

METHOD DEVELOPMENT FOR THE FATIGUE LIFE OF ENGINE HOUSINGS



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AGENDA

- Problem
- Dynamic approach
- Structure of the model
- Excitation data
- Calculation steps / time
- Results
- Summary and outlook



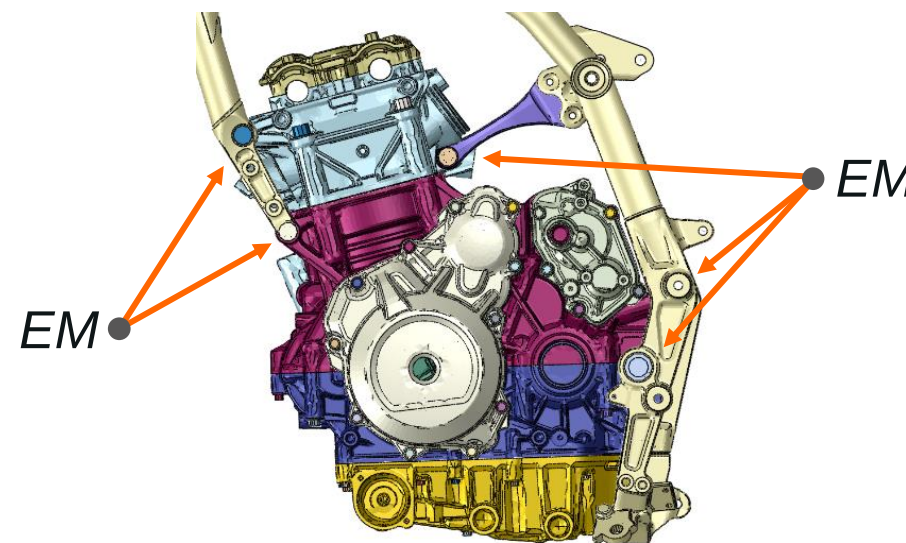
PROBLEM

DEFINITION

- Low safety factors at the engine mounts
- No failure at the engine mountings in reality
 - Evaluation of endurance vehicles
 - Strength tests

APPROACH

- Investigations on the current calculation approach (quasi-static) for fatigue life simulation
- Comparison with a dynamic approach



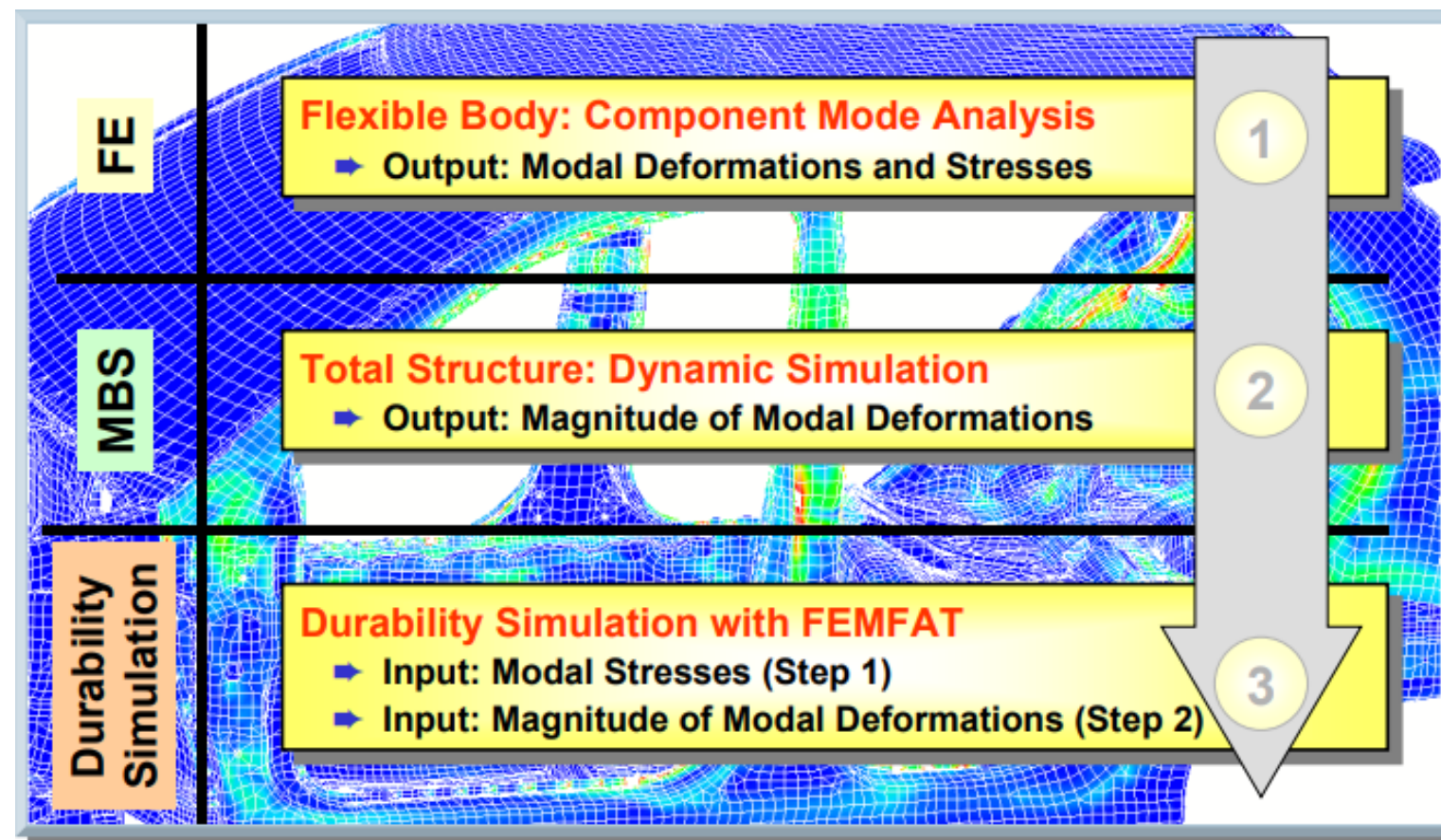
Problem



DYNAMIC APPROACH

FOUNDATION OF THE DYNAMIC METHOD

Dr. P. Fischer, W. Witteveen: *Integrated MBS-FE-Durability Analysis of Truck Frame Components by Modal Stresses* [1]

