CFturbo

All-New Hydraulic Design of an Electrical Automotive Coolant Pump

by Sascha Henoch and Ralph Peter MUELLER

- TENGAM Engineering Inc., is an automotive supplier that manufactures injection-molded magnets
- The company has decided to enter a new market segment: **electric automotive coolant pump**
- In cooperation with CFturbo, Inc. an all-new product has been created, a pump with a brushless electric motor
- CFturbo was responsible for the hydraulic design, CFD simulations, and optimization.
- Design targets
  - Compact dimensions
  - High efficiency
  - Low noise

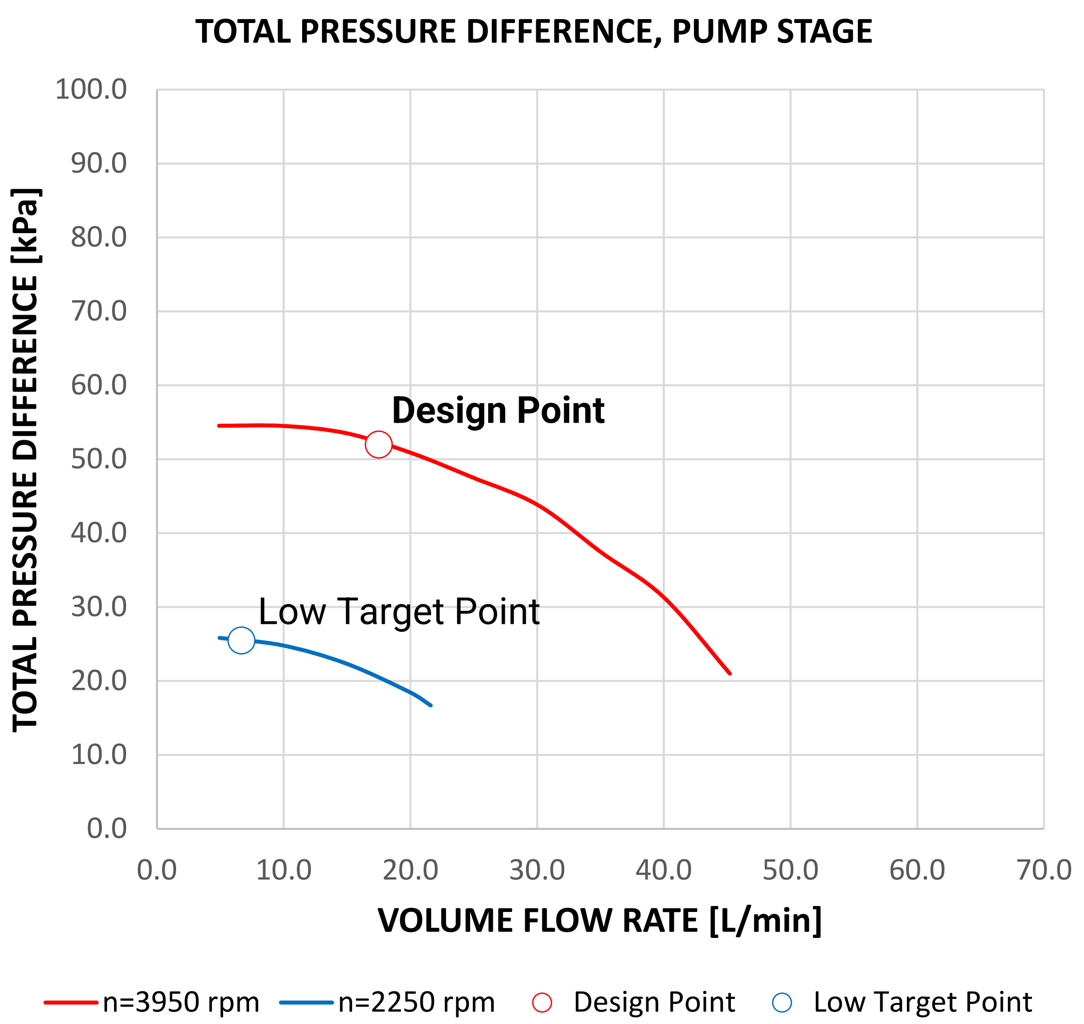
Fluid Glycol water mixture 50% - 50% at 20°C

Design point

Volume Flow Rate	17.5	L/min
Pressure Difference	52.0	kPa
Rotational Speed	3950	rev/min
Specific speed (EU)	20	

Low Target Point

Volume Flow Rate	6.67	L/min
Pressure Difference	25.5	kPa
Rotational Speed	2250	rev/min
Specific speed (EU)	12	



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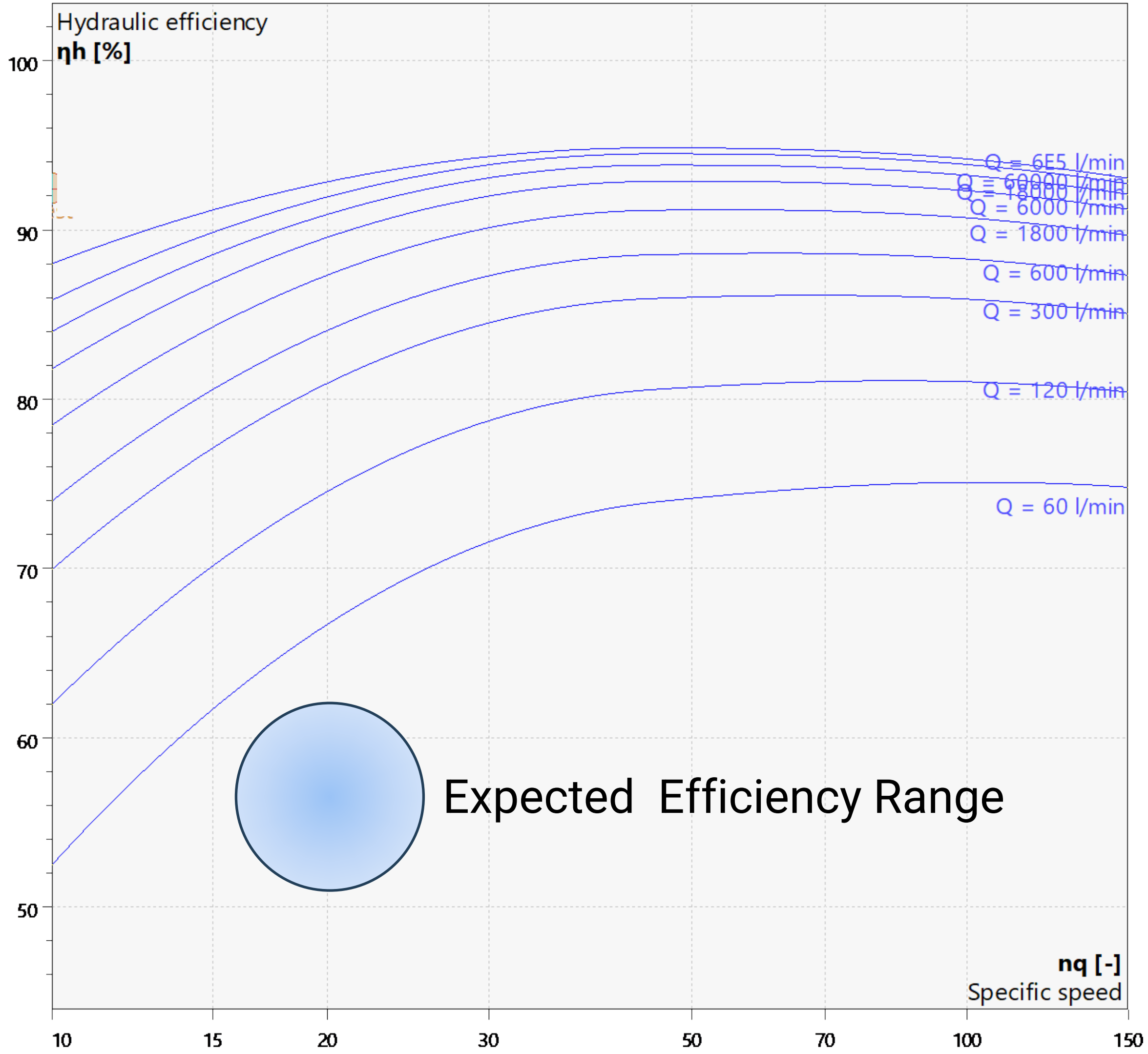


CFD in modern product development

- CFD plays a crucial role in modern product design in the automotive industry
- Frontloading simulation: implement CFD simulations from the very beginning in the development process
- Meet design targets
- Get optimal solutions
- Reduce product development time and cost

