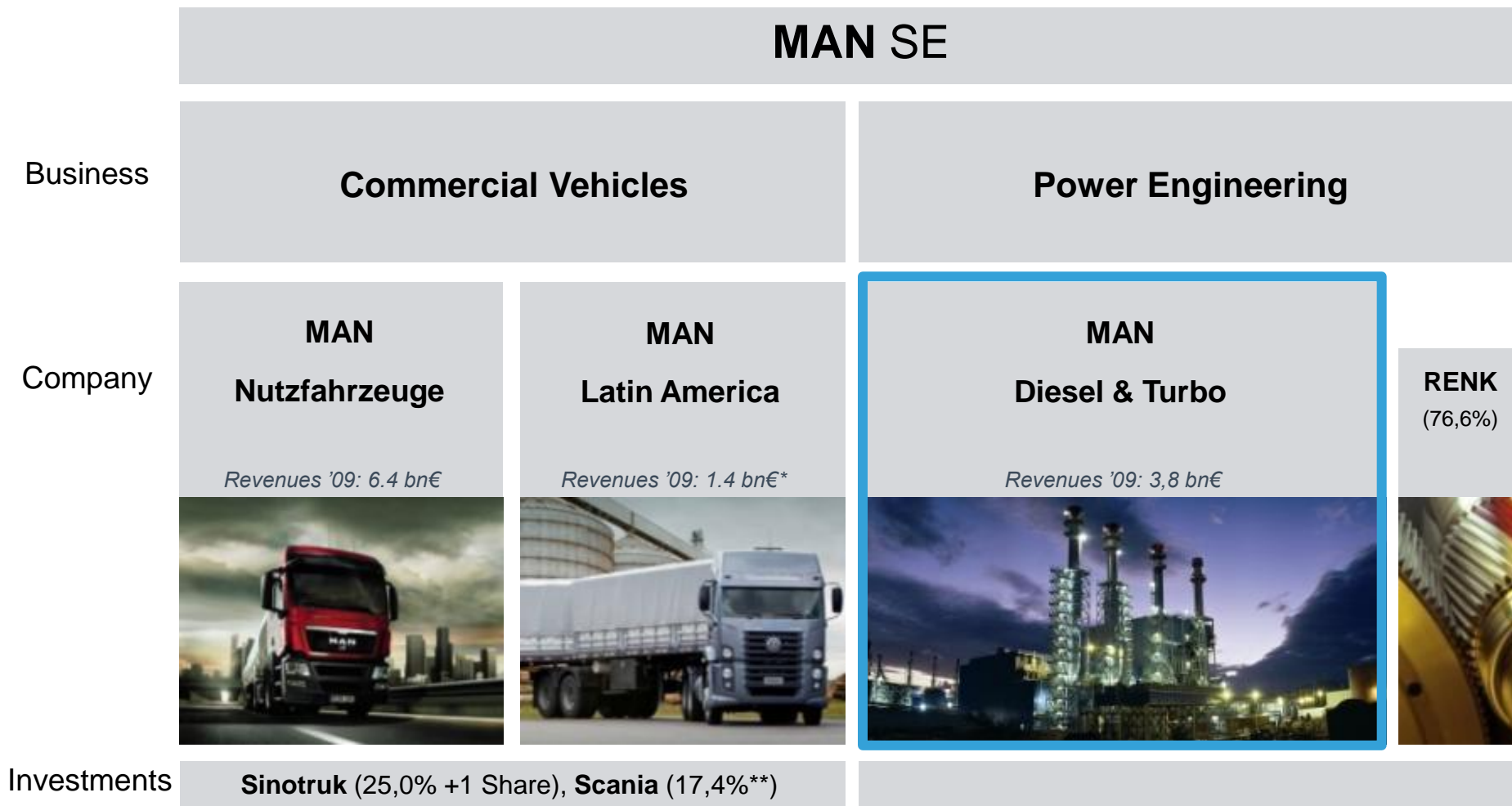
The background of the slide is a high-speed, blue-tinted photograph of a fluid jet striking a curved metal surface, likely a cylinder head, creating a large splash and spray. This image serves as a visual metaphor for the fluid-structure interaction being discussed.

# Thermo-Mechanical Analysis of a cylinder head at MAN Diesel & Turbo SE considering Fluid Structure Interaction

Petra Steffe, Mirko Bugsch,  
Andreas Linke, Dietmar Pinkernell  
(MAN Diesel & Turbo SE)

