MACHINE LEARNING-BASED SURROGATE MODEL IN CENTRIFUGAL PUMP DESIGN

SPE-GCS: AI Accelerated Physics Based Modelling and its Role in Energy Industry

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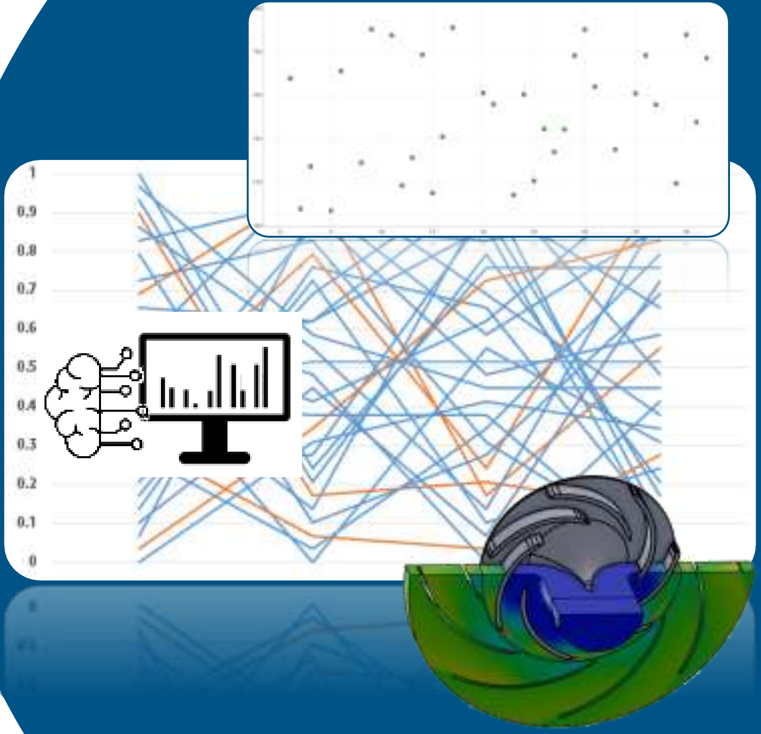

Gulf Coast Section

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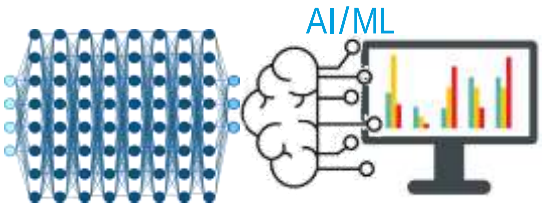
BENEFITS OF SOLUTION



Deep Neural Network:
AI/ML uses existing data to accelerate early stage designs predictions in a wider design space

Left shifting of project execution

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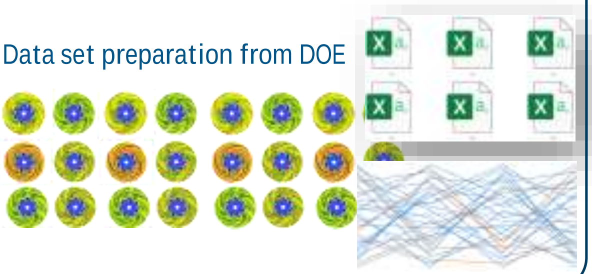
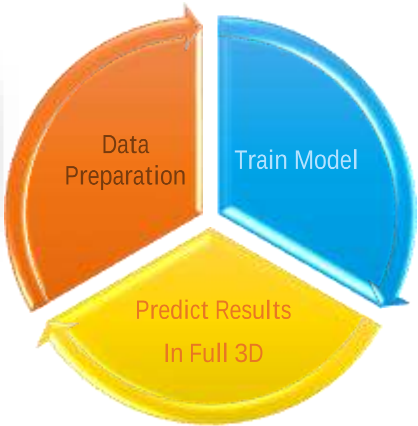
MACHINE LEARNING FOR 3D DESIGN EXPLORATION