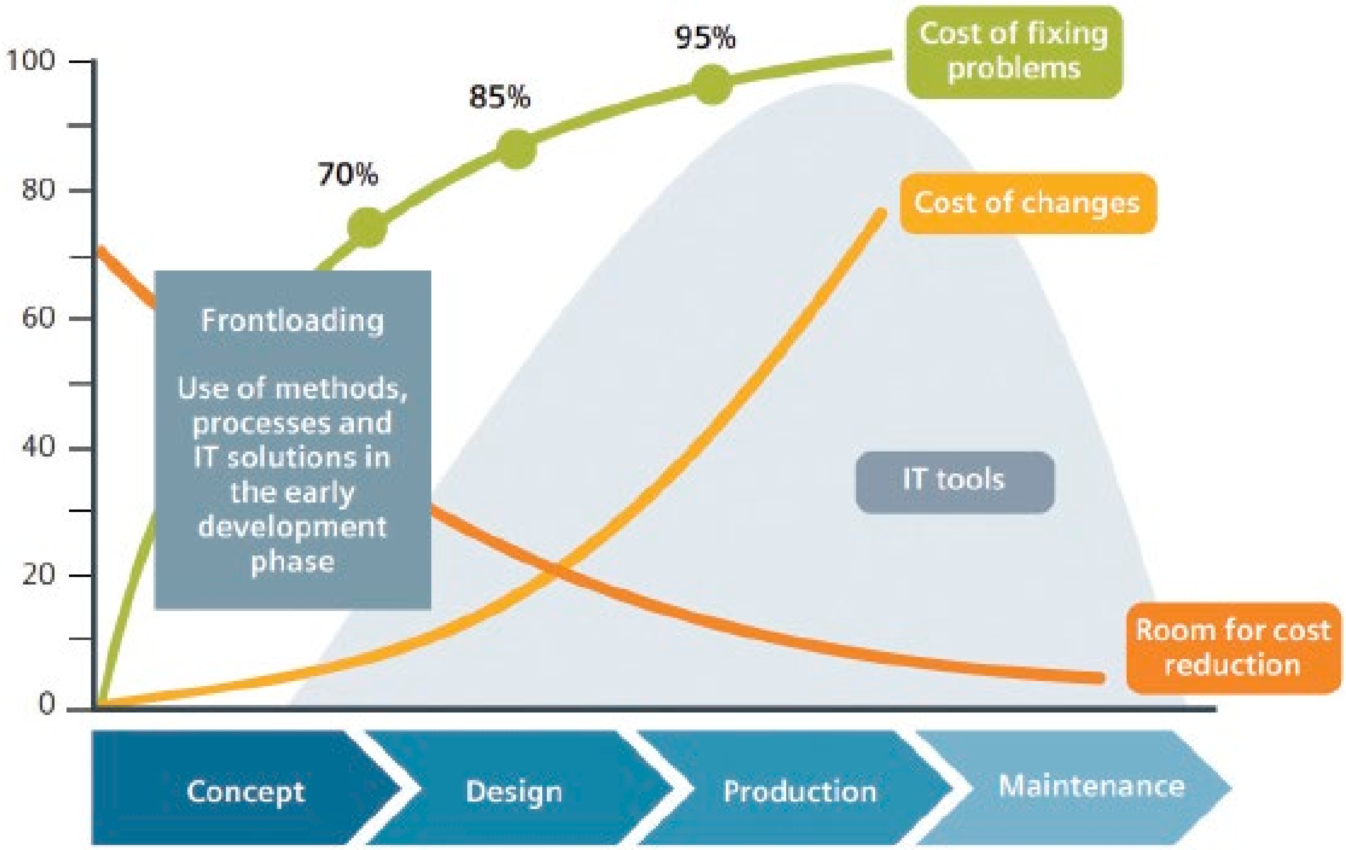
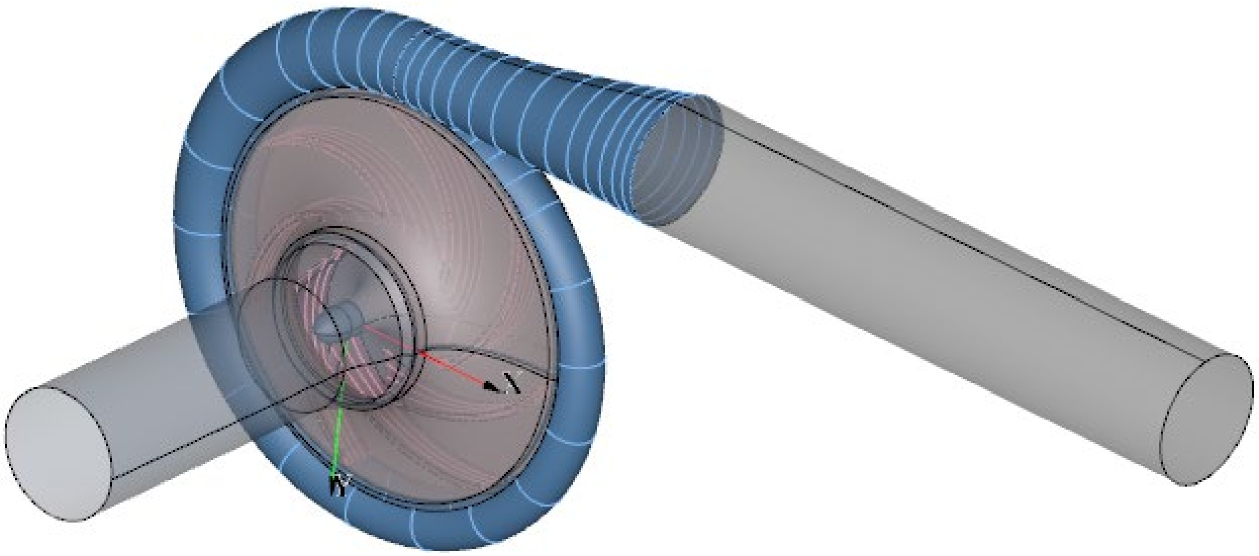
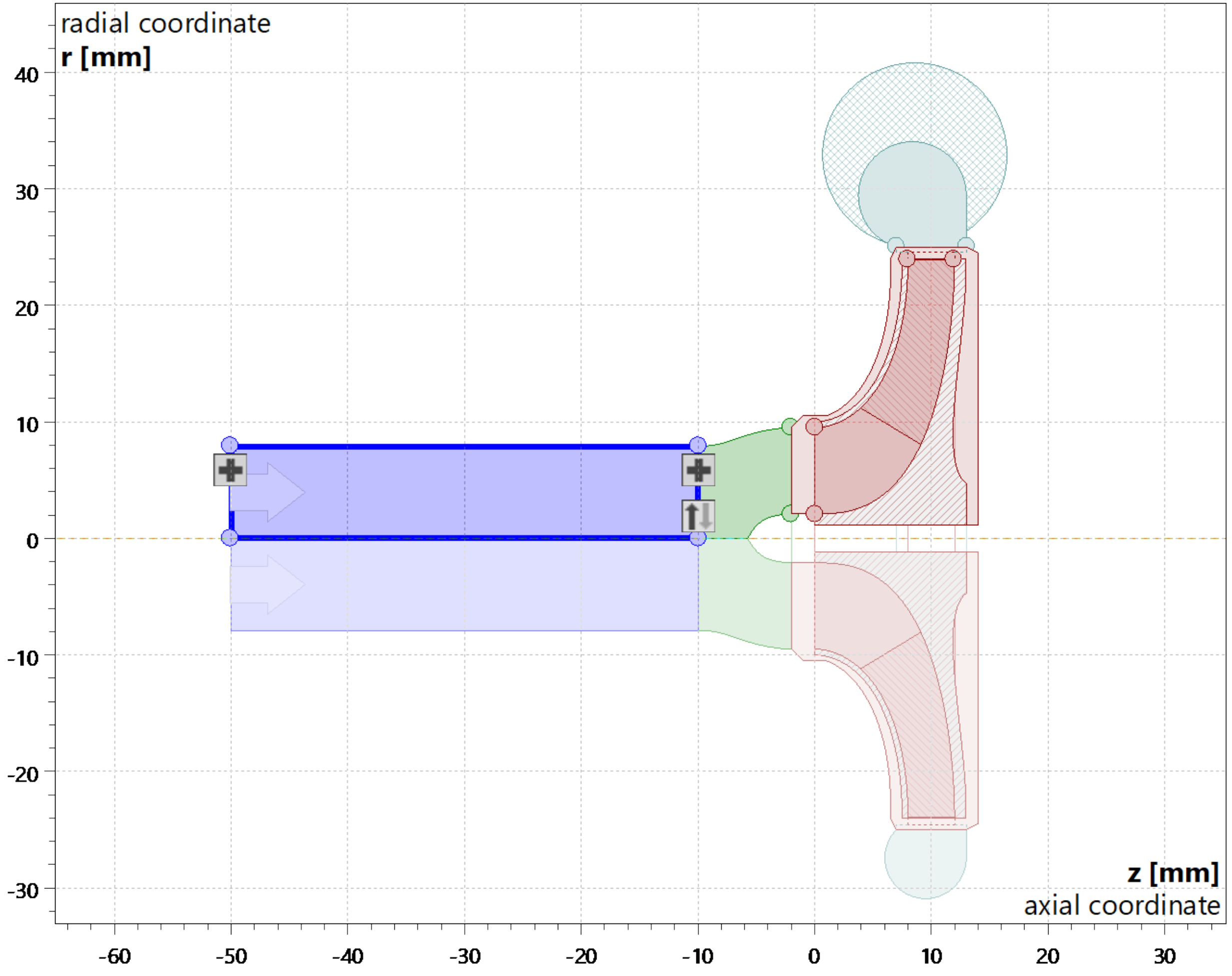


Image source: Prof. Dr. Martin Eigner, VPE, TU Kaiserlautern

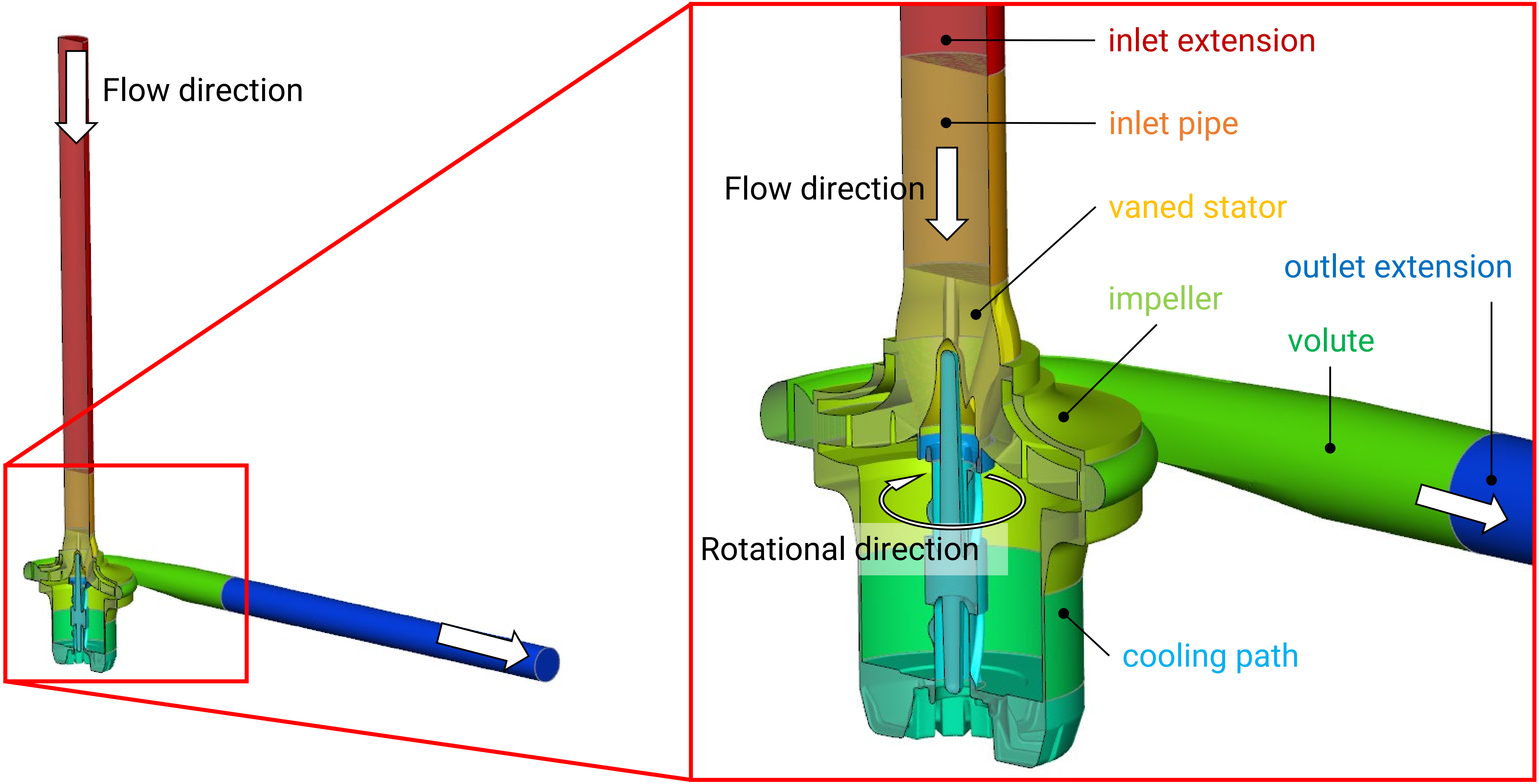
Initial design phase

- Start with a reduced pump model
- Gradually increase complexity





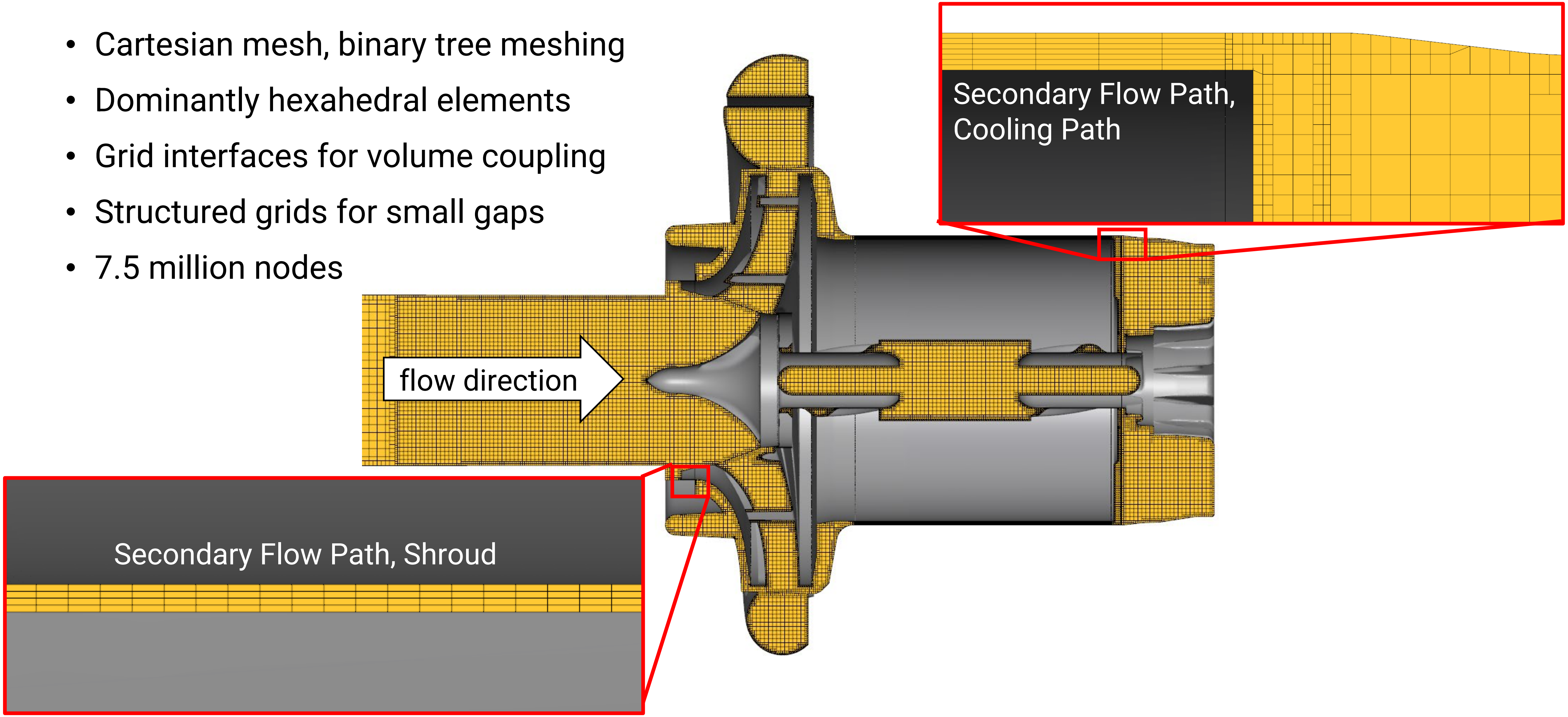
Model Setup



Flow direction
inlet extension
inlet pipe
Flow direction
vaned stator
outlet extension
impeller
volute
Rotational direction
cooling path

