Outlet Volute Optimization of the Dragon Heart, a Total Artificial Heart for Pediatric Patients

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School of
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DISCLOSURE
USPTO Patent Issued and Patent Pending; No Other Disclosures

Motivation and Clinical Significance

- ~15 million children die or are disabled by cardiac disease
- ~40,000 born with Congenital Heart Disease
  - ~14,000 with Heart Failure(HF)
- HF Treatment:
  - Drug therapies to treat symptoms
  - Gold standard for end-stage HF is Heart Transplantation
    - Pediatric has the highest waitlist mortality (13-17%)
      - Limited donor organ availability
      - Donor-Recipient Size Matching
      - Limited Bridge-to-Transplant Therapies
  - Mechanical Circulatory Support (MCS)

[1-18,25]

Existing Technology

The use of MCS in children has increased from 63% to 73%

VADs

Bi-VADs

TAH

[6, 13-18, 24, 26-29]

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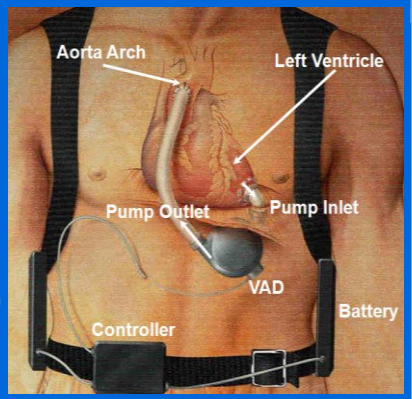
Ventricular Assist Device

VADs

- Supports 1 ventricle



Bi-VADs

TAH

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Ventricular Assist Device

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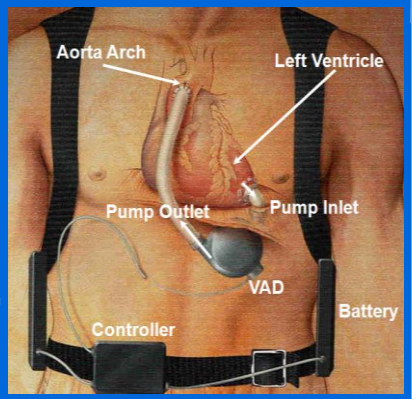
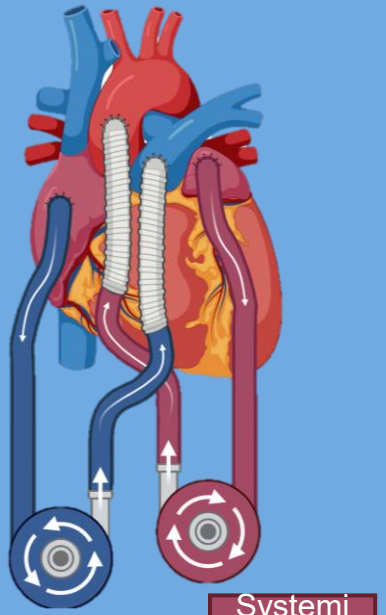
- Supports 1 ventricle



Bi-VADs

- Support both ventricles



TAH

[6, 13-18, 24, 26-29]

Existing Technology

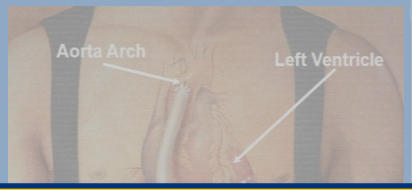
The use of MCS in children has increased from 63% to 73%

Ventricular Assist Device

Total Artificial Heart

VADs

- Supports 1 ventricle



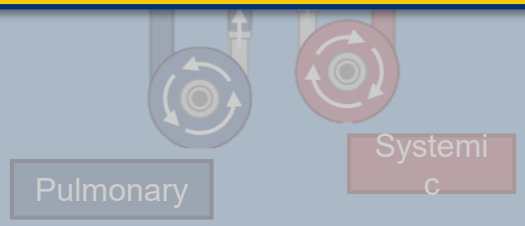
Bi-VADs

- Support both ventricles

TAH

- Support whole circulatory system

- Pediatric MCS development lags far behind adult devices
  - Need Total Artificial Heart (TAH) designed for children
  - Span the pediatric age range
  - Safe and effective Mechanical Circulatory Support (MCS)



- Only 1 Approved for Peds
  - Children > 11 y/o

[6, 13-18, 24, 26-29]

To address the unmet clinical need: We are developing the ***Drexel Dragon Heart (DH)***, a novel hybrid, continuous-flow, magnetically levitated TAH for pediatric patients

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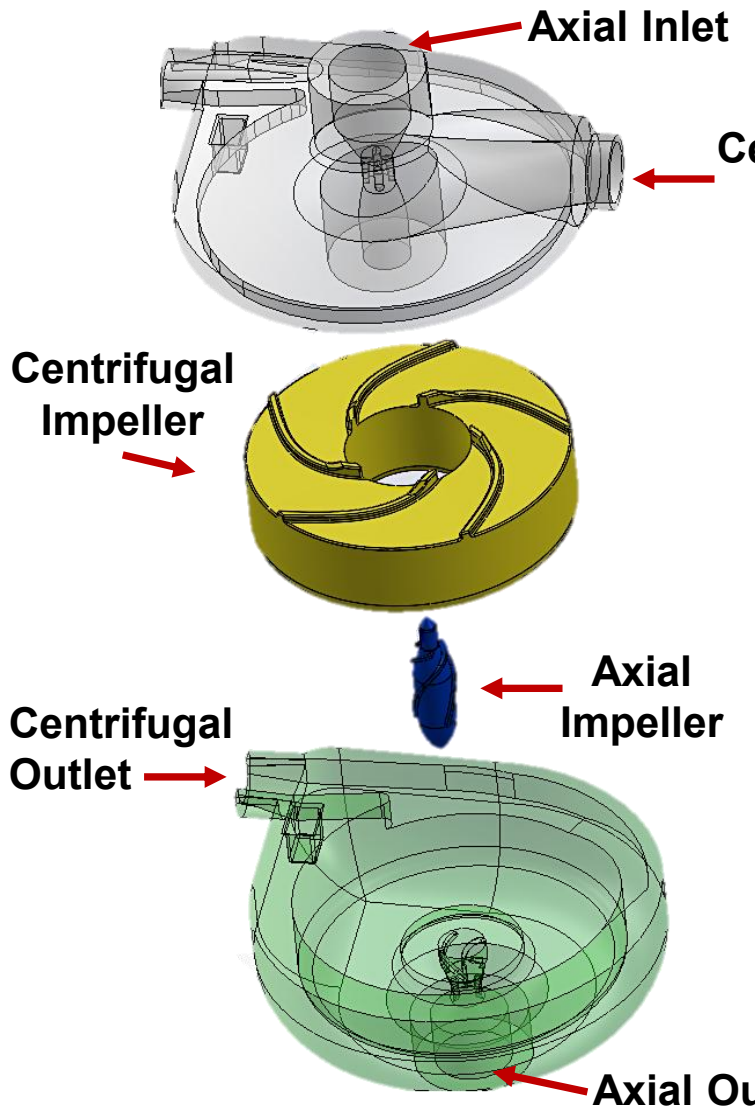
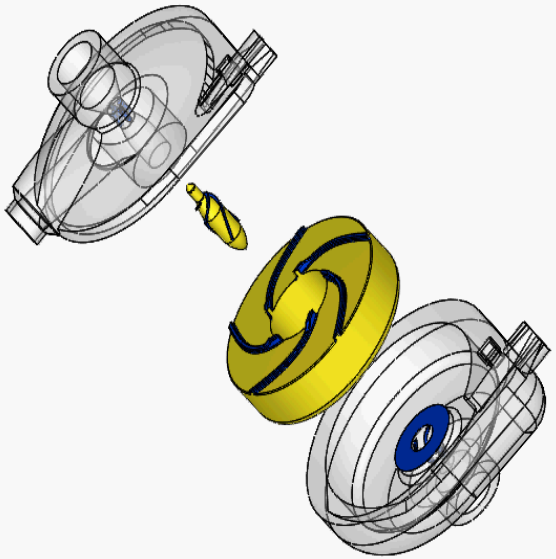
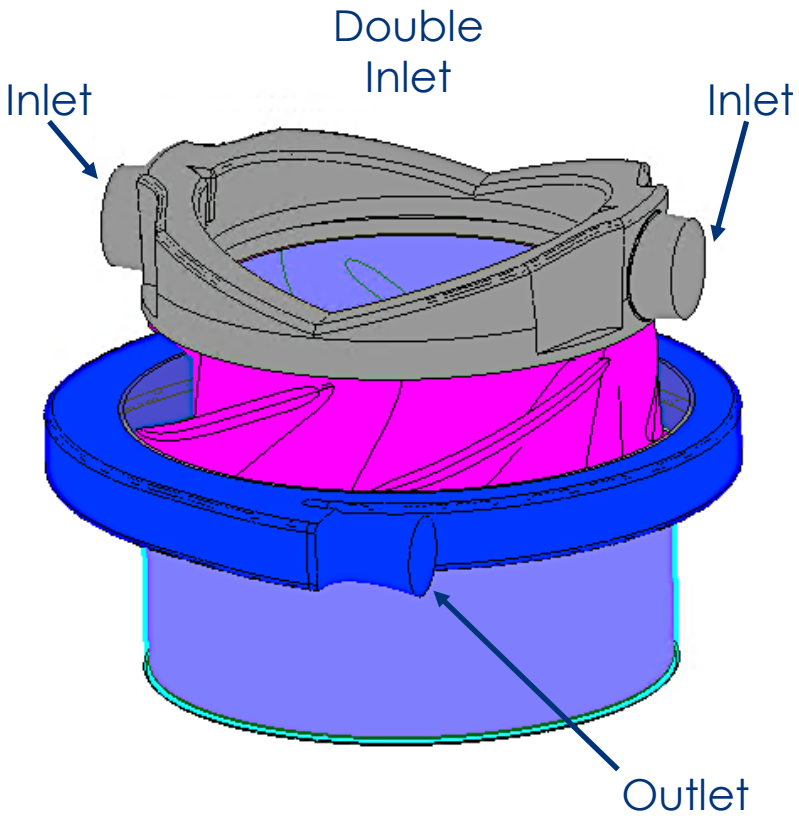
Axial Impeller

