Fast Centrifugal Oil Pump Design and Automated Evaluation by 3D-CFD

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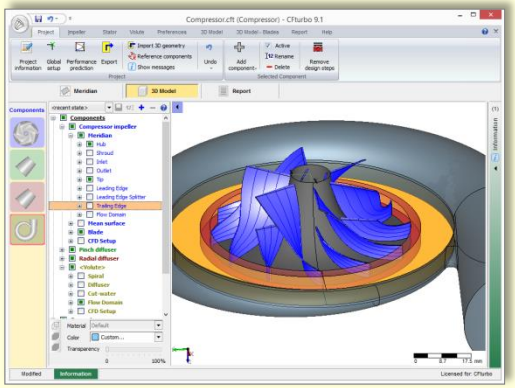
CFturbo® - The Turbomachinery Design Company

CFturbo® Software & Engineering GmbH

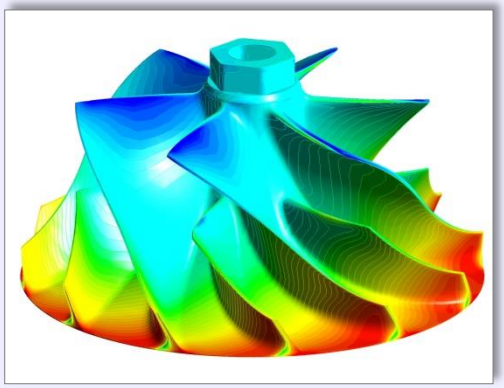
CFturbo® Software

- Turbomachinery Design Software
- Automated Workflows



Engineering

- Turbomachinery Conceptual Design
- CFD/FEA Simulation
- Optimization



CAD & Prototyping

- 3D-CAD Modeling
- Prototyping
- Testing, Validation

CFturbo® - Input and Output Data

Define operating point
Q, Δp, speed, Fluid properties
Inlet conditions

Fundamental equations
Euler-eq. of Turbomachinery,
Continuity equation,
Momentum equation, …

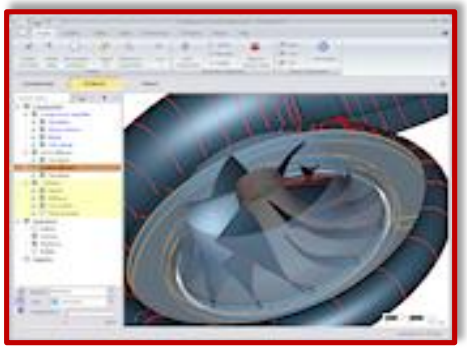
Empirical functions
Public knowledge,
Proprietory Know-How

