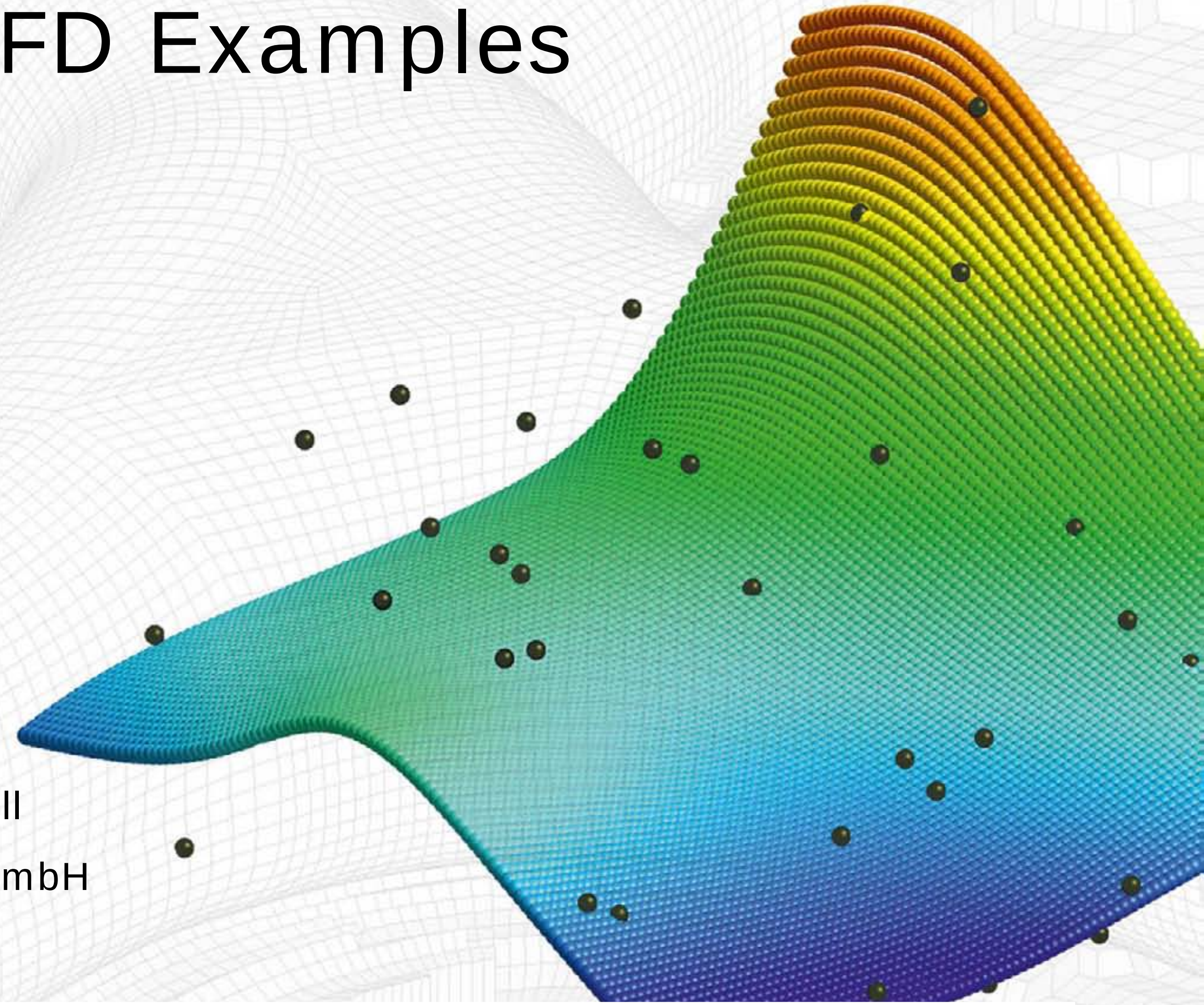
CFD Examples



Dr.-Ing. Johannes Will

President Dynardo GmbH

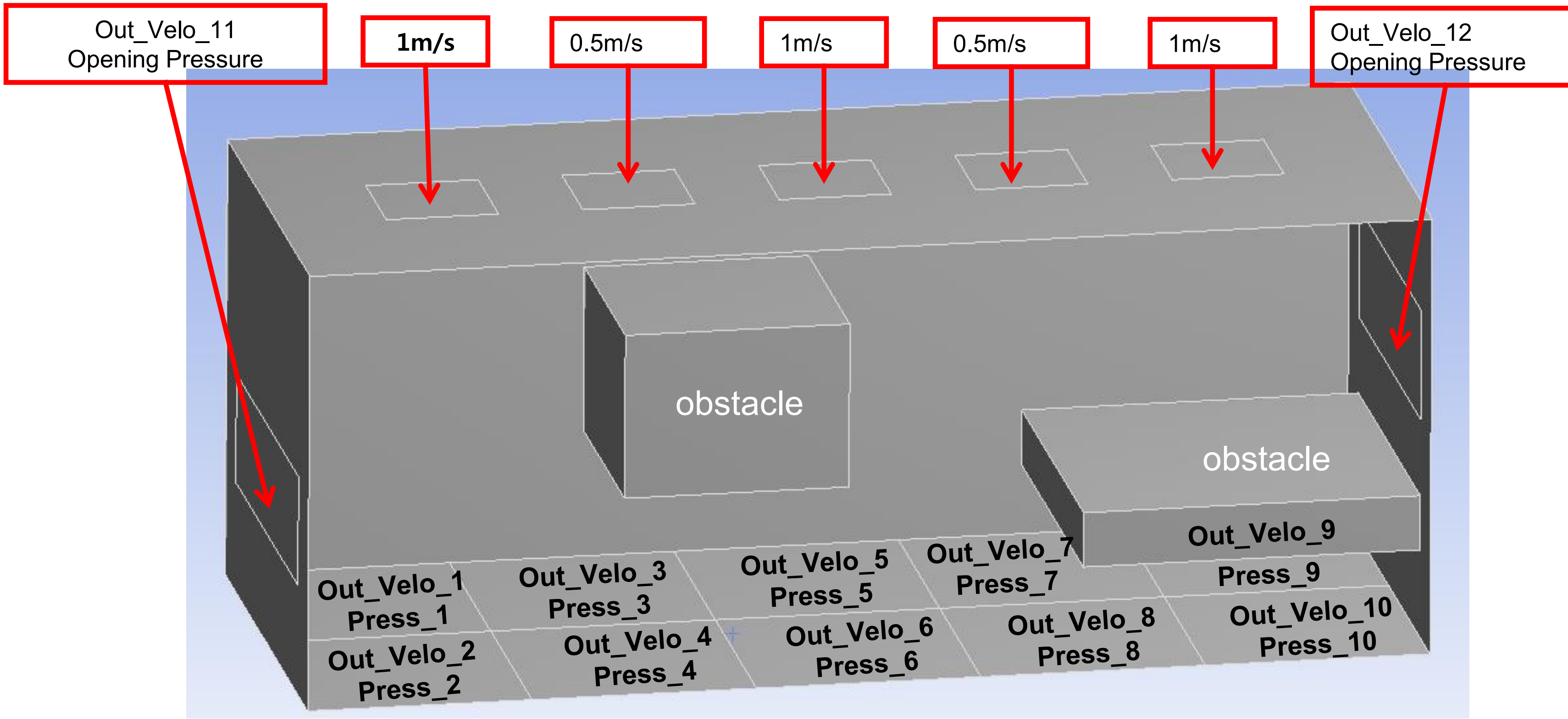
Flow Simulation of LCD Manufacturing Process

Task:

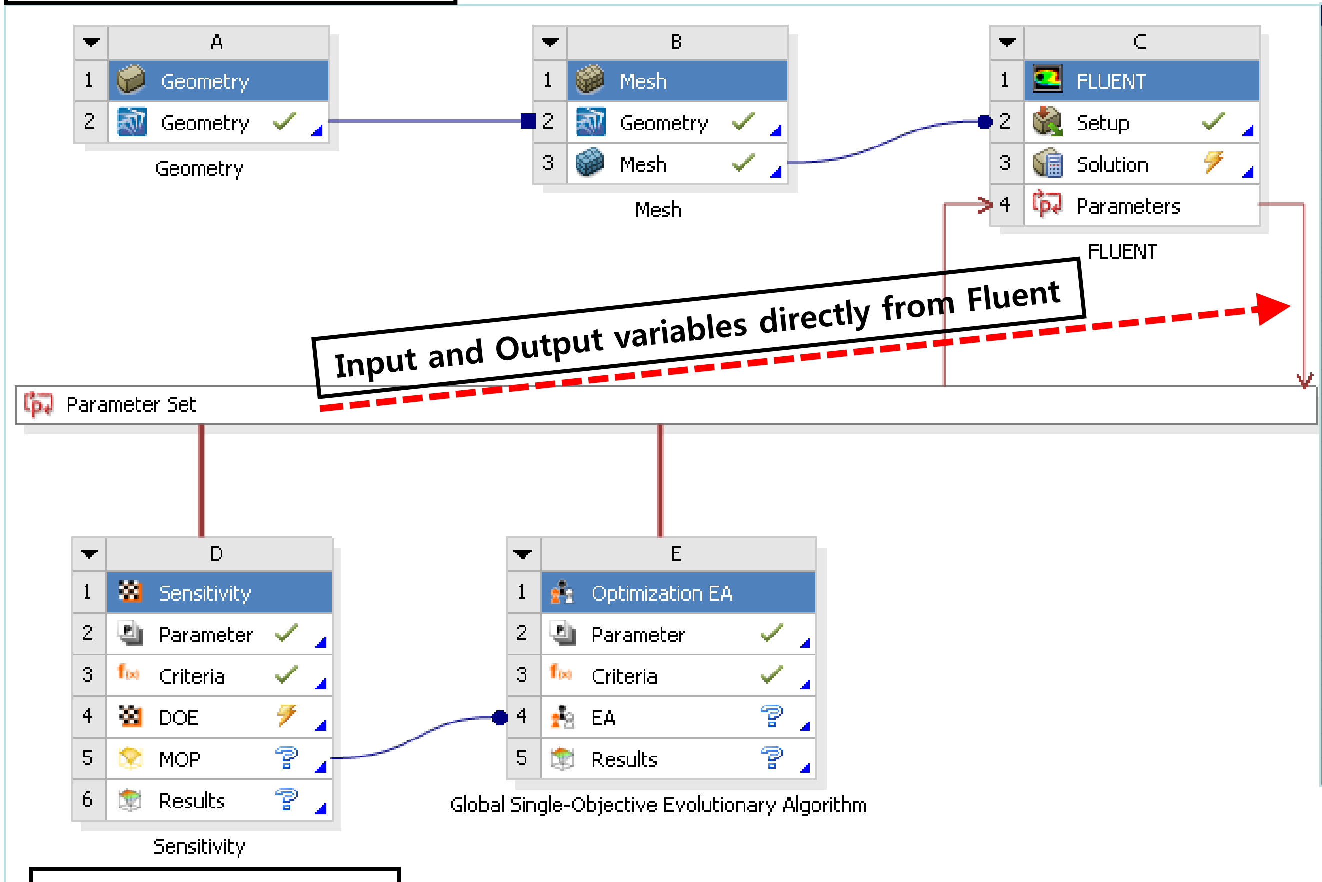
- Optimization the flow conditions at a LCD manufacturing process
- Inputs:
  - lab geometry
  - 5 windows (velocity)
  - **reference scenario** with well known flow condition (velocity measurement points: 2 doors and 10 fields inside the lab)
- **Goal:**
  - **Identification of the parameters** to find the reference scenario.
  - Possibility to vary 10 pressure fields inside the lab.
  - Start at a give initial condition (far away from goal).
  - **Minimizing** the error ranges comparing with the reference values.