The DH's Innovation

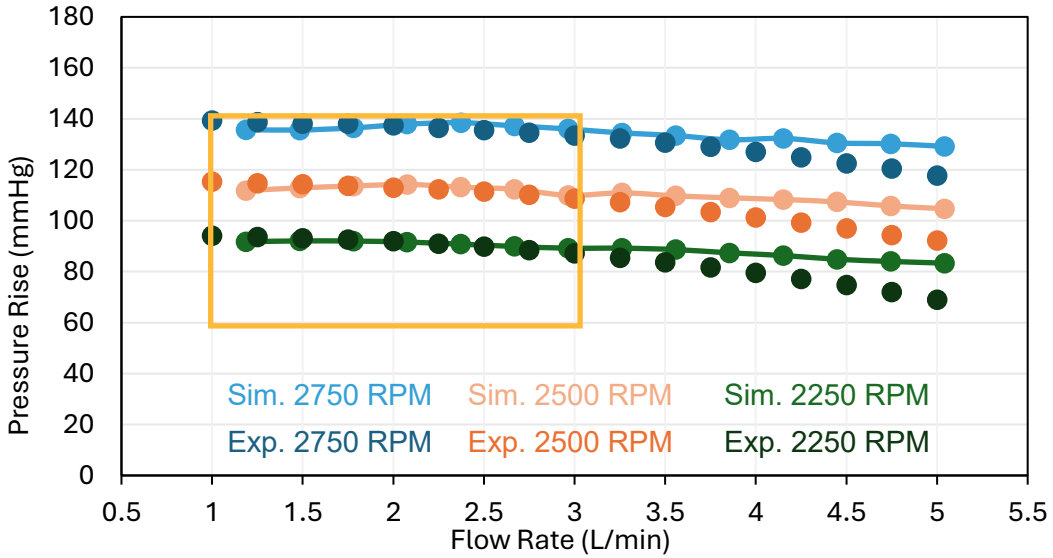


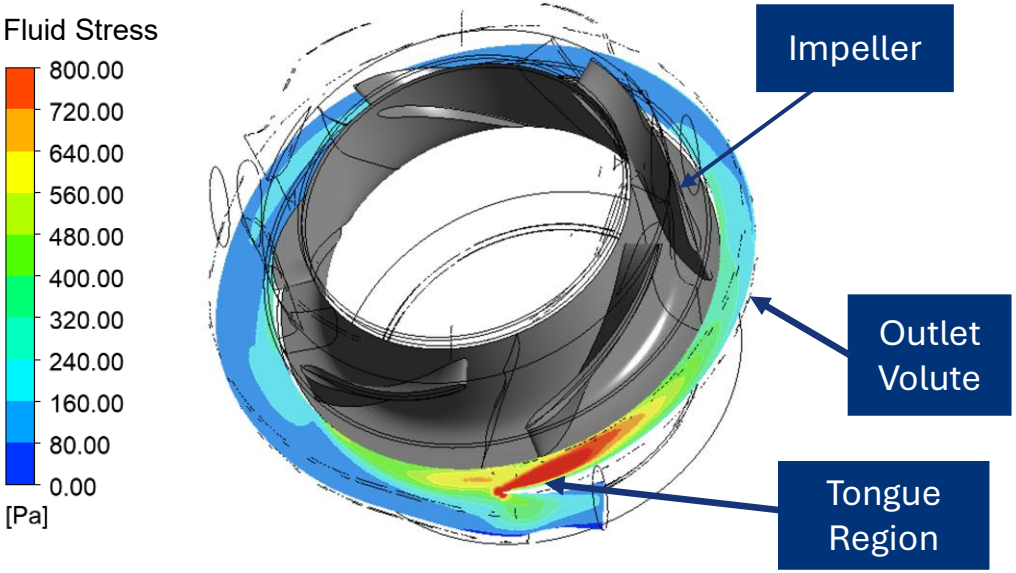


Previous Work: DH7



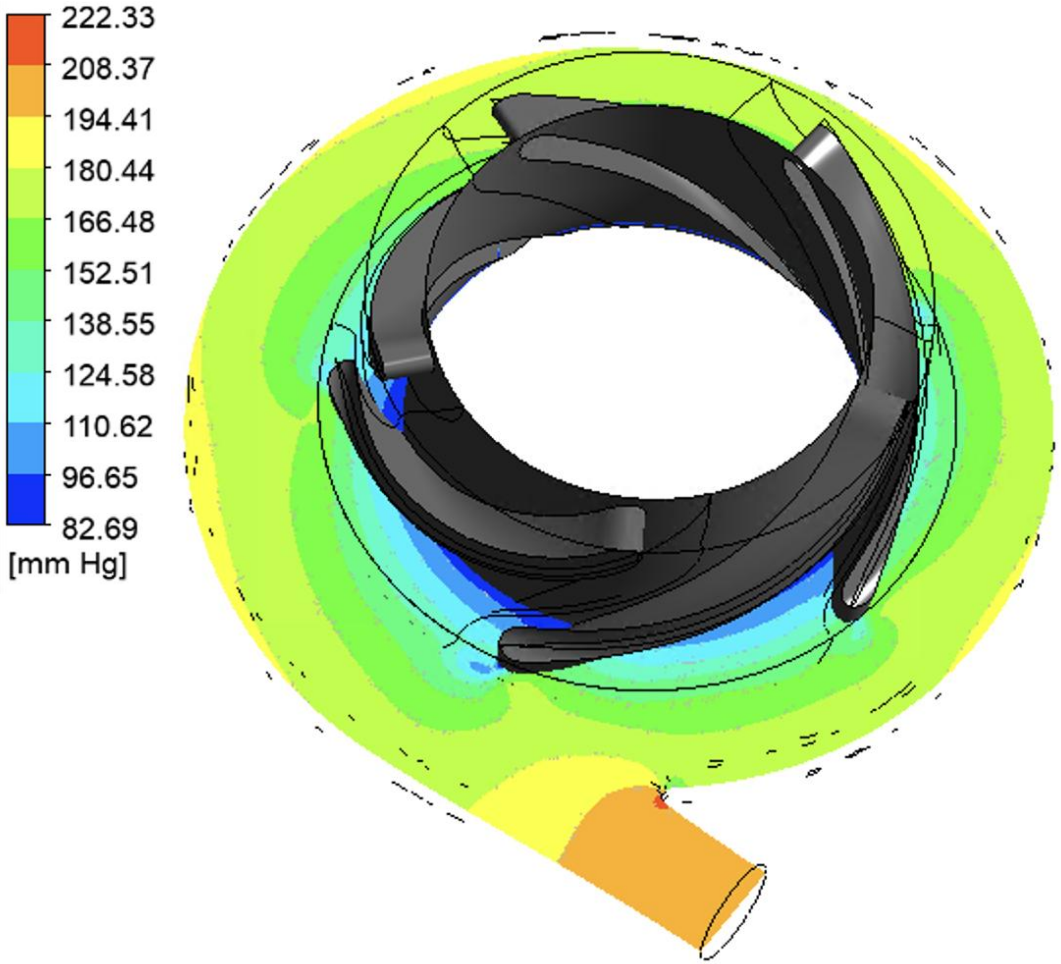
Diameter: 56 mm





[19-23, 30-34]

Outlet Volutes of Blood Pumps

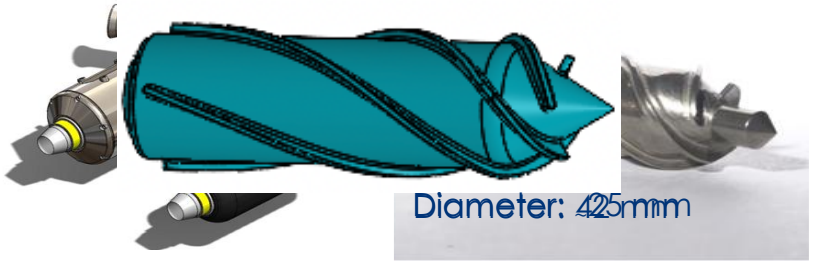


Outlet Volute Effect:

1. Flow Stagnation
2. Pressure Generation
3. Fluid Stress

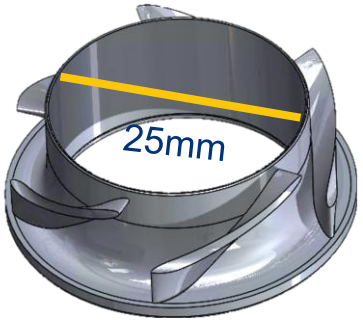
DH7 to DH8: Size Reduction

New Axial Impeller:

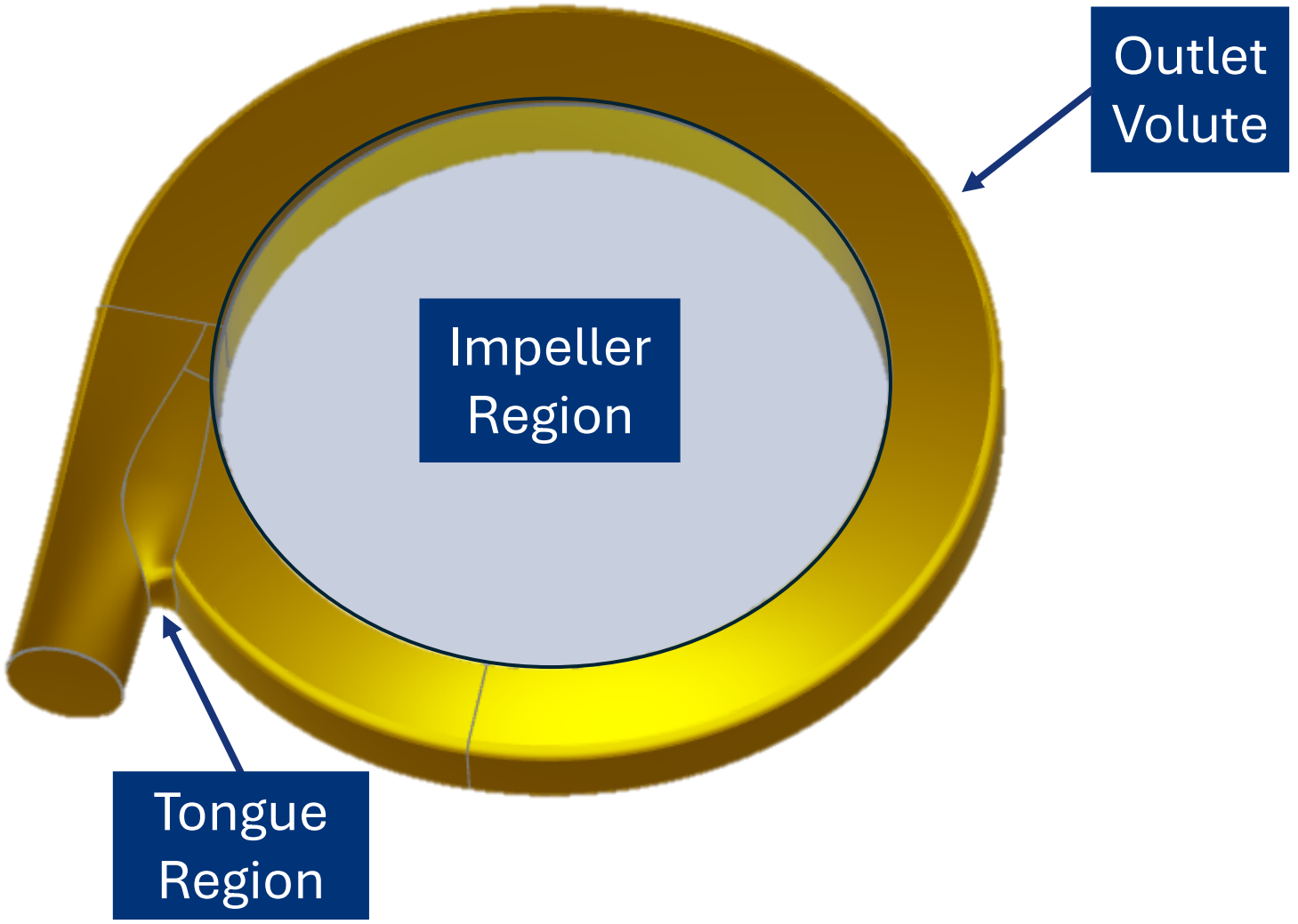


New DH8 Impeller:

~40% size Reduction

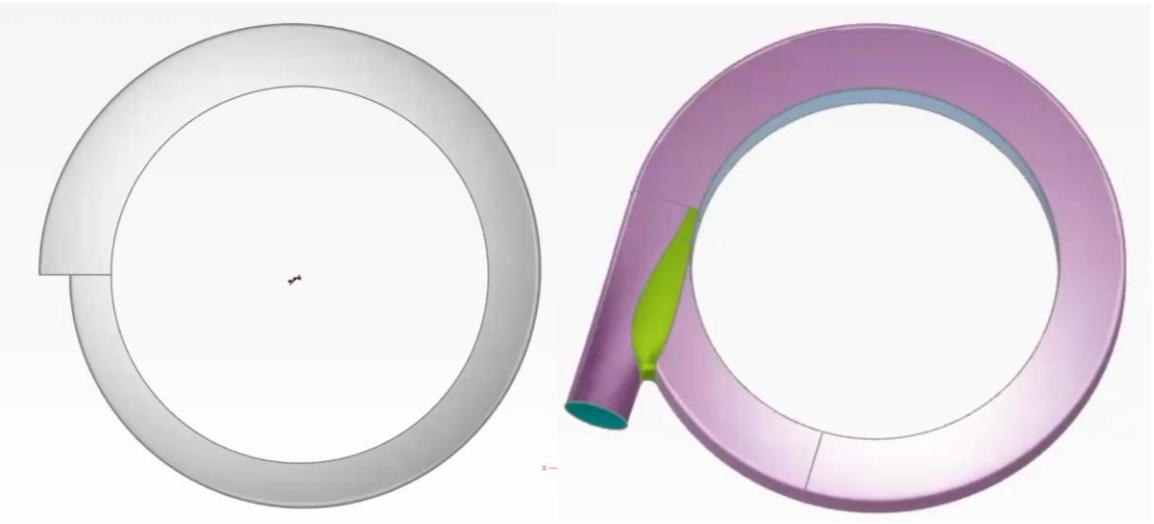


New Base Volute

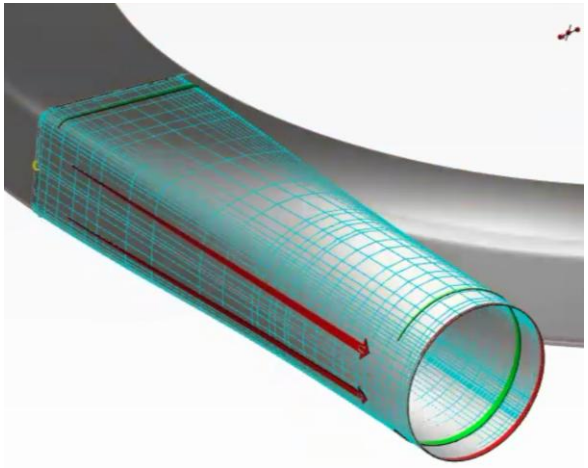


Design Variables

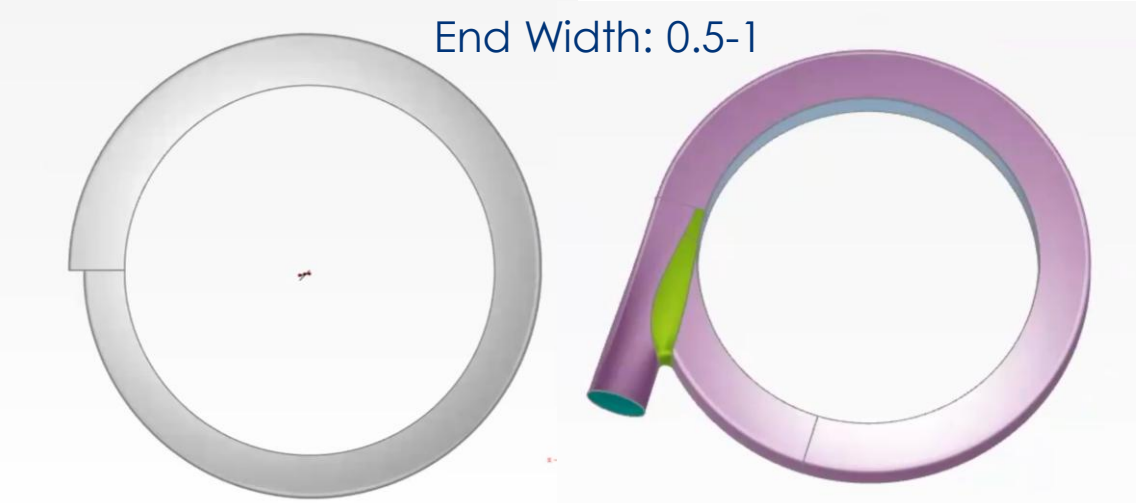
Start Width: 0.35-0.55



Tangent Factor: 0.8-1.5

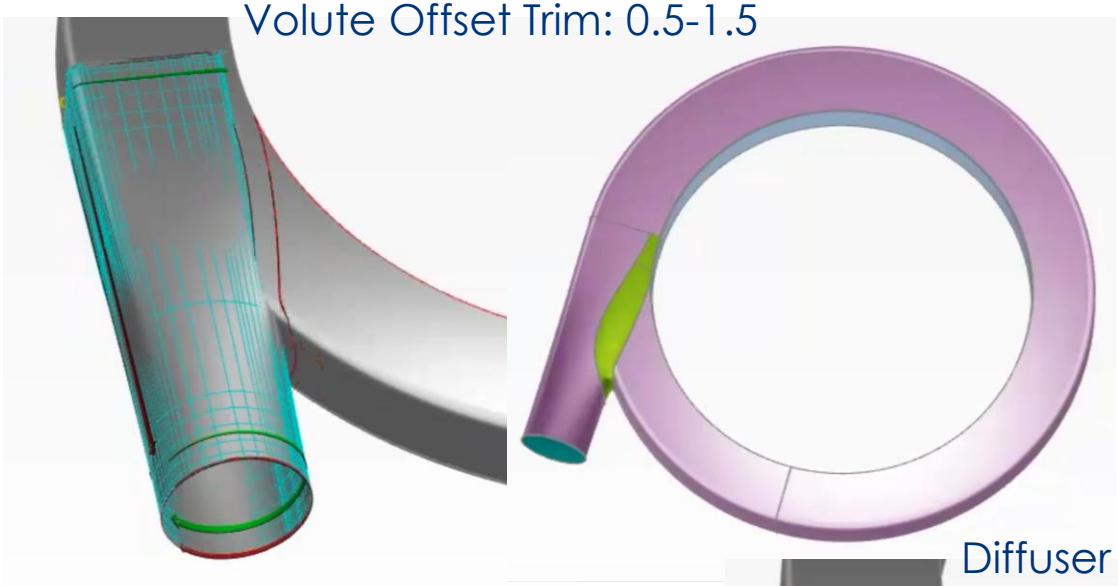


End Width: 0.5-1



Design Variables

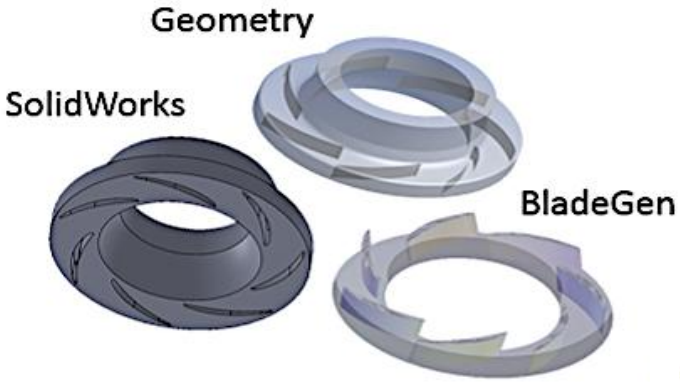
Volute Offset Trim: 0.5-1.5



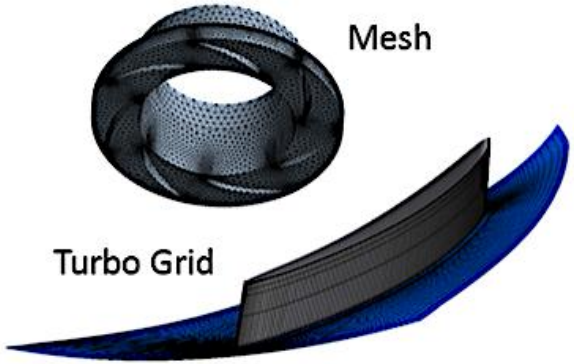
Diffuser Offset Trim:0.5-1.5

Typical Ansys Process

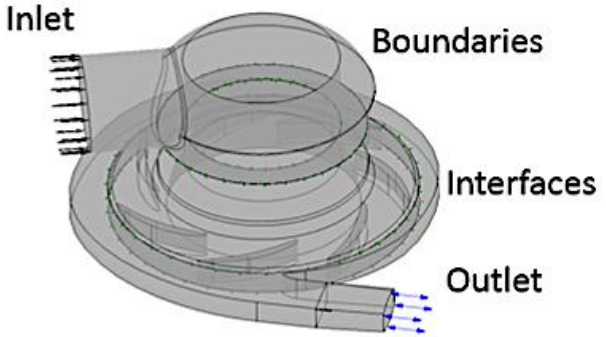
1. Design



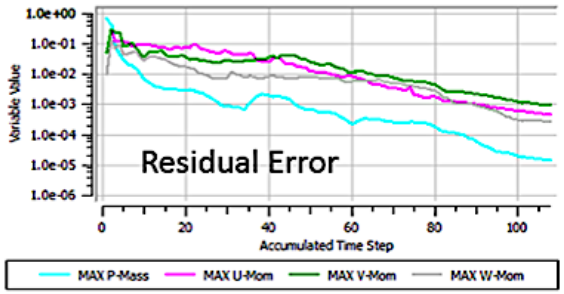
2. Mesh



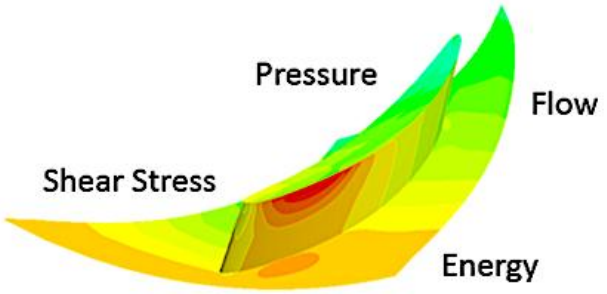
3. CFX Pre



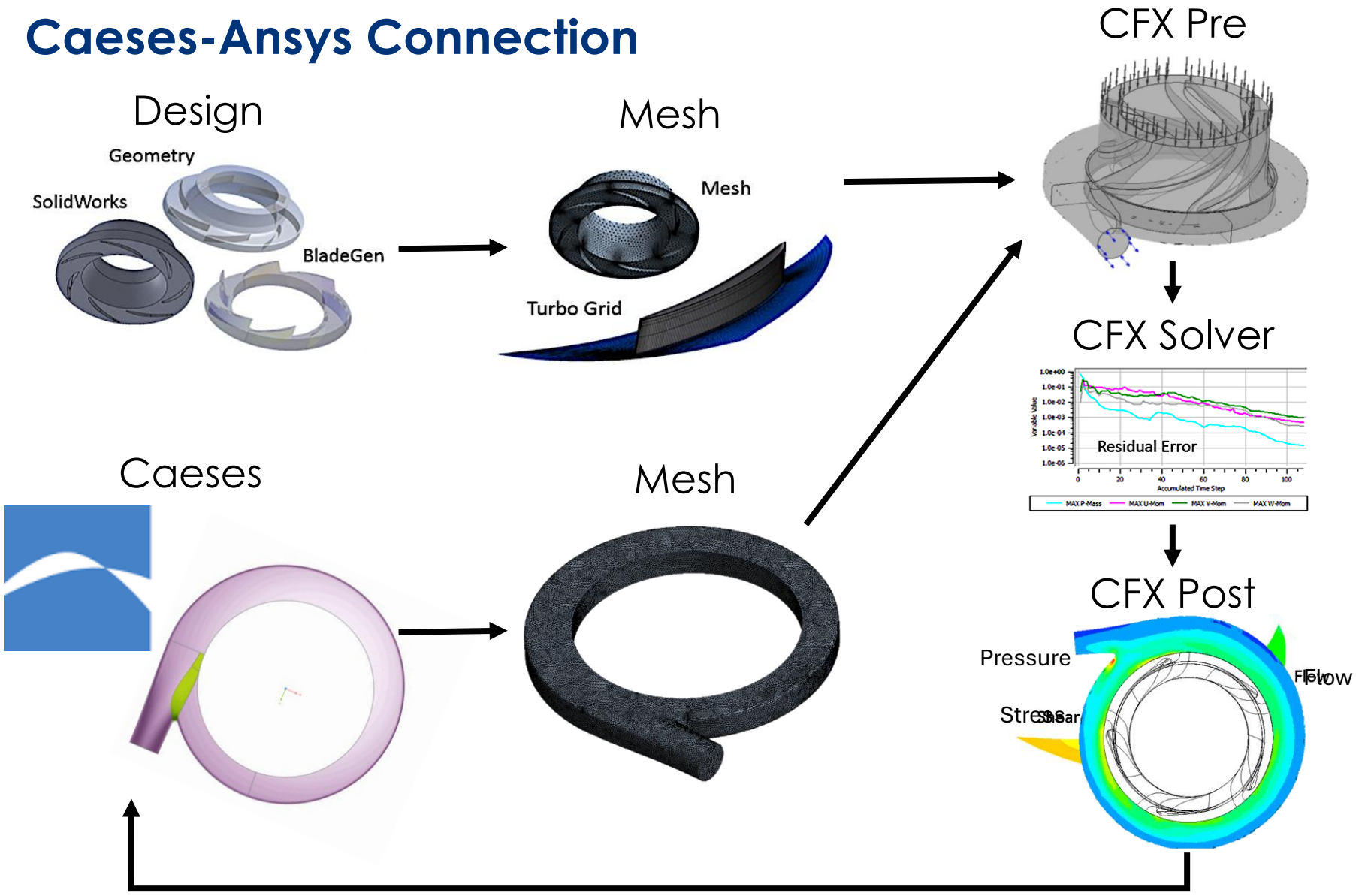
4. CFX Solver



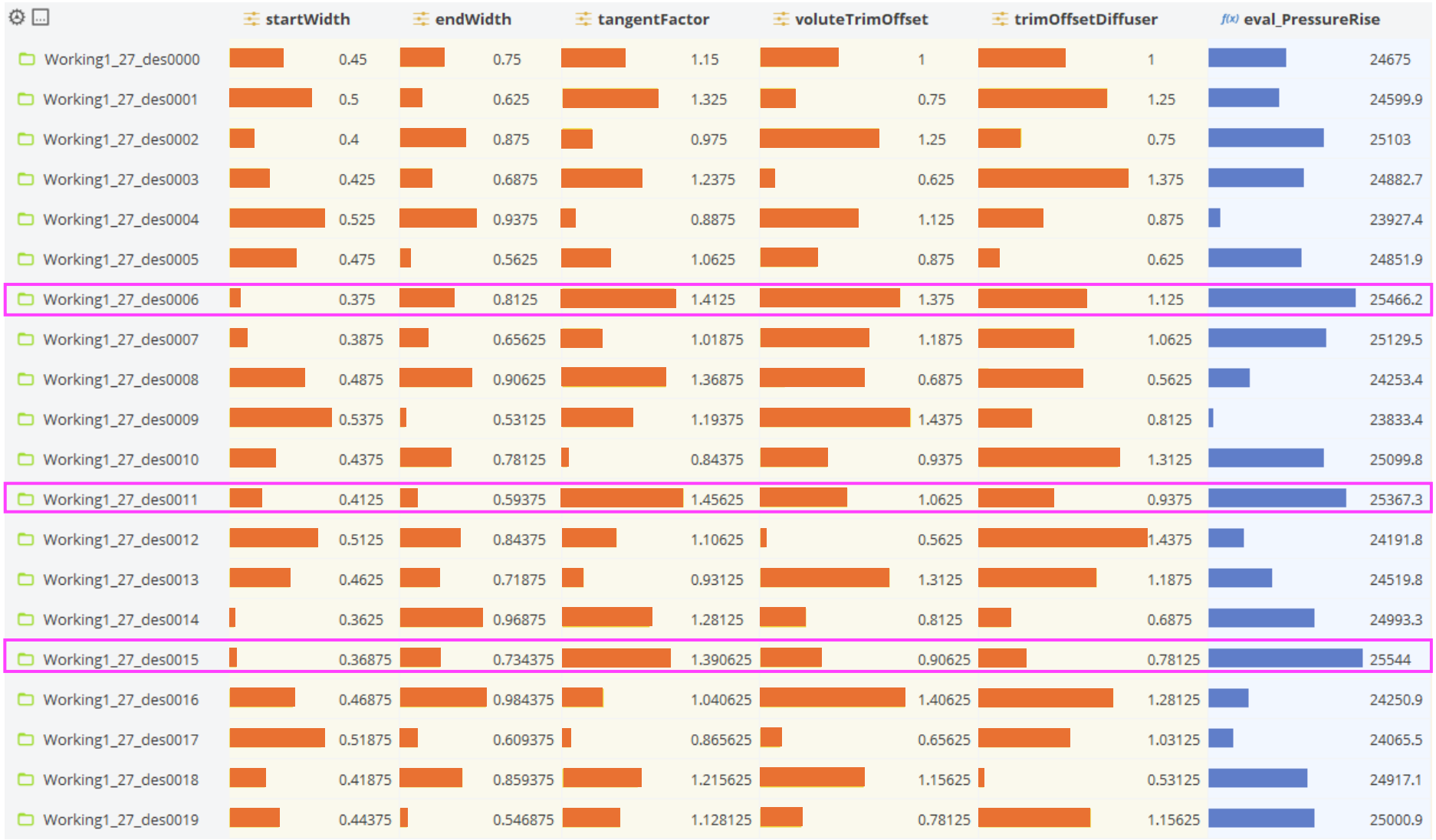
5. CFX Post



Caeses-Ansys Connection



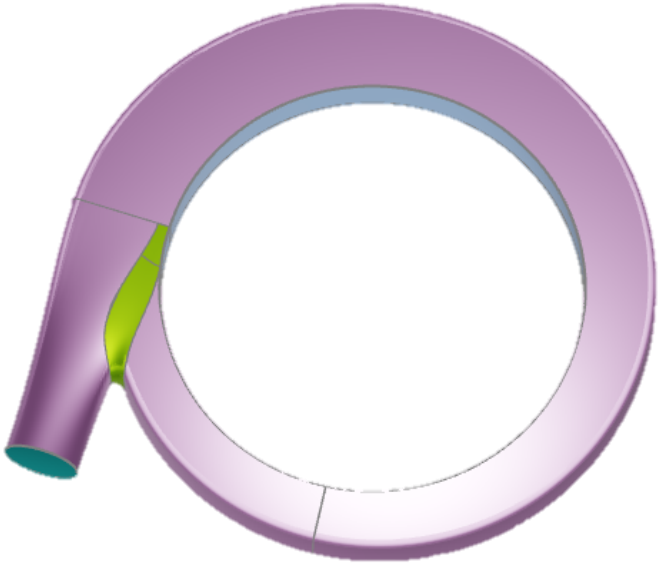
Optimization Results



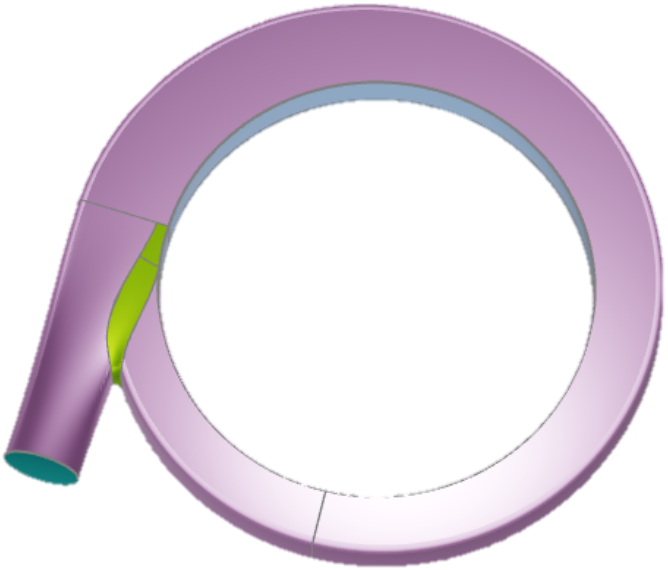
	startWidth	endWidth	tangentFactor	voluteTrimOffset	trimOffsetDiffuser	f(x) eval_PressureRise
Working1_27_des0000	0.45	0.75	1.15	1	1	24675
Working1_27_des0001	0.5	0.625	1.325	0.75	1.25	24599.9
Working1_27_des0002	0.4	0.875	0.975	1.25	0.75	25103