Reference geometry – elements, **from CFturbo**

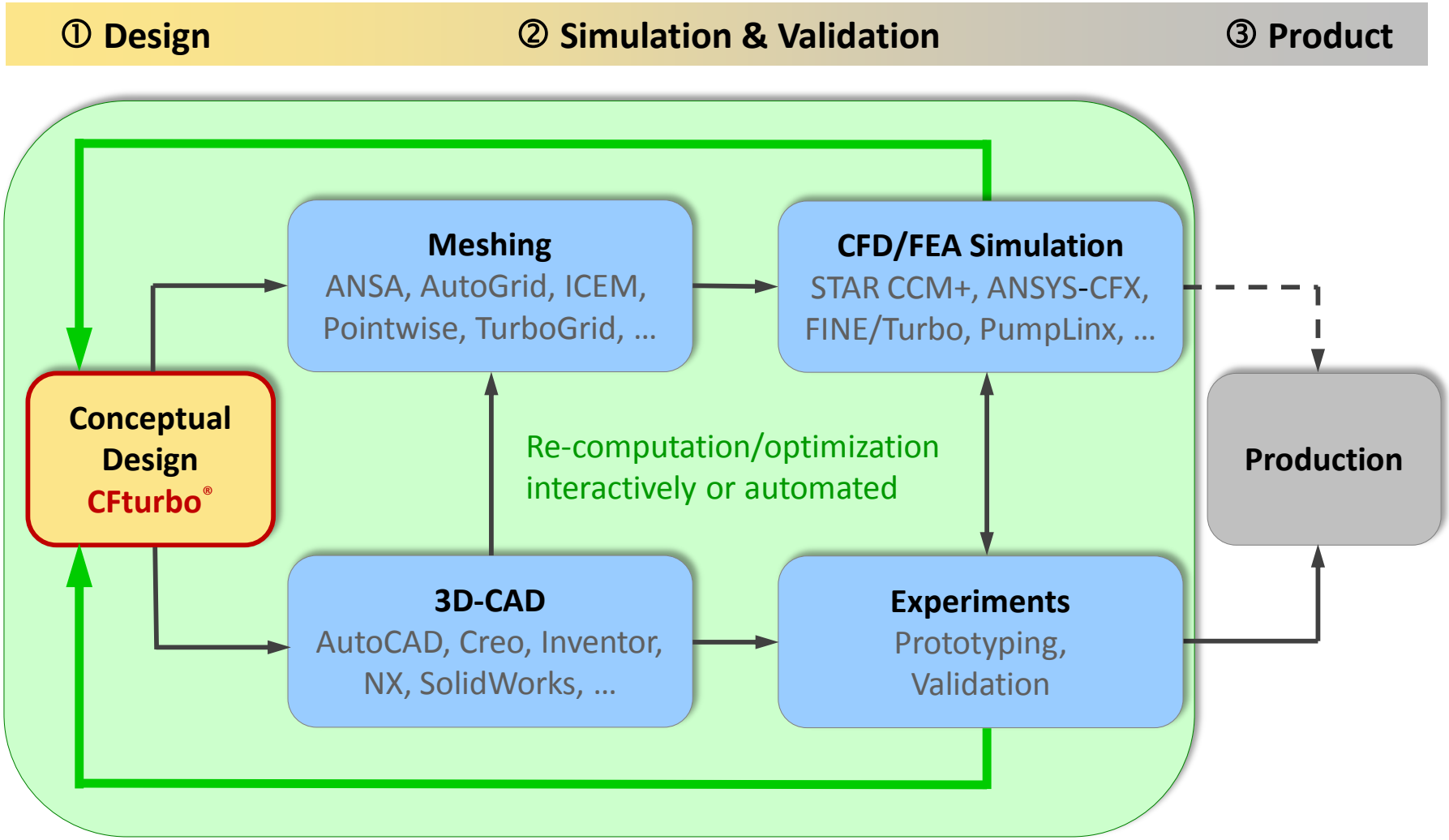
CFturbo®

Existing geometry-elements, **imported**

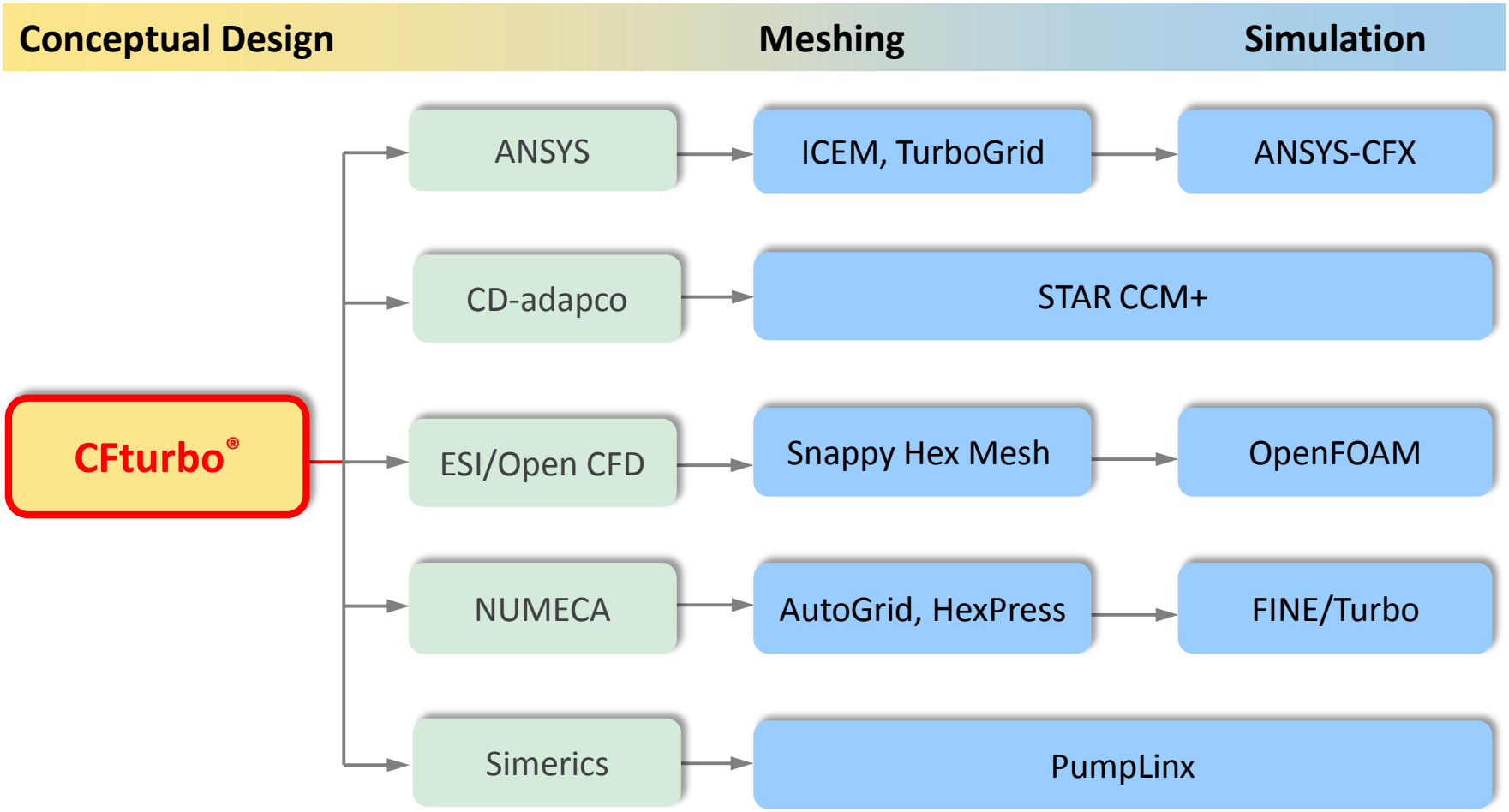
New and / or modified components



Turbomachinery Development Process using CFturbo®



CFturbo® - Interfaces to selected 3D-CFD-Codes

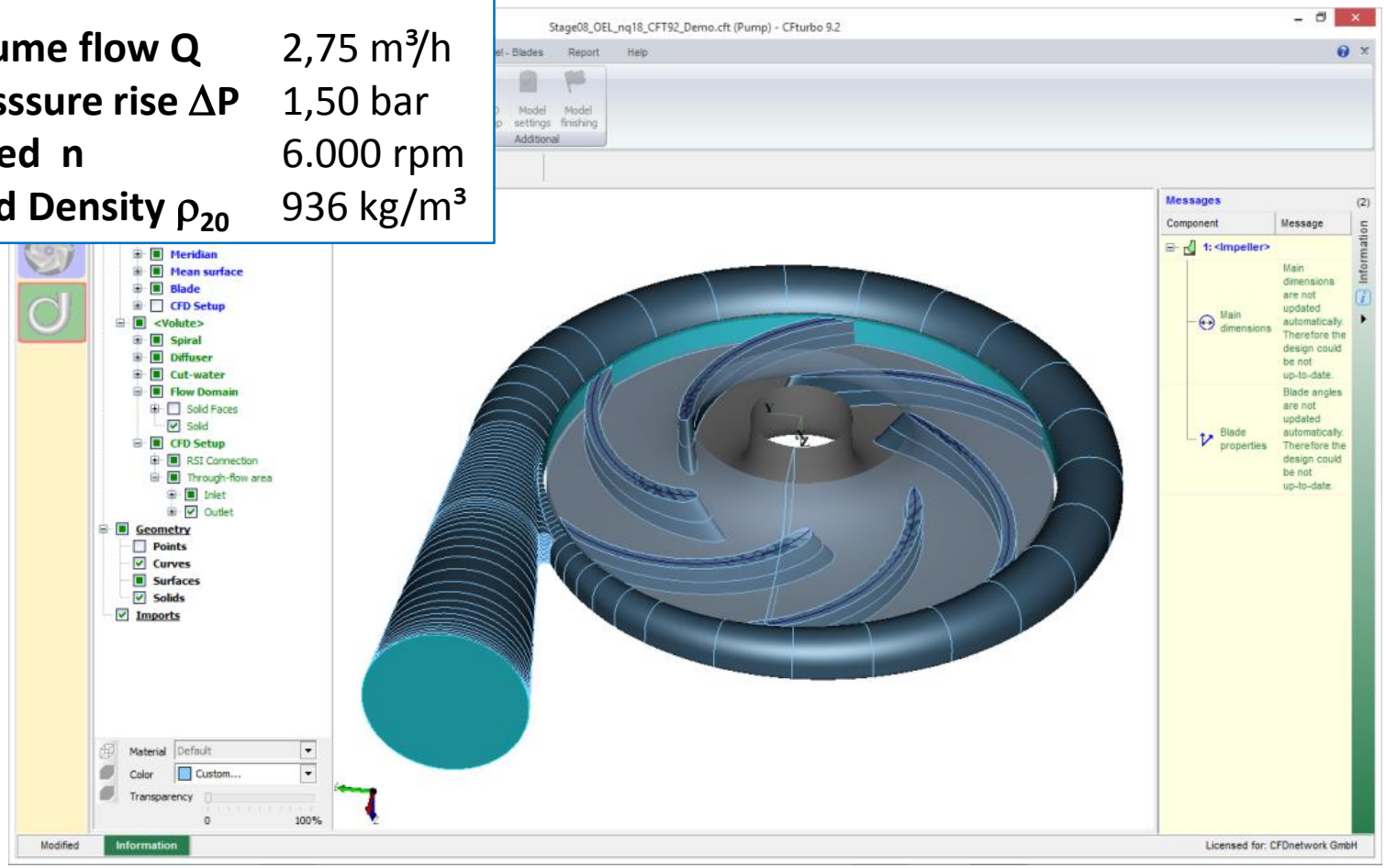


Seamless interfaces for automated workflows and optimization

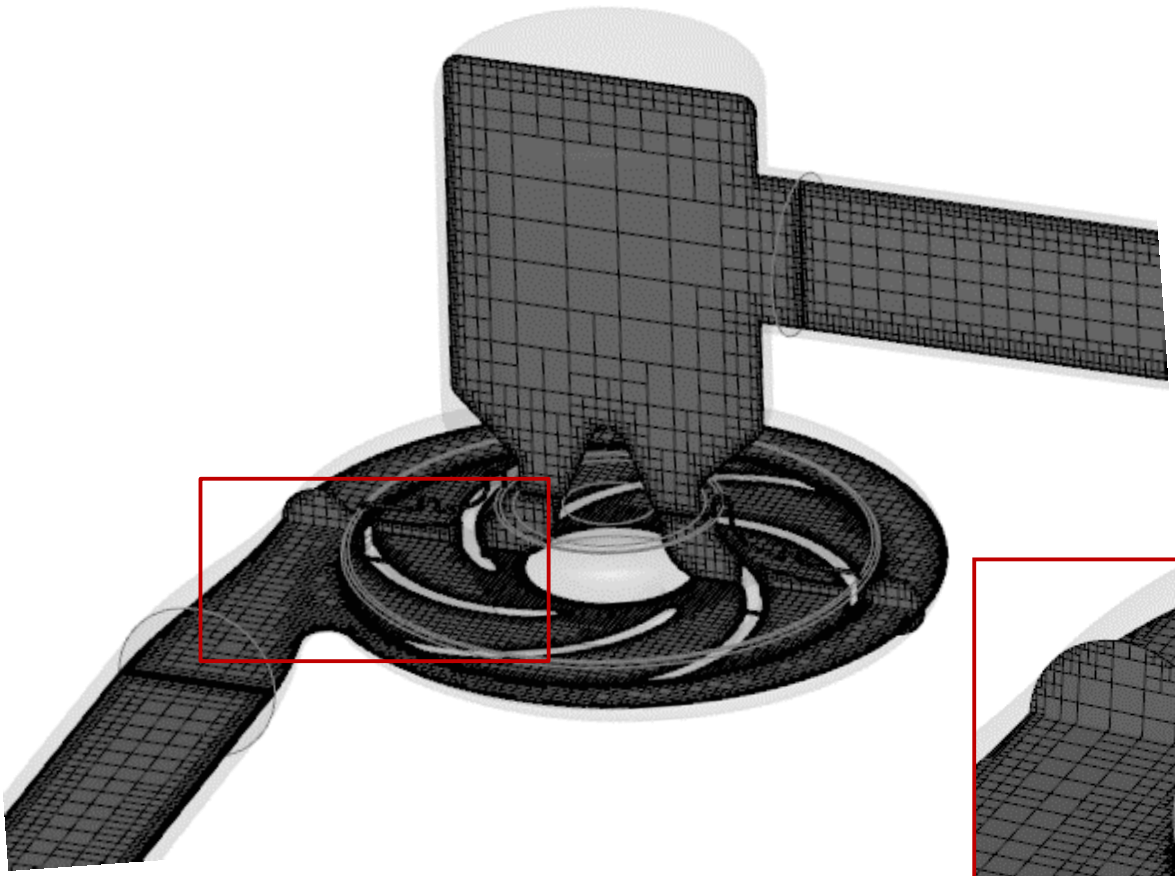
Conceptual Design of the Pump Stage

DESIGN POINT

Volume flow Q	2,75 m³/h
Presssure rise ΔP	1,50 bar
