

PAT Impeller Optimization

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PAT – Pump As a Turbine

PROS

- lower investment costs
- lower maintenance costs
- accessibility of spare parts
- availability of technical support

- drinking water approval
- resistance to chemicals

CONS

- lower peak efficiency compared to turbines
- characteristics in turbine mode usually not known
- steep efficiency curve
- very limited operating range

- **hard to fit the desired operating point** exactly
- **decrease in overall efficiency** / energy production usually much higher than expected
- prone to **cavitation, vibration** etc.

PAT optimization

- existing small HPP with DET 450 pump
- 8-pole generator
- electric power output 55 kW



PAT optimization

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- electric power output 55 kW

- lower power output than investor expected
- operation accompanied by noise and vibration
- impeller is prone to cavitation damage
- refurbishment is needed more often

- measurement on site not highly reliable
- $Q = 650 \text{ l/s}$
- $H = 14.5 \text{ m}$
- hydraulic efficiency approx. 70 %

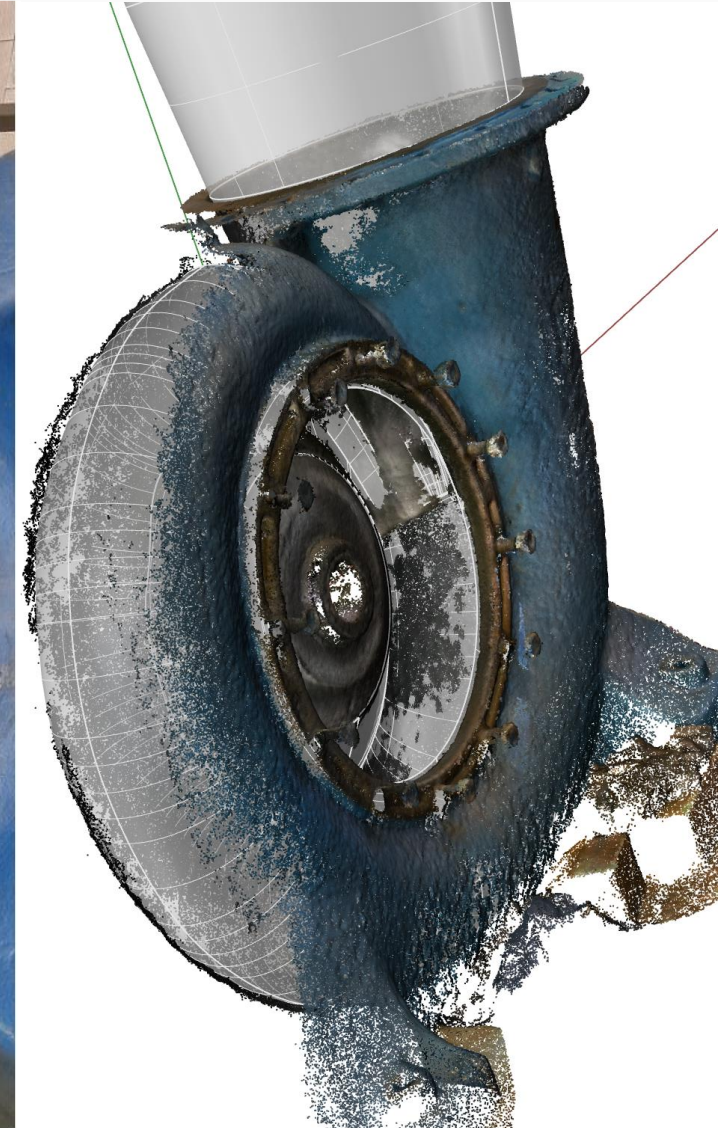


Reverse engineering

→ hydraulic profile, impeller

challenges:

- poorly accessible internal parts
- impeller flow channels too narrow
- color and reflectance of surface
- data processing
 - scanner
 - Dot3D (*PointCloud*)
 - CloudCompare
 - Rhinoceros



Existing state evaluation

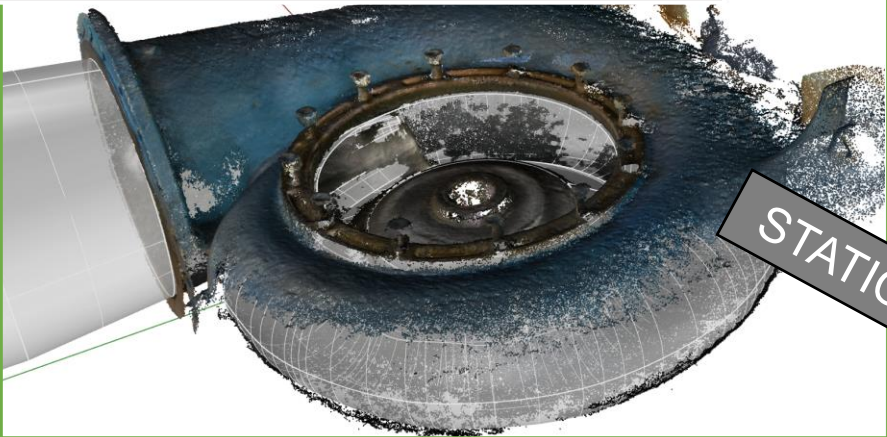
- CFD analysis based on the reverse engineered geometry
- suboptimal flow patterns confirmed in the impeller and draft tube

proposed solution:

