Improved Bioprosthetic Heart Valve Design: A 3D Computational Model To Assess the Effect of Geometrical Parameters on Structural Deterioration

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Introduction

Prosthetic Heart Valves

Mechanical Aortic valves
Thrombosis
Anticoagulation (fatal side effects)

Bioprosthetic Aortic Valves
No anticoagulation
A too short lifetime

➢ **The Goal**

Improvement of BAVs design:
- **Lower Pressure Drop**
- **Less Structural Valve Deterioration (SVD)**

Materials and Methods

➢ Modeling

The Geometry — **Loads** — **Material properties**

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Finite Element Models

Structural Analysis (ABAQUS)

Fluid Structure Interaction (Comsol)

➢ Design Parameters

(1) Leaflet Angle (2) Radial Curvature (3) Circumferential Curvature

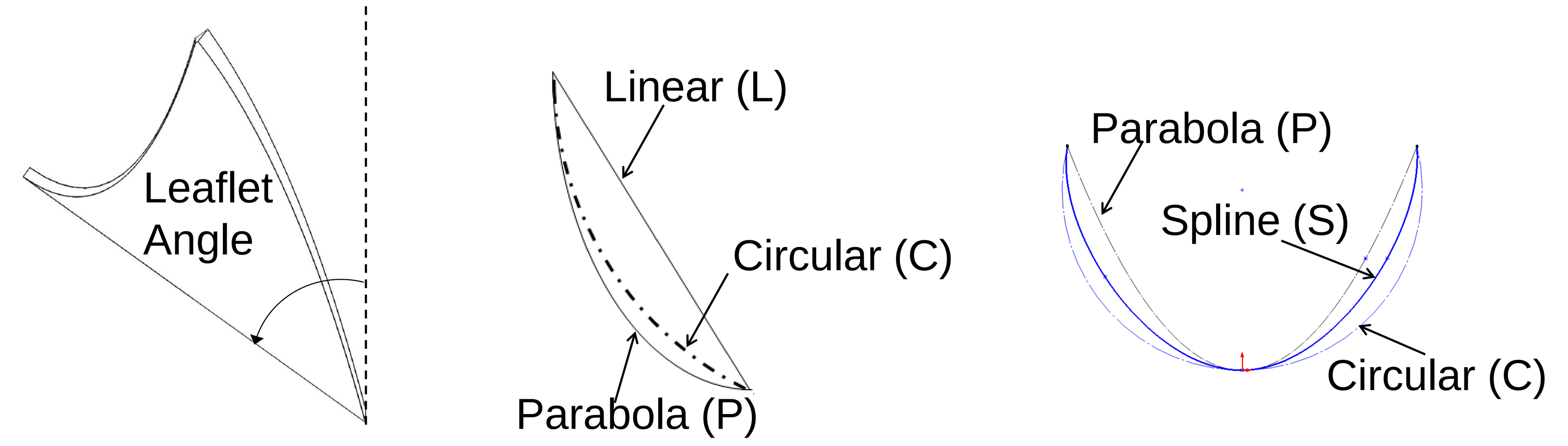

Table 1: Case studies with different curvatures and angles. LA: Leaflet Angle, RC: Radial Curvature, CC: Circumferential Curvature, L: Linear, P: Parabolic, C: Circular