Speed n	6.000 rpm
Fluid Density ρ_{20}	936 kg/m³



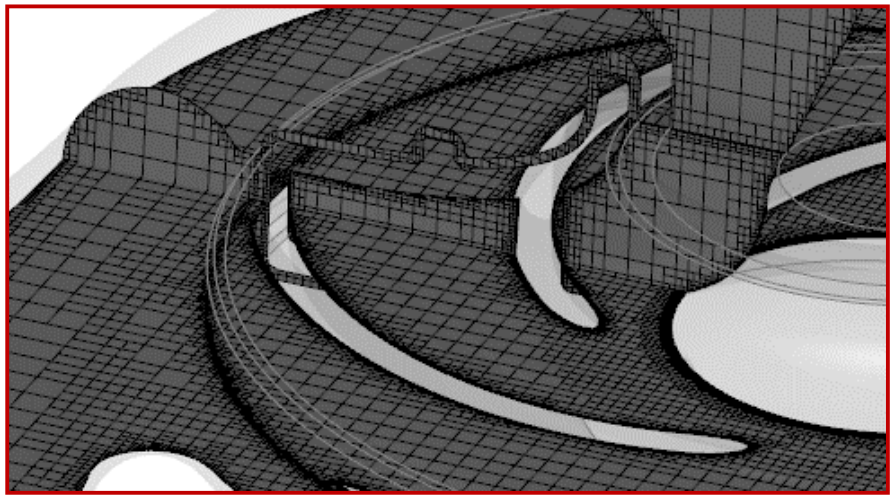
Automated Meshing



Direct Interface in CFturbo

Using PumpLinx® to create carthesian binary tree mesh

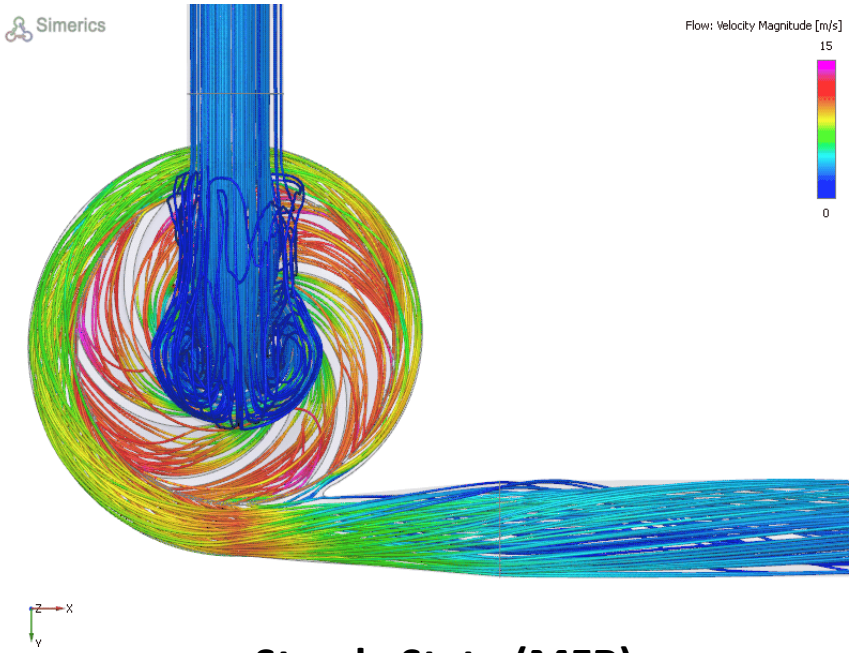
Approx. 2,0 mio. nodes



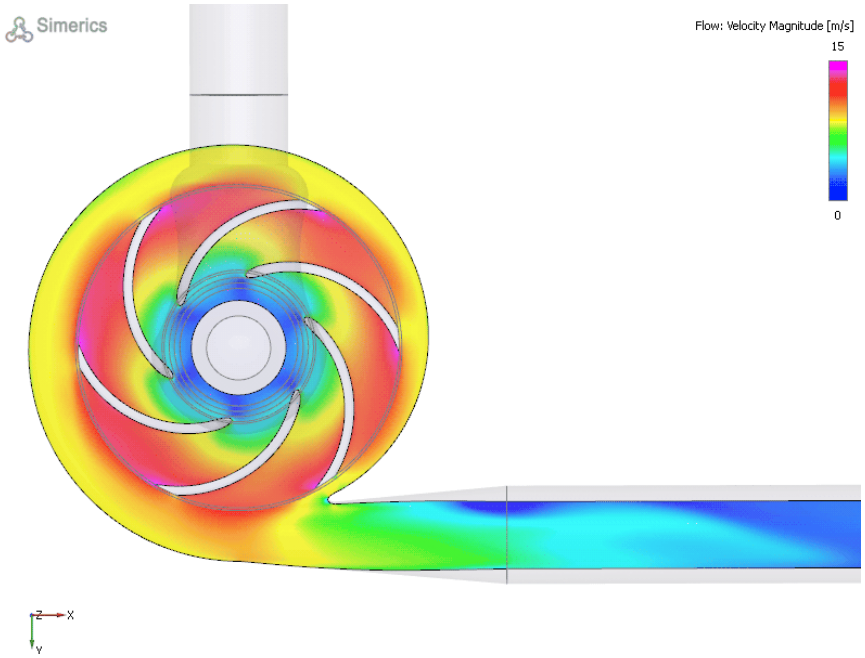
Steady State (MFR) and Transient Simulation

Hardware: Modern desktop workstation, 8 cores

Computational time - Steady State (MFR) 20 … 30 min. /operating point
- Transient 3 hours/operating point
- Batch mode runs



Steady State (MFR)



