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FloEFD Simulation Conference 2017

Numerical and Experimental Investigation of an Automobile Turbocharger Using FloEFD

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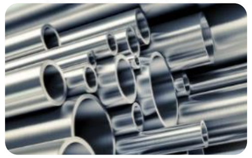
Borusan R&D

29.11.2017

...BORUSAN GROUP...

STEEL

BORUSAN MANNESMANN



BORÇELİK

KERİM ÇELİK

Business Partners

ArcelorMittal

LOGISTICS

BORUSAN LOJİSTİK

ENERGY

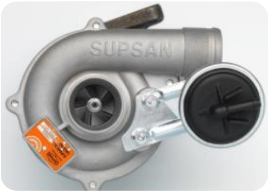
BORUSAN — EnBW Enerji Ortaklığı

Business Partners

EnBW AG EnBW

AUTOMOTIVE

SUPSAN Automotive Components



Business Partners

EATON

DISTRIBUTORSHIP

Borusan Otomotiv

LAND ROVER

JAGUAR

BORUSAN CAT

BORUSAN ARGE

*...**Borusan R&D** was founded at the beginning of 2015. Borusan Group create R&D strategies and implement R&D studies through this company...*

Background and Aim of the Study

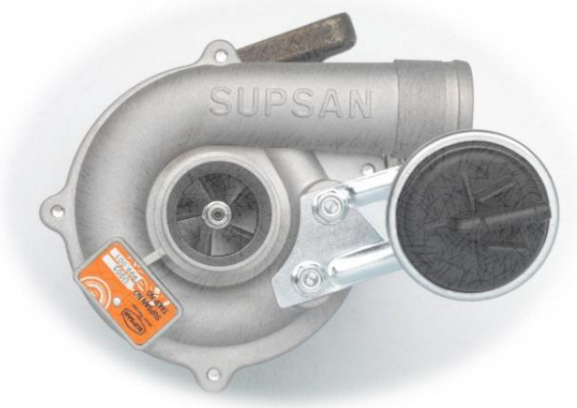
SUPSAN
Automotive Components

The largest engine valve manufacturer in Turkey

Supplies products and services to national and international **automobile, light and heavy commercial vehicle, tractor, and heavy construction** equipment manufacturers

Exports to **Italy, Germany, France and the USA**

...Supsan was having its turbochargers produced by its suppliers...



...Supsan's desire to design its own turbos and Borusan R&D's capabilities were merged in a turbo design project...

BORUSAN ARGE

Concept Design

Design, 3D Modelling, Technical Drawing

Collision, Strength, Fatigue, Metal Forming Simulations

Computational Fluid Dynamics (CFD)

Prototyping

Testing and Verification

CONTENT

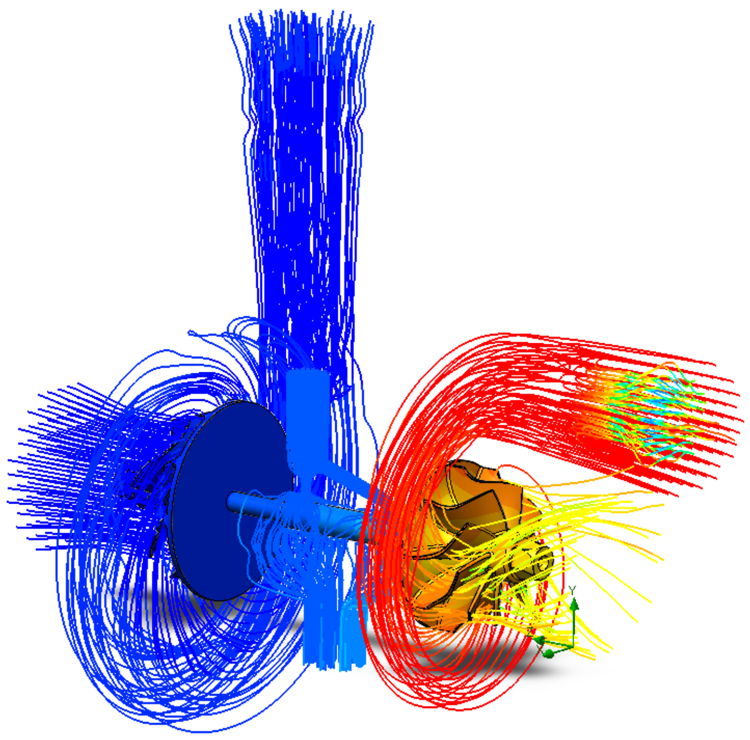
Turbocharger Description

Test Setup and Data

Numerical Modeling

Results and Discussion

Conclusion



Turbocharger Description

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Turbocharger Description

The turbine wheel is connected by a shaft to a compressor wheel and the two wheels turn together