Working1_27_des0003	0.425	0.6875	1.2375	0.625	1.375	24882.7
Working1_27_des0004	0.525	0.9375	0.8875	1.125	0.875	23927.4
Working1_27_des0005	0.475	0.5625	1.0625	0.875	0.625	24851.9
Working1_27_des0006	0.375	0.8125	1.4125	1.375	1.125	25466.2
Working1_27_des0007	0.3875	0.65625	1.01875	1.1875	1.0625	25129.5
Working1_27_des0008	0.4875	0.90625	1.36875	0.6875	0.5625	24253.4
Working1_27_des0009	0.5375	0.53125	1.19375	1.4375	0.8125	23833.4
Working1_27_des0010	0.4375	0.78125	0.84375	0.9375	1.3125	25099.8
Working1_27_des0011	0.4125	0.59375	1.45625	1.0625	0.9375	25367.3
Working1_27_des0012	0.5125	0.84375	1.10625	0.5625	1.4375	24191.8
Working1_27_des0013	0.4625	0.71875	0.93125	1.3125	1.1875	24519.8
Working1_27_des0014	0.3625	0.96875	1.28125	0.8125	0.6875	24993.3
Working1_27_des0015	0.36875	0.734375	1.390625	0.90625	0.78125	25544
Working1_27_des0016	0.46875	0.984375	1.040625	1.40625	1.28125	24250.9
Working1_27_des0017	0.51875	0.609375	0.865625	0.65625	1.03125	24065.5
Working1_27_des0018	0.41875	0.859375	1.215625	1.15625	0.53125	24917.1
Working1_27_des0019	0.44375	0.546875	1.128125	0.78125	1.15625	25000.9