Transient

Design & Simulation Process

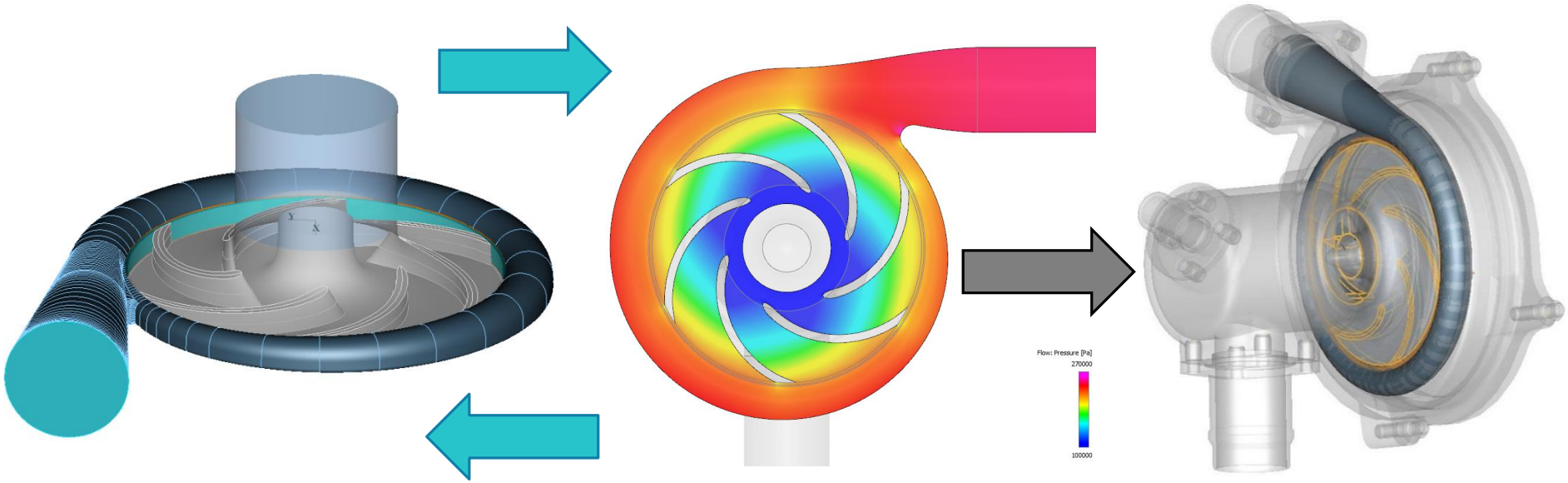
CAE-engineering process to design and simulate the oil pump, 8 model variations, delivery time less than one week

Design point defintion

Volume flow Q	2,75 m³/h
Presssure rise ΔP	1,50 bar
Speed n	6.000 rpm
Fluid Density ρ_{20}	936 kg/m³

Modified fluid data for simulation (oil)

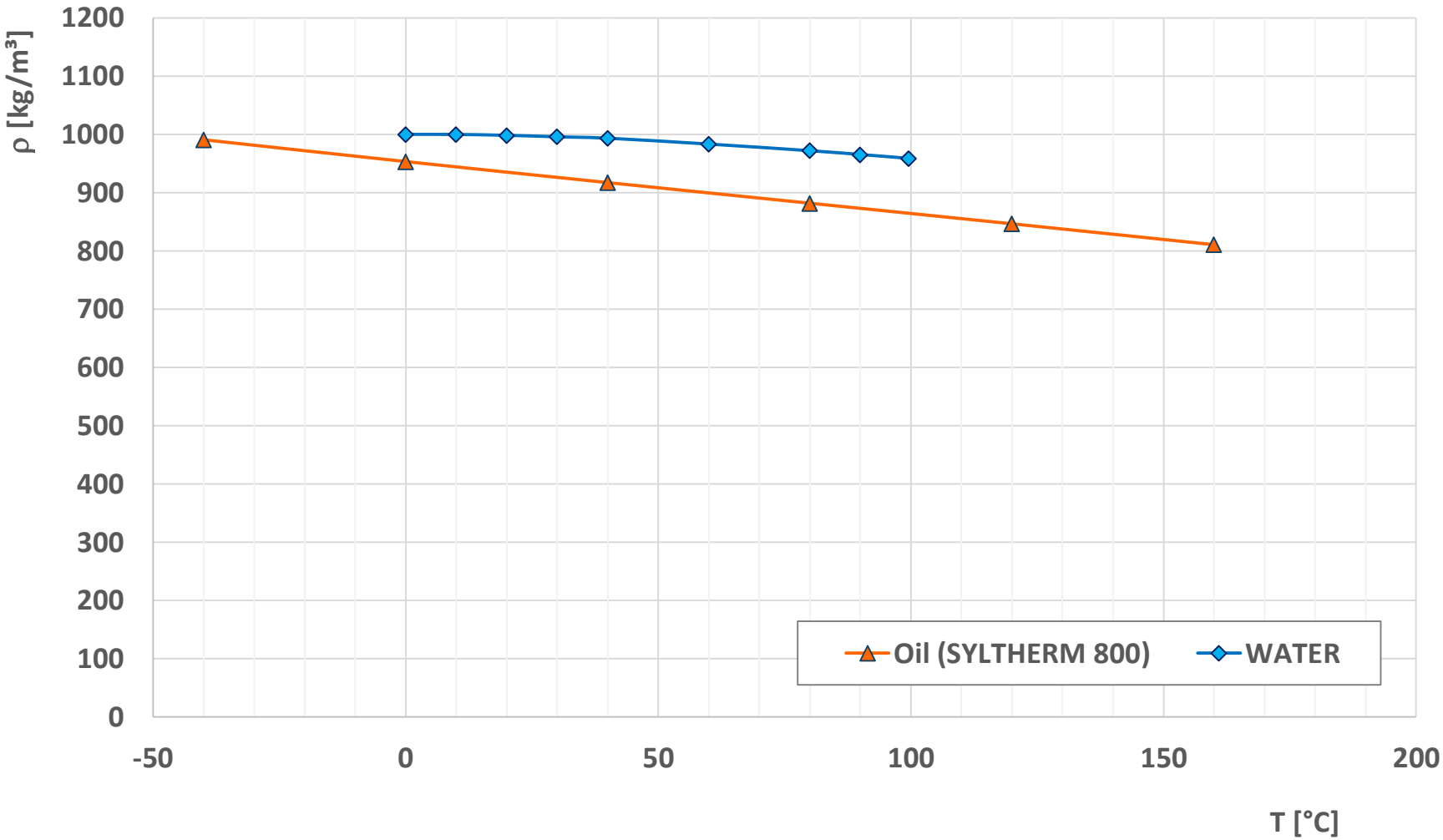
Density (20°) ρ_{20}	936 kg/m³
Density (70°) ρ_{70}	890 kg/m³
Viscosity (20°) ν_{20}	**0.009 Pa s**
Viscosity (70°) ν_{70}	**0.004 Pa s**