# MAN Group Corporate Structure



**MAN Group 2009: 12.0 bn€ Revenues, 47,700 Employees**

\* April-December 2009

\*\* Voting Rights

# Product Range by Strategic Business Unit



## Engines & Marine Systems



## Turbomachinery



## Power Plants



## After Sales





# MAN Diesel & Turbo SE Engine portfolio

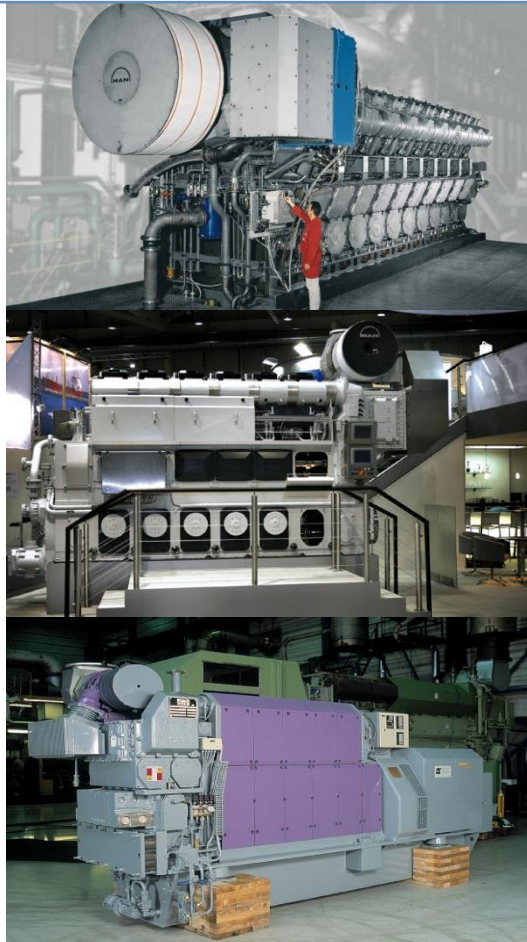


## 4-stroke medium speed

21.600 kW



500 kW

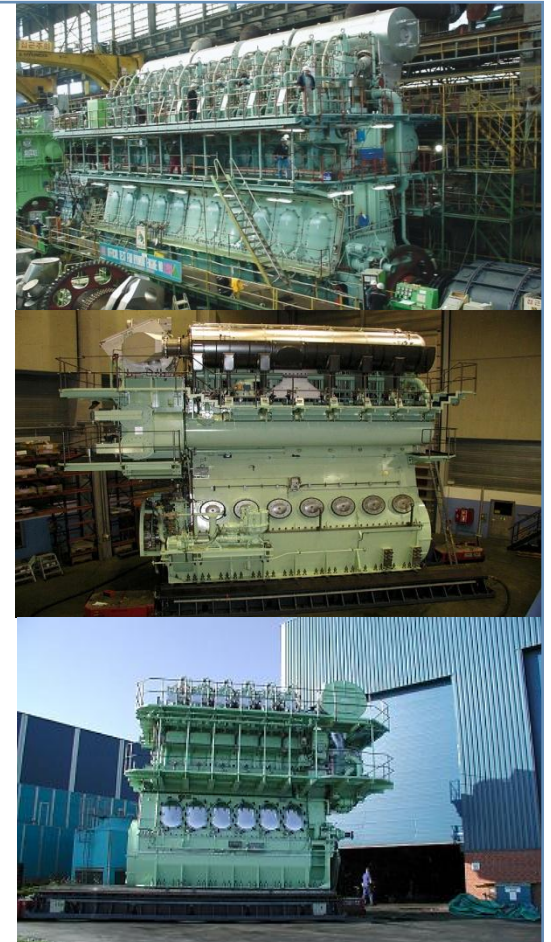


## 2-stroke low speed

97.300 kW



2.000 kW



# Diesel engines in comparison



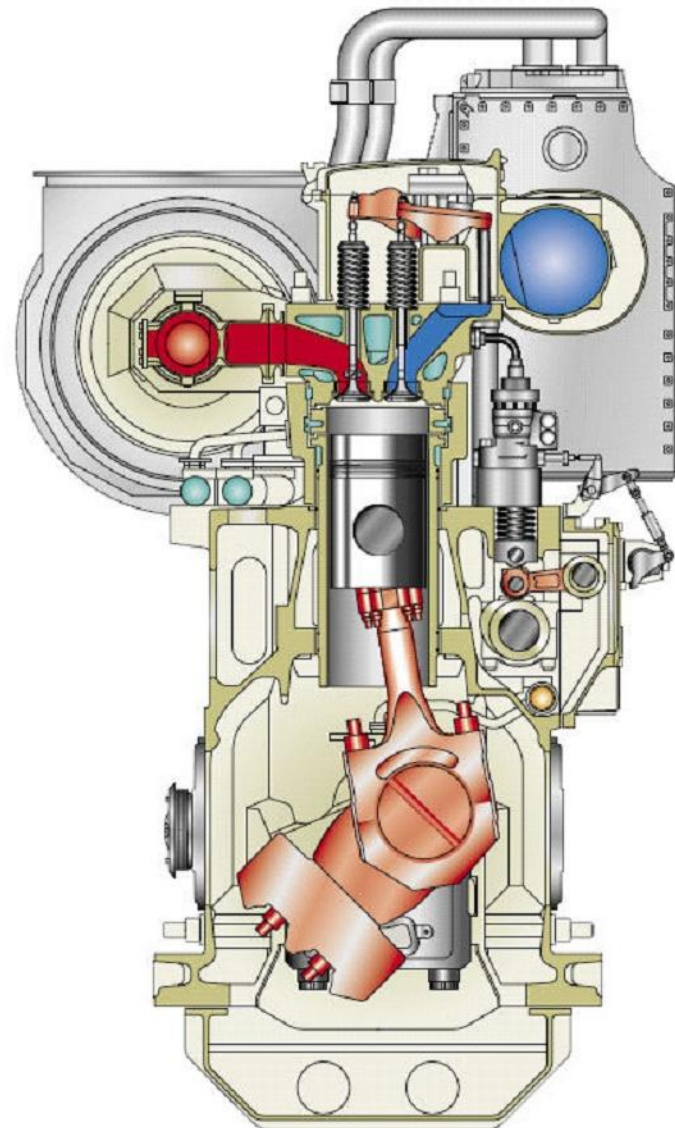
Car engine,  
0.5 l cubic capacity/ cyl.



Truck engine,  
2 l cubic capacity/ cyl.



4 stroke – medium speed engine  
L48/60,  
108 l cubic capacity / cyl.





# Four-stroke Medium-speed Engine

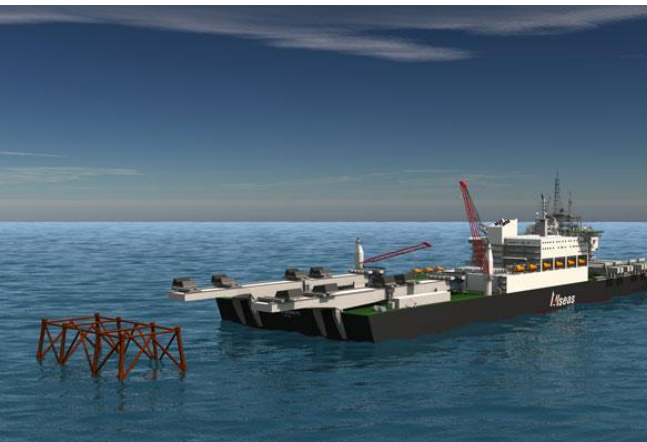
## The World's Largest Vessel



Pieter Schelte  
8 x 20V32/44CR  
1 x 8L32/44CR  
94,6 MW

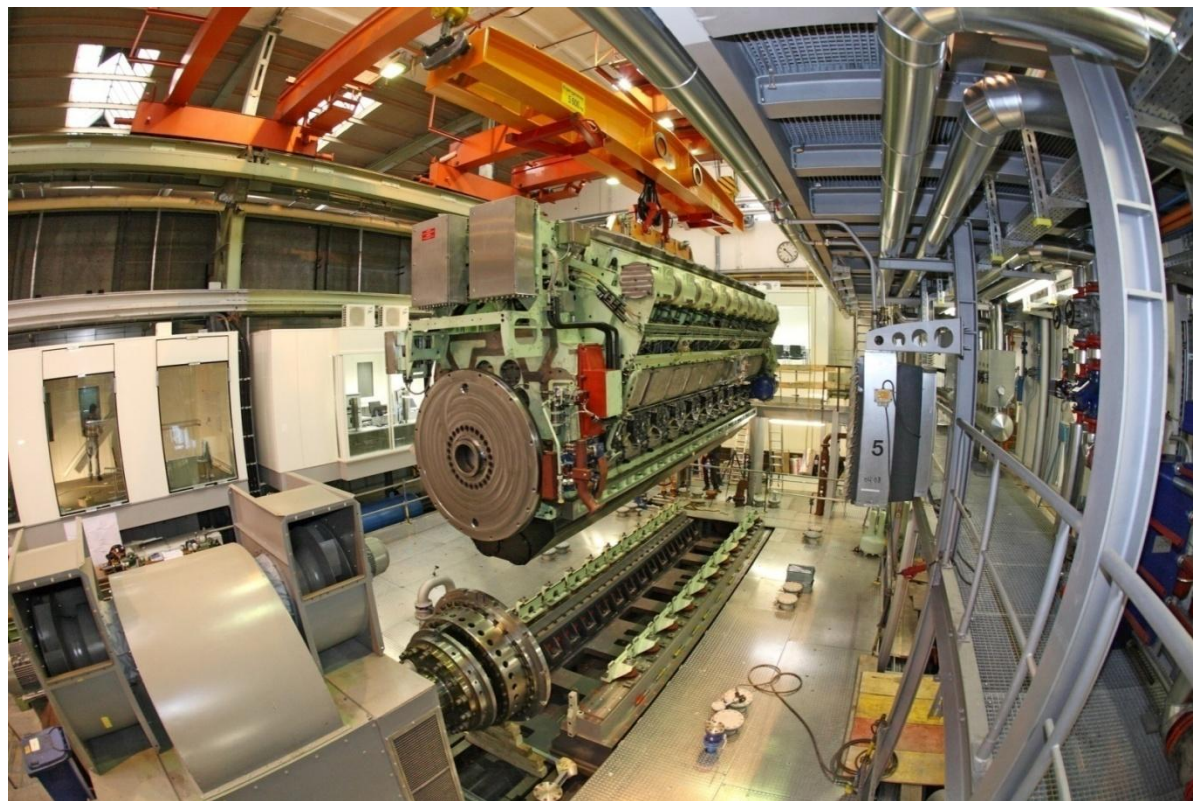
Dynamically positioned  
platform installation /  
decommissioning and  
pipelay vessel

