A System to Quantify 3D Spatial Deformation of Heart Valve Leaflets

Team 8

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Client: Dr. Wei Sun, University of Connecticut, weisun@engr.uconn.edu
Overview

• Introduction
• Project Description
  – Objective
  – Methods
• Budget
• Conclusions
EXECUTIVE SUMMARY
• Heart valve replacement is common treatment for heart valve disease
• Fail because of design
• Create device to measure strain
• Provide comparison between available valves
1.1. Background

1. INTRODUCTION
• Dr. Wei Sun has research experience with the biomechanics of heart valve biomaterials

• Dr. Sun would like to quantify 3D bioprosthetic heart valve (BHV) deformation, obtaining data for several different kinds of heart valves
1. INTRODUCTION

1.2. Purpose
• Design and construct device to measure strain during static and dynamic loading.
• Results will compare various BHVs
• Valve with best design will show better distribution of strains
• Information will aid in improving design of future valves
1. INTRODUCTION

1.3. Previous Work

1. INTRODUCTION
• Commercial products available are used to simulate complex pressure cycles
• Dr. Sun has worked with similar setup
  – Tested one particular BHV
  – Loaded at quasi-steady state
2. PROJECT DESCRIPTION

2.1. Objective
Goal of Valve Design

- Eliminate Stress Concentrations
- Eliminate Backflow and Back Pressure
- Increase Valve Longevity
  - Heart Beats Approximately 100,000 Times a Day
Proposed System Components

- Fluid Chamber
  - Houses valve
- Strain Measurement System
  - Capture Deformation
- Pressure Transducerer
  - Measure Transvalvular Pressure
- Computer Algorithm
  - Numerically Construct Data
2. PROJECT DESCRIPTION

2.2. Methods
Valve Sizes and Types

- Mounting Plates need to be Specific
  - Eliminate Leakage
Capture Deformation

- Track Marker Movement
- Borescopes
- 3 Cameras—Costs vs. Benefits
Transvalvular Pressure

• Closed State: Highest Bearing Load
  – Transvalvular Pressure
• Opened State: Little-to-No Load
  – General Valve/Leaflet Shape
Deformation Gradient
Fung Model

\[ F = \begin{bmatrix} \lambda_1 & \kappa_1 \\ \kappa_2 & \lambda_2 \end{bmatrix} = \begin{bmatrix} 1 + \frac{\partial u_1}{\partial X_1} & \frac{\partial u_1}{\partial X_2} \\ \frac{\partial u_2}{\partial X_1} & 1 + \frac{\partial u_2}{\partial X_2} \end{bmatrix} \]
## Preliminary Budget

- **Major components supplied**
- **Keep budget to a minimum**

<table>
<thead>
<tr>
<th>Component</th>
<th>Material</th>
<th>Price Rate</th>
<th>Estimated Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid chamber</td>
<td>.220 inch clear acrylic Plexiglas</td>
<td>$5.84 Sq. Ft</td>
<td>$24</td>
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<tr>
<td>Fluid</td>
<td>Saline</td>
<td>$4.99/500ml</td>
<td>$20</td>
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<tr>
<td>Rotating base</td>
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</tr>
<tr>
<td>Mounting post</td>
<td></td>
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<td>$20</td>
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<tr>
<td>Interchangeable valve mounts</td>
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<td>$25</td>
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<tr>
<td>7&quot; Rigid borescope</td>
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<tr>
<td>Fluid pumping system</td>
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<tr>
<td>Pressure transducer</td>
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<tr>
<td>Cameras</td>
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<tr>
<td>Heart valves</td>
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<tr>
<td>Computer hardware/software</td>
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<td></td>
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</table>

Total Estimated Price: $119
4. CONCLUSIONS
• Heart valve strain measurement system with static and dynamic loading conditions
• Transvalvular pressure measured using a pressure transducer
• LabVIEW controlled with automatic data visualization and analysis
  – Marker techniques and the DLT algorithm will allow Abaqus to generate 3D images of the stress concentrations across each leaflet
• Superior experimentation
  – Rigorous experimental validation of numerical results
  – Dr. Sun’s accurate material properties modeling
Questions?