

Random vibration analysis of a piston compressor



In my presentation I will address the following topics

Short introduction of the company

- Past and the present of Knorr-Bremse
- Introduction of Engineering Calculations at Knorr-Bremse

Brief overview of (piston) compressors

Random vibration calculation workflow of a piston compressor

- Modeling considerations and simplifications
- Introduction of the used models
- Overview of the FEMFAT Spectral model

Practical use case(s) of the calculation method

- Design modification based on fatigue results

Further improvement directions

- Sine on random modeling research





KNORR-BREMSE



1905

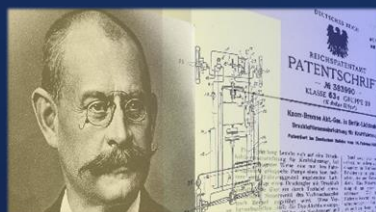
1922

1960

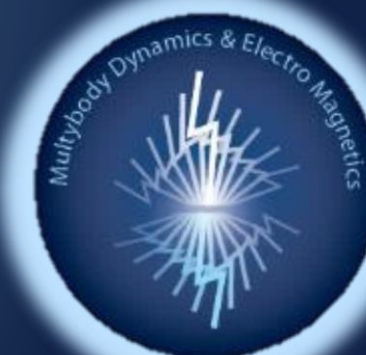
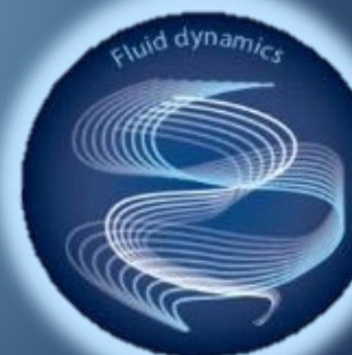
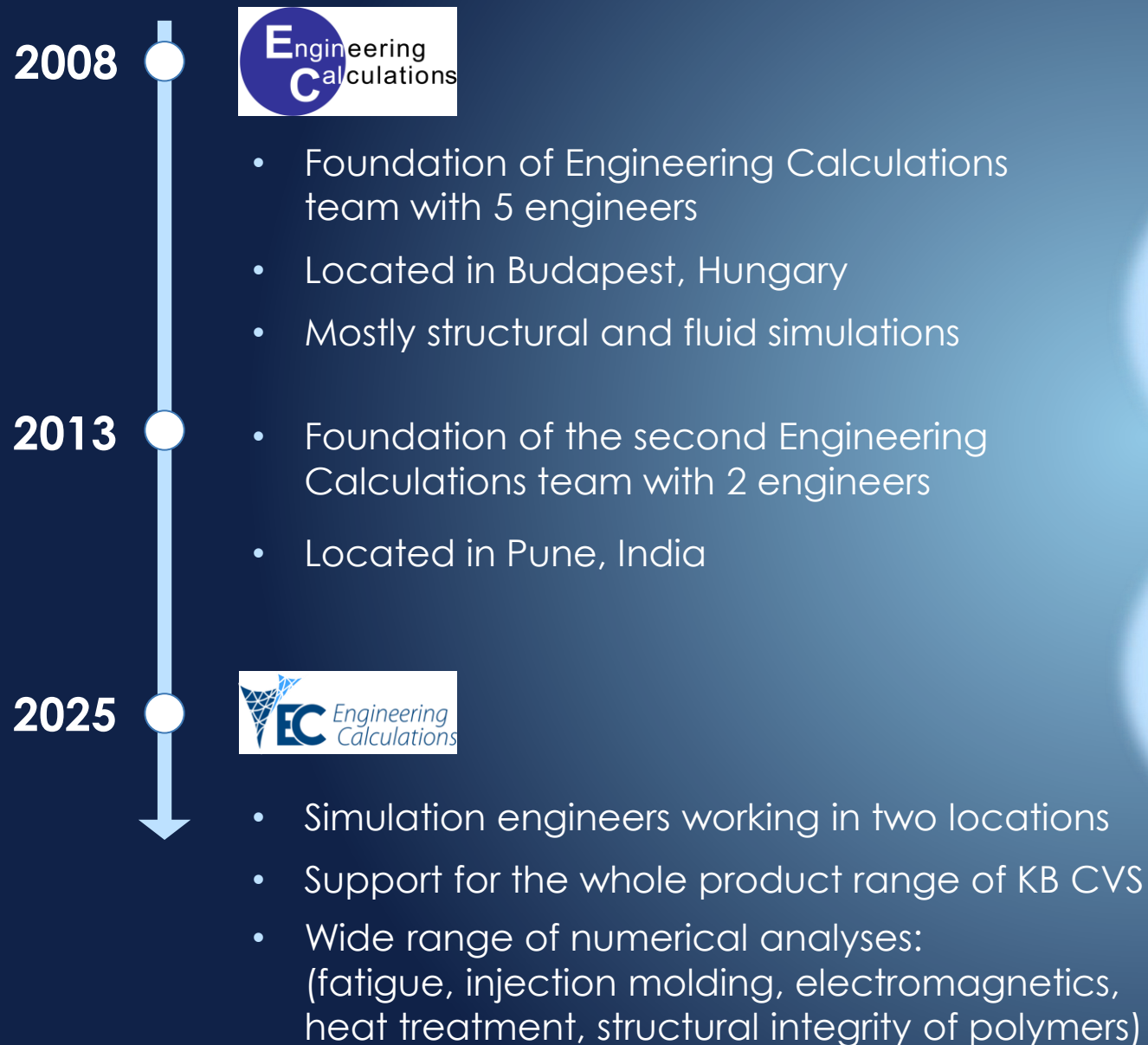
1981

1989

2010

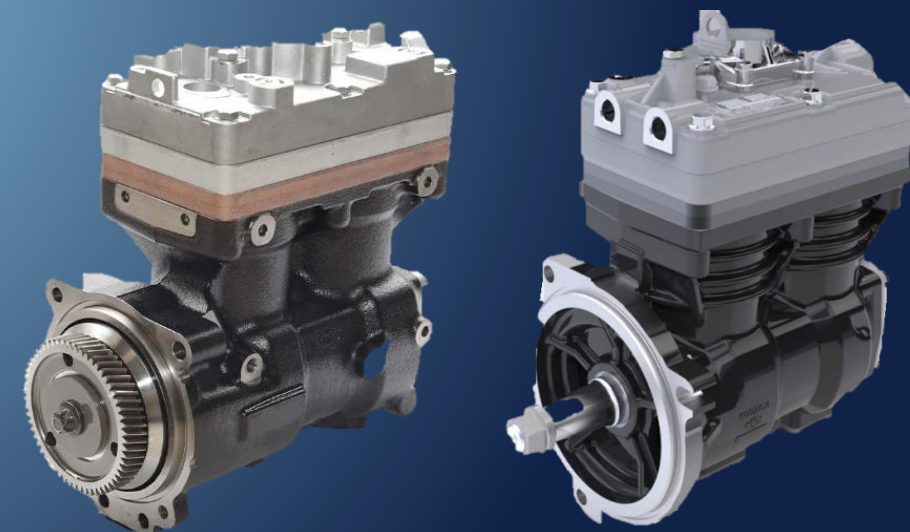
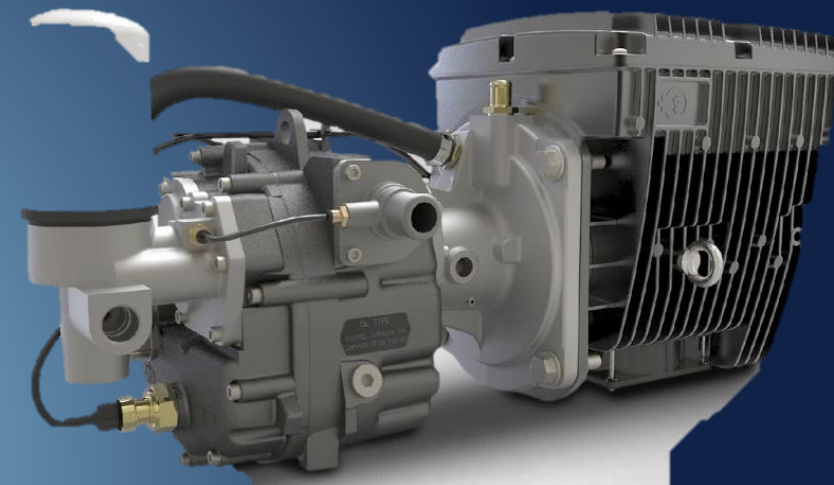


