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Thermal Management of a Turbocharger for Unsteady Operation

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Company Profile

INTEGRATED
DESIGN
ANALYSIS
GmbH **InDesA**

Consulting- &
Engineering Services

Simulation and Analysis
of complex fluid flow and heat
transfer systems
for engineering and industrial
applications



- **Vehicle Thermal Management**
- **Engine Thermal Management**
- **Electronics & Battery Thermal Management**
- **Heat Exchanger Thermal Analysis**
- **Turbomachinery Flow and Thermal Analysis**
and more ...

3D CFD/CHT Analysis



1D System Analysis

GT-SUITE

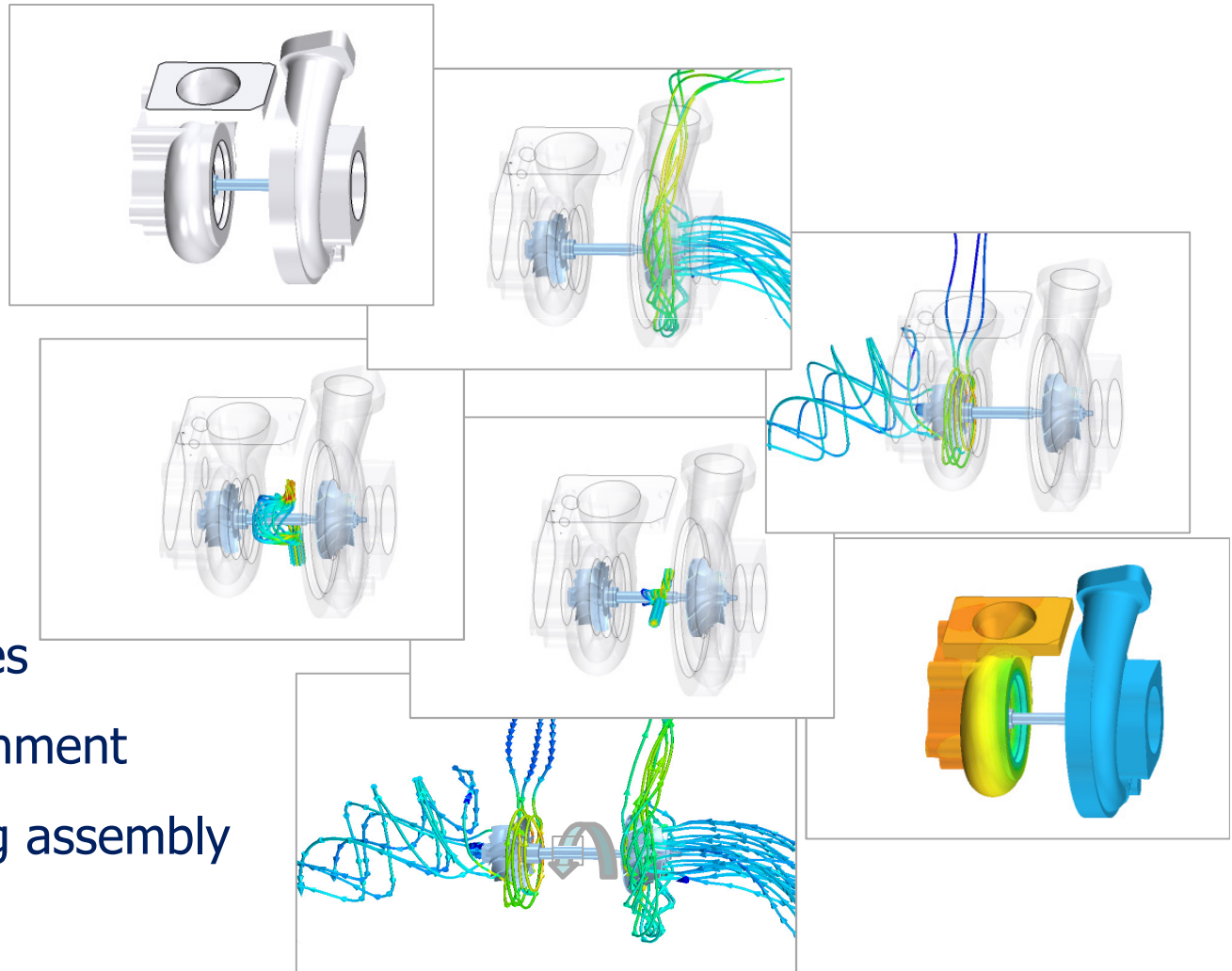


Thermal Management of a Turbocharger

Motivation

Complete flow and thermal analysis of a turbocharger:

- Compressor flow
- Turbine flow
- Coolant flow
- Oil flow
- Structure heat fluxes
- Radiation to environment
- Flow driven rotating assembly



Thermal Management of a Turbocharger

Motivation



Motivation:

Thermal reliability of materials

→ Materials selection, durability, costs

Radiation trough turbocharger surface

→ Thermal damaging of adjacent parts; → Heat shields

Oil coking in the slide bearing

→ Oil damaging, bearing damaging; → Cooling concepts

Compression- and Flow loss in the compressor

→ temperature increase in charging air; → dimensioning intercooler

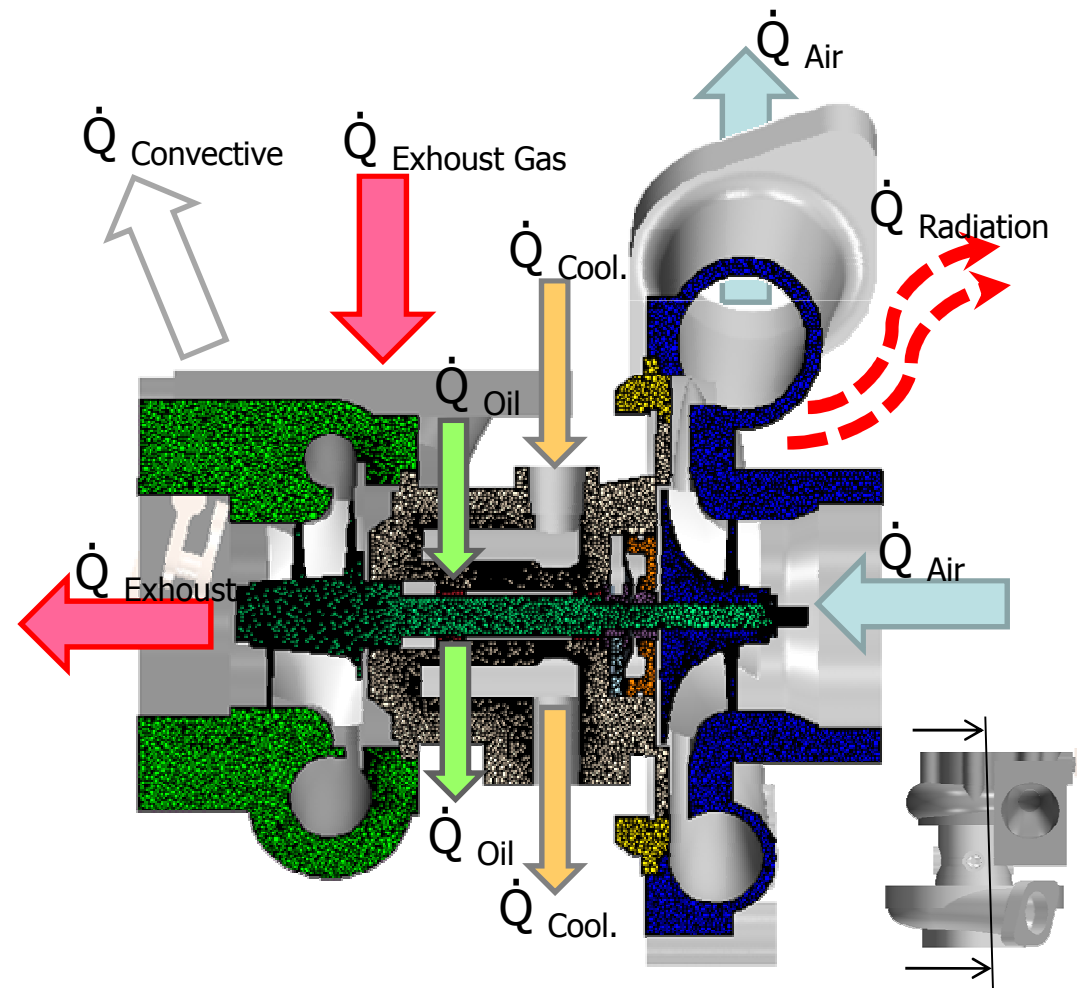
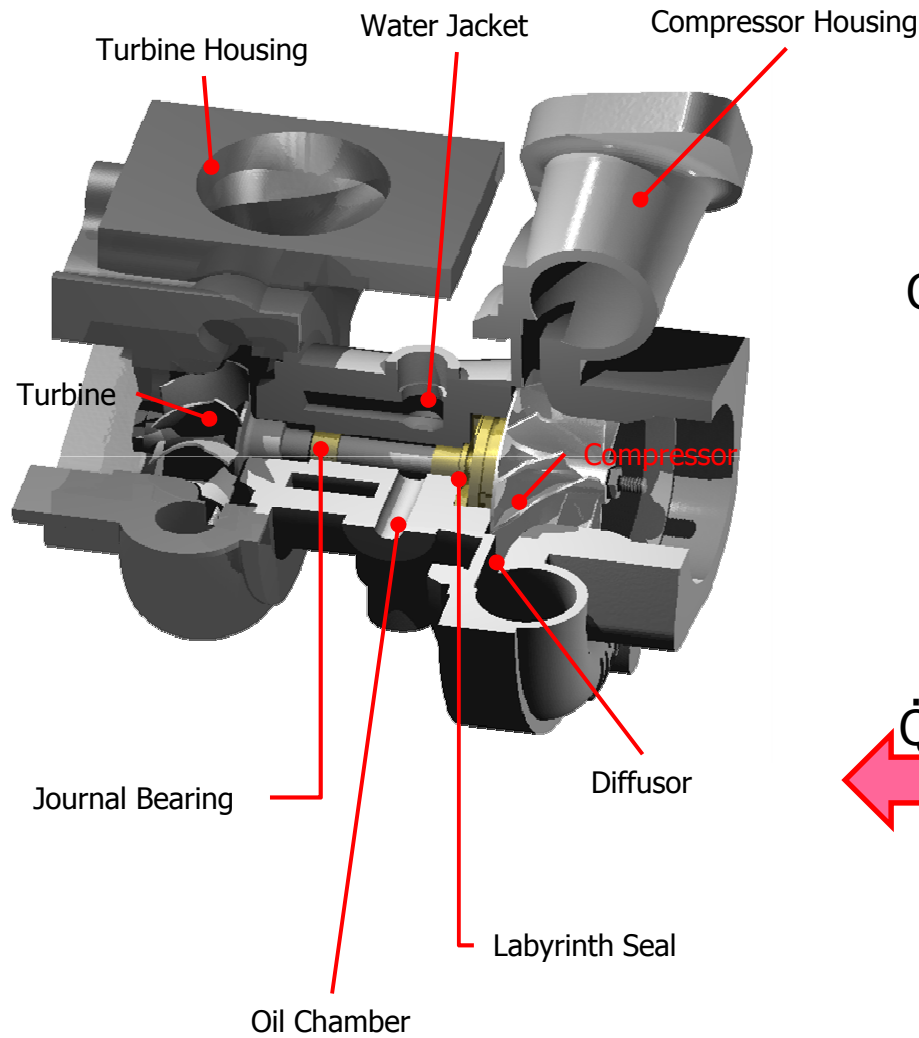
→ Influencing local speed of sound and Mach number

→ Influencing acoustic transmission

→ Influencing the compressor filling limits.