Computational Grid

- Cartesian mesh, binary tree meshing
- Dominantly hexahedral elements
- Grid interfaces for volume coupling
- Structured grids for small gaps
- 7.5 million nodes



Simulation and Optimization Setup

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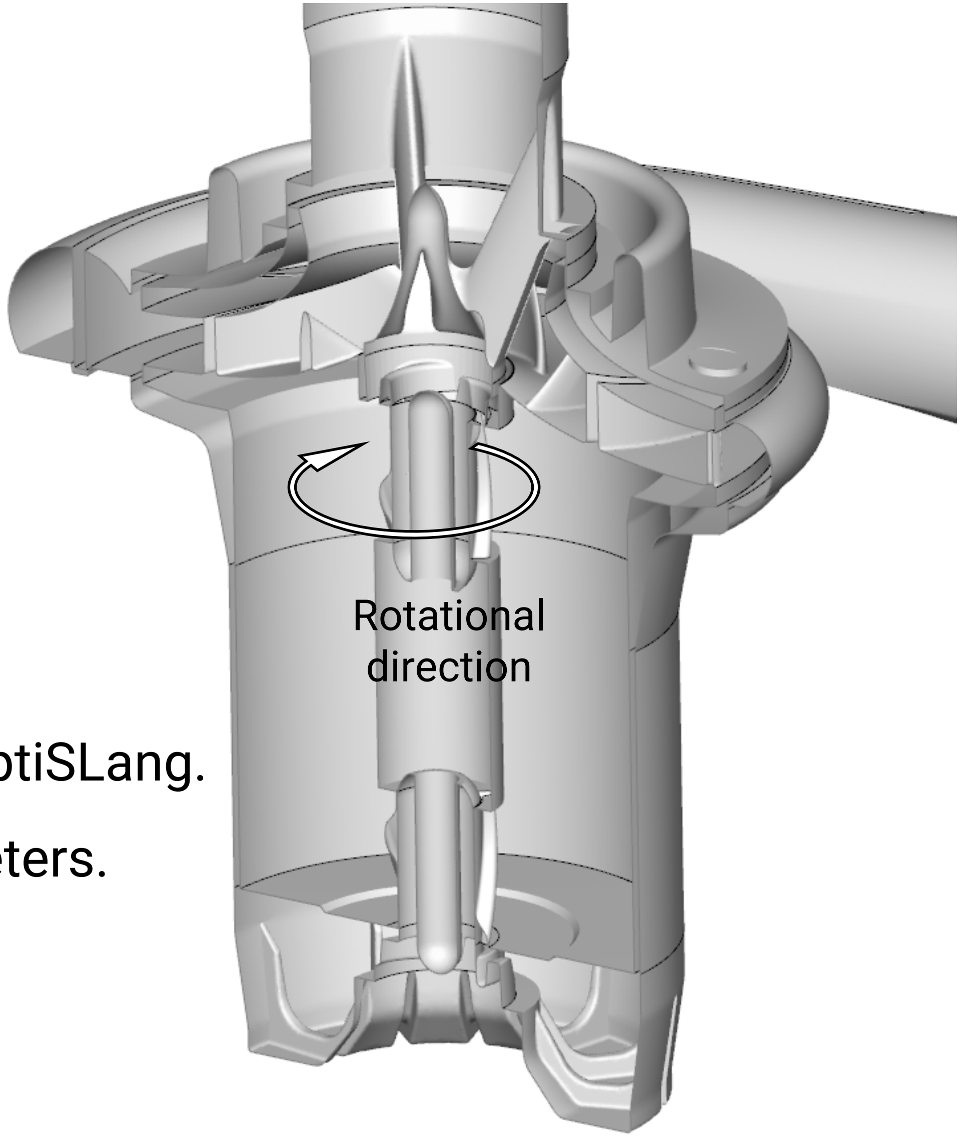
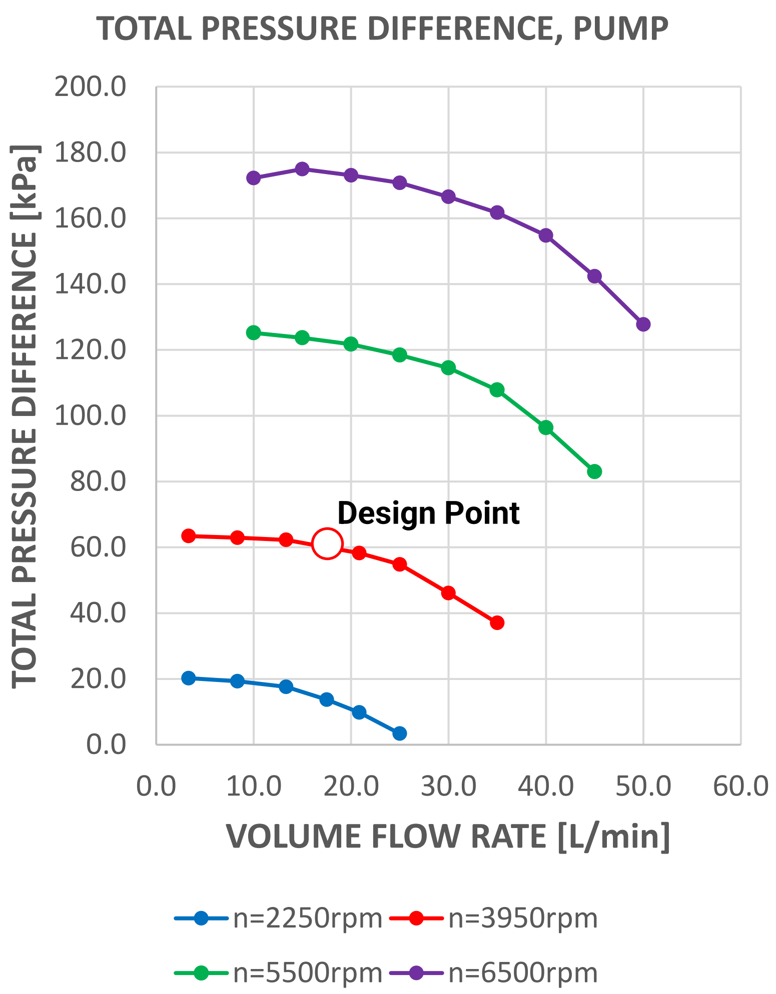
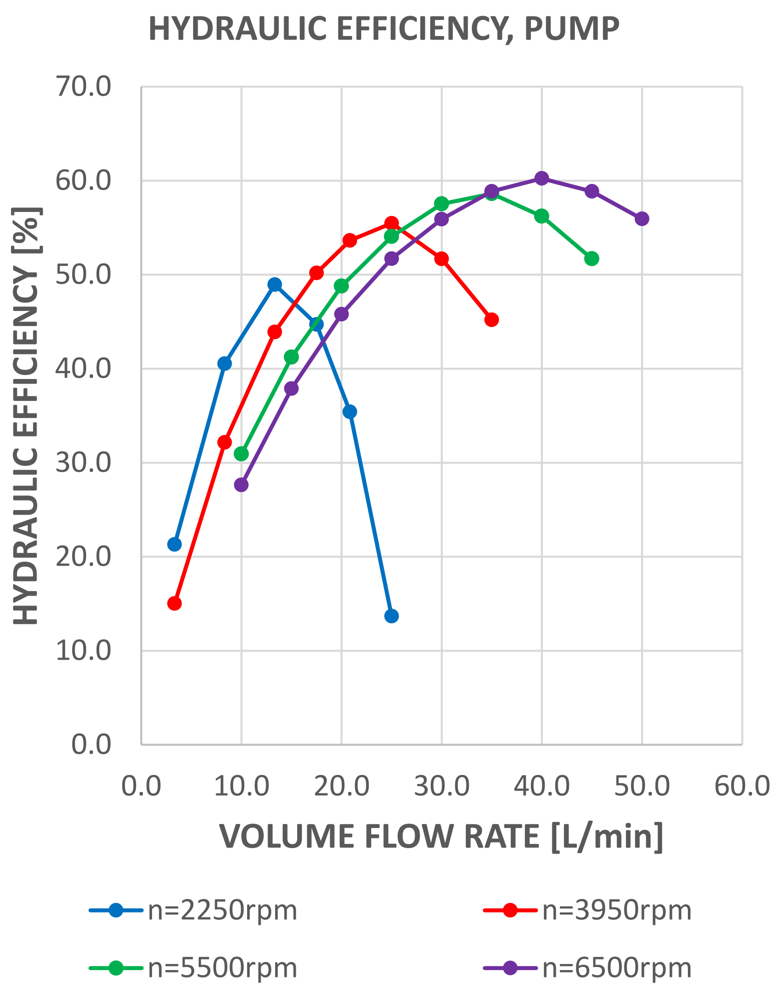
- Isothermal
- Steady-state (MFR) and transient simulations
- High-order discretization scheme (space, time)
- RNG-based k- ε turbulence model
- Unified wall function
- Hydraulic smooth surfaces

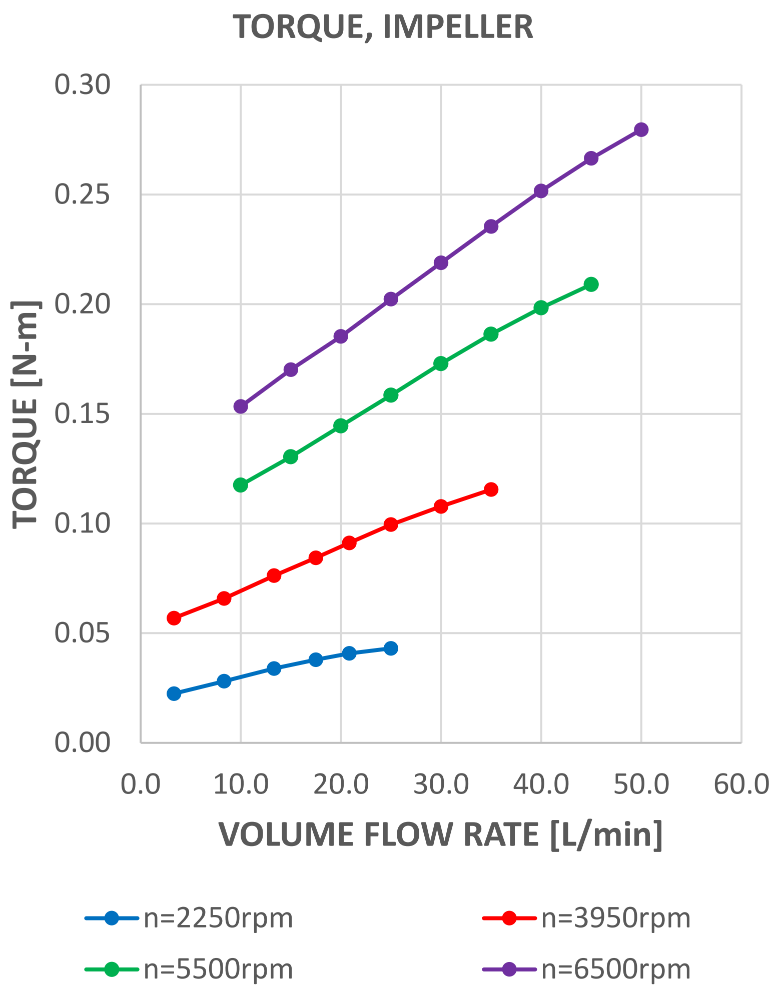
- **Design optimization:** CFturbo + Simerics-MP + Dakota/optiSLang.
- Statistical methods to identify the most sensitive parameters.
- Surrogate-assisted optimization.