- Solve this tasks by using **optiSLang inside ANSYS Workbench.**

Flow Simulation of LCD Manufacturing Process



Schematic Process Flow



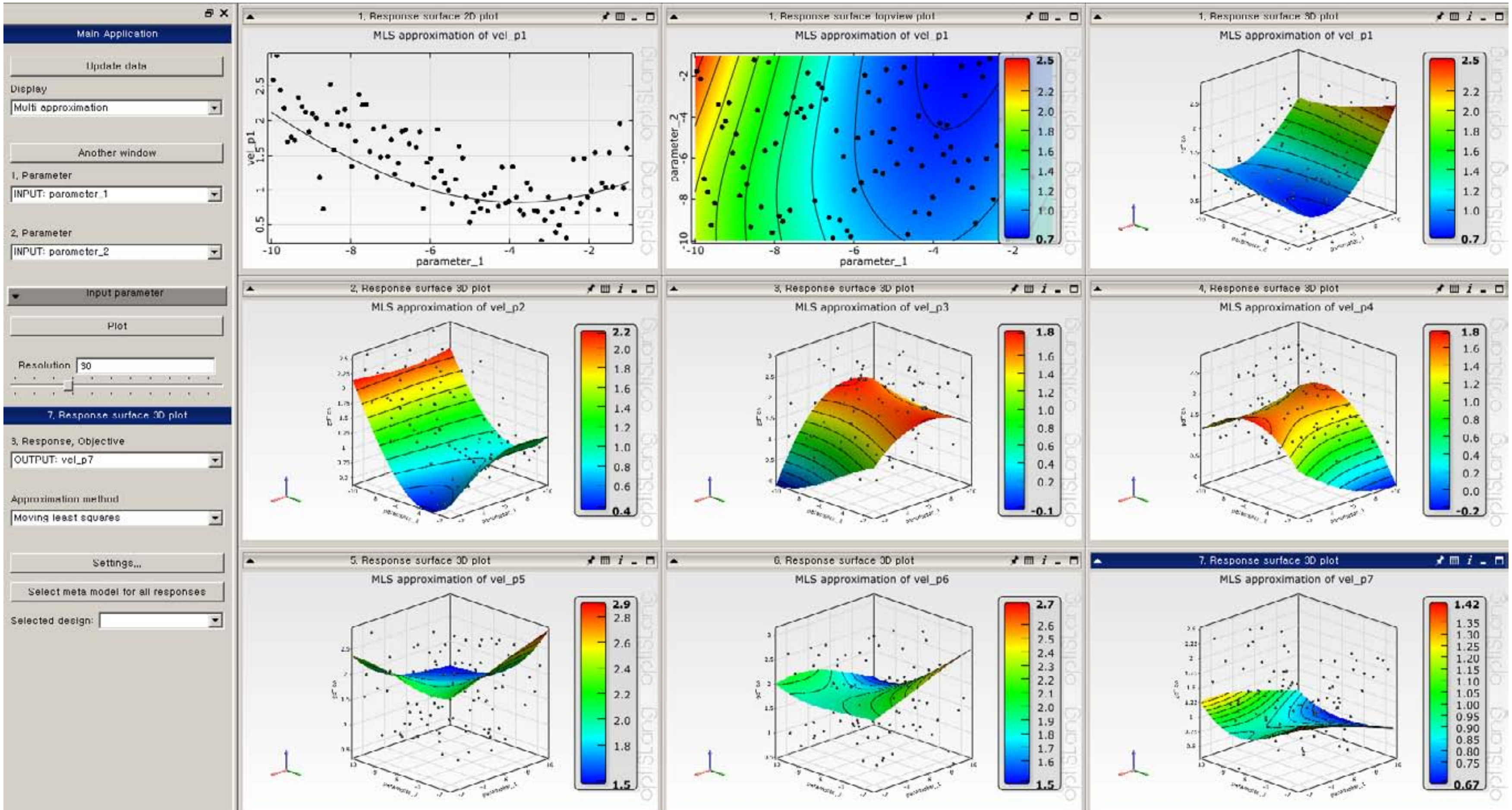
Outline of All Parameters

	A	B	C	D
1	ID	Parameter Name	Value	Unit
2	Input Parameters			
3	FLUENT (C1)			
4	P1	parameter-1	-5	Pa
5	P2	parameter-2	-5	Pa
6	P3	parameter-3	-5	Pa
7	P4	parameter-4	-5	Pa
8	P5	parameter-5	-5	Pa
9	P6	parameter-6	-5	Pa
10	P7	parameter-10	-5	Pa
11	P10	parameter-8	-5	Pa
12	P9	parameter-7	-5	Pa
13	P11	parameter-9	-5	Pa
*	New input parameter	New name	New expression	
15	Output Parameters			
16	FLUENT (C1)			
17	P12	vel_p1	0.32912	m s^-1
18	P13	vel_p2	0.32781	m s^-1
19	P14	vel_p3	1.3942	m s^-1
20	P15	vel_p4	1.3621	m s^-1
21	P16	vel_p5	1.6789	m s^-1
22	P17	vel_p6	1.7447	m s^-1
23	P18	vel_p7	0.34139	m s^-1
24	P19	vel_p8	0.34781	m s^-1
25	P20	vel_p9	0.16417	m s^-1
26	P21	vel_p10	0.11068	m s^-1
27	P22	vel_out1	2.6899	m s^-1
28	P23	vel_out2	2.7654	m s^-1
29	P24	vel_point23	0.758	m s^-1
30	P25	vel_point24	2.6068	m s^-1

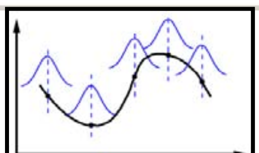
Sensitivity Analysis to check parameter importance and identify best possible meta model (MOP)

Using evolutionary algorithm (EA) at MOP

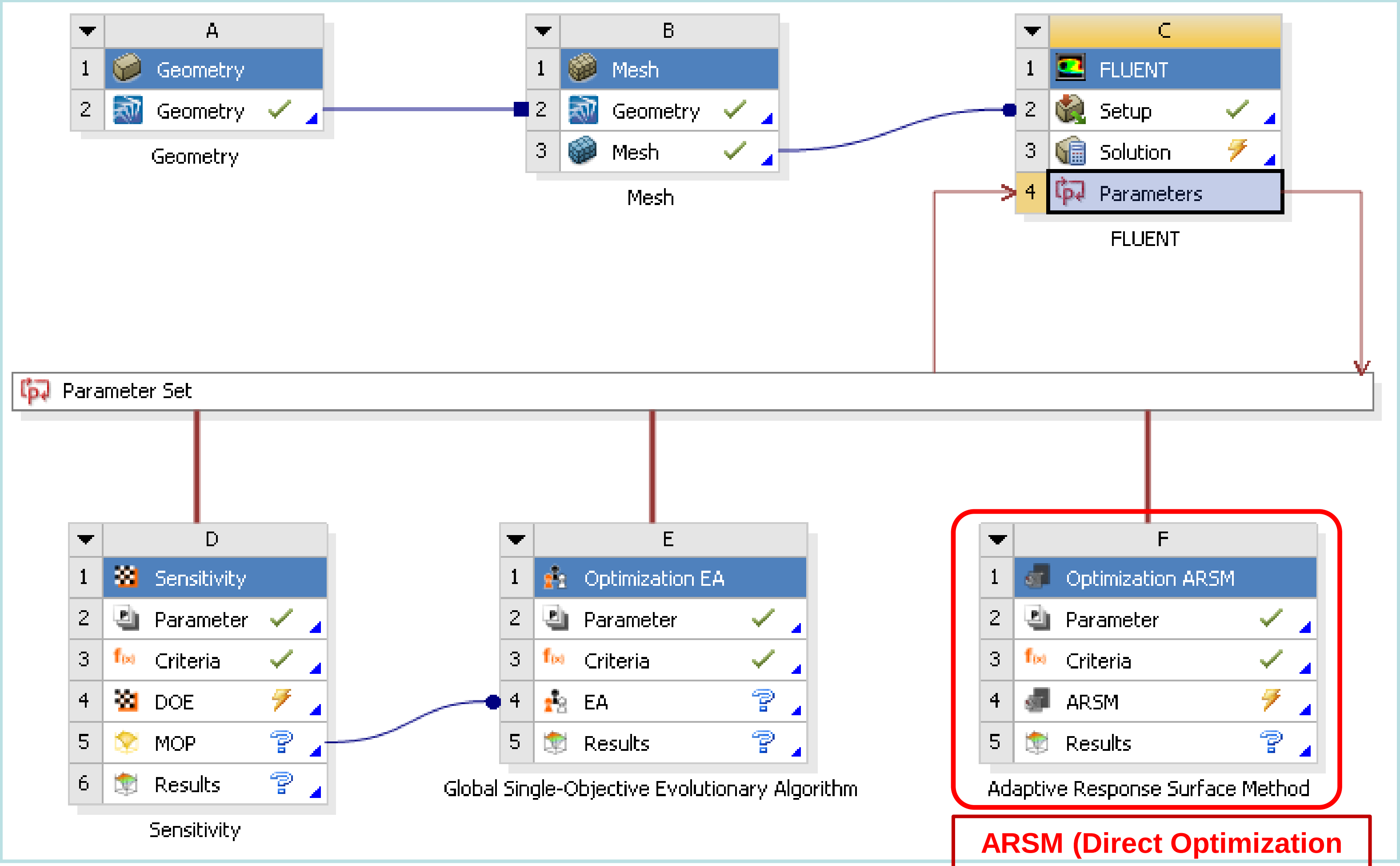
How linear are the correlations?



We made regression model of each input vs. output
- Regression model: MLS (Moving Least Square)

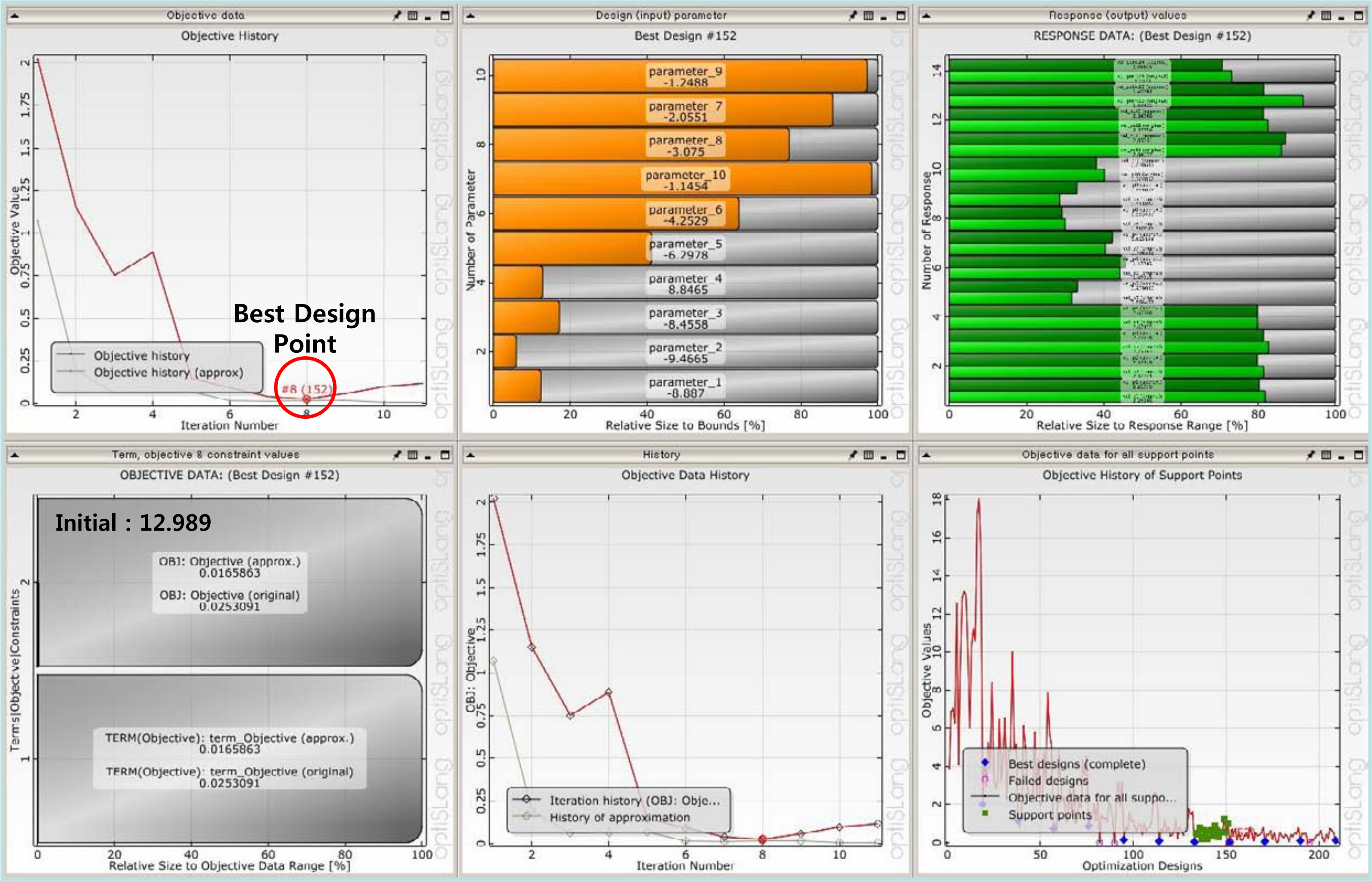


changing optimization method from global regression model using MOP to direct optimization method (ARSM)