382 m Length  
117 m width  
12 knots  
450 Persons



# 20V32/44CR

## Test engine assembly



**560 kW/cyl. @ 750 min-1**  
**fulfilling TIER 2**  
**emissions reg.**

**bore 320 mm**

**stroke 440 mm**

**length ~ 10 m**

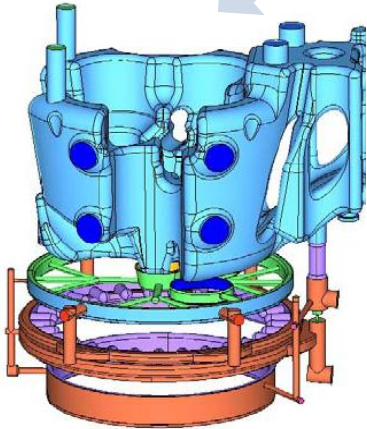
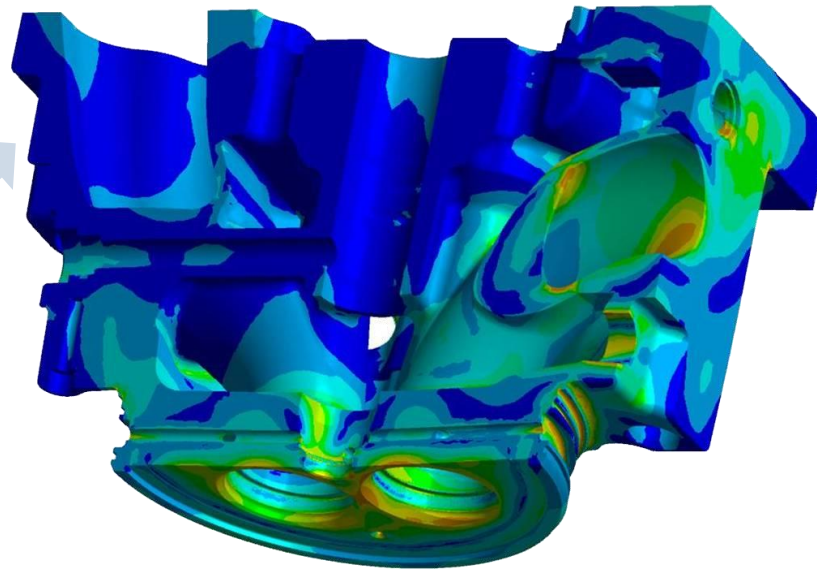


# Simulation method

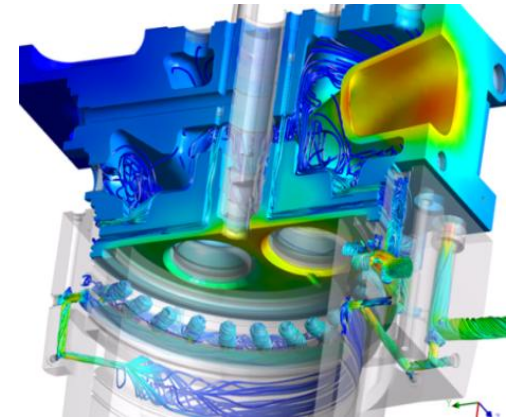
## Fluid structure interaction



FEM – Thermomechanical Stress Analysis  
and Strength Evaluation



CAD – Geometry

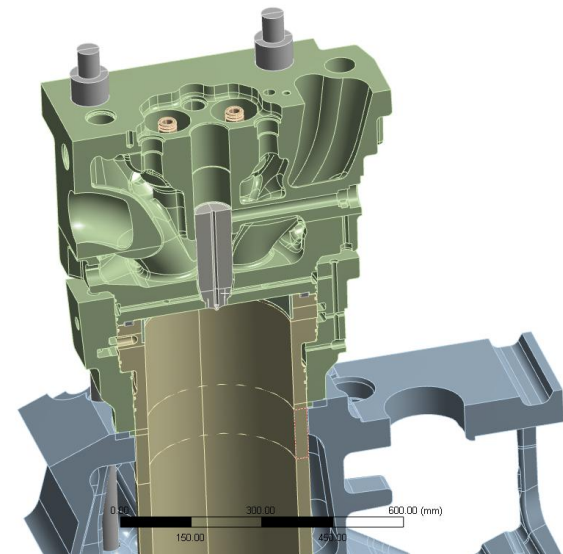
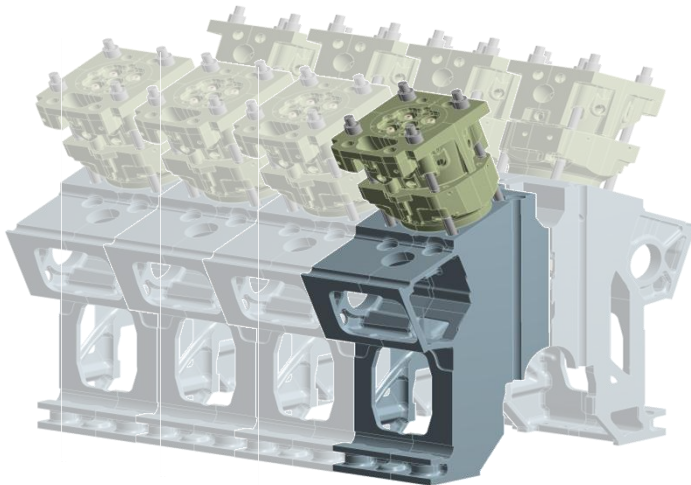
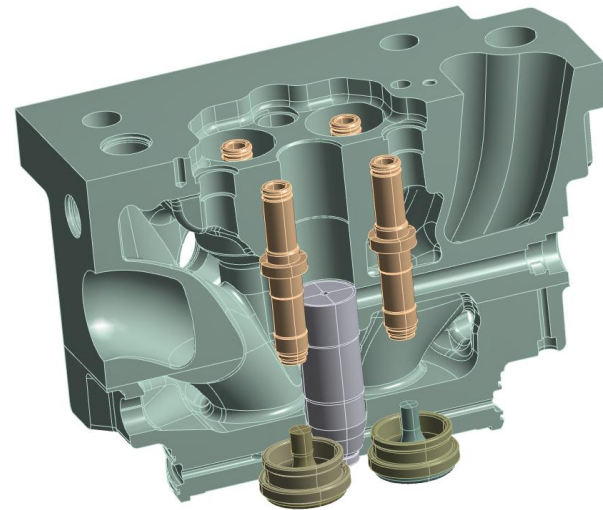
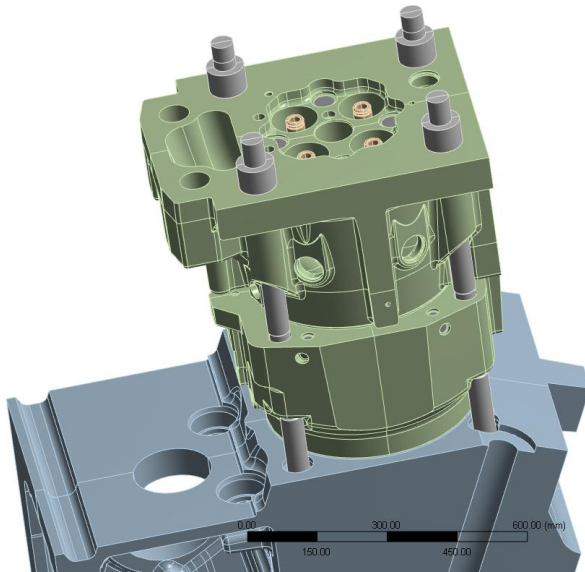


