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Life Time Prediction of a Charge Air Cooler using FEMFAT

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Introduction

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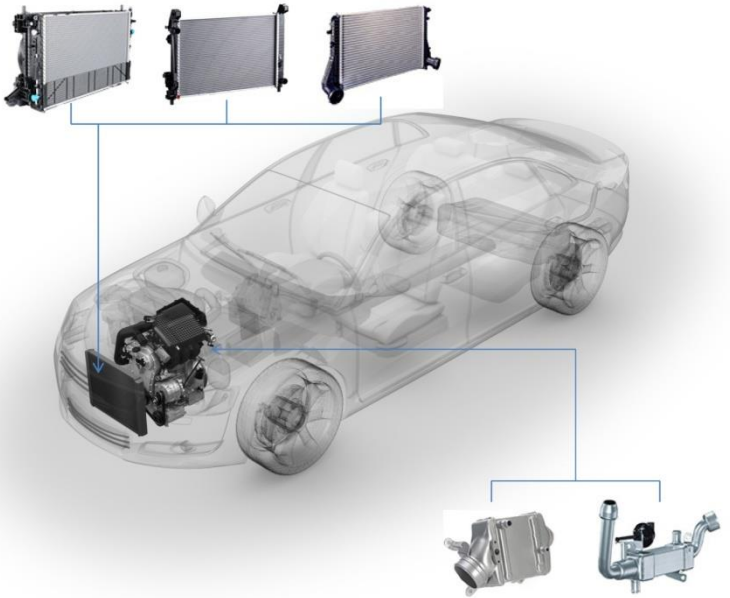
- **Charge air cooler (CAC):**
  - It is a heat exchanger used to transfer heat from compressed charged air into the ambient air.
- **Need:**
  - Charging process is used to increase engine performance.
  - Real compressors increase the pressure and temperature of air, but with a reduction in density
  - Cooling is done to increase the air density again.
- **Benefits:**
  - Increases engine output.
  - Reduces operating temperatures; improves durability.
  - Helps to reduce exhaust emissions (CO, Particulate, NOx).
- **Parts:**
  - Tanks, Core (Headers, Tubes, Fins).
- **Position in vehicle:**
  - On front side of vehicle for direct charge air cooler.
  - On engine or near to engine for indirect charge air cooler.

Direct full-face charge air cooler

Direct compact CAC (with complete module)



Experimentation

1. Leak Test
2. Impact Strength / Drop Test
3. Burst Test
4. Performance Test
5. Pressure Cycle Durability Test
6. Vibration Test
7. **Thermal Cycle Test (TCT)**

Thermal cycle test (TCT) simulation

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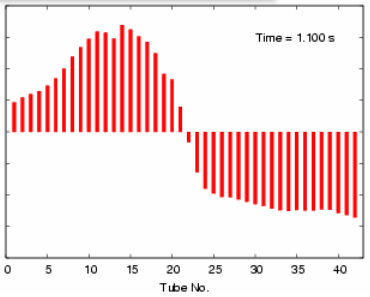
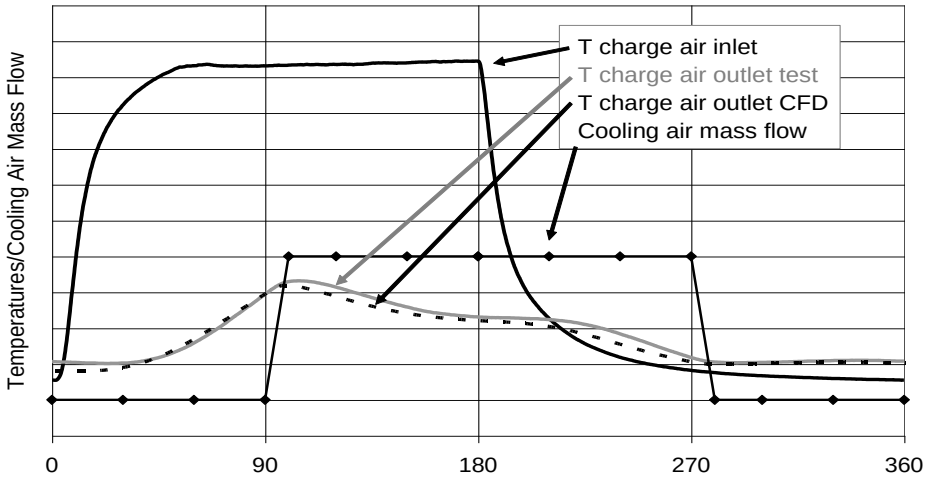
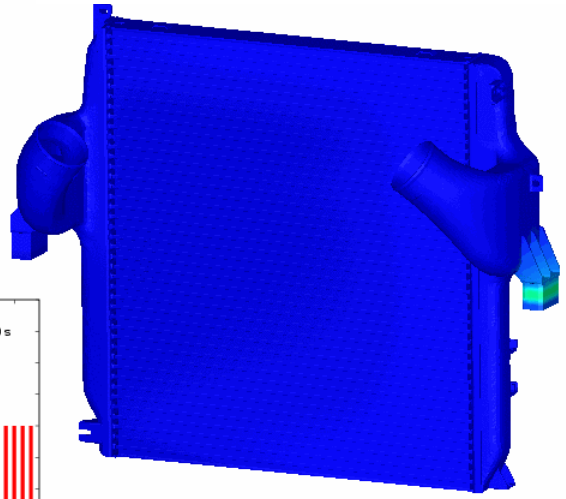
Transient CFD: Simulation of full Test Cycle