Engineering Calculations introduction



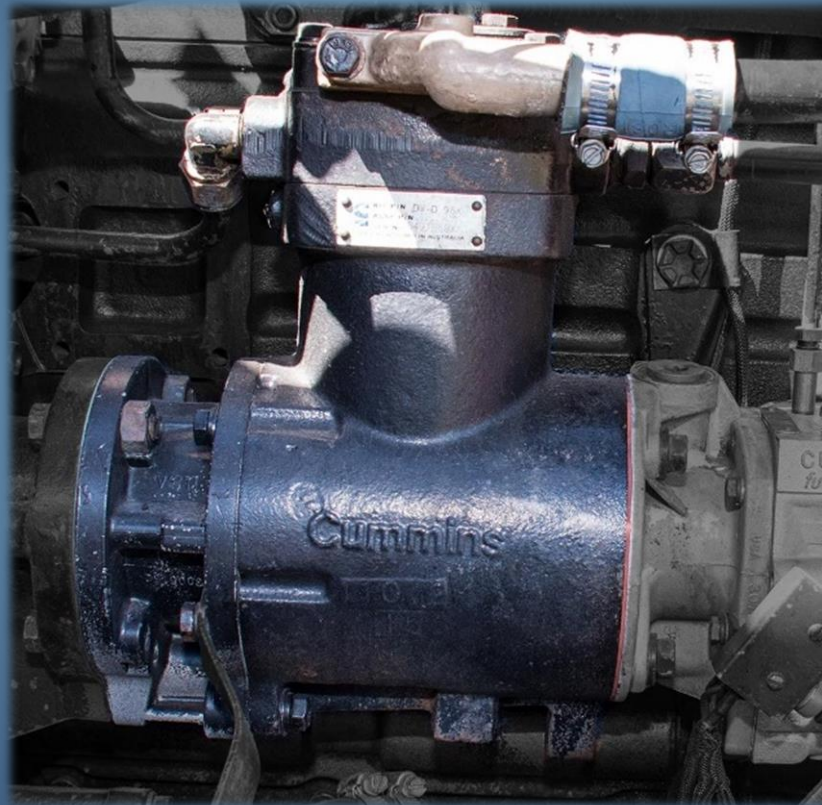
The importance of air compressors throughout the years

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- Converting power into potential energy (pressurized/compressed air)
 - Piston-type compressors – 17th century
 - Electric motor-driven compressors – 19th century
 - Screw and centrifugal compressors
 - Oil-free technology compressors
 - Wide spectrum of industries (automotive, manufacturing, construction, food industry...)



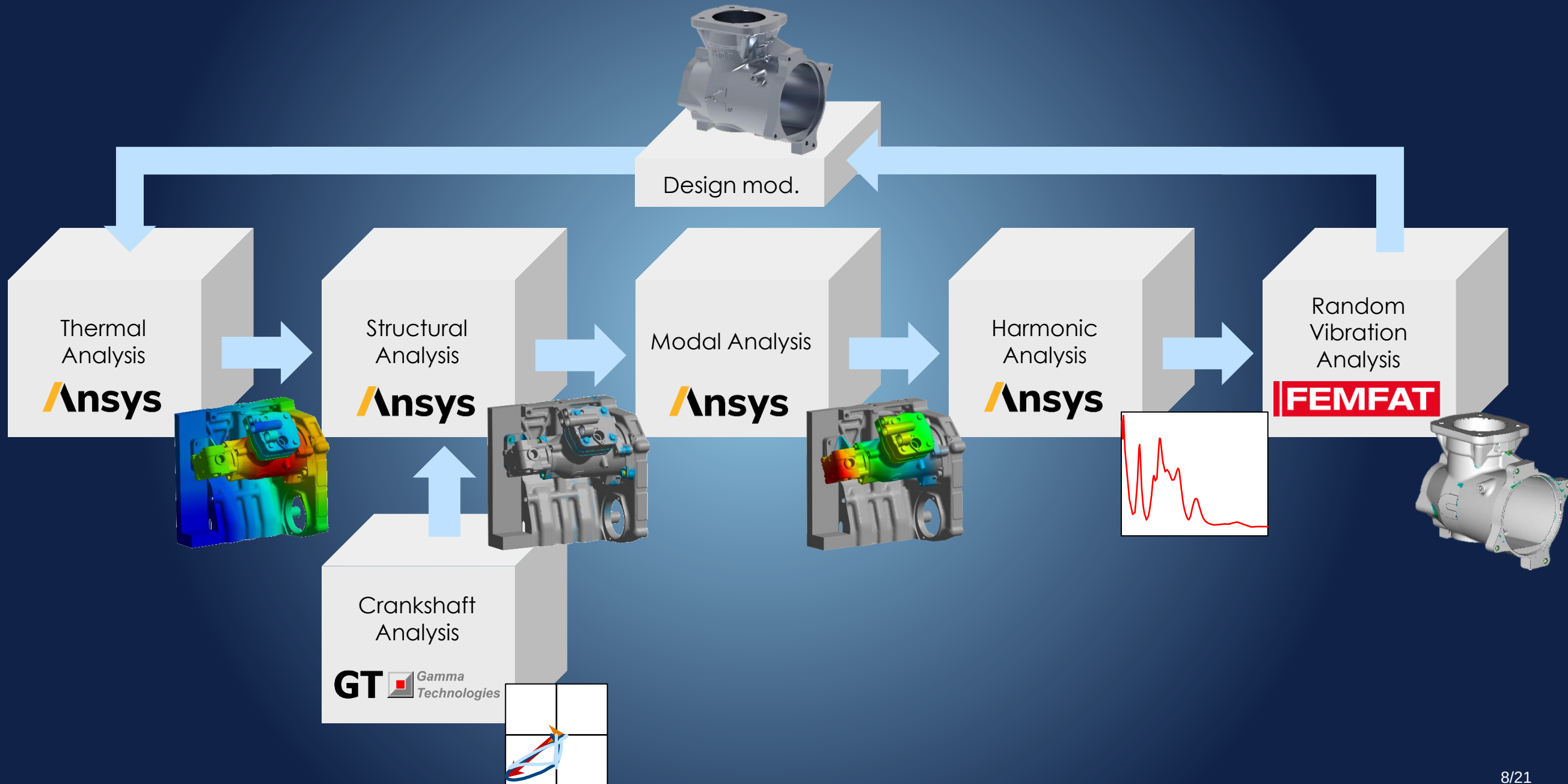
General overview of the service requirements and analysis solutions for a compressor

- Free Air Delivery
- System Pressure
- Operating temperature range
- Operating RPM range
- Energy consumption
- Durability of the components due to operational loads and vibration
- Sealing capability



- Fatigue analyses
- Thermal and thermoshock analyses
- Modal, harmonic and random vibration analyses
- 1D and 3D flow analyses
- Valve investigations
- Lubrication and oil carry-over analyses
- FSI analyses (Fluid-Structure Interaction)