Parametrized models: Geometry, BCs
Run a DOE

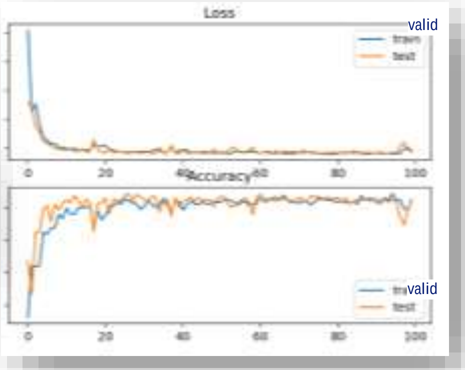
Data set preparation from DOE





Train Model Accuracy & Loss

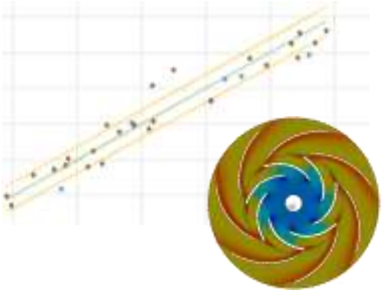
Data Set



Quasi-interactive design explorations – Predictions in the matter of minutes

Input Parameters

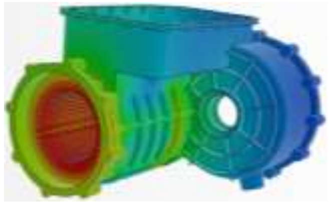
Prediction Output



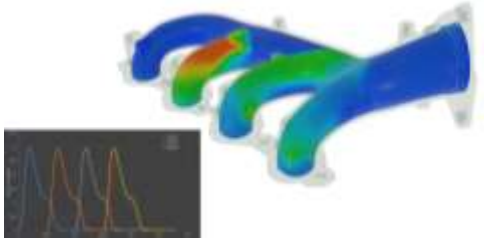
3DEXPERIENCE © CFD | KEY VALUES

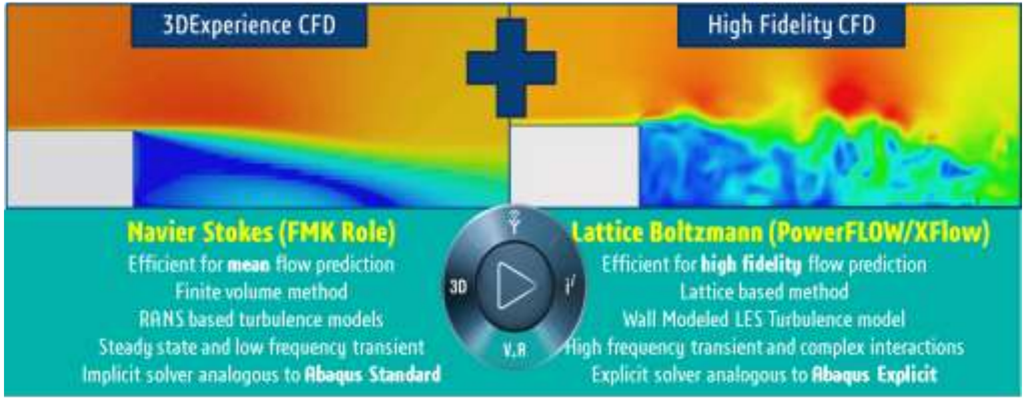
- Designer centric user experience
  - CAD & PLM-embedded CFD
  - Guided User Interface
  - Automatic fluid volume extraction
  - One-click simulation model update with design changes
- Advanced design exploration
  - Process automation for trade-off studies
  - Multi-objective design space optimization
  - Analytics driven decision support
- Validated for accuracy and efficiency
  - RANS based steady-state and long transient simulations
  - Native conjugate heat transfer
  - Laminar and turbulent flow with intelligent near– wall treatment
  - Robust hex-dominant body-fitted mesh with boundary layer
- Unified multiscale multi-physical environment
  - Capture multidisciplinary requirements (FSI, 3D CFD +1D)