Small but complex automotive component

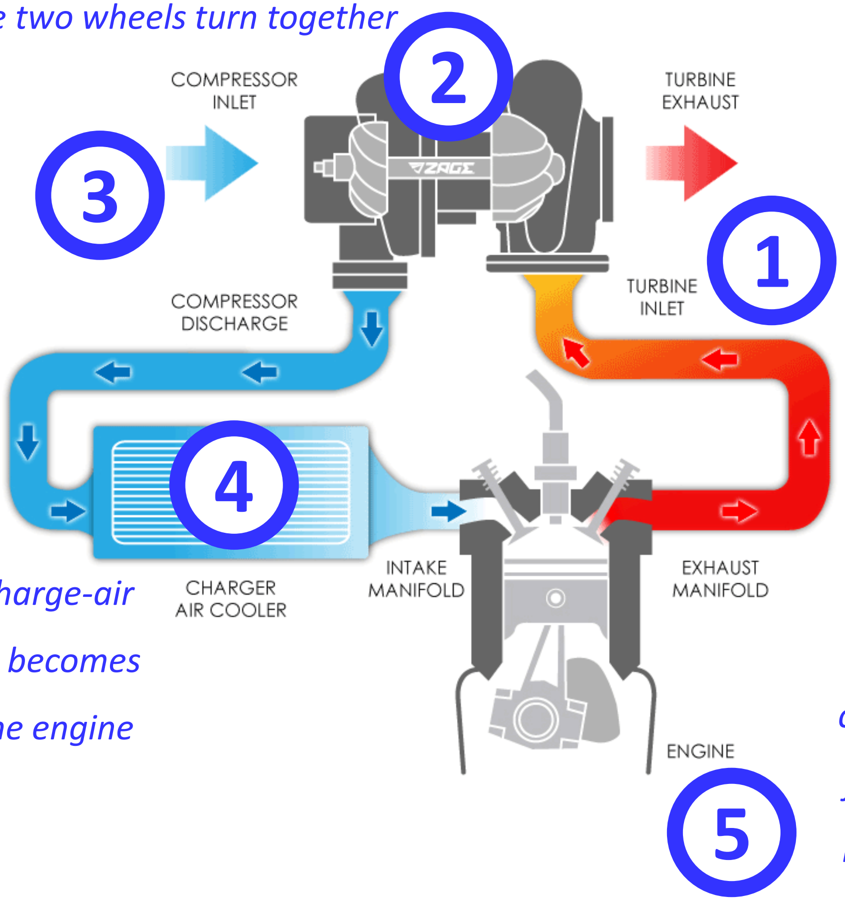
Two different turbomachinery

Compressor sucks and compresses ambient air

A turbocharger uses the engine's wasted exhaust gas to drive the turbine wheel

Multidisciplinary design study

High temperatures at turbine region

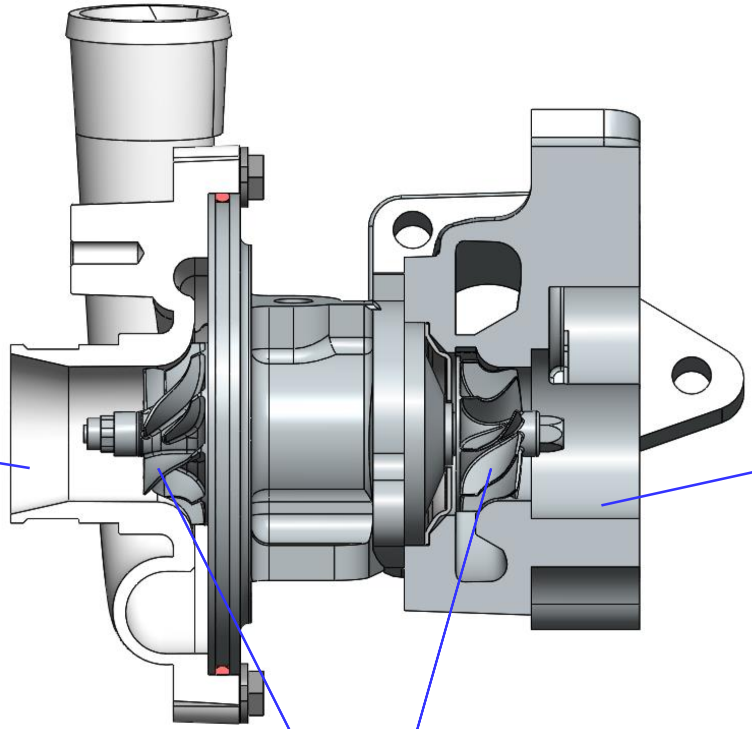


Air is passed through a charge-air cooler, where it cools and becomes denser before entering the engine

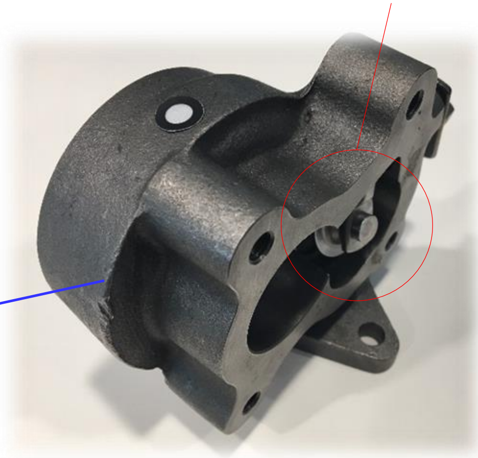
The presence of this compressed air makes the fuel burn more efficiently by delivering more power

Turbocharger Description

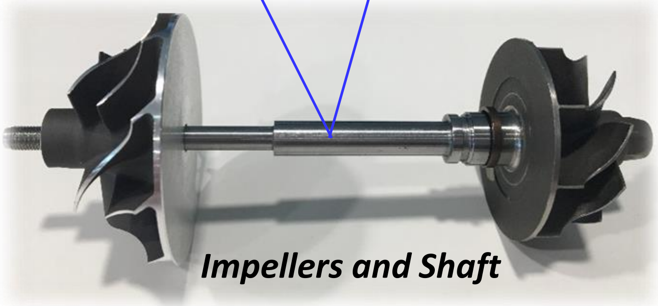
Compressor Housing



RPM control with wastegate actuator



Turbine Housing



Impellers and Shaft

Small scale turbo being used in:

Renault Clio 1.5 L 65 HP

Renault Kangoo 1.5 L 65 HP

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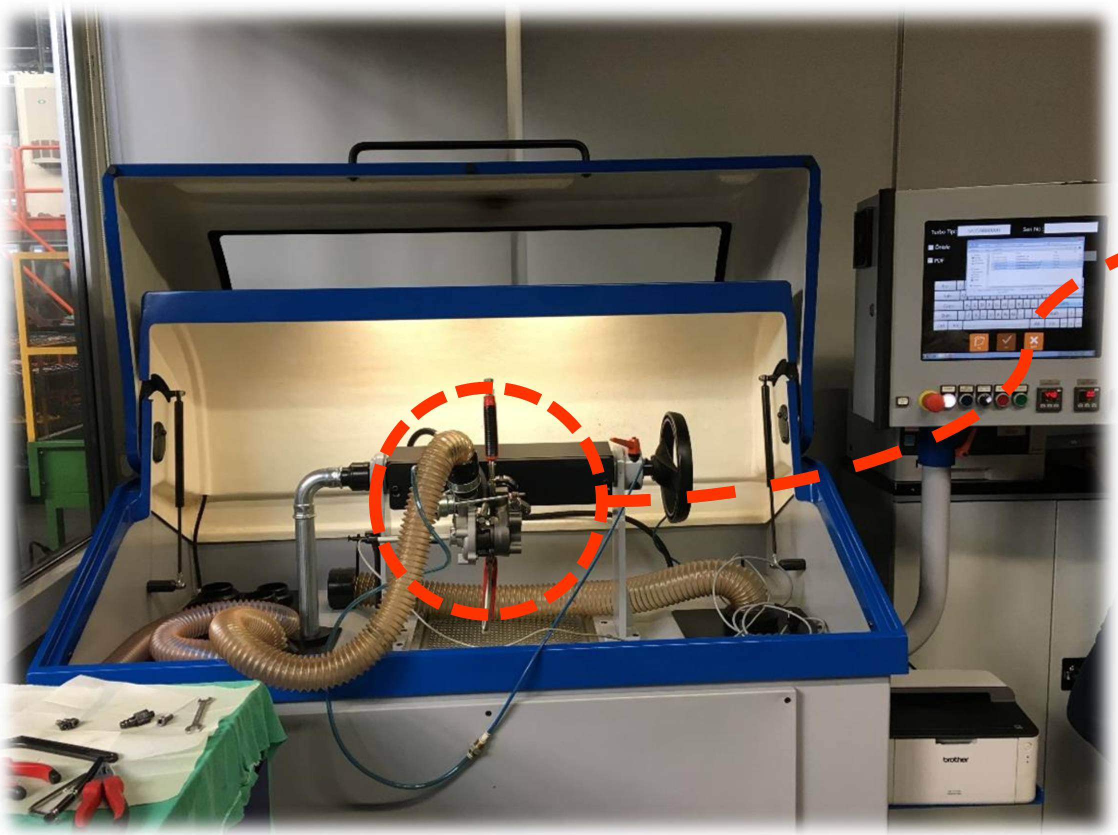
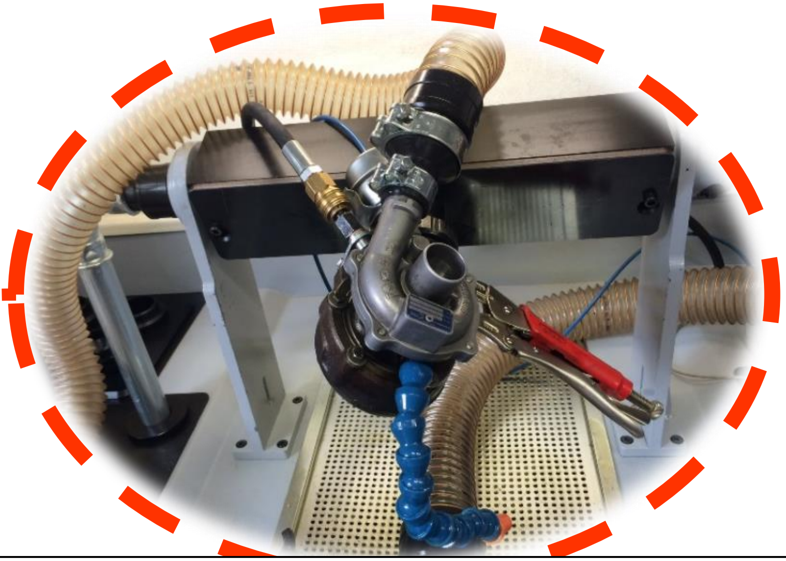
Test Setup





