



Insight into the CLAAS measurement concept development to determine structural loads in field conditions for product dimensioning.



Hans Dück / Carsten Sander / Jens Nöring | CSE - SU ENG - Structural Simulation



Agenda:

1. Short introduction of the CLAAS group
2. Background and motivation
3. How does it work?
 - a) Prerequisites for this method
 - b) Method principles and mathematics
4. Practical examples
5. Conclusion

The Group. Numbers, facts and figures.

Legal form

KGaA mbH (commercial partnership limited by shares)

Supervisory Board and Shareholders' Committee

Cathrina Claas-Mühlhäuser (Chairperson)



Revenue 2024	€ 5 bn
Profit before taxes	332.3 million €
International share of revenue	76.8 %
Employees worldwide	11,905

The Group. Product Range



Combines



Forage harvesters



Tractors



Forage harvesting machines



Telehandlers



Balers



Service & Parts



Software and Systems



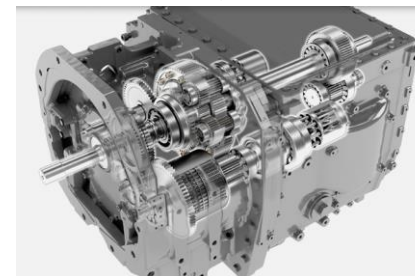
TERRA TRAC track roller unit



Axles



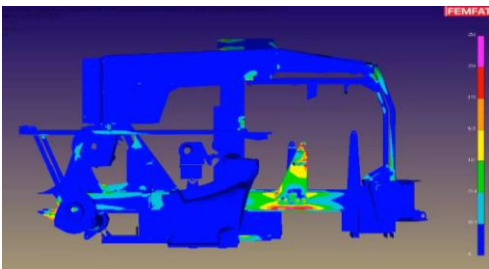
Hydraulic pumps & Control valves



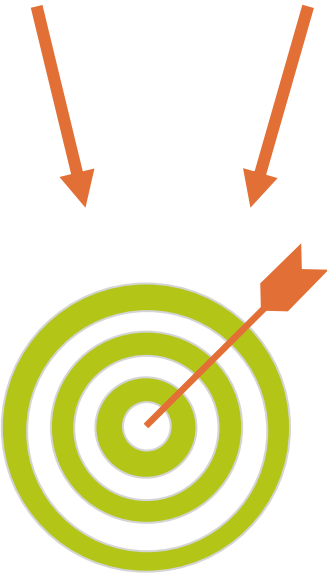
Gearboxes CVT

Background and motivation I

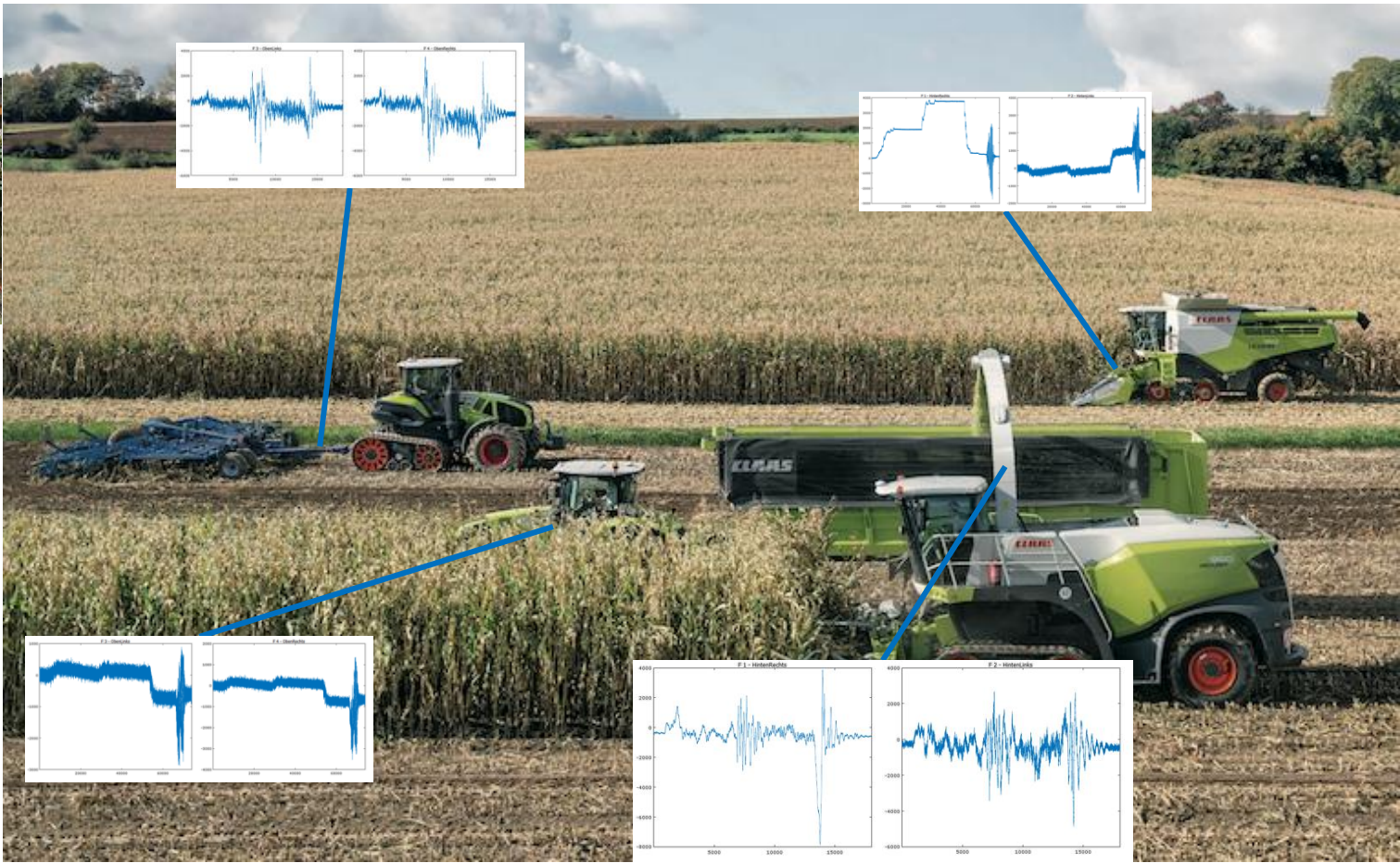
Simulation



Test

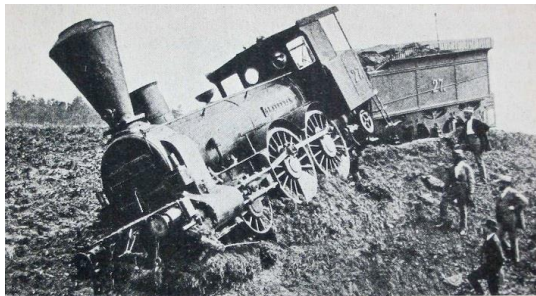
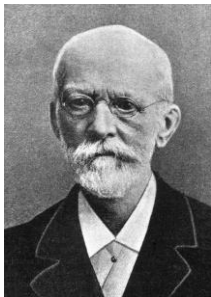


FIRST TIME RIGHT



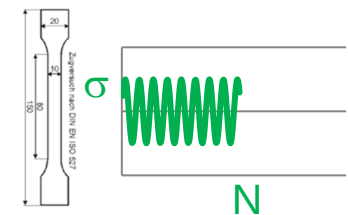
[Sch17] SCHMIDTKORD, Thorsten: TERRA TRAC. <http://www.claas.de/faszination-claas/themen/terra-trac>. Version: Oktober 2017. – [Online; accessed 14. Okt. 2018]