CFD – Temperature  
Distribution



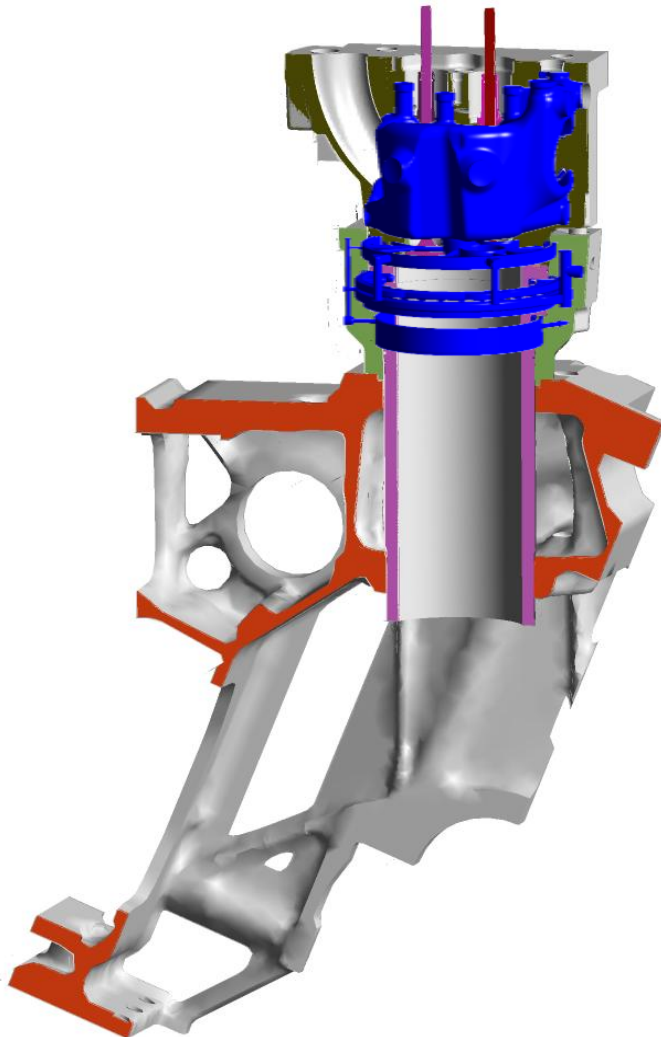
# V32/44CR

## Simulation model and cylinder head geometry



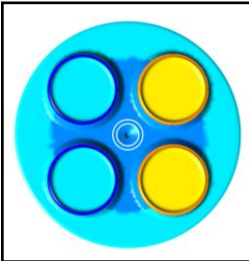

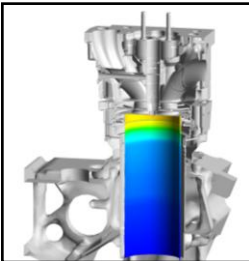
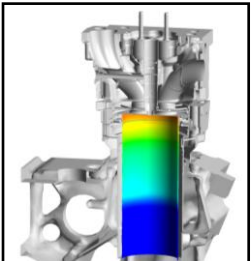
# V32/44CR