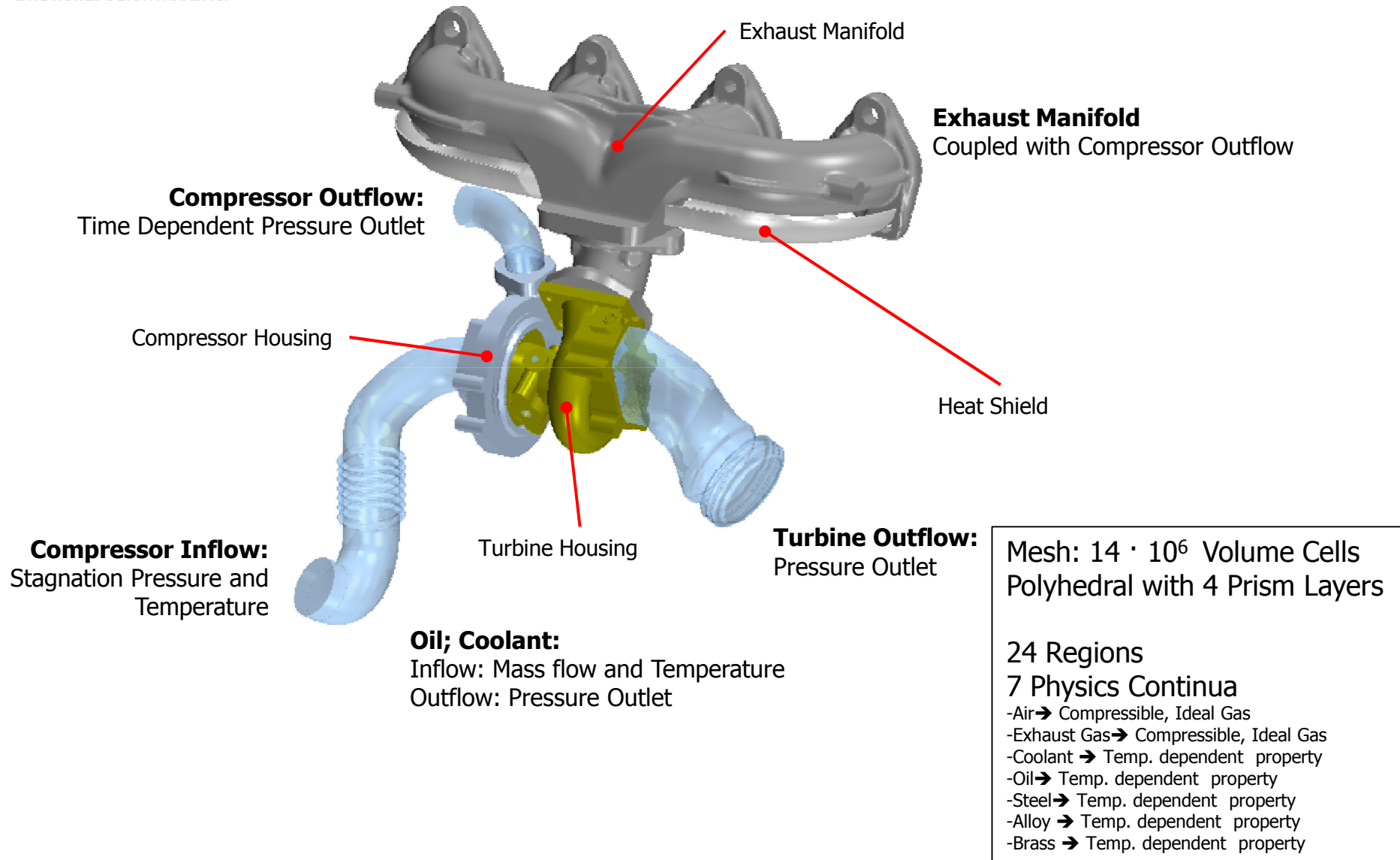
Thermal Management of a Turbocharger

Heat Fluxes on Turbocharger



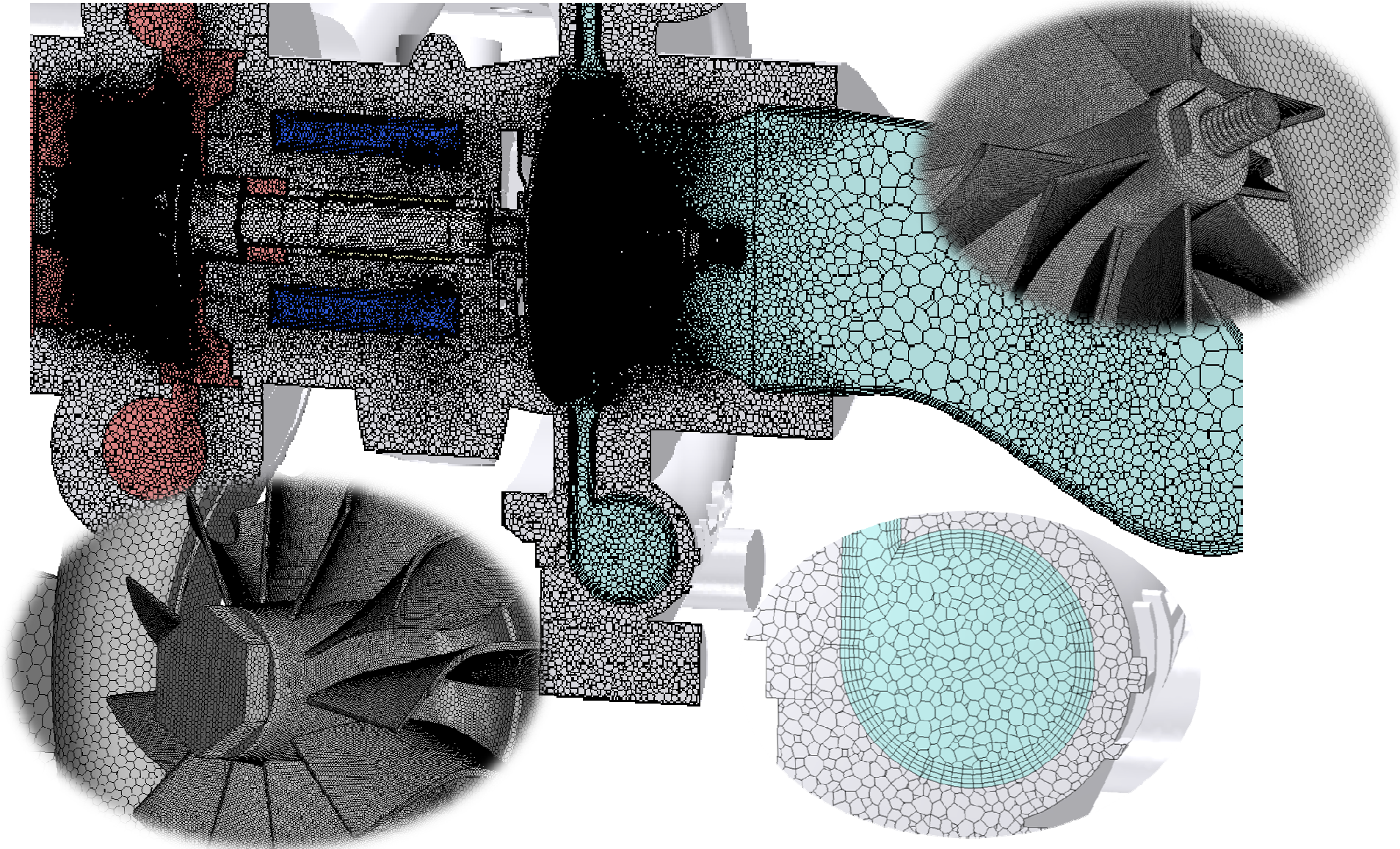
Thermal Management of a Turbocharger

Model Description



Thermal Management of a Turbocharger

Mesh details

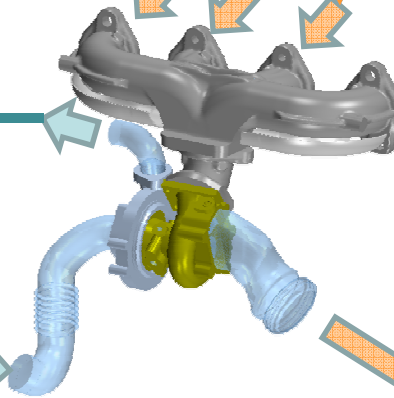
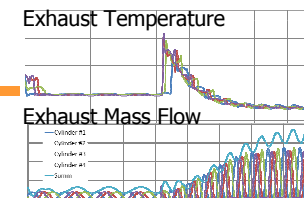
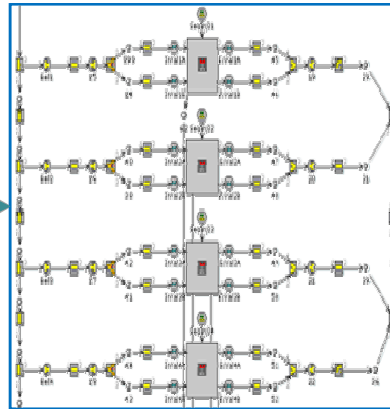


Thermal Management of a Turbocharger

Methodology

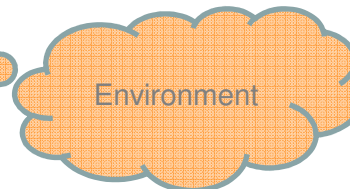
1D GT-Power Engine Model

Delivers Time Dependent:
Intake Pressure
Exhaust Mass Flow
Exhaust Temperature



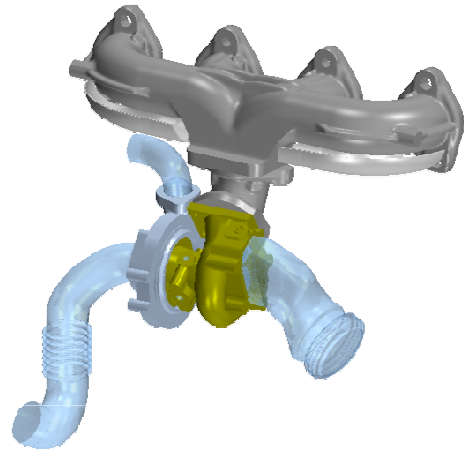
3D StarCCM+ turbocharger Model:

Predicts Time Dependent:
Air Mass Flow
Turbine Rotating Rate
Temperature Distribution on Manifold and Turbocharger
Thermal Stress



Thermal Management of a Turbocharger

Fluid-Structure Coupling



Mass Flow in Exhaust Manifold: Time Dependent

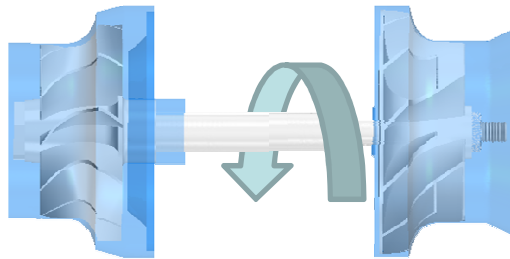
$$\dot{m}_{Exhaust} = \dot{m}_{Fuel} + \dot{m}_{Compressor}$$

$$T_{Exhaust} \approx \frac{\dot{m}_{Fuel} \cdot H_{Fuel}}{C_p \cdot \dot{m}_{Exhaust}} + T_{Compressor}$$

