Objectives of Work Package

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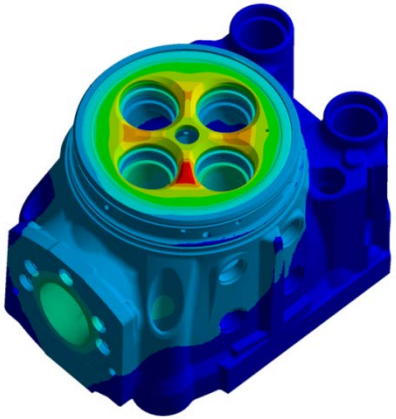
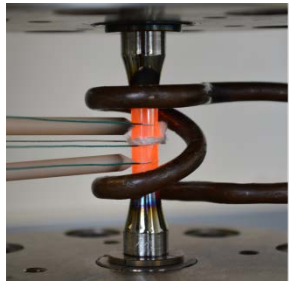
Deputy: Santiago Uhlenbrock , MAN-ES-AUG

WP 4.1 New materials and design for cylinder heads

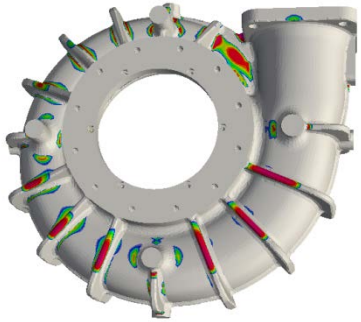
- Improvement of thermomechanical cycle resistance of factor 2 under increased temperature of 50 K
- decreased weight of cylinder head of 20%





WP 4.2 New materials for the turbocharger turbine casing

- Typical Load Cycles for Ferry Applications
- Improvement of thermomechanical cycle resistance under increased temperature of 70 K under corrosion environment



Partners:

MAN

Fraunhofer IWM

Hochschule Offenburg
University of Applied Sciences

Fraunhofer ICT

BAM
Bundesanstalt für Materialforschung und -prüfung

Structure: subprojects, partners, roles

BAM

Materials testing (TMF) under realistic load condition; material models life time prediction for iron and nickel k casting materials.

FG

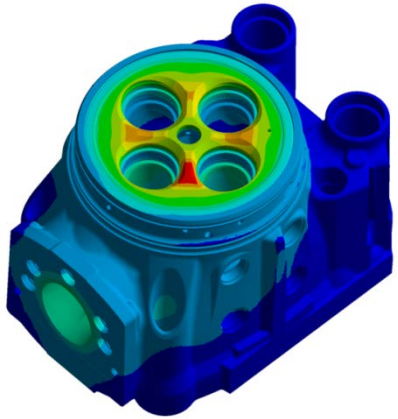
Materials testing (LCF and TMF) and establishing the model concept for TMF life prediction (IWM)
Establishing the concept for validation of the developed models for TMF life prediction on the basis of TMF loaded samples with component-like features and for performing validation tests. (ICT)

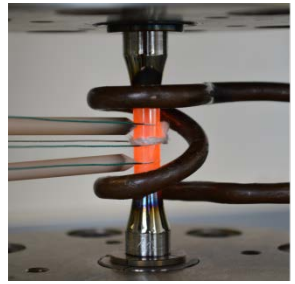
HSO

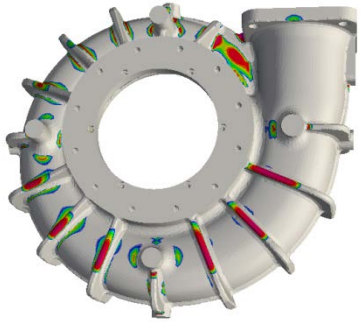
Development of model concept to assess the TMF life of cylinder head in finite-element calculations

MAN Energy Solutions

Selection of suitable materials and material treatment processes, providing components for material tests.







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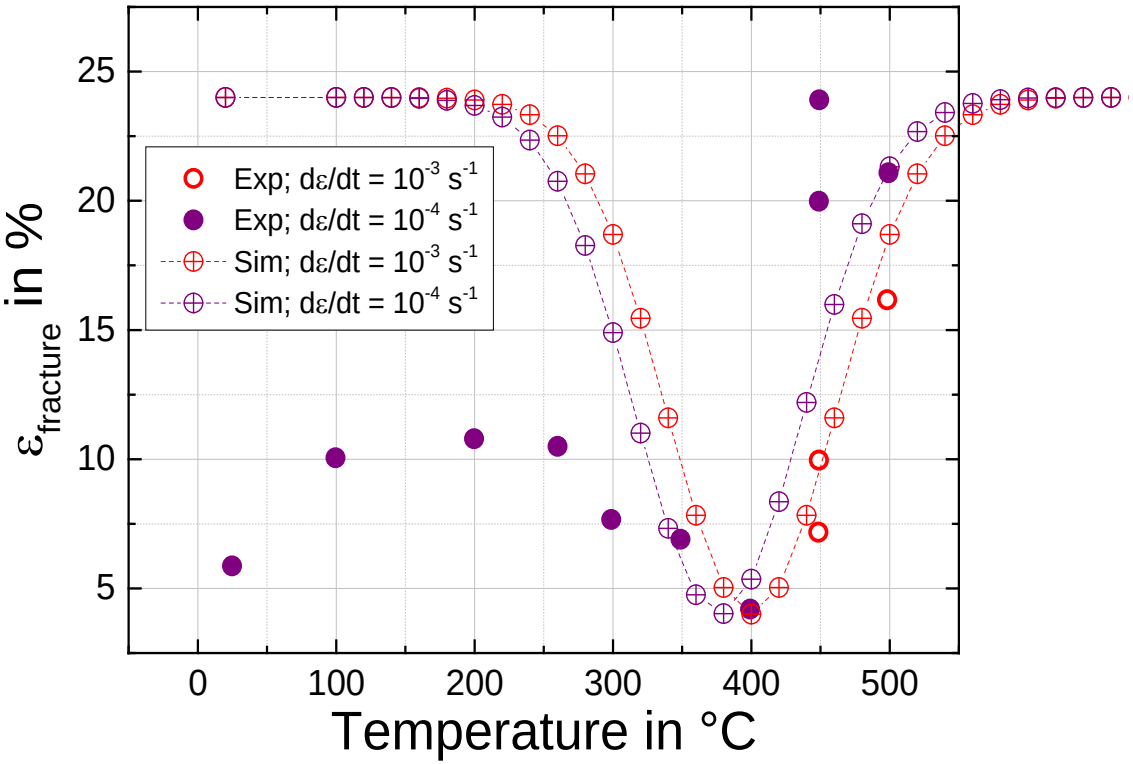
Results within WP4.1