MRF or Sliding Mesh


Transient simulations

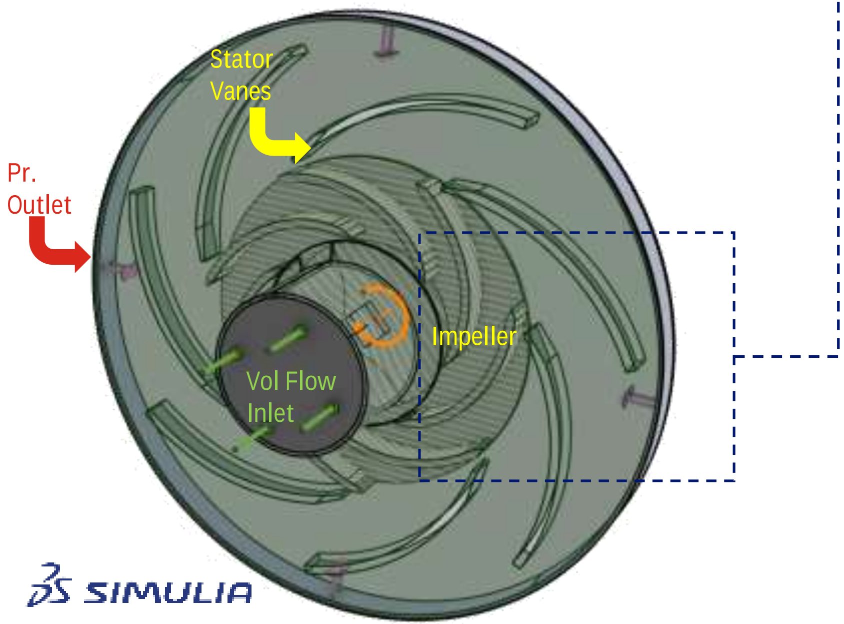

Incompressible Flow

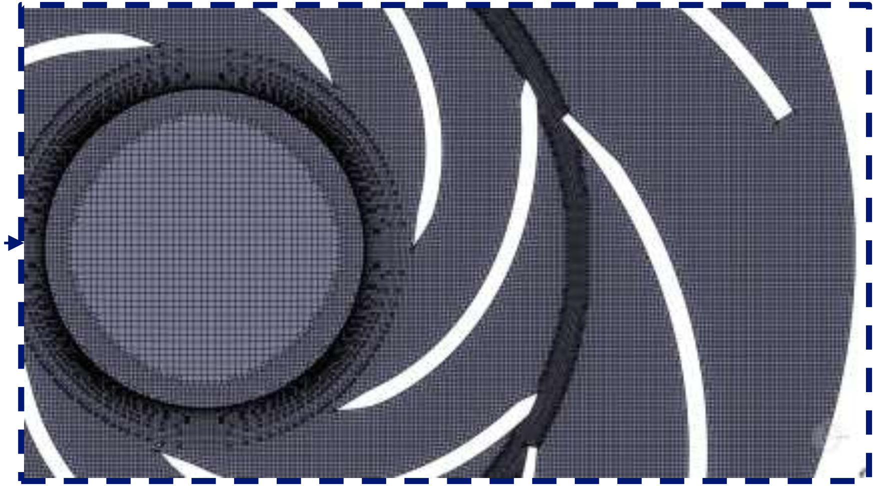




ERCOFTAC PUMP | BASELINE MODEL

- Vol Flow Inlet = 0.3m^3/s | Impeller RPM = 2000 | Atmos Outlet
- Steady-state MRF, SST-kw
- KPI: Total Head Rise [Pa] across the system
- Hex mesh grid used as input (~3.5M elements for full domain)