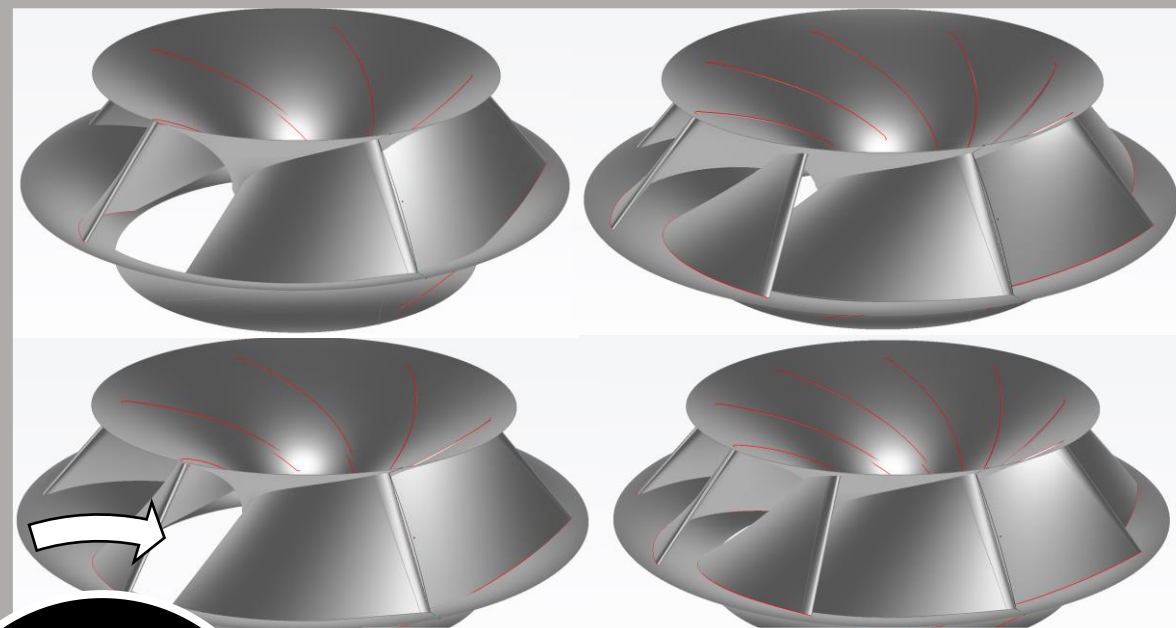
- reduce the flow rate by 30%: 650 l/s → 450 l/s
 - loss reduction increases the head by 10%
 - use optimised impeller increase efficiency by 15-20%
- same output (55 kW) with less water
- rest of the system stays unchanged