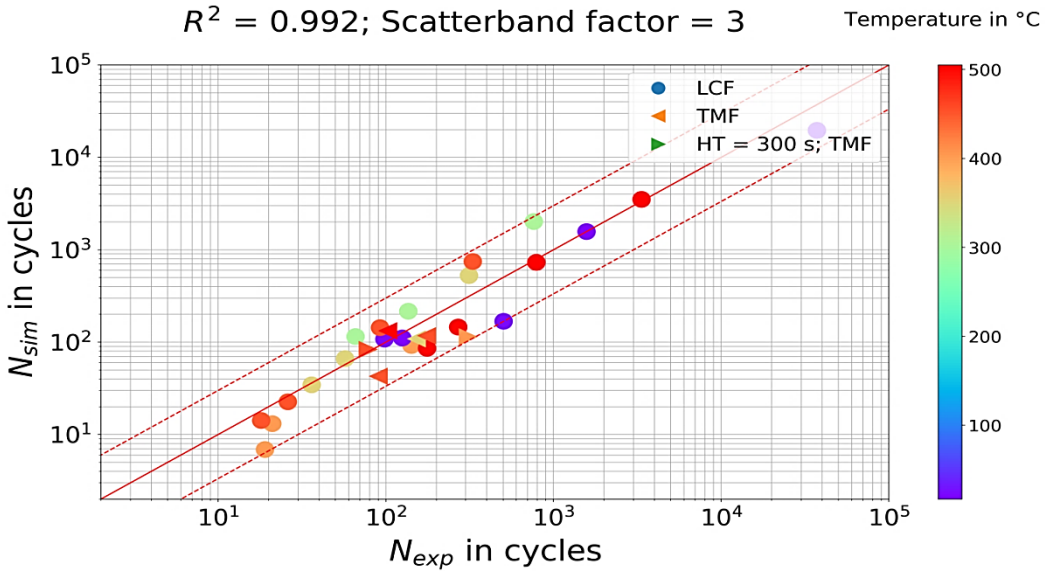
Experimental vs. simulated fracture strain values



$$\varphi(T) = e^{-\frac{(T-T_m)^2}{w^2}}$$

Results within WP4.1

Life Prediction for LCF / TMF



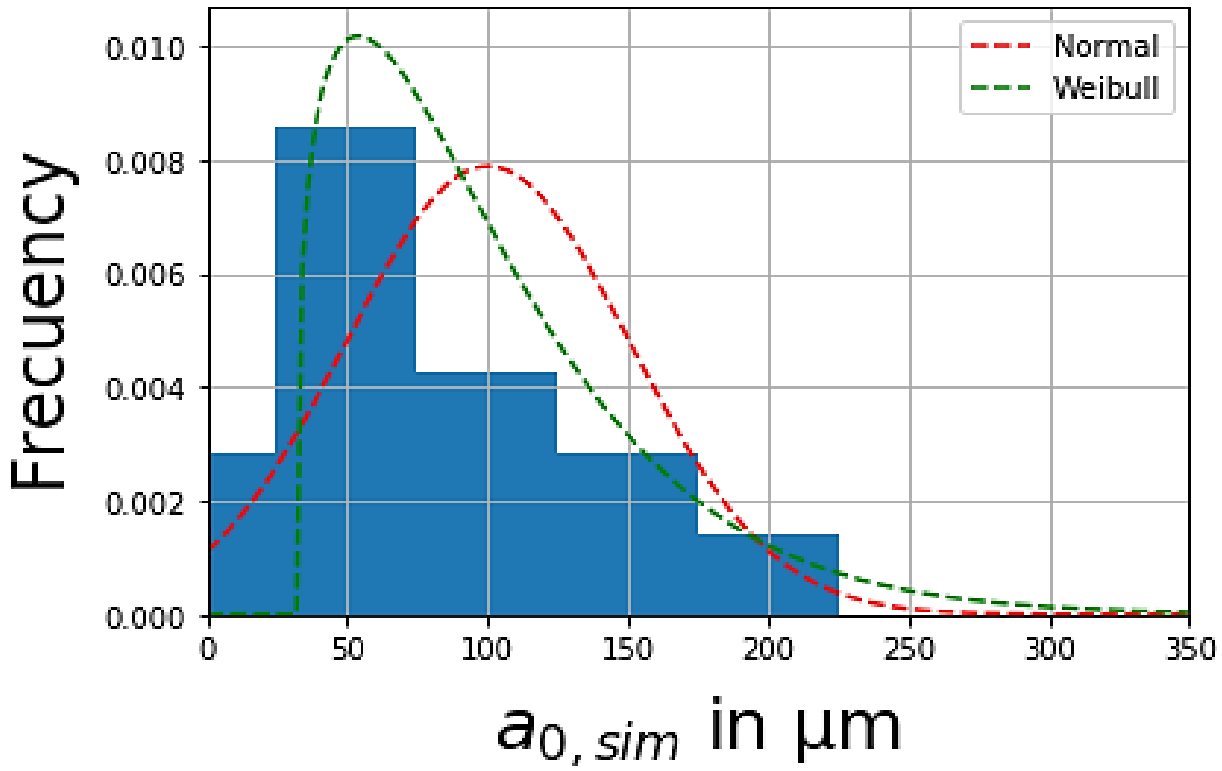
$$N_{tot} = \frac{a_f^{1-B} - a_0^{1-B}}{\beta_{IE}(T) * (1-B)} * \left(\frac{Z_D}{\sigma_{cy}}\right)^{-B}$$

includes:

- intergranular embrittlement
- time dependent behaviour

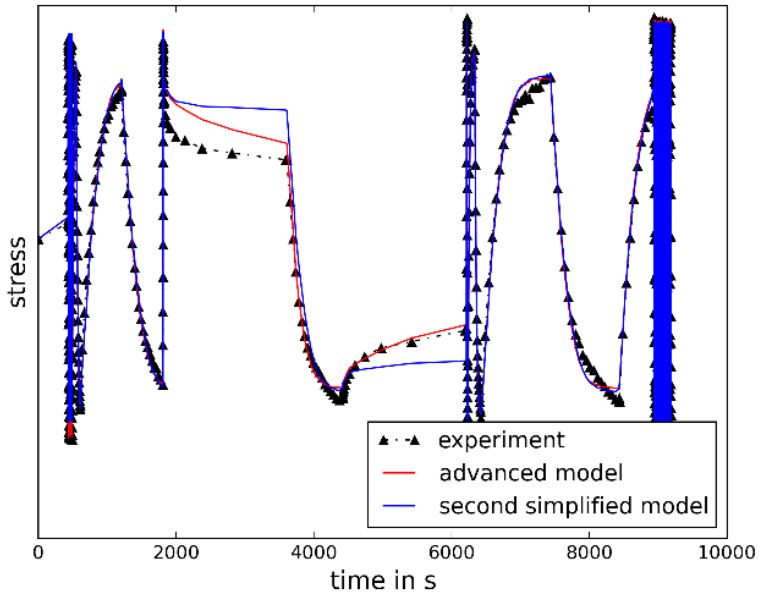
Results within WP4.1

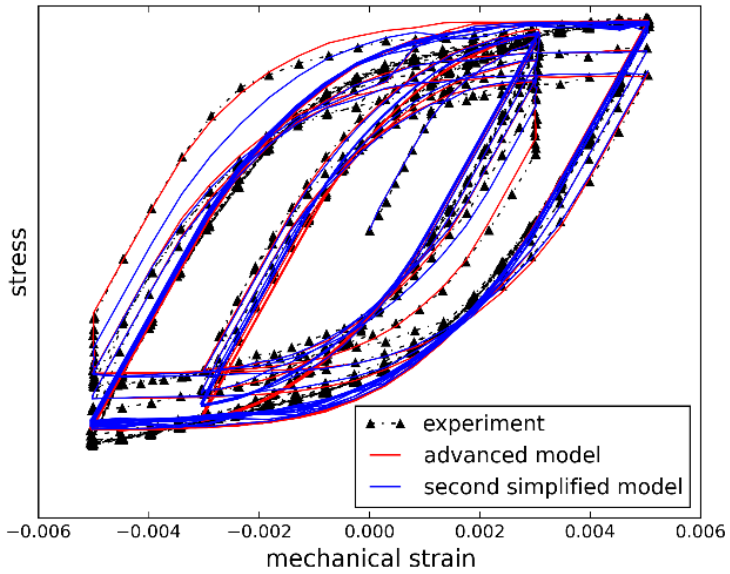
Probability distribution function of the inferred initial defect size