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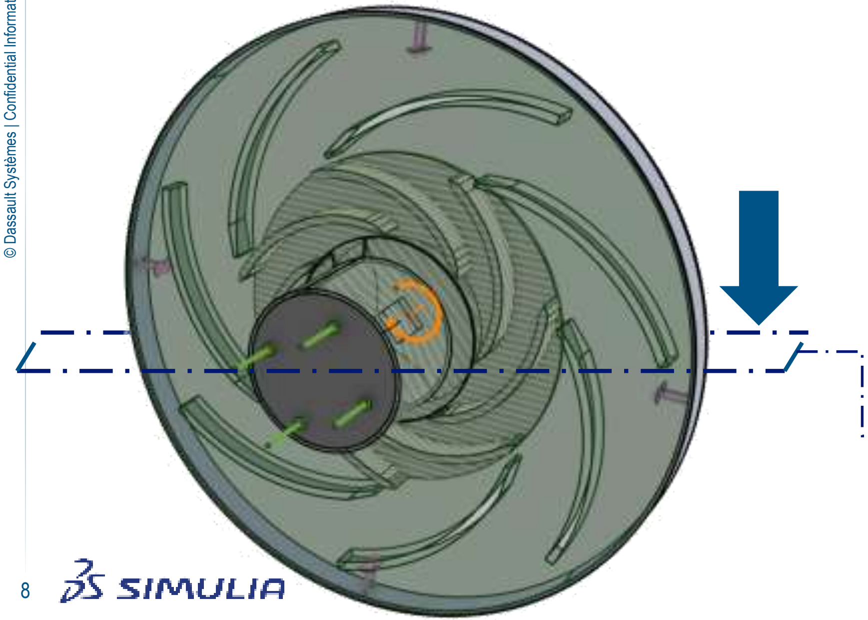
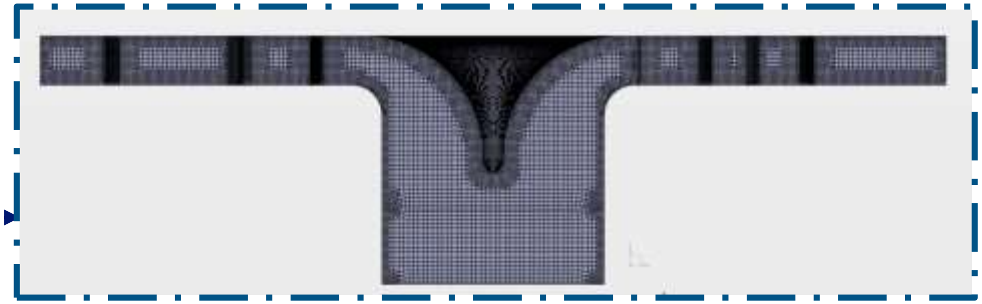
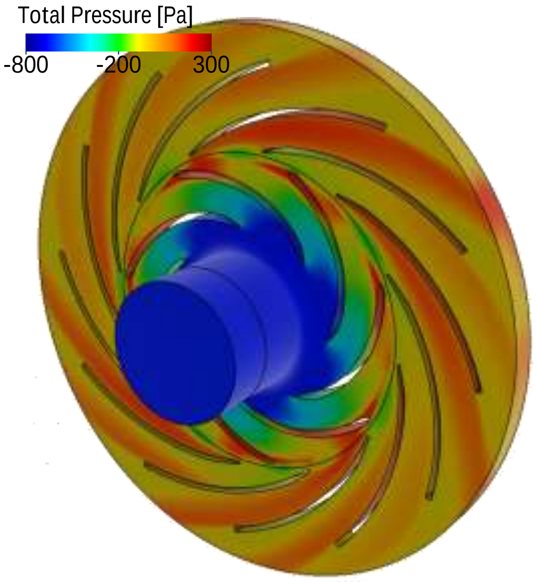