Turbocharger Rotating Rate: Time Dependent

$$\alpha \approx \frac{M_{Turbine} - M_{Compressor} - M_{Friction}}{J}$$

Where: α = Angular Acceleration
 J = Momentum of Inertia

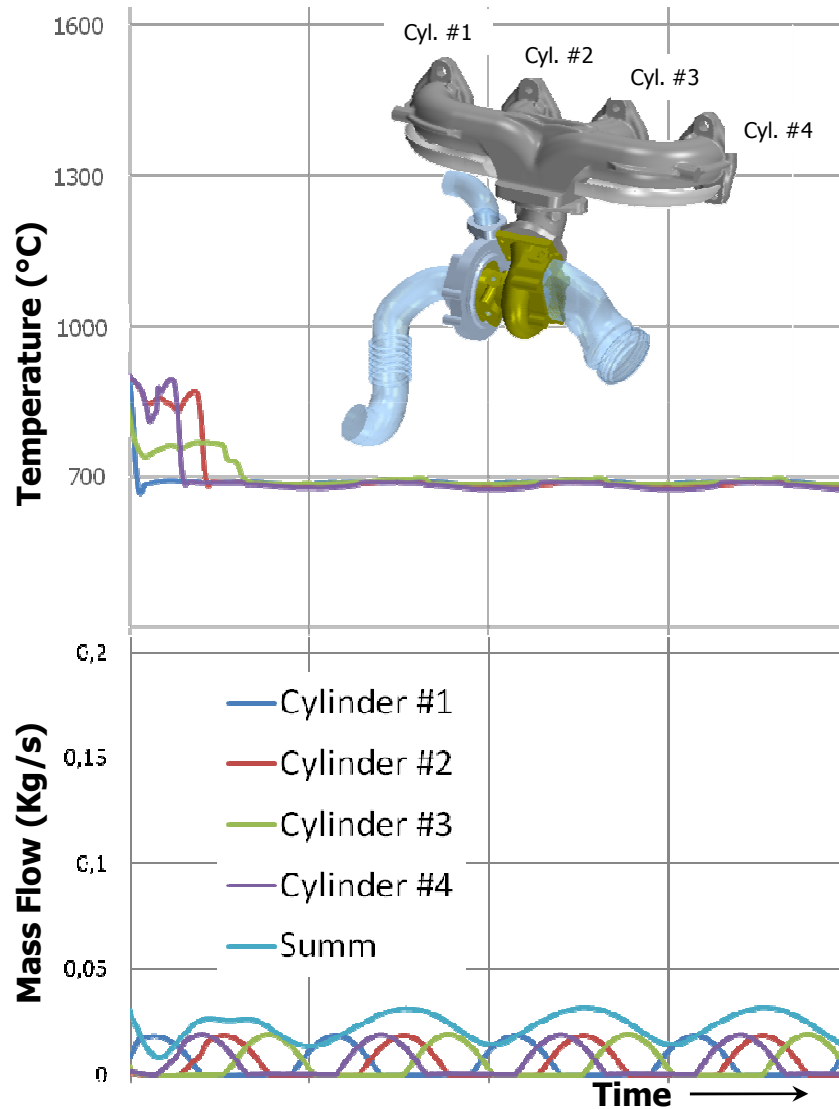


$$\omega = f(\alpha; Time) \Rightarrow \dot{m}_{Compressor}$$



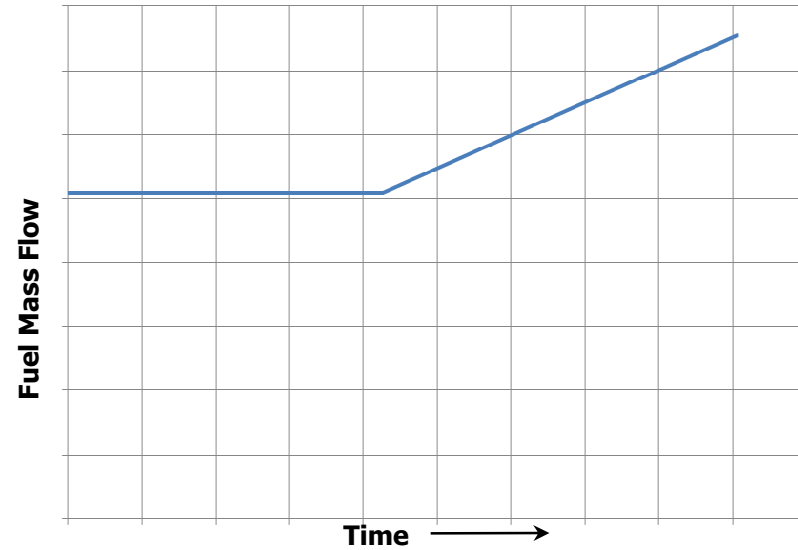
Thermal Management of a Turbocharger

Boundary Conditions



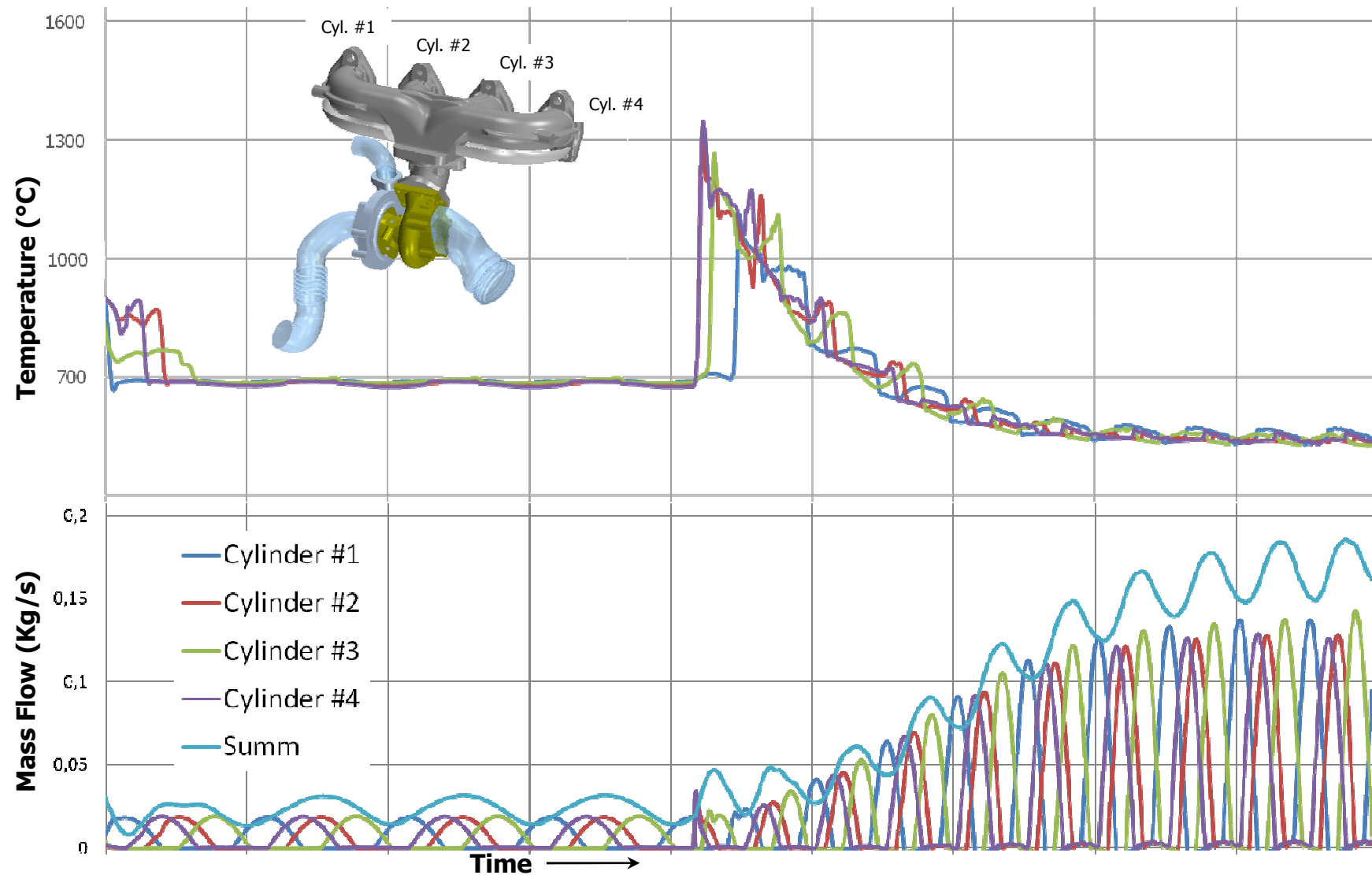
Firing Order: 1; 5; 4; 8; 2; 3; 6; 7 (assumed)