Turbocharger Test Device

12 different test cases, varying from 25.000 rpm to 105.000 rpm

Parameters that can be measured via this device:

Compressor:
- Rotation
- Flow Rate
- Pressure Ratio

Turbine:
- Rotation
- Flow Rate
- Inlet Pressure

Turbocharger Description

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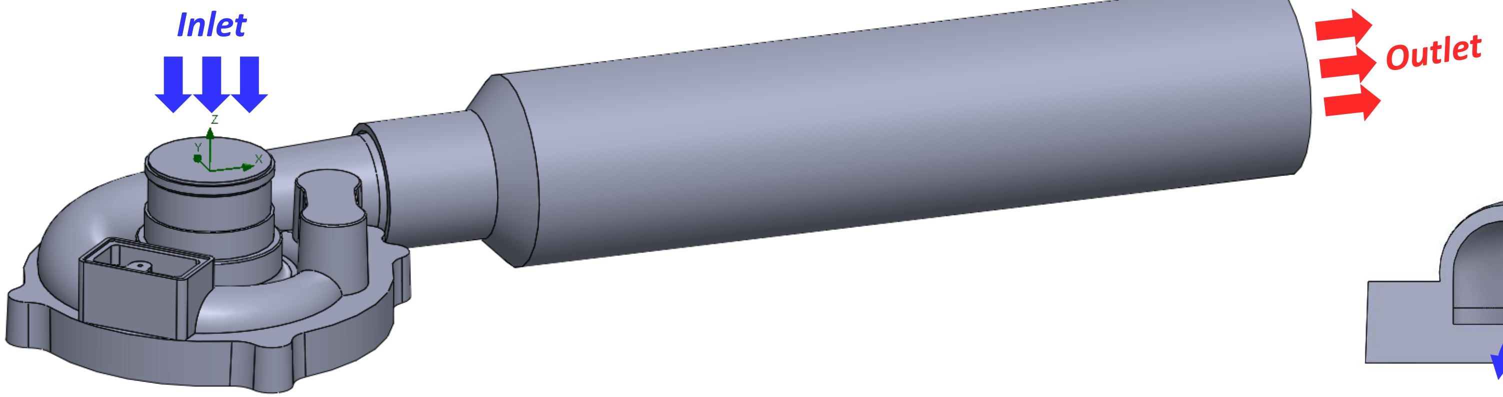
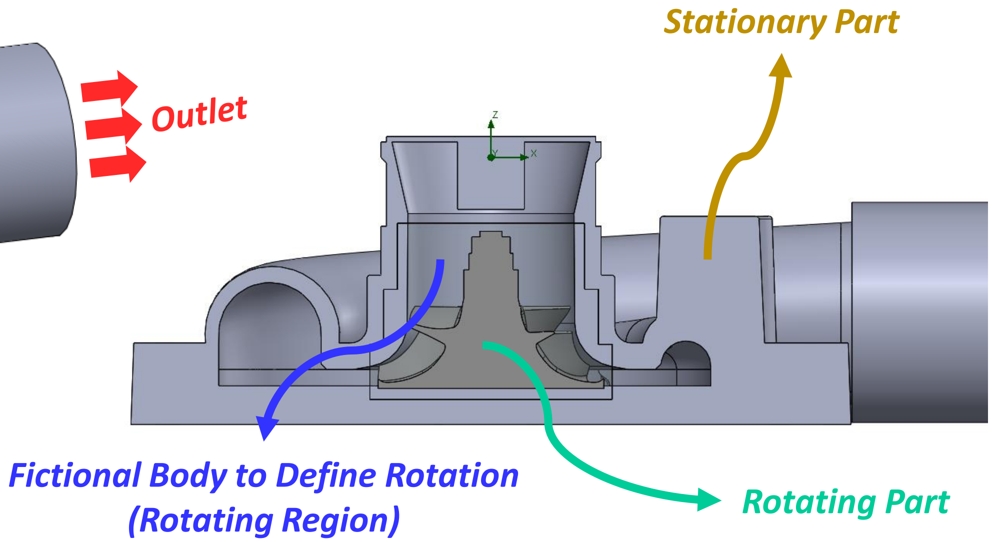
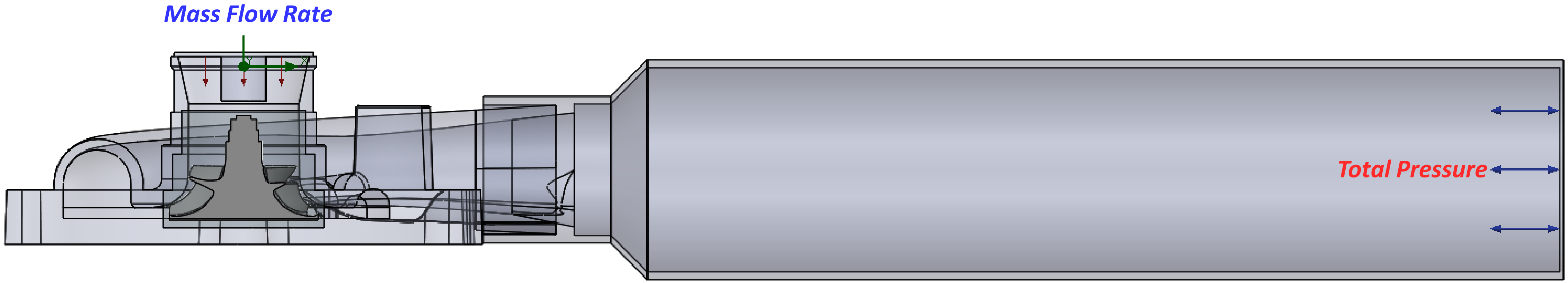
Numerical Modeling – Compressor