Overview of the calculation workflow



Modeling considerations and simplifications



Operating pressure of the cooling channels



Operating pressure of the discharge circuit



Bearing forces



Internal pressure of the cylinders



Heat distribution (stationary) of the compressor assembly



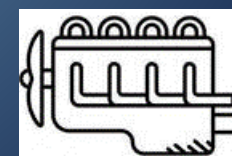
Tightening force of the bolts



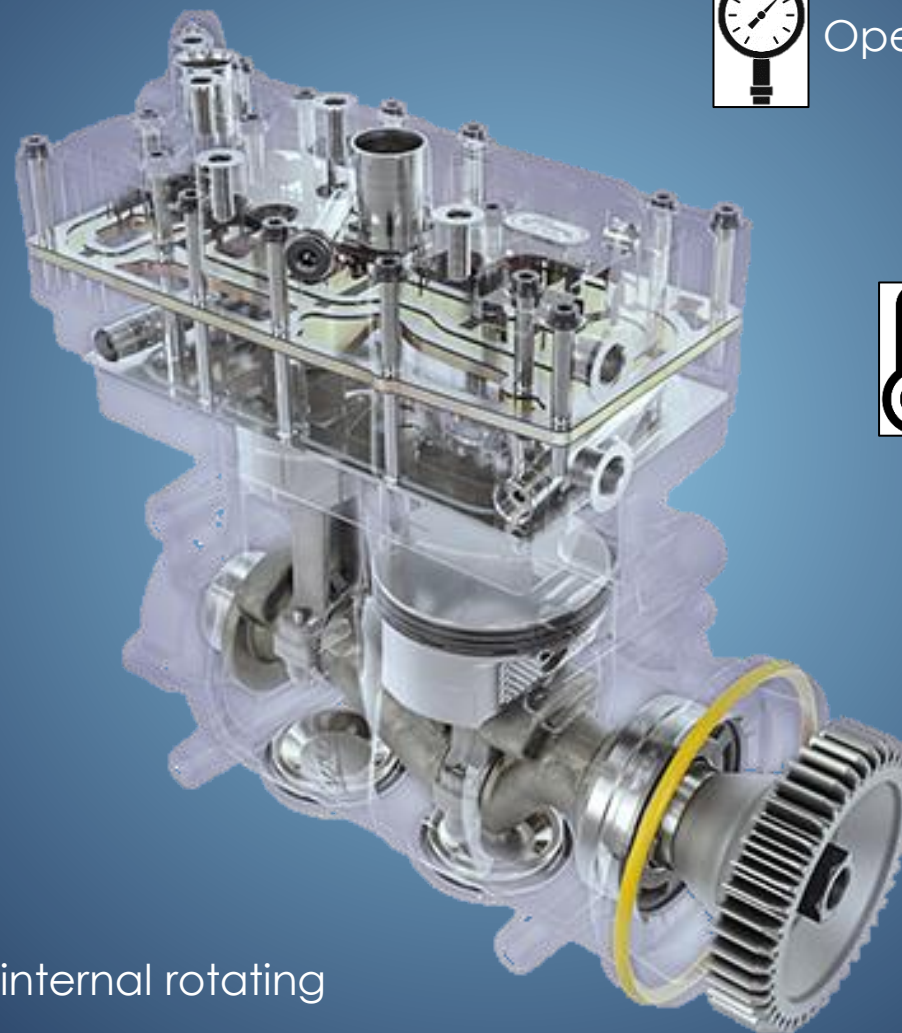
Vibrational excitation coming from the vehicle



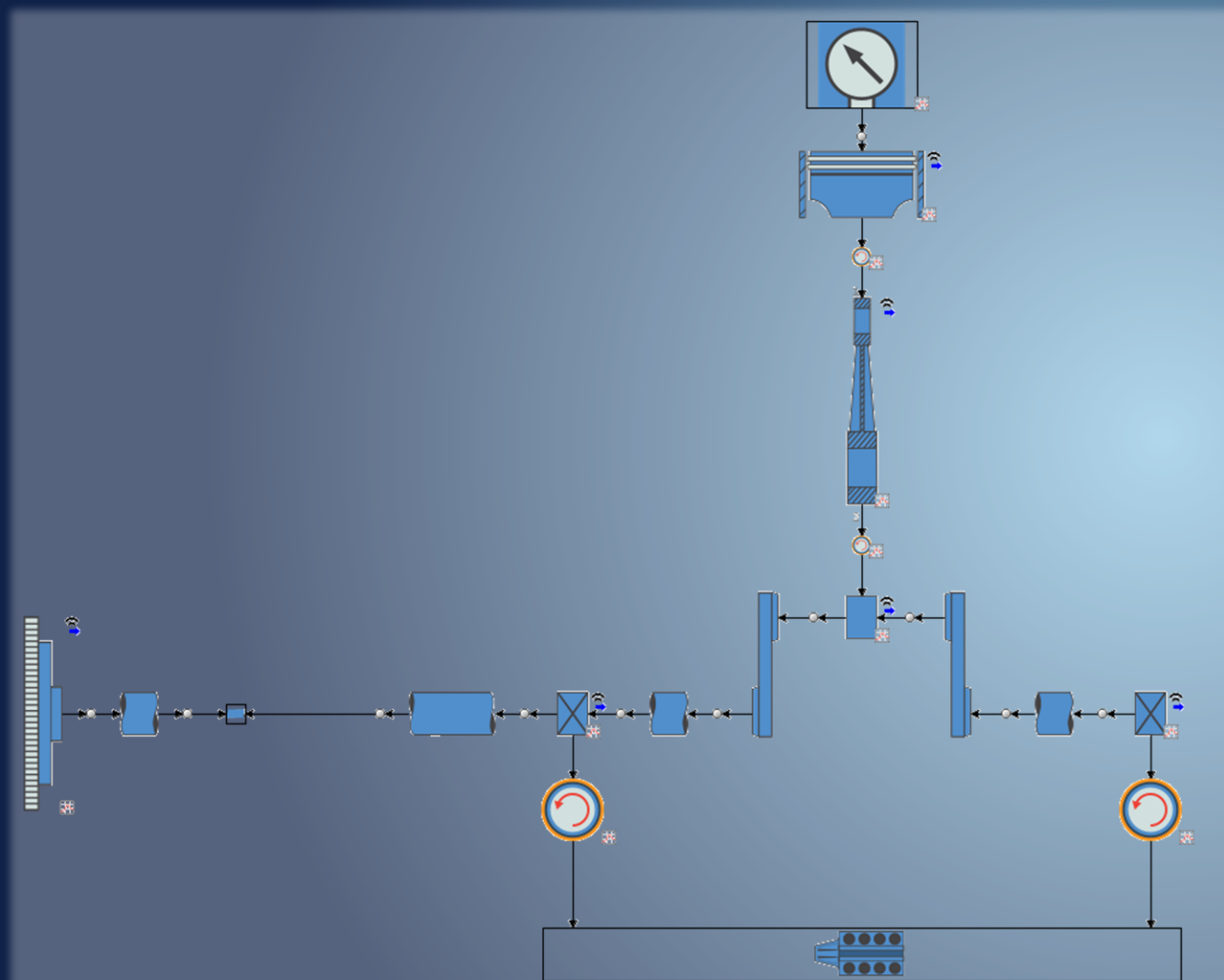
Inertia of the internal rotating components