From Steady State Solution, the fuel mass flow is assumed to increase linearly:



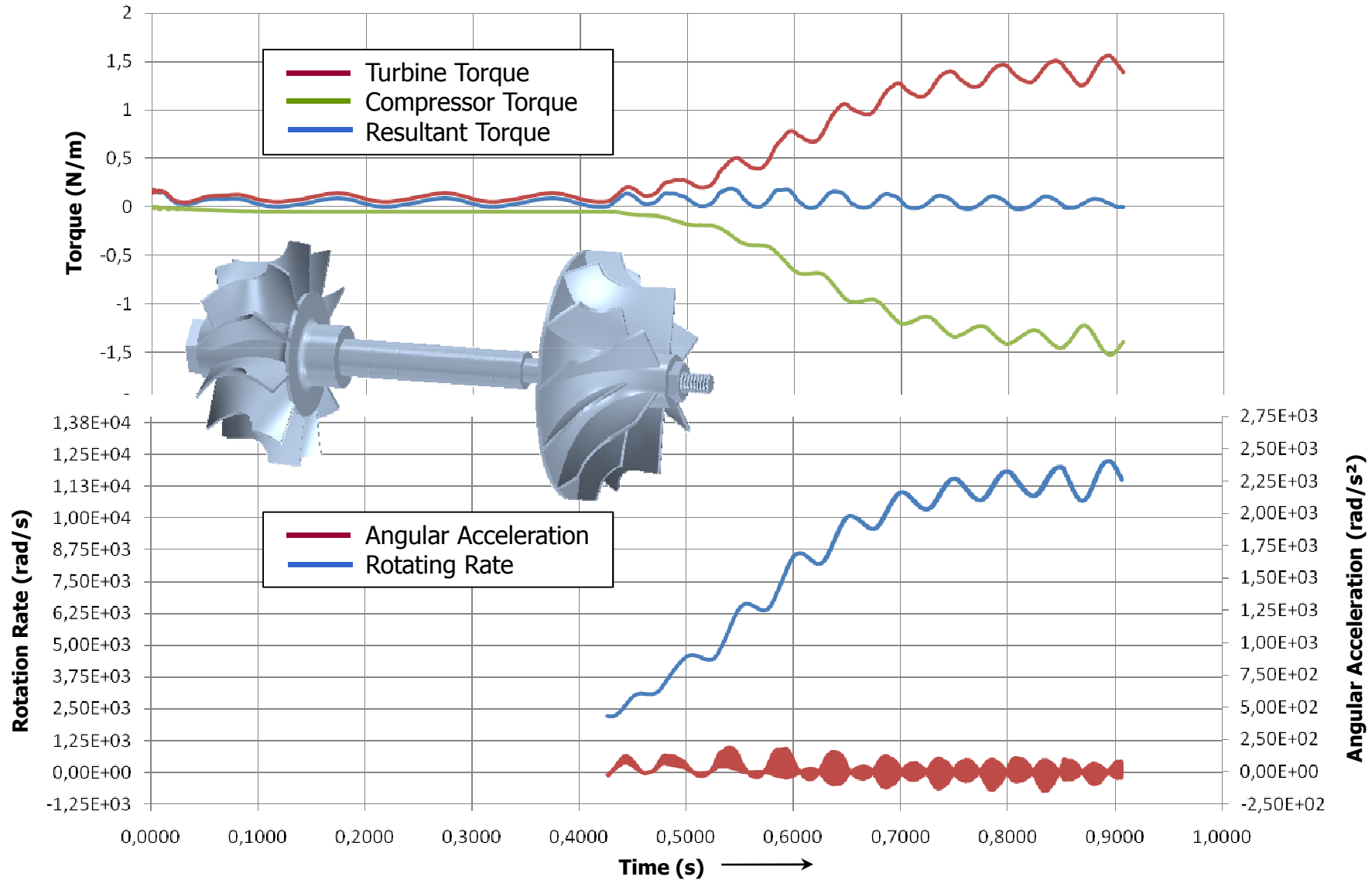
Thermal Management of a Turbocharger

Boundary Conditions



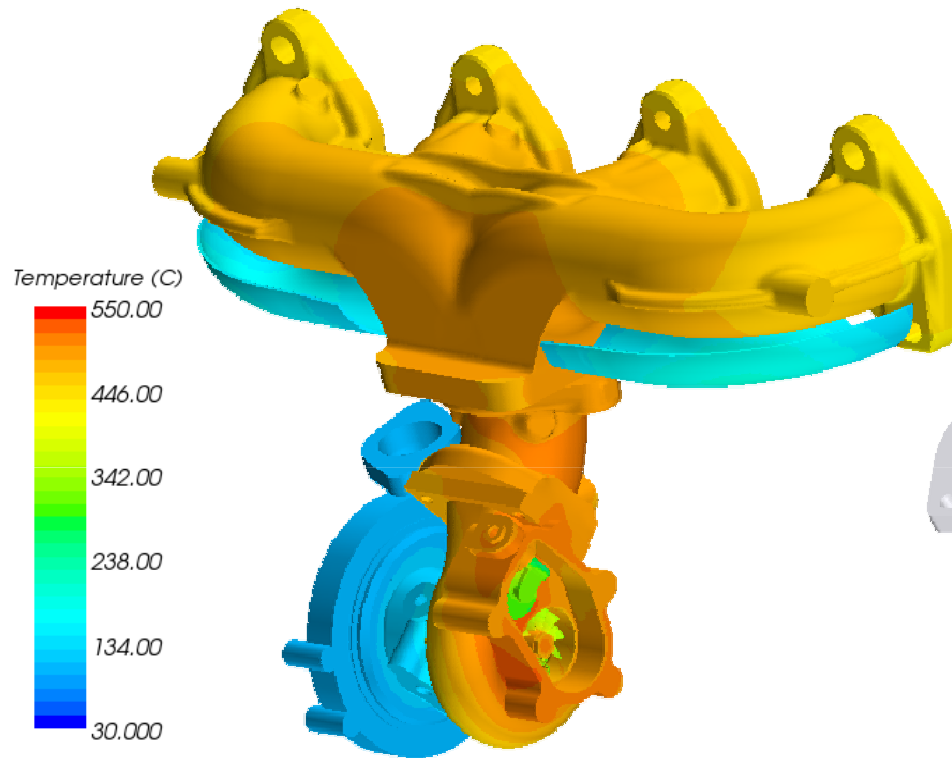
Thermal Management of a Turbocharger

Dynamic Result: Acceleration of TC



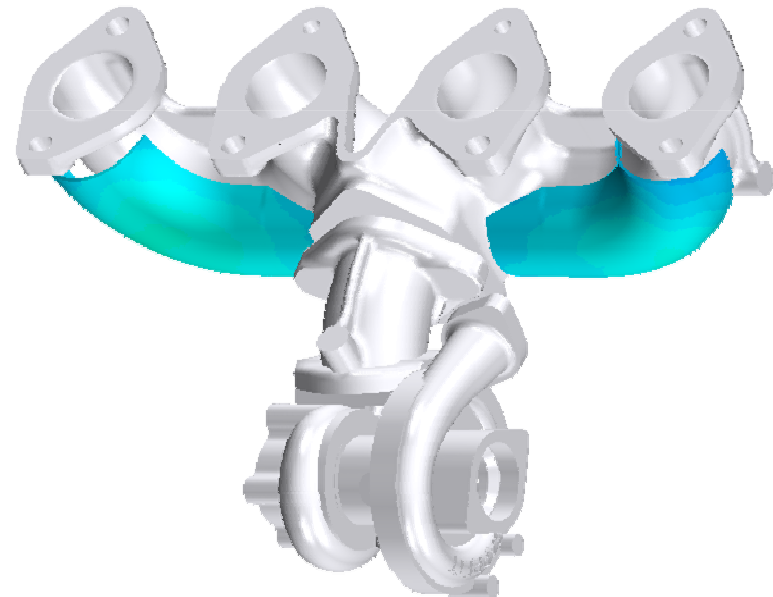
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Dynamic Result: Acceleration of TC