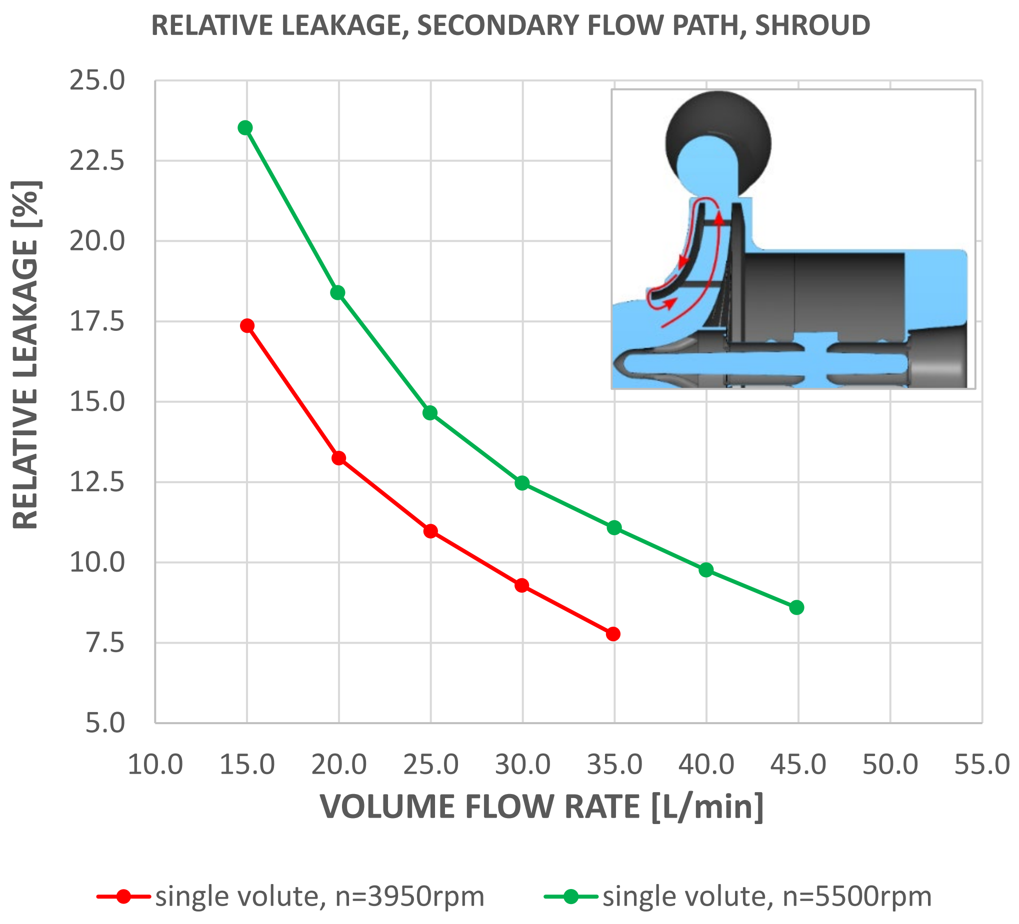
Transient flow, 4 impeller revolutions, 5 hours (AMD Ryzen Threadripper Pro 3945WX, 8 threads)

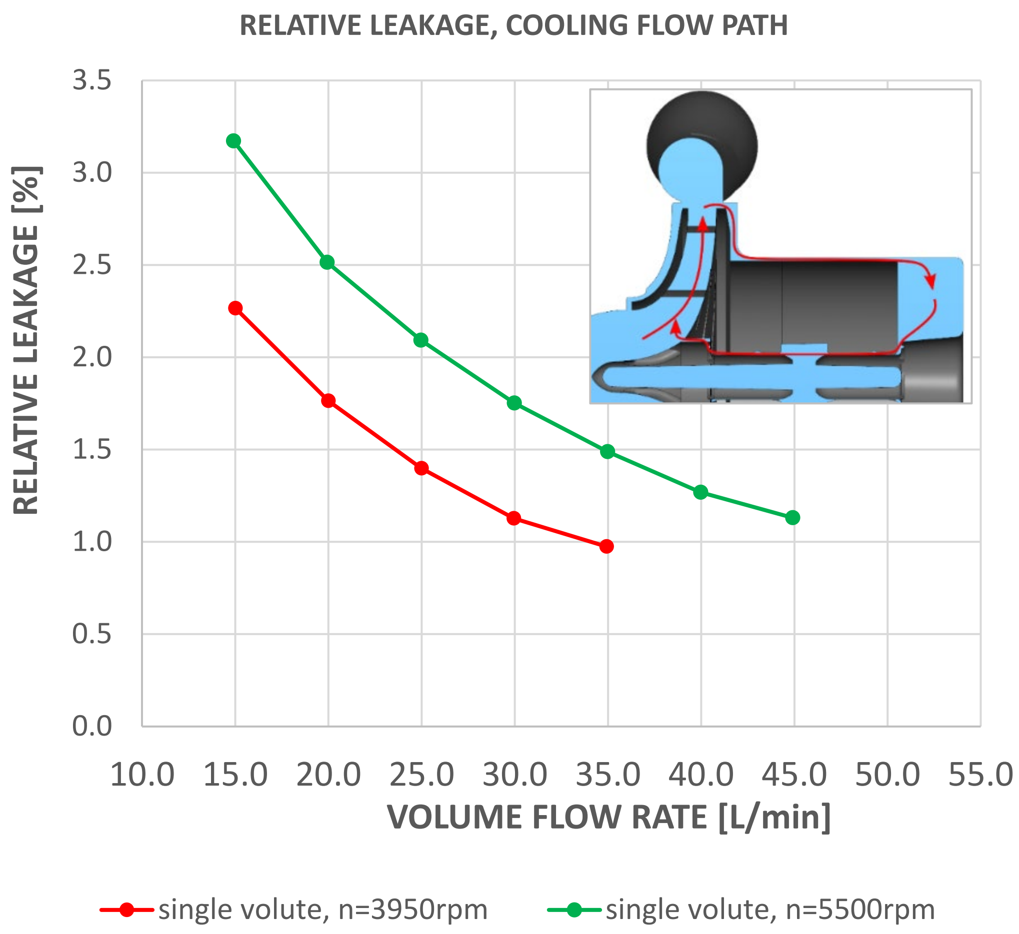






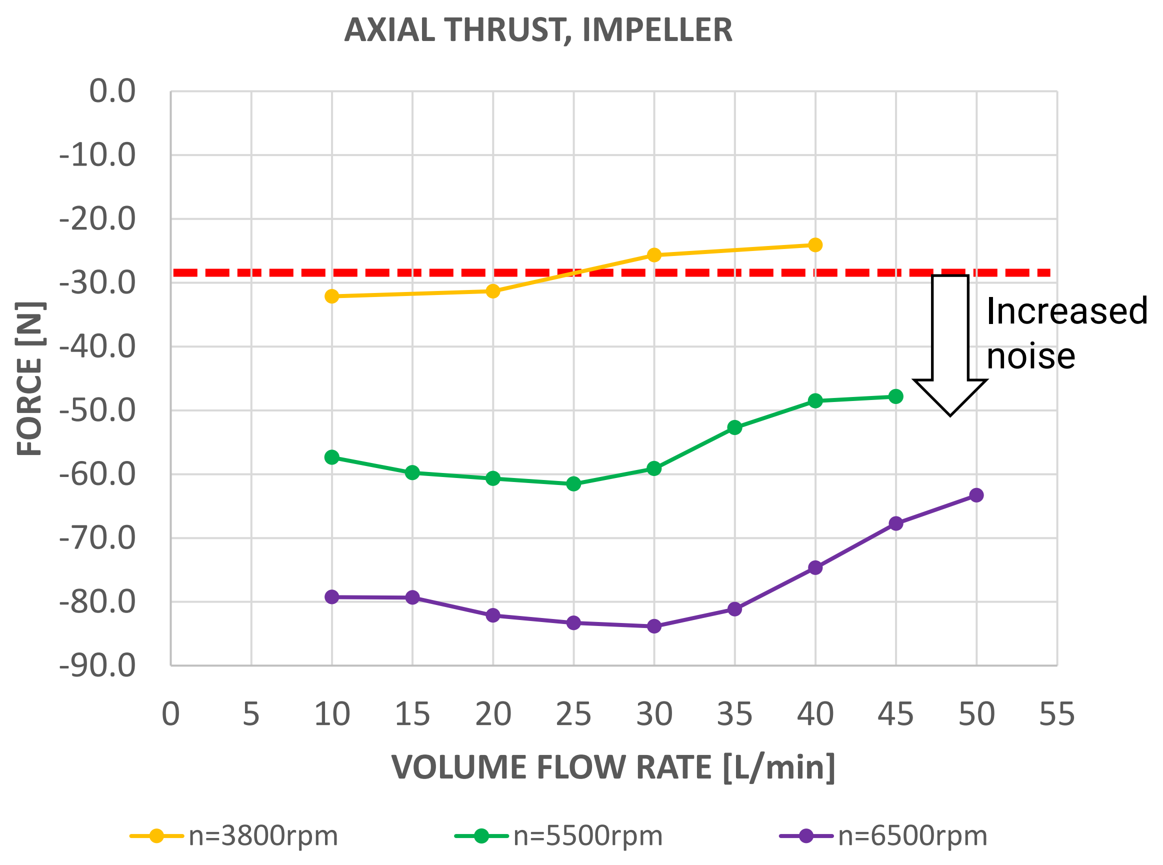
Leakage flow needs to be considered, even in the early development stage.

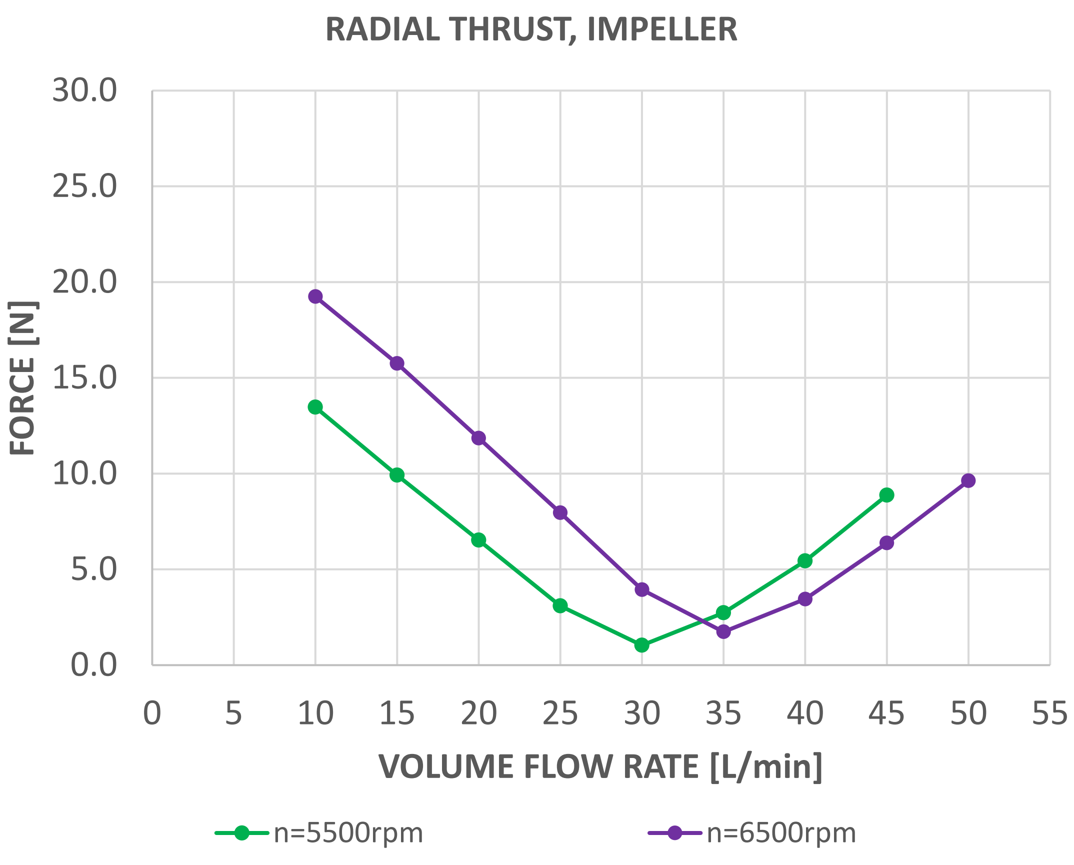




Prototype testing the initial design model → some operating points were noise-wise conspicuously

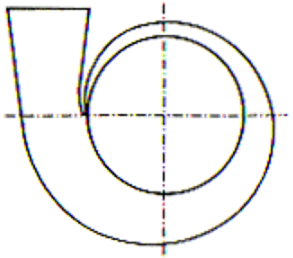
Noticeable wear at the axial thrust bearing was visible after prototype testing





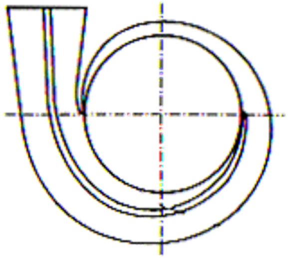
Test Results – Analysis and Solution

- **Double volute design** to limit radial force level in off-design points



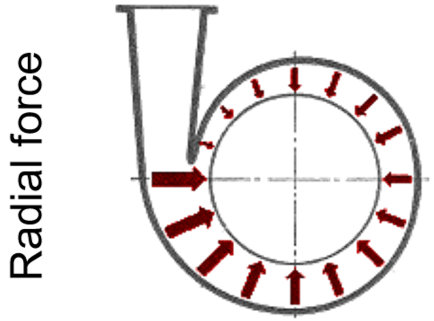
Single volute

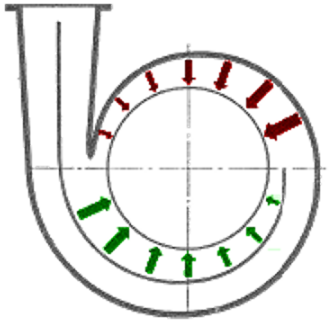
- Lowest production cost
- Preferred for low energy transmission