REVERSE ENGINEERING



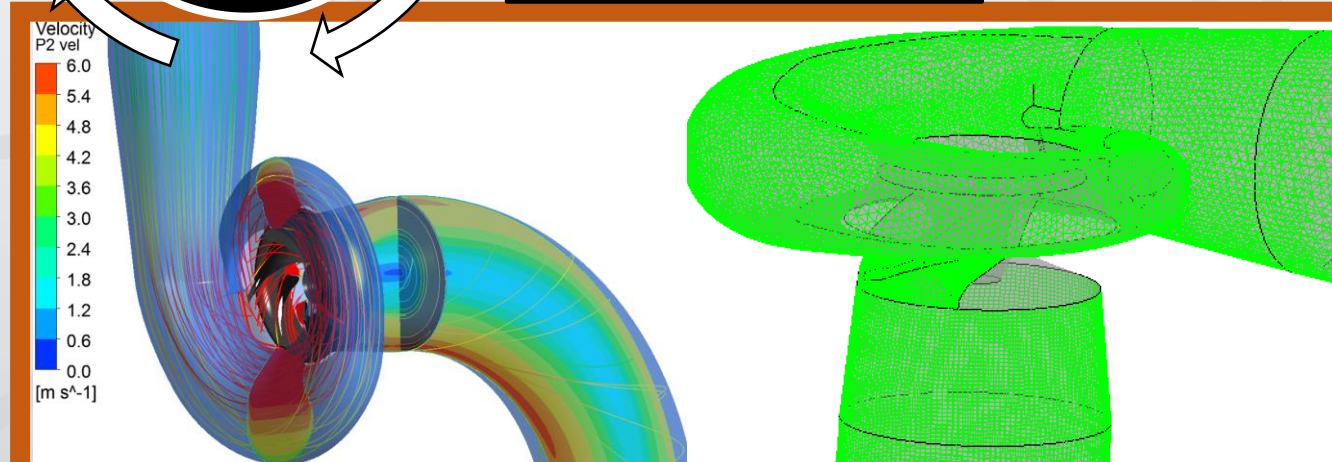
STATIC GEOMETRY



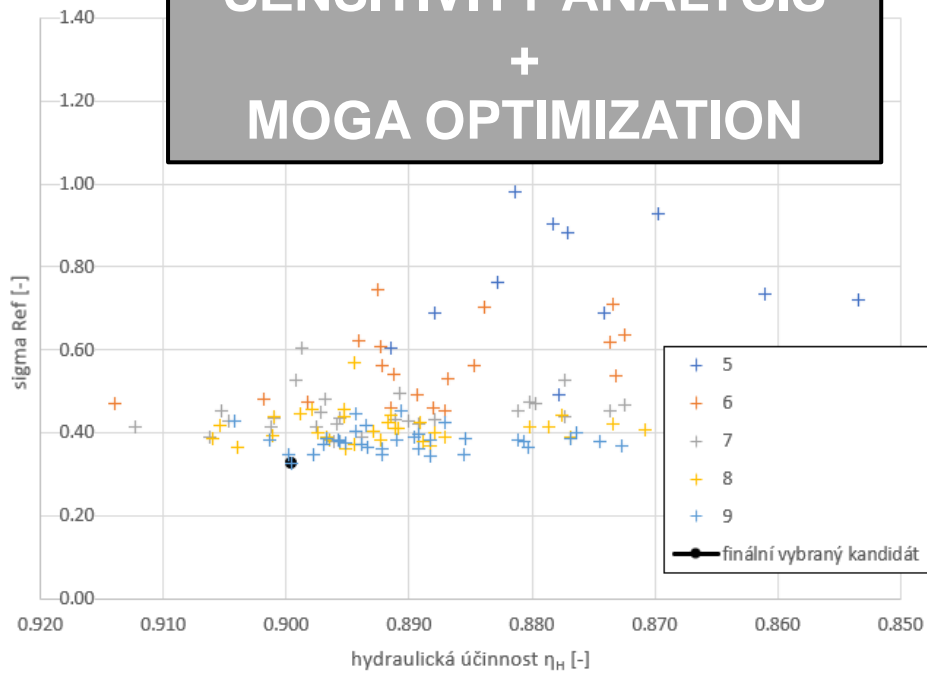
FULLY PARAMETRIC MODEL
IN CAESES



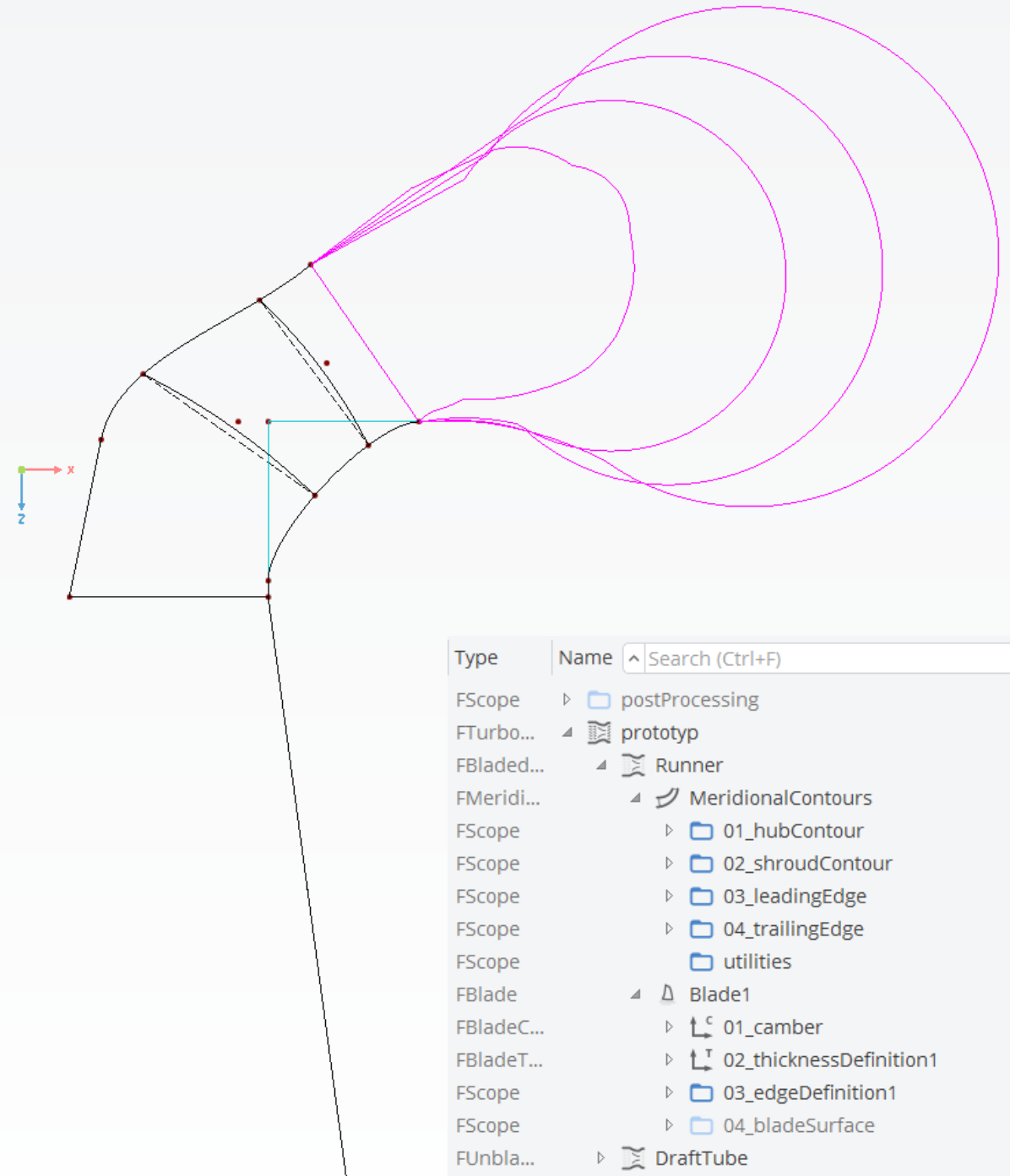
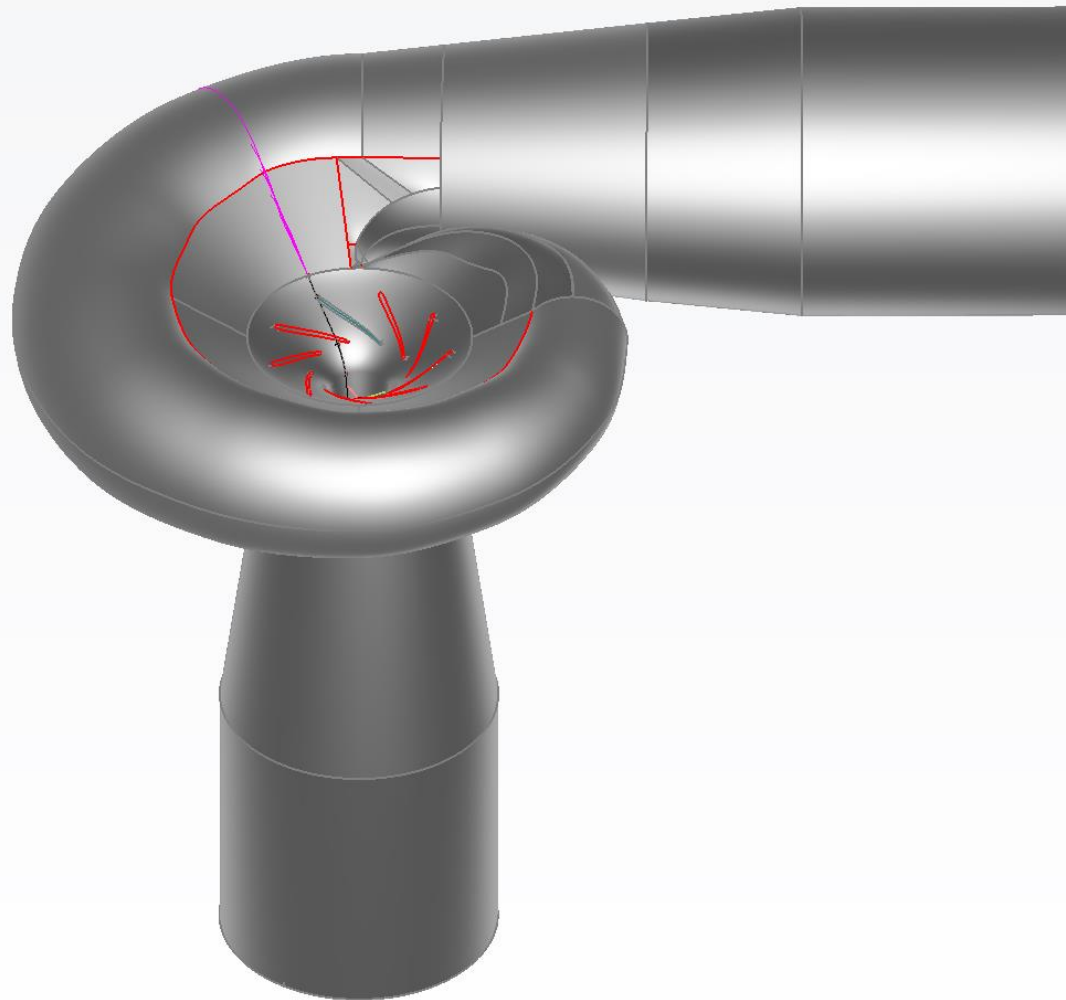
CFD ANALYSIS