Background and motivation II



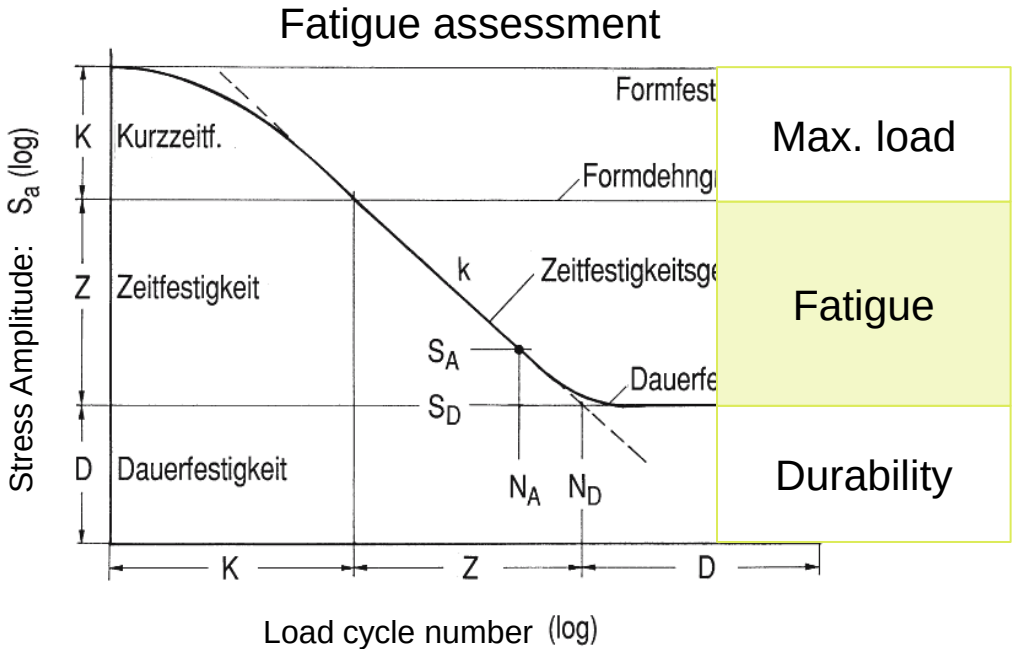
Key challenge:

- Translation from local stress to outer loads and finally damage values!

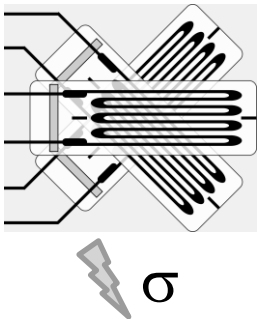


Repetitive stress cycles lead to breakage

Stress amplitude times cycle number = damage



The stress time curves can only be measured by strain gauges at few locations.



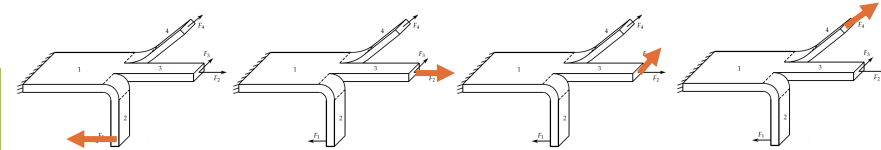
Outer loads like tyre forces, accelerometers and pin force measurements are easier measurable.





Pre-Processing

- Unit load cases
- Influence matrix



$$\begin{bmatrix} \epsilon_{x,e_1}/f_1 & \epsilon_{x,e_1}/f_2 & \dots & \epsilon_{x,e_1}/f_n \\ \epsilon_{y,e_1}/f_1 & \epsilon_{y,e_1}/f_2 & \dots & \epsilon_{y,e_1}/f_n \\ \gamma_{xy,e_1}/f_1 & \gamma_{xy,e_1}/f_2 & \dots & \gamma_{xy,e_1}/f_n \\ \epsilon_{x,e_2}/f_1 & \epsilon_{x,e_2}/f_2 & \dots & \epsilon_{x,e_2}/f_n \\ \vdots & \vdots & \ddots & \vdots \\ \gamma_{xy,e_n}/f_1 & \gamma_{xy,e_n}/f_2 & \dots & \gamma_{xy,e_n}/f_n \end{bmatrix}$$