ARSM (Direct Optimization without Sensitivity)

Optimization Results (ARSM)



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Output Variables History

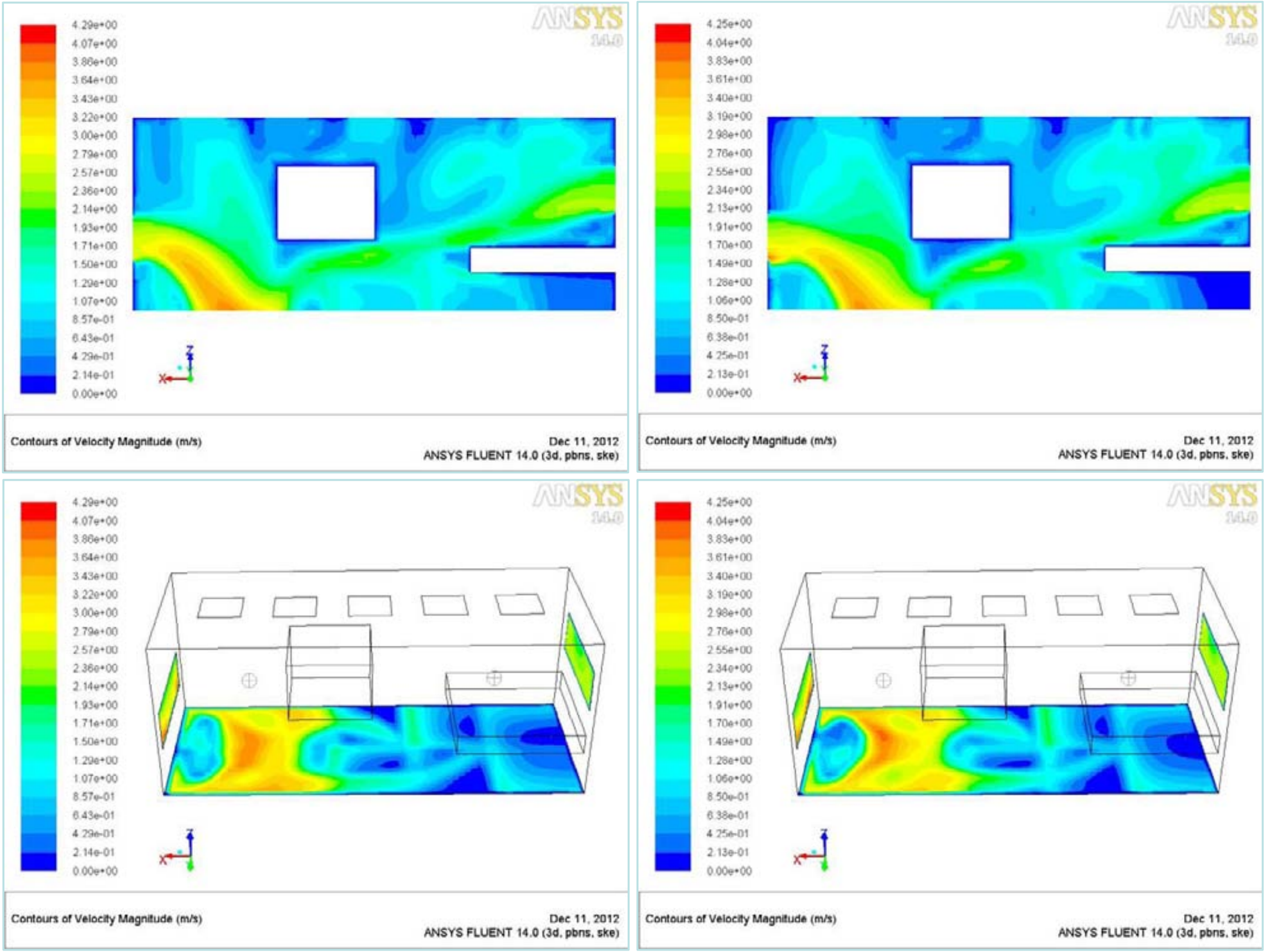
		Velocity [m/s]				Error [%]			
	Target Value	Initial(1)	inter3(59)	iter4(76)	iter7(152)	Initial(1)	inter3(59)	iter4(76)	iter7(152)
v1	**2.219**	0.329	1.986	2.329	**2.262**	574.468	11.732	-4.723	**-1.901**
v2	**2.323**	0.327	2.269	1.997	**2.374**	610.398	2.380	16.324	**-2.148**
v3	**2.719**	1.394	2.973	2.345	**2.753**	95.050	-8.544	15.949	**-1.235**
v4	**2.675**	1.362	2.924	2.487	**2.674**	96.402	-8.516	7.559	**0.037**
v5	**0.953**	1.679	0.541	0.711	**0.896**	-43.240	76.155	34.037	**6.362**
v6	**1.074**	1.745	1.043	1.200	**1.073**	-38.453	2.972	-10.500	**0.093**
v7	**0.846**	0.341	0.358	0.708	**0.786**	148.094	136.313	19.492	**7.634**
v8	**0.609**	0.347	0.498	0.469	**0.569**	75.504	22.289	29.851	**7.030**
v9	**0.597**	0.164	0.725	0.925	**0.512**	264.024	-17.655	-35.459	**16.602**
v10	**0.682**	0.11	0.853	0.630	**0.707**	520.000	-20.047	8.254	**-3.536**
out1	**2.798**	2.689	3.052	3.090	**2.846**	4.054	-8.322	-9.450	**-1.687**
out2	**2.409**	2.765	2.692	2.280	**2.377**	-12.875	-10.513	5.658	**1.346**

Very Good

Reasonable

Good Optimum Results
Total iteration number: 152

Result Comparison: Velocity [m/s]

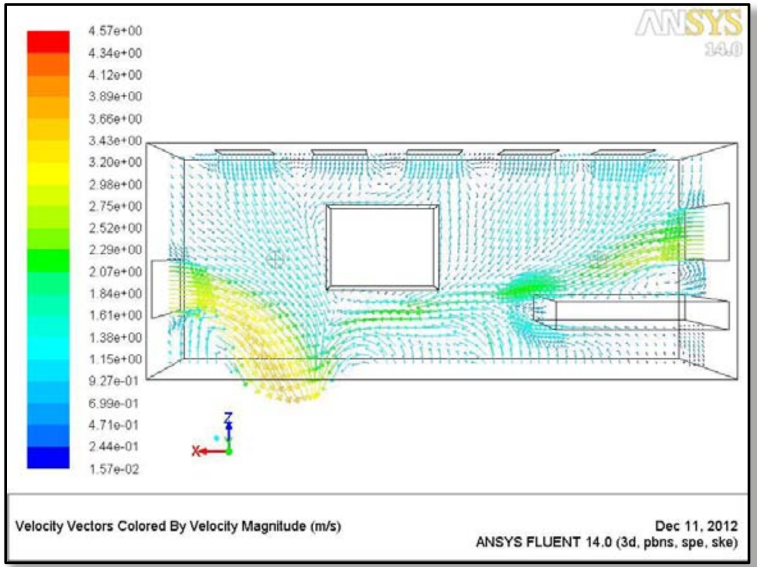


Optimal Solution using optiSLang

very good results

Target Solution (exact calculation)

Flow Simulation of LCD Manufacturing Process

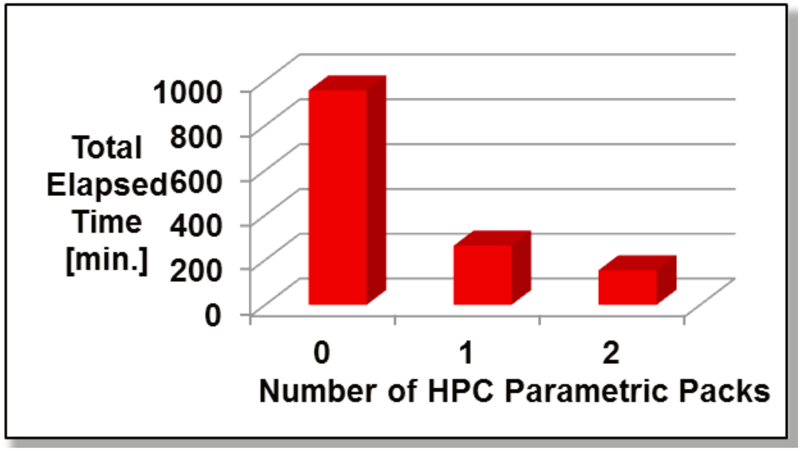


Problem Description

- Identify model inflow parameter to match outflow
- Identified output velocities have to be in 10% error ranges comparing with reference values
- Input parameter: 10 pressure areas
- 100 design points