## Cooling system of liner and cylinder head



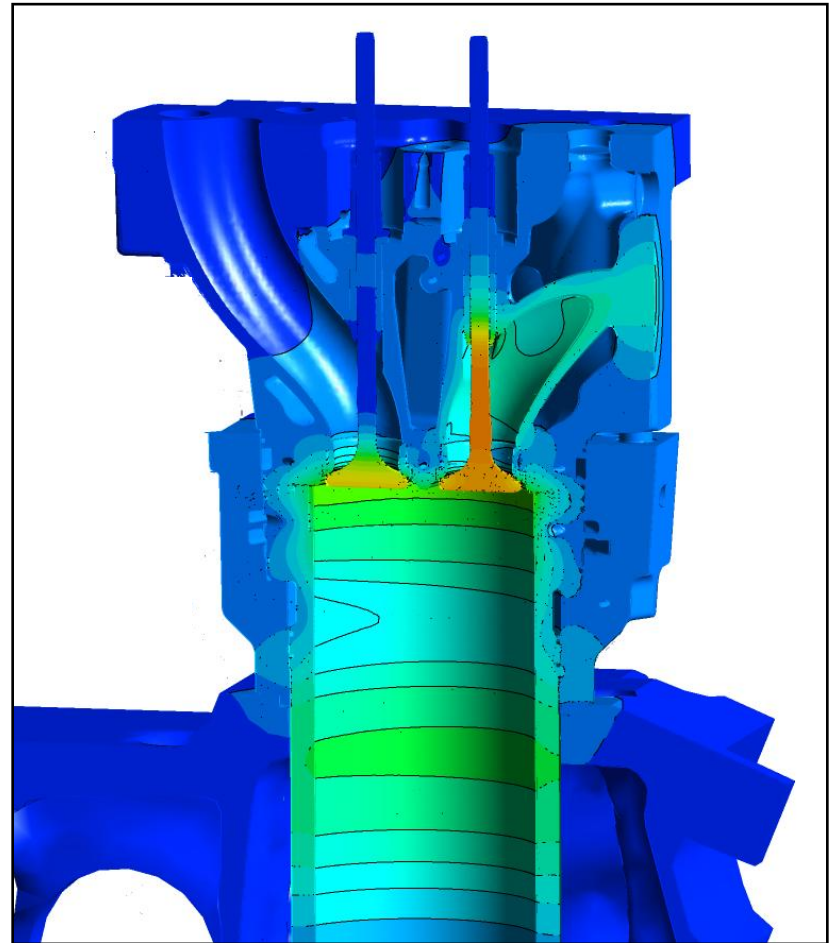
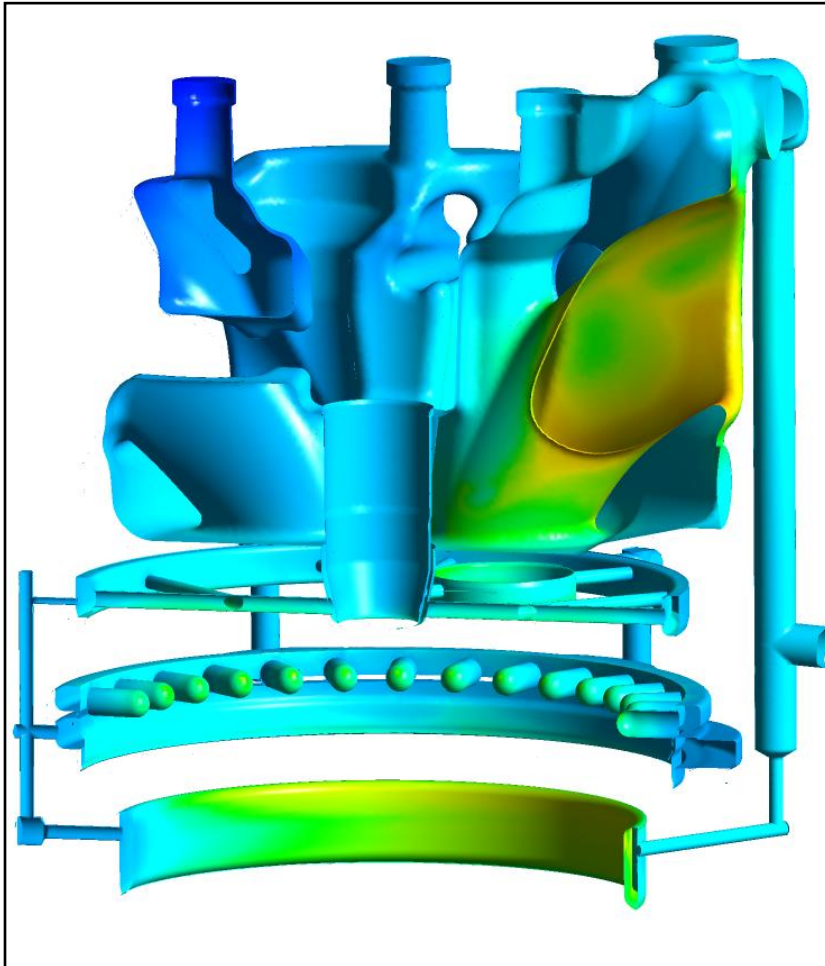
	nodes	elements
Fluid	11 Mio.	14 Mio.
Solid	2,5 Mio	9 Mio.



	Heat transfer coefficient	Reference temperature
Bottom of cylinder head		
Cylinder liner		
Inlet channel Outlet channel Oil channels Injection nozzle cooling External walls	HTC	$T_{ref}$

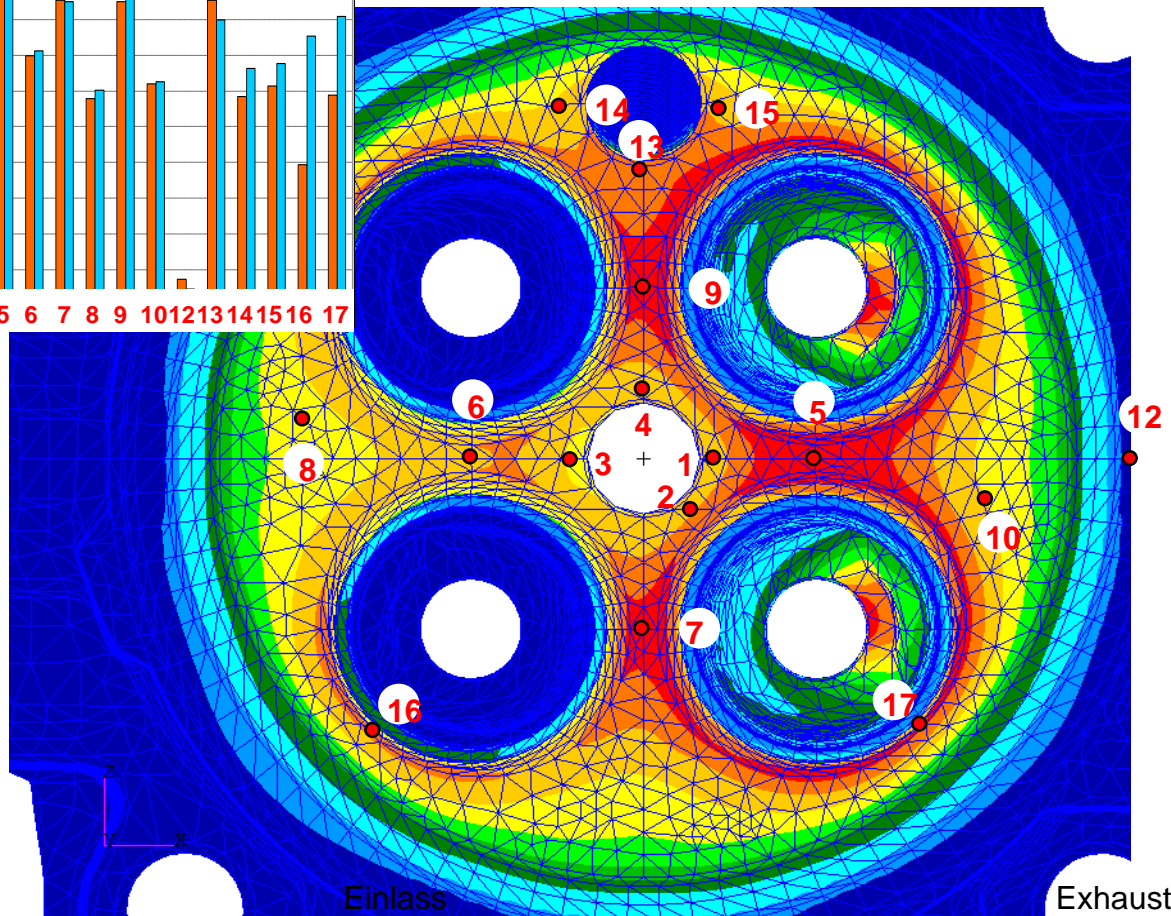
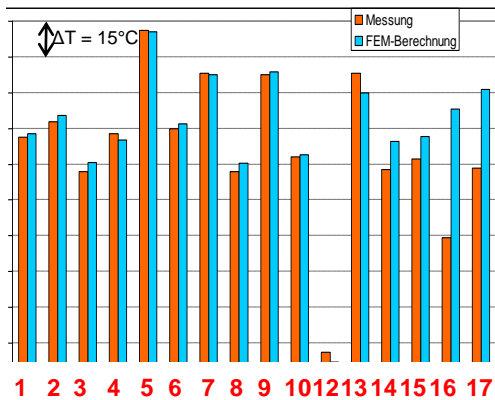
# CFD

