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Life Time Prediction of EGR Cooler using FEMFAT

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Contents

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MAHLE worldwide

Driven by performance

- A leading global development partner for the automotive and engine industry.
- Units: Engine Systems and Components, Filtration and Engine Peripherals, Thermal Management business unit.
- MAHLE Group ranks among the top three systems suppliers worldwide.

Key data:

- 140 production locations on five continents
- Approximately 65,000 employees

Introduction to EGR Cooler

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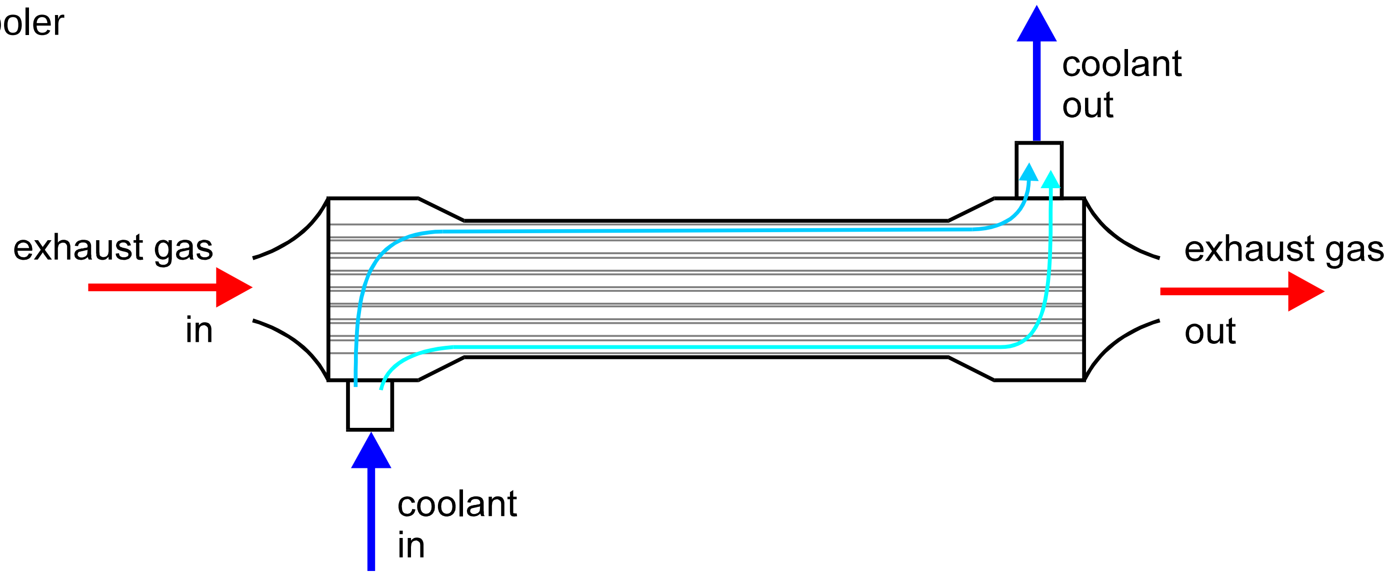
- NOx (Oxides of Nitrogen) is formed in combustion chambers of engine at peak operating temperatures.
- To reduce the NOx emissions from the engine, we require optimum combustion temperature
- By recirculating some amount of exhaust gas (around 20%) through EGR into the engine combustion chamber, the peak temperature can be reduced during combustion.
- The main function of EGR Cooler (Exhaust Gas Recirculation Cooler) is to cool exhaust gas to a optimum temperature and recirculate it to the engine.
- This is necessary to meet stringent emission regulation norms.
- Main Parts of EGR Cooler
  - Diffuser
  - Housing
  - Header
  - Tubes
  - Coolant ports



Introduction to EGR Cooler

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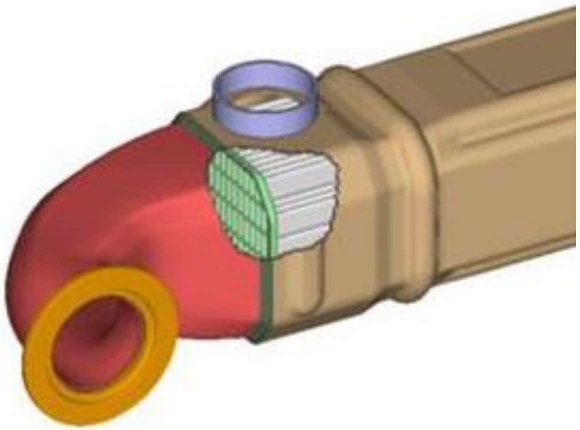