New Results within WP4.1

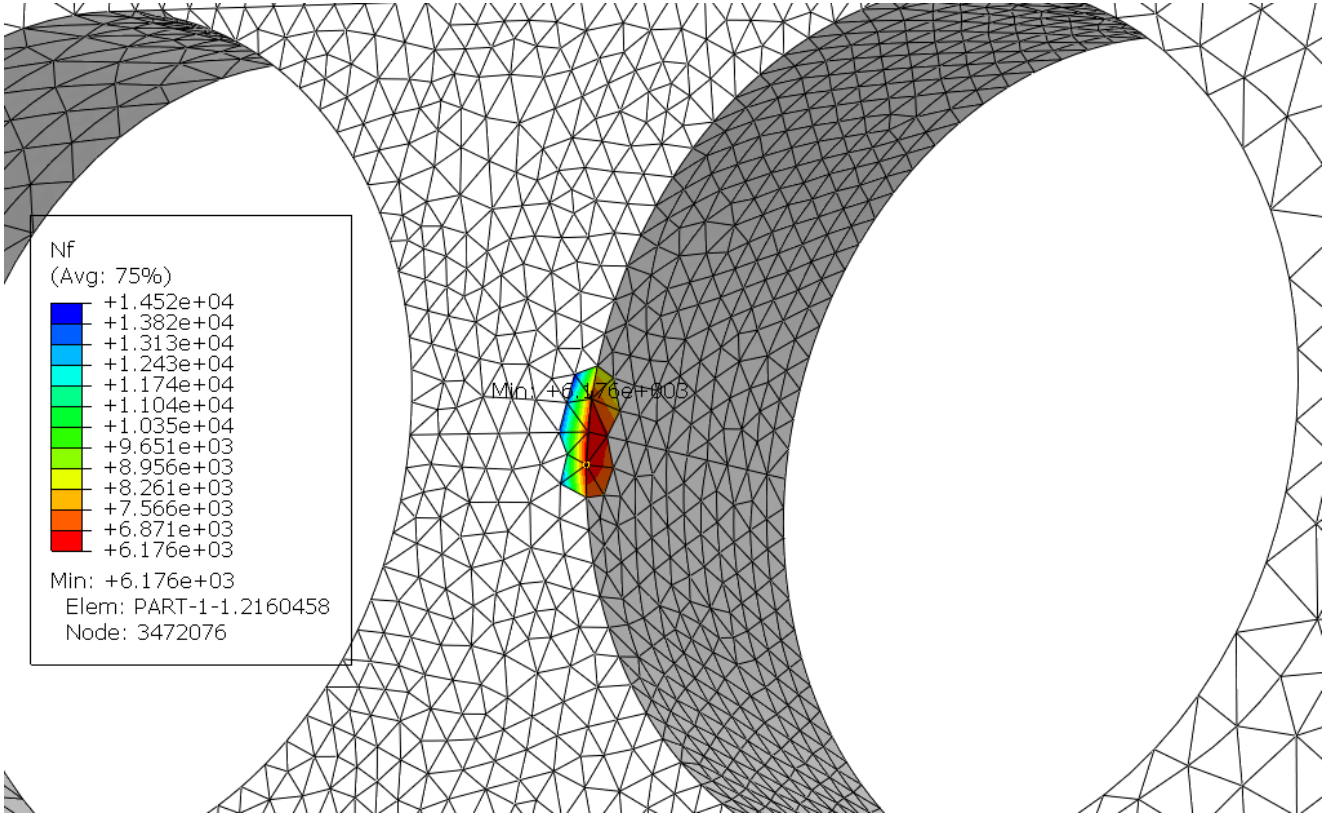
Advanced vs. Simplified Model





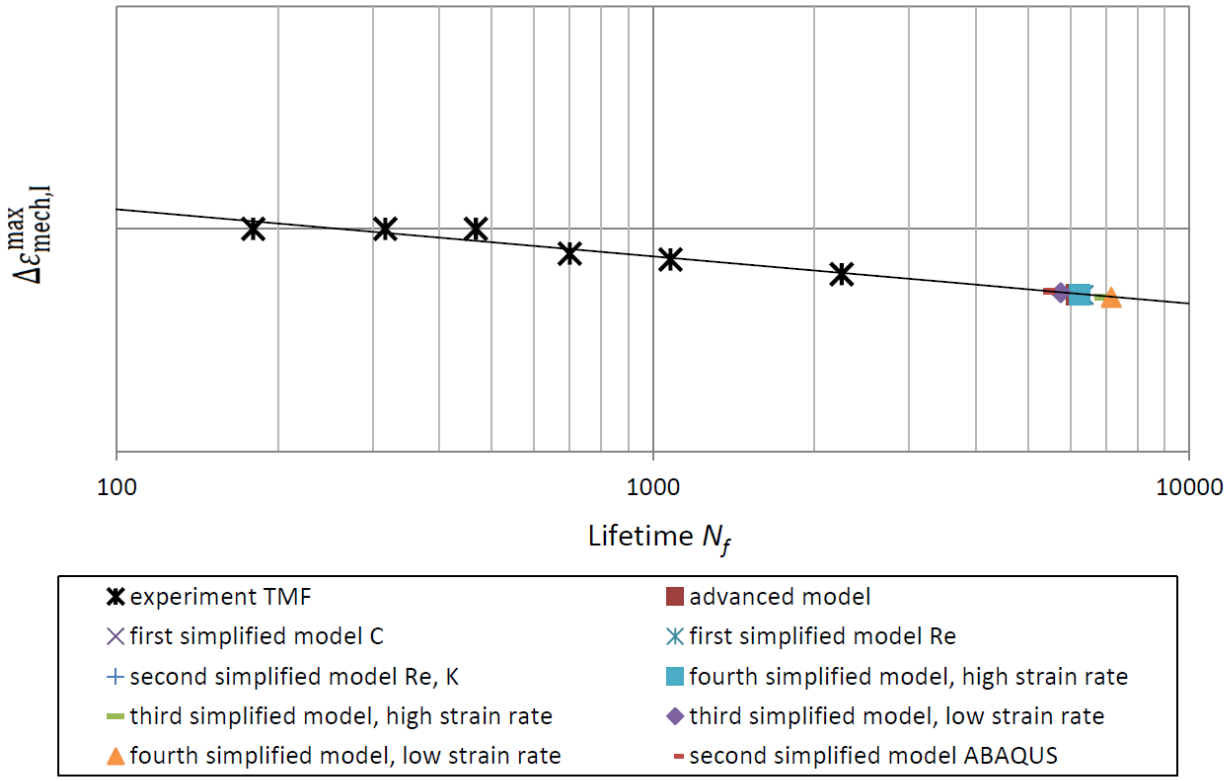
New Results within WP4.1

Finite-element model of the cylinder head specimen showing the number of cycles to failure *Nf* in the critical area of the advanced model for material F