Top Performing Models

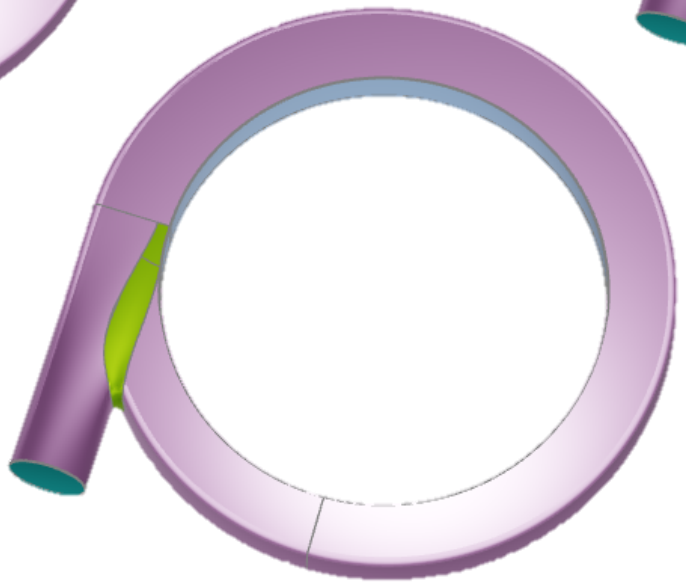
Model 6



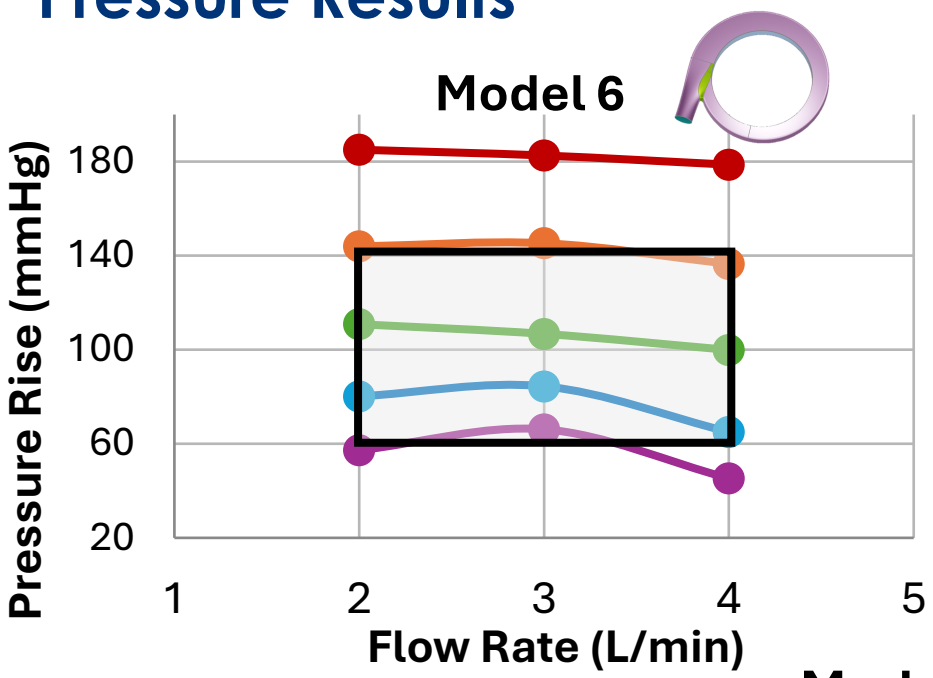
Model 15

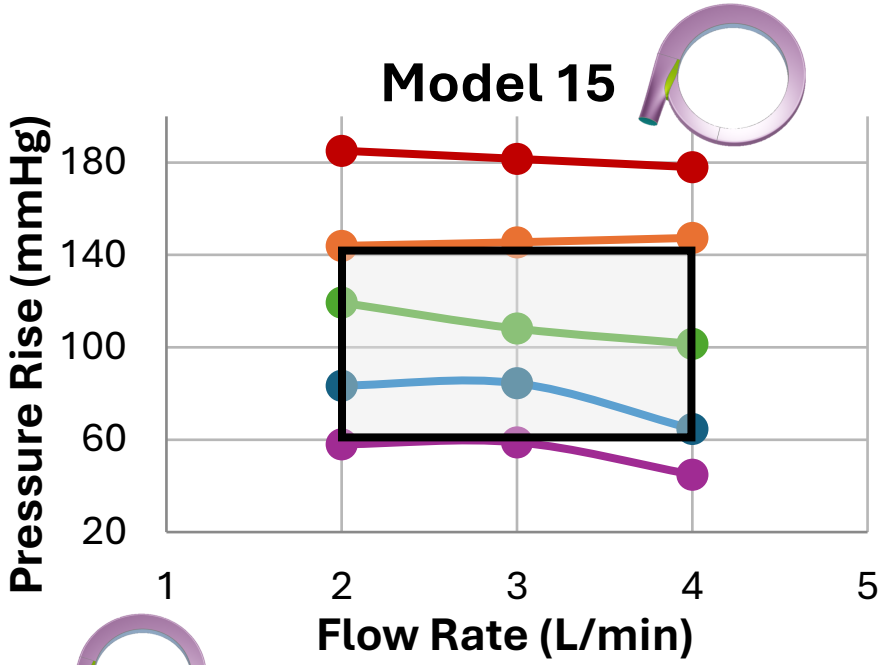


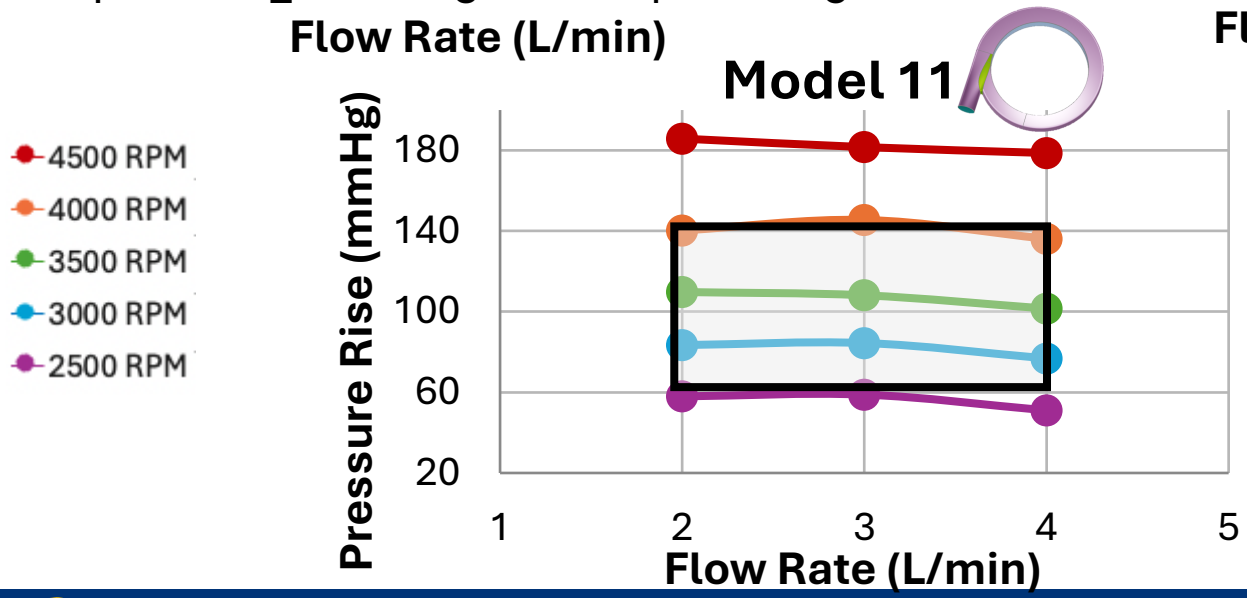
Model 11



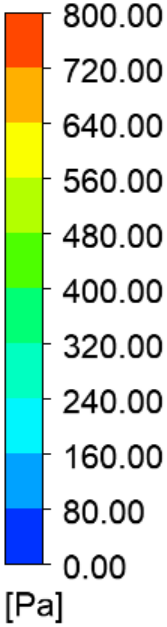
Pressure Results



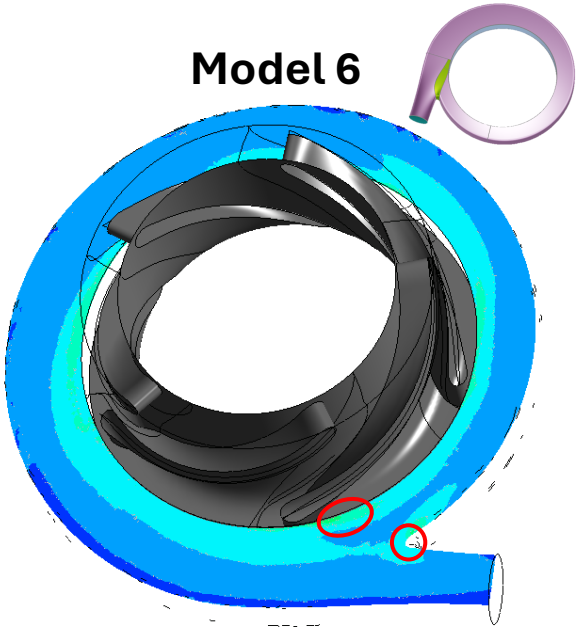




Stress Results

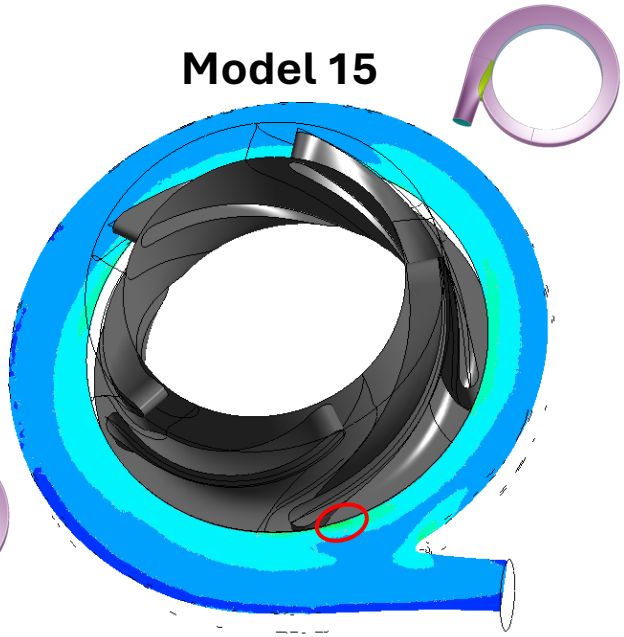


Model 6



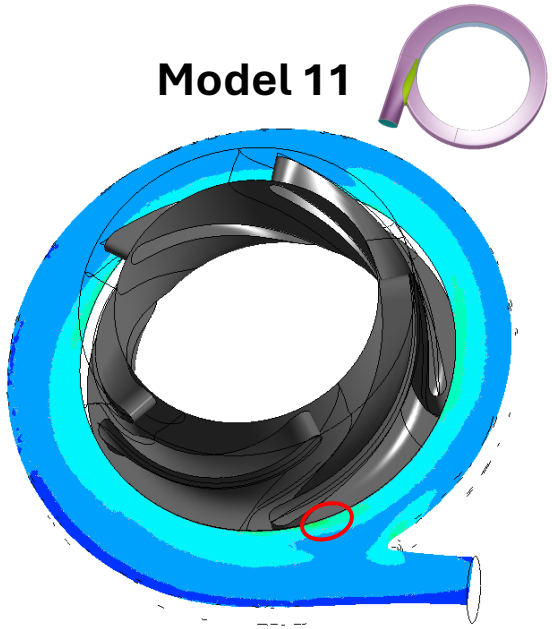
Avg. Stress = 139.57 Pa
Max Stress = 400.27 Pa