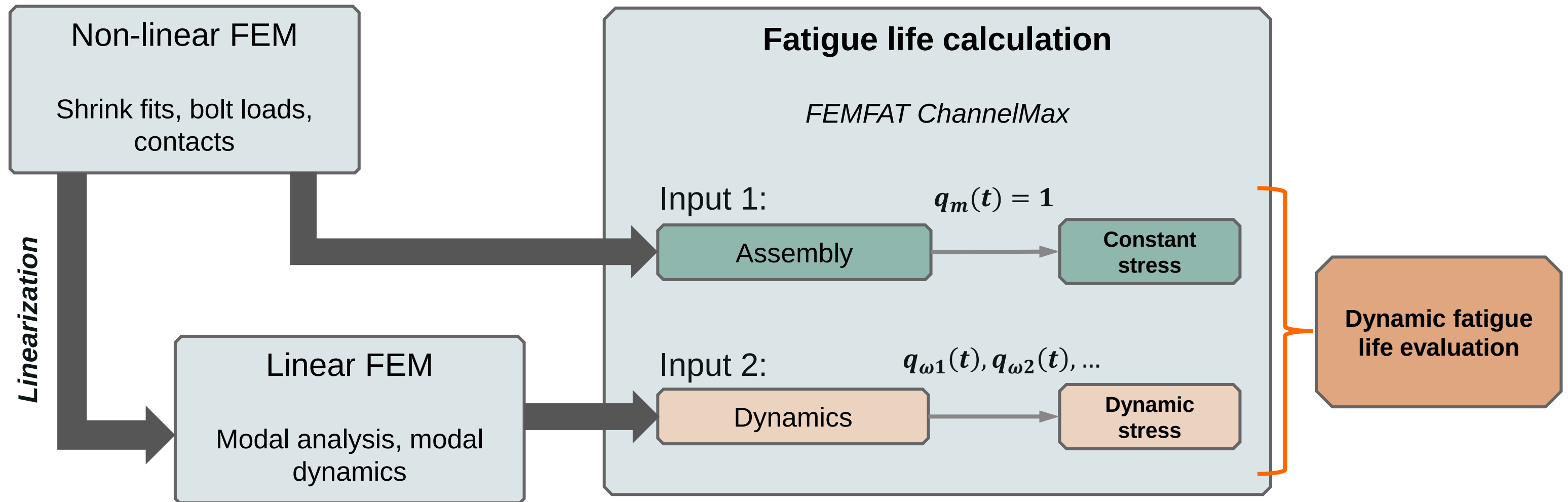


Implementation of the methodology
in *ABAQUS* with an overall vehicle model

Dynamic approach



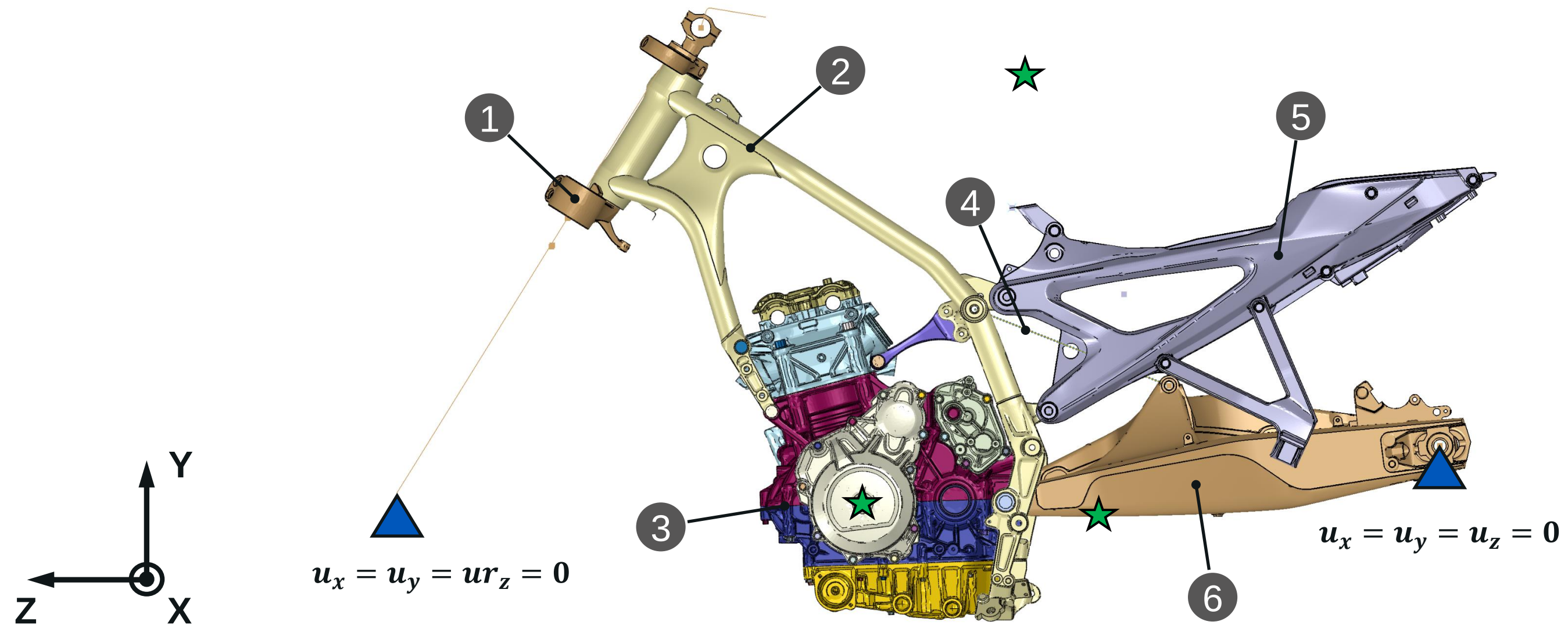
DYNAMIC APPROACH FLOW CHART



Dynamic approach



STRUCTURE OF THE MODEL OVERVIEW



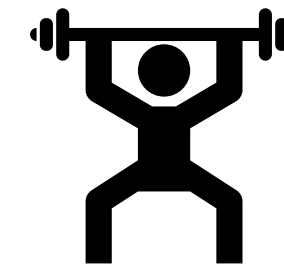
Structure of the model



STRUCTURE OF THE MODEL PROPERTIES

- Substructures
 - CMS-Condensation (Retained Eigenmodes until 1000 Hz)
- Damping
 - Critical damping fraction [2]
- Mass points for the missing engine parts
- A total of 3 173 812 Nodes
 - Without mass points, substructures.. > 8 000 000 Nodes