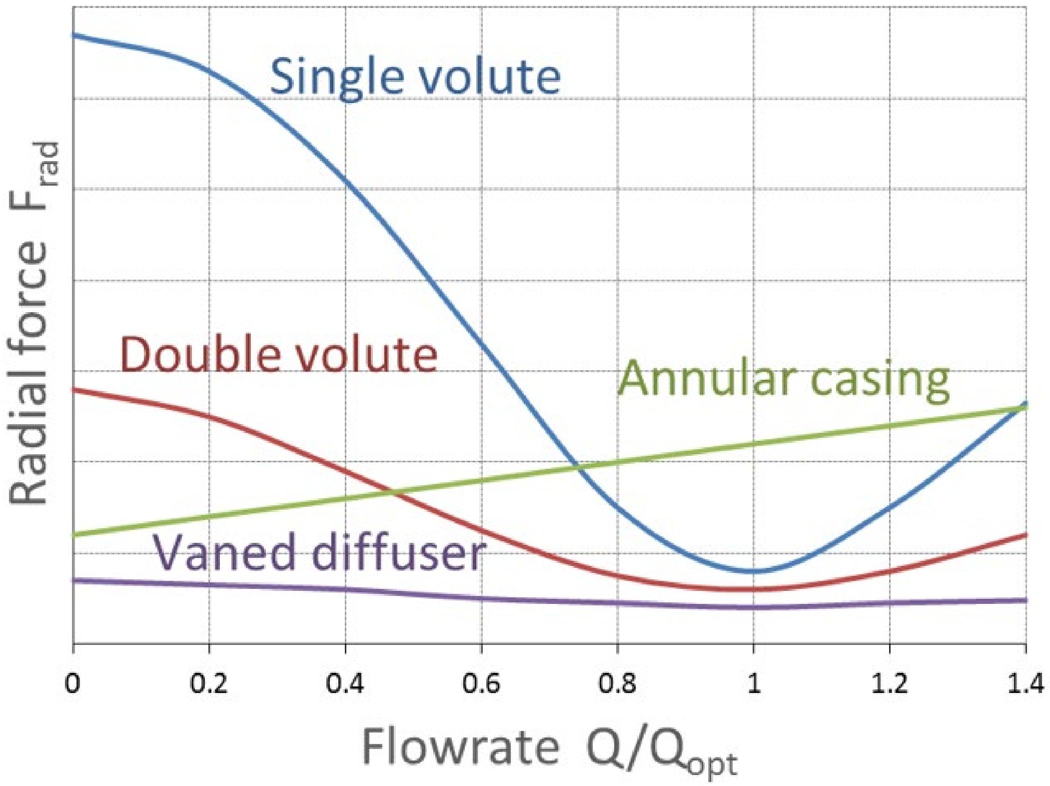


Double volute

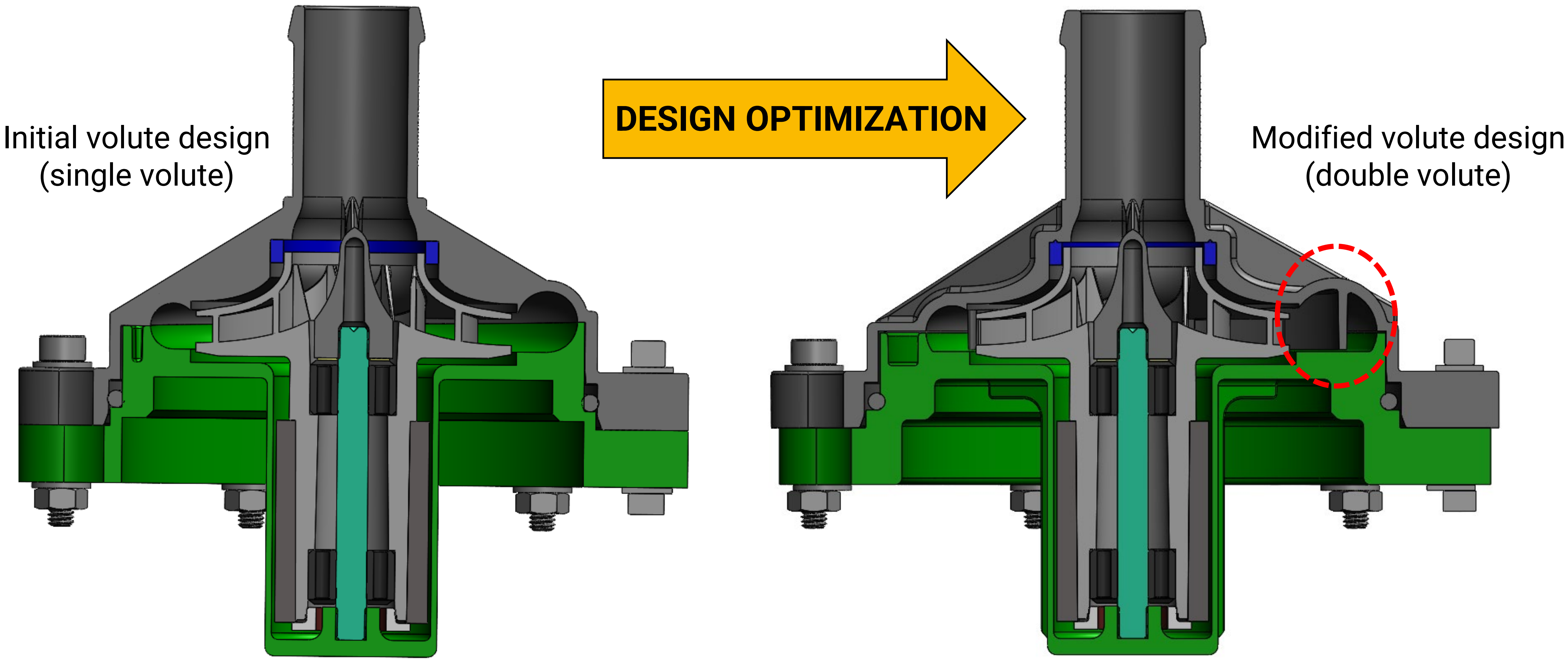
- Reduction of radial forces
- Common pressure joint



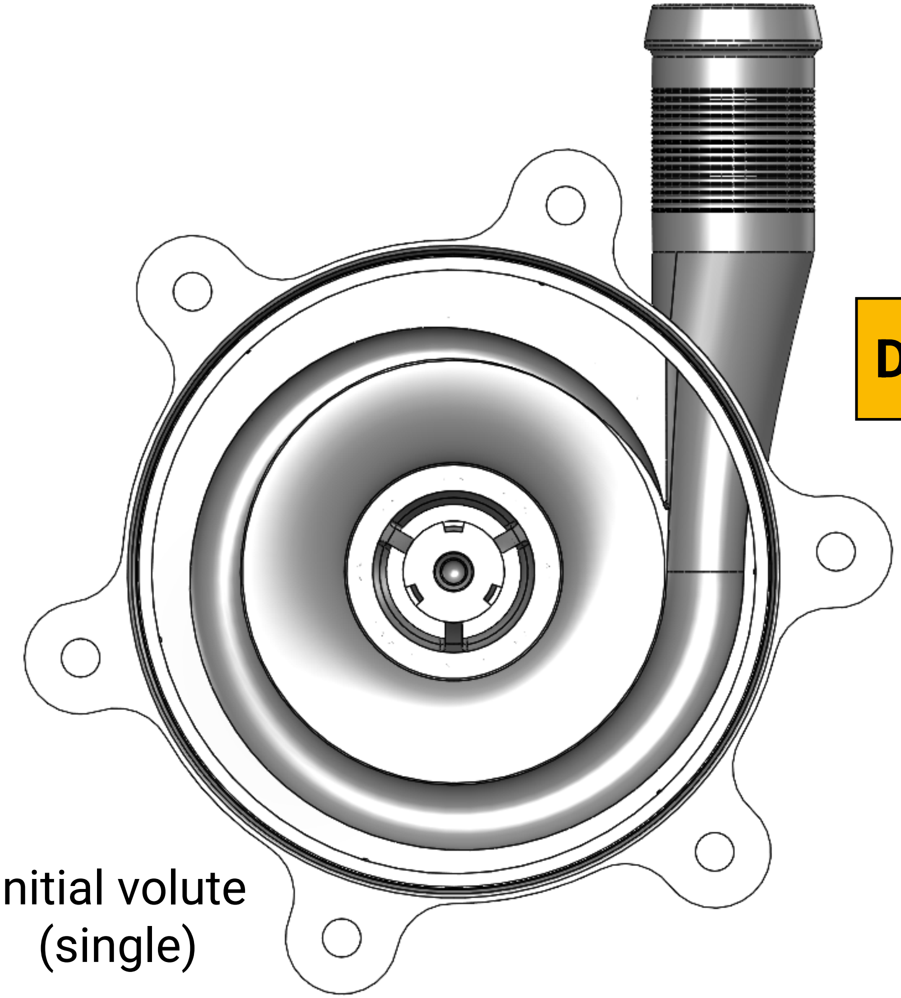




Double volute design to limit radial force level in off design points

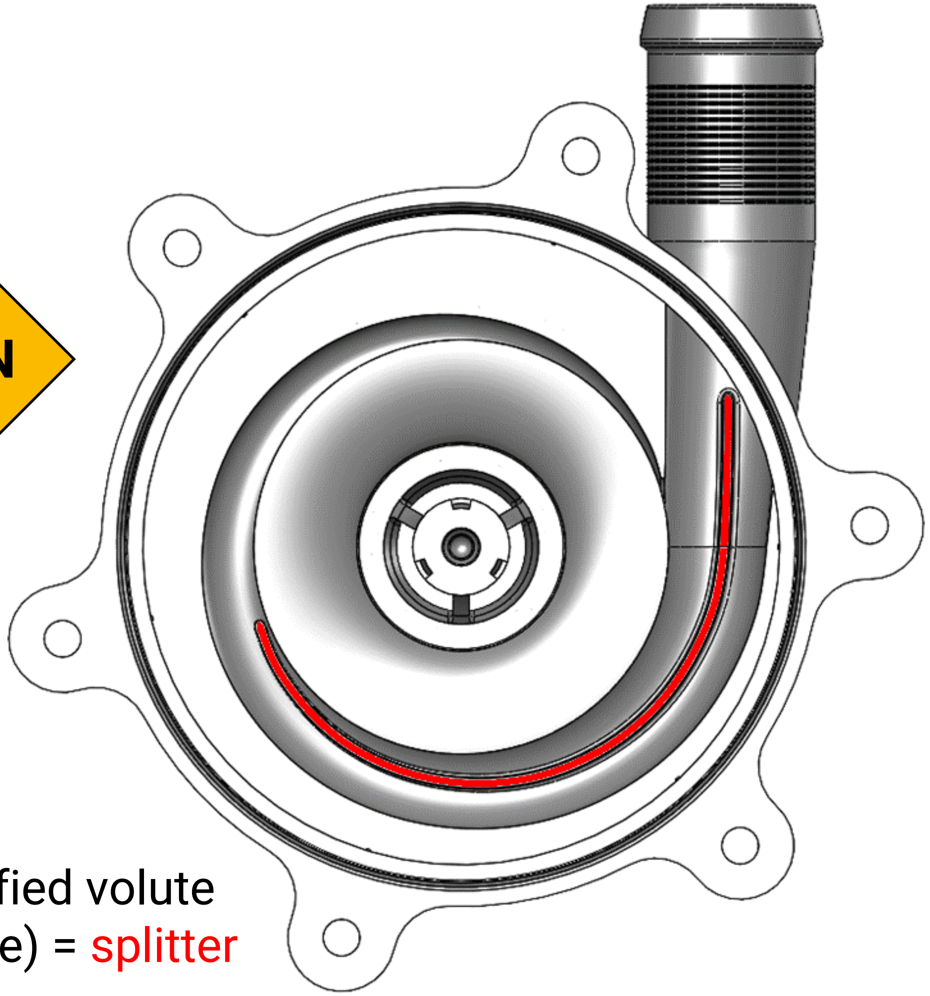


Double volute design to limit radial force level in off-design points



Initial volute
(single)