Model 15



Avg. Stress = 144.76 Pa
Max Stress = 410.10 Pa

Model 11

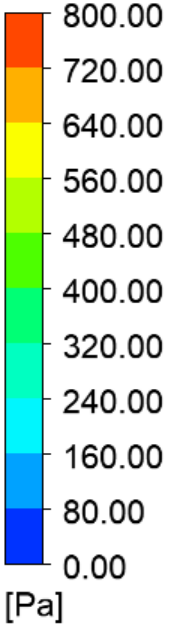


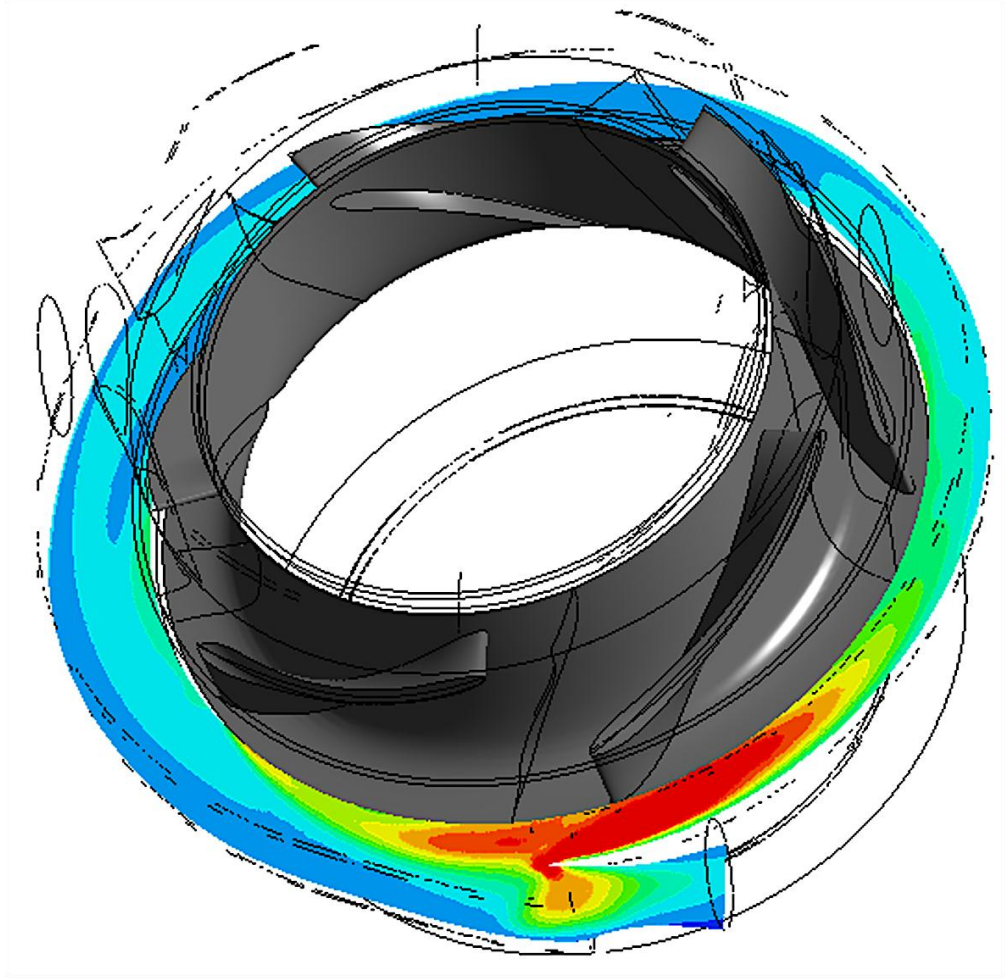
Avg. Stress = 144.76 Pa
Max Stress = 410.10 Pa