Temperature Load Mapping on FE Model

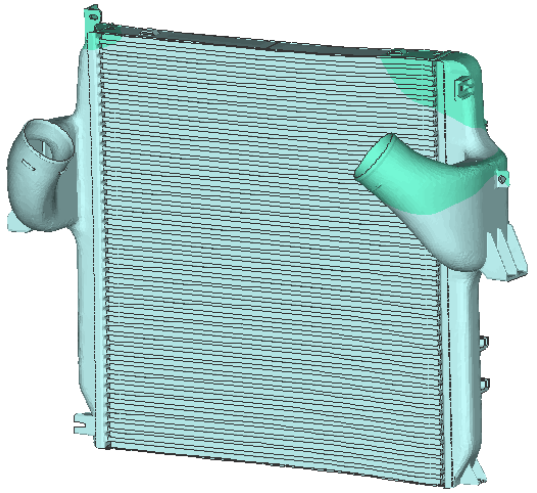
Structural Analysis







CFD ➔ Temperature and flow distribution



FEA ➔ Global deformation & local stress prediction

Need of FEMFAT

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- Limitations in current evaluation:
  - Current approach is limited to obtaining deformation and stress results from linear static analysis.
  - Focus is kept on evaluation of tubes (considering experience from past). Other possible failure locations may get ignored due to this limited scope of evaluation.
  - Difficult to predict life cycles without FEMFAT.

- Comparison approach not always reliable:
  - Deciding a better design based on a comparison between “stress range” of different designs can not be always reliable.

Analysis Overview

- A thermal cycle test was carried out on a simple compact direct CAC.
- While doing simulation, a study was done to check the effect of change in loading and boundary conditions on the results.
- The test conditions were divided into following 3 different scenarios:
  - A: Only thermal load
  - B: Thermal load + pressure load.
  - C: Thermal load + pressure load, use of isolators.
- Scenario “C” represents the conditions as used in test.
- A linear static FE analysis was done for all the three cases.
- After doing stress and deformation evaluation, FEMFAT evaluation was done using TransMAX module.

FEMFAT Workflow

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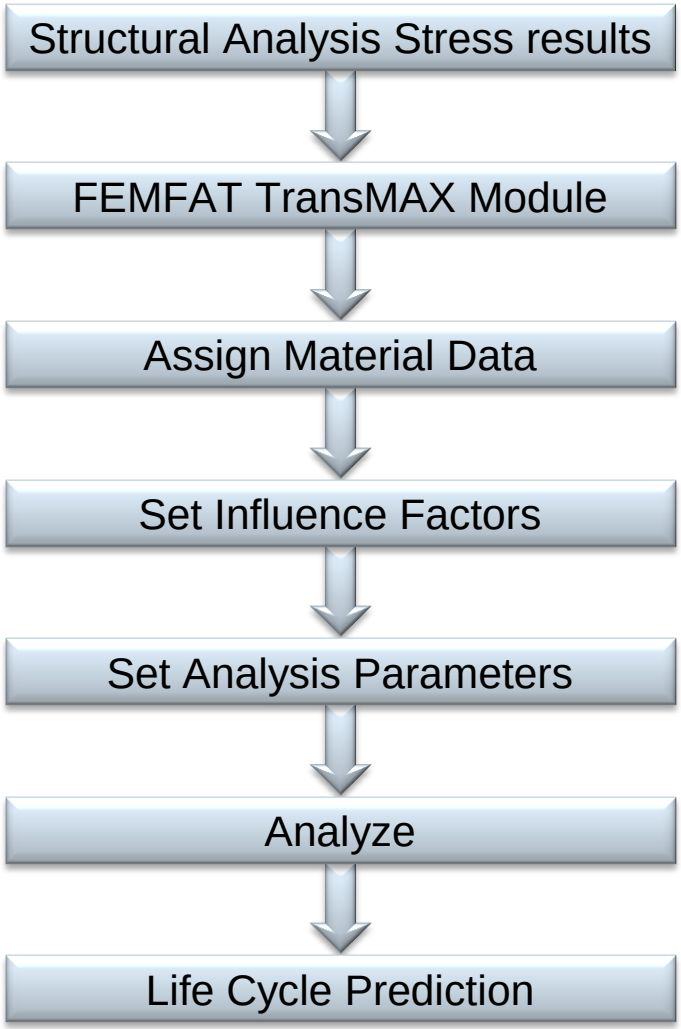
Import the FE model and results for all time steps in FEMFAT