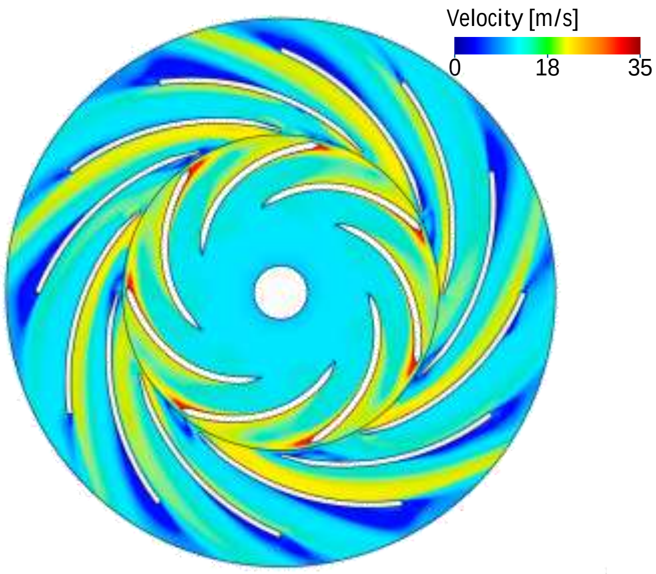


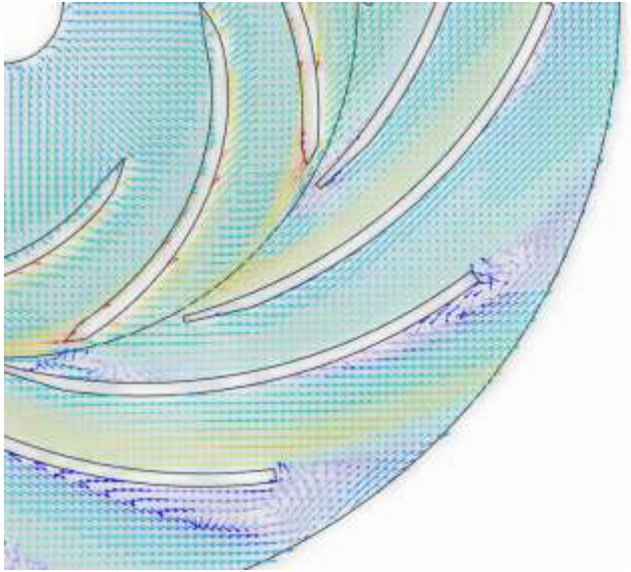
ERCOFTAC PUMP | BASELINE MODEL

- Within 7% of value from Ubaldi, et al.
- Total gauge pressure and velocity plots

Total Pressure, mass Flow avged [Pa]		CPUh
CFD	Ubaldi Exp **	
809.8	757	16







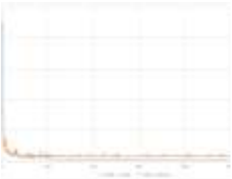
** Ubaldi, Marina, Pietro Zunino, Giovanna Barigozzi, and Andrea Cattanei. "An experimental investigation of stator induced unsteadiness on centrifugal impeller outflow." In *Turbo Expo: Power for Land, Sea, and Air*, vol. 78835, p. V001T01A002. American Society of Mechanical Engineers, 1994

WORKFLOW

Inputs:
- CFD Parametric DOE Results

If Model is not already trained

1 — Machine Learning Training — Order of hours

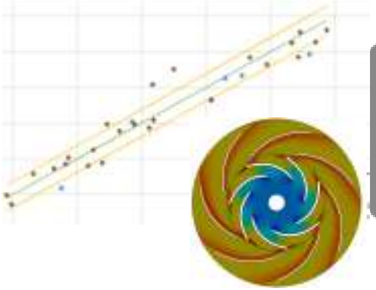


If Model is already trained

2 — Machine Learning Inference

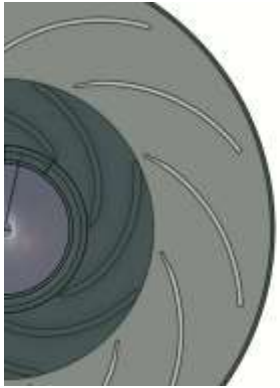
3 — Post Processing — Order of mins

Outputs:
- Predicted 3D Fluid Field (Velocity, Pressure, etc.)
- Predicted 1D Metrics (Pressure, X-Force, etc.)