SENSITIVITY ANALYSIS + MOGA OPTIMIZATION



Parametric model



Type	Name	Search (Ctrl+F)
FScope	postProcessing	
FTurbo...	prototyp	
FBladed...	Runner	
FMeridi...	MeridionalContours	
FScope	01_hubContour	
FScope	02_shroudContour	
FScope	03_leadingEdge	
FScope	04_trailingEdge	
FScope	utilities	
FBlade	Blade1	
FBladeC...	01_camber	
FBladeT...	02_thicknessDefinition1	
FScope	03_edgeDefinition1	
FScope	04_bladeSurface	
FUnbla...	DraftTube	

Impeller geometry

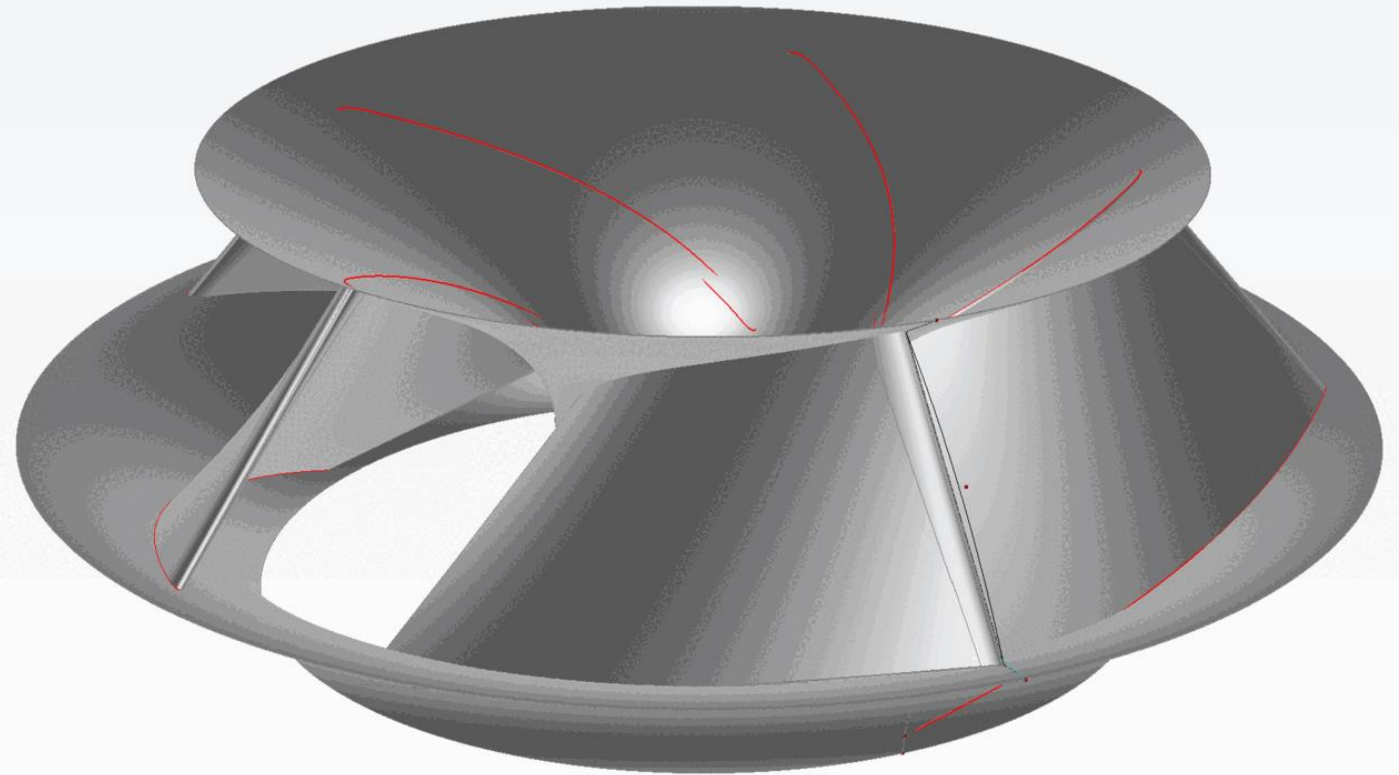
fixed and restricted surfaces:

- inlet contours
- tangent of the hub and shroud on the inlet
- shape of the hub

free surfaces:

- shape of shroud
- outlet diameter
- number of blades
- shape of the blades
- the leading edge and trailing edge position

→ **11 free parameters**



Software Connection | Computations

Name Search (Ctrl+F)

Computations

- Connector1
 - configurationGenInt1
- Applications

Connector1

General

Execution Settings

Host: resourceManagerSetupLocal

Application: localApplication2

Asynchronous Update:

Remove existing Result Files:

Preprocessing Commands: [|TurboGridExport1.run()]

Configuration

file_path: "F:/01_pracovni/Povodi Ohre/09_Jesenice_8302304A140" / getDesignDir() + "/" + "Connector1"

meshCount_runner: 66667 / meshCountRunner

Ansys_path: "c:\program files\ansys inc\v232"

static_path: "F:/01_pracovni/Povodi Ohre/09_Jesenice_8302304A140/28_design_OK/static"

PlaneOut_Position: 0.5952 / |prototyp|DraftTube|PlaneOutPosition

sigmaPlant1: 0.1 / |postProcessing|sigma_evaluation|sigmaPlant_position|sigmaPT_pos_1

sigmaPlant2: 0.2 / |postProcessing|sigma_evaluation|sigmaPlant_position|sigmaPT_pos_2

sigmaPlant3: 0.3 / |postProcessing|sigma_evaluation|sigmaPlant_position|sigmaPT_pos_3

sigmaPlant4: 0.4 / |postProcessing|sigma_evaluation|sigmaPlant_position|sigmaPT_pos_4

sigmaPlant5: 0.4 / |postProcessing|sigma_evaluation|

TaskMonitor | fileViewer1 | tableViewer1 | softwareConnector1

Overview | TG_runner.tse | CFXpre.pre | session.cse | solverFile.cst | Report.txt | TG_runner.tst | CFXpre.ccl

Input Geometry | Input Files

Input Files

- solverFile.cst
- TG_runner.tse
- TG_runner.tst
- CFXpre.ccl
- CFXpre.pre
- session.cse

Connector1

Result Files | Result Values

Report.txt

ANSYS Report
ANSYS User: AnsysReport1
Date: 2023/10/10 11:27:46

Contents:
1. File Report
Table 1: File Information
2. Mesh Report
Table 2: Mesh Information
3. Physics Report

16.7392 secs in worldtime]