- There is large temperature differences between inlet gas (800ºC) and coolant(<100ºC).
- This results in thermal shock and induce high thermal stresses at the Inlet region
- Results in Header bar crack , Horizontal Tube crack
- Temperature Cycle Test at Mahle Behr is capable of reproducing this failure mechanism
- TCT virtual Simulation in early development phases should help to reduce number of real time TC tests, which is expensive and time consuming

Simulation work flow

Transient CFD: Simulation of full Test Cycle

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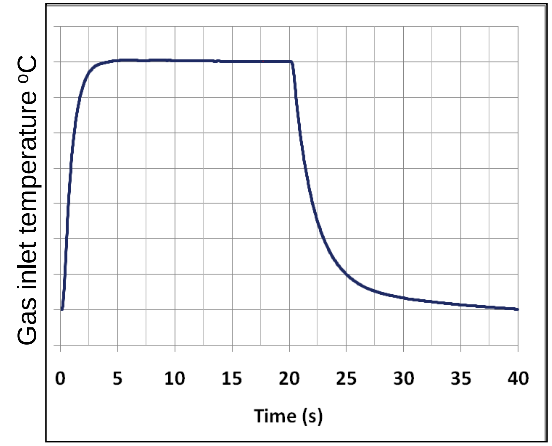
Temperature Load Mapping on FE Model

↓

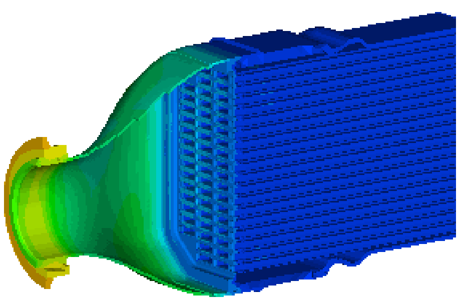
Structural Analysis stress output

↓

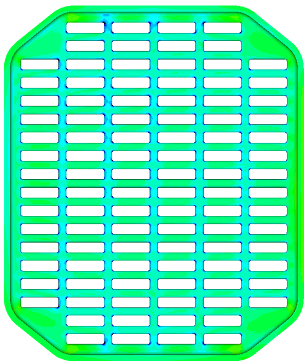
FEMFAT Life prediction



Temperature cycle test for an EGR cooler



CFD ➔ Temperature flow distribution



FEA ➔ Stress Output

Simulation work flow

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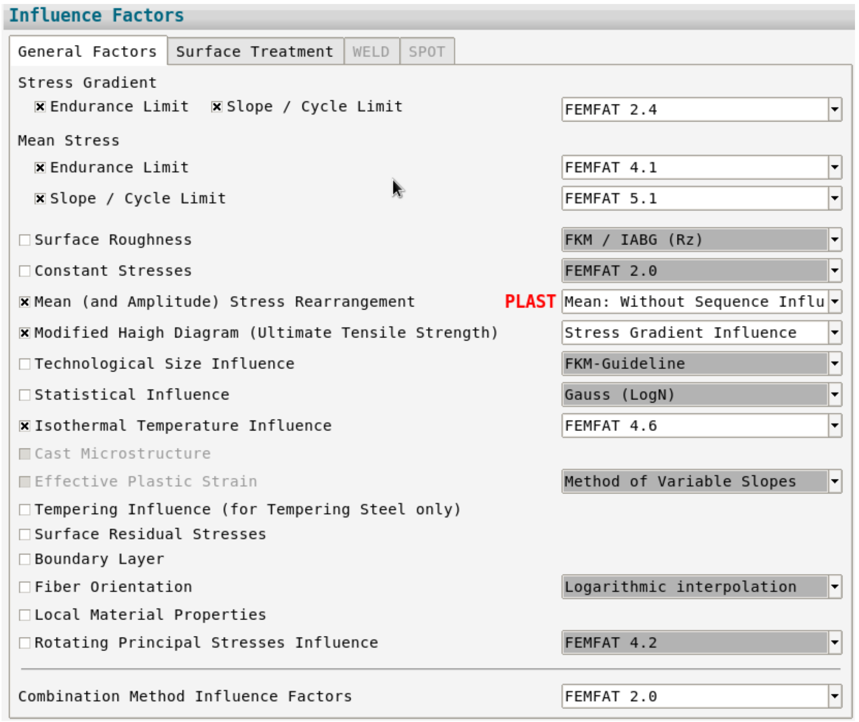
- FE – Work Flow
  - Heavy Duty Truck EGR cooler was considered for analysis
  - FE modeling was carried according to Mahle Behr specific FE methodology.
  - In CFD, Flow conditions were considered according to Mahle Behr Specific methodology and only gas temperature vary over time.
  - Stress range for critical tube is observed.