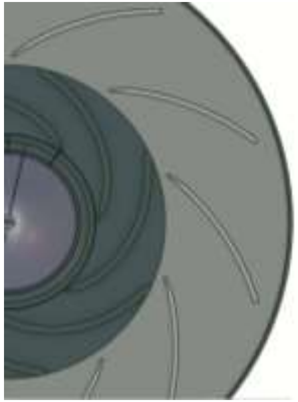


ERCOFTAC PUMP | DOE

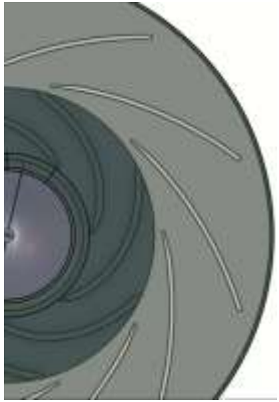
Vane Inlet Angle →
[Range = 25º]



Vane Thickness →
[Range = 6mm]



Vane Outlet Angle →
[Range = 25º]

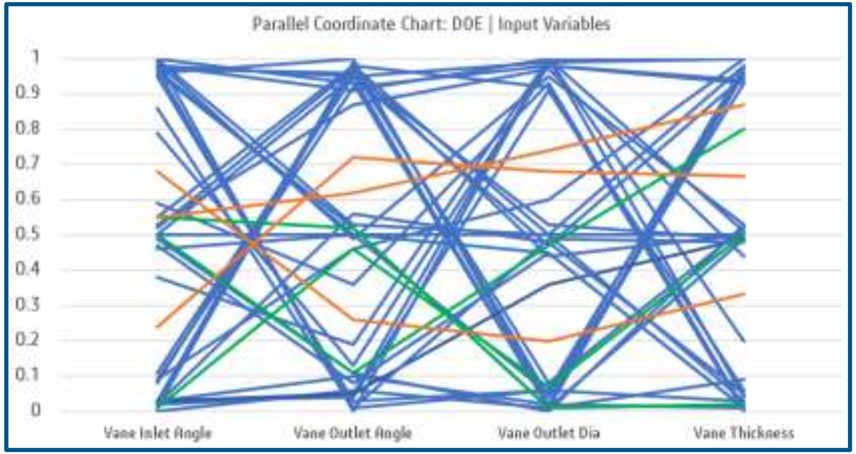


Chord Length →
[Range = 50mm]

- FMK DOE containing 42 simulations, 4 parameters
  - Adaptive DOE for the initial design spread
- 36 Training set, 6 held-out set [3 test + 3 validation]

Run#	Vane Inlet Angle	Vane Outlet Angle	Vane Outlet Dia	Vane Thickness
37	0.5	0.11	0.47	0.8
38	0.55	0.52	0.01	0.02
39	0.01	0.46	0.07	0.5
40	0.55	0.62	0.74	0.87
41	0.24	0.72	0.68	0.67
42	0.68	0.26	0.2	0.33

▪ Test ▪ Validation



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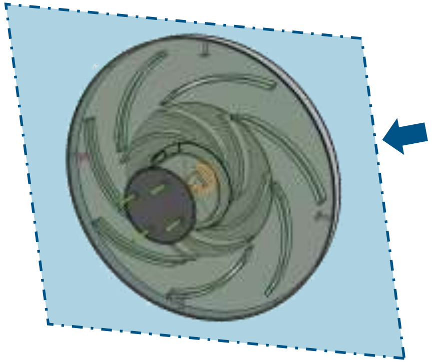
ERCOFTAC PUMP | 3D SLICE PREDICTIONS