## Results of wall and solid body temperatures





# Model validation and optimization using results of temperature measurements

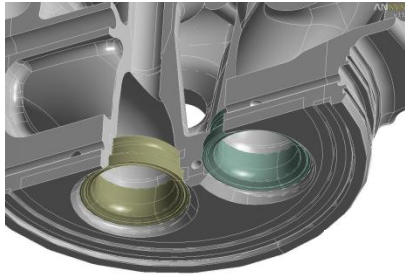


- Heat up of cooling water: deviation of CFD results from measurement  $< 0.5 \text{ }^{\circ}\text{C}$
- Measured temperatures of cylinder head and liner met by coupled analysis within local tolerance of  $< 15 \text{ }^{\circ}\text{C}$

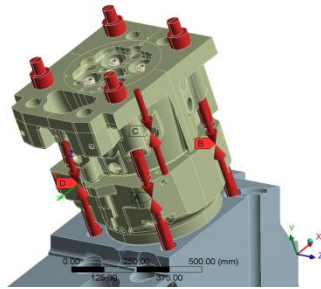
(Cylinder head seen from the bottom)

# FEM

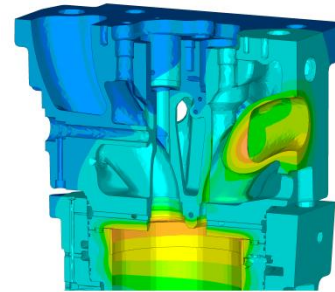
## Load steps and boundary conditions



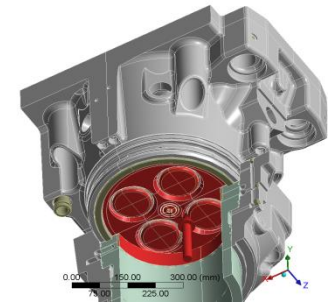
(nonlinear contacts  
with oversizes/gaps)



(bolt pretension)



(temperature field)



(max. gas pressure)

Load step 1: press fits of seat rings, valve guide and injection nozzle

Load step 2: assembly (cold) with 100% bolt pretension forces

Load step 3: assembly (hot) → with temperature field

Load step 4: assembly (hot) + max. gas pressure

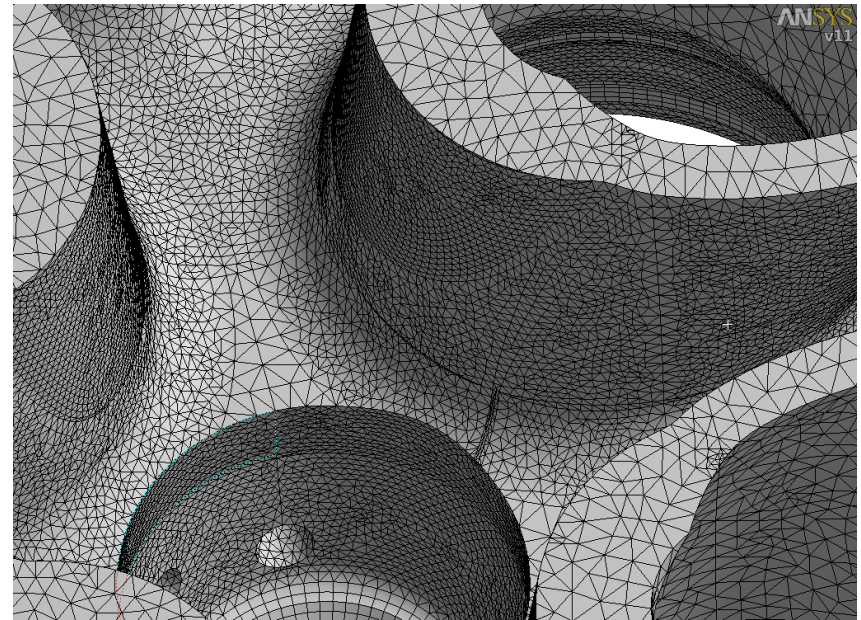
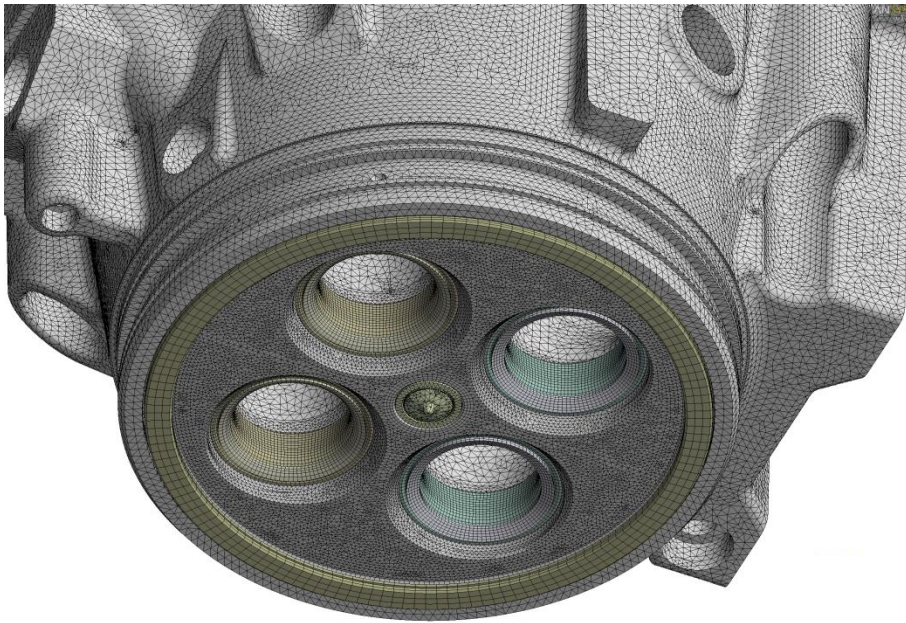
Load step 5: assembly (cold) → cool down of engine

(Load step 6: assembly (cold) + max. gas pressure)



