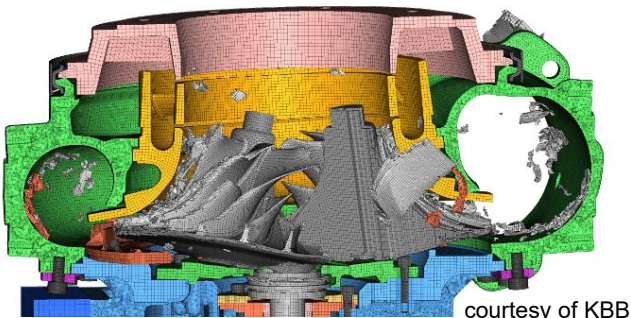


Containment Simulation at **INPROSIM**'s

- Many years of experience as a market leader in containment simulation for turbocharger and further turbo machinery
- Contact partner offering comprehensive expert knowledge in analysing cases of damage in the field of containment
- Working for many globally operating turbo machinery manufacturers
- Active member of FVV (“science for a moving society”)
- Chairman of research project FVV0936 “containment safety”
- Sound knowledge of materials and their implementation in containment simulation
 - non-linear deformation behaviour
 - temperature and strain rate dependency
 - dynamic hardening, triaxiality
 - complex failure behaviour



INPROSIM

Innovative Produkt Simulation GmbH

- Engineering office for services in FEM calculation and CAE simulation
- Focus on crash simulation and short-time dynamics for the protection of man and goods

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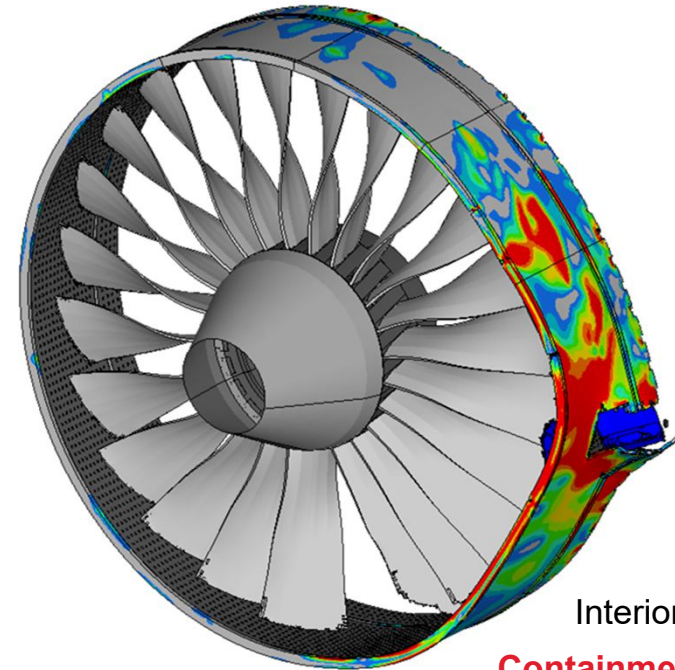
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Crash and Short-time Dynamics
for a successful development
for the protection of people
and goods



CAE
Crash
Automotive

Interior / Kopfaufprall

Containment Simulation
Engines / Turbo Machinery

Validation and Matching of Tests

Machinery and Facility Engineering

Modelling of Material Characteristics

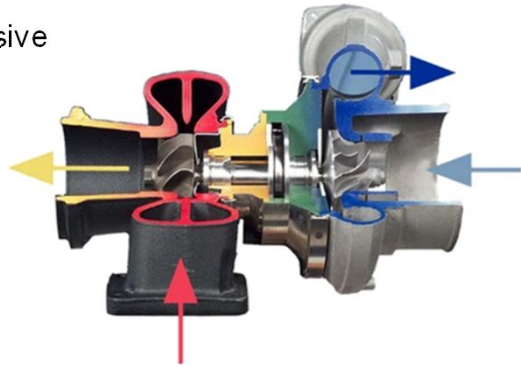
Statically Loaded Systems / Structures

Drop Tests for Consumer Goods / Packaging

Status quo

Safeguarding of the turbo charger's containment safety

- Nowadays, the verification of a turbo-charger's containment safety is still mainly provided by tests
- A comprehensive application of containment simulation is not usual yet



Testing

Safeguarding of the turbo charger's containment safety by tests

- Performance of 3 tests mostly to ensure statistical coverage
- Weakening the impeller determines the burst speed and the fracture pattern

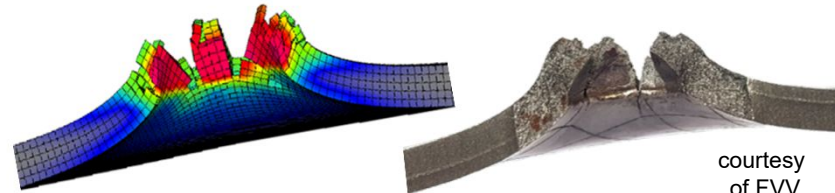
Uncertainties in tests

- Real / natural burst scenario not captured due to the prior weakening of the impeller
- Scatter band of the material properties and of the operating conditions not captured
- Capturing of „worst-case“ scenarios with maximum damage not beyond doubt

Simulation

Safeguarding of the turbo charger's containment safety by simulation

- No need of weakening the impeller and the risk of its uncertain influence on the containment behaviour
- Simulation of arbitrary impact locations for arbitrary fracture patterns
- Investigation of hub / disk and rim bursts as well as of blade loss and any combination of the fracture patterns
- Capturing of the scatter band of the material properties and of the operating conditions
- Determination of worst-case scenarios by a wide range of arbitrary combinations



courtesy of FVV

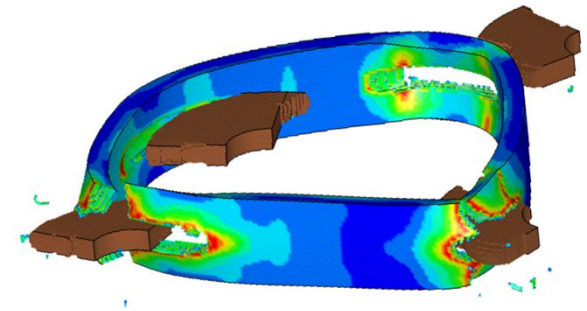
Simulation and testing

- Simulation in the run-up to a test helps to determine test parameters and even to prevent unsuccessful tests
- Containment tests allow for a validation and enhancement of simulation models
- Material tests allow to reduce uncertainties in materials' description in simulation

Summary

Safeguarding of the containment safety by a comprehensive process

- A turbo charger's containment behaviour is far too complex to be covered in-depth by individual tests
- Simulation enables to represent a wide variety of burst scenarios, parameters and scatter bands
- Only a combination and comparison of simulation and testing allows for a sound evaluation of the containment safety



Simulation in the development process

- Early on evidence about the containment potential of a new turbo charger's design
- Determination of possible weak points
- Optimisation concerning structure and best possible material usage
- Overarching evaluation of entire product families as well as of diverse variants