DESIGN OPTIMIZATION



Modified volute
(double) = splitter

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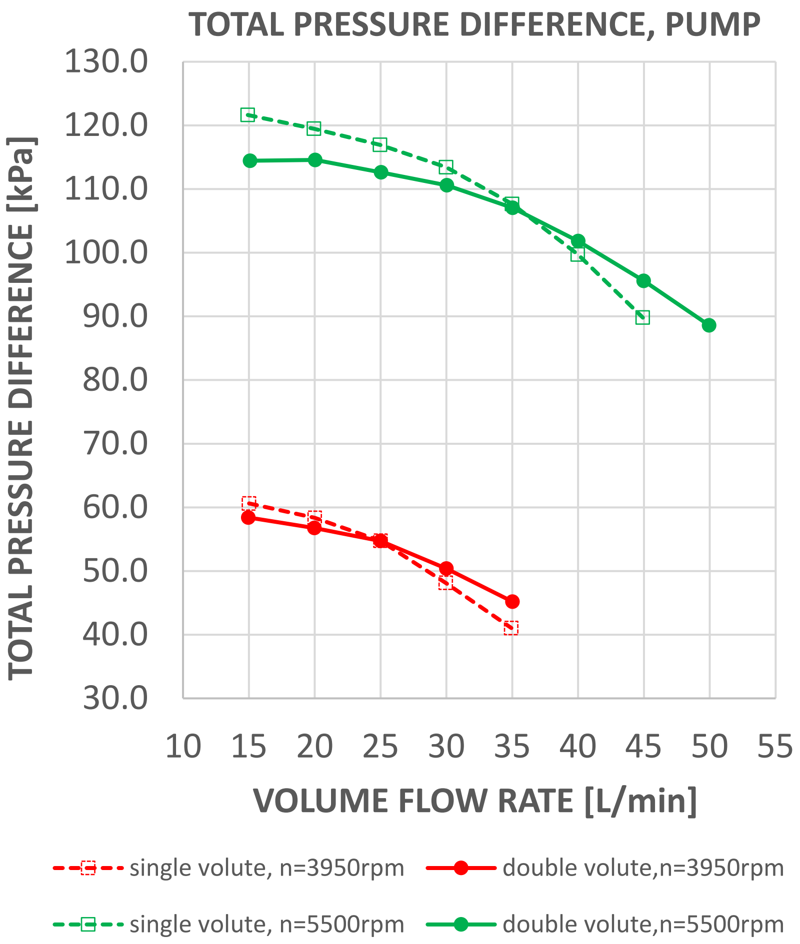
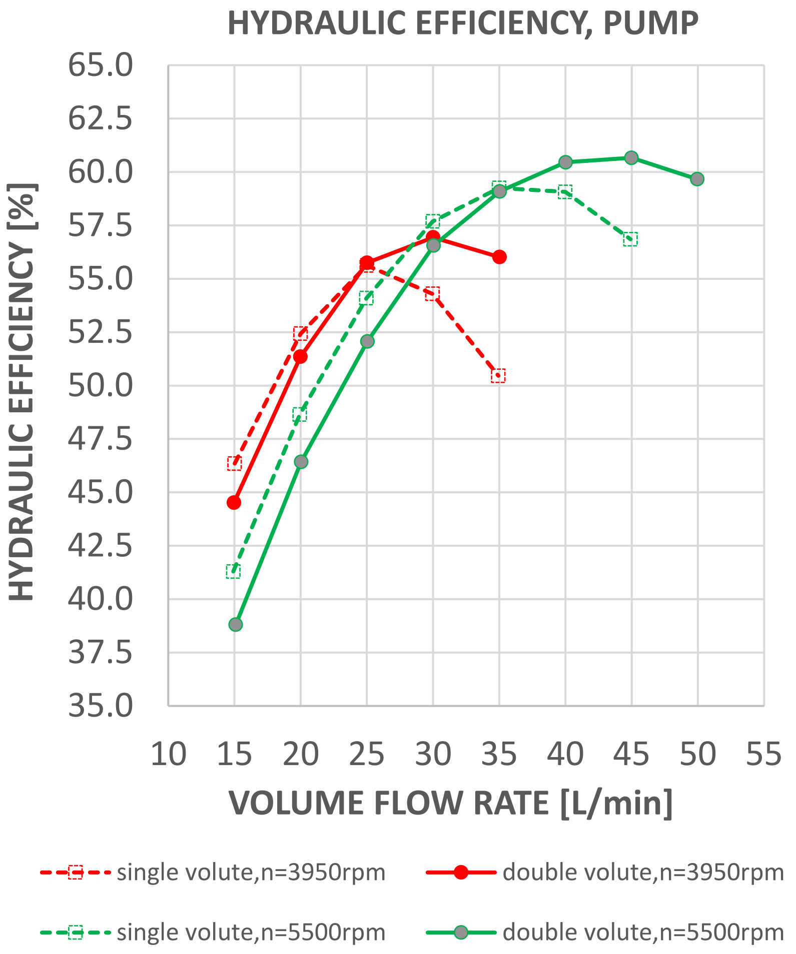
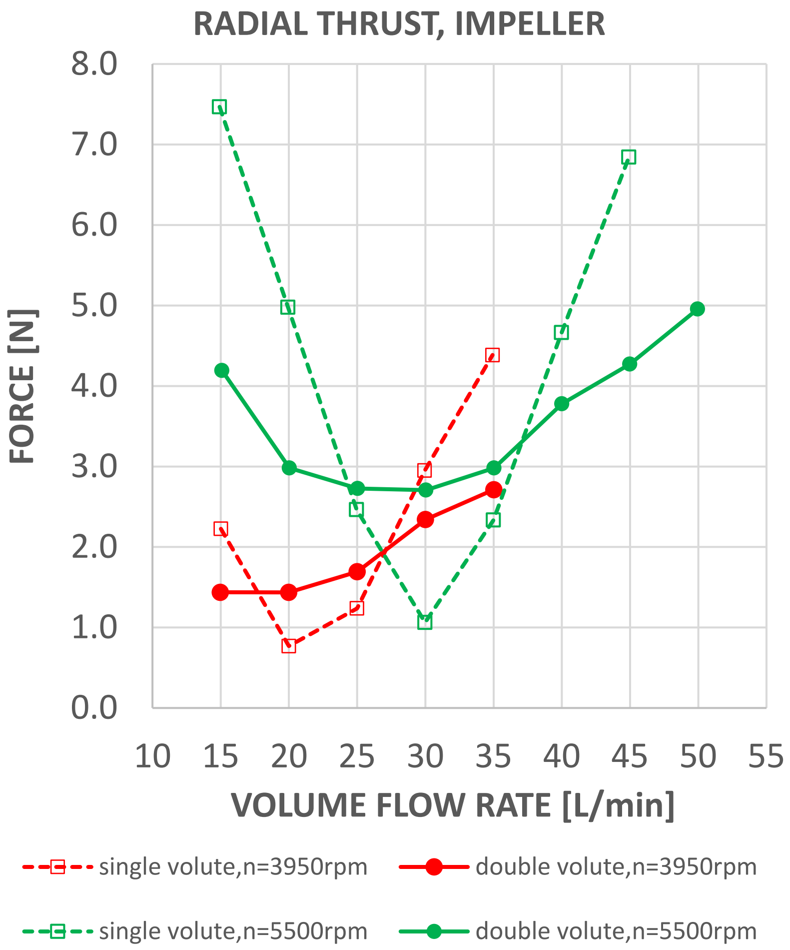
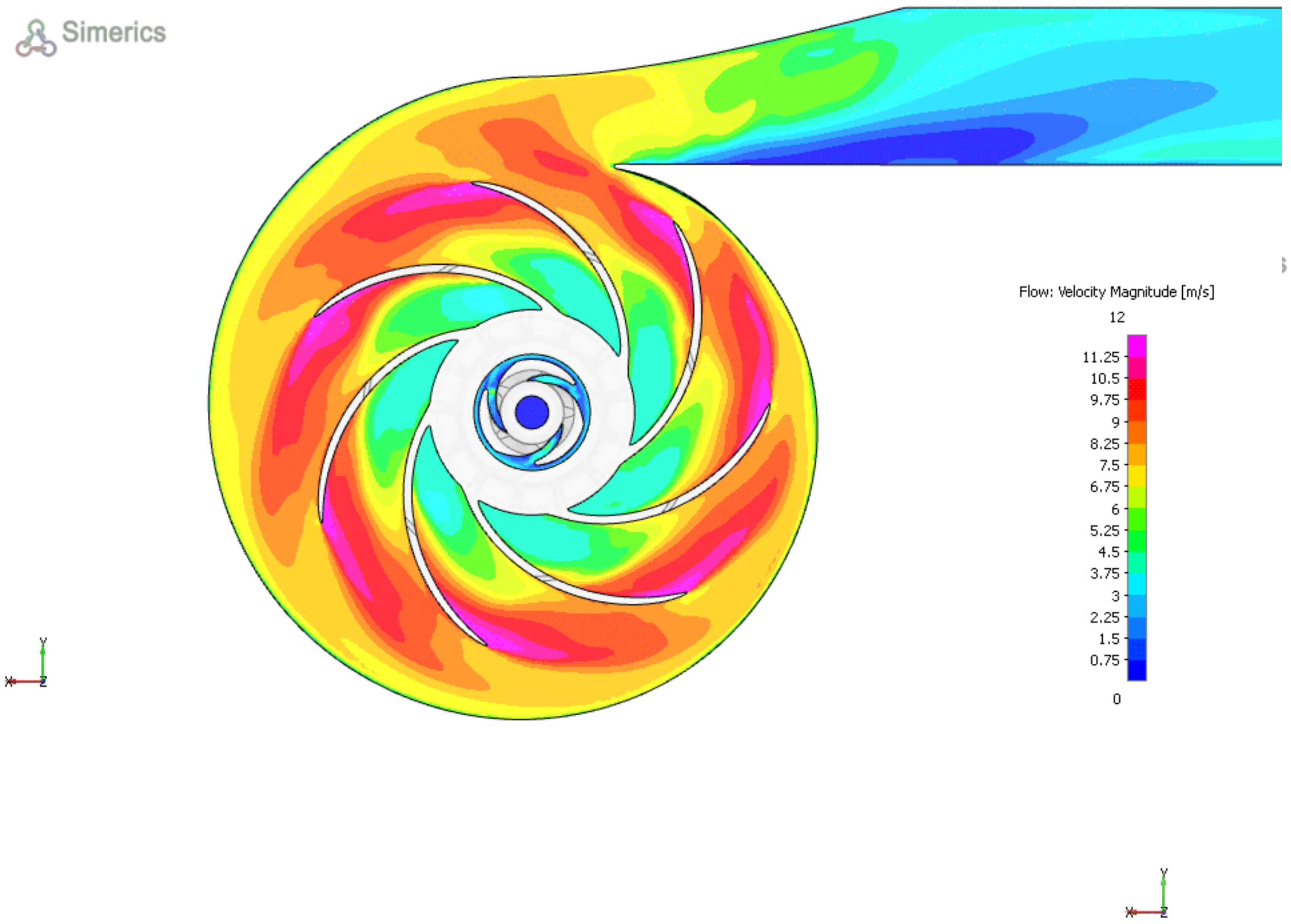
Volute with splitter → optimize design to maintain efficiency

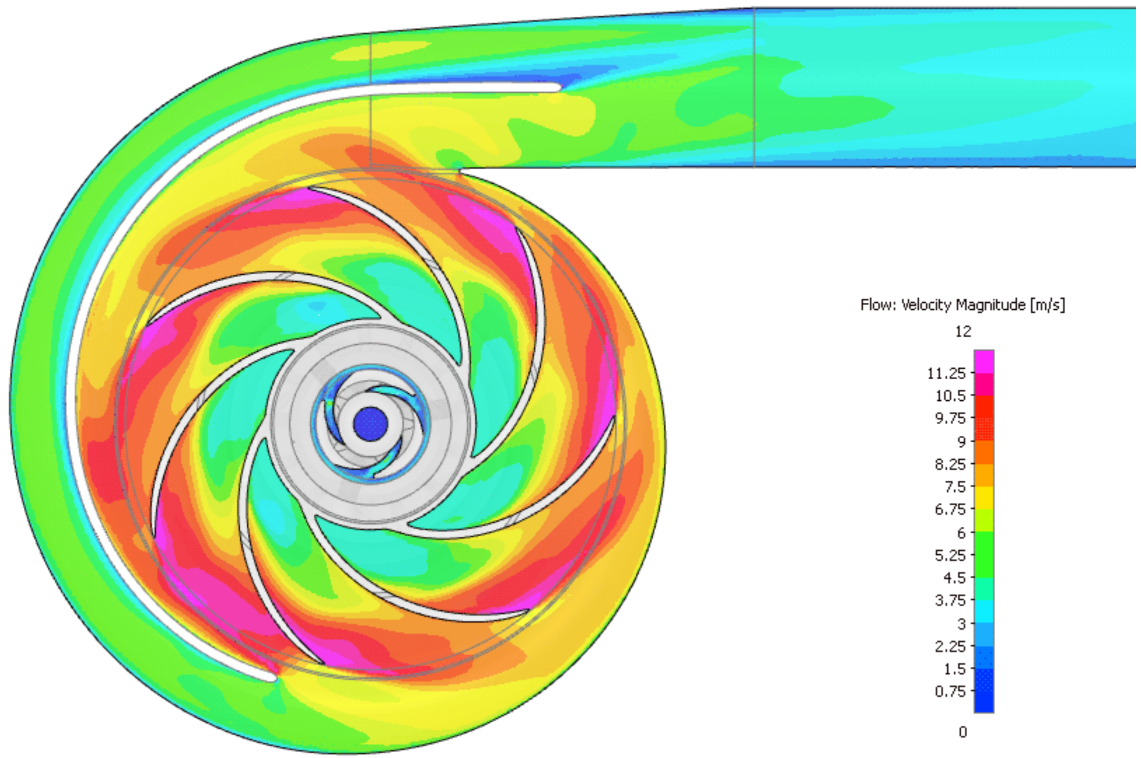






n=5500 rpm, Q=35 l/min





Design point adjustment

Design Point Adjustment

- A customer demand forced a **design point shift**, that needs substantially higher pump performance!