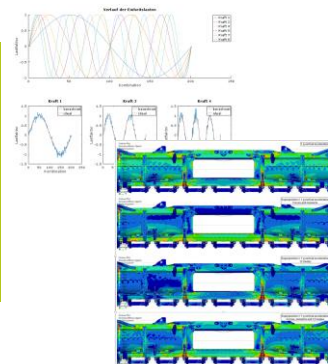
Solving

- Preselection
- Optimization



Post-Processing

- Error effects analysis
- FEM comparison

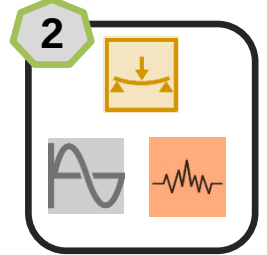




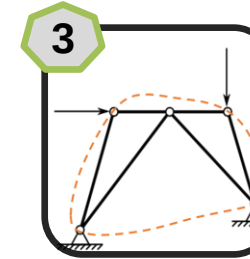
Validation order



Static / dynamic



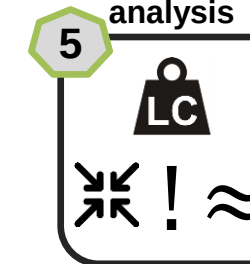
Cut free



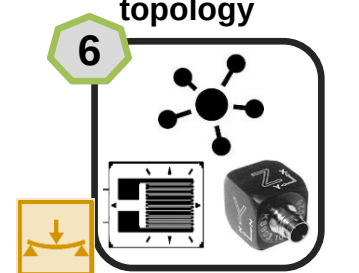
Load range

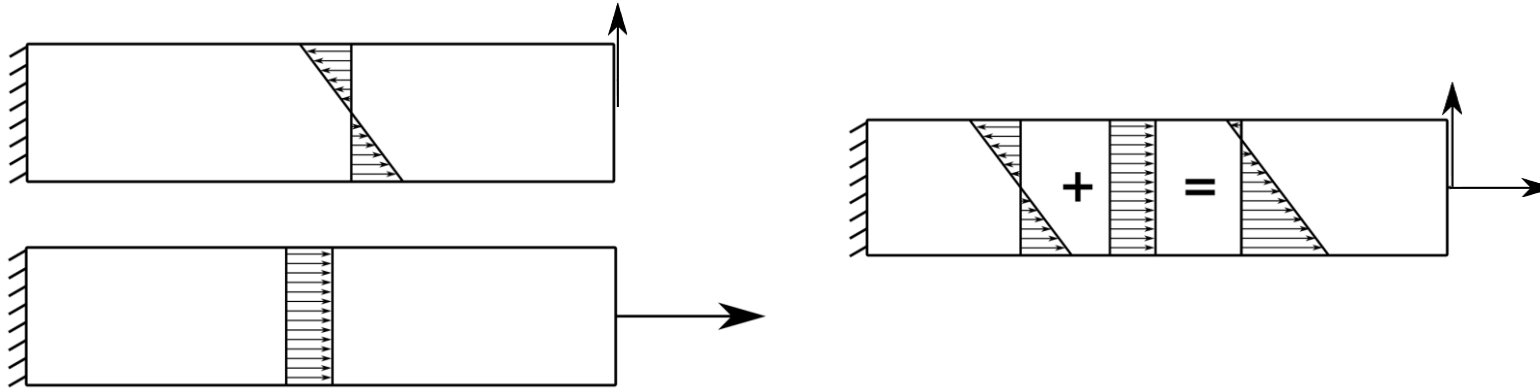


Load analysis

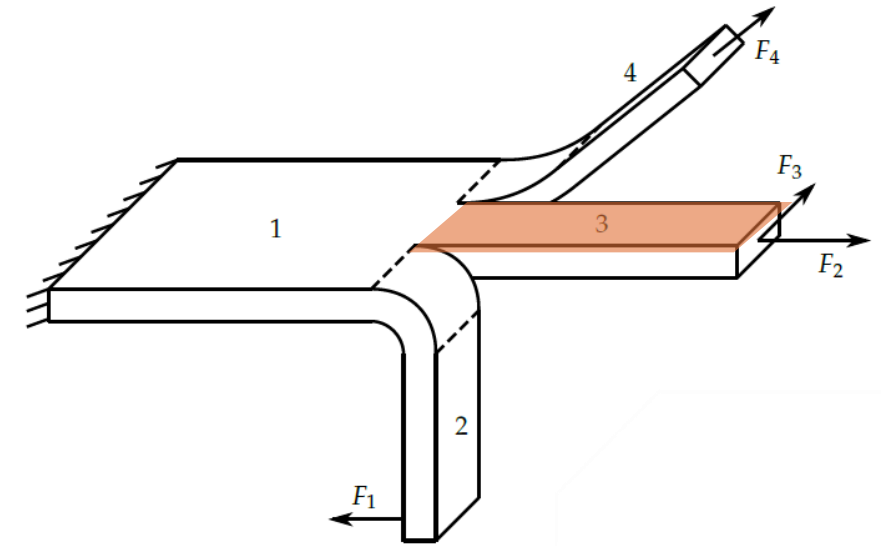


Sensor topology





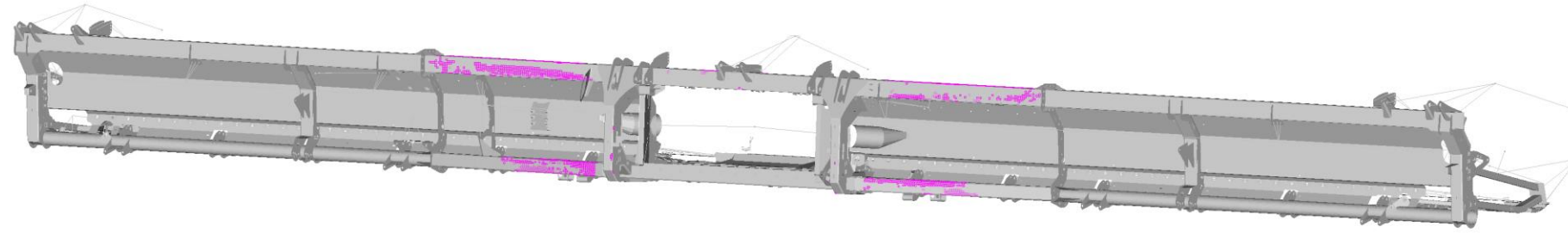