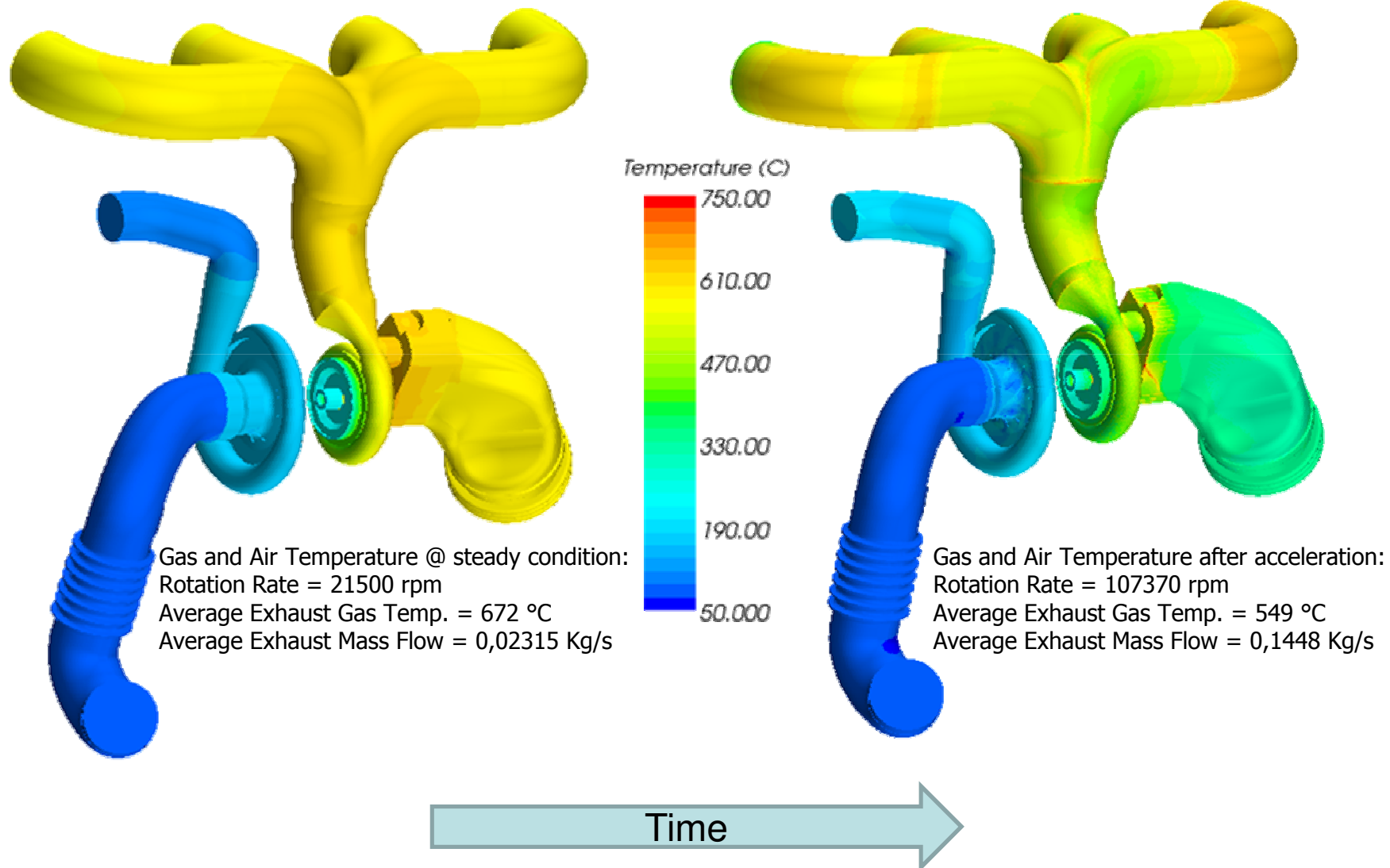
Solid temperature distribution

Heat Shields:
Incident Radiation: = 862 W
Average Temperature = 136 °C



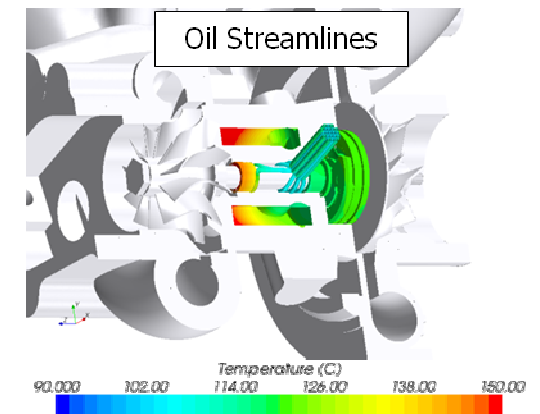
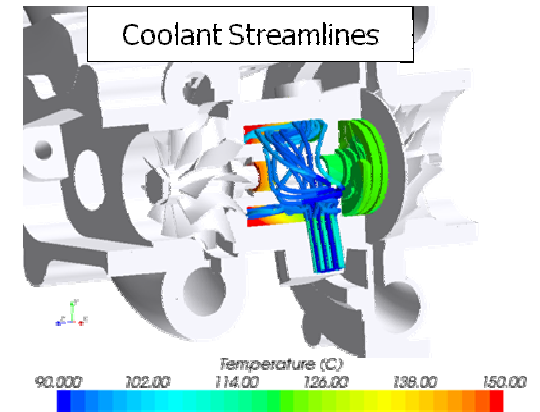