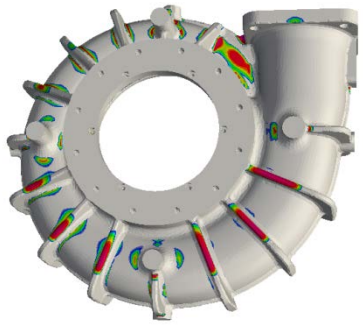
New Results within WP4.1

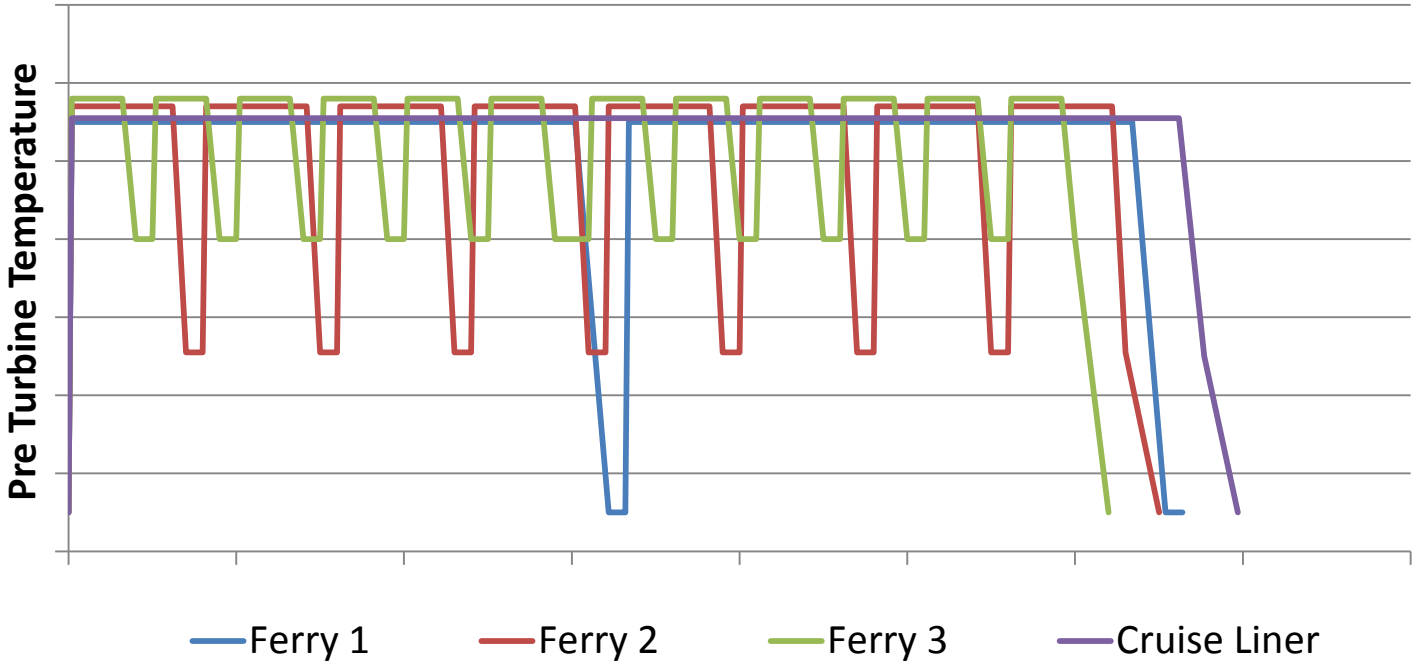
Wöhler curve with calculated lifetimes of the different models for material F



Introduction WP4.2

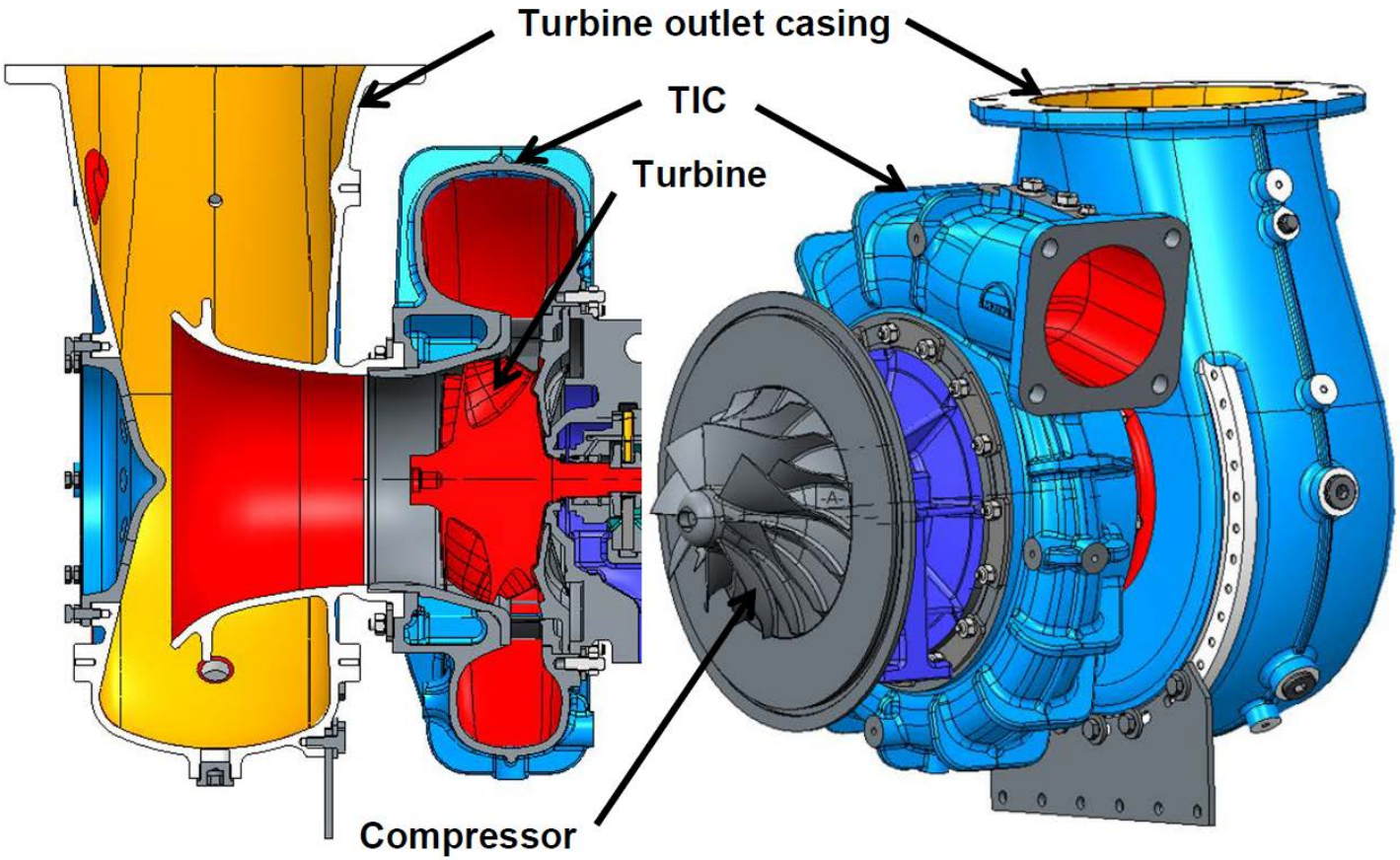
- Ferry applications are very cyclic marine applications. Thermo-mechanic fatigue damage is dominant compared to creep damage.
- Cruise liner applications are stationary applications with large dwell times at elevated temperature. Creep damage is dominant compared to thermo-mechanic fatigue damage.