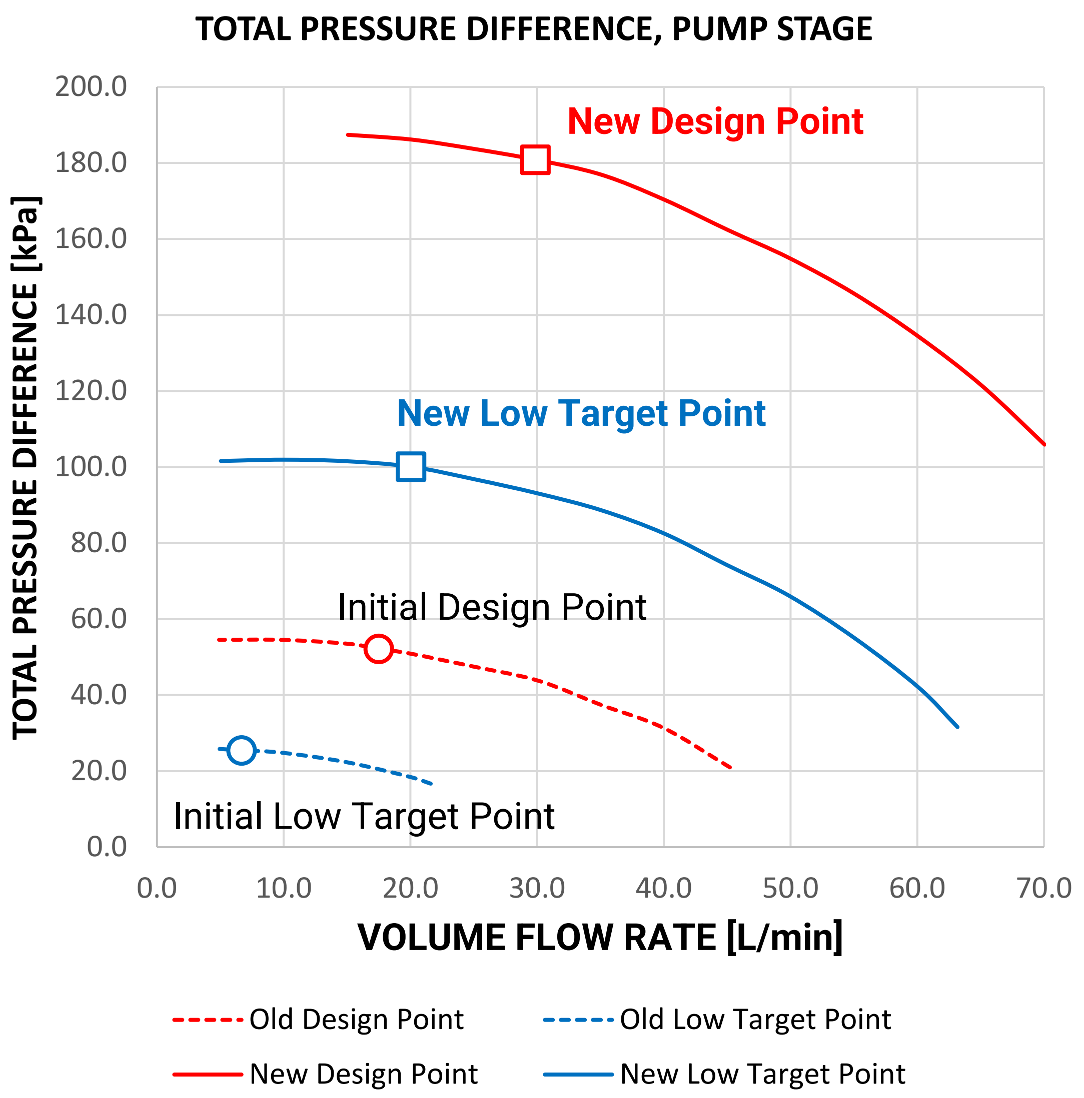
New Design point

Volume Flow Rate	35.0	L/min
Pressure Difference	180.0	kPa

New Low Target Point

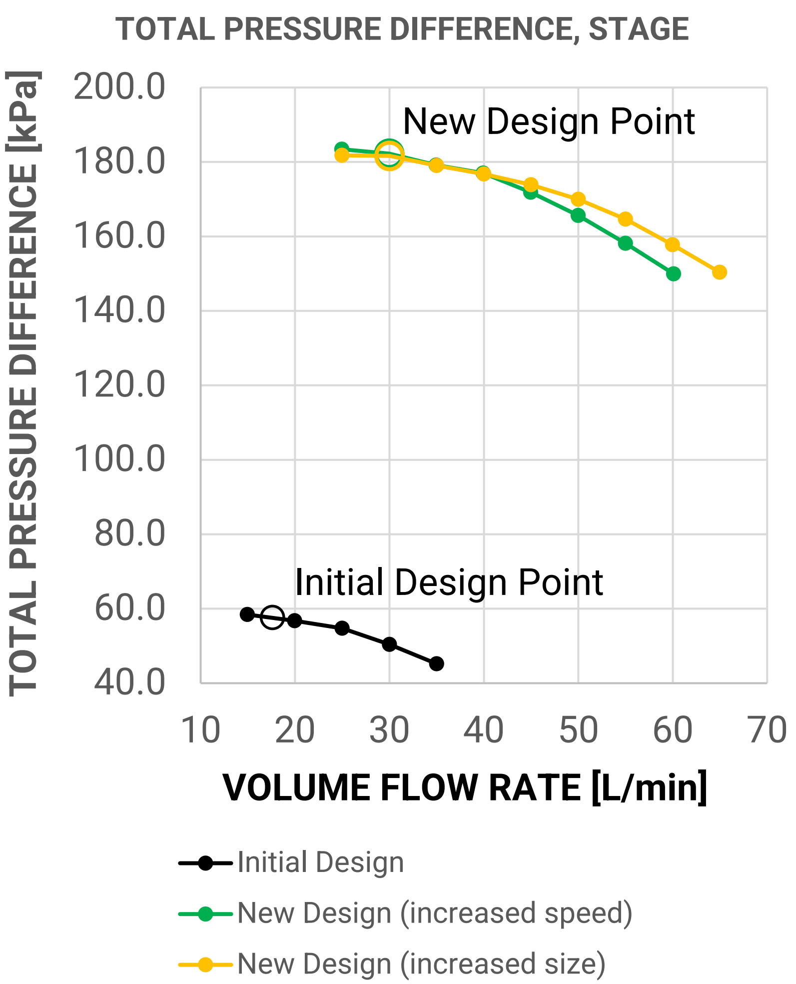
Volume Flow Rate	20.0	L/min
Pressure Difference	100.0	kPa

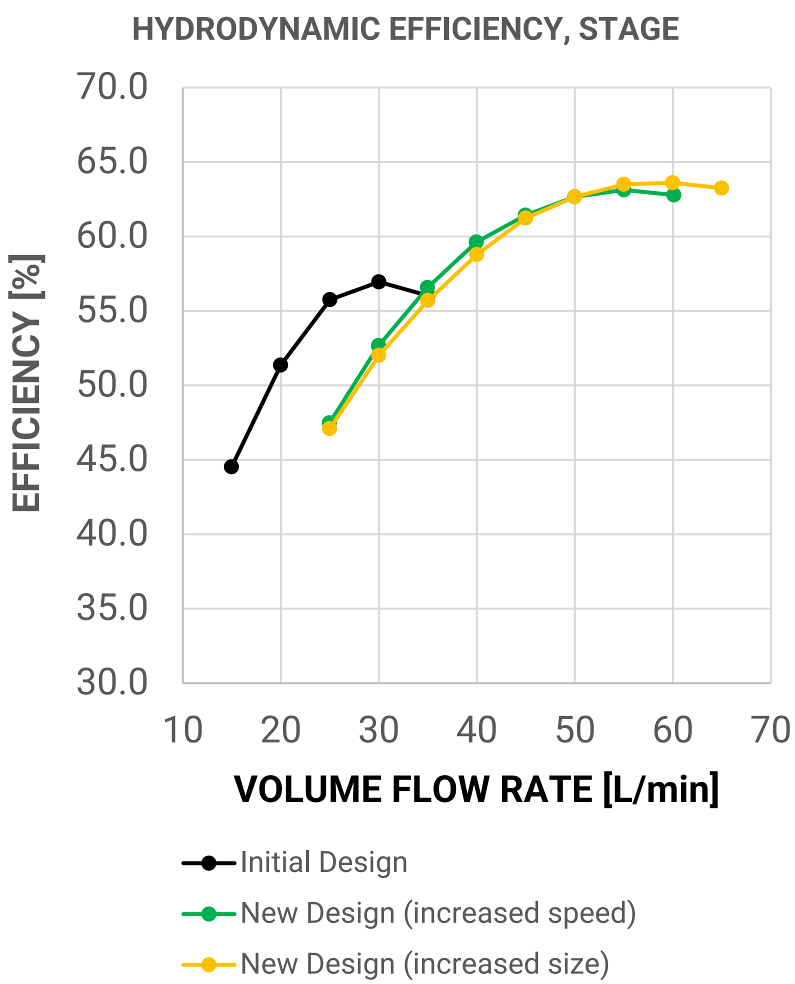
Re-design, design exploration, optimization.

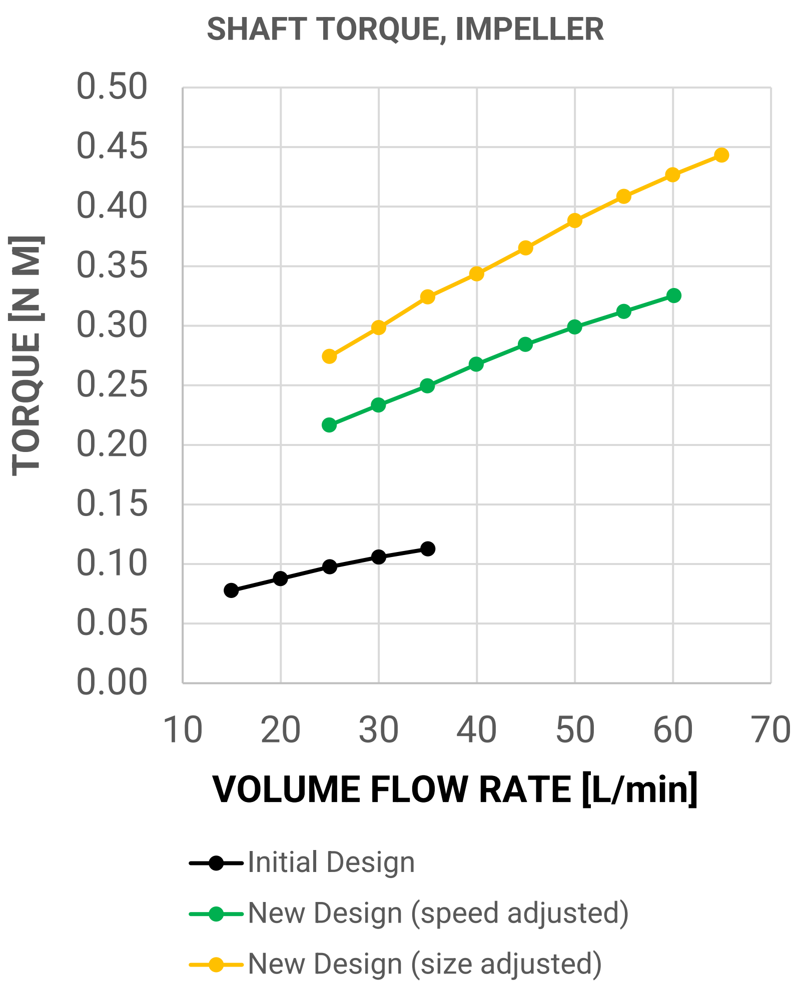


Design Point Adjustment – CFD Results

Using optimization, two new designs were identified for the adjusted design point.