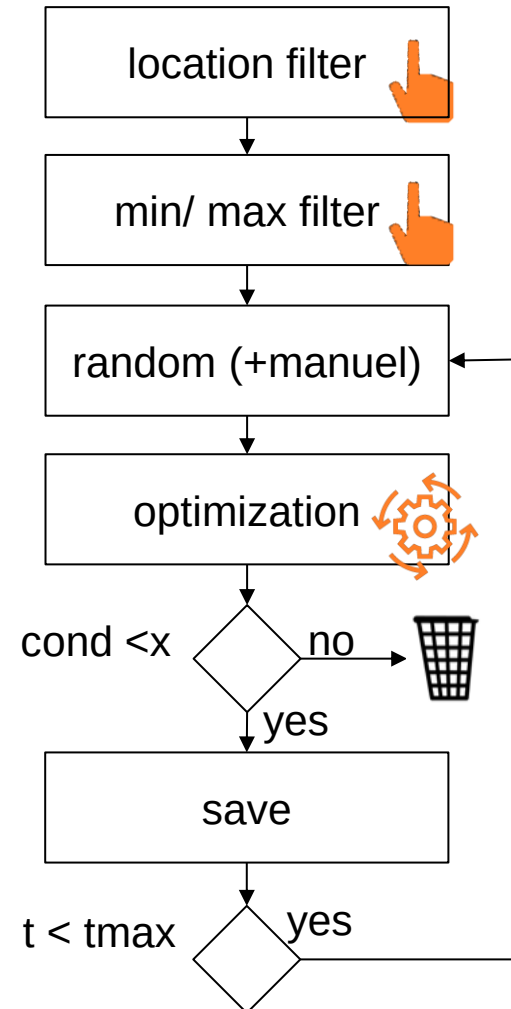
$$\underbrace{\begin{bmatrix} \epsilon_{x,e_1,l f_1} & \epsilon_{x,e_1,l f_2} & \cdots & \epsilon_{x,e_1,l f_n} \\ \epsilon_{y,e_1,l f_1} & \epsilon_{y,e_1,l f_2} & \cdots & \epsilon_{y,e_1,l f_n} \\ \gamma_{xy,e_1,l f_1} & \gamma_{xy,e_1,l f_2} & \cdots & \gamma_{xy,e_1,l f_n} \\ \epsilon_{x,e_2,l f_1} & \epsilon_{x,e_2,l f_2} & \cdots & \epsilon_{x,e_2,l f_n} \\ \vdots & \vdots & \ddots & \vdots \\ \gamma_{xy,e_m,l f_1} & \gamma_{xy,e_m,l f_2} & \cdots & \gamma_{xy,e_m,l f_n} \end{bmatrix}}_{\mathbf{A}}$$