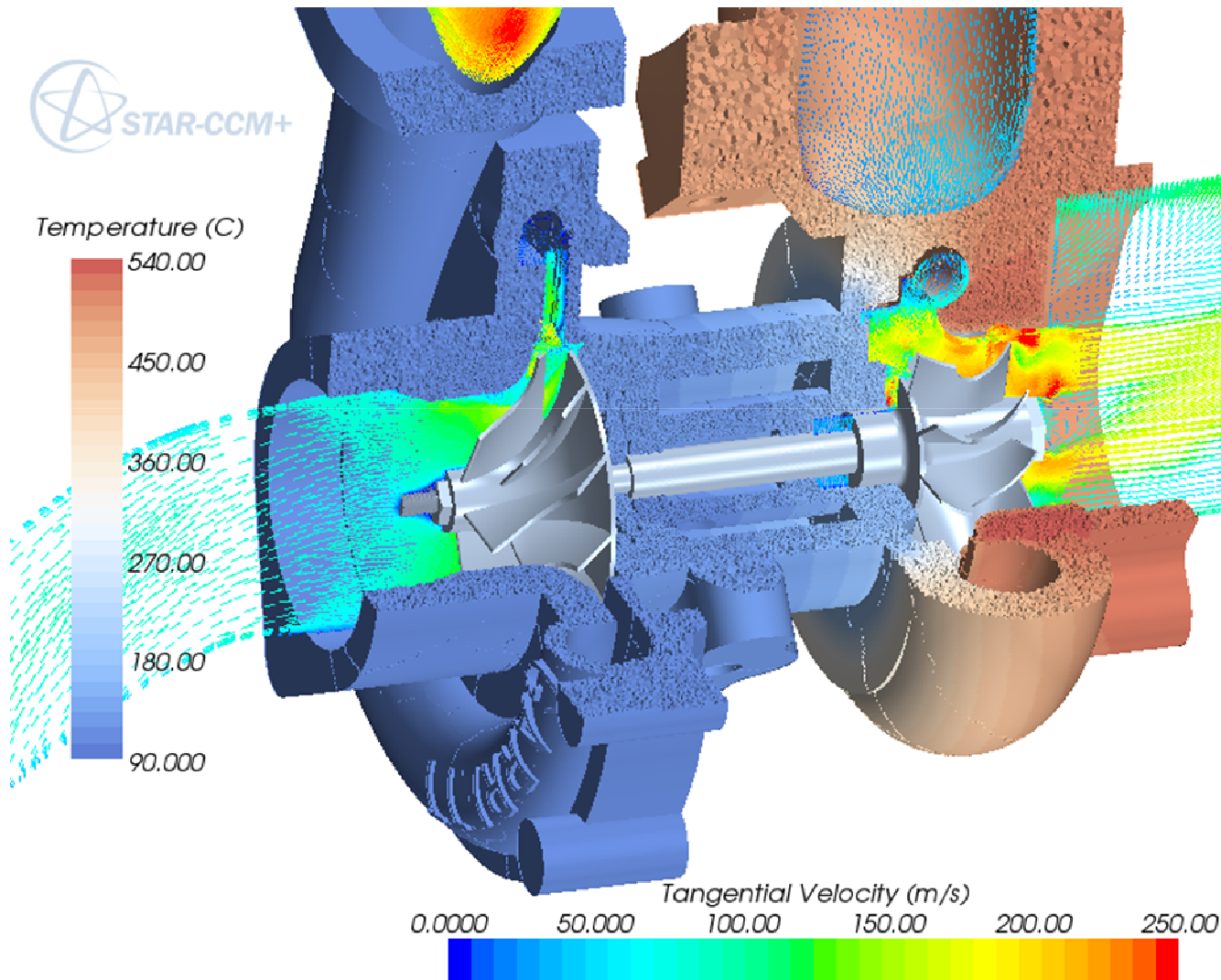
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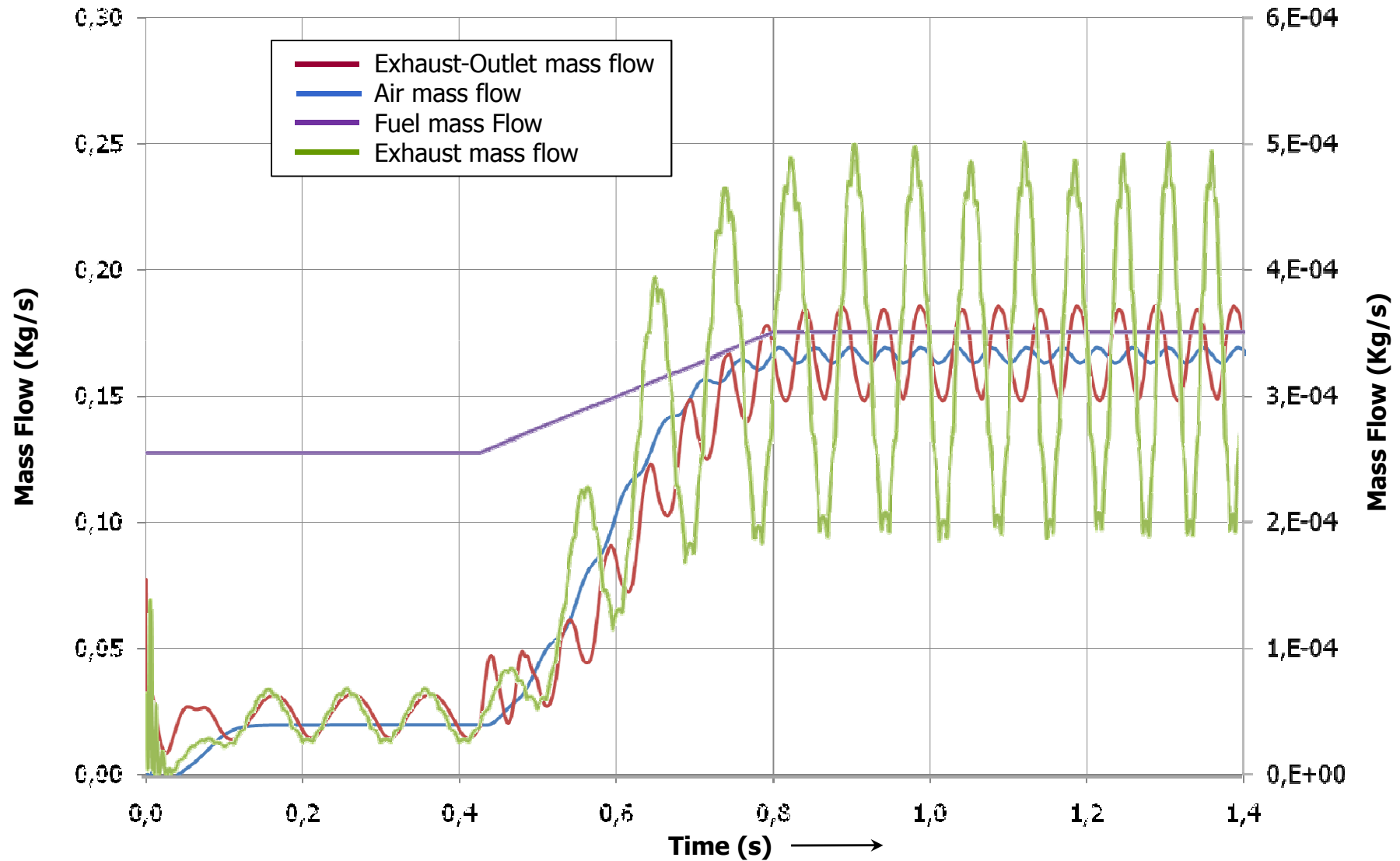
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Dynamic Result: Acceleration of TC