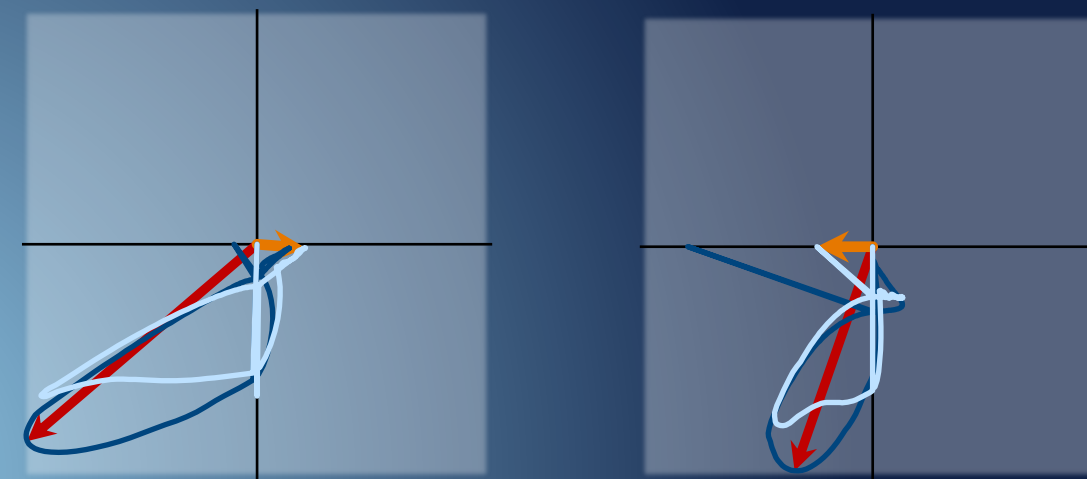
Mounting points on the engine



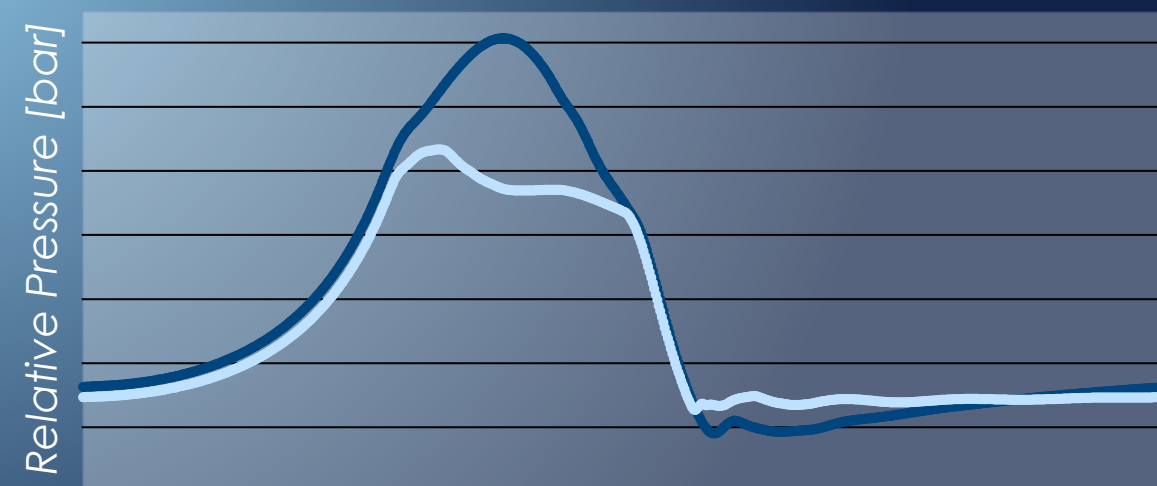
Cranktrain model (GT)



Schematic cranktrain model



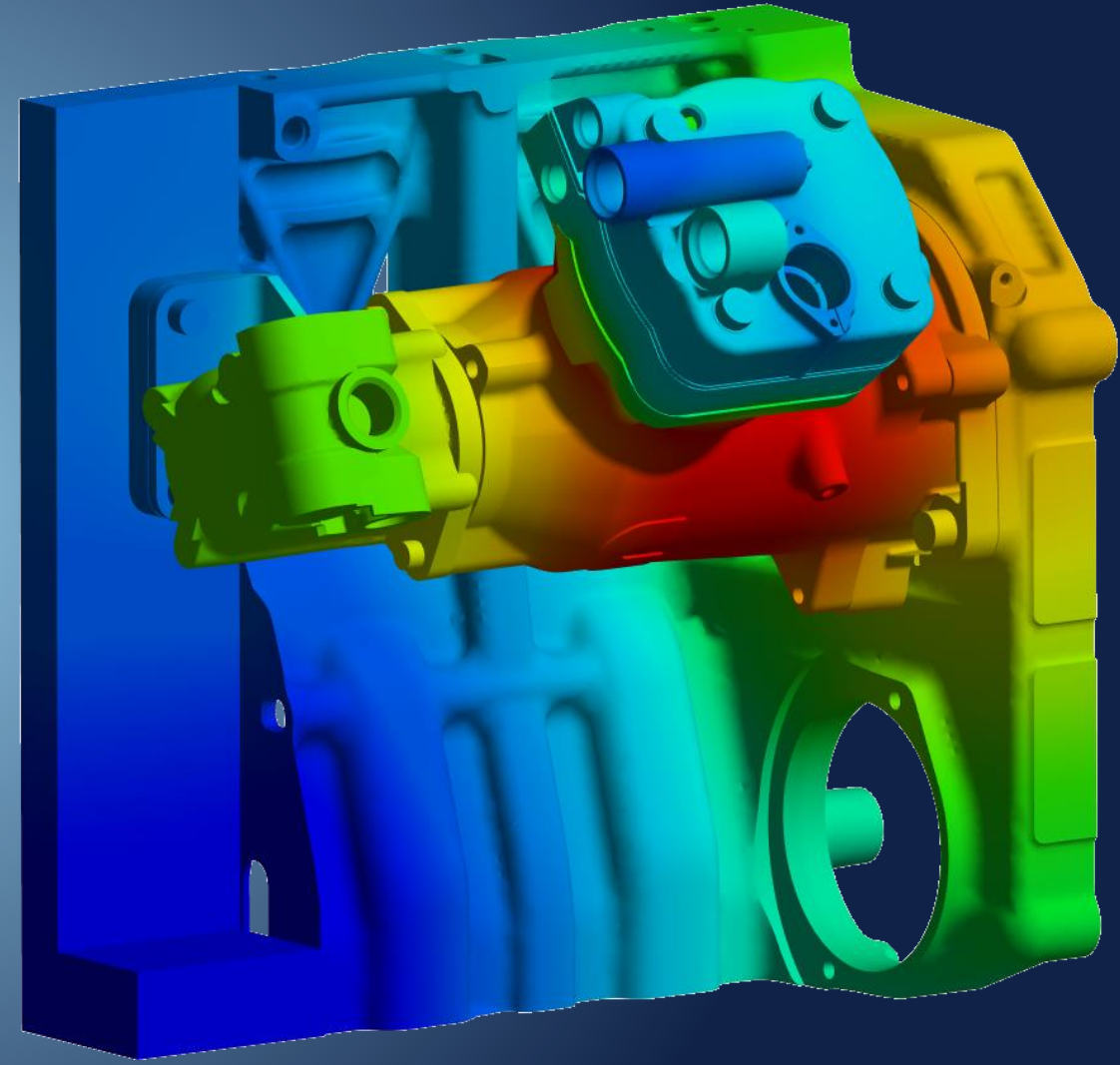
Bearing force components [N]



Crank angle [deg]