Simulation work flow

- FEMFAT Input:
  - Material : FEMFAT Material class "Higher Strength Weldable Structural Carbon" , modified according to Mahle Behr EGR cooler Test conditions.
  - Influence factors:



  - Analysis parameter – Damage (Miner modified method)

Results – Max.Stress plot

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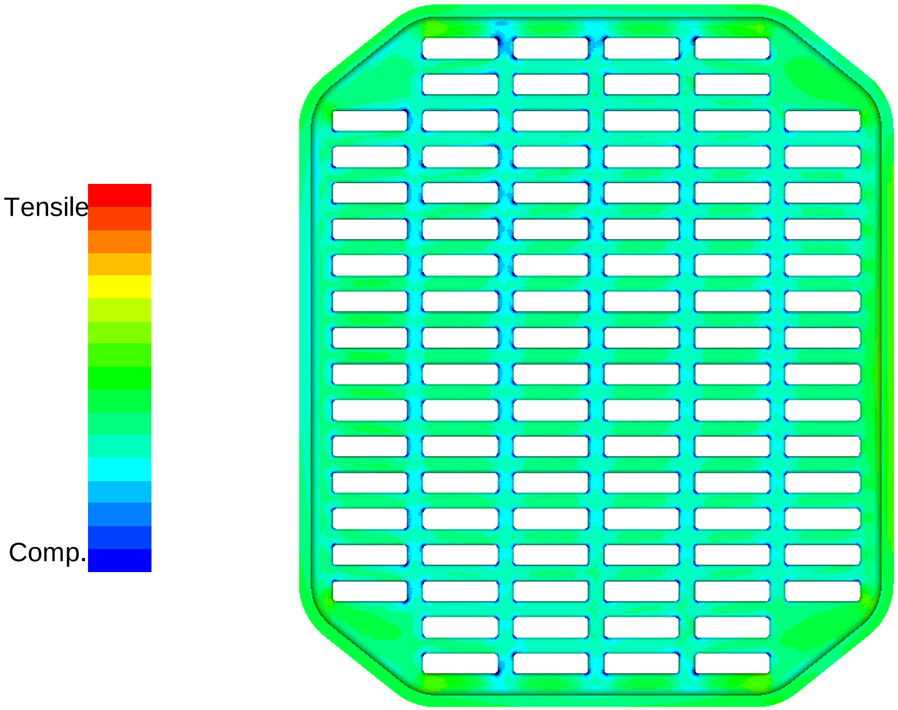
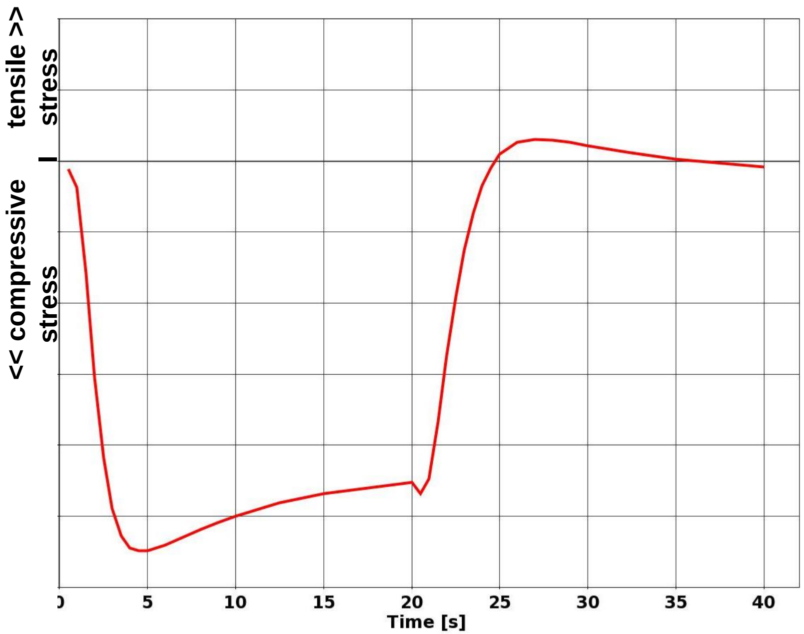
- Calculated principal stress [MPa] over time