Material from FEMFAT database can be used or can be created with any internal database

- Stress gradient
- Mean stress
- Stress rearrangement

Analysis target is decided
- Damage calculation
- Safety factor calculation

Evaluation

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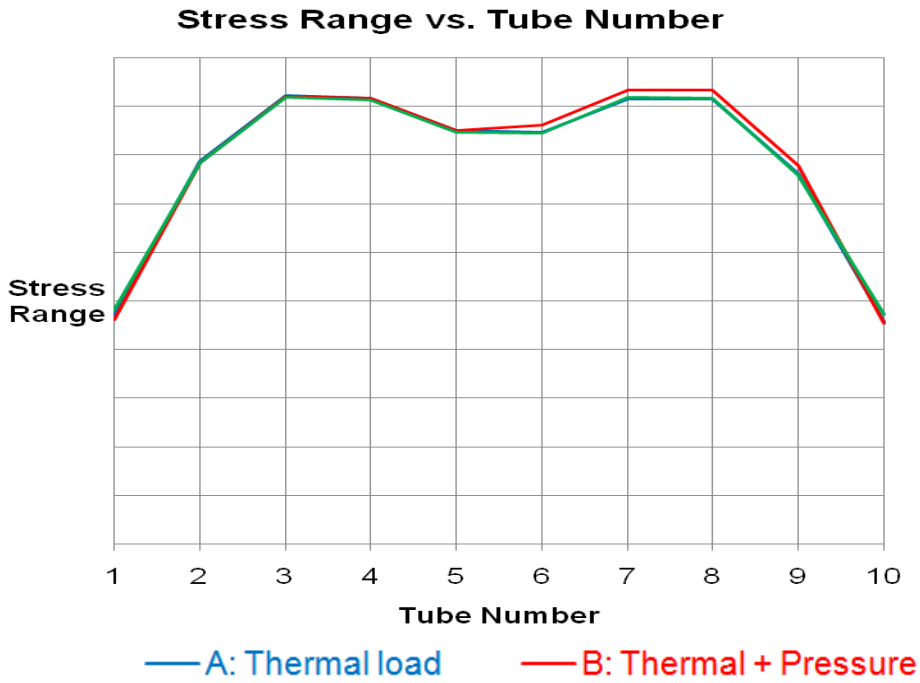

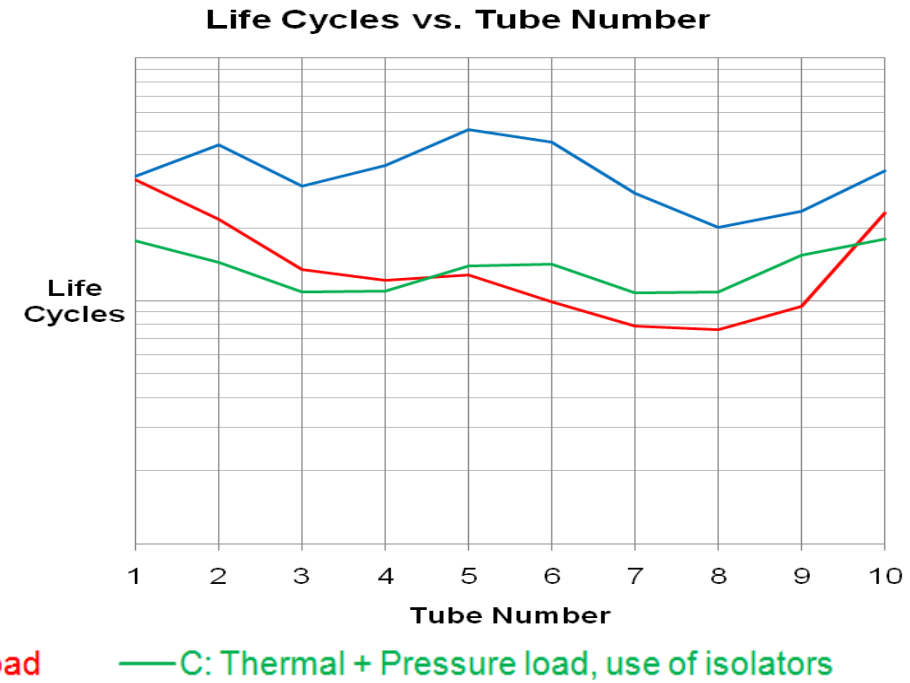

- Same stress range results → Different life cycles
  - In this case the complete cycle (stress variation over time) was shifted to a tensile or compressive zone, keeping the stress range constant.
  - FEMFAT uses “amplitude” and “mean” stress for calculation of life, which was different for each of the case.