8 Designs **8 Performance curves** **1 Prototype built**

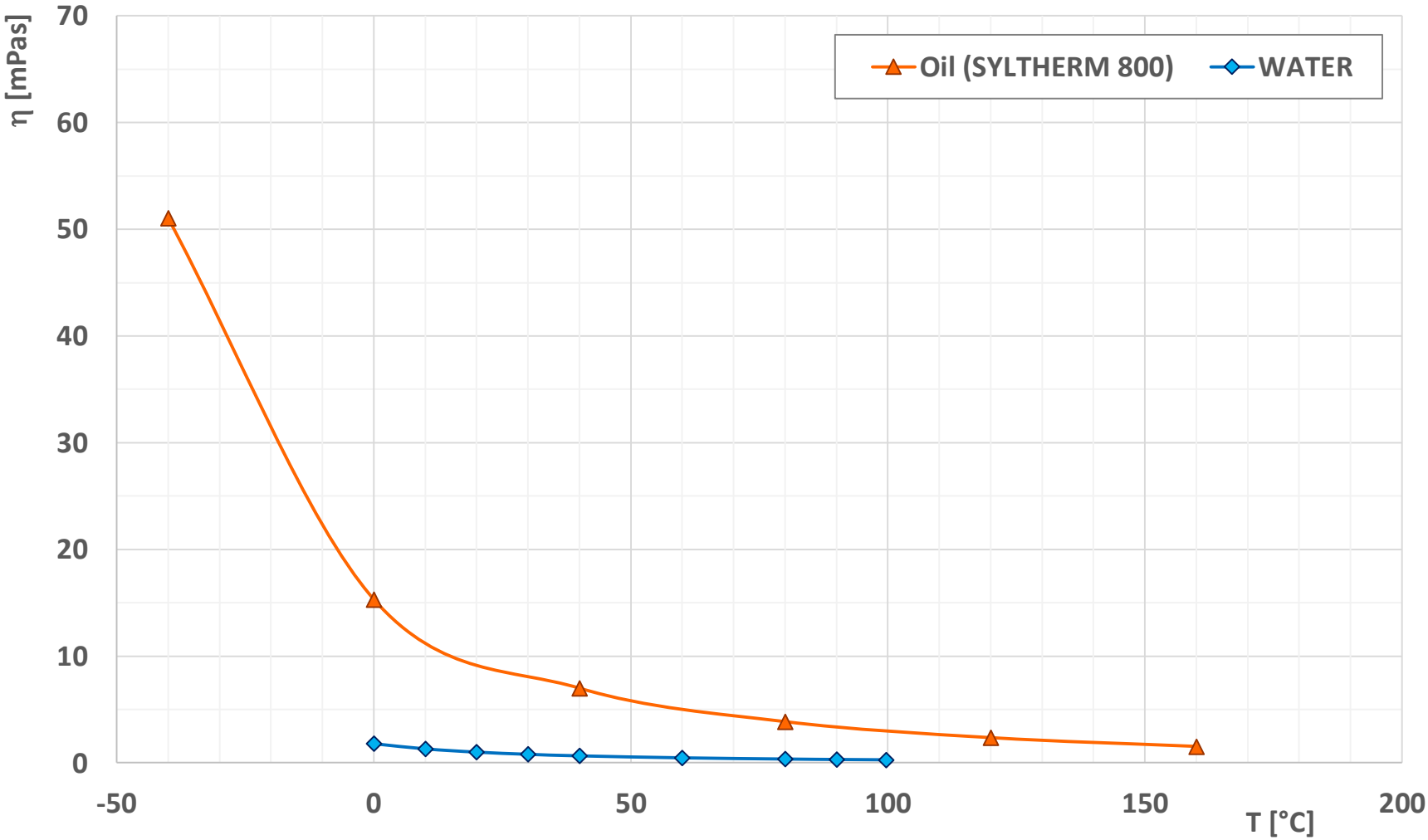
Fluid Properties

Density= f (Temperature)



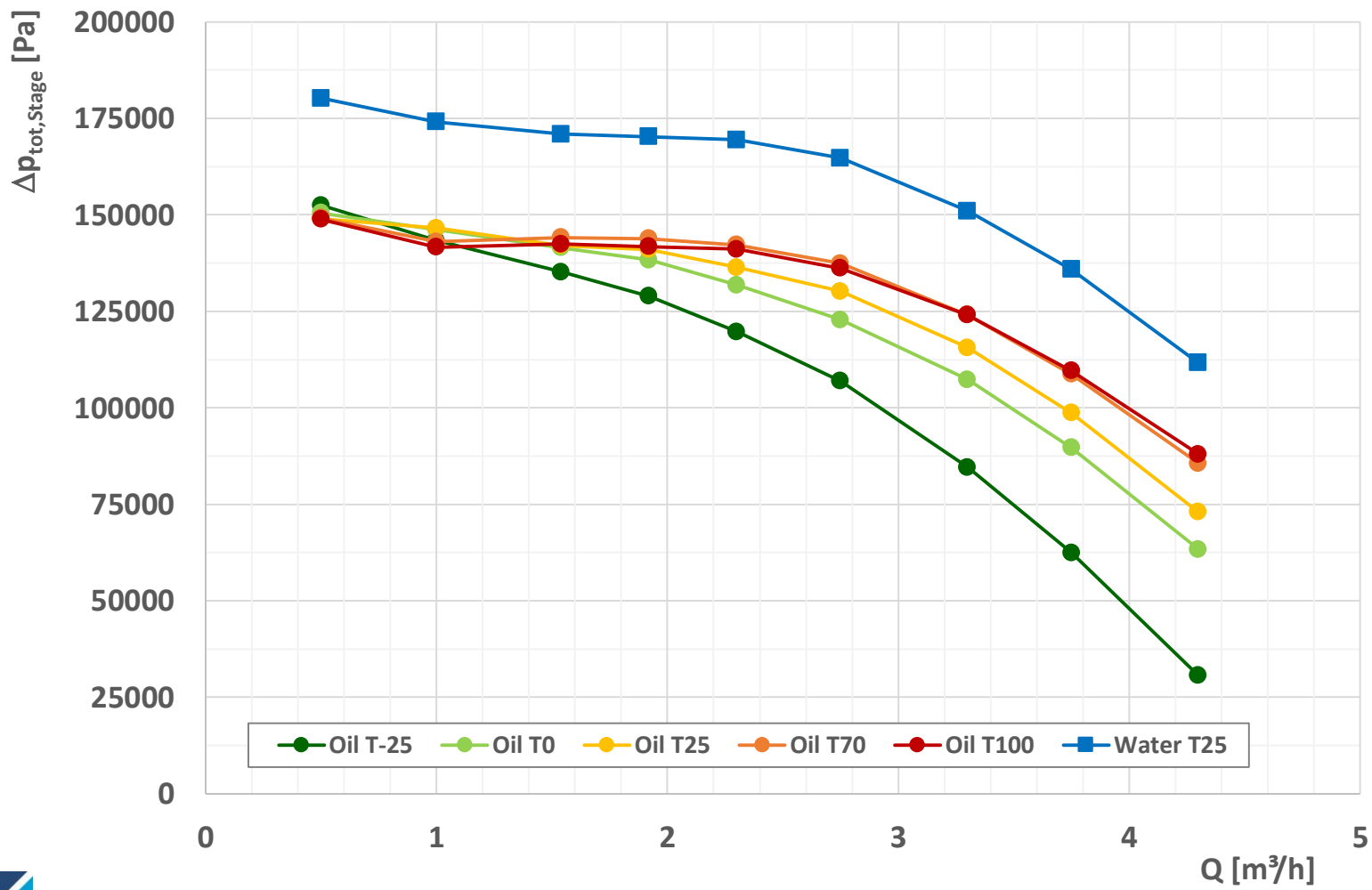
Fluid Properties

Dynamic Viscosity = f (Temperature)



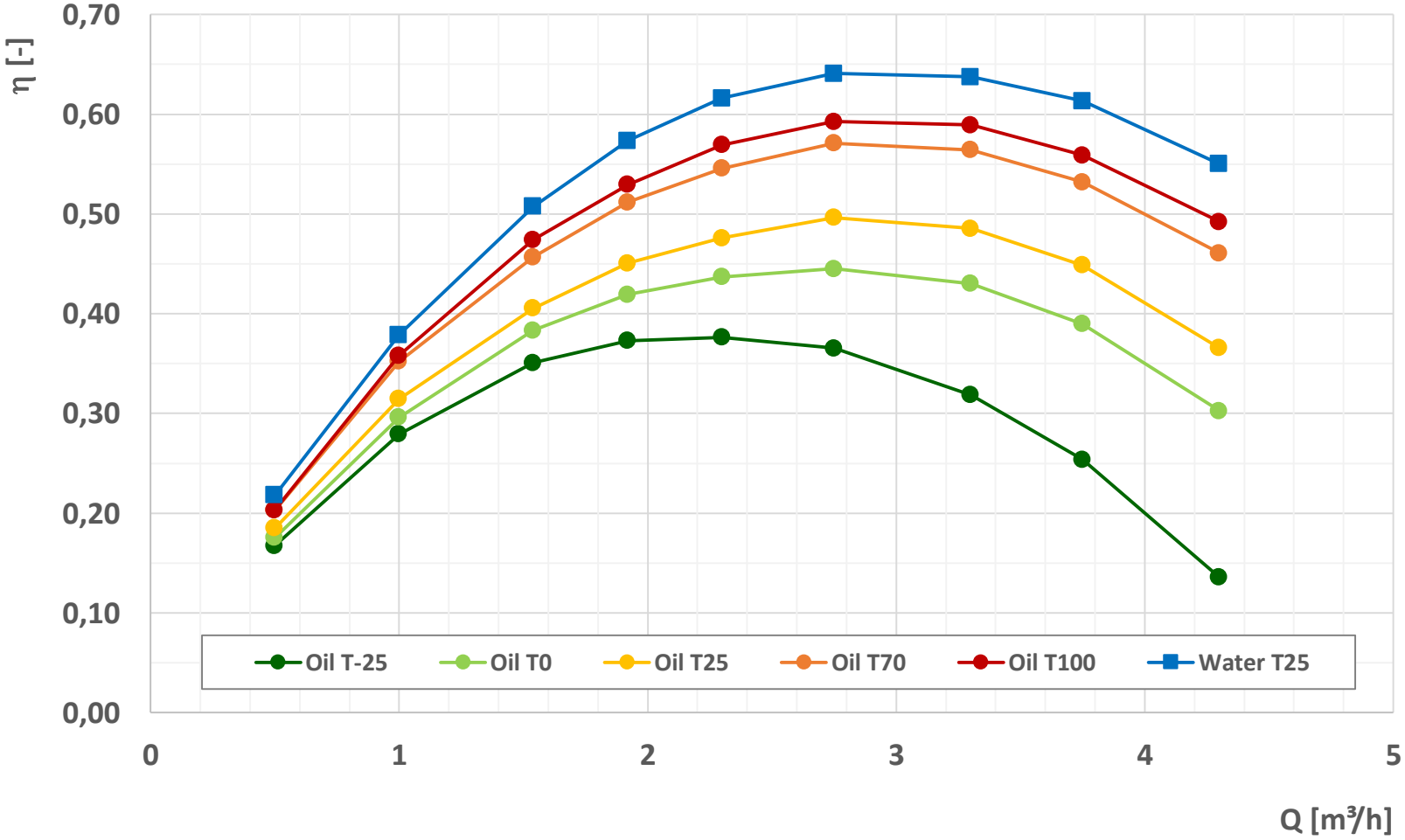
Simulation Results – MFR

Pump Performance Curves = f (Volume Flow, Temperature)



