from coronary and lower limb stents which aim to treat obstructive arterial disease rather than embolic disease. Some studies show that covered stents [1] and close cell design stents [2] are somewhat better in this regard but not significant and come along with other issues.

In this paper, we analyzed the deformation, and mechanical behavior of the carotid artery stents. Commercial finite element software ANSYS was used for the modeling and stress analysis, and Goodman method was applied to the fatigue analysis. The final target will be the design of new carotid artery stents which provide better performance.

METHODS
Both Palmaz and other types of stents are built using design tools and the finite element models are then constructed. The Material for stent is stainless steel and Platinum–10% iridium. The material properties are listed in Table 1.

We apply the Goodman method [3] for the stent fatigue analysis. In this method a graphical approach for relating alternating stress (σa) and mean stress (σm) with the material strength limits is used. σm and σa in the stent depended on the pressure variation during the cardiac cycle. The maximum principal stress component at the beginning (Pmin=0MPa) and end (Pmax=0.1MPa) of the external pressure-loading step, is used to calculate σm and σa. Fatigue safety factor (FSF) and contour plot of 1/FSF are calculated based on [4] as

\[
\frac{1}{FSF} = \sigma_m + \sigma_a
\]

where Sult is the ultimate strength and Se is the fatigue endurance strength.

RESULTS AND DISCUSSION
The fluid dynamics analysis was tried first for the carotid artery before the fatigue analysis. Figure 2 shows the wall shear stress (WSS) distribution of the artery under constant
flow (0.45 m/s). Figure 3 shows the stress concentration of the stent.

**Figure 2**: Carotid artery wall shear stress.

**Figure 3**: Stress concentration of the stent.

More detailed study results will be reported accordingly.

**CONCLUSIONS**

To improve stent performance in carotid artery, numerical modeling and simulation method was used for hemodynamics and stent fatigue analysis based on some assumptions. Preliminary simulations can give carotid artery hemodynamics and the corresponding stent fatigue information. Fully fluid structure models will be used in the following detailed studies. The current numerical method will validate the prototypes and provide guideline for carotid stent design.

**Table 1**: Material properties of stent and membrane

<table>
<thead>
<tr>
<th>Materials</th>
<th>Density (kg/m³)</th>
<th>Young’s modulus (MPa)</th>
<th>Poisson’s ratio</th>
<th>Yield stress (MPa)</th>
<th>Ultimate strength Sₘₜₜ (MPa)</th>
<th>Fatigue endurance strength Sₑ (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stent A</td>
<td>7860</td>
<td>193000</td>
<td>0.27</td>
<td>217</td>
<td>617</td>
<td>309</td>
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<tr>
<td>Stent B</td>
<td>21502</td>
<td>224</td>
<td>0.37</td>
<td>285</td>
<td>875</td>
<td>263</td>
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<tr>
<td>Artery</td>
<td>1050</td>
<td>1.75</td>
<td>0.499</td>
<td></td>
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**REFERENCES**