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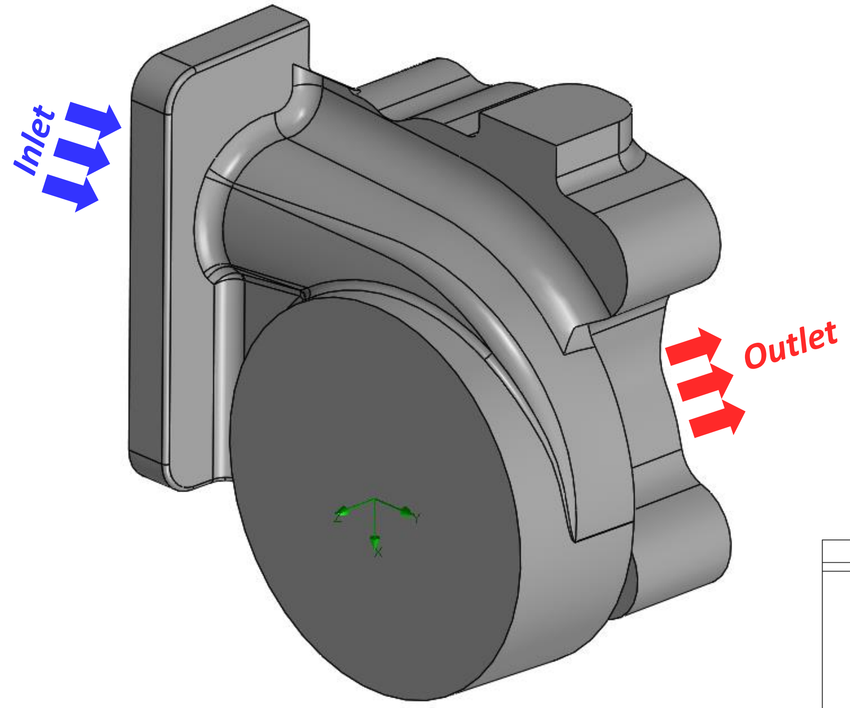
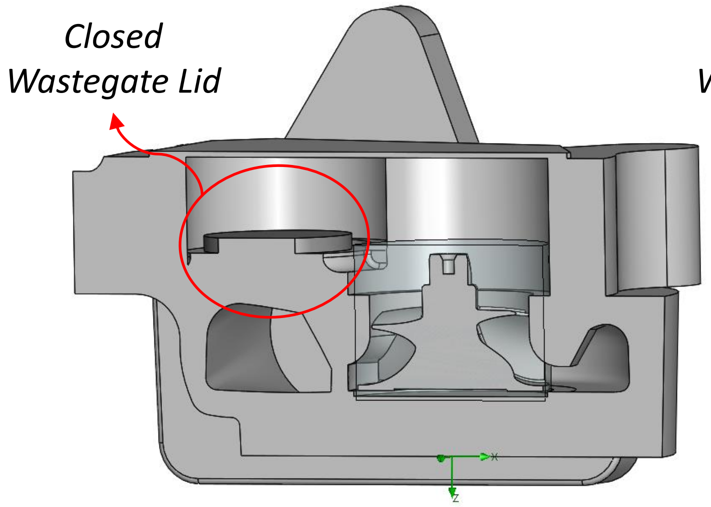
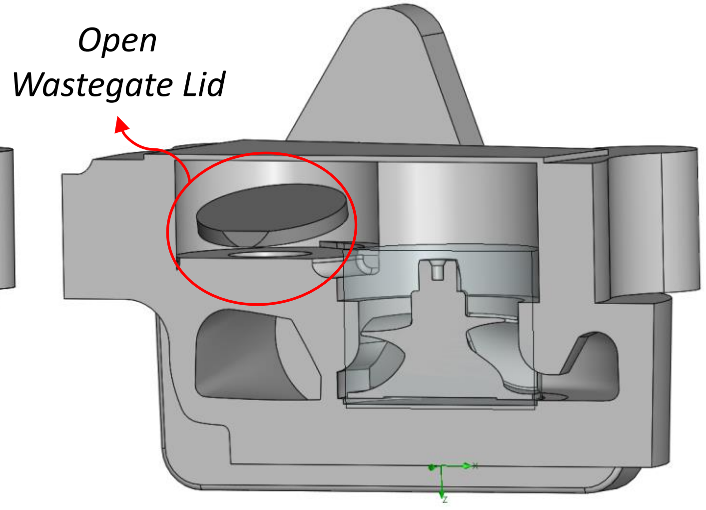
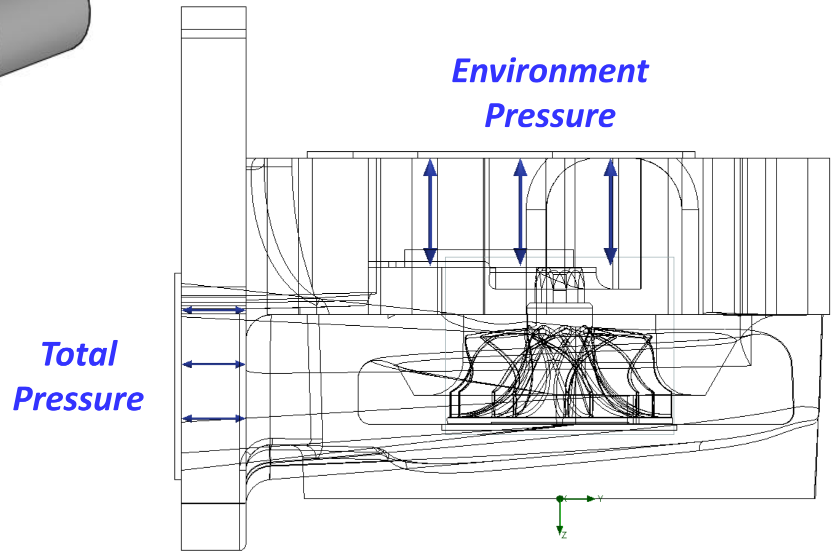
Numerical Modeling – Turbine









...Two wastegate lid positions at different rotational speeds were investigated...

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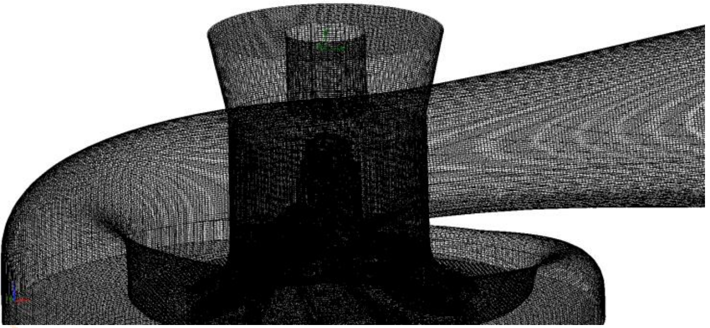
Numerical Modeling

Case	Rotational Speed [rpm]	Inlet Mass Flow Rate [kg/s]	Outlet Total Pressure [Pa]
1	51.670	0,03222	108.222
2	64.753	0,04270	114.138
3	86.010	0,06236	122.298
4	88.217	0,06704	127.398
5	101.050	0,08087	131.682
6	104.953	0,08778	136.884

Boundary Conditions for Compressor

Case	Rotational Speed [rpm]	Inlet Total Pressure [Pa]	Outlet Pressure [Pa]	
1	24.550	111.486	101.325	Wastegate is open
2	44.360	121.133	101.325	
3	57.120	130.652	101.325	
1	26.270	111.398	101.325	Wastegate is closed
2	47.370	121.276	101.325	
3	63.090	131.656	101.325	

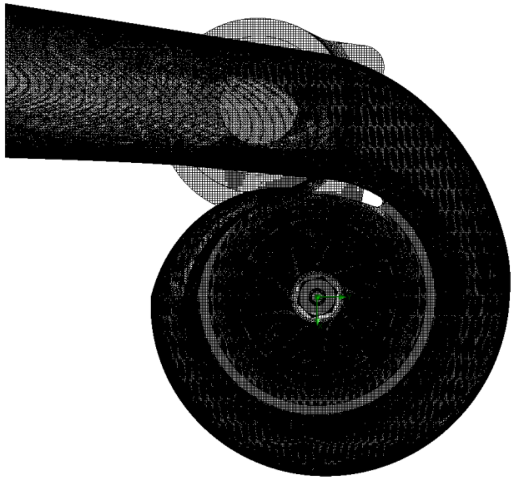
Boundary Conditions for Turbine



...3 different meshes were used without mesh refining...