Structure of the model



Big problem size



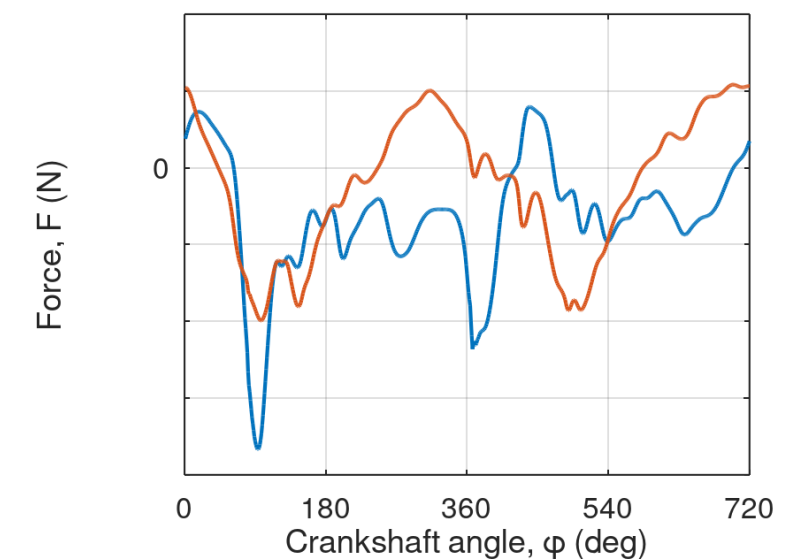
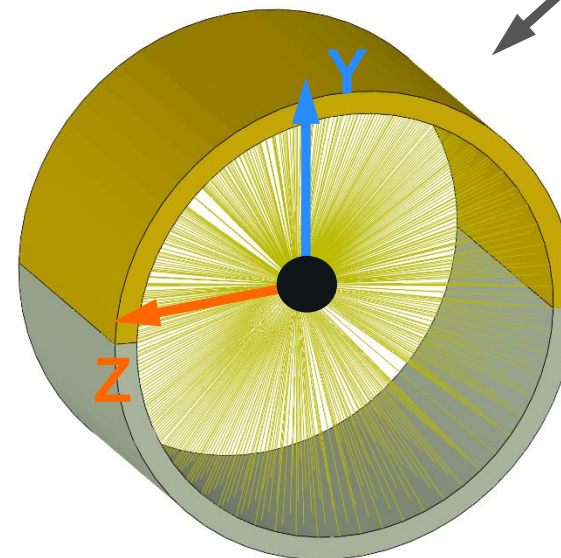
**Dynamic implicit calculation impossible
with existing model size**

EXCITATION DATA

MBS SYSTEM

- Simple MBS for the reaction forces
 - No overall engine movement in the MBS
- Output at 10000 RPM
 - Assumption: Constant time increment for each degree
 - Modal dynamics procedure possible

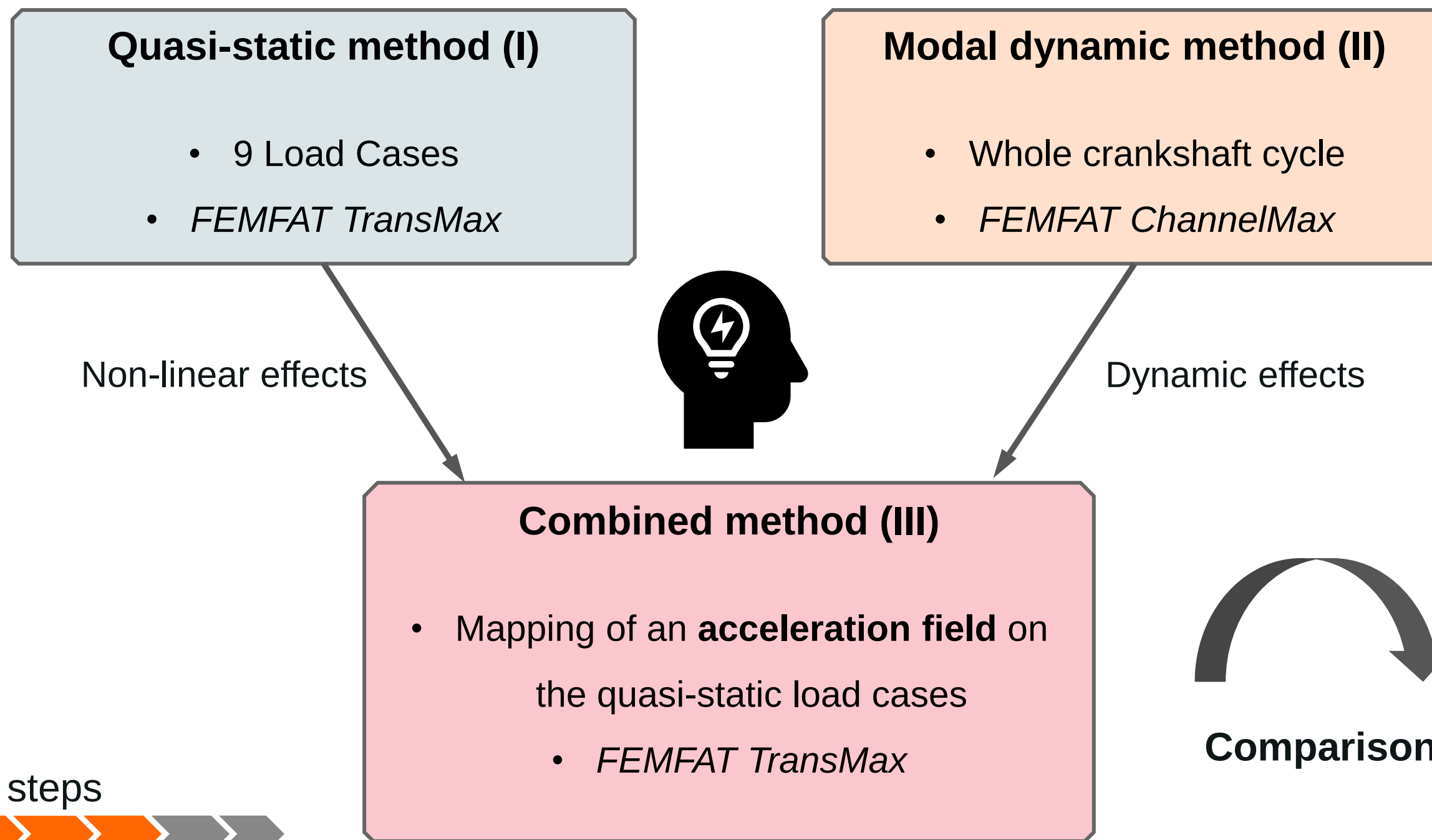
Gas forces (both cylinders)
 Piston side forces
 Main bearings
 Balancer shaft bearings
 Input shaft bearings
 Output shaft bearings



Excitation data



CALCULATION STEPS OVERVIEW



Calculation steps



CALCULATION STEPS

CALCULATION TIME

- Quasi-static assembly steps

$t_1 \approx 30\ h$

- Modalanalysis

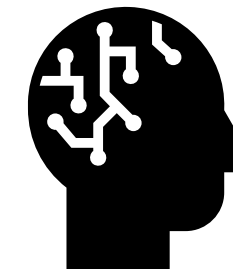
$t_2 \approx 3\ h$

- Modal Dynamics

$t_3 \approx 1\ h$

- Fatigue life calculation

$t_4 \approx 1\ h$



Dynamic simulation in 4h done (16 Cores, 1 GPU)