Results - FEMFAT

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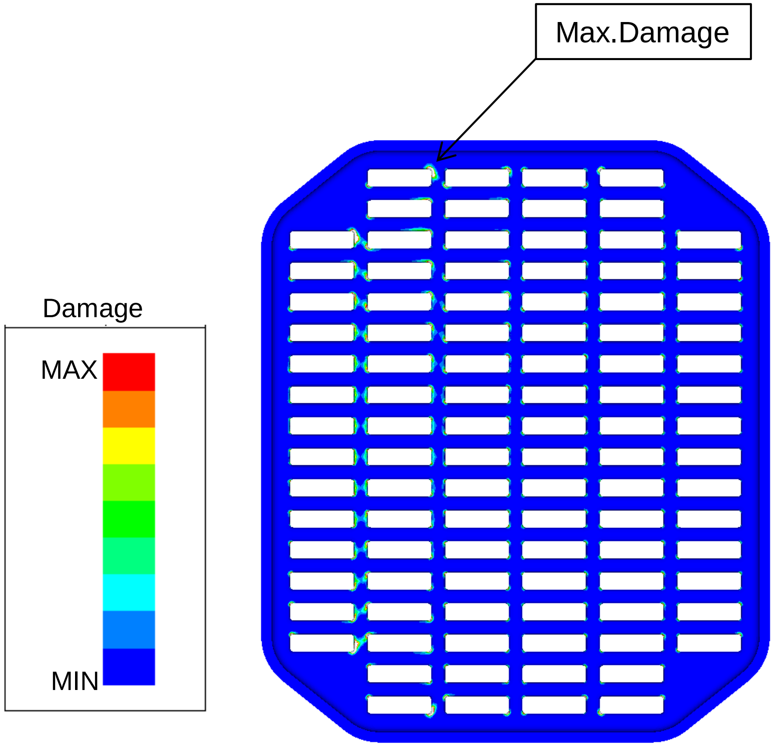