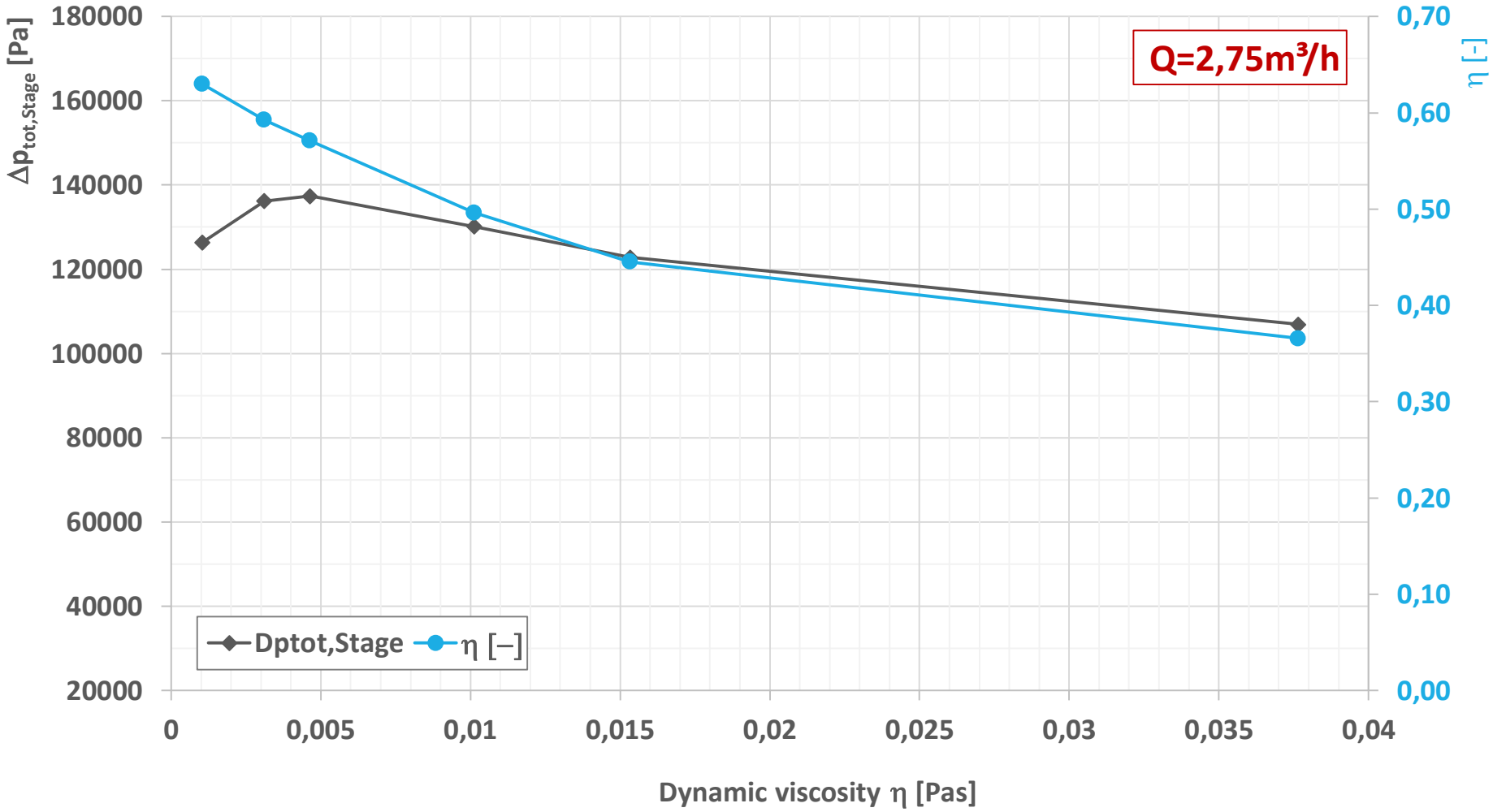
Simulation Results – MFR

Hydraulic Efficiency = f (Volume Flow, Temperature)



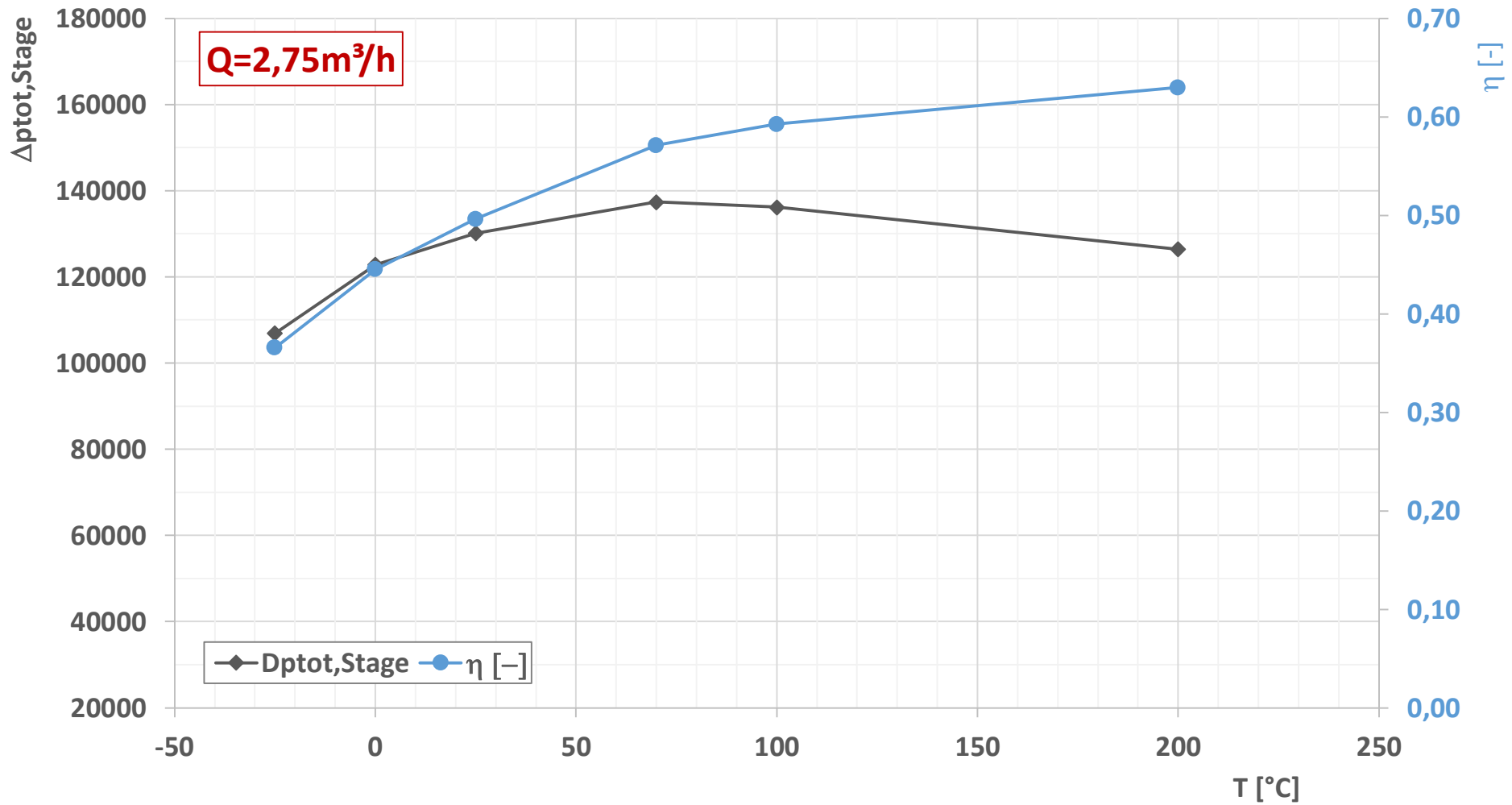
Simulation Results – MFR

Hydraulic Efficiency, Total Pressure Difference = f (Dynamic Viscosity)