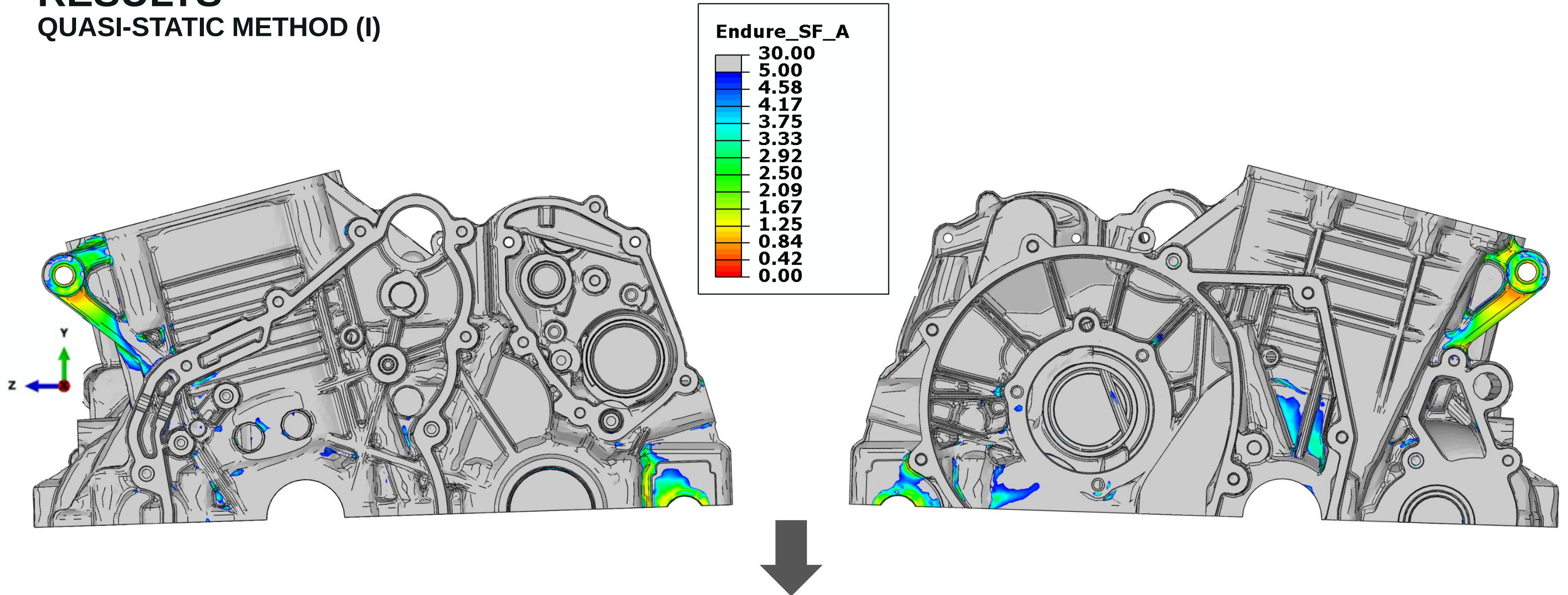
71 Modal stresses with modal coordinates

Calculation steps



RESULTS

QUASI-STATIC METHOD (I)



Engine housing has limited fatigue life

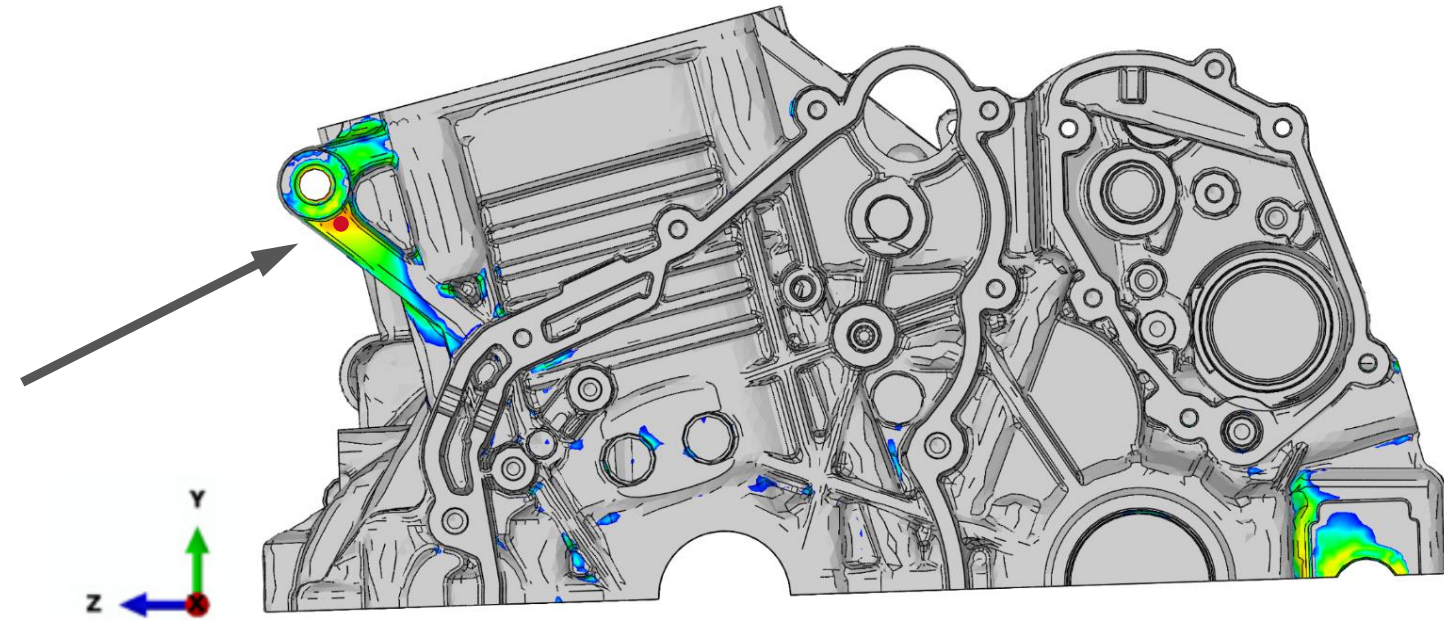
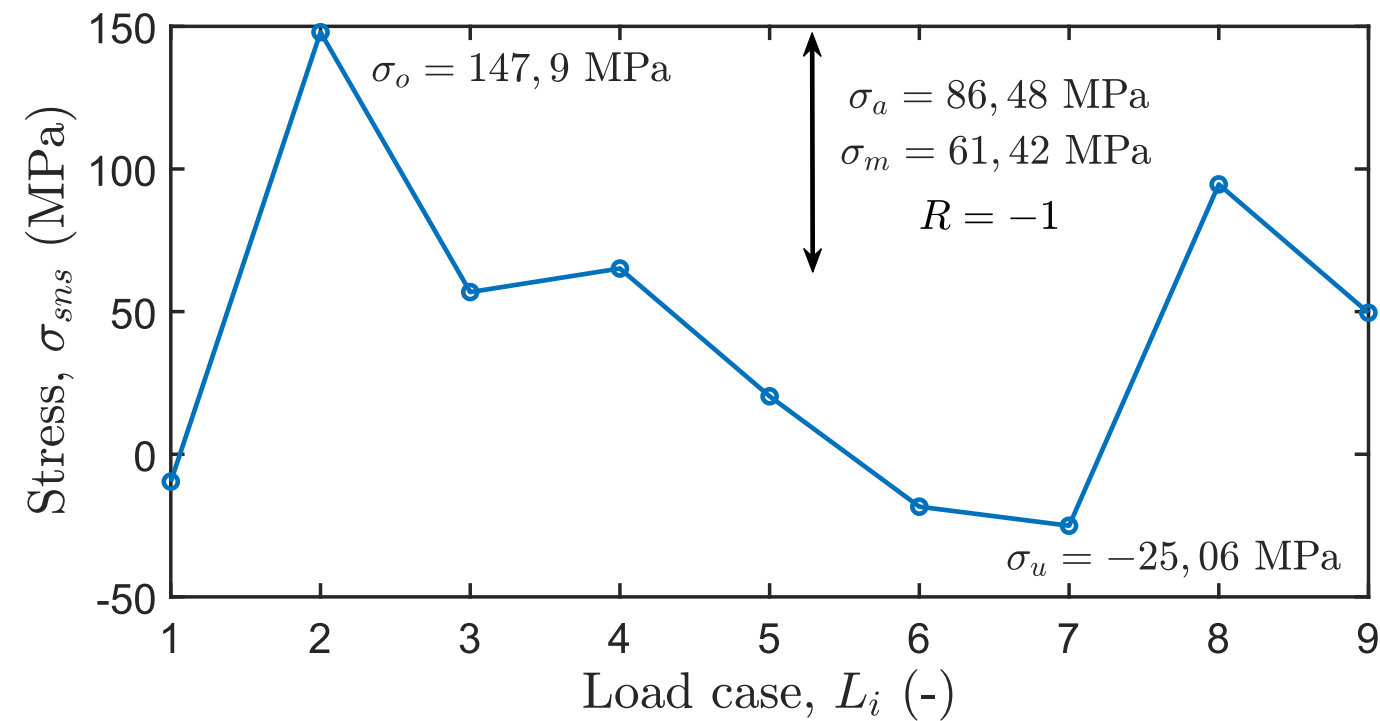
$$S_F < 1$$