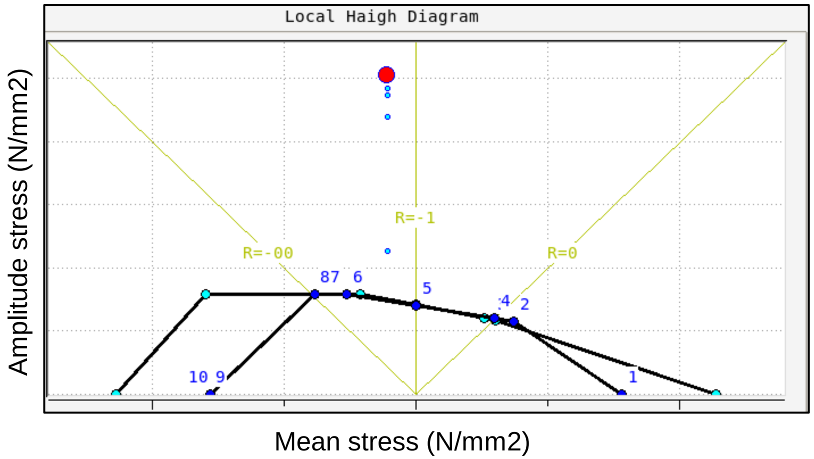

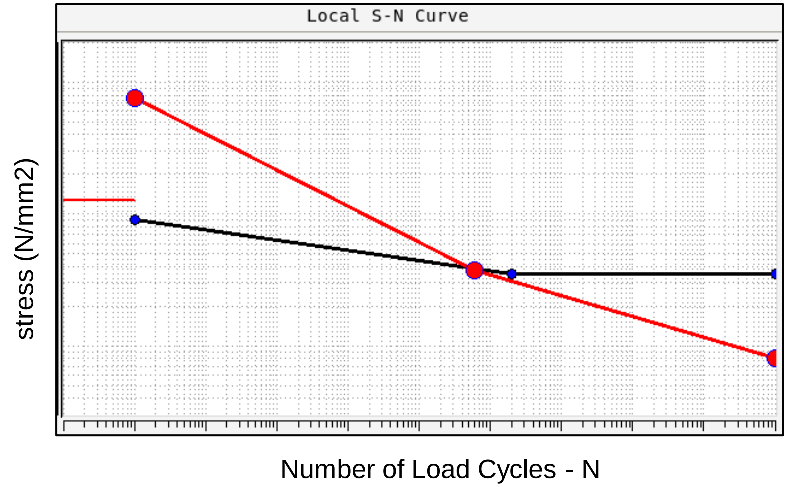

Conclusion

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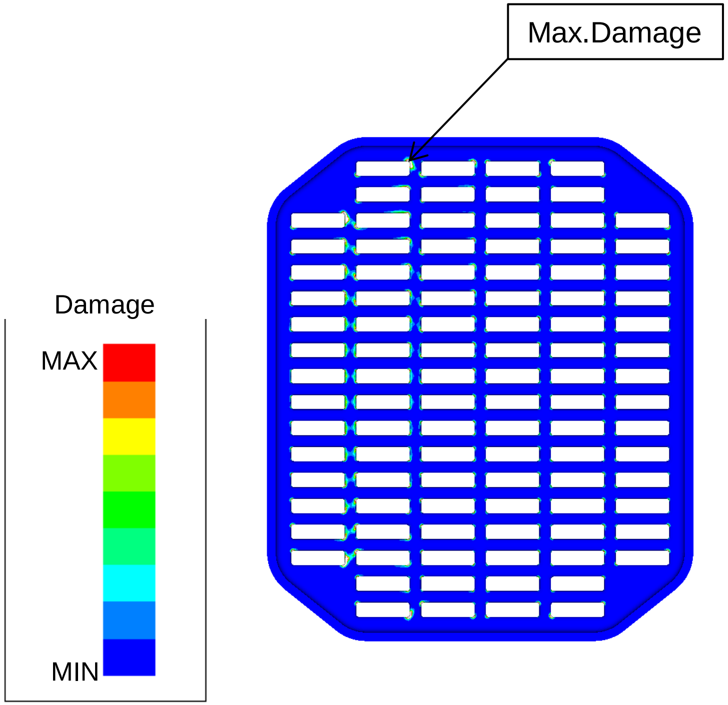
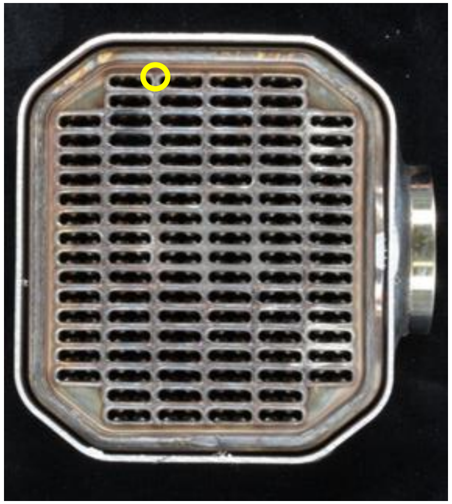
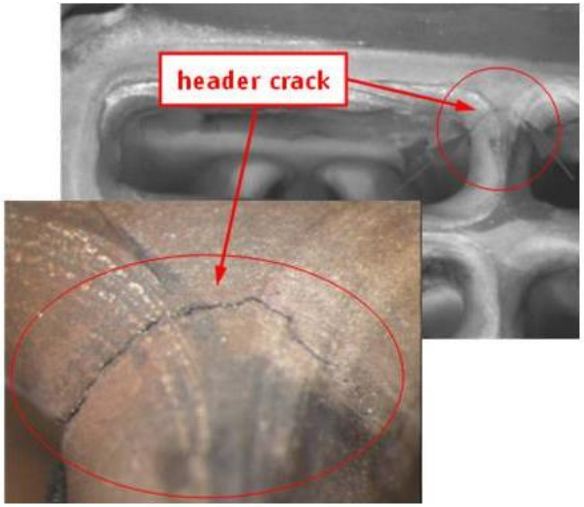
- From the FEMFAT simulation, the most damaged position matches with typical failure location for thermal cycle simulation.



Test results





Thank you !

References

- "Transient CFD Simulation of Exhaust Gas Recirculation coolers for further structural analyses" by Julie Paterson, Stephanie Larpent, Nuria Fernandez, Wolfram Kuhnel, Claudia Lang, Friedrich Brotz, Thomas Heckenberger, SAE paper, 2009-09M-0132