- 4,9 M cells
- 7,3 M cells
- 9,6 M cells

- 6,1 M cells
- 8,4 M cells
- 11,1 M cells



Turbocharger Description

Test Setup and Data

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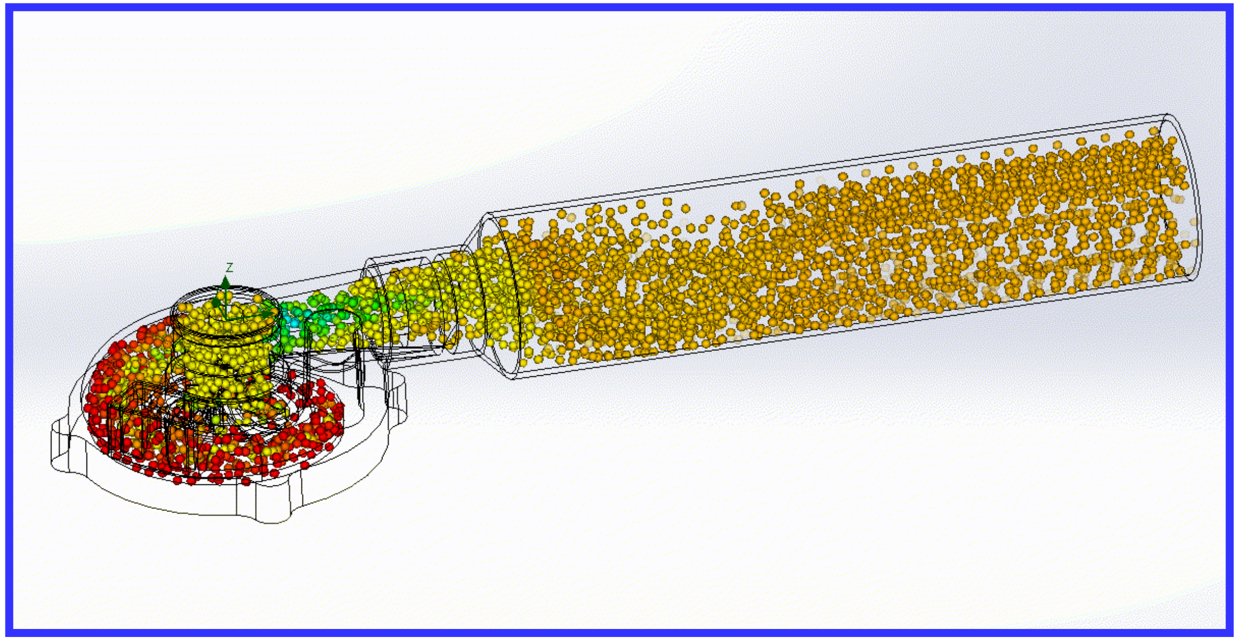
Results and Discussion – Compressor

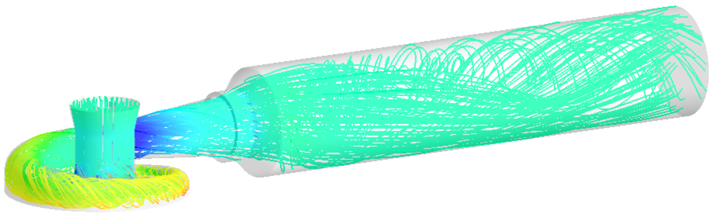


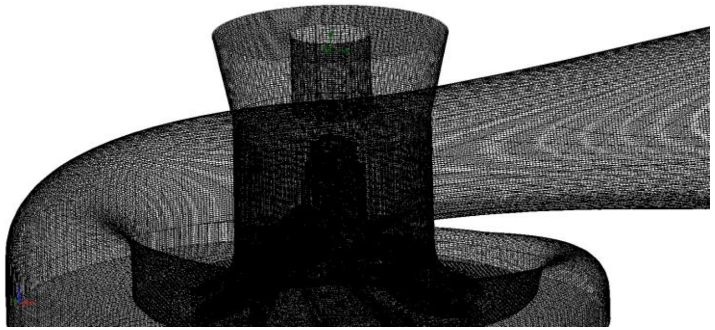
Compressor Pressure Animation @FloEFD

	Case	Test Results [m³/s]	FloEFD Results [m³/s]	Deviation [%]
1	51.670 rpm PR = 1,061	0,02520	0,02550	1,19
2	64.753 rpm PR = 1,119	0,03167	0,03240	2,31
3	86.010 rpm PR = 1,199	0,04316	0,04520	4,73
4	88.217 rpm PR = 1,249	0,04454	0,04680	5,07
5	101.050 rpm PR = 1,291	0,05199	0,05550	6,75
6	104.953 rpm PR = 1,342	0,05428	0,05830	7,41

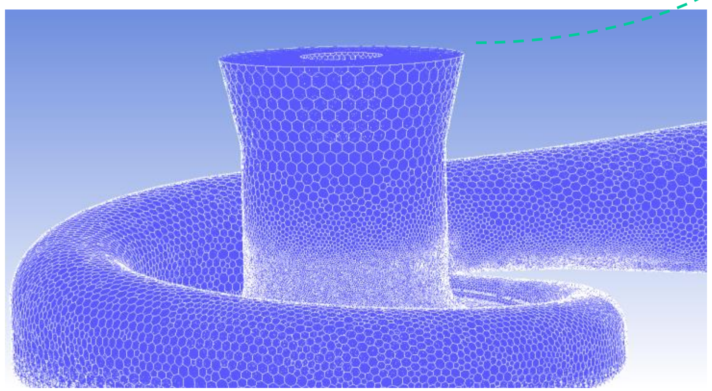
Max. 8% deviation from test results

Results and Discussion – Compressor





Cartesian mesh
k-ε turbulence model



Polyhedral mesh
Spalart – Allmaras turbulence model

	Case	Test Results [m³/s]	FloEFD Results [m³/s]	Another Code Results [m³/s]
1	51.670 rpm PR = 1,061	0,02520	0,02550 (1,19 %)	0,02551 (1,23 %)
2	86.010 rpm PR = 1,199	0,04316	0,04520 (4,73 %)	0,04518 (4,68 %)
3	104.953 rpm PR = 1,342	0,05428	0,05830 (7,41 %)	0,05832 (7,44 %)

Different mesh types, different turbulence models

Max. 7% deviation from test results

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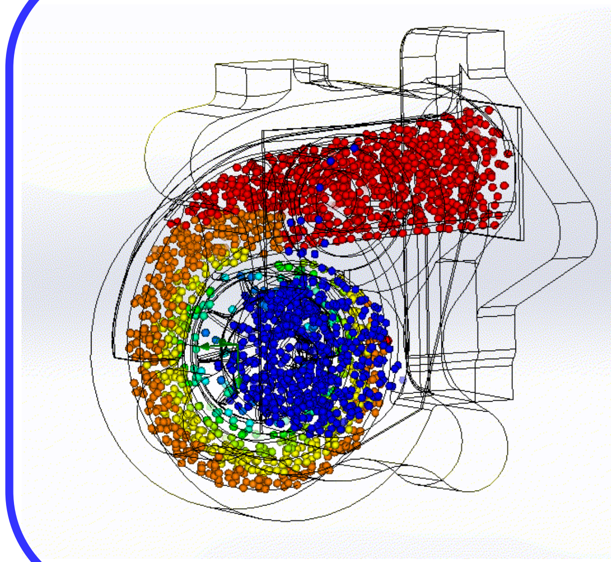
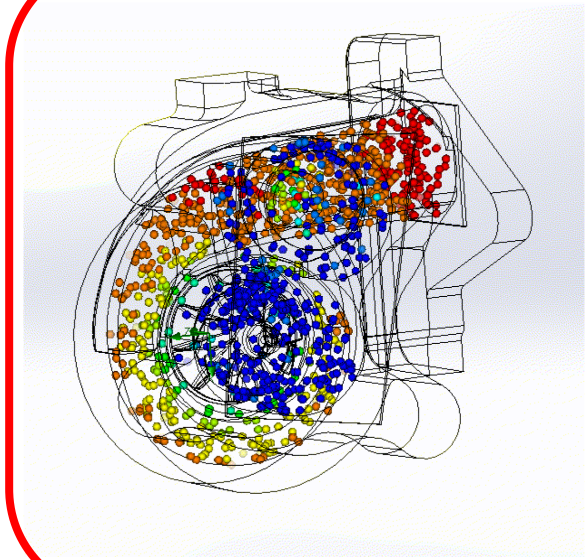
Results and Discussion – Turbine