Results



RESULTS

QUASI-STATIC METHOD (I)



- Stress at the node depends on the defined load cases
 → Critical load cases must be known in advance
- No correlation between the load cases

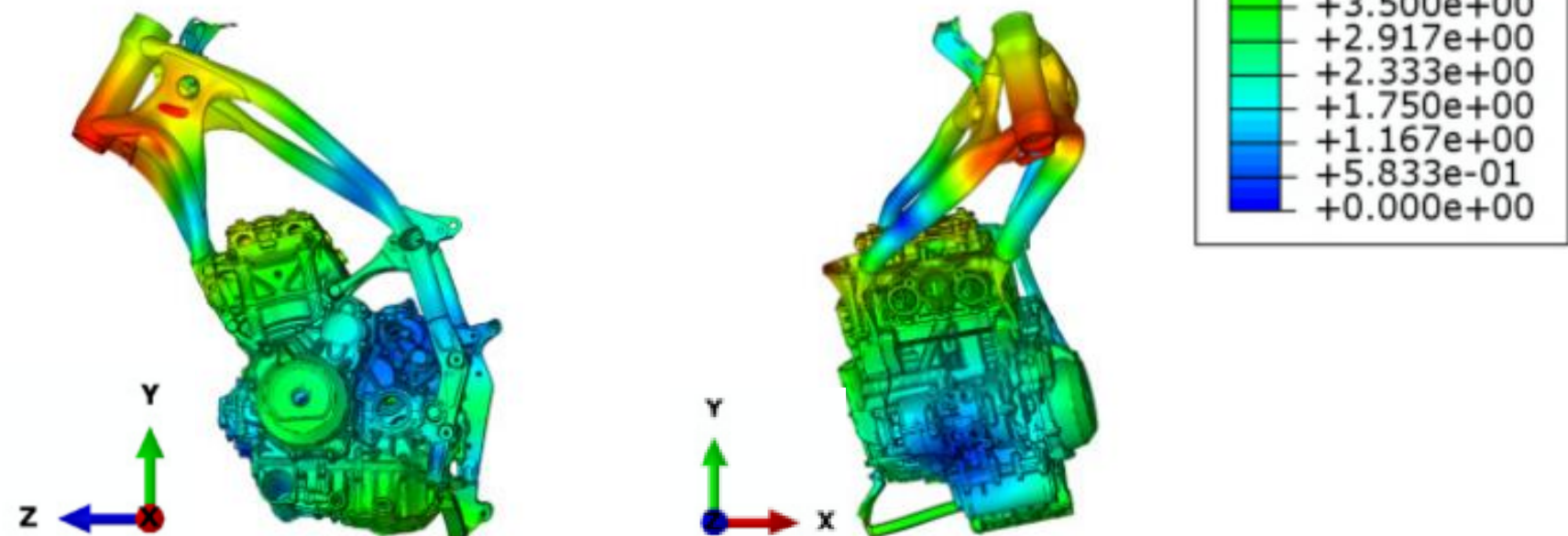
Results



RESULTS

MODALANALYSIS (II)

- An overall of 71 Eigenmoden in the range of 1 – 750 Hz
- Excitation is in the same range (First order: 166,6 Hz) as the Eigenmoden
→ Dynamic approach required