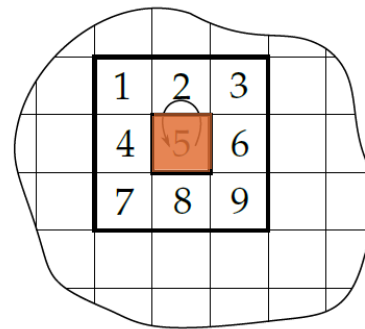
$$\mathbf{A}^T \cdot \mathbf{A} \cdot \mathbf{l f} = \mathbf{A}^T \cdot \mathbf{y}$$

$$\mathbf{l f} = \left(\mathbf{A}^T \cdot \mathbf{A} \right)^{-1} \cdot \mathbf{A}^T \cdot \mathbf{y}$$

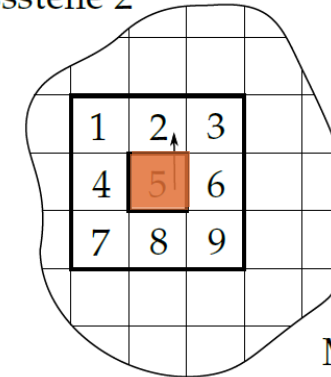
$$\mathbf{l f} = \mathbf{A}^+ \cdot \mathbf{y}$$