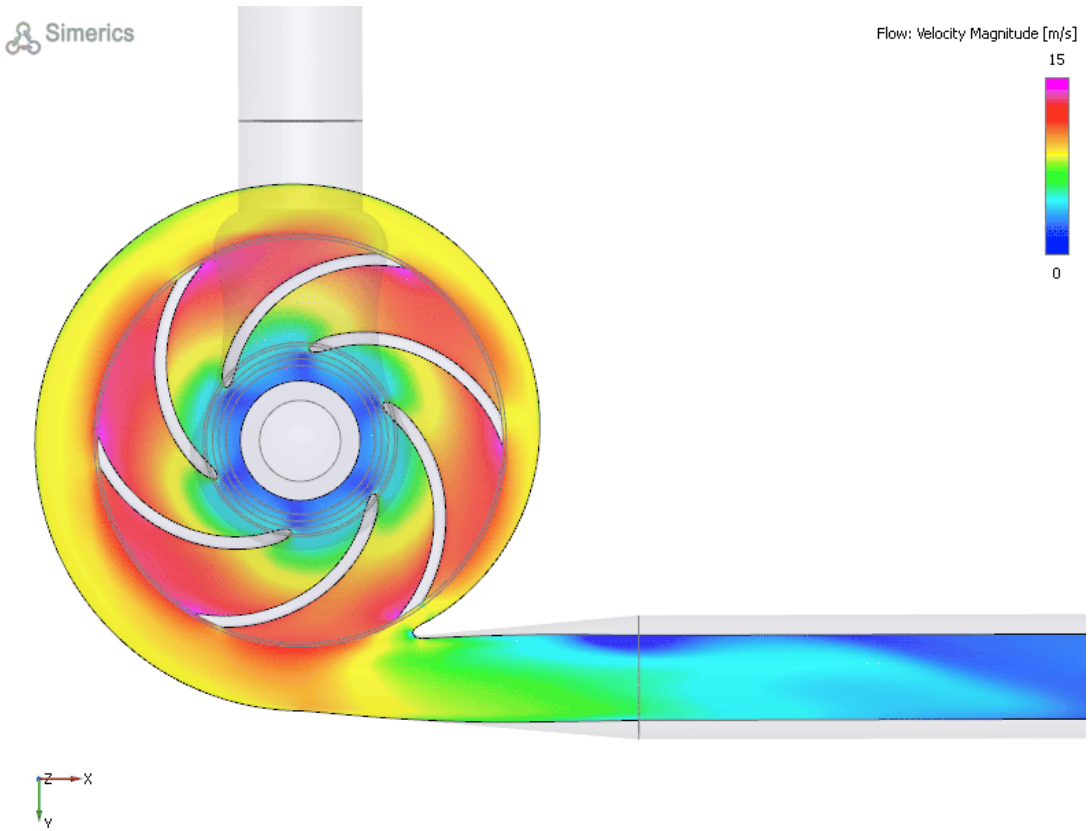
Simulation Results – MFR

Hydraulic Efficiency, Total Pressure Difference = f (Oil Temperature)



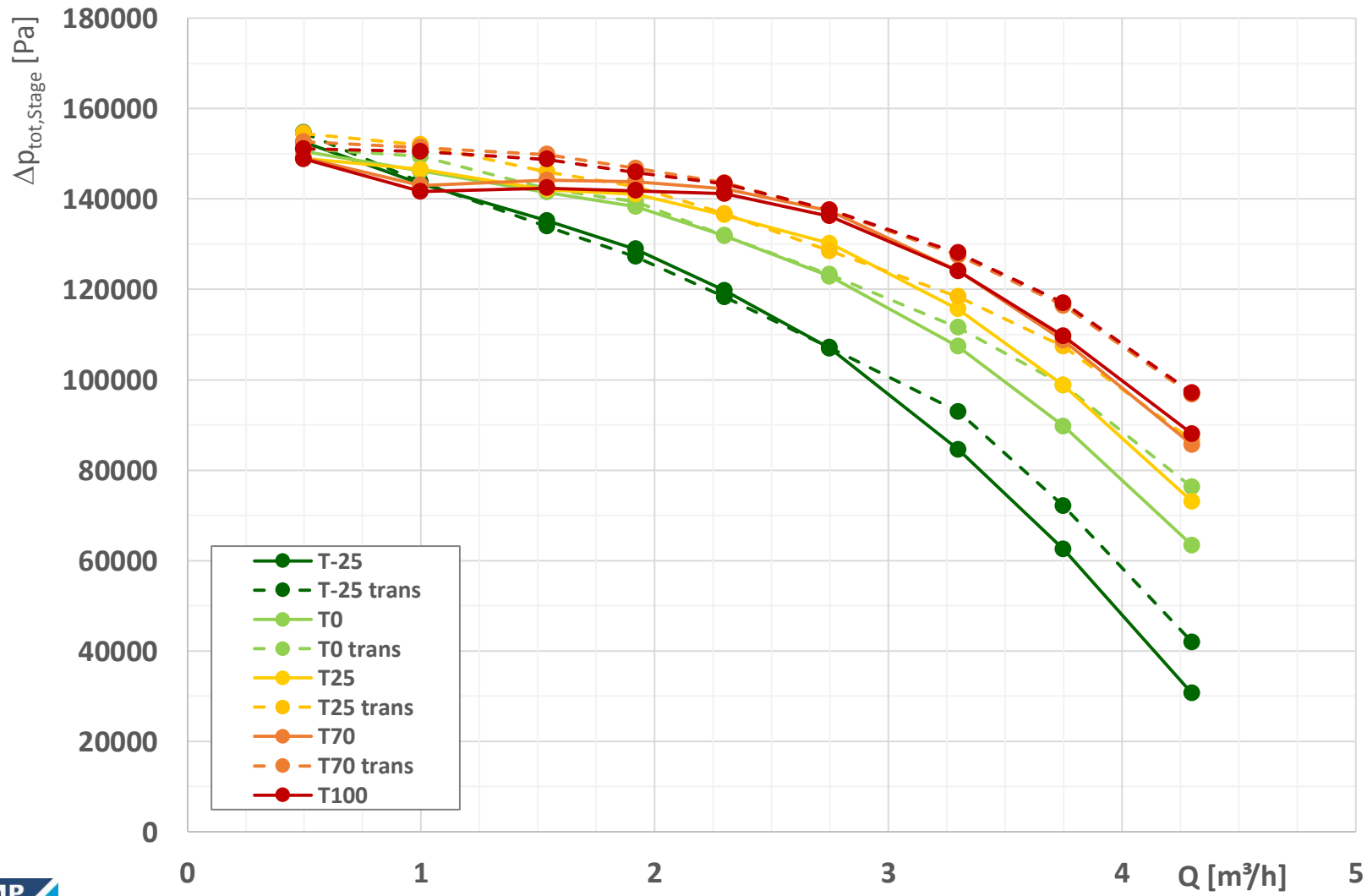
Results – transient flow

Static Pressure and Velocity Magnitude @ [T=70°C, Q=2.75 m³/h)