CFD

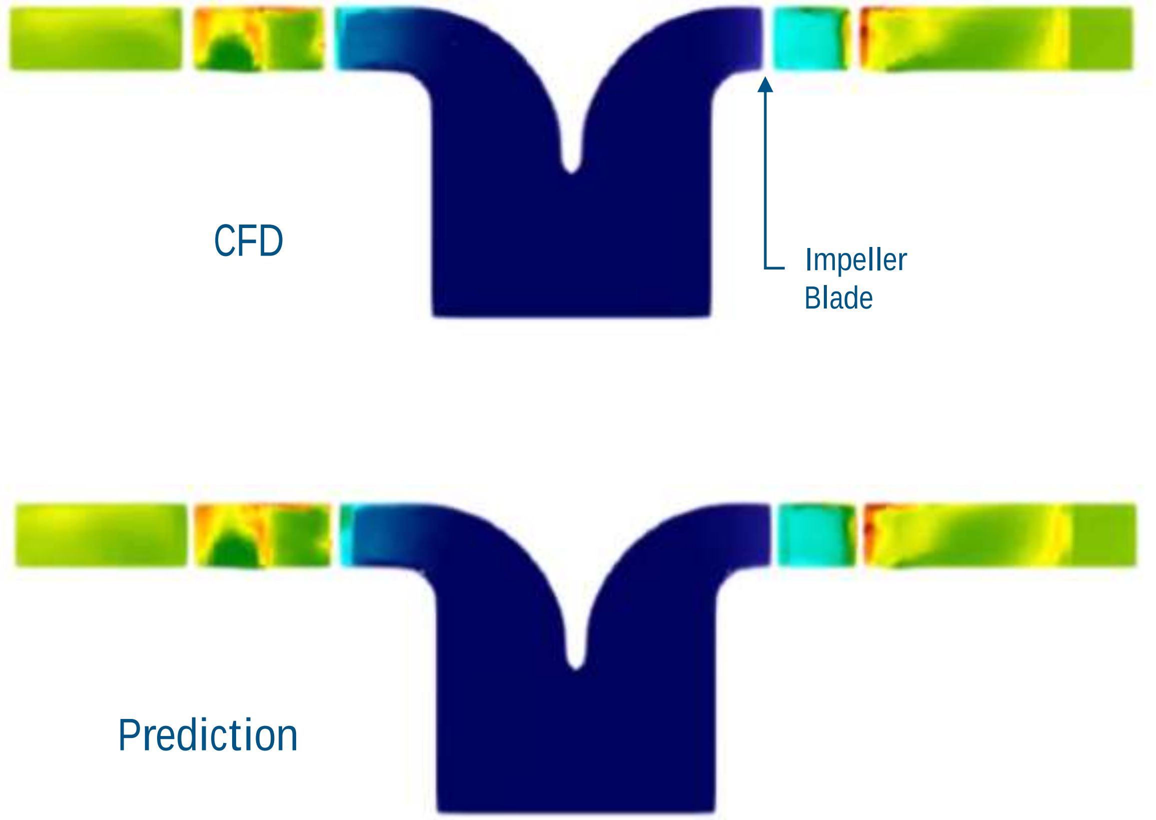
Total Pressure - Gauge [Pa]

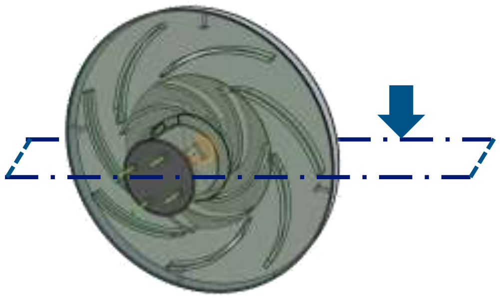
-1000 0 1000

Prediction

Center-aligned slice of total pressure around the blades and vanes show good correlation