3L/min, 3500 RPM

Stress Results

DH7

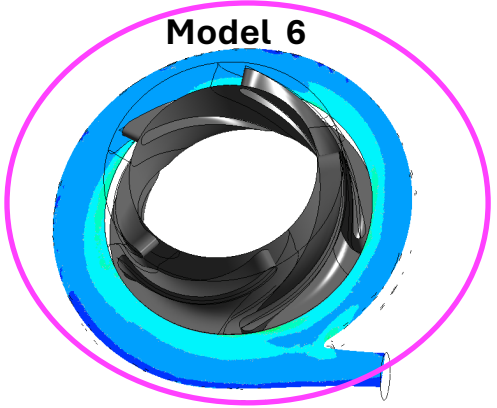




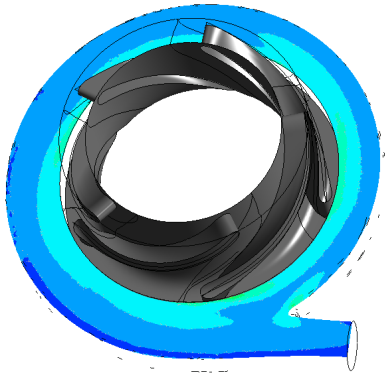
3 L/min, 2750 RPM

~50% Reduction in Stress

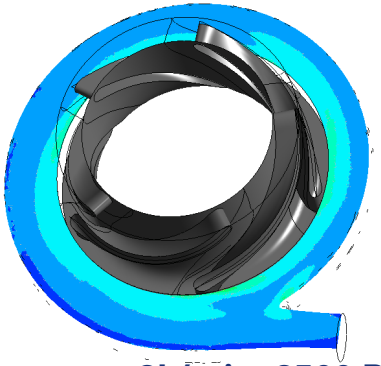
Model 6



Model 11



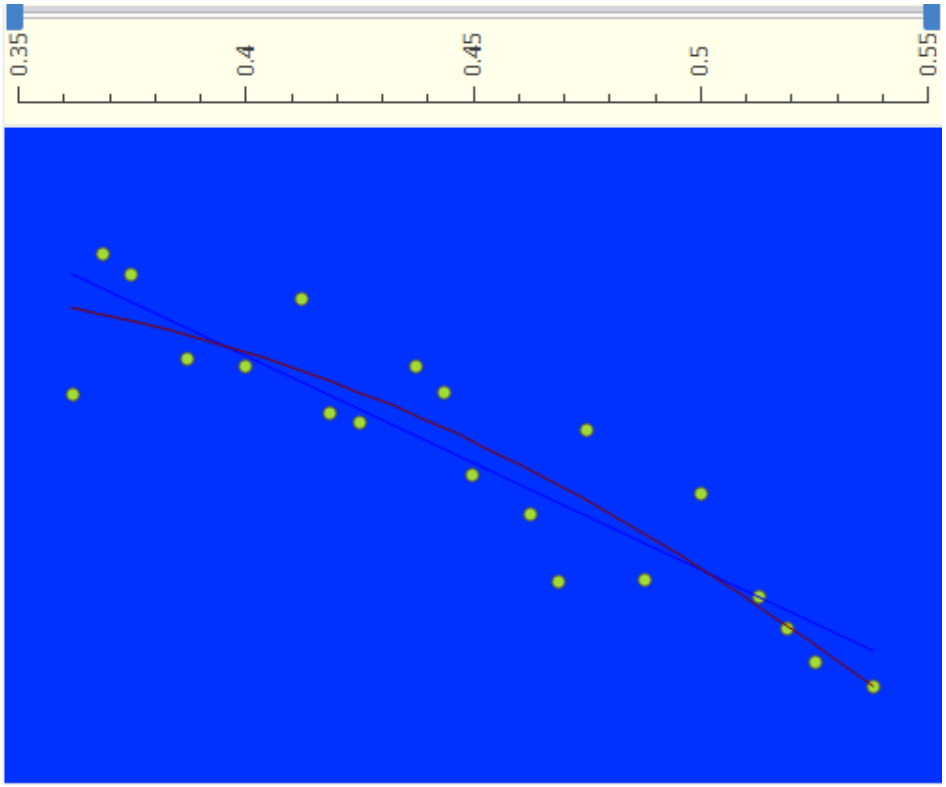
Model 15



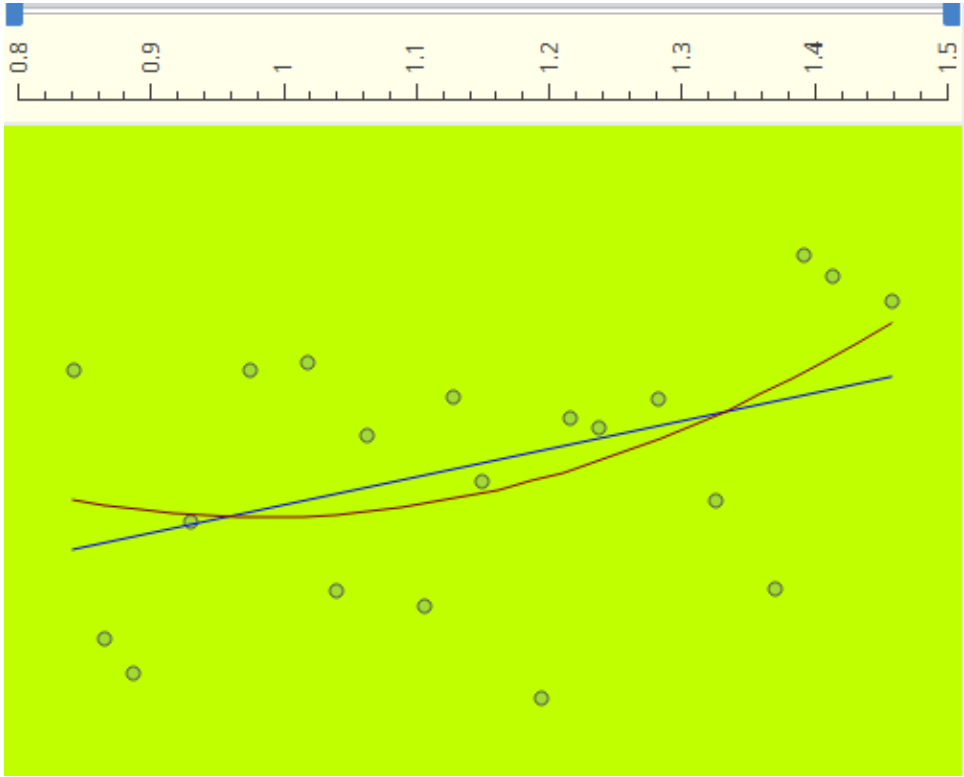
3L/min, 3500 RPM

Influential Parameters

Start Width: Negative Correlation



Tangent Factor: Slight Positive Correlation



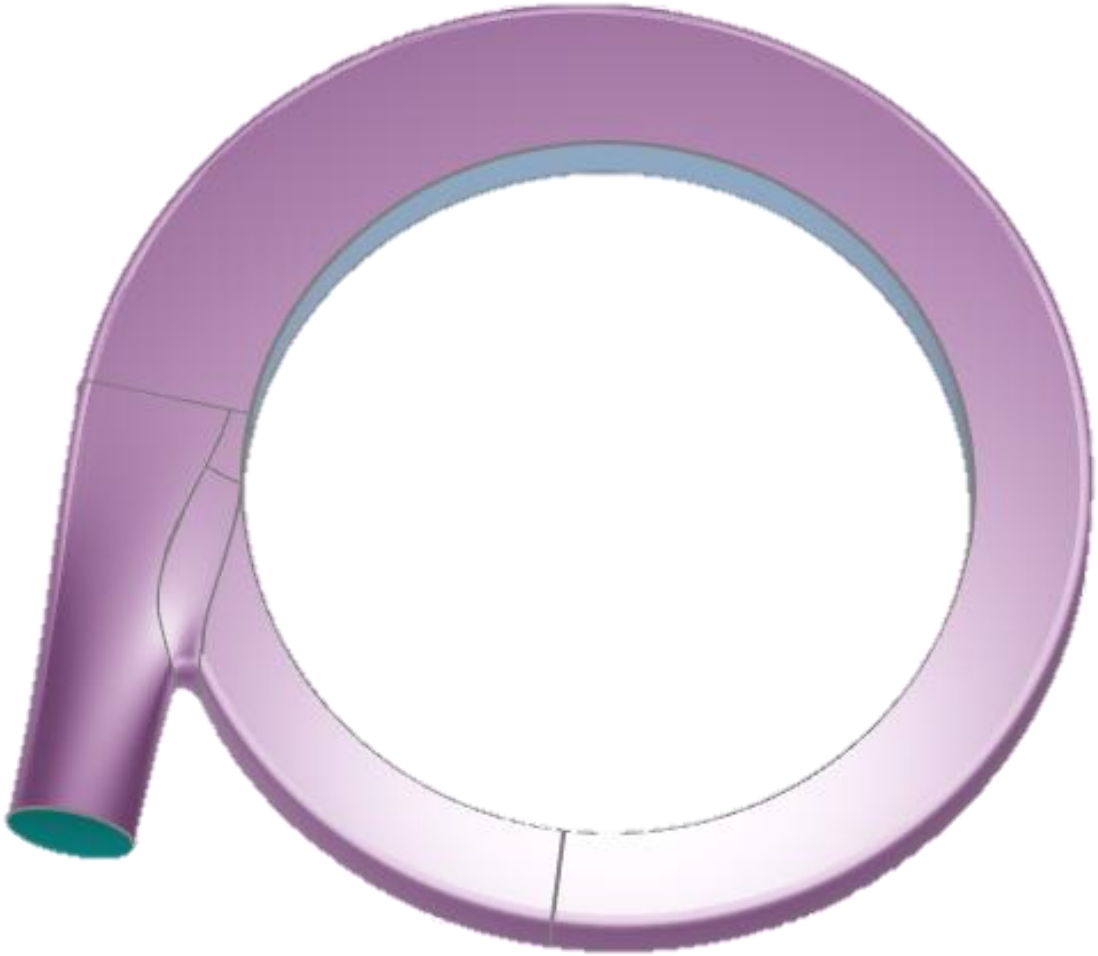
TSearch

- 50 iterations based on Model 6

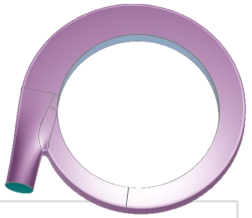
Parameter	Value Range
Start Width	0.3-0.55
End Width	0.5-1
Tangent Factor	0.8-1.6
Volute Trim Offset	0.5-1.5
Diffuser Trim Offset	0.5-1.5