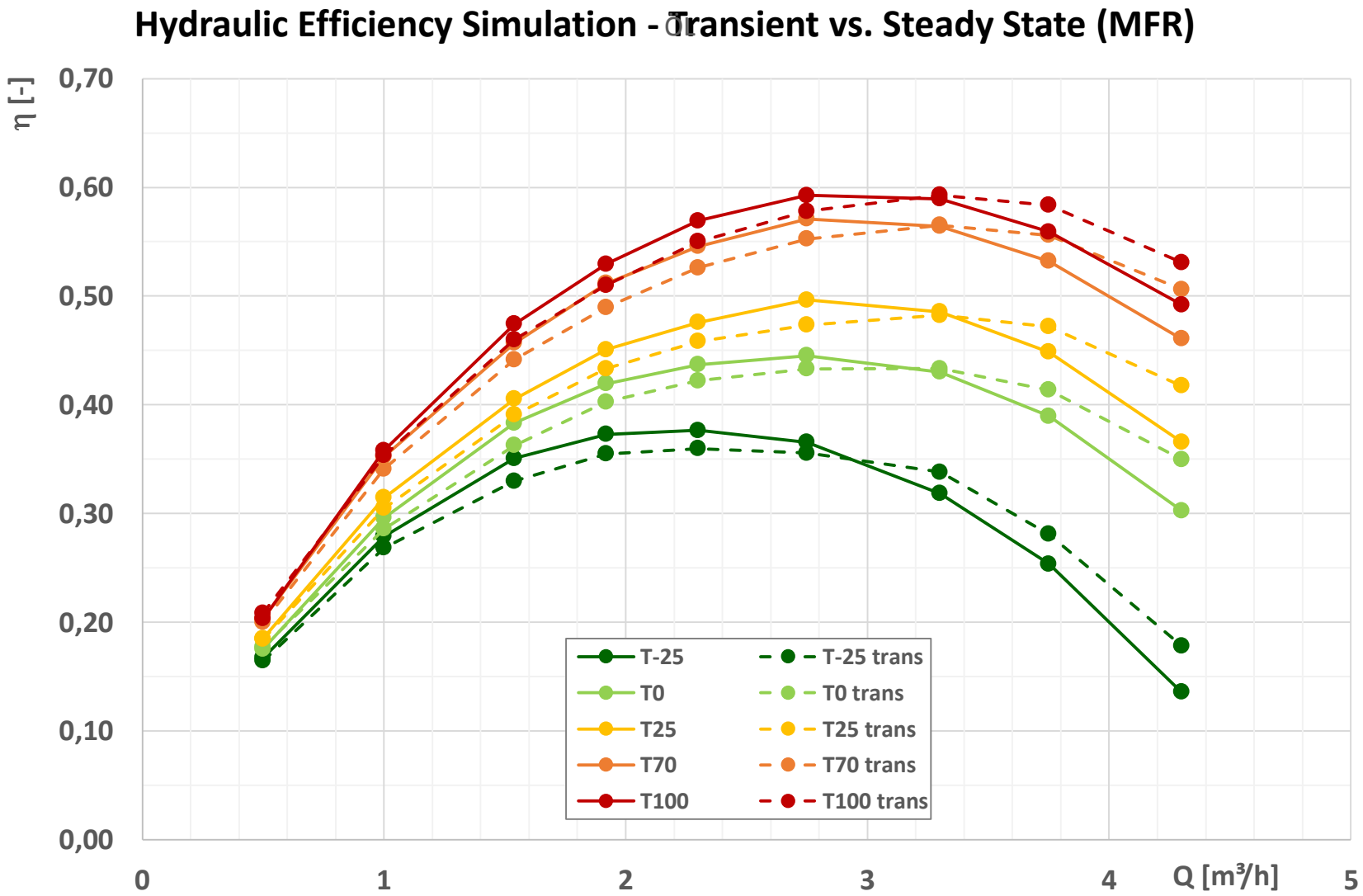


Results – transient flow

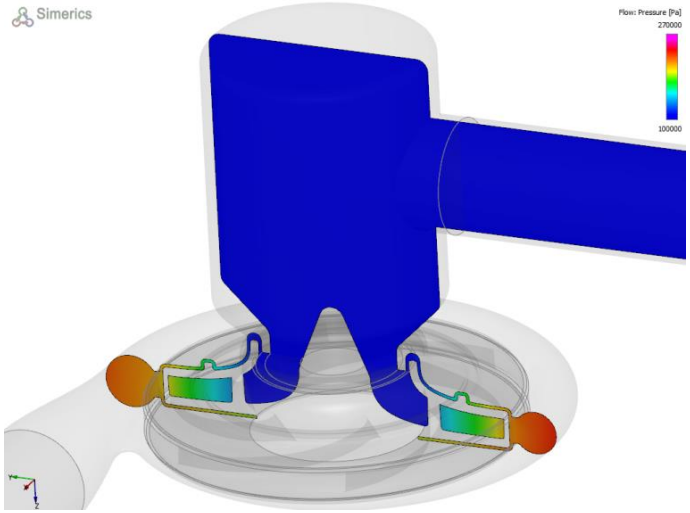
Performance Map Simulation - Transient vs. Steady State (MFR)

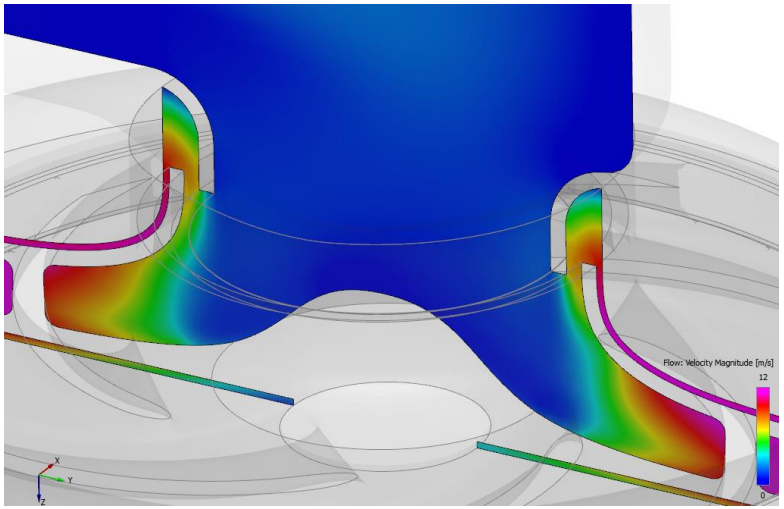


Results – transient flow



Summary - Important Issues for successful design





- Consider all details of pump geometry in early design stage, if possible
- For oil pumps the temperature dependency of fluid properties is important to perfomance map simulation and efficiency prediction
- Density and viscosity are design relevant and should be used by empirical correlations in early conceptual design phase of a project
- Transient 3D-CFD-simulations should be used for a more accurate perfomance prediction and design decisions, compared to MFR

Summary

The classical design theory of centrifugal pumps uses a large empirical data base for parameters that cannot be easily described using a pure theoretical approach. This empirical knowledge has been achieved on the basis of centrifugal pumps meant to convey water and has been proven to be reliable over the last decades.

On the other hand due to the fact that the automotive sector is under strong pressure to develop more efficient cars the hybridization of the complete drive concept is proceeding significantly. In this context it is more and more interesting to use centrifugal pumps for the transport of oil in the engine or gear box. Here the higher viscosity of oil against water is an issue that weakens the so far used set of empirical co-relations in the design process, because it cannot easily transformed into a comprehensive and reliable empirical knowledge basis for the design of centrifugal oil pumps.

It is state of the art that in the design process of centrifugal pumps simulation techniques are widely used prior a real hardware test. This saves a lot of time and money as the first prototype is very close to a hydraulically good machine. By trend the design of centrifugal oil pumps is a more lengthy process compared to that of water pumps as the empirical data base is weaker and more design cycles are necessary. Therefore a highly automated and robust workflow is desired that comprehends both the CAD-design of the pump as well as the test of the current design using modern simulation techniques.

In this paper a method has been presented that uses empirical correlations to adapt water pump design rules to oil pumps and establishes and fully automated CFD workflow for virtual testing. It allows an almost immediate response from the simulation environment once the design of the hydraulic components has been finished. Using this approach design and test are not any longer separate processes but are seamlessly connected. One gets a straight answer on every design parameter change and can go through the design process very intuitively and is herewith not reliant on an accurate empirical data basis. In future more and more correlations can be computed for oil and other fluids by the use of cloud computing. New knowledge will become available for conceptual design of oil pumps too.