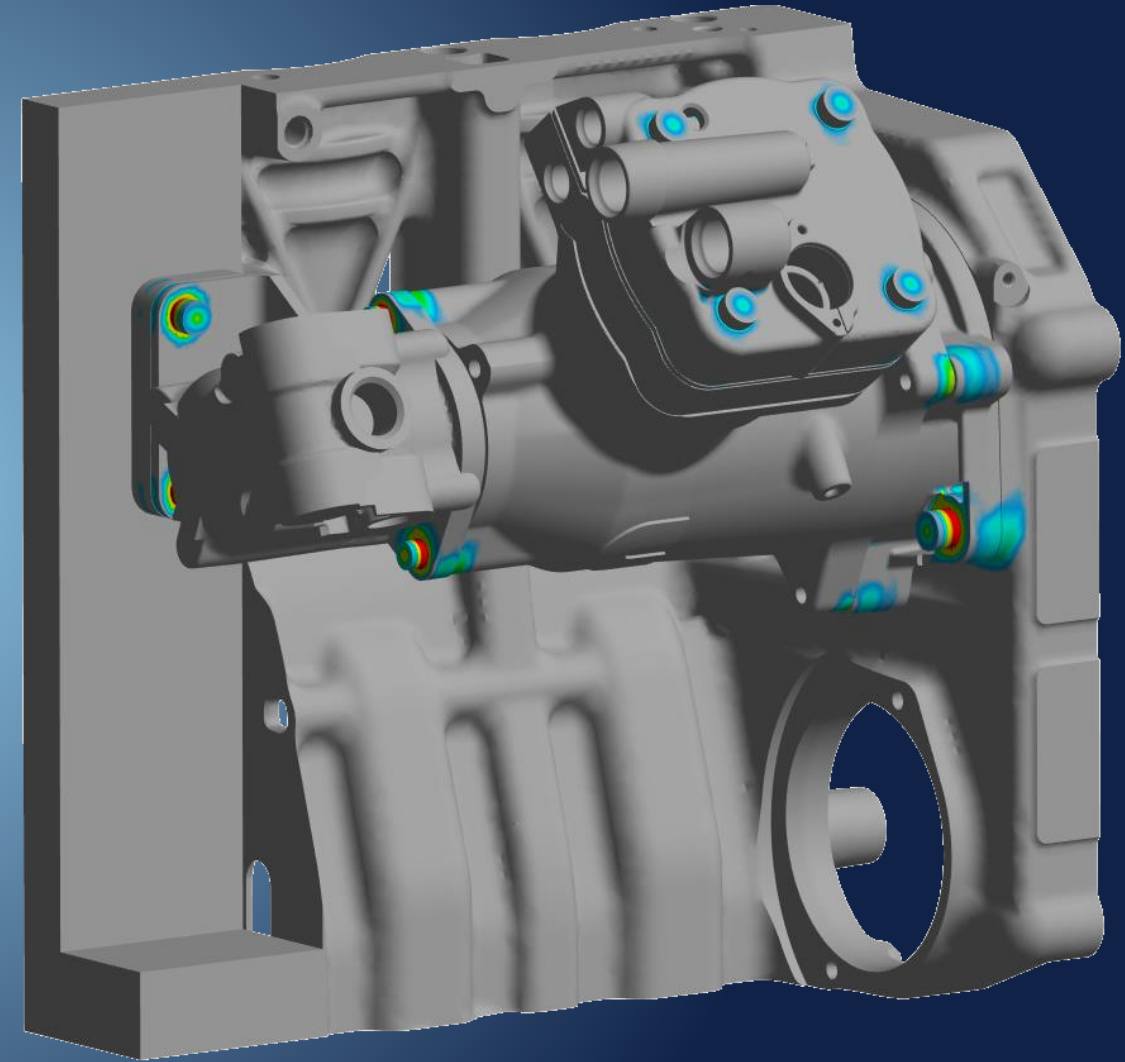
Thermal model (ANSYS)

- Ambient air
- Cooling channels
- Intake channels
- Discharge circuit
- Cylinder wall
- (Lubricant etc.)



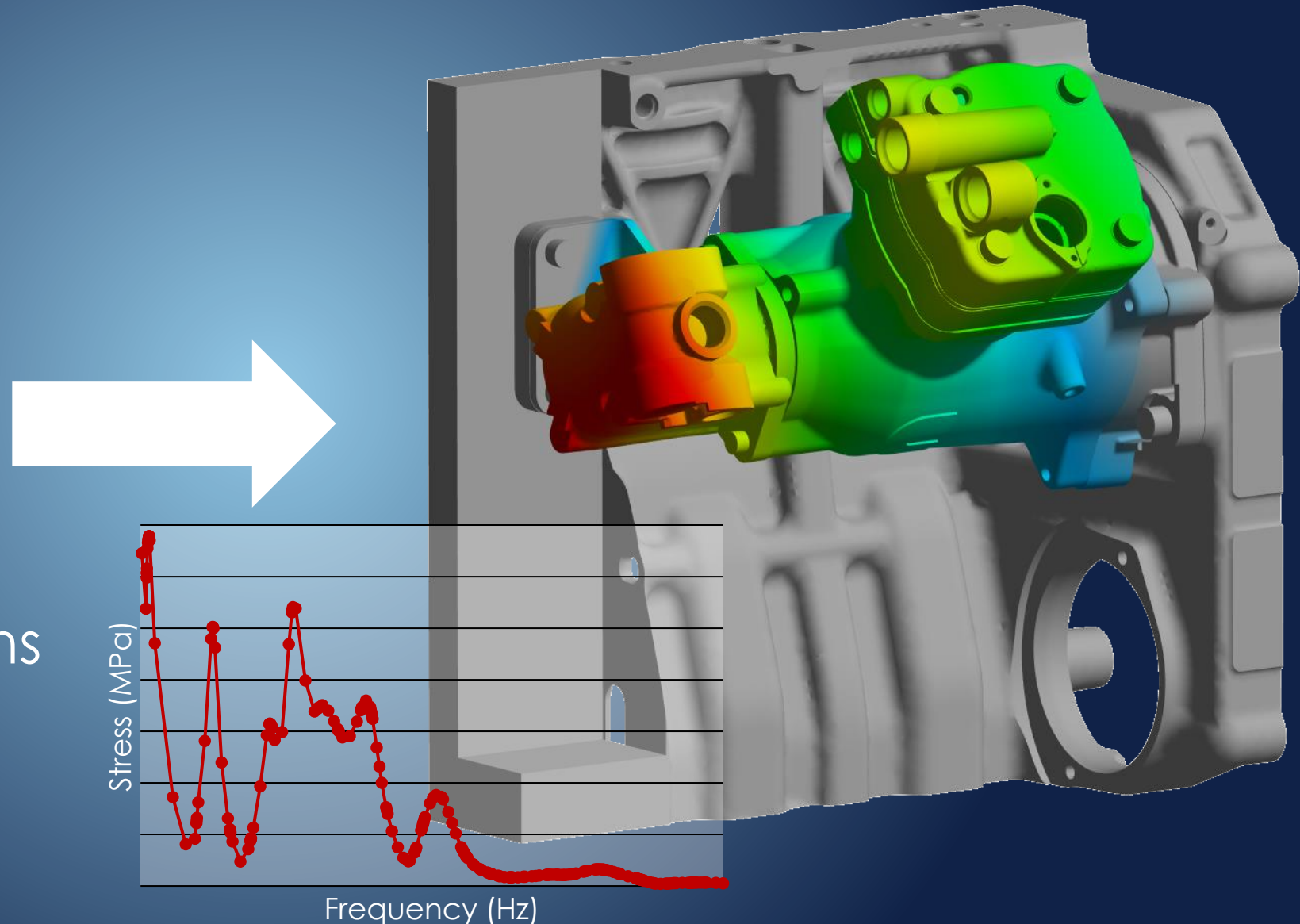
Structural model (ANSYS)

- Heat expansion
- Cooling channel pressure
- Discharge circuit pressure
- Gravity
- Bolt tightening
- (Bearing forces etc.)