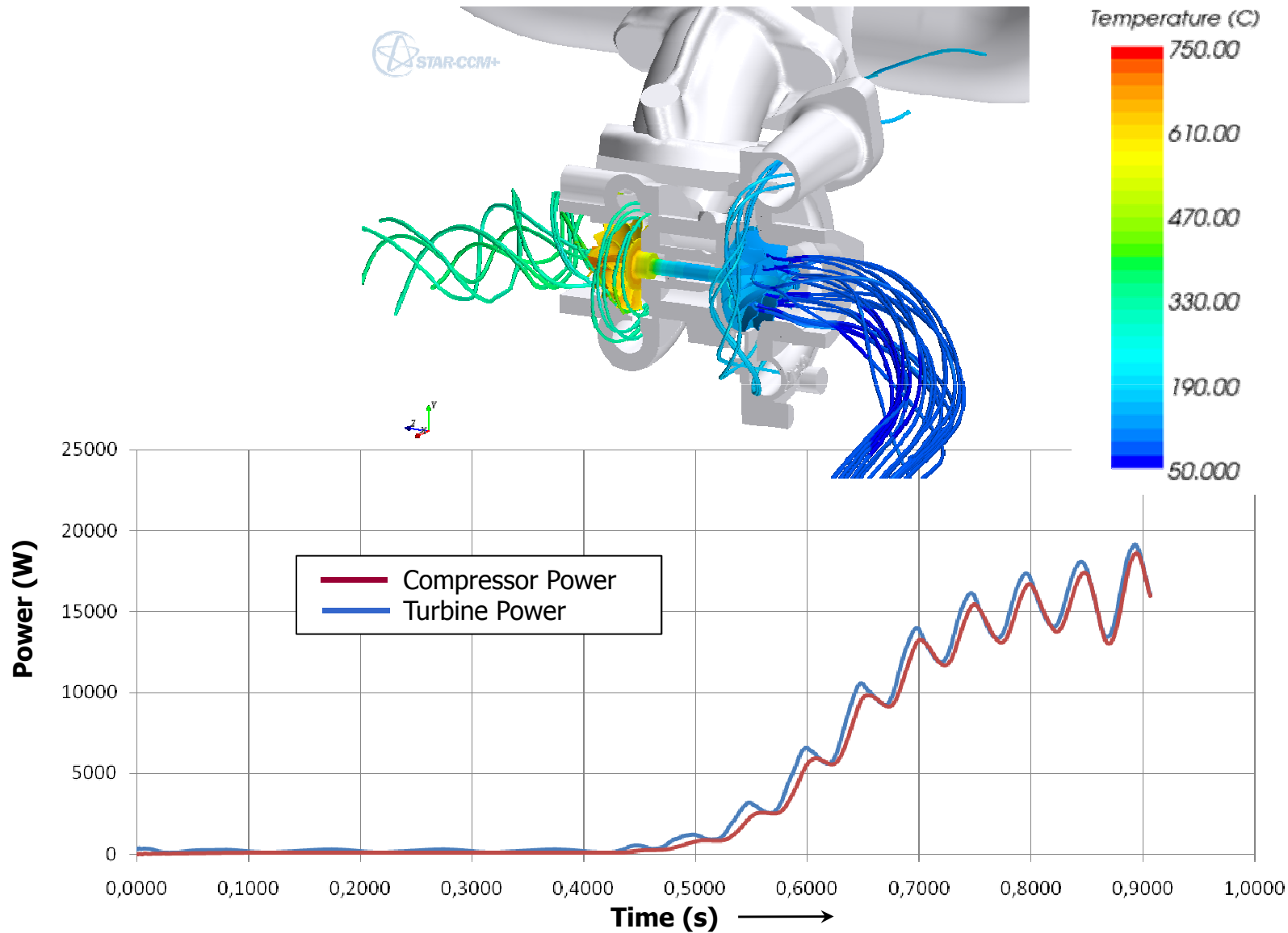
Thermal Management of a Turbocharger

Dynamic Result: Acceleration of TC



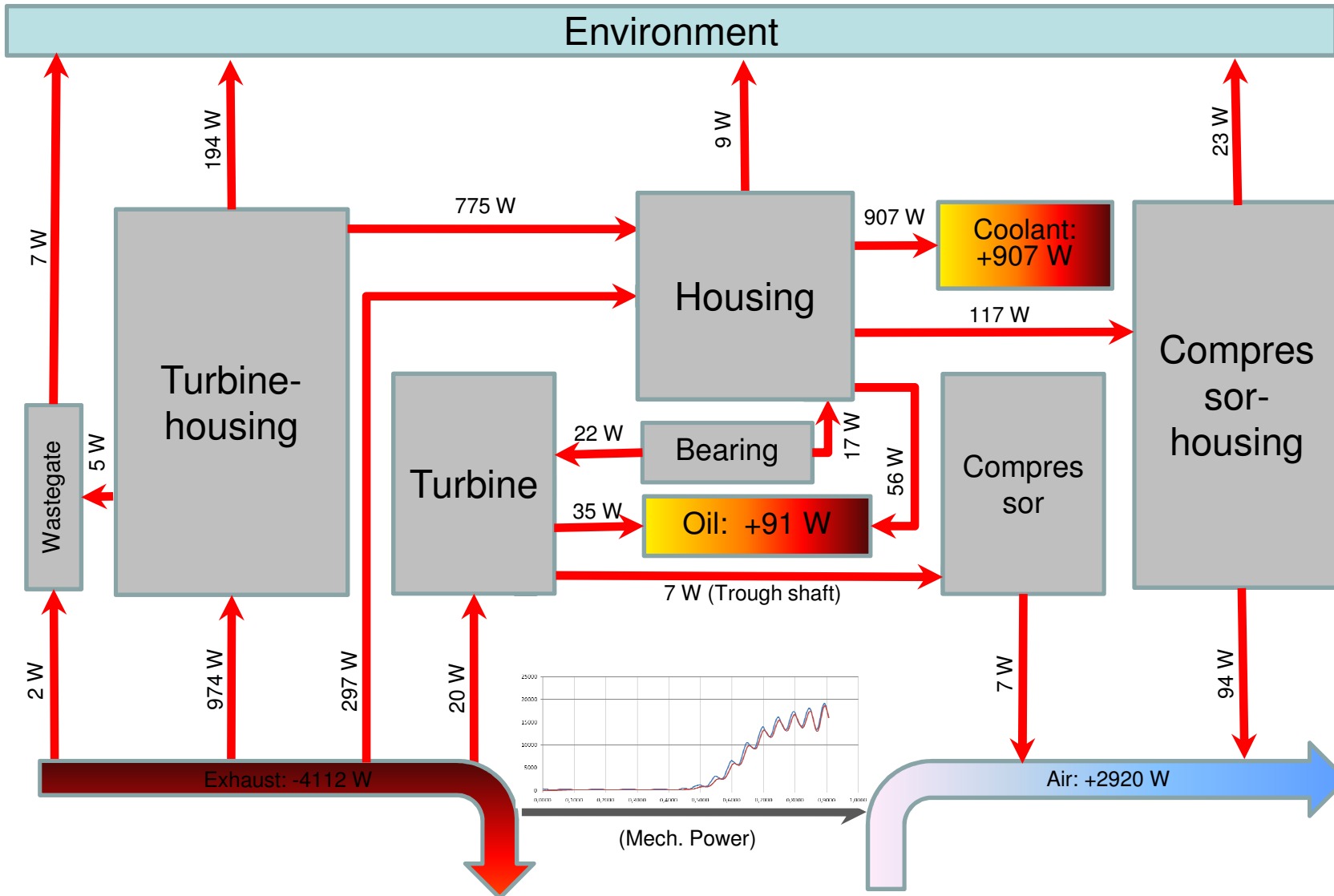
Thermal Management of a Turbocharger

Dynamic Result: Acceleration of TC



Thermal Management of a Turbocharger

Dynamic Result: Acceleration of TC



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**Thank you
for your attention**



Turbocharger: Thermal analysis