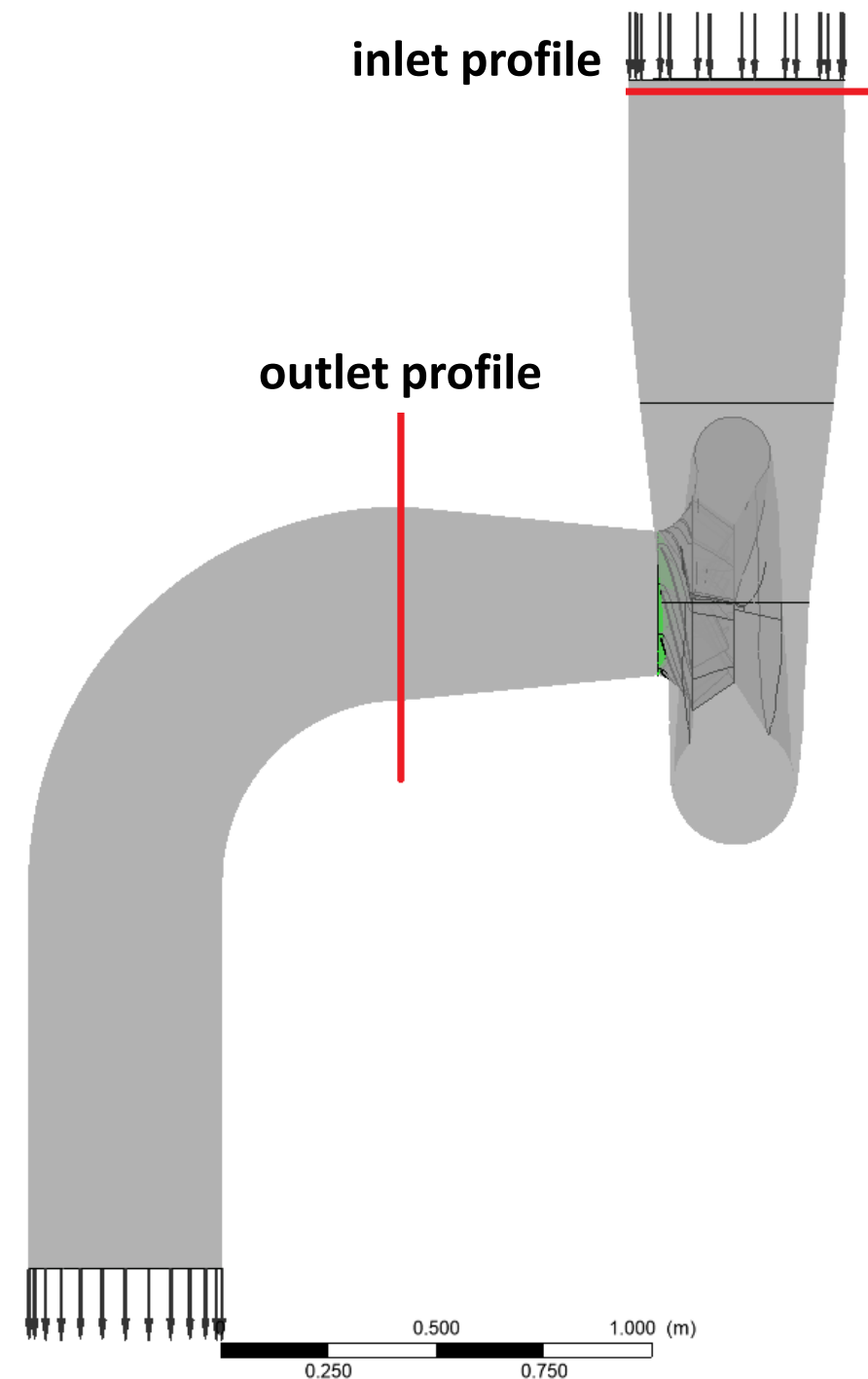
CFD analysis

mesh

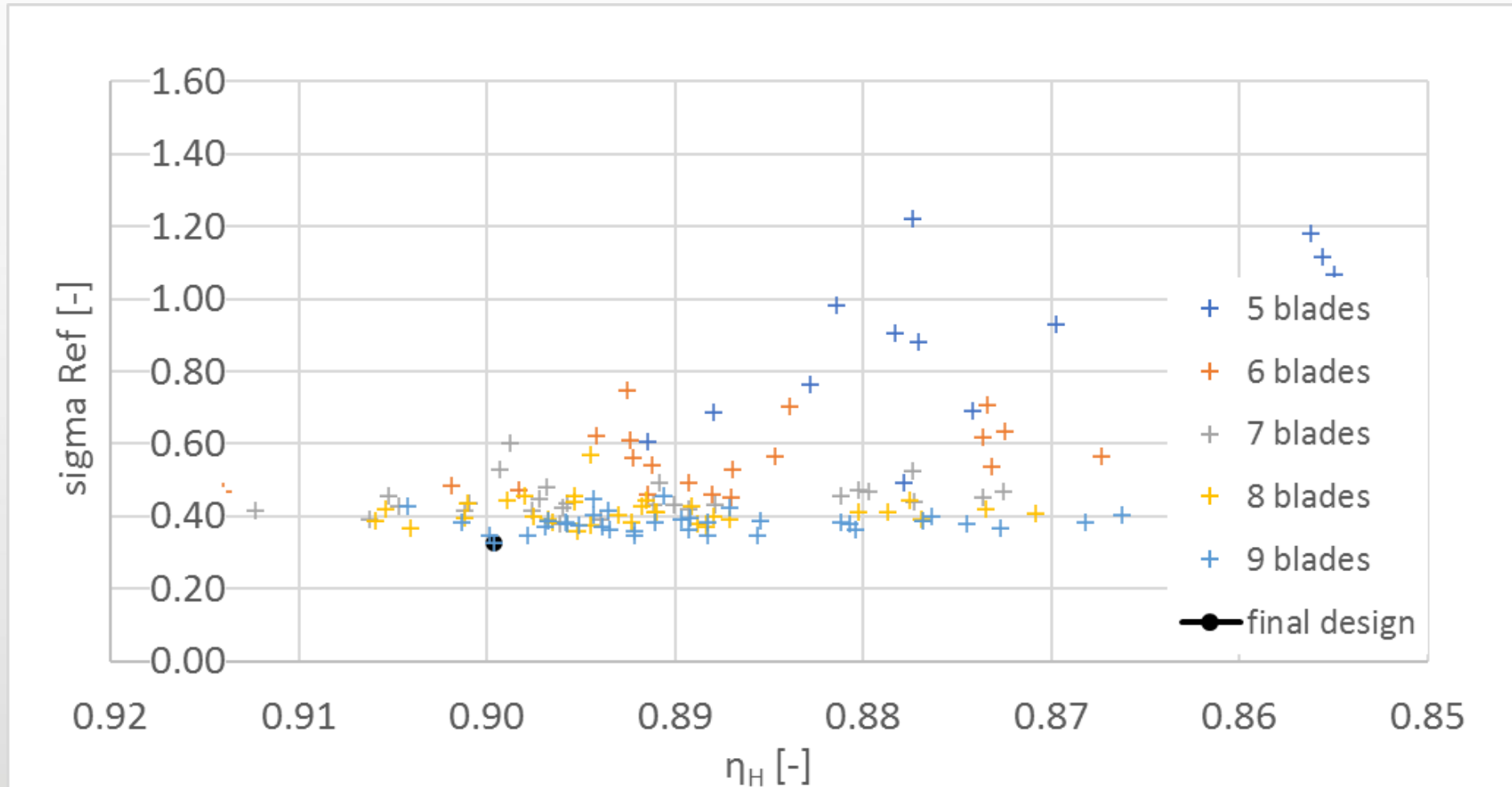
- unstructured mesh for volute (ICEM CFD)
- structured mesh for impeller section (TurboGrid)
- structured mesh for draft tube (ICEM CFD)
- 0.5 million of elements in total

CFD setting:

- steady state simulation (RANS)
- rotational periodicity – only 1 section of impeller
- interface Stage (Mixing plane)
- Total Pressure on inlet, Pressure on outlet