Evaluation

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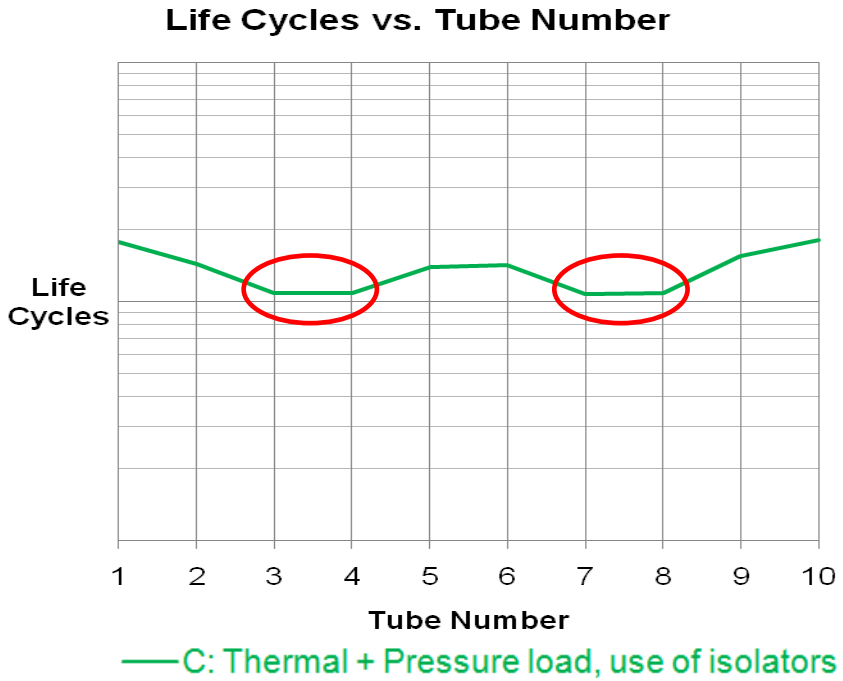

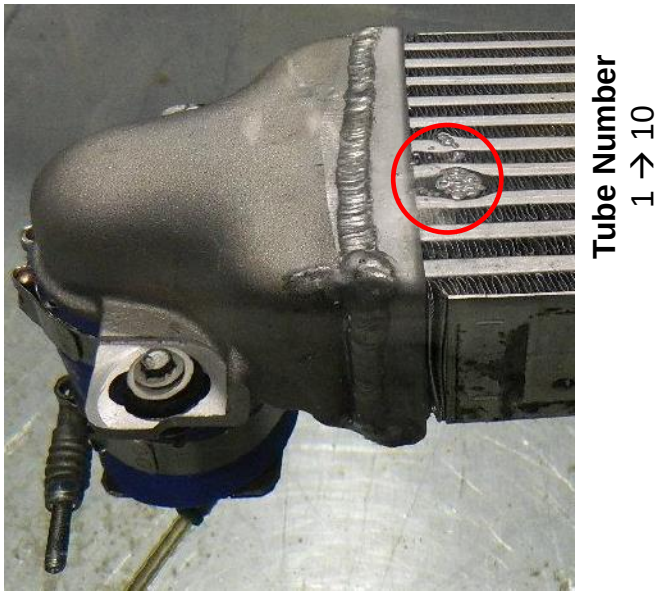

Test Picture

- Validation:
  - Minimum life location predicted by FEMFAT was matching with the test results.
  - But, there was a difference in exact number of life cycles predicted by FEMFAT and as observed in test.

Future Scope

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- Calibration of FEMFAT process
  - Need to work on correlation with test to improve accuracy of life prediction
- Application of FEMFAT
  - Other products such as radiators, iCACs
- Life prediction for plastic tanks

References

1. Brotz, F; Kühnel, W; Chen, Y: Virtual Temperature Cycle Testing of Automotive Heat Exchangers by Coupled Fluid Structure Simulation, SAE, 2008, Paper 2008-01-1210

2. FEMFAT 5.1 User Help Manual

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Thank you!!!

Questions...