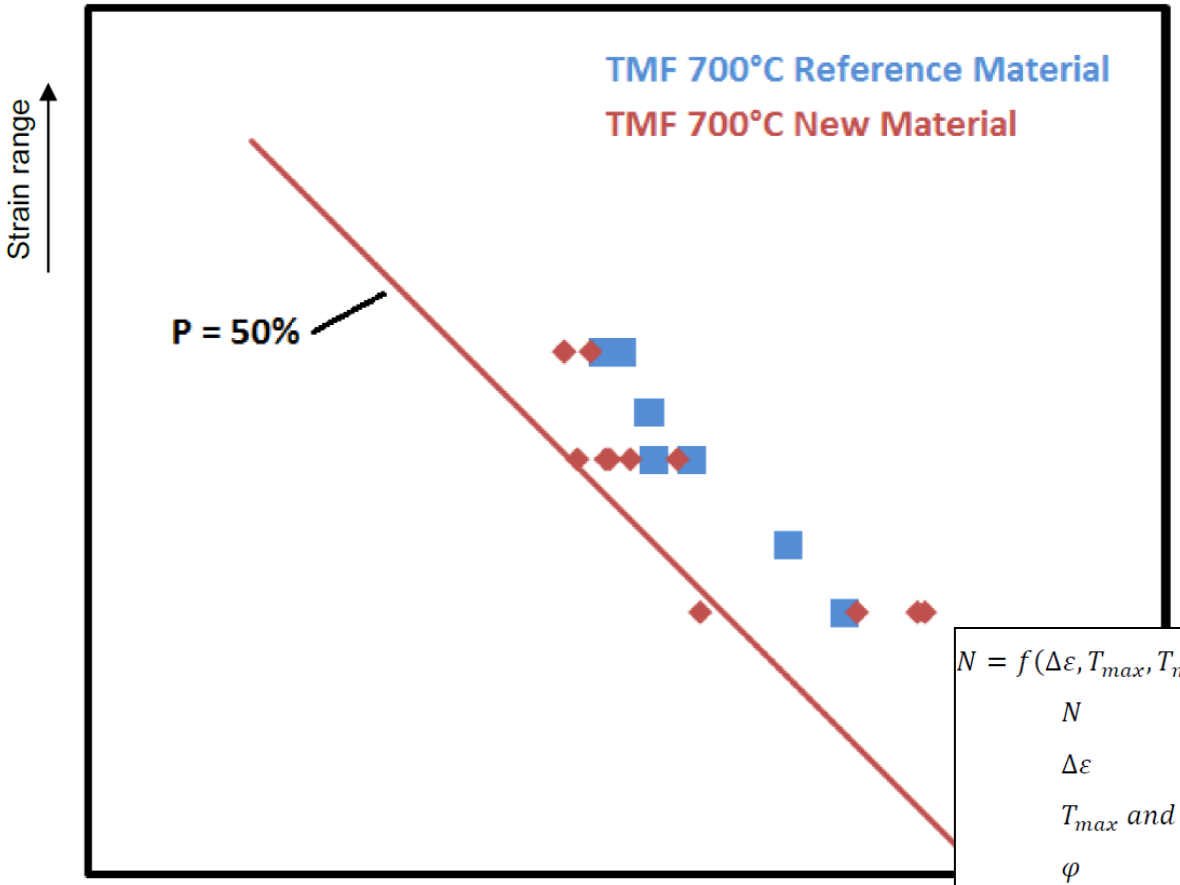
Results within WP4.2

- Hot end of a radial turbocharger



Results within WP4.2

- TMF model for 700°C and P = 50%

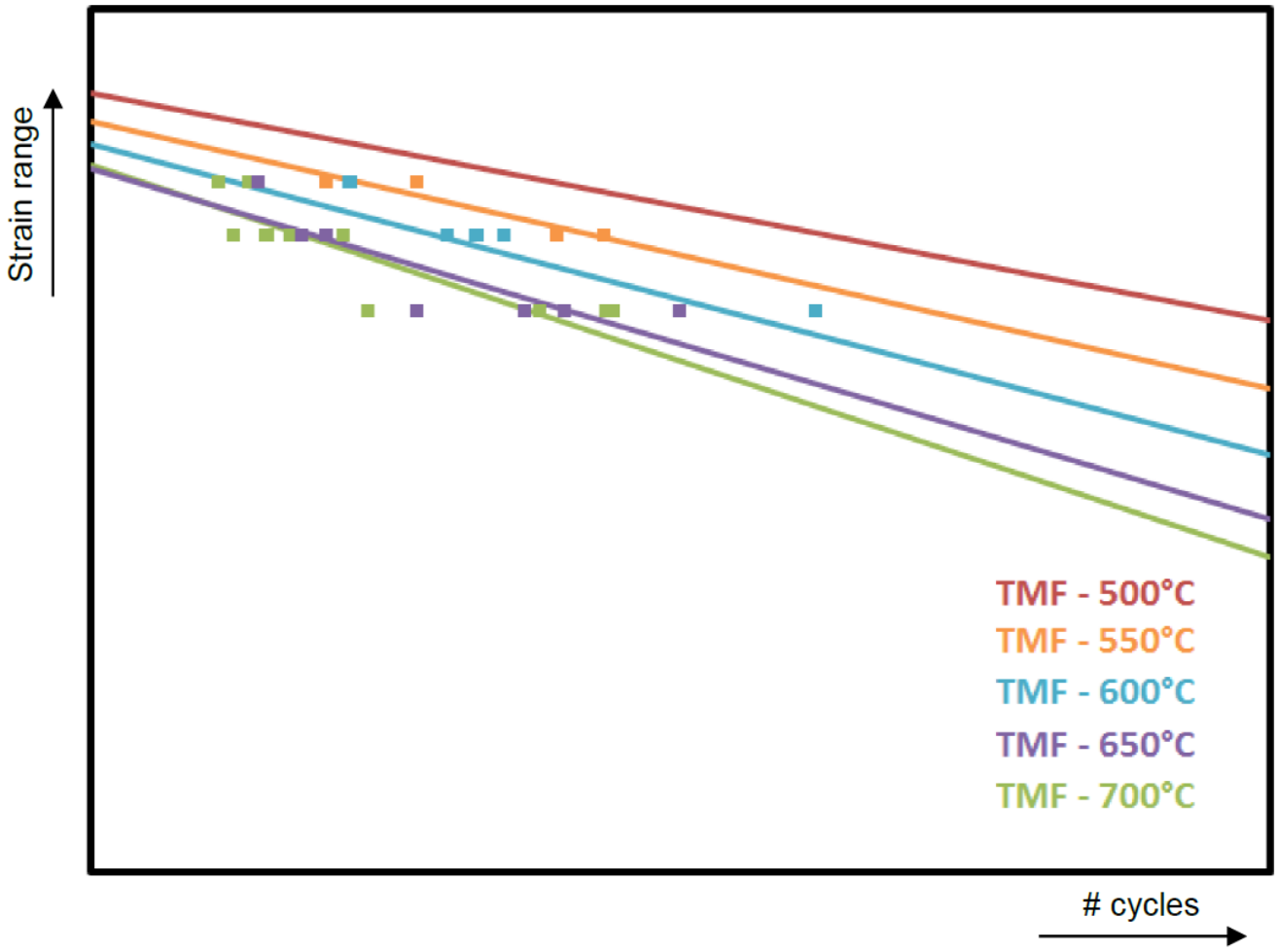


$N = f(\Delta\varepsilon, T_{max}, T_{min}, \varphi, P)$

N	– Attainable number of cycles
$\Delta\varepsilon$	– Strain Range
T_{max} and T_{min}	– Maximum and Minimum Temperature
φ	– Phase Angle
P	– Probability Level