# FEM

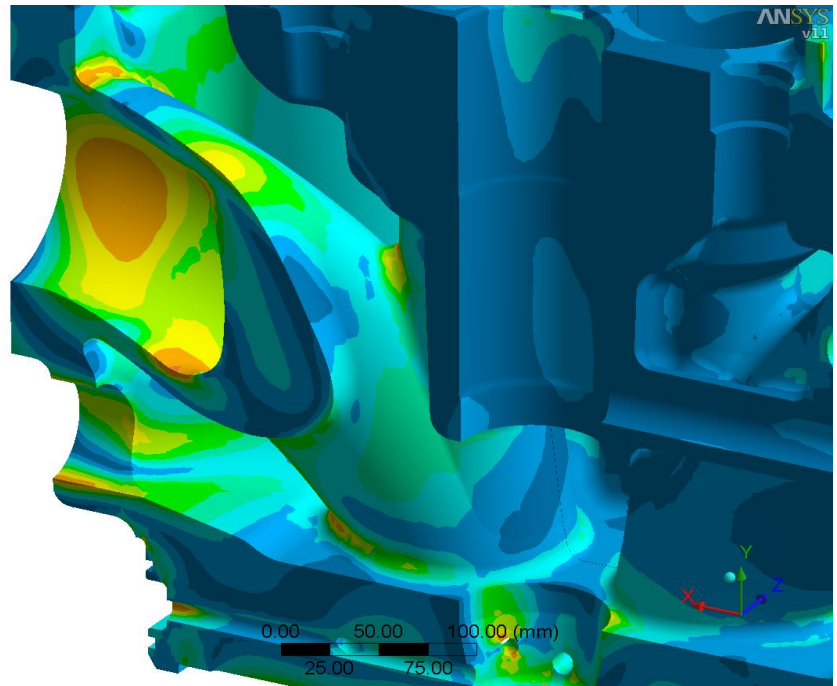
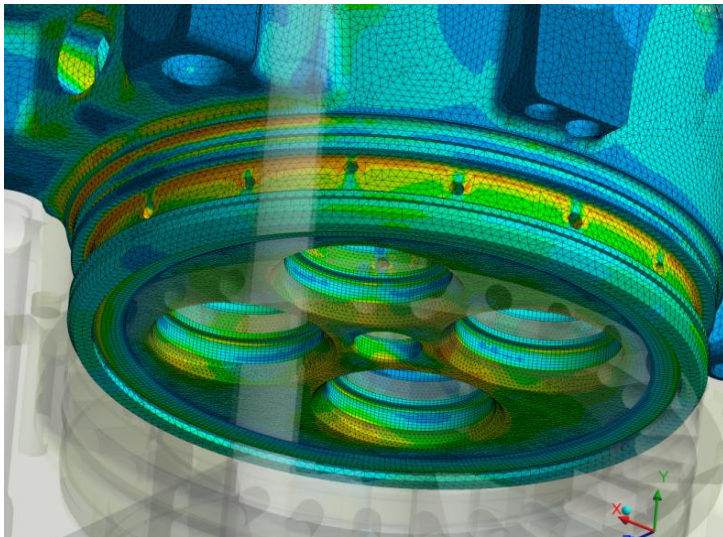
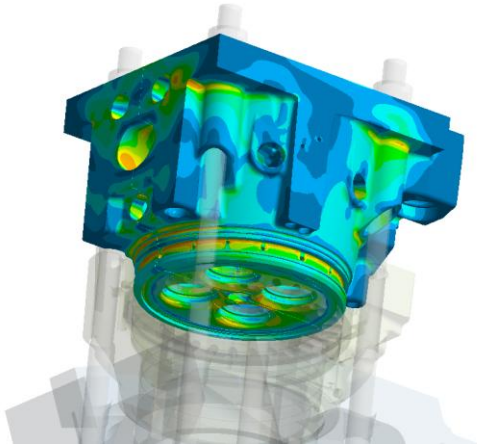
## Mesh and contact regions



- overall about **3.2 mio. nodes** and **1.73 mio. elements**
- about **60 contact regions**