Sensitivity analysis and optimization



$P = 55 \text{ kW} \pm 5\%$

$$P = \eta H \rho g Q$$

$Q = 465 \text{ l/s} \pm 2.5\%$

Final design

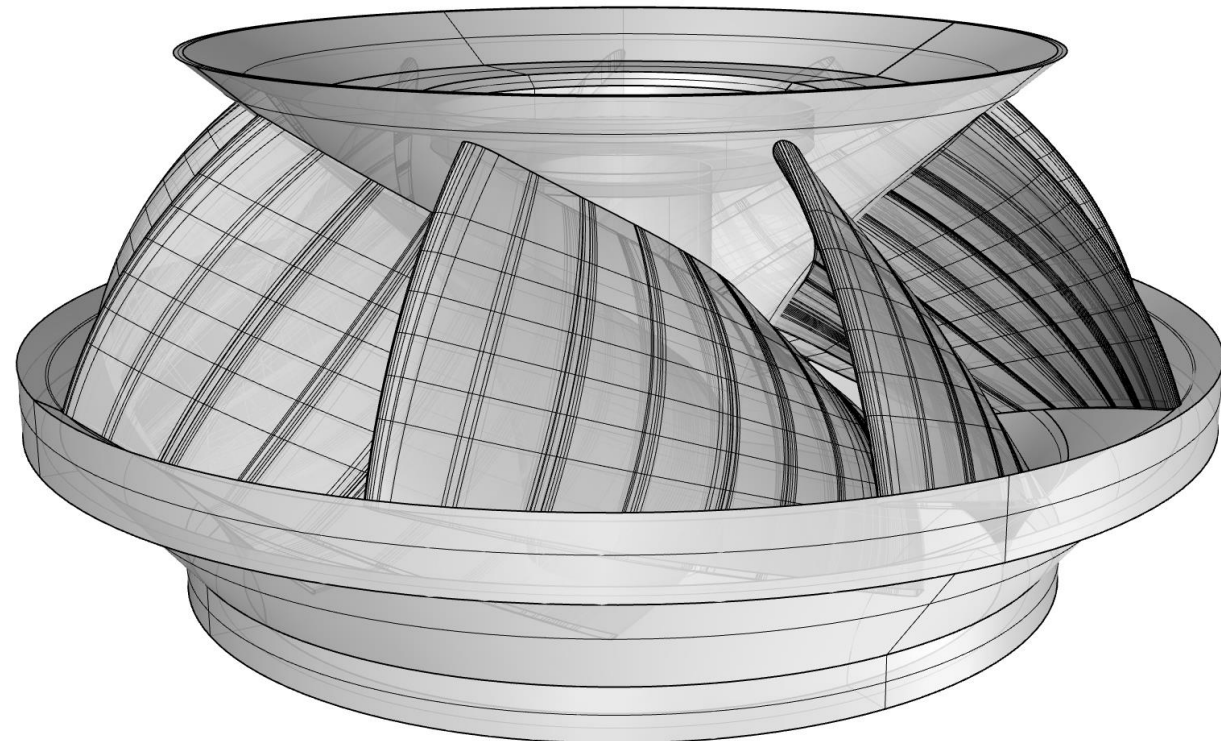
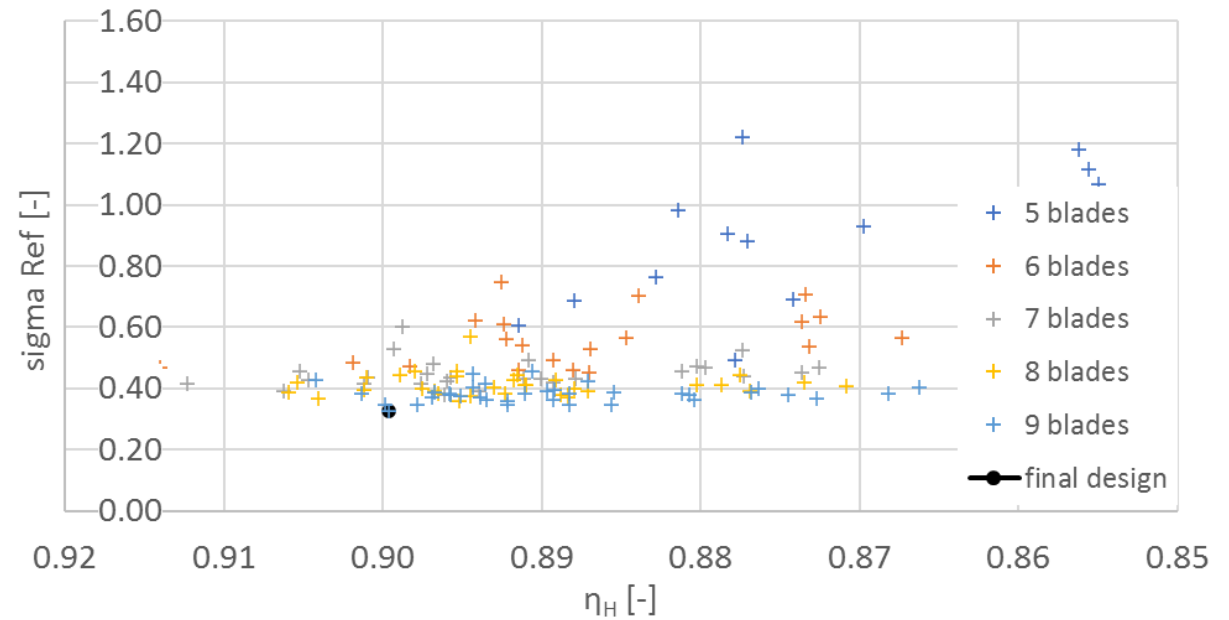
impeller

- nine blades
- outlet diameter 0.45 m \rightarrow 0.33 m
- smooth connection with the volute

results:

- 30% decrease of flow: 0.650 l/s \rightarrow 0.459 l/s
- 20% increase in hydr. efficiency up to 89,9%
- decrease of sigma parameter: 0.6+ \rightarrow 0.2

- \rightarrow **55 kW output using less water**
- \rightarrow **higher total energy production**