Closed Wastegate Pressure Animation

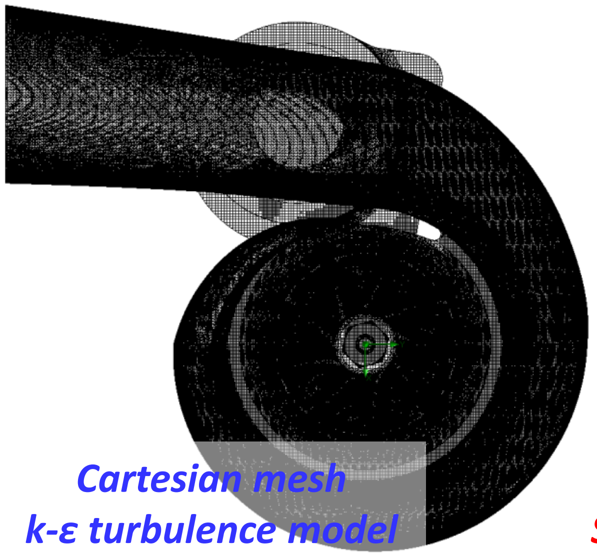


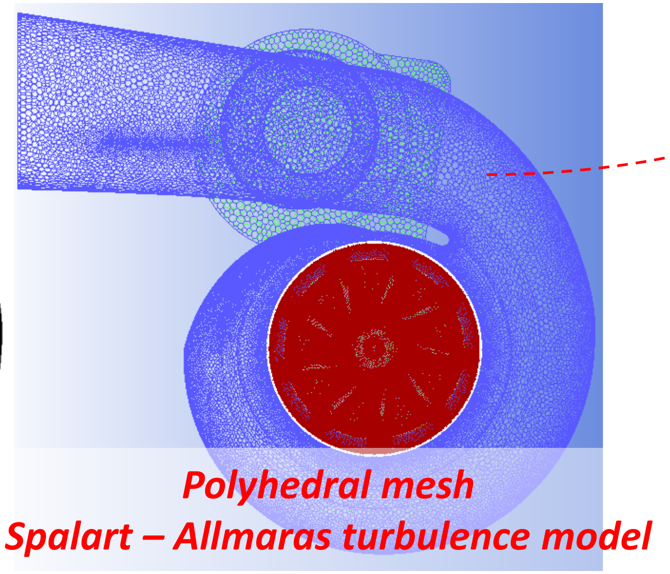
Open Wastegate Pressure Animation

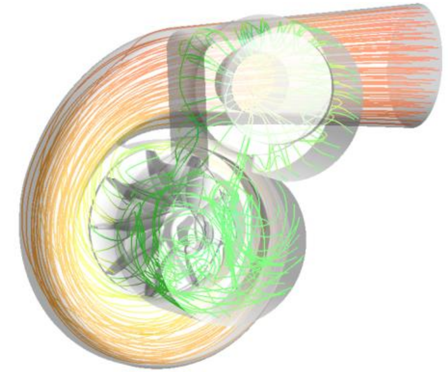
	Case	Test Results [kg/s]	FloEFD Results [kg/s]	Deviation [%]
1	26.270 rpm	0,01839	0,01695	-7,83
2	47.370 rpm	0,02592	0,02460	-5,08
3	63.090 rpm	0,03253	0,02946	-9,44

	Case	Test Results [kg/s]	FloEFD Results [kg/s]	Deviation [%]
1	24.550 rpm	0,03194	0,02950	-7,65
2	44.360 rpm	0,04550	0,04240	-6,81
3	57.120 rpm	0,05642	0,05280	-6,41

Results and Discussion – Turbine







	Case	Test Results [kg/s]	FloEFD Results [kg/s]	Another Code Results [kg/s]
1	24.550 rpm	0,03194	0,02950 (-7,65%)	0,02925 (-8,43%)
2	44.360 rpm	0,04550	0,04240 (-6,81%)	0,04209 (-7,49%)
3	57.120 rpm	0,05642	0,05280 (-6,41%)	0,05254 (-6,87%)

	Case	Test Results [kg/s]	FloEFD Results [kg/s]	Another Code Results [kg/s]
1	26.270 rpm	0,01839	0,01695 (-7,83%)	0,01689 (-8,15%)
2	47.370 rpm	0,02592	0,02460 (-5,08%)	0,02457 (-5,20%)
3	63.090 rpm	0,03253	0,02946 (-9,44%)	0,02996 (-7,89%)

...Different mesh types, different turbulence models...

...Max. 9% deviation from test results...