# FEM

## Results – stresses load step 4

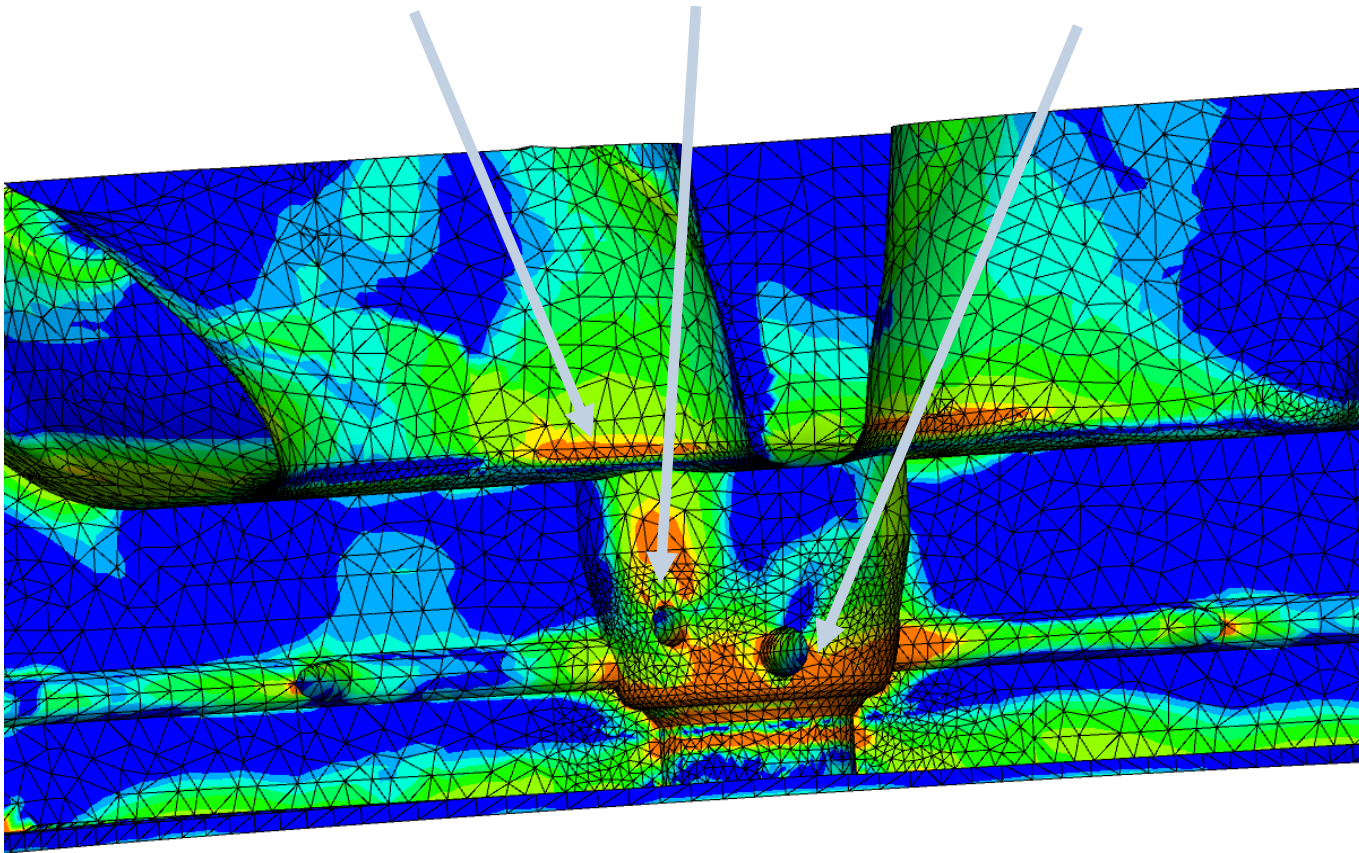




# FEM: Validation of simulation by results of measurements



## Measurements with strain gauges in areas of high stress



Deviation measured stress  $\Leftrightarrow$  calculated stress < 15%

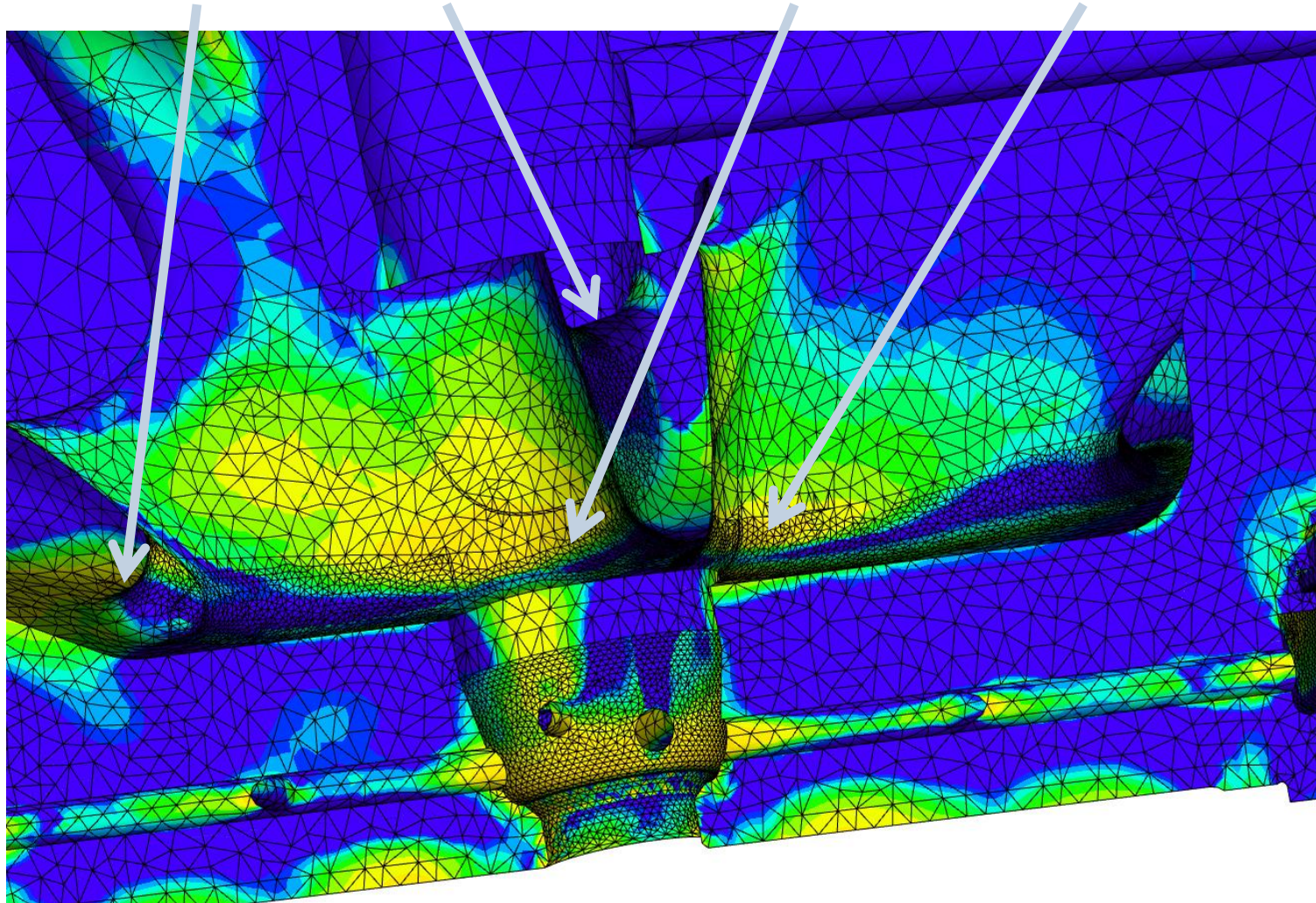


# V32/44CR

## Fatigue assessment



**Safety against fatigue improved after design optimization**



# Summary



FEM simulation time: ~10Mio DOF, 4 CPUs, 16Gb RAM : 48 h

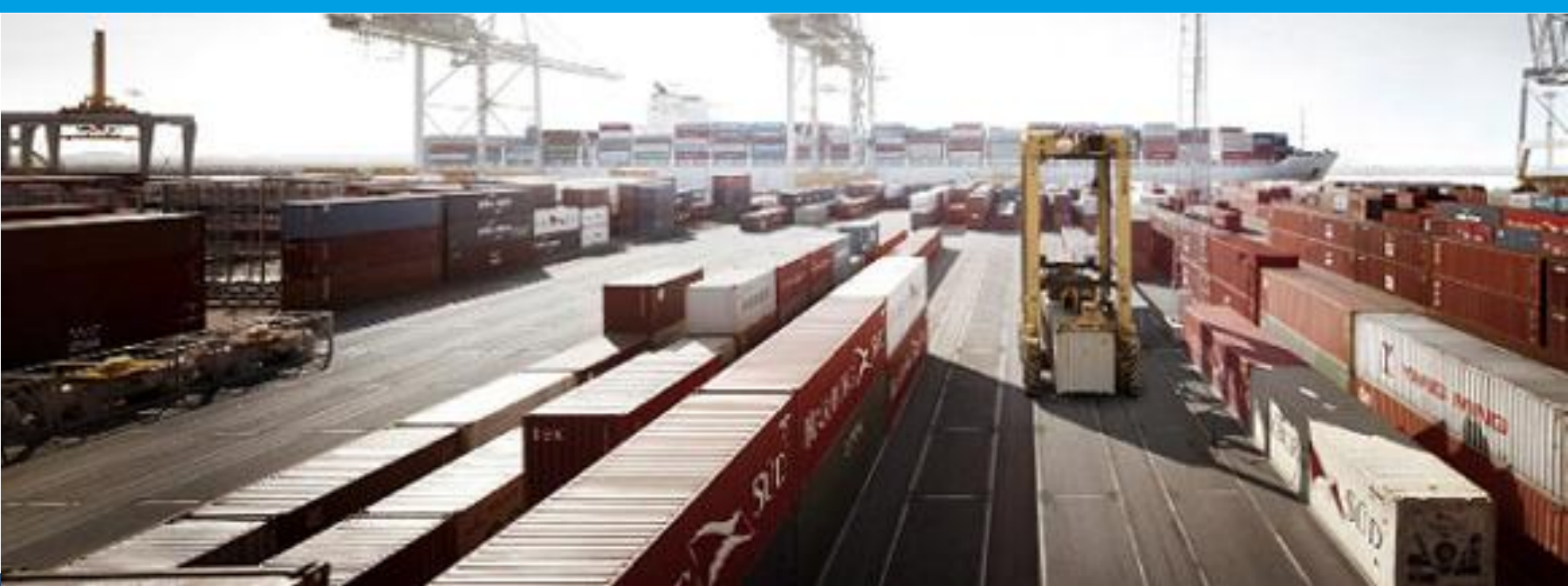
This method will be used in later design states and for the final evidence of safety against fatigue.

CFD provides much more information on a much higher level than „VDI Wärmeatlas“ regarding not only temperature field of the solid parts but also pressures and velocities of the cooling water.

Thermo-mechanical analysis of a cylinder head using fluid structure interaction allows convenient setup of the simulation model and time saving investigation of design variants in the development process.



# Thank you for your attention.



Kann man 50% des Welt-  
handels mit einer 113 Jahre alten  
Idee bewegen? MAN kann.