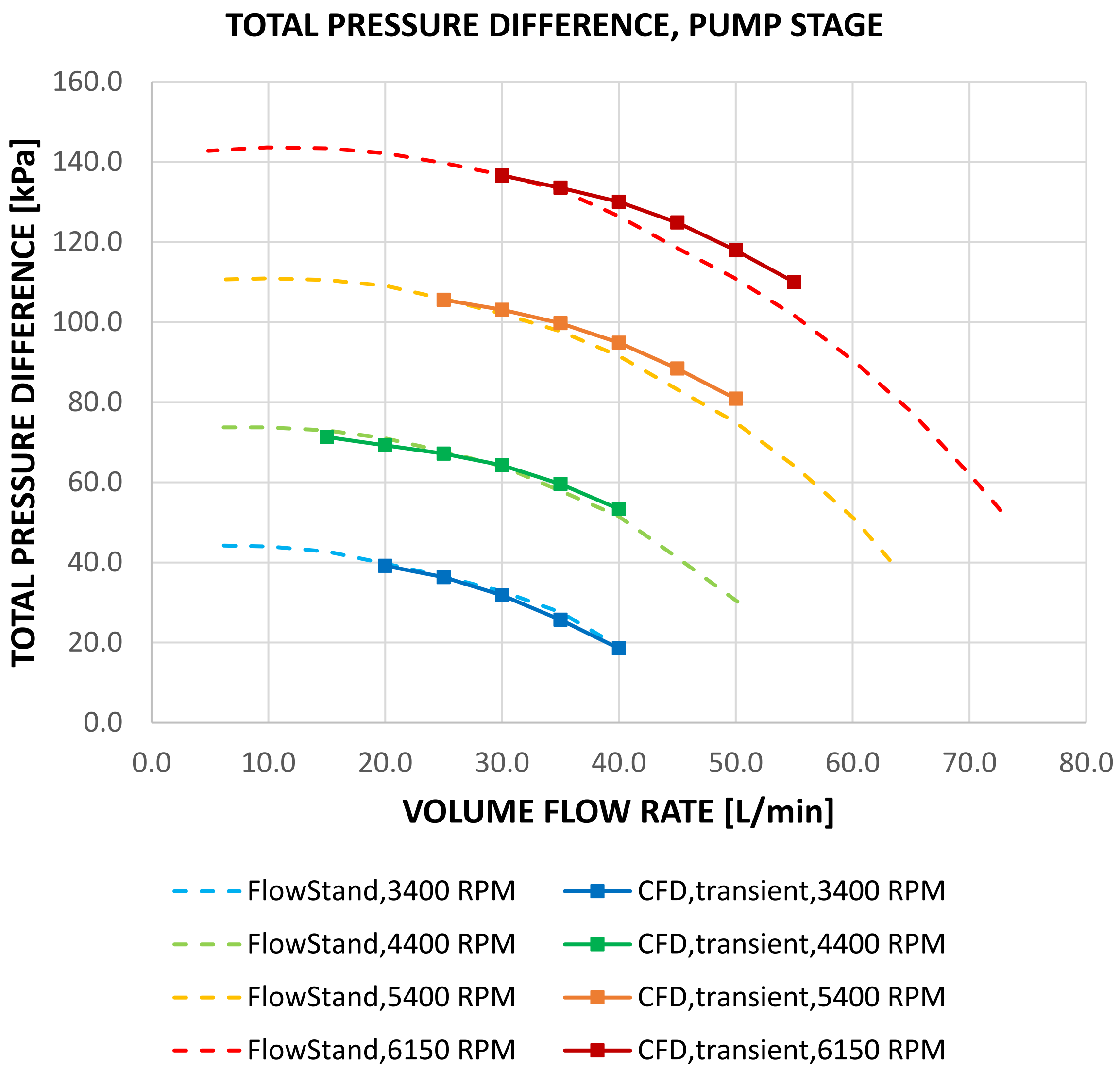


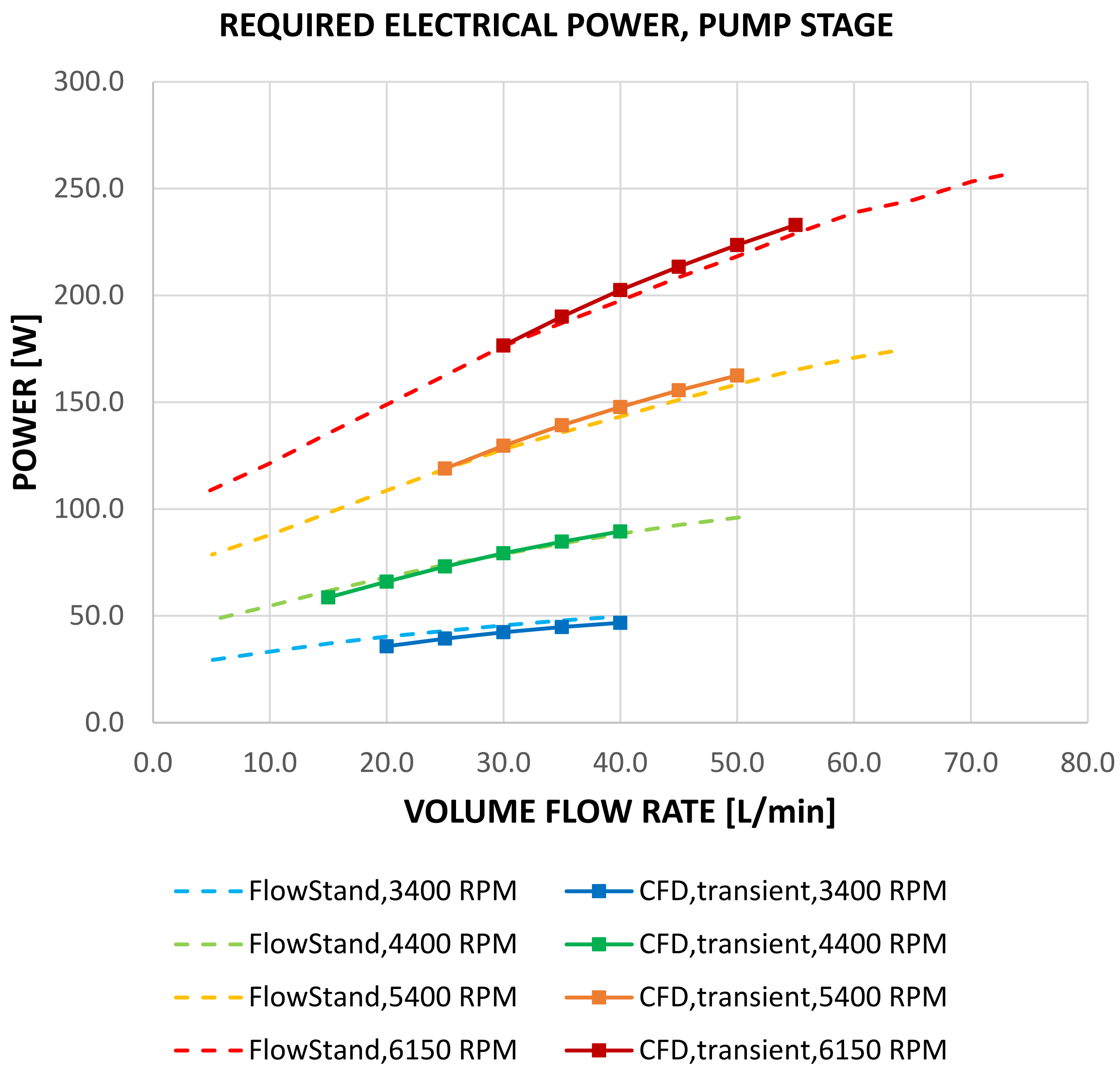




Manufacturable product

Manufacturable Product – Final Tests and CFD Results

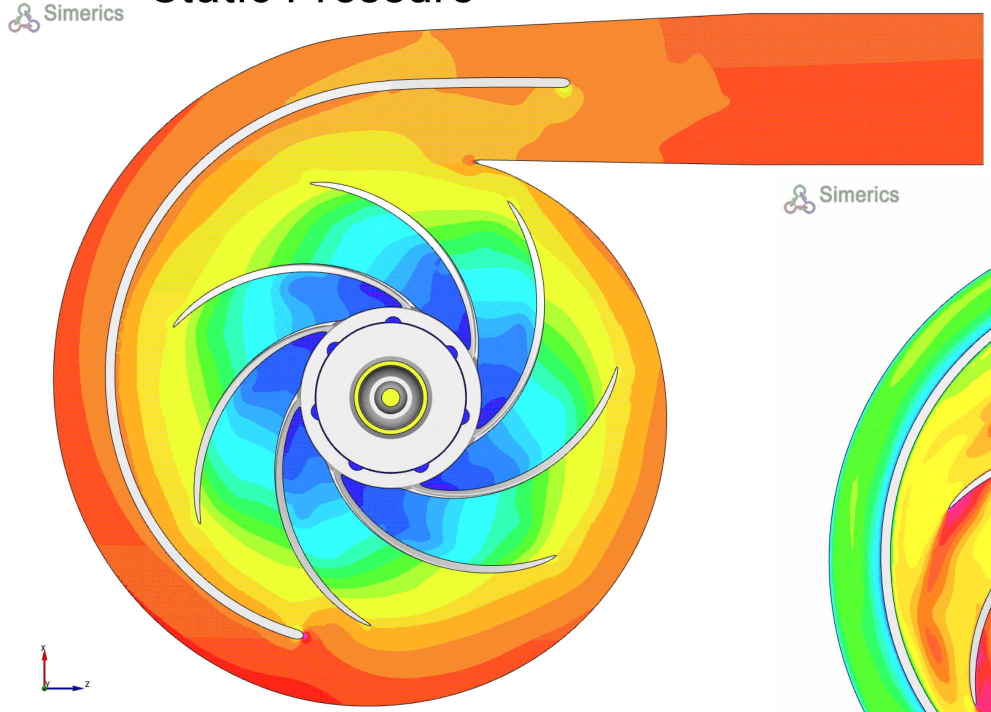




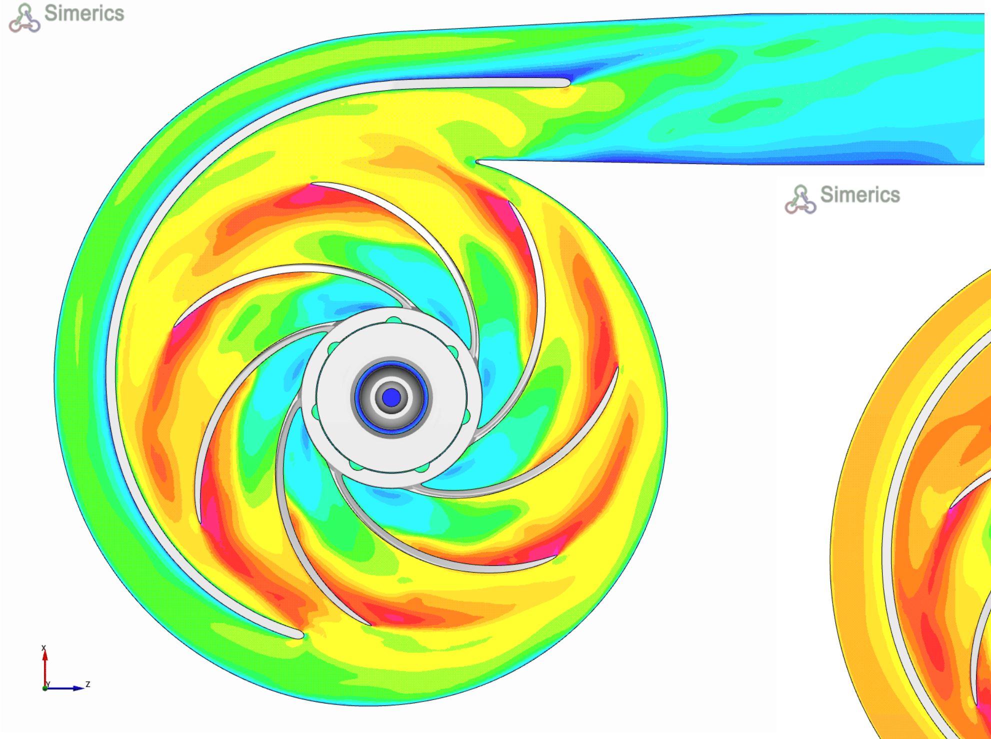
Market-ready Product – Test and CFD Results

n=6150 rpm, Q=45 l/min

Static Pressure



Velocity Magnitude



Total Pressure