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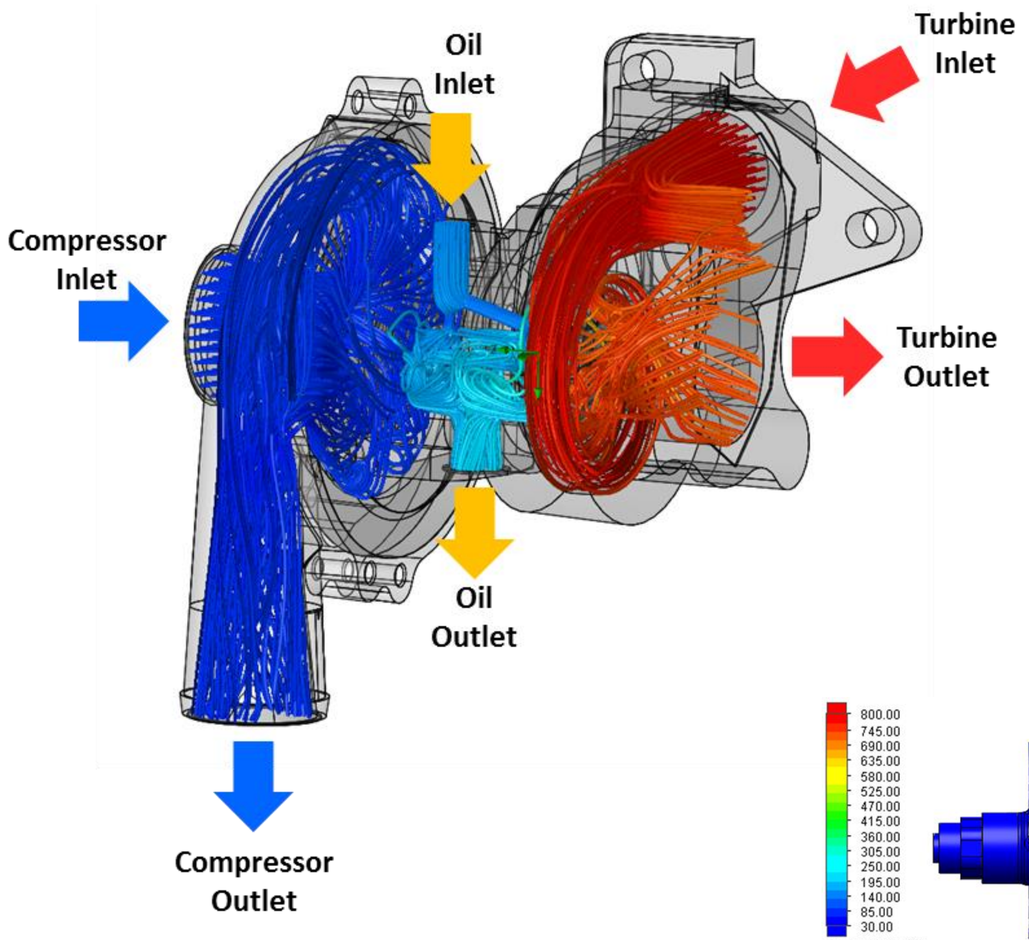
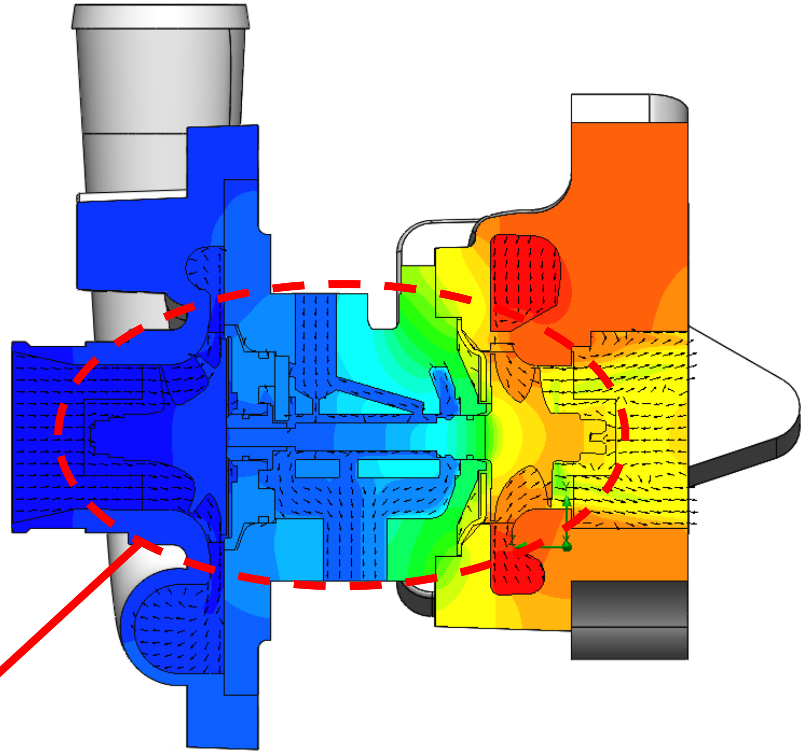
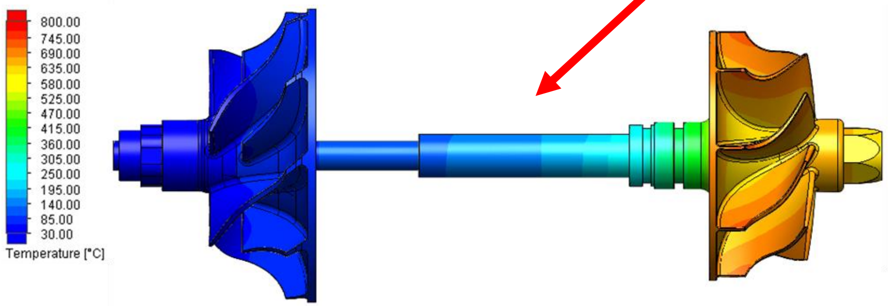
Results and Discussion – Thermal



...Thermal analyses for different turbine impeller materials were performed...





...Temperature distribution was used to calculate thermal expansions around housing region...

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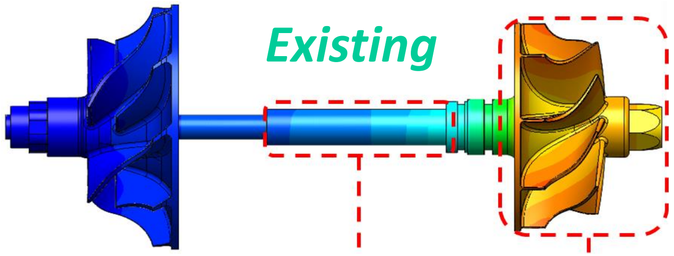
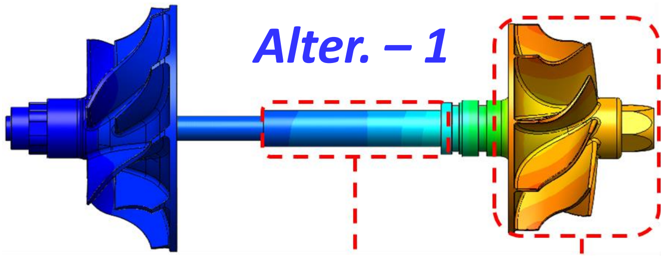
Results and Discussion – Thermal

Existing



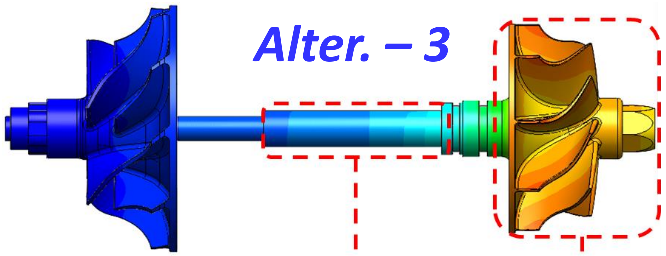
Shaft Surface Temperatures		Turbine Surface Temperatures	
Min. Temp [°C]	123,1	Min. Temp [°C]	404,3
Avg. Temp [°C]	161,6	Avg. Temp [°C]	656,0
Max. Temp [°C]	263,7	Max. Temp [°C]	727,3

Alter. – 1



Shaft Surface Temperatures		Turbine Surface Temperatures	
Min. Temp [°C]	122,9	Min. Temp [°C]	427,3
Avg. Temp [°C]	161,2	Avg. Temp [°C]	656,7
Max. Temp [°C]	269,9	Max. Temp [°C]	726,6

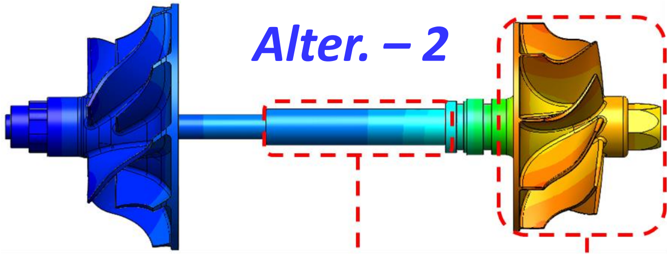
Alter. – 3



Shaft Surface Temperatures		Turbine Surface Temperatures	
Min. Temp [°C]	123,1	Min. Temp [°C]	398,9
Avg. Temp [°C]	160,2	Avg. Temp [°C]	656,7
Max. Temp [°C]	261,8	Max. Temp [°C]	729,6

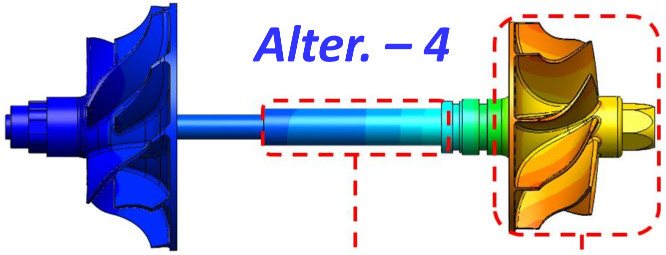
...4 possible turbine impeller material alternatives were examined and compared...