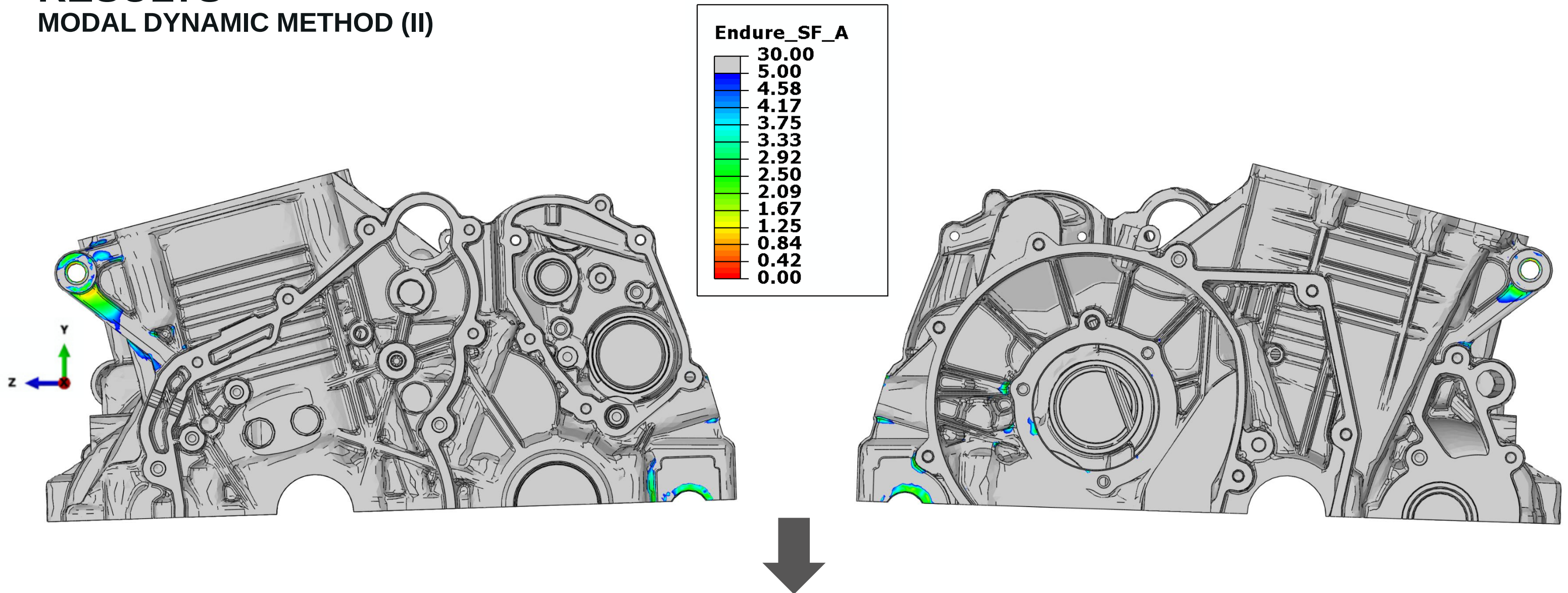


Results



RESULTS

MODAL DYNAMIC METHOD (II)



→ Engine housing is designed for operational stability

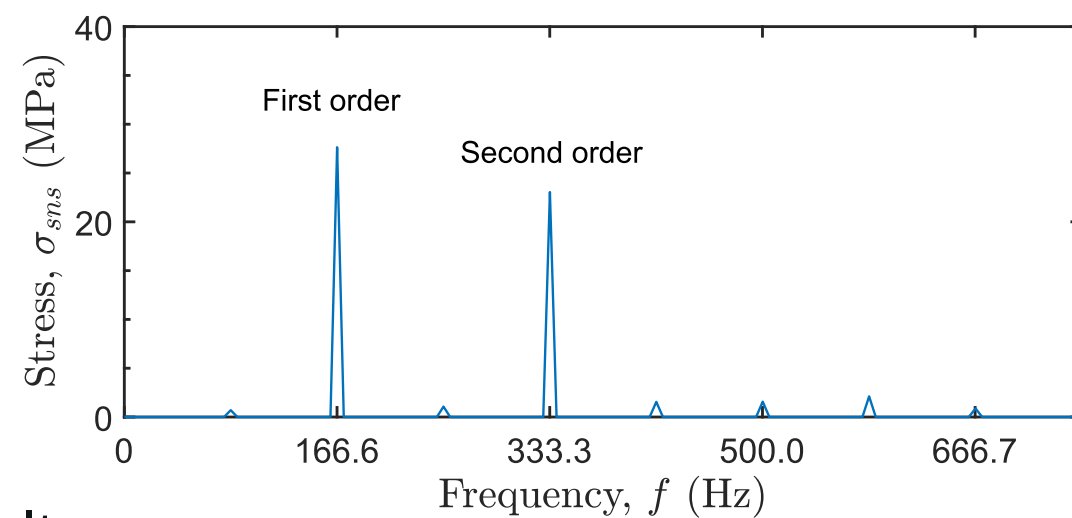
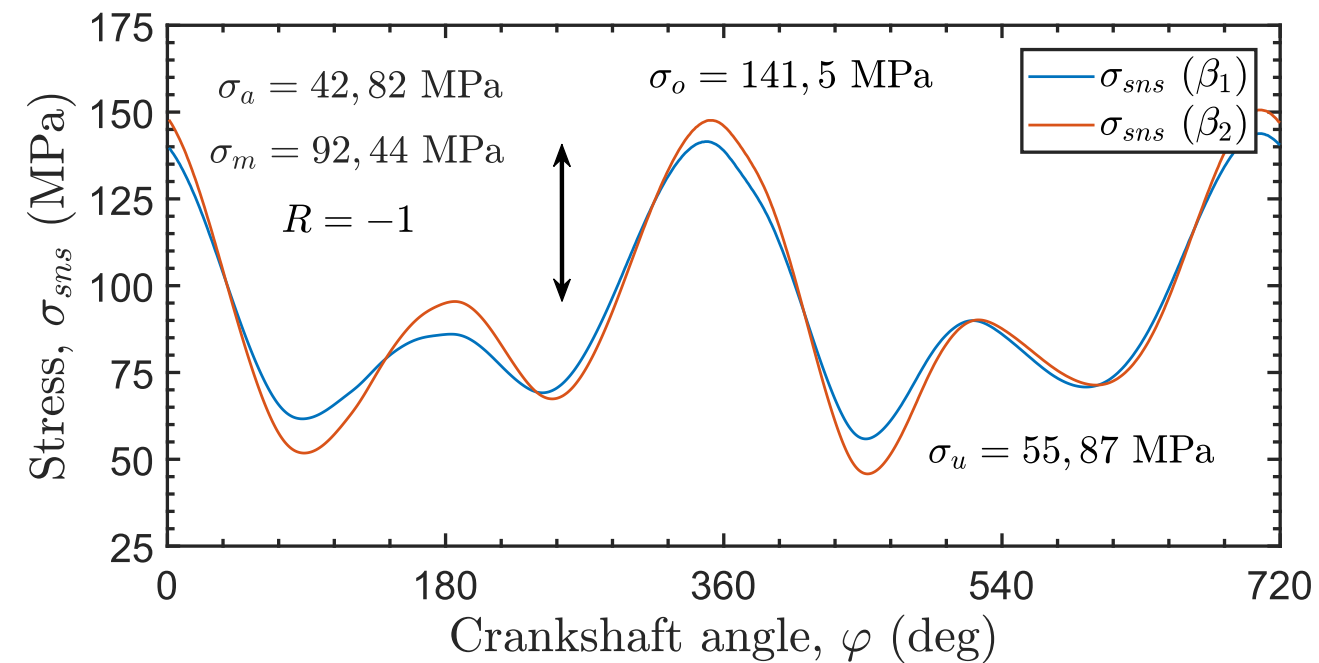
$$S_F > 1$$