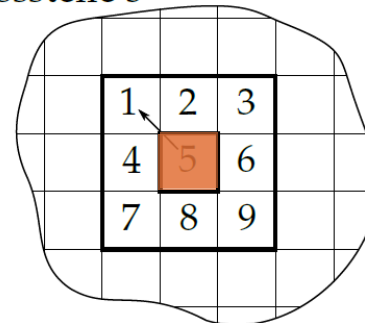
Messstelle 1



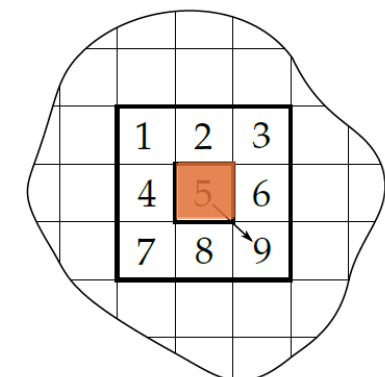
Messstelle 2



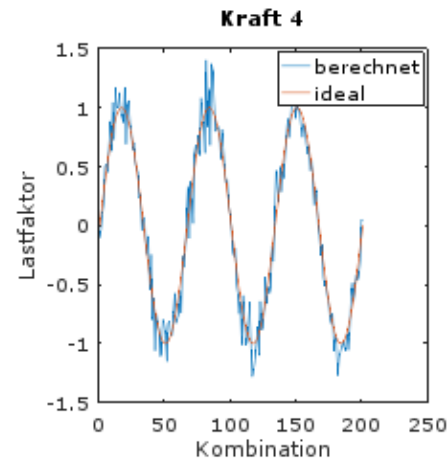
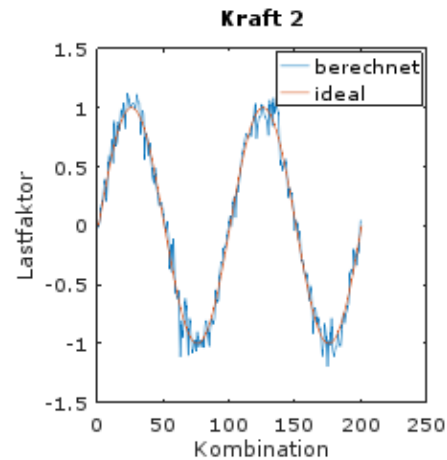
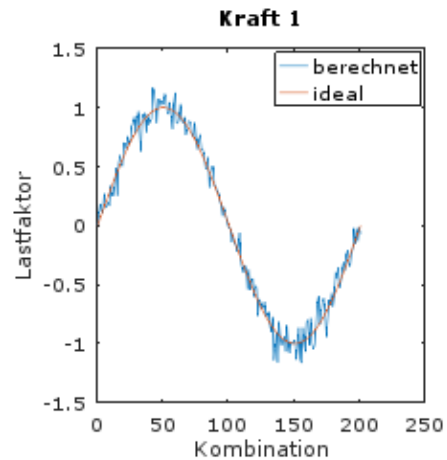
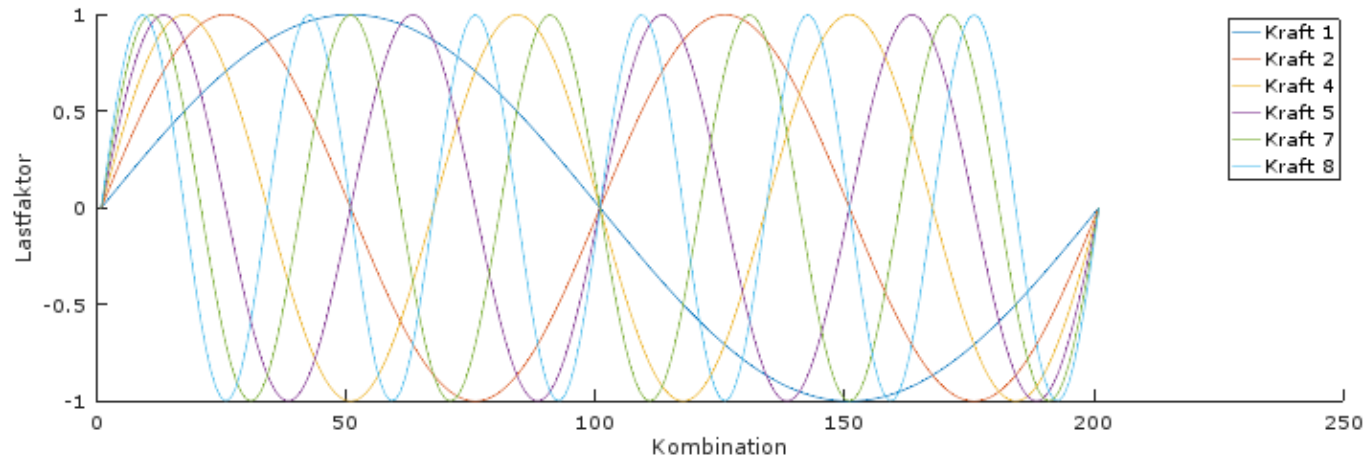
Messstelle 3



Messstelle 4



Verlauf der Einheitslasten



Virtual
measurement

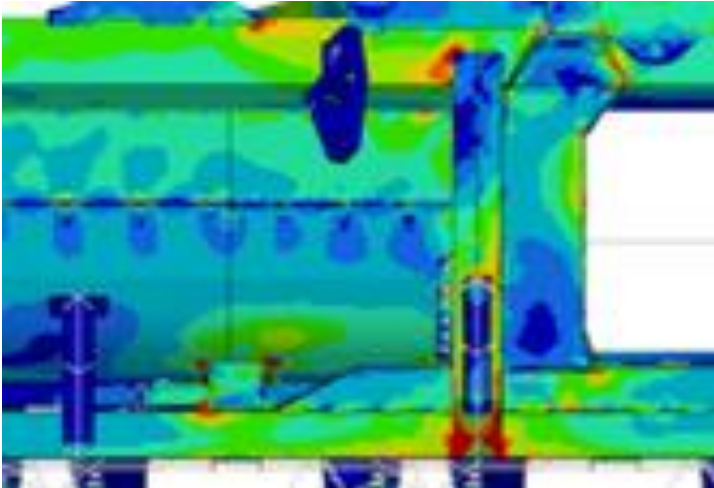


Apply
disturbance