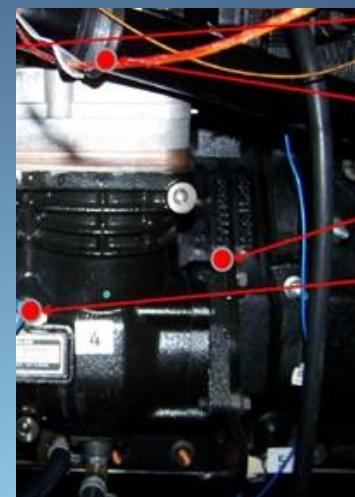
Modal and Harmonic models (ANSYS)

- Calculate eigenmodes for 1,5x range of PSD excitation range
- Create the transfer functions for all directional excitations

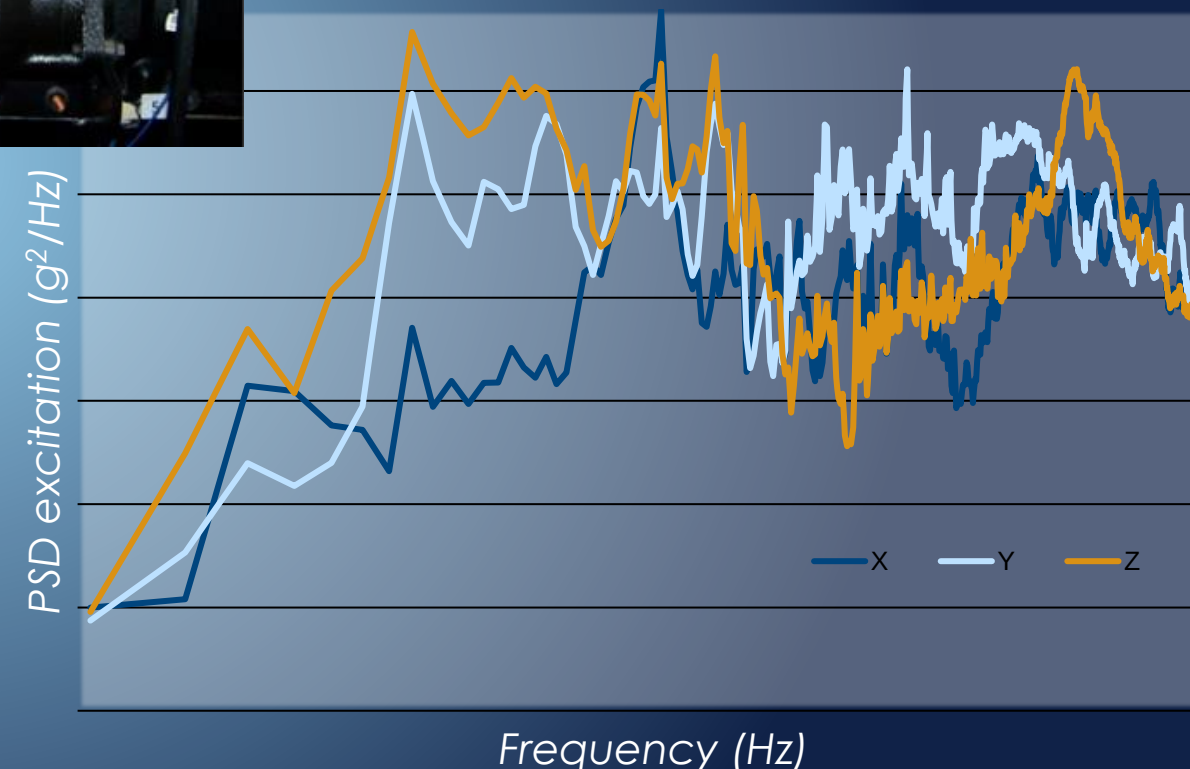


FEMFAT Spectral model

- Import the modal stresses
- Import the transfer functions
- Import the constant stresses
- Define the PSD excitation profile and duration time
- Consider the effect of temperature distribution
- Consider the effect of surface roughness