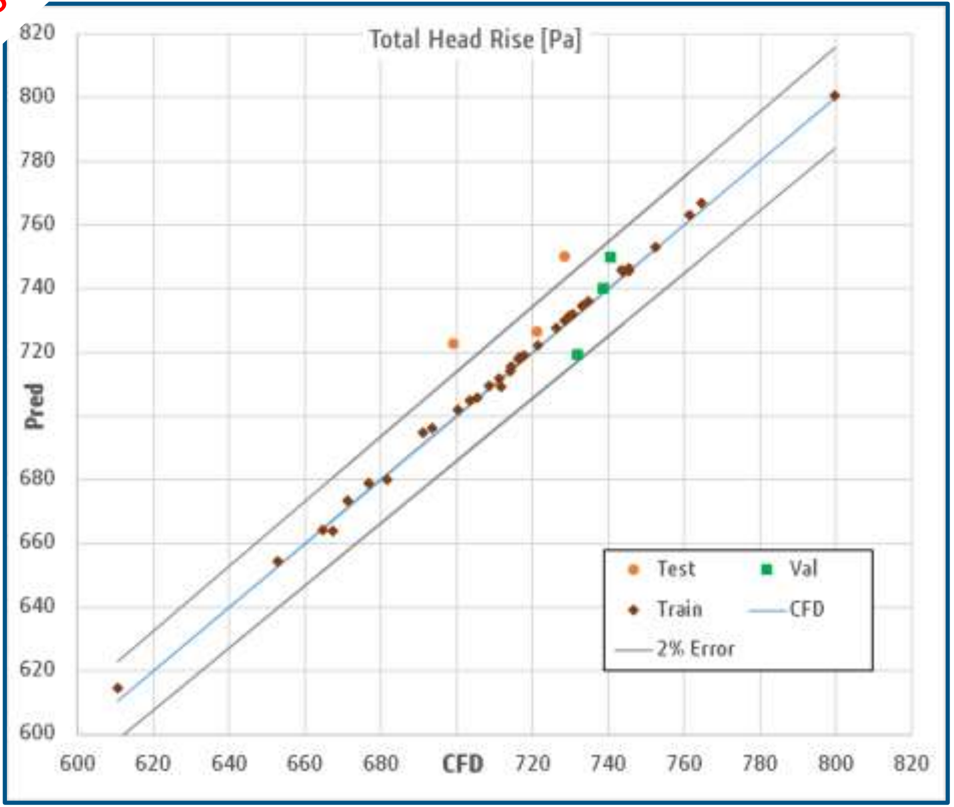
ERCOFTAC PUMP | 3D SLICE PREDICTIONS

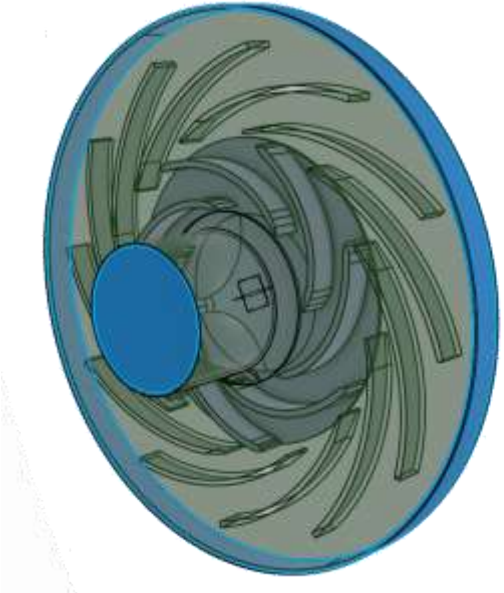




Top-view slice of total pressure around the blades and vanes show good correlation

ERCOFTAC PUMP | 3D PREDICTIONS





- Head rise is the difference between 3D integration of inlet and outlet total pressure
- Overall average prediction error is around 1.72%

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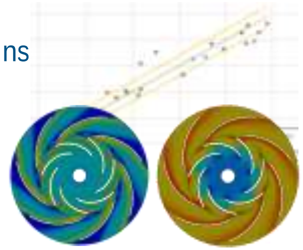
CONCLUSIONS

- Quality of data is crucial for any ML program
  - SIMULIA offers best-in-class multi-scale and multi-physics portfolio options
- AI/ML can be used successfully with parameterized DOEs built on 3DExperience CFD
  - Average total head rise prediction error under 1.72%
  - 3D field data is available for every predicted run in a matter of minutes
- Detailed 3D field prediction – Fluid and Surface data
- Reduced hardware requirements – Single GPU sufficient
- Expanding across other fluids applications

Input Parameters

Order of mins

Prediction Output



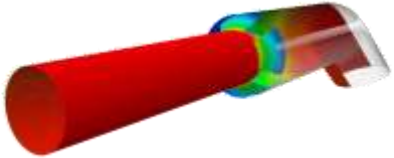
Particle Tracking

Acoustics

dBMaps & SPL

Internal Flows

Mass Flow, Temperature & Pressure Drop



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