Results

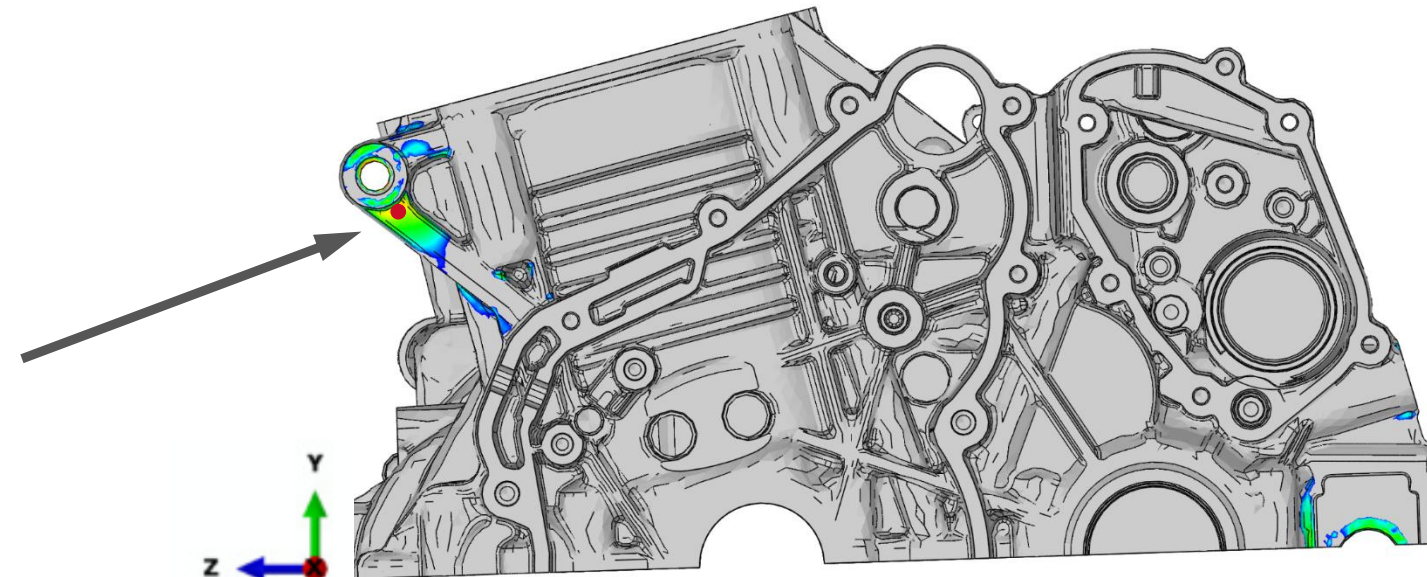


RESULTS

MODAL DYNAMIC METHOD (II)



Results



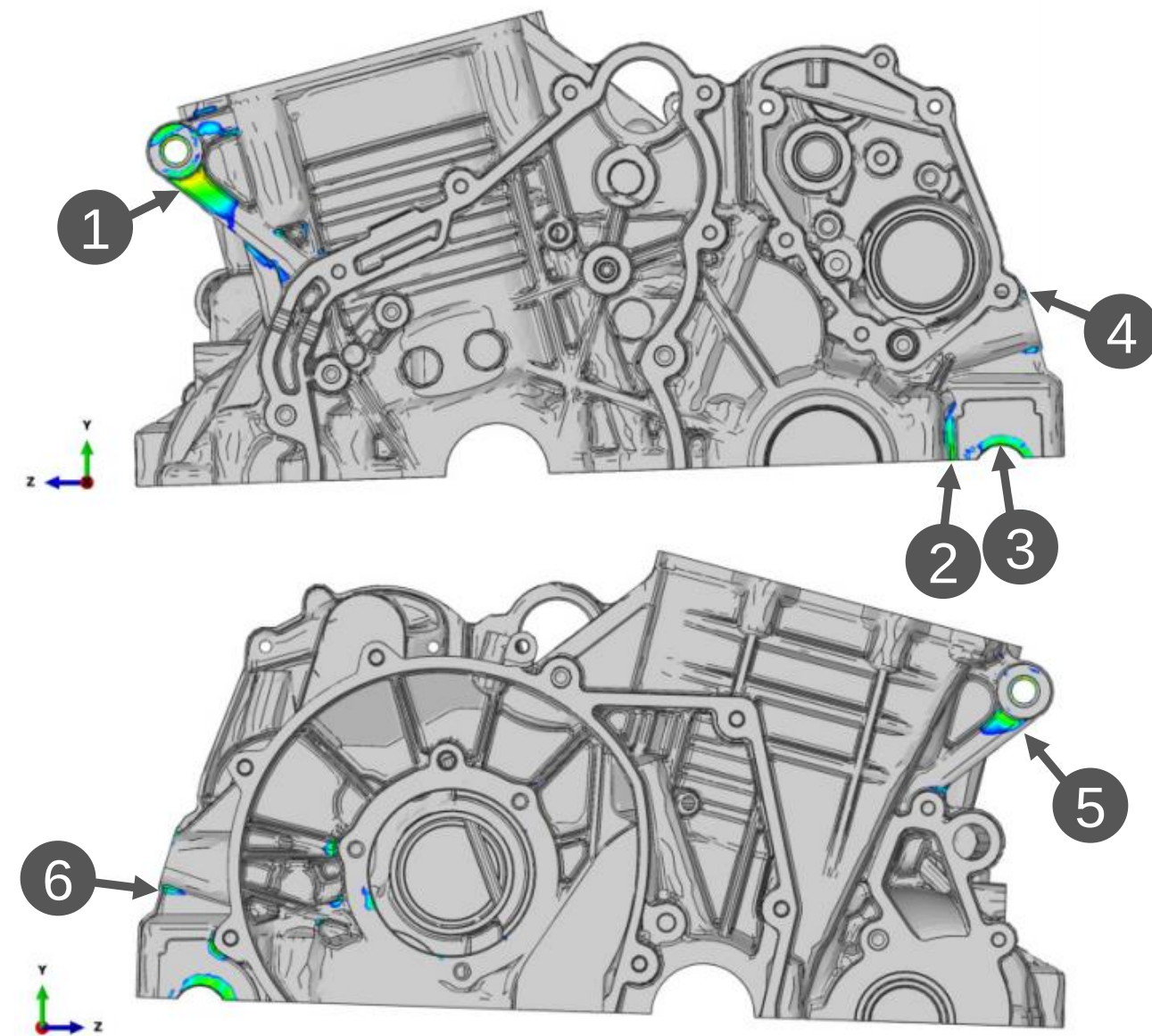
- Damping influences the stresses at the node
→ Influence on the safety factors
- At the considered node, only the first two motor orders are dominant for stresses

RESULTS

COMPARISON OF THE QUASI-STATIC (I) AND DYNAMIC METHOD (II)

- Significant differences
 - Safety factor depends on the method
- Lower safety factors for the quasi-static method
 - Higher load at the engine mounts

	Quasi-static (I)	Modal Dynamic (II)
1	0,75	1,08
2	1,11	2,37
3	6,50	4,17
4	3,64	2,07
5	0,69	2,30
6	6,69	2,87