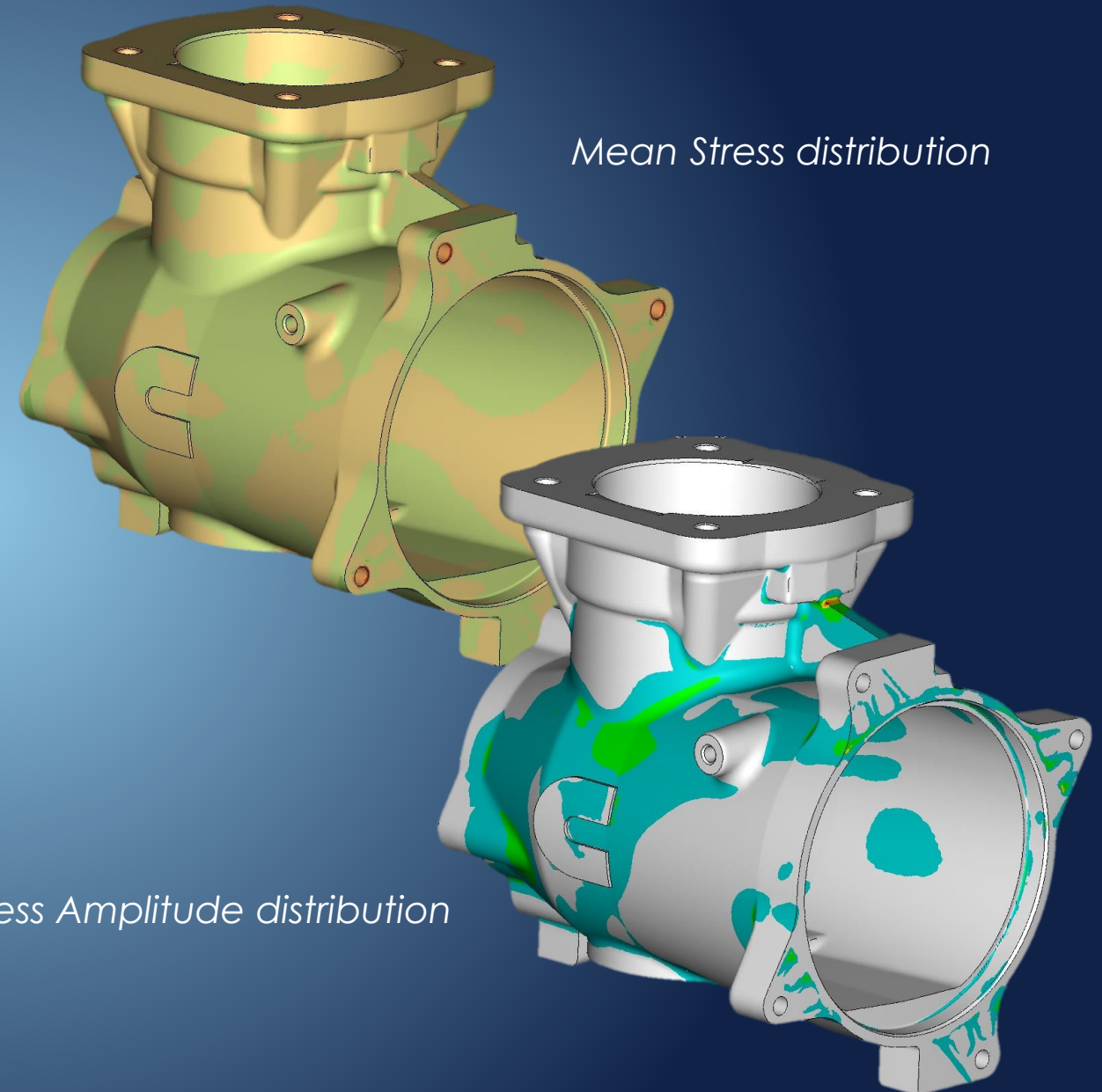


Example of measurement points on the compressor for the PSD excitation profile

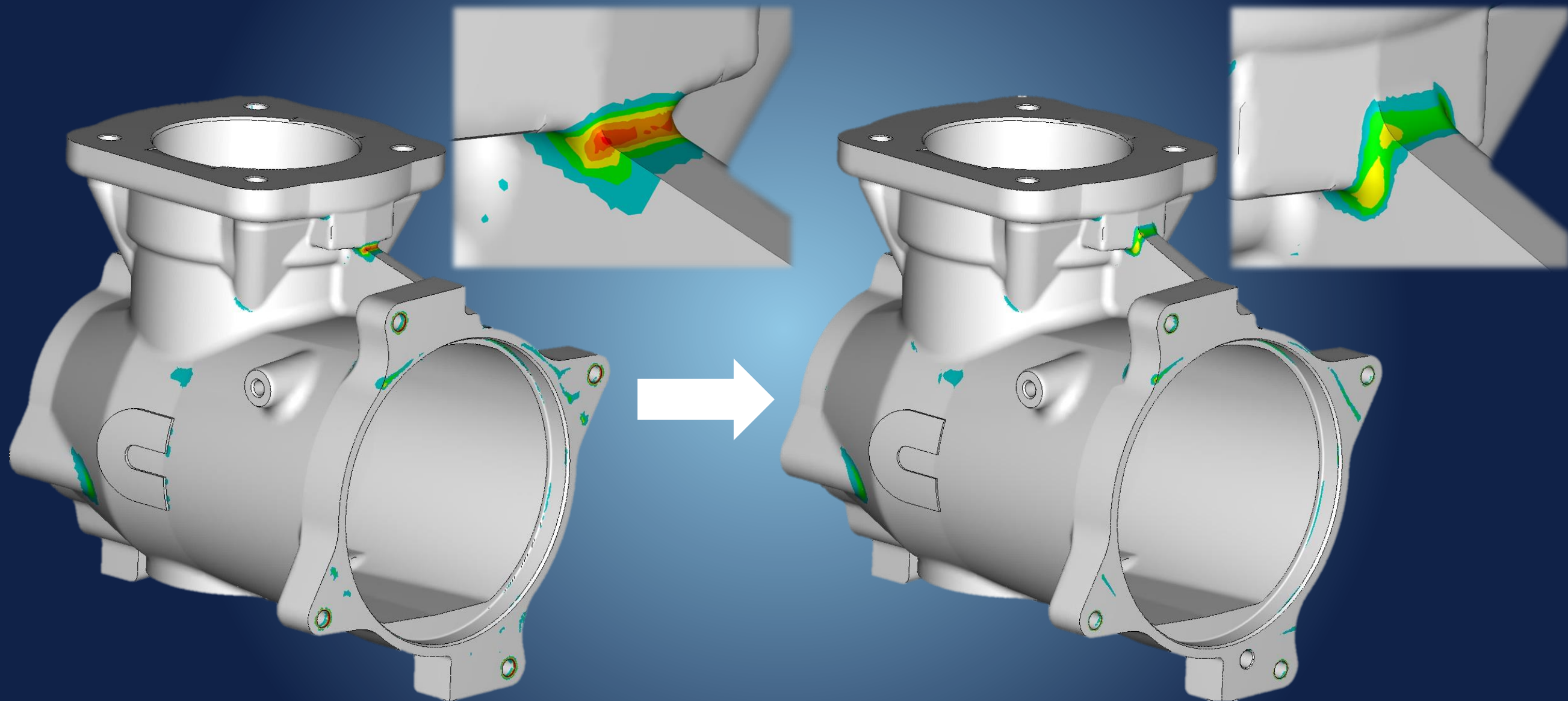


FEMFAT Spectral model

- Create calculation for the required excitation directions
- Combine the results of the individual excitation calculations and calculate damage

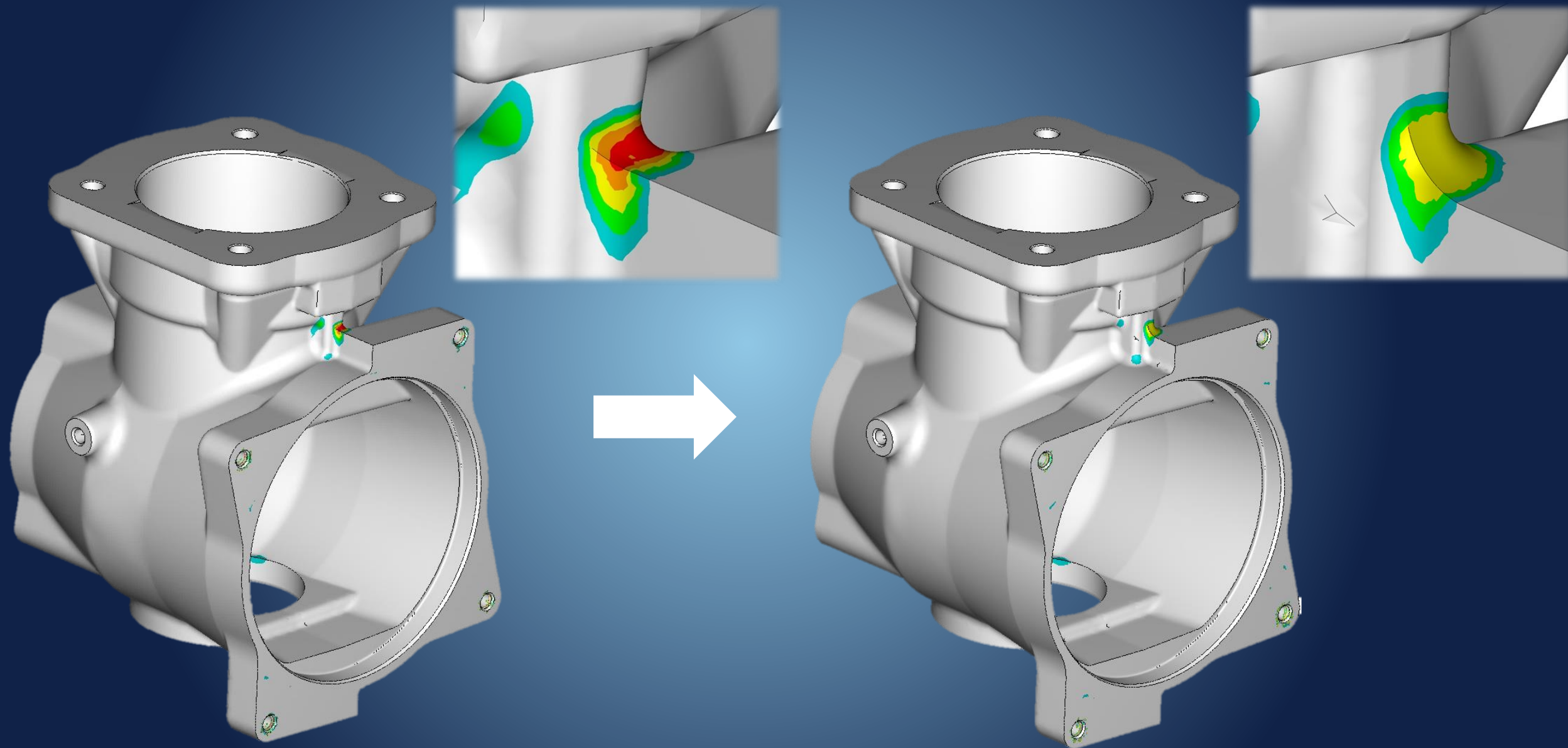


Design modification based on fatigue results



Accumulated Damage distribution

Design modification based on fatigue results



Accumulated Damage distribution

Further improvement directions

Mechanical modeling considerations

- Uncertainties coming from assembling process (compressor to engine)
- Material defects/pores in the casting
- Investigation under operating conditions (Sinusoidal excitation coming from the rotating/moving components)
- Considering the crankshaft in the model
 - Stiffening effect of the crankshaft
 - Uncertainties regarding the tolerance field