Case	1	2	3	4	5	6	7	8	9	10
LA°	54	54	54	-	-	45	48	51	58	62
RC	L	L	L	P	C	L	L	L	L	L
CC	P	S	C	C	C	C	C	C	C	C

Results

❑ Pressure Drop was Altered by Design Parameters

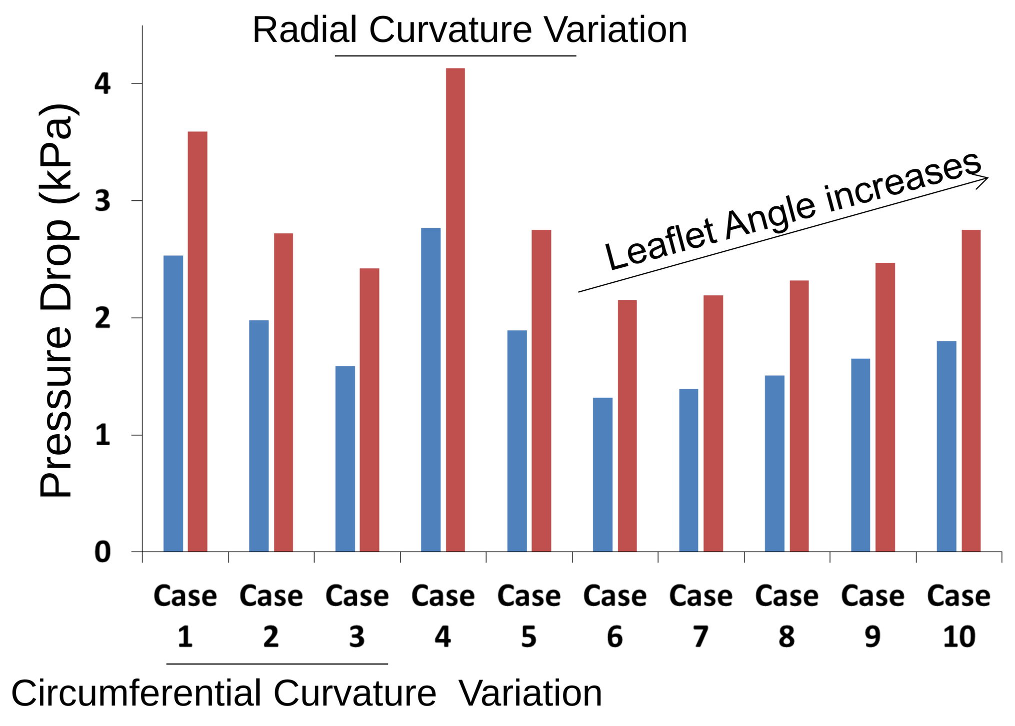

Fig. 1: The mean and maximum pressure drop across the valve. When a parabola was used for the circumferential (Case 1) or radial curvature (Cases 4), the pressure drops were the highest. A circular circumferential curvature, a linear radial curvature, and a leaflet more inclined toward the sinus led to lower pressure drops.

❑ Stresses were Altered by Design Parameters

Open Configuration

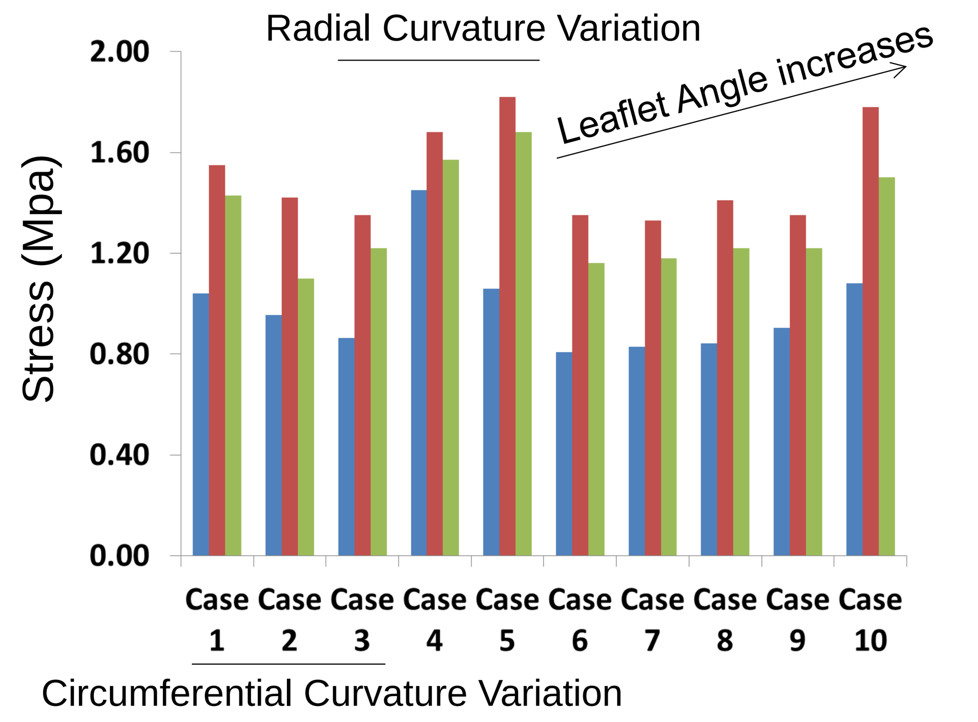

Fig. 2: von Mises (blue), first principal (red) and third principal (green) stresses when the valve was fully-opened (Time=0.19s-peak inlet flow). The value of third principal stresses was multiplied by -1. Note that in Cases 6-9, unlike the first and third principal stresses, von Mises stress increased monotonically.