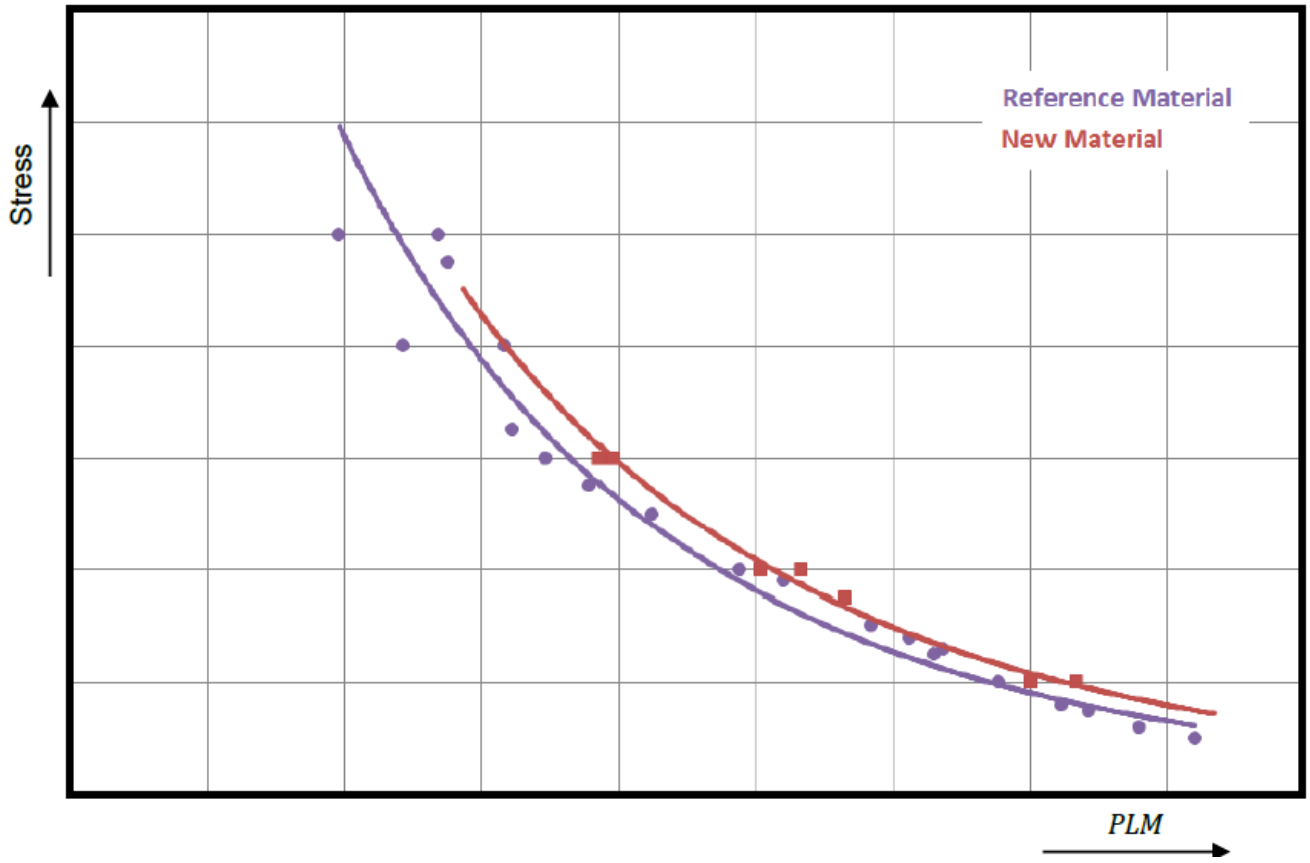
Results within WP4.2

- Average lifetime model for test sample size

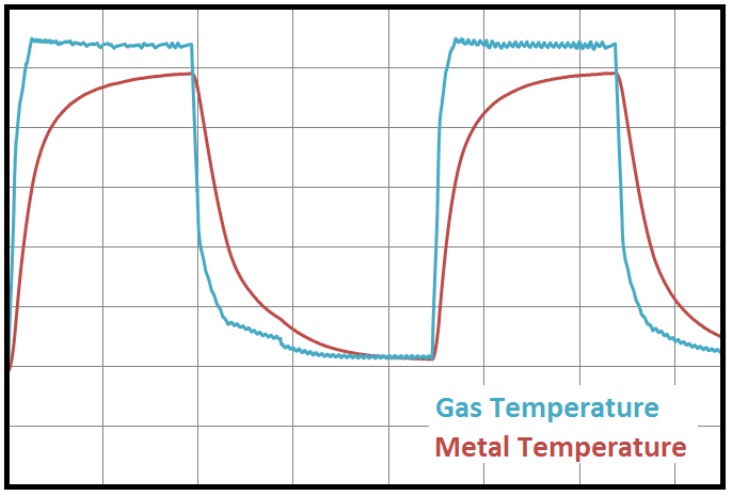


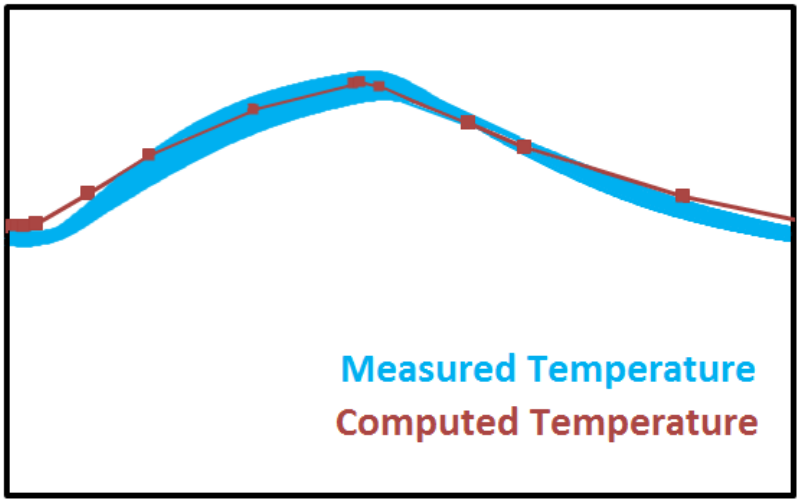
Results within WP4.2

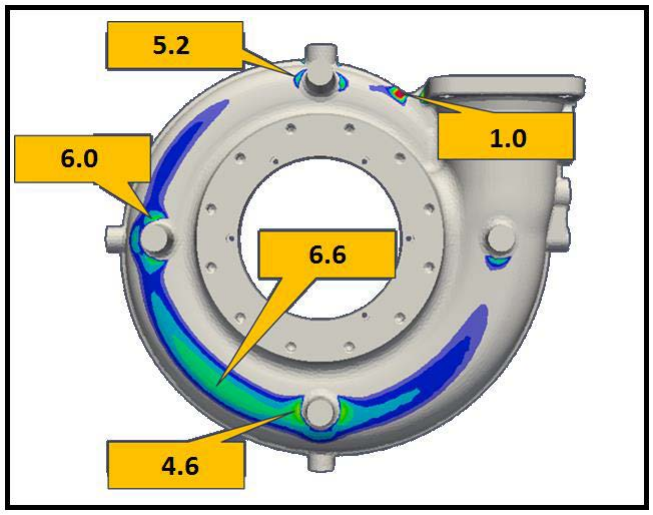
- Comparison of creep behaviour reference/new material



Results within WP4.2







Location	Prediction accuracy
1	-23%
2	-20%
3	-16%
4	-16%
5	8%
6	33%
7	>100%
8	>100%

Prediction accuracy of TMF lifetime

Final results & Achievements

WP 4.1 New materials and design for cylinder heads

- Pilot study on Material
- Selection of appropriate material by Indicator
- Design and construction of component test rig
- evaluation the selected material in detail (isothermal complex LCF tests, TMF, metallographic investigations)
- New material model development
- Test rig for cylinder head equivalent specimen
- Optimization of Cylinder Head

WP 4.2 New materials for the turbocharger turbine casing

- Selection of appropriate materials for future turbocharger applications
- Optimization of the manufacturing route to avoid misalignment
- Material characterization / tests for material model development (LCF/TMF/Creep)
- material model development for fatigue and creep
- validation of developed material model within application on TC inlet casing on hot burner test rig: deviation of max. 23% of predicted life

Conclusions

Exploitation:

- Results from WP4 implemented into newest design of 45/60, first engines in field in 2019
- TC successful tested and design is proofed
- Method for design established for future product development