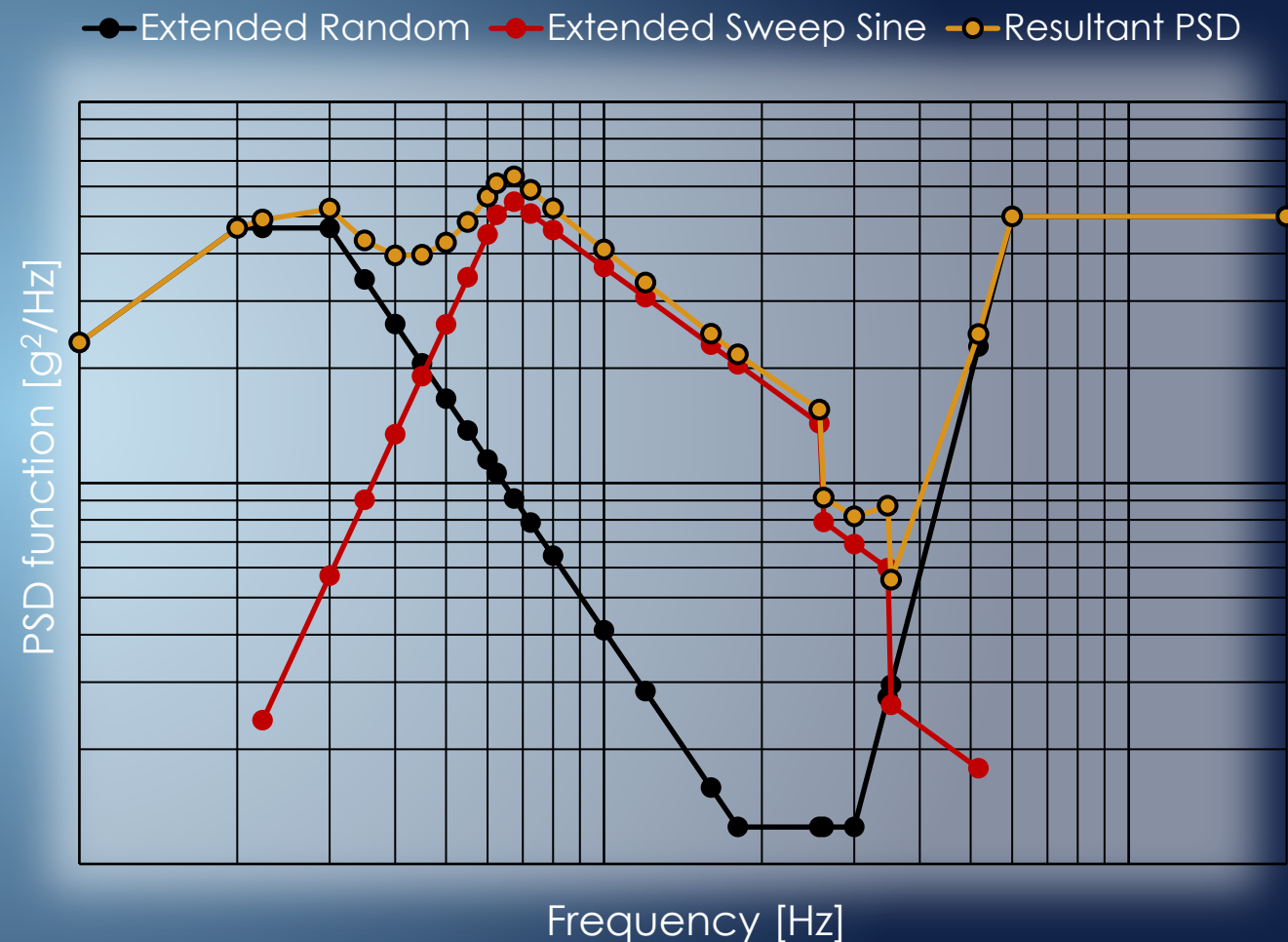
Mathematical modeling considerations

- Calculations with reduced eigenmode number
- Considering the impact of frequency spacing on the damage calculation
- Calculating the aggregate resultant damage coming from the harmonic and random excitation

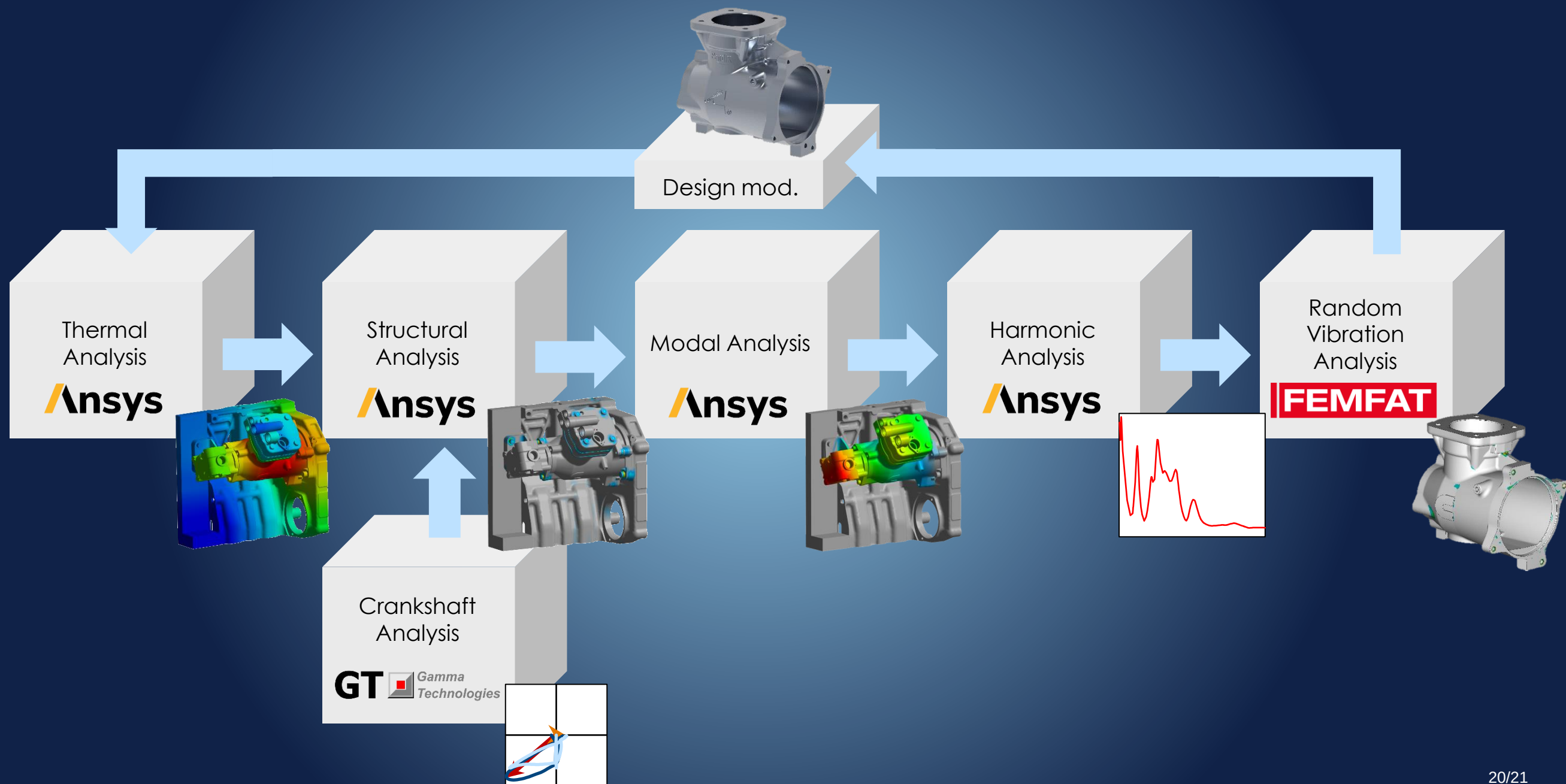
Sine on random modeling research – open questions

- The loads (bearing forces and cylinder pressure) can be calculated with the GT-model. These could be introduced as harmonic excitations on the compressor model.
- The remaining question is the aggregation/combination of the different excitation profiles. There are two solutions for this:
 - Summary of the PSD profiles and evaluation of the damage based on the combined profile.
 - Evaluation of the harmonic and the random vibrational excitations and the summary of these damages.

(Both methods call for further evaluation methods/models in FEMFAT.)



Overview of the calculation workflow



Thank you for your attention!