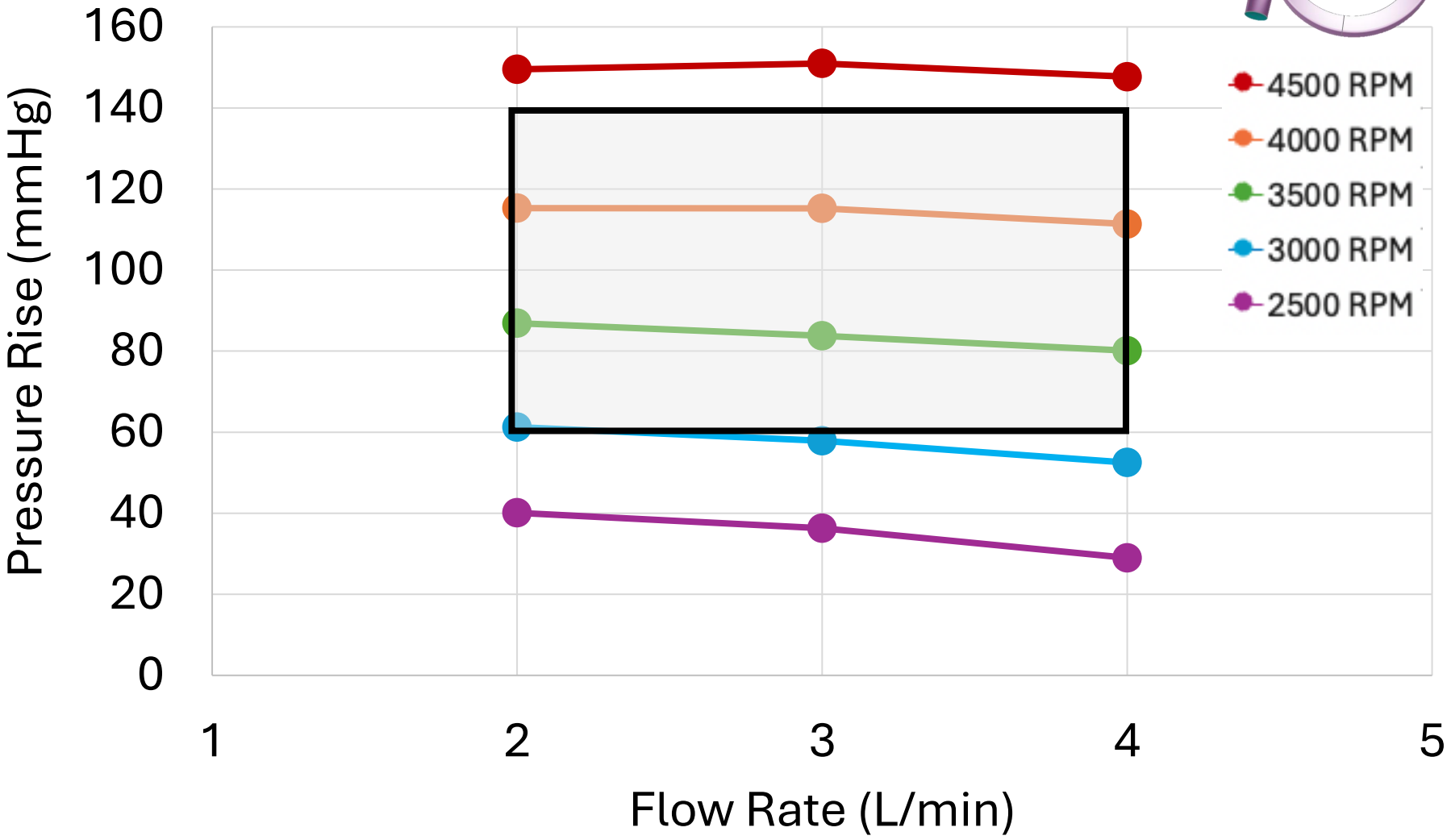
Top Performing Model

Model 34

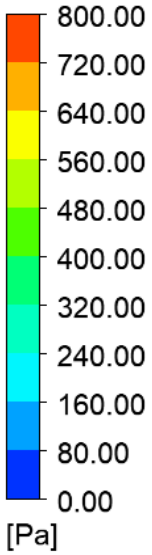


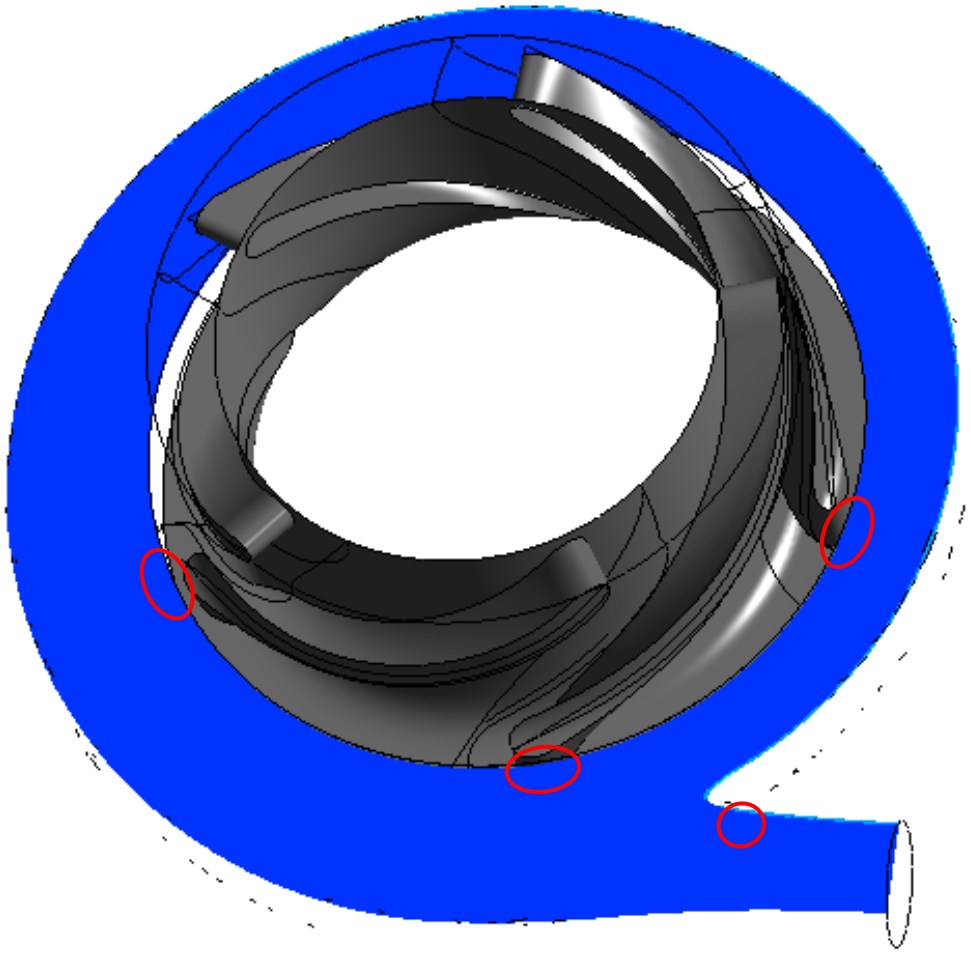
Pressure Results

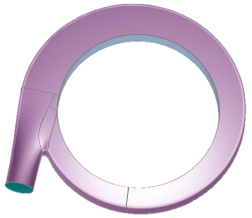




Stress Results







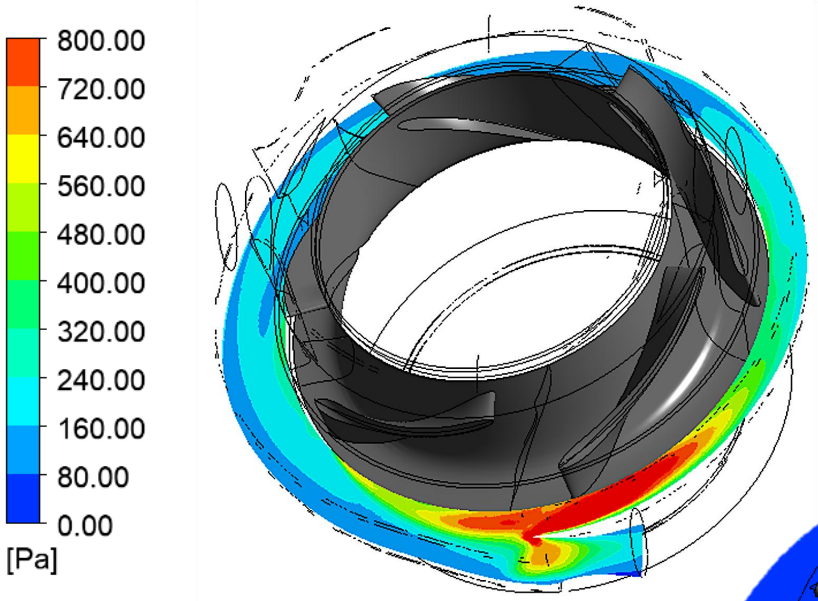
Avg. Stress = 125.72 Pa

Max Stress = 467.39 Pa

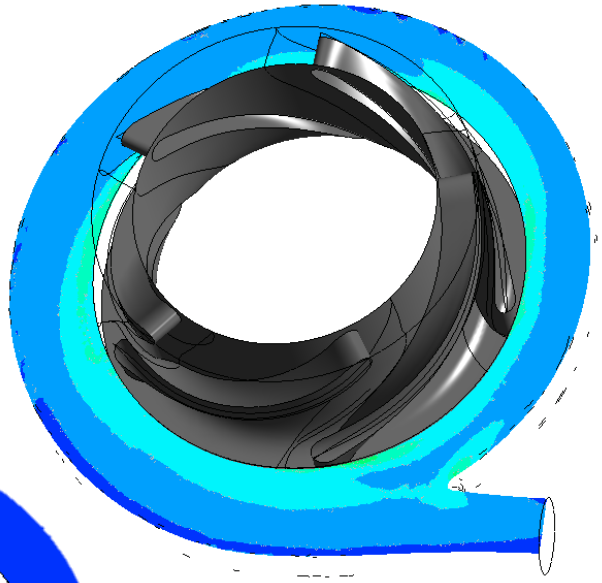
3L/min, 3500 RPM

Stress Results

DH7



Model 6



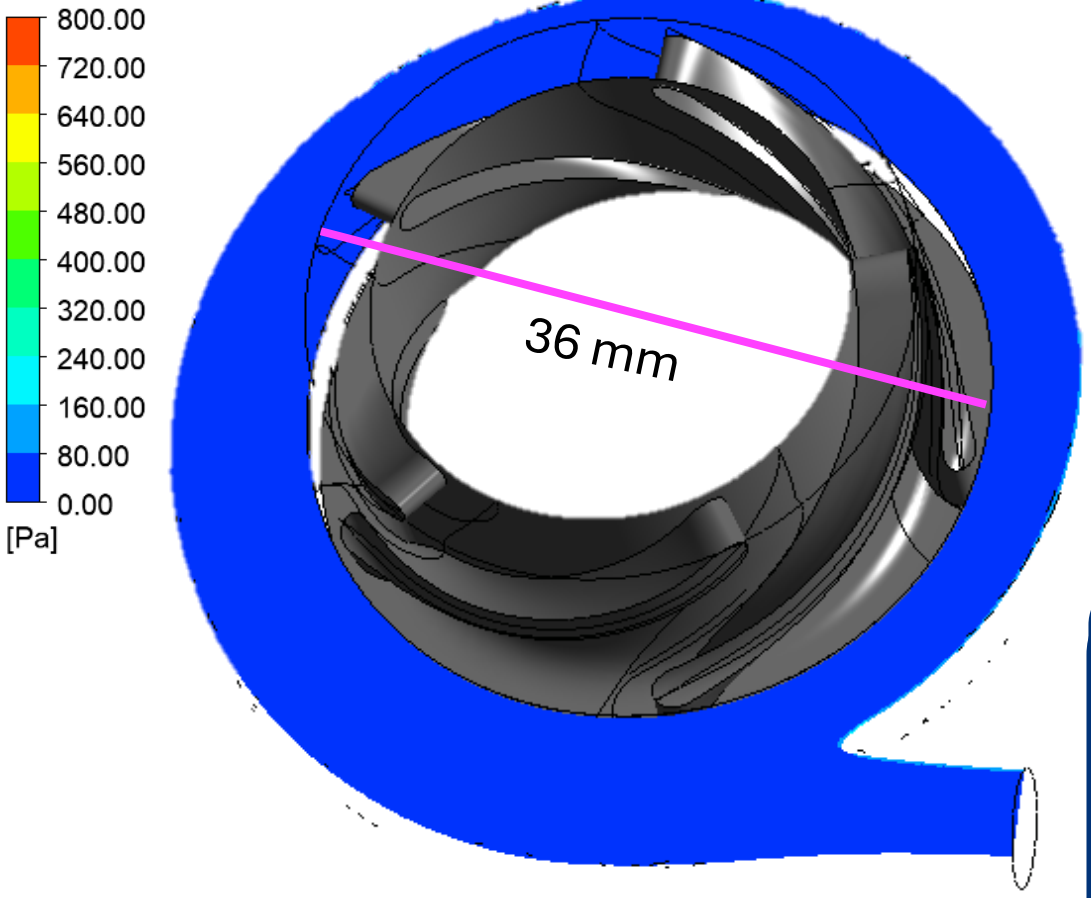
Model 34

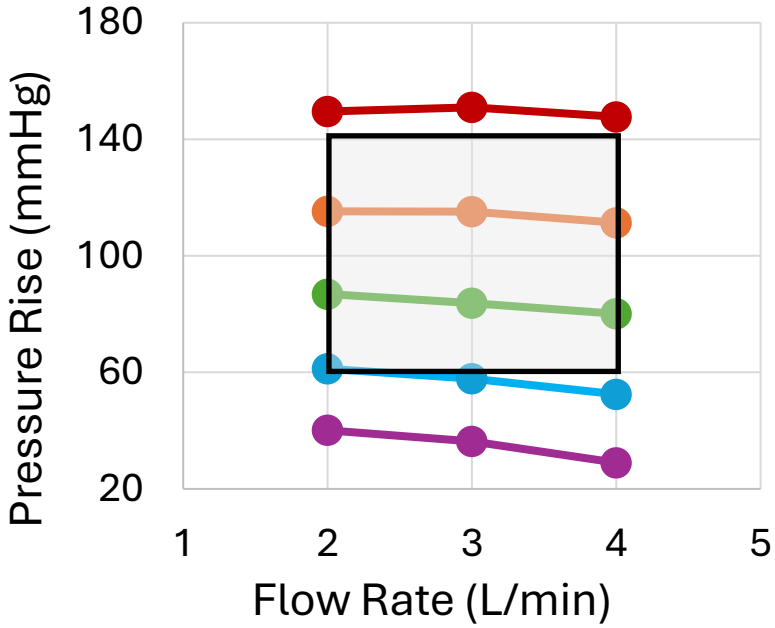
~50% Reduction in Max Stress

3 L/min, 2750 RPM

3L/min, 3500 RPM

Conclusions





Caeses Specific Success

- Streamlined the Optimization
- ↓ Computational & Design Time
- Incredible Caeses Team!

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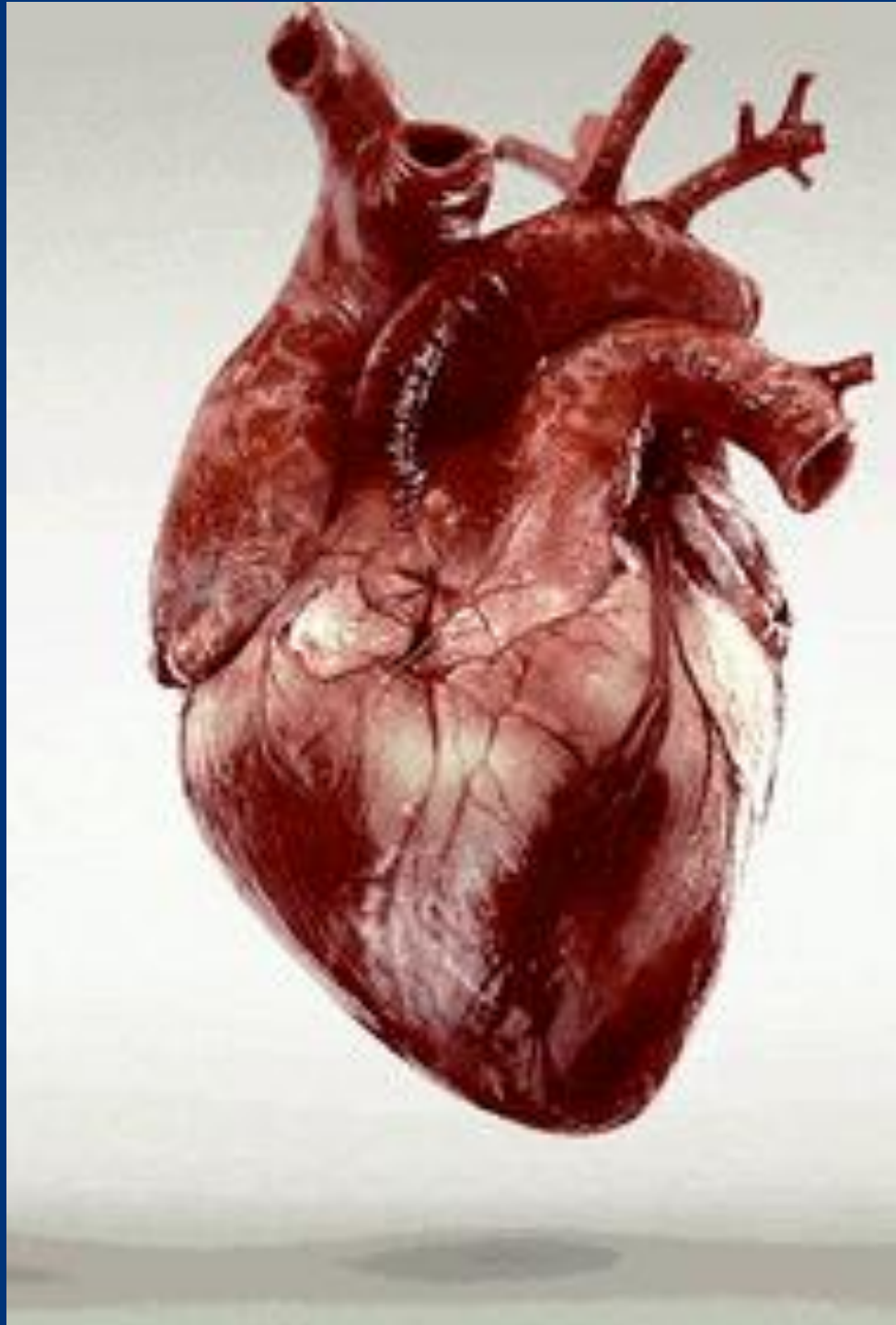
Thank you for listening!

Questions?



Thank you for listening!

Questions?