Licensing Solution

- 1 Ansys Fluent
- 2 Ansys HPC Parametric Packs



Result/Benefit

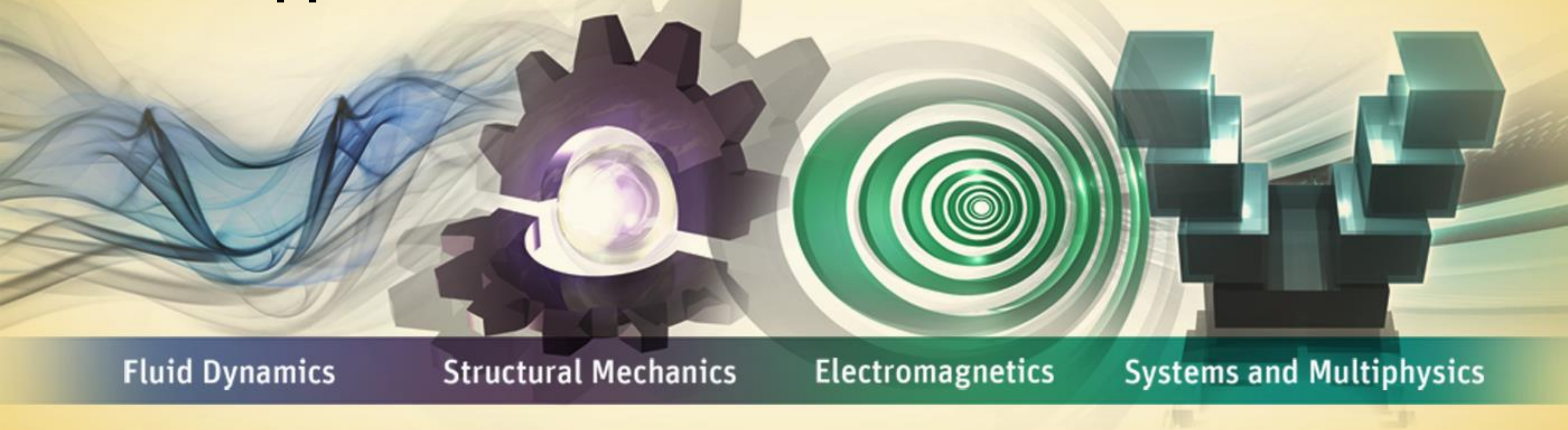
- ~6,2x speedup

ANSYS

Realize Your Product Promise™

Multi-Physics Design Optimization of an Axial Compressor

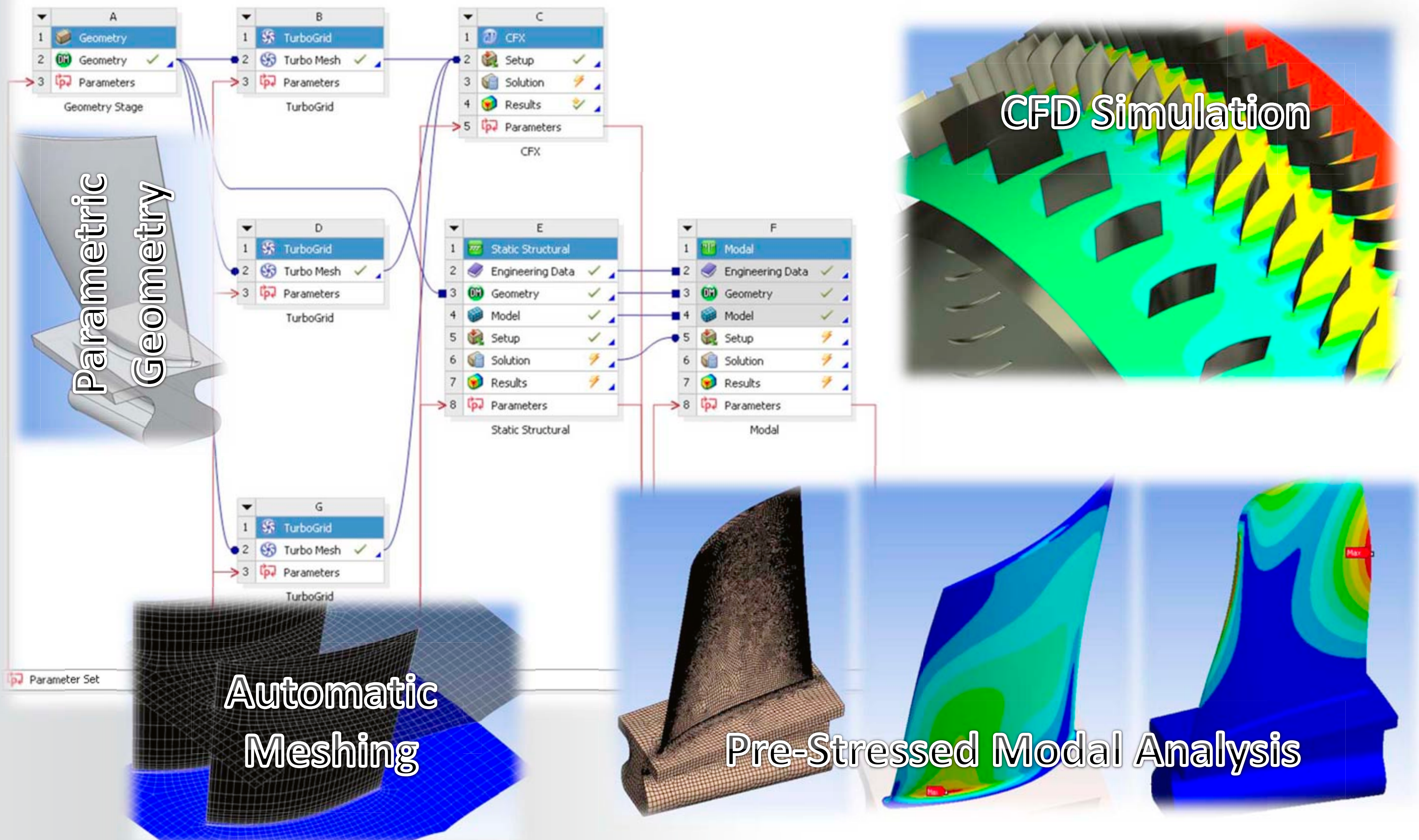
Application and Best-Practice Guide-Lines



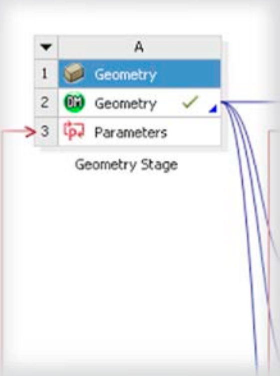
Johannes Einzinger, ANSYS

ANSYS

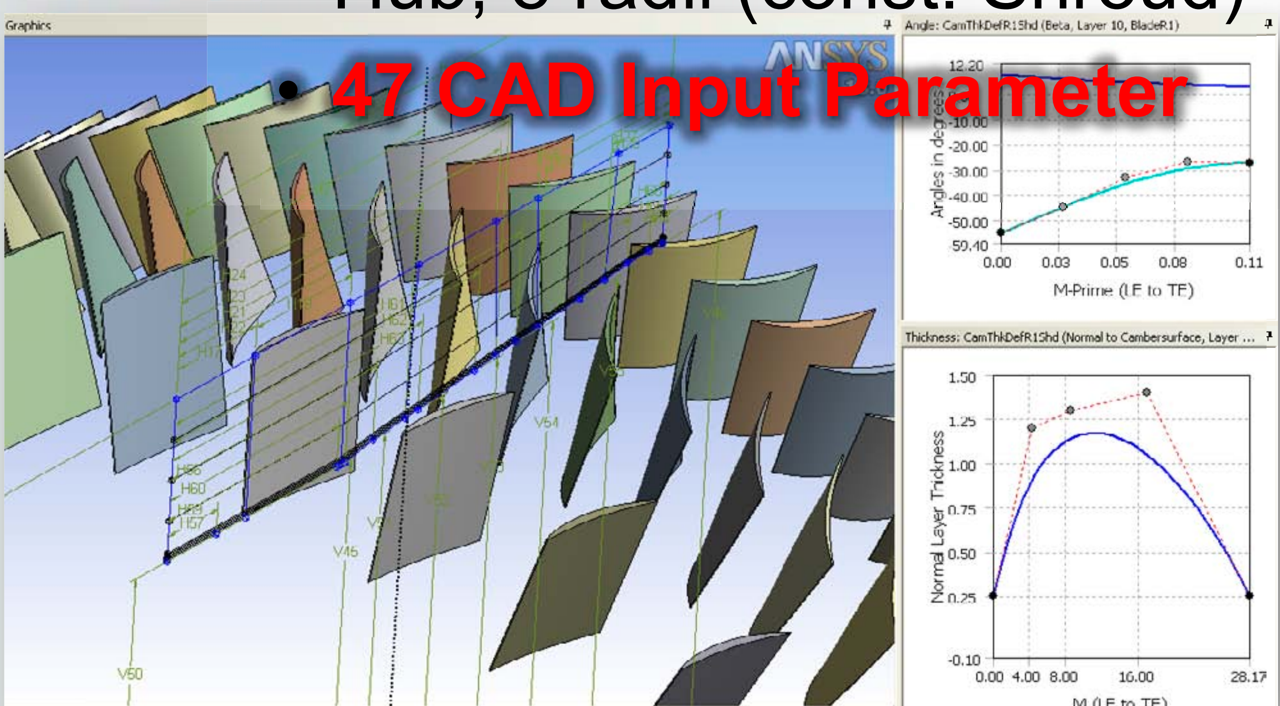
Application Overview

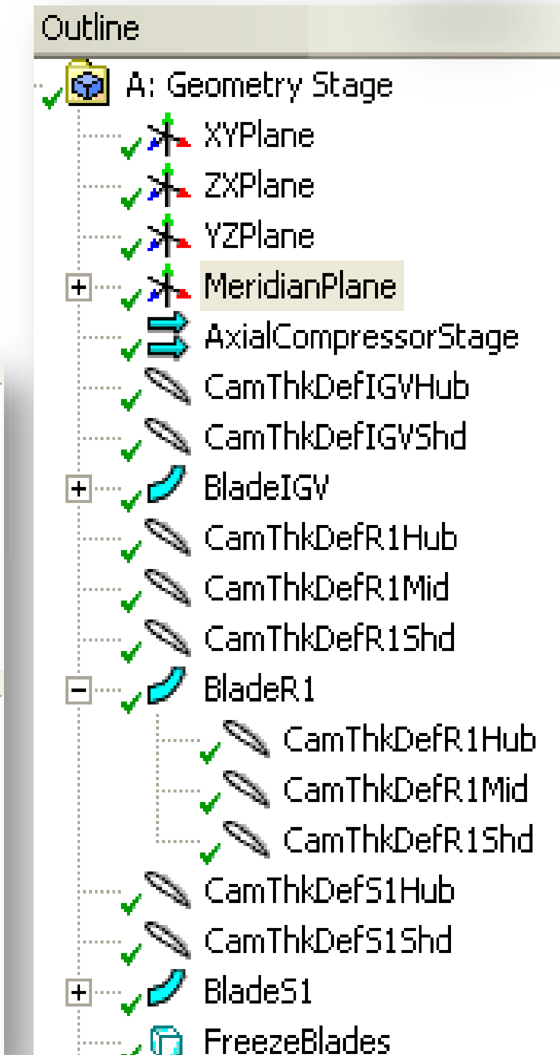


Geometry, Aero Dynamic

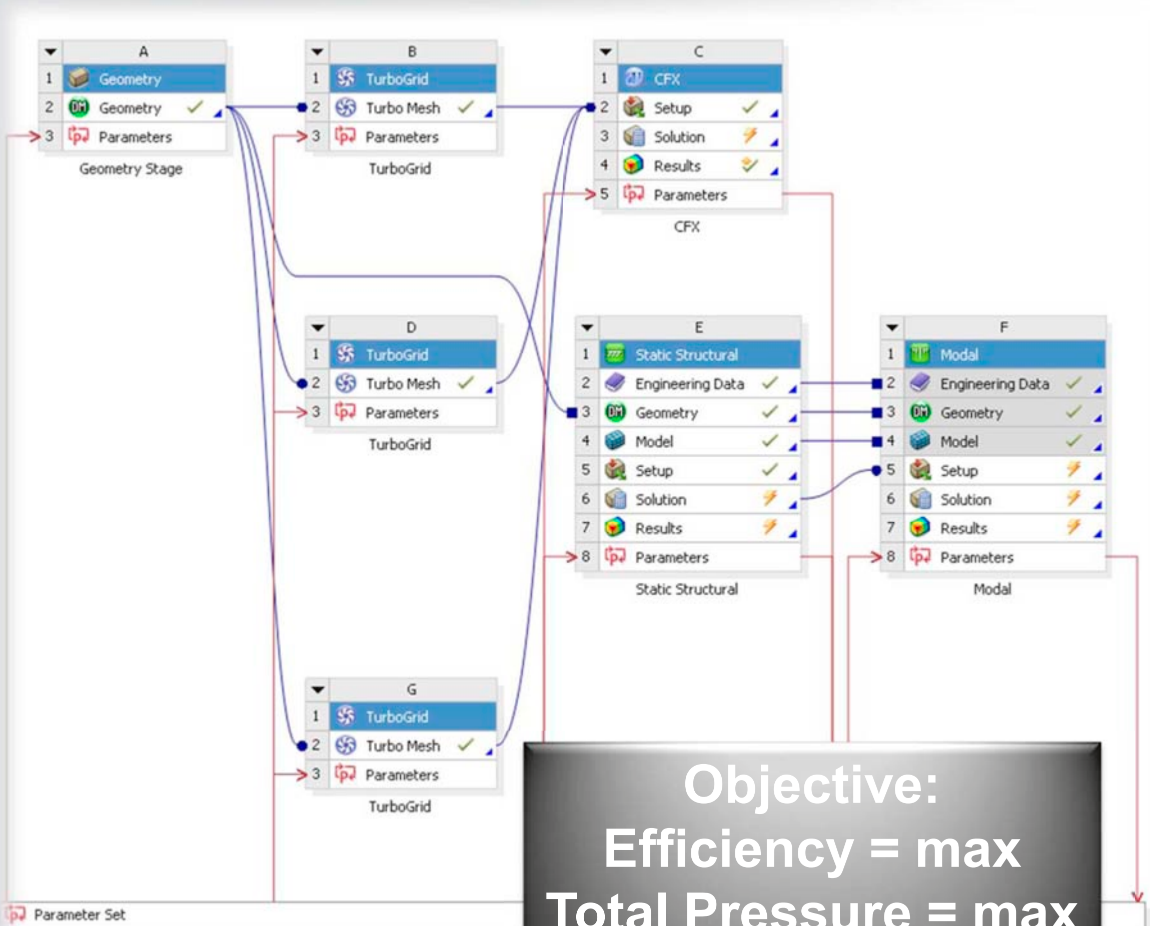


- Camber/Thickness for
  - IGV, R1, S1; 2-3 Layers
  - 5 β_i per Layer, 3xThk
- Hub, 8 radii (const. Shroud)
- **47 CAD Input Parameter**





Process and Objectives



Objective:
Efficiency = max
Total Pressure = max
Stress < Limit
No Resonance

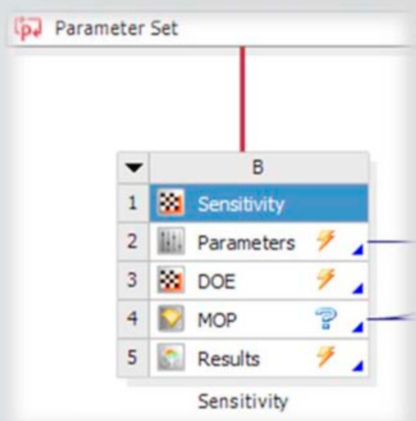
Input Parameters	
Geometry Stage (A1)	
TurboGrid (B1)	
TurboGrid (D1)	
TurboGrid (G1)	
CFX (C1)	
P16	nPitchS1
P15	nPitchR1
P14	nPitchIGV
P17	myAirCP
P18	myAirR
P19	myomega
P20	mymass
P21	Ttin
P22	ptin
Static Structural (E1)	
P89	Face Sizing Element Size
P90	Mesh Max Size
P91	Mesh Min Size
P92	Mesh Max Face Size
P93	Rotational Velocity Z Component
P94	ViewExpand ARG1
P111	Density
P112	Young's Modulus
P113	Poisson's Ratio
Modal (F1)	
New input parameter	New name
Output Parameters	
Charts	