Closed Configuration

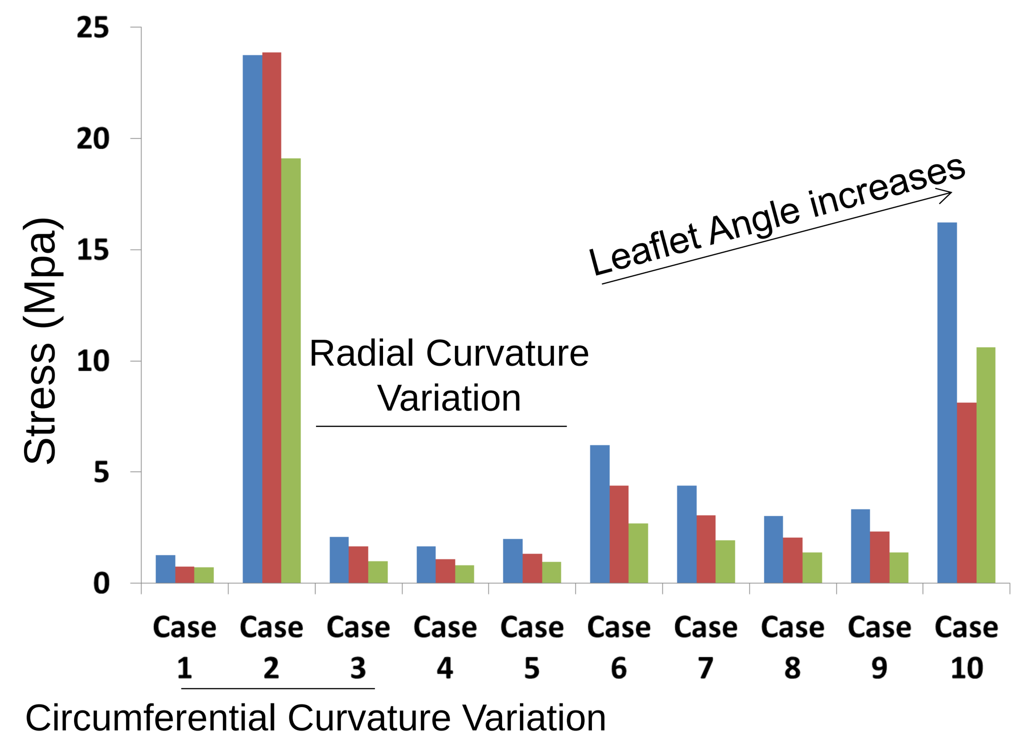

Fig. 3: : von Mises (blue), first principal (red) and third principal (green) stresses when the valve was closed. The value of third principal stresses was multiplied by -1. The stresses in the closed and open configurations, do not change the same way when design parameters changed.