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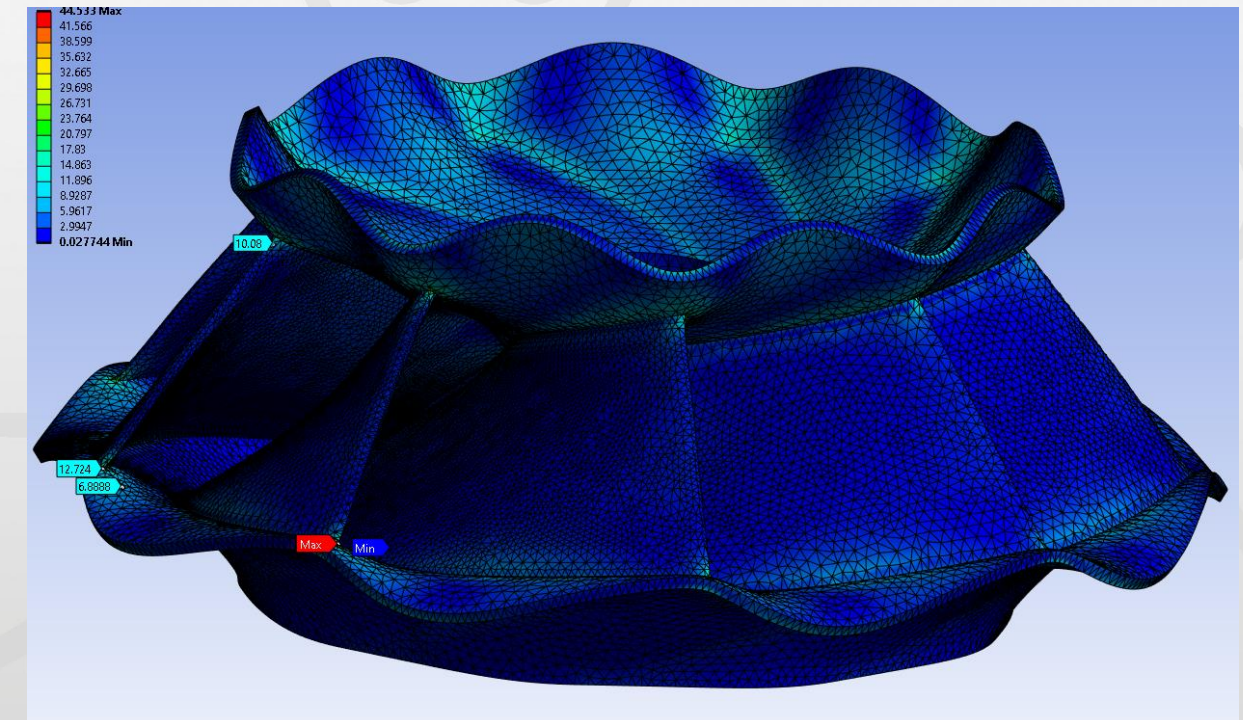
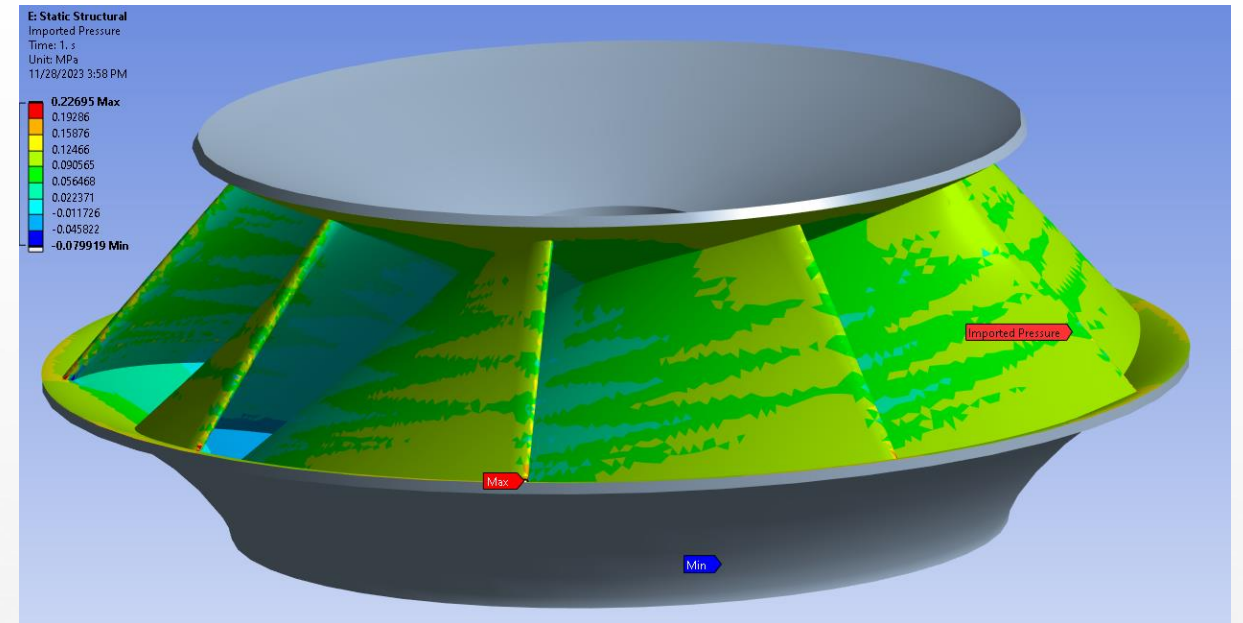
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- **55 kW output using less water**
- **higher total energy production**

to be tested on site

- no vibration, cavitation induced noise
- increase endurance of the impeller



Optimized impeller



Original impeller



PROJECT TEAM



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Eva Bílková
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Petr Rýznar
Tomáš Zatloukal

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