47 (59) Input Parameter

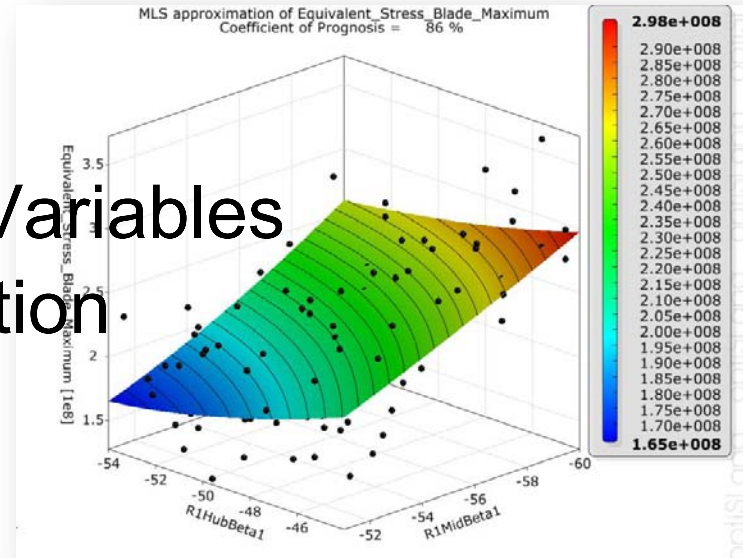
11 Input Constraints

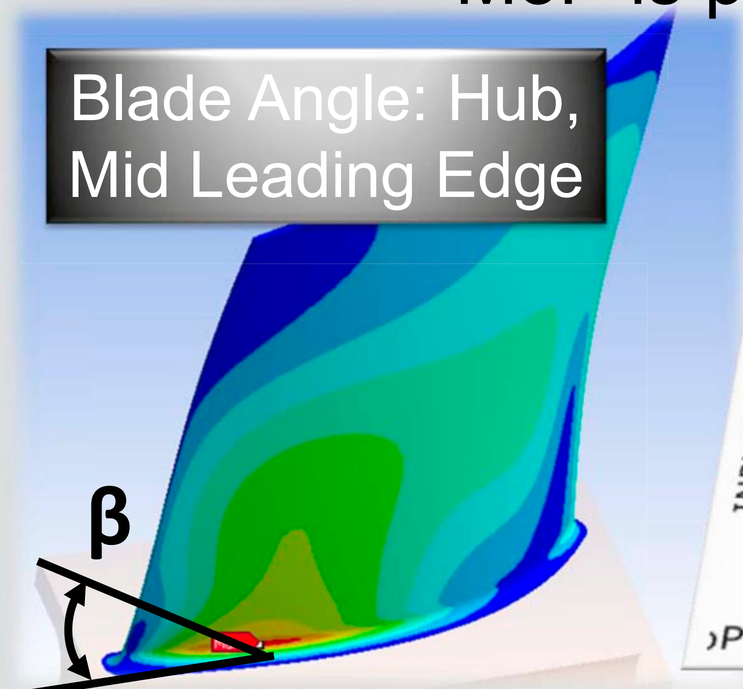
24 Output Parameter

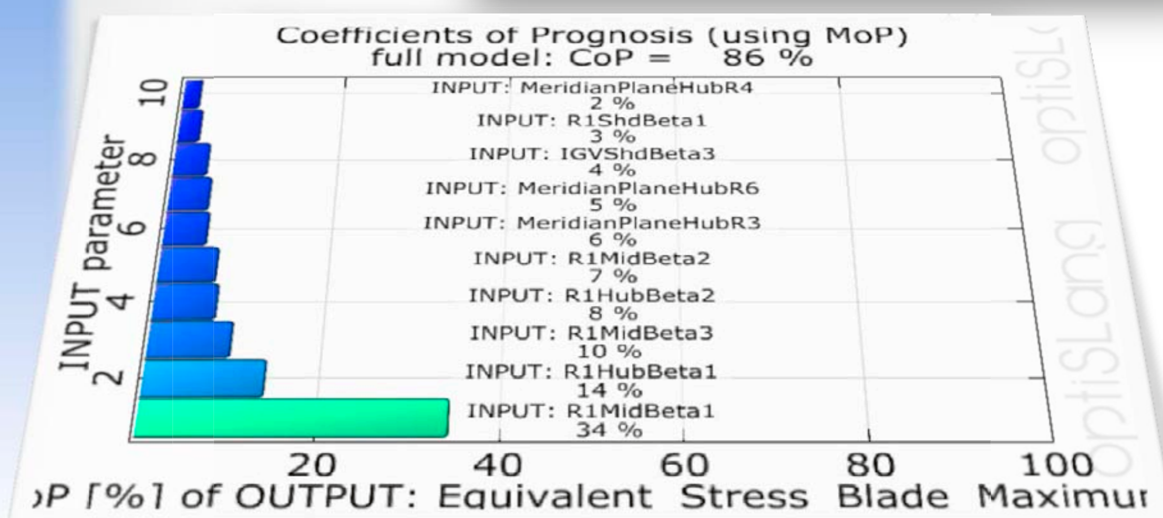
Forecast quality of maximal stress



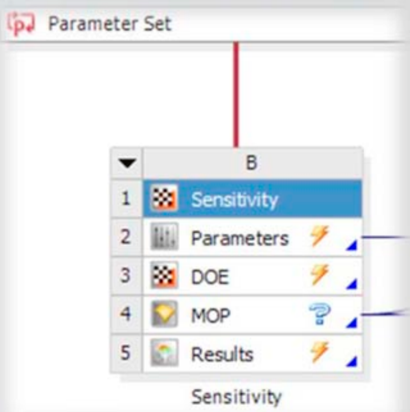
- CoP=86%
  - Statistic is reliable
  - Detect important Variables
  - Parameter Reduction
- MoP is plausible





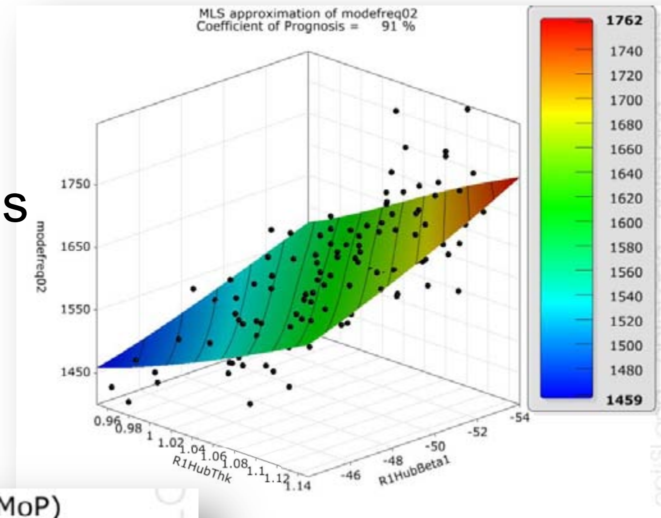


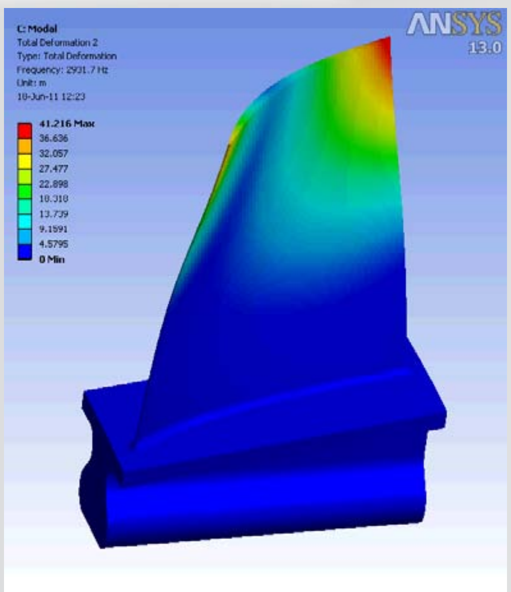
Forecast quality of constraints

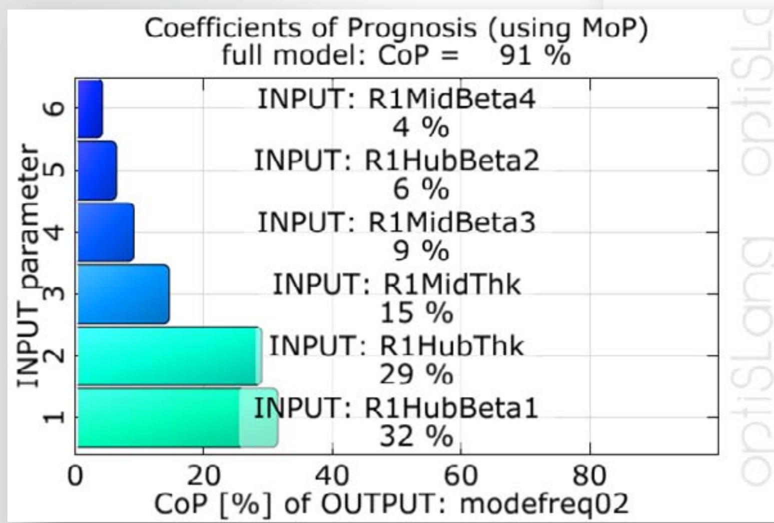


Eigen Mode:

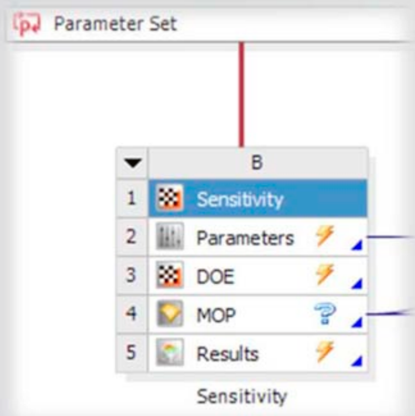
- CoP=91%
  - Statistic is reliable
  - Detect important Variables
  - Parameter Reduction
- MoP is plausible

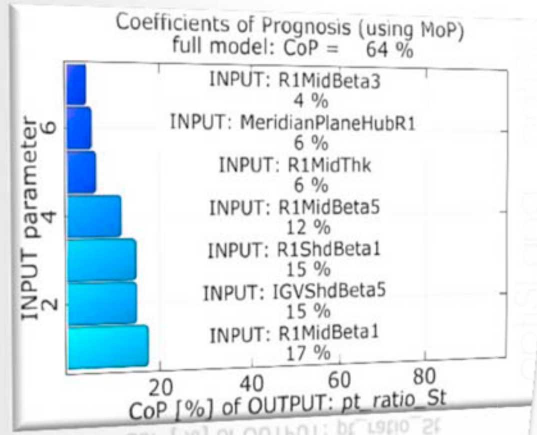


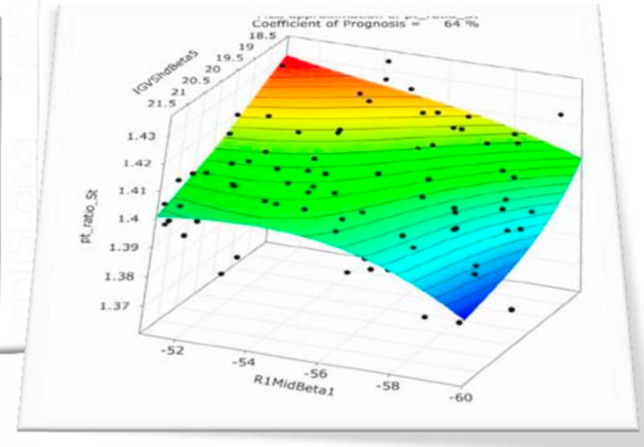




Forecast quality performance

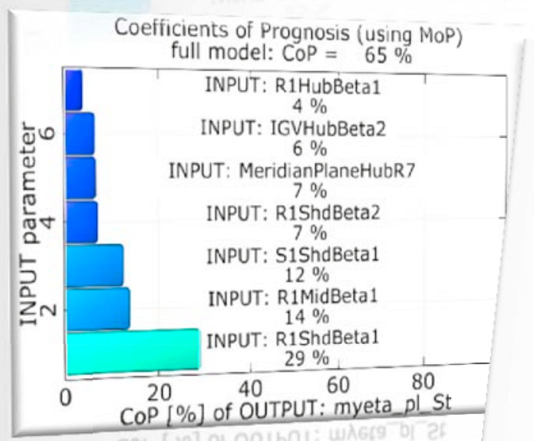


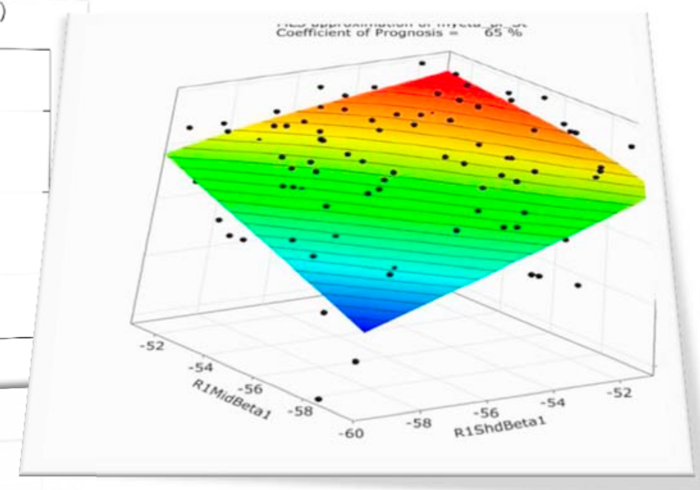




Aero Dynamic:

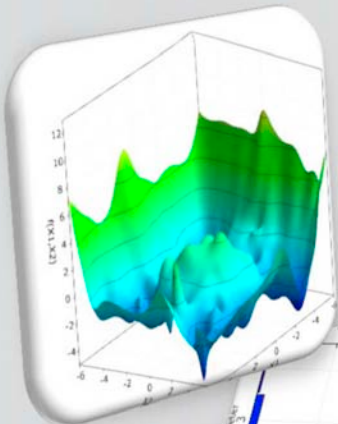
- CoP=64% and 65%
- Important Variables
  - Parameter Reduction possible
- MoP is plausible

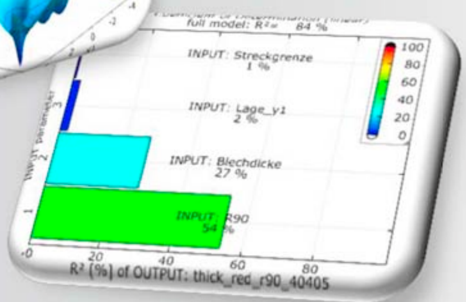




ANSYS

optiSLang Strategy





Quality of Response Surface Approximation

100%

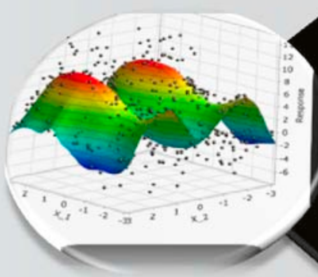
Coefficient of Prognosis

0%

Optimization on Response Surface

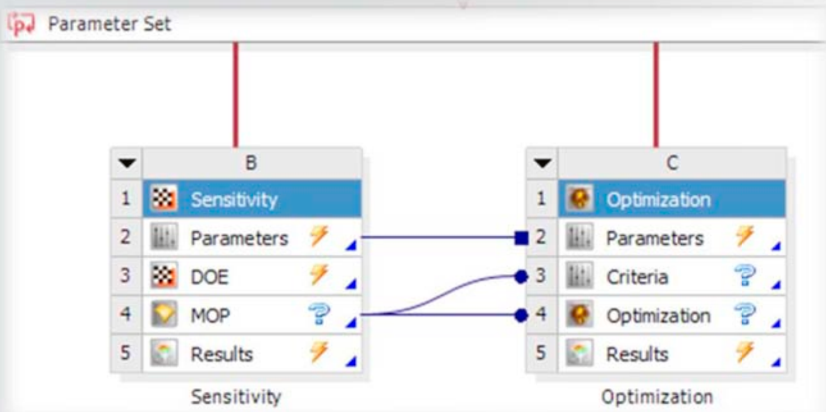
Design Optimization

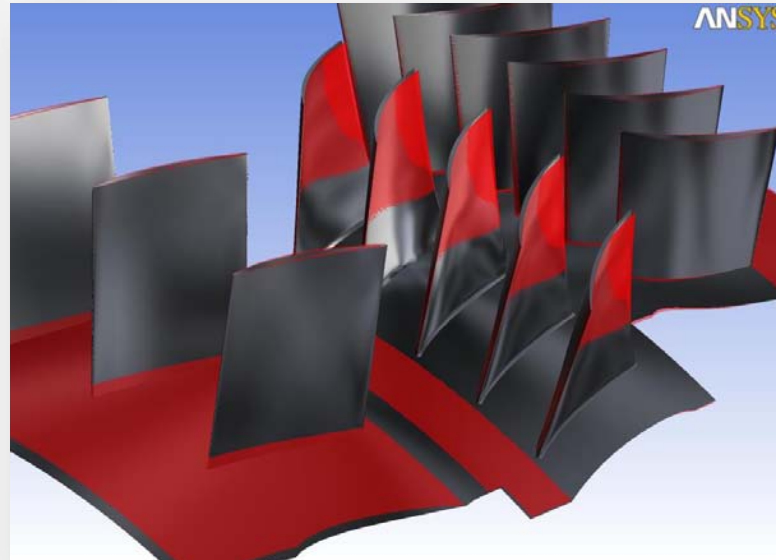
New MOP in reduced Parameter Sub-Space



Meta-Model of optimal Prognosis

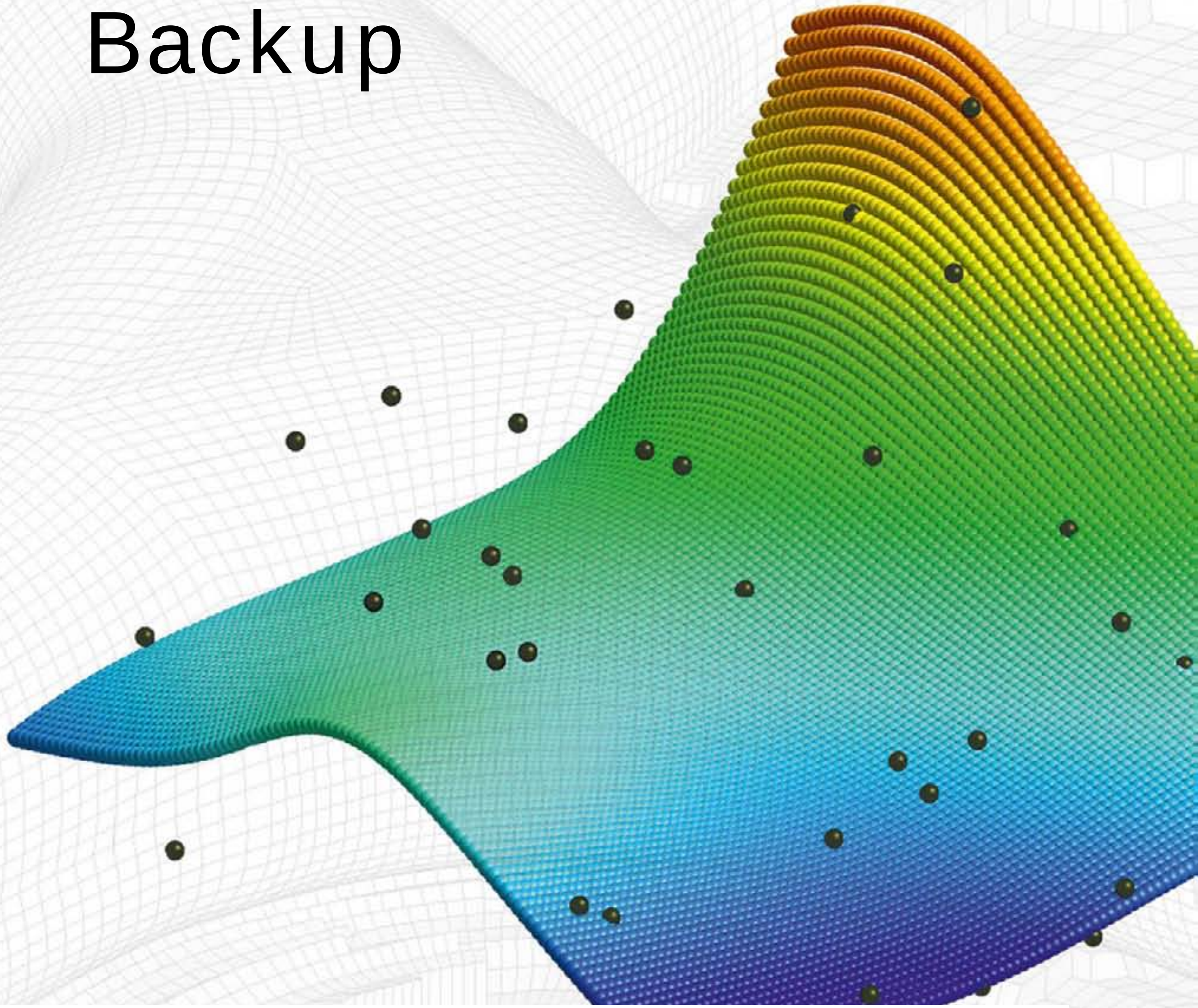
Design Optimization, Summary





	Initial Design	Best Design SA	Best Design Solved (MoP)	Best Design ARSM
Efficiency [%]	87.0	88.0	88.9 (91.0)	88.9
p_{tot} Ratio [-]	1.41	1.41	1.41 (1.44)	1.41
Max. Stress [MPa]	219	235	232 (230)	239
#Designs	1	150	1 (0)	100

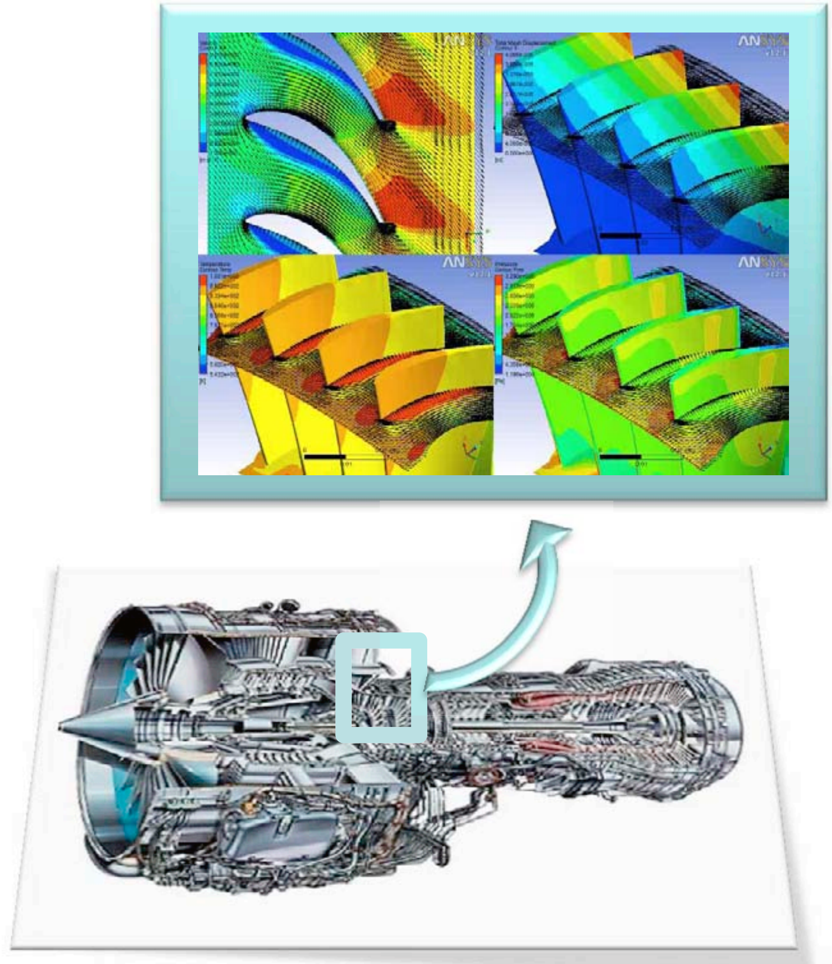
Backup



Optimization of Turbo maschines

- Turbo Machines show:
  - Rotating and stationary Parts
  - Transient Flow Field
  - Choke, Stall…
  - Dynamic Blade Loading
  - …