❑ Leaflet Twisting due to Parabolic Curvature

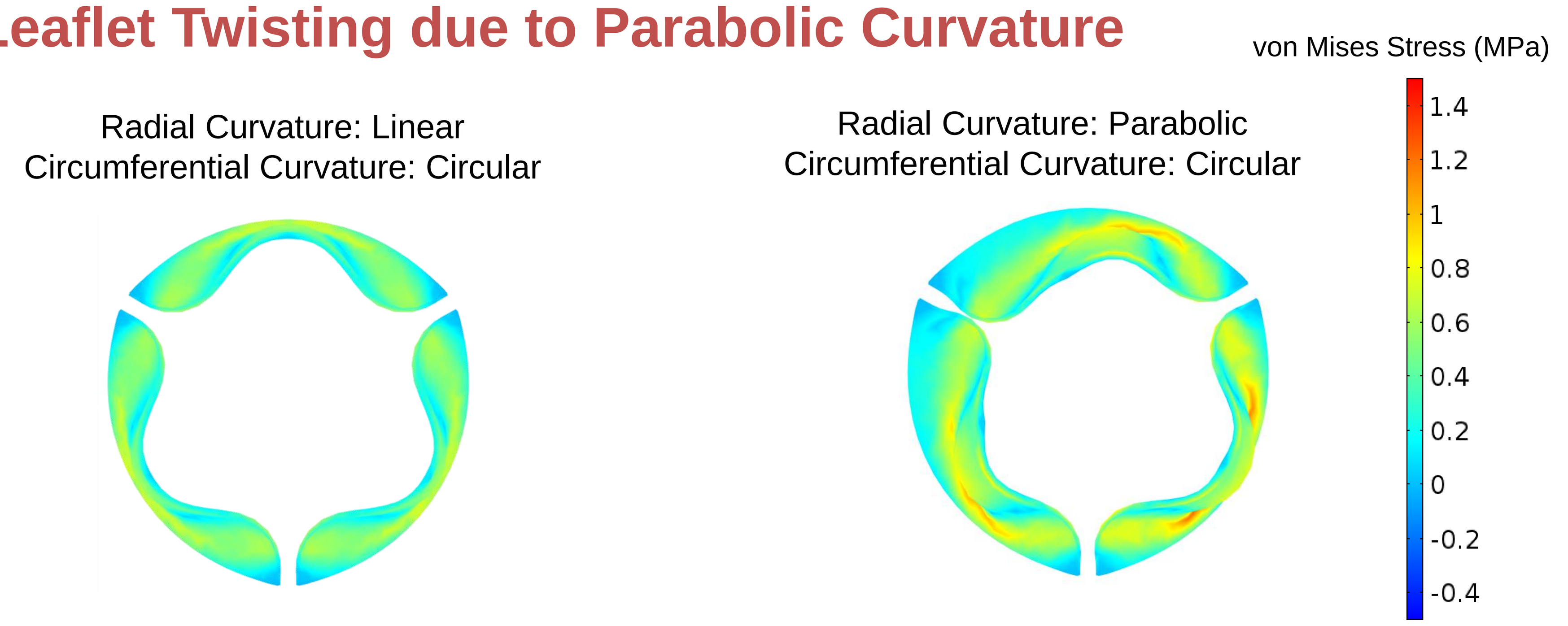

Fig. 4: A parabolic radial curvature caused leaflet twisting in valve dynamics.

❑ SVD and Locations of Maximum Stress

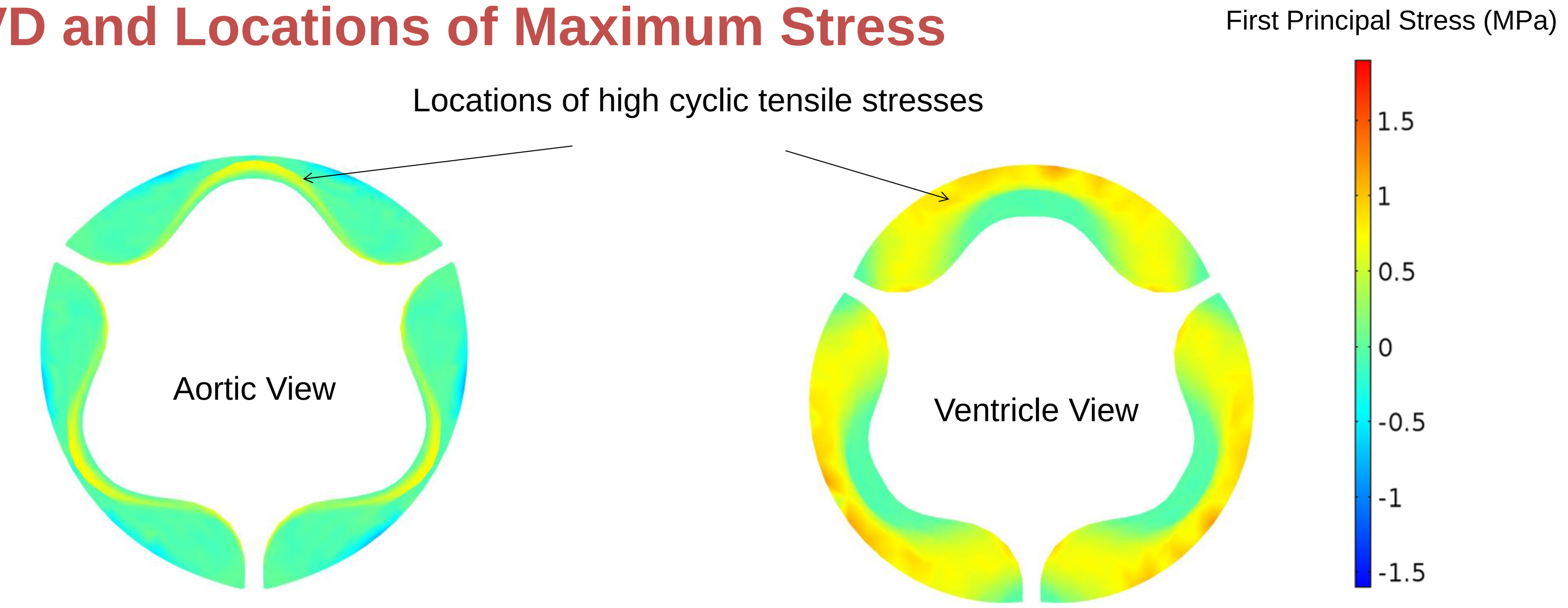

Fig. 5: The locations of high cyclic stresses confirms the locations of SVD reported in accelerated tests [1] and the buckling failure [2]. The compressive stresses pattern was similar.

Discussion

➢ A linear radial curvature, circular circumferential curvature, and/or a lower leaflet angle leads to lower pressure drop

➢ A parabolic circumferential, a non-linear radial curvature, and/or a larger leaflet angle could lead to:

Higher stress when the valve is **open**

Lower stress when valve is **closed**

➢ A valve design with a lower pressure drop might have higher chances of SVD

References

[1] Sacks MS, Schoen FJ. J Biomed Mater Res. 2002;62(3):359-371.
[2] Vesely I, Boughner D, Song T. Ann Thorac Surg. 1988; 46(3):302-308.