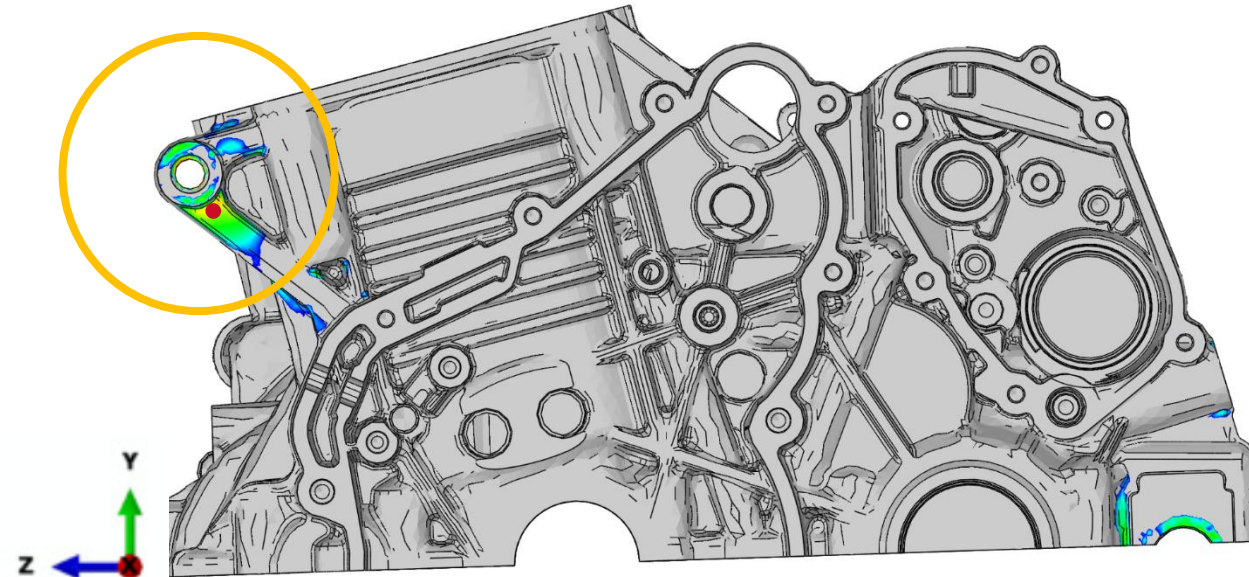
Results



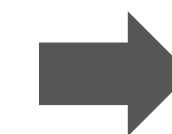
RESULTS

COMBINED METHOD (III)

- 2 Load cases $\varphi_{KW} = 360^\circ$ und $\varphi_{KW} = 452^\circ$
- Mapping of the acceleration field only for the engine
- No damping considered in combined method (III)
- Influence of non-linearities and consideration of dynamic effects



	Quasi-static (I)	Modal Dynamic (II)	Combined Method (III)
S_F	0,87	1,12	0,98
LC_1	-15,71 MPa	138,9 MPa	137,6 MPa
LC_2	126,6 MPa	55,87 MPa	32,92 MPa



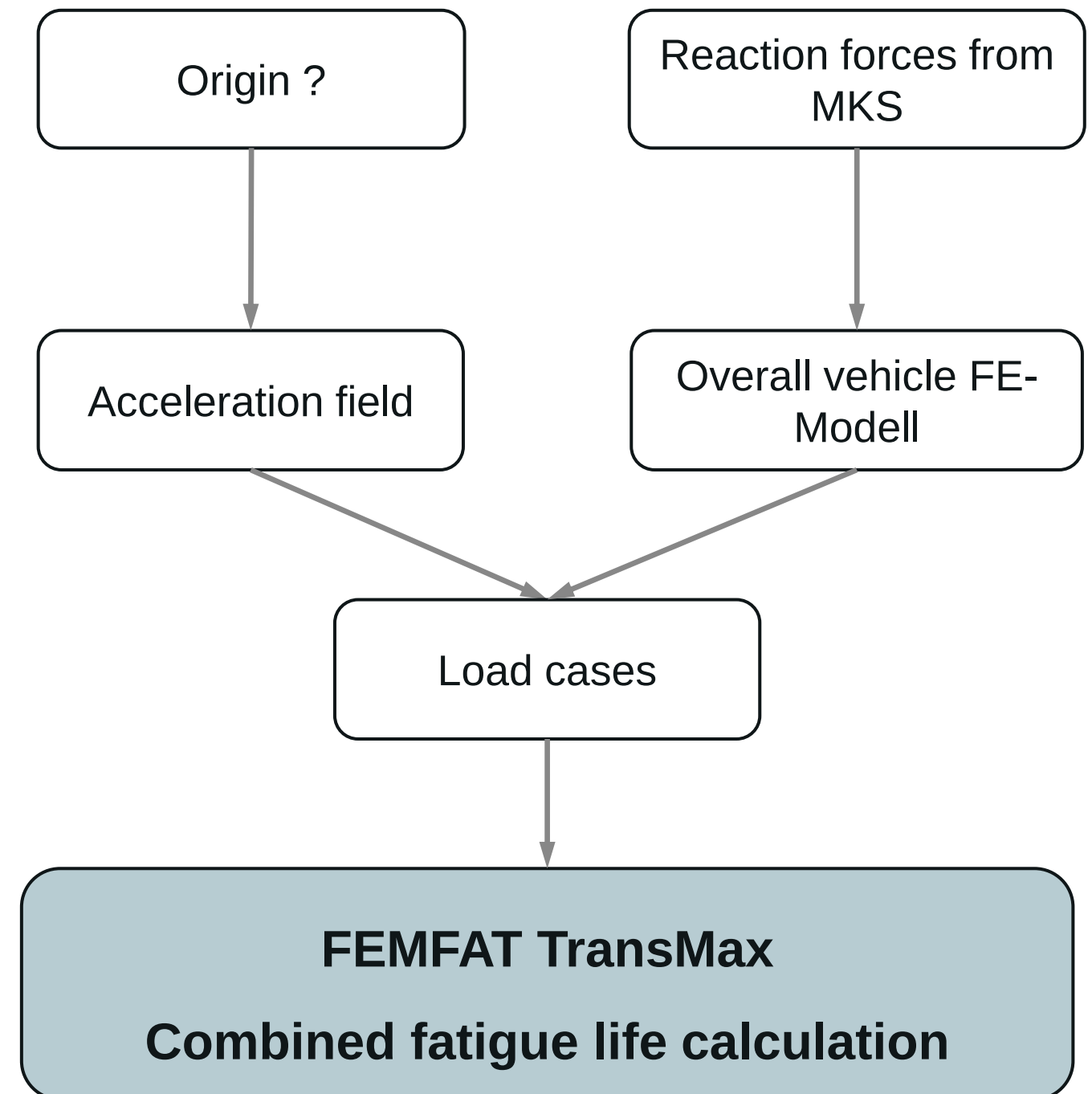
Acceleration field has huge influence on the stress

Results



SUMMARY AND OUTLOOK

- Combining the quasi-static and modal dynamic approach has huge advantages
 - Influence of **non-linearities** and **dynamic effects**
- **Research** to optimize the method
 - Damping, Mapping of the acceleration field, etc.
- Development of a **combined workflow** for engine housings



LITERATUR

- [1] Fischer P. & Witteveen W.: Integrated MBS-FE-Durability Analysis of Truck Frame Components by Modal Stresses. *ADAMS User Meeting* (2000)
- [2] Dassault Systemes Abaqus Inc.: Abaqus User Manual. *Abaqus Online Documentation, Version 6.11* (2014)



A light gray silhouette of a world map serves as the background for the slide.

**VIELEN DANK
FÜR EURE AUFMERKSAMKEIT**

**THE OPPORTUNITIES
ARE ENDLESS
WHEN YOU ARE
FEARLESS**