High Requirement for Optimization



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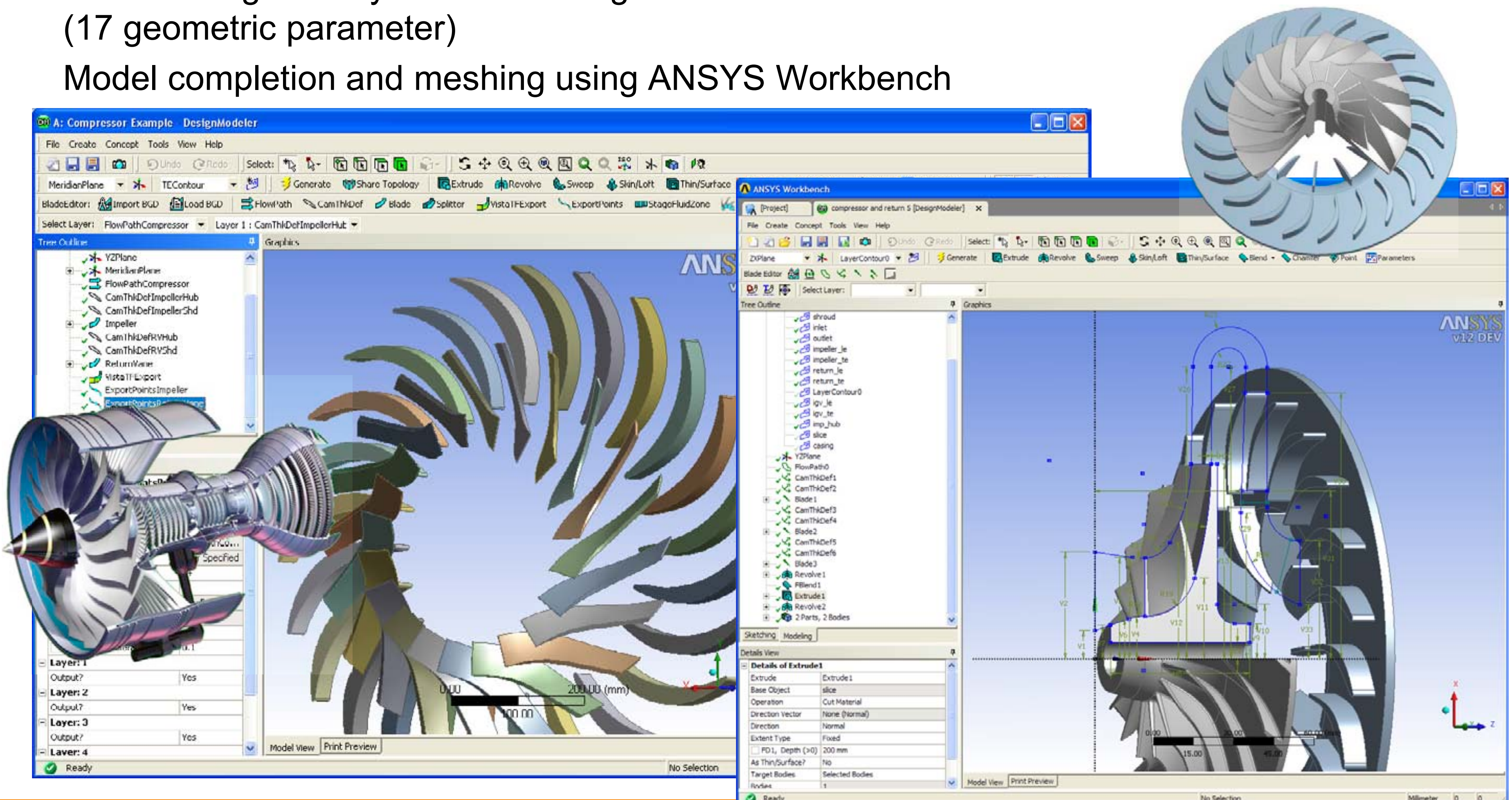
RDO Centrifugal Compressor

Parameterization

Parametric geometry definition using ANSYS BladeModeler (17 geometric parameter)

Model completion and meshing using ANSYS Workbench



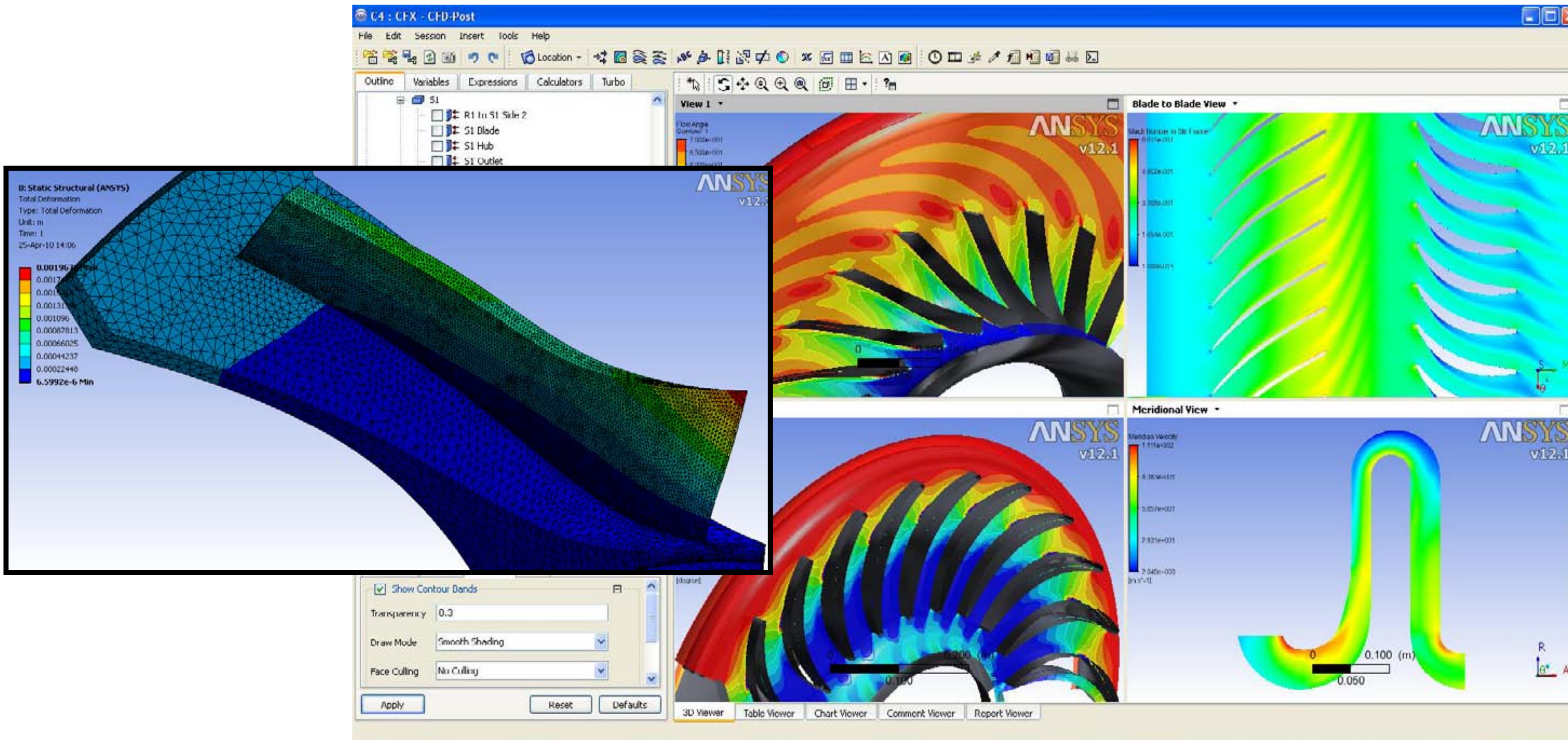
by courtesy of ANSYS

RDO Centrifugal Compressor

Fluid Structure Interaction (FSI) coupling

Parametric fluid simulation setup using ANSYS CFX

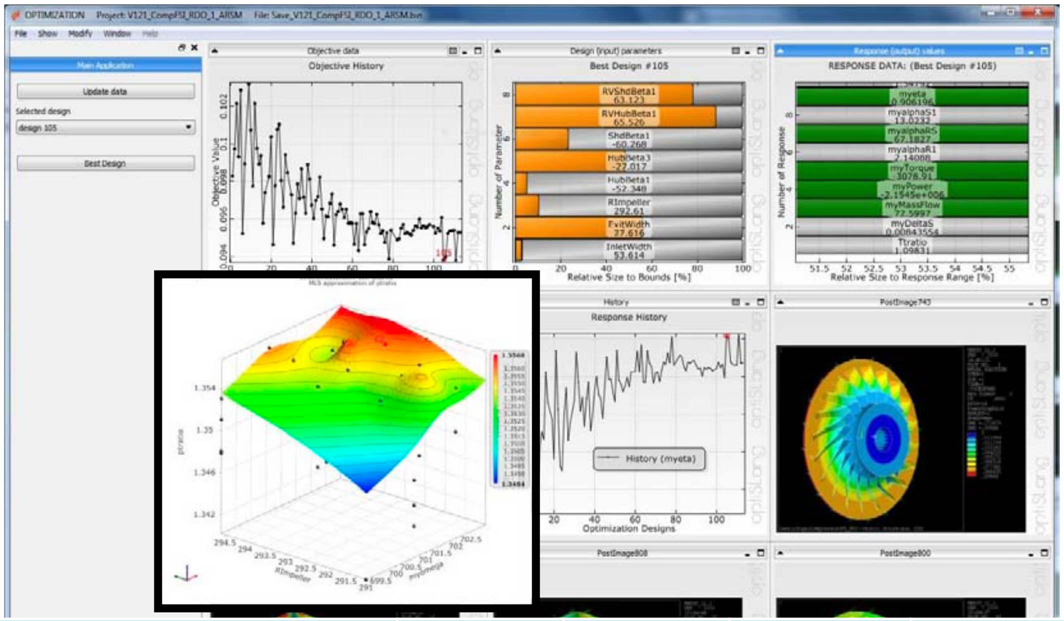
Parametric mechanical setup using ANSYS Workbench



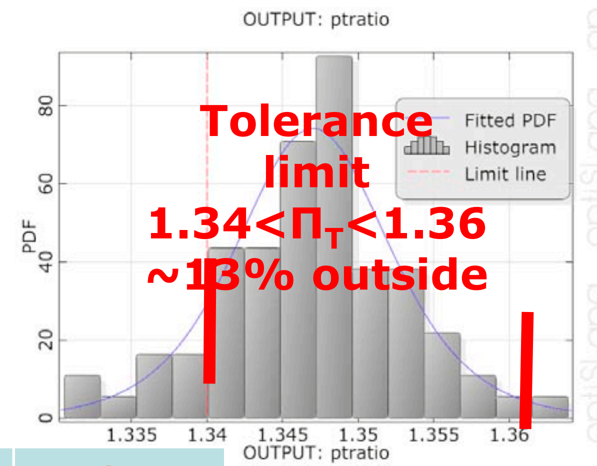
RDO Centrifugal Compressor

Optimization goal: increase efficiency

Constraints: 2 pressure ratio’s, 66 frequency constraints, Robustness



Input Parameter	21
Output Parameter	43
Constraints	68



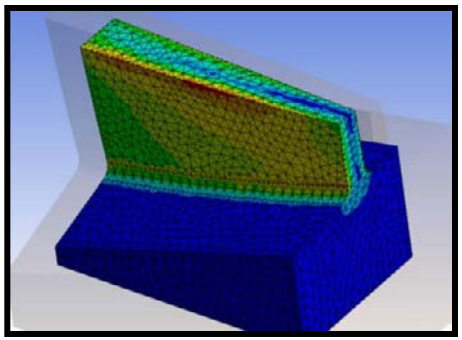
Statistic data	
Max:	1.364
Sigma:	0.006107
Kurtosis:	3.589
Fitted PDF: Logistic	
Sigma:	0.006107
Limit x = 1.34	
P_fit =	0.110889