Alter. – 2



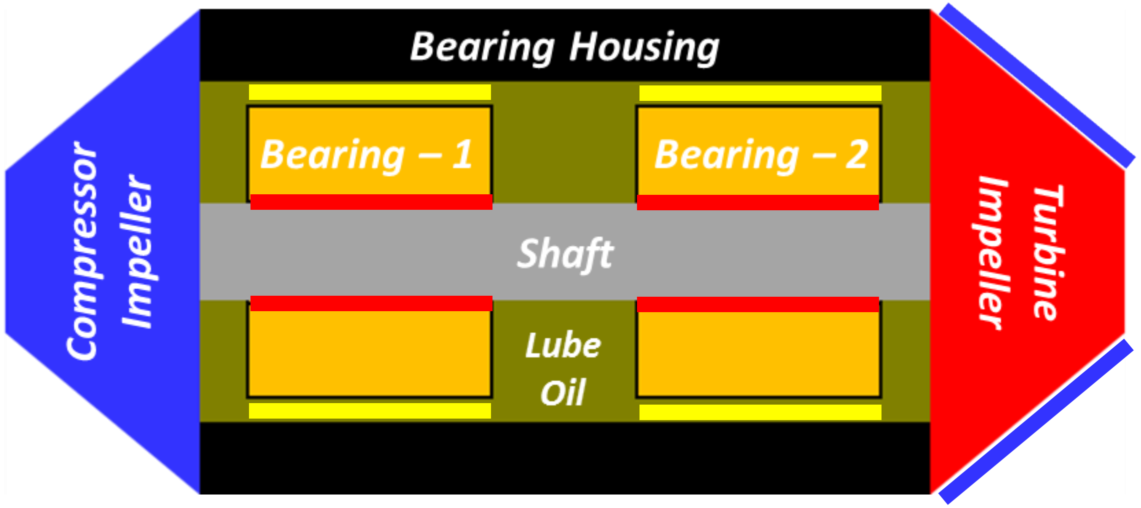
Shaft Surface Temperatures		Turbine Surface Temperatures	
Min. Temp [°C]	125,6	Min. Temp [°C]	430,3
Avg. Temp [°C]	164,2	Avg. Temp [°C]	657,5
Max. Temp [°C]	273,4	Max. Temp [°C]	725,7

Alter. – 4

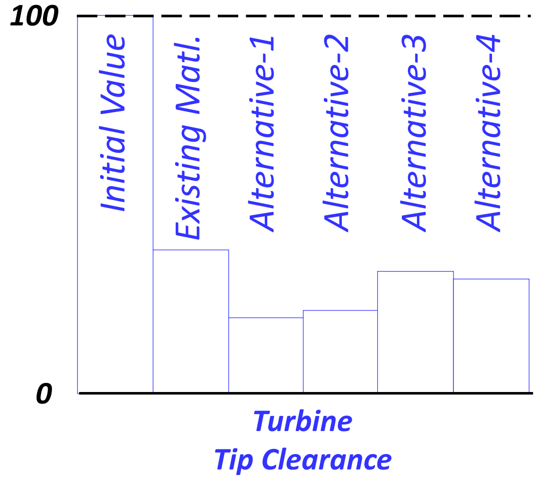


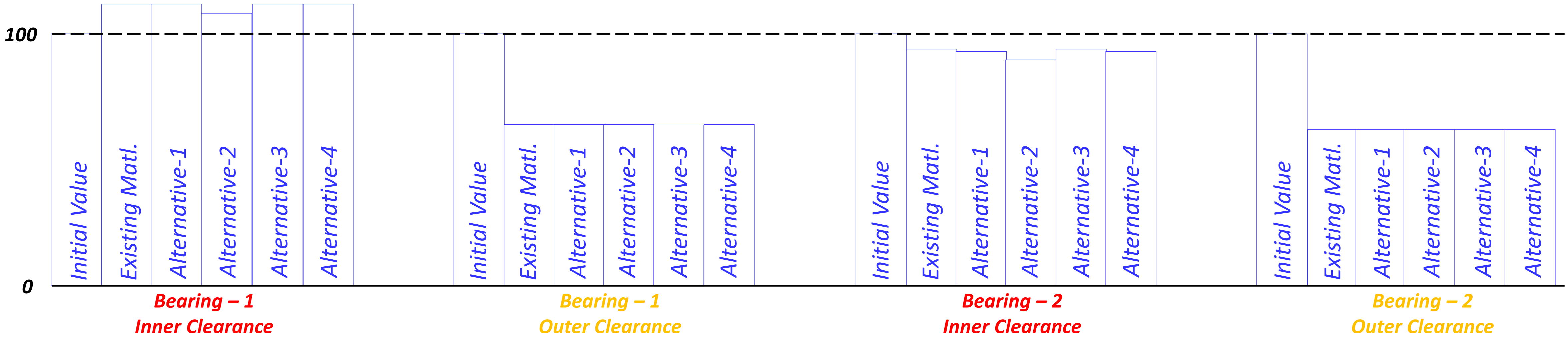
Shaft Surface Temperatures		Turbine Surface Temperatures	
Min. Temp [°C]	122,9	Min. Temp [°C]	409,4
Avg. Temp [°C]	162,4	Avg. Temp [°C]	653,2
Max. Temp [°C]	266,0	Max. Temp [°C]	727,7

Results and Discussion – Thermal



...Turbine impeller material substitution was evaluated according to thermal results...





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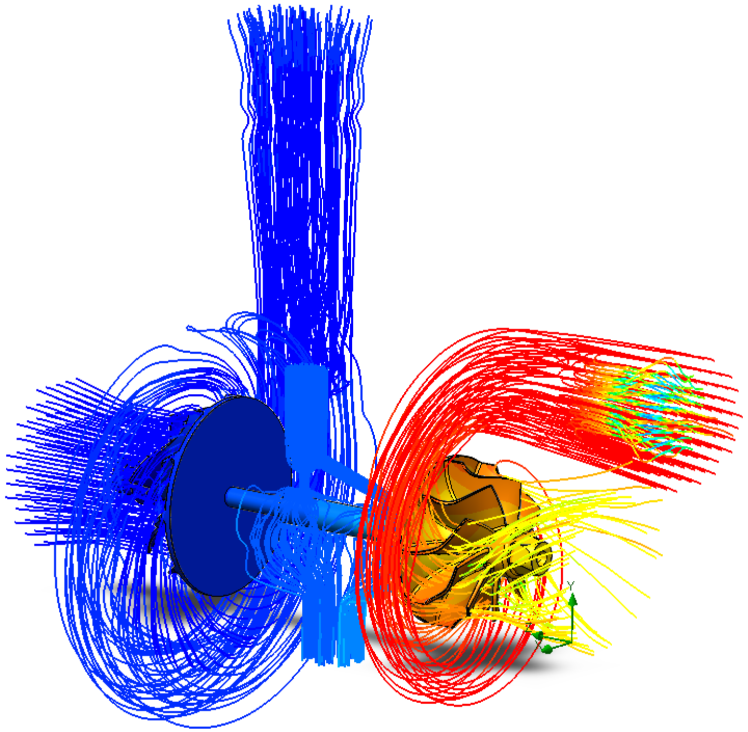
Conclusion

...We performed centrifugal compressor simulations...

...We performed whole turbo thermal simulations...



...We performed radial turbine simulations...

...We calculated thermal expansion and clearances during operation...

...We obtained radial and axial loads at the housing region...

...We have found chance to substitute turbine material with cheaper one...

...Thanks to FloEFD...

...THANK YOU FOR LISTENING...