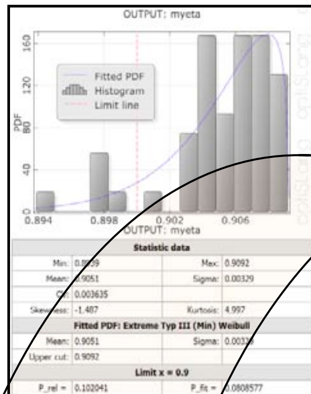
	Initial	SA	ARSM I	EA I	ARSM II	ARSM III
Total Pressure Ratio	1.3456	1.3497	1.3479	1.3485	1.356	1.351
Efficiency [%]	86.72	89.15	90.62	90.67	90.76	90.73
#Designs	-	100	105	84	62	40

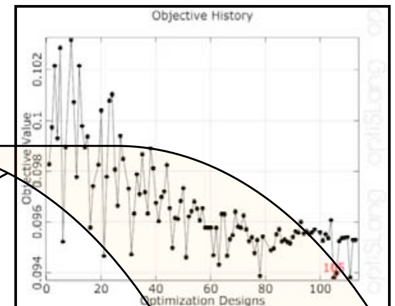
by courtesy of ANSYS

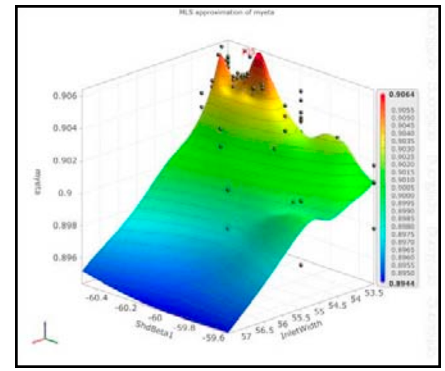
RDO Centrifugal Compressor

Robust Design Optimization with respect to 21 design parameters and 20 random geometry parameters, including manufacturing tolerances. Robust Design was reached after 400+250=650 design evaluations consuming.



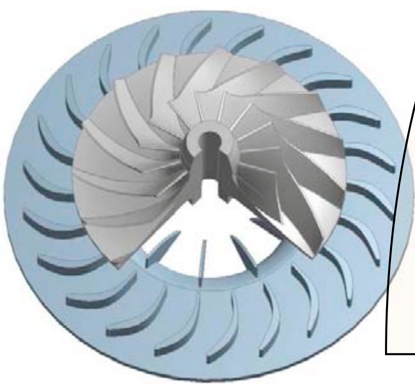


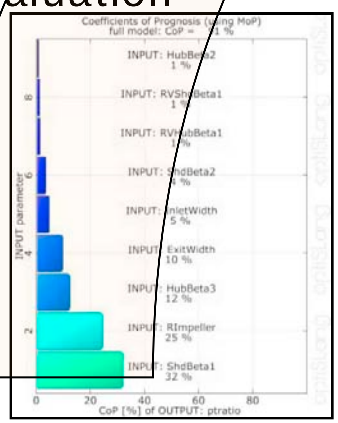


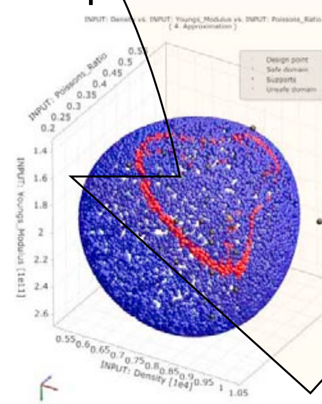


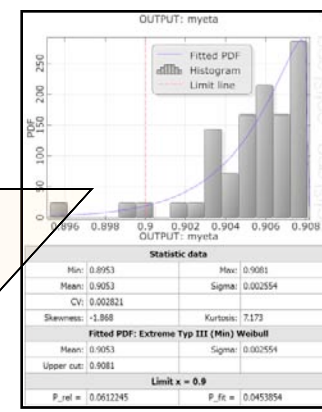
Robustness evaluation

RDO optimization









Sensi + first optimization step

Robustness proof using Reliability Analysis

Global Sensitivity Analysis of GDI Nozzle

• According to the European policy of new car registrations, the CO_2 **targets have to be reached step by step** on average from 2012 until 2015 as shown in the graph.

• Soot emission and CO_2 emission are **affected by the injection pressure**.

• **Dimension of the nozzle** has effect on the injection pressure. Therefore they are defined as the input parameters.

• From sensitivity analysis **important input parameters** effecting the particular output can be determined.

• Also worked out the **improvement potential and direction**.

• Predicted trends have been **confirmed** by spray and engine experiment results and methodology was **implement** into nozzle design development cycle.

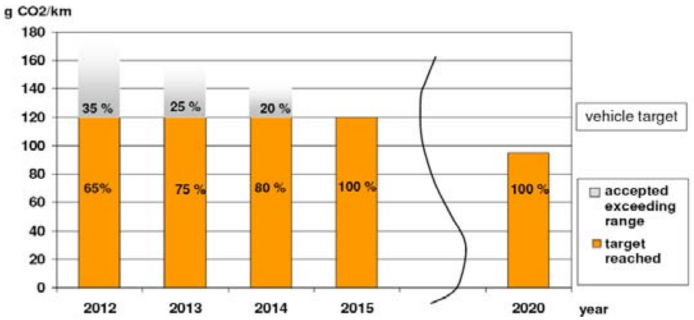


Fig: European CO_2 Emission Targets

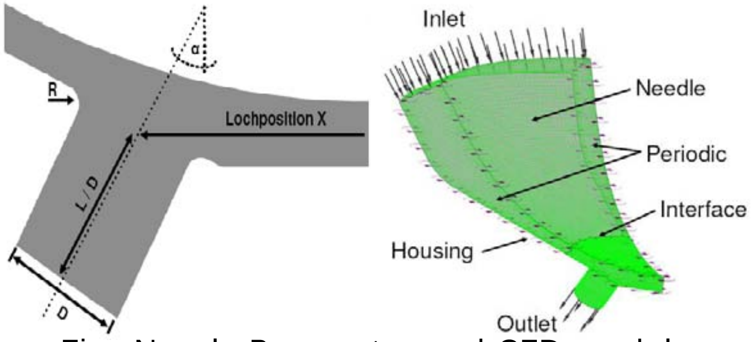


Fig: Nozzle Parameter and CFD model

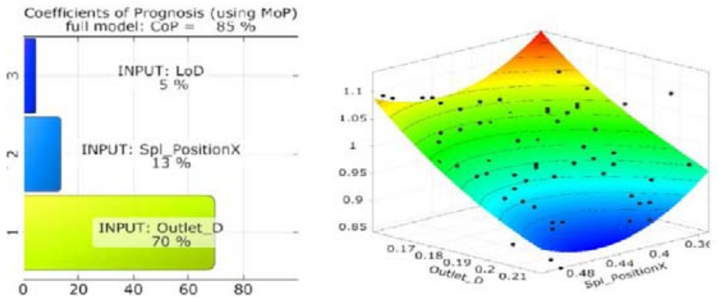
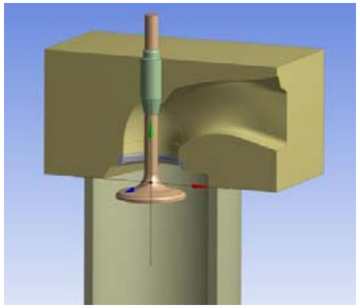


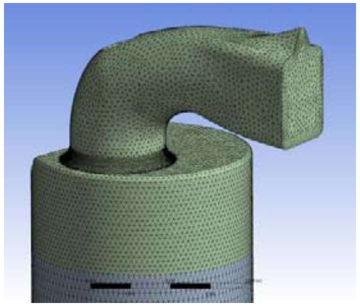
Fig: CoP and Meta Model of Injection Velocity

by courtesy of CONTINENTAL

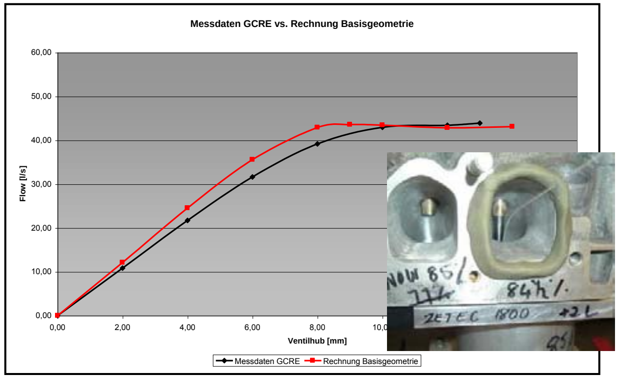
Optimization of a cylinder head



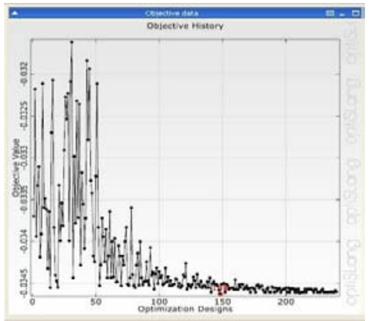
Construction of a parametric cylinder head in SolidWorks



Fluent Mesh in Ansys Workbench

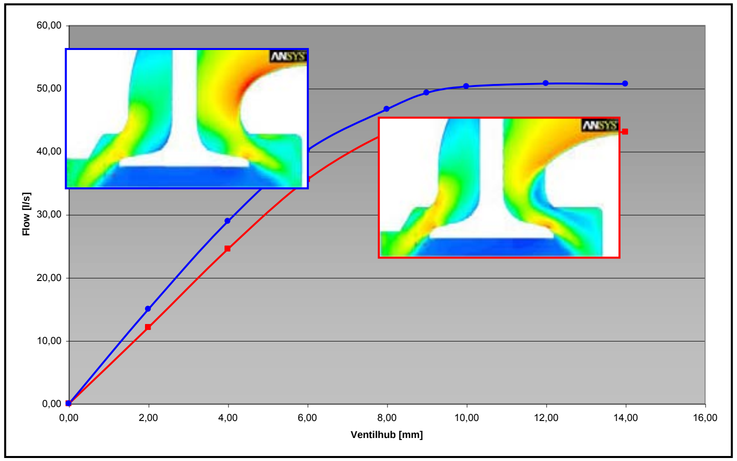


Comparison of Fluent results (red) with real-life flow test => Satisfying results match



Variation of valve seat angles and port geometry to maximize inlet flow

Use of Evolutionary algorithm



Inlet flow enhancement of ≈ 6 % by valve seat, ≈ 14 % through port optimization => Total flow improvement of ≈ 20 %

by courtesy of MicroConsult Engineering

Optimization of Process Parameters for Paint Application

- Quality of paint is important – Corrosive resistance and quality impression (marketing).
- **BMW has developed State of Art procedure to optimization the paint parameters using ANSYS Fluent and optiSLang thus reducing the development time for new car by 50%.**
- This approach predicts the paint thickness with **high accuracy** compared to measurements .
- **Following parametric** is considered based on the paint process
  - ➢ Painting distance and Paint mass flow
  - ➢ Rotational velocity of the paint bell
  - ➢ Strength of the electrical field
  - ➢ Mass flow rate of the guiding air

Fig: Paint Process During Manufacturing Phase

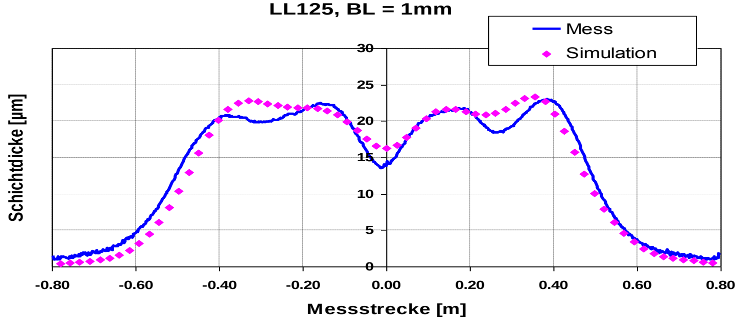


Fig: Comparison of Test and Simulation

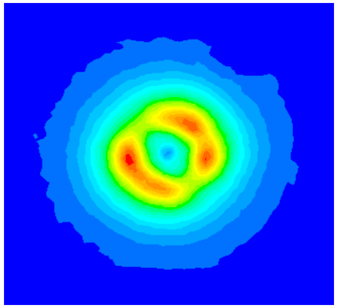


Fig: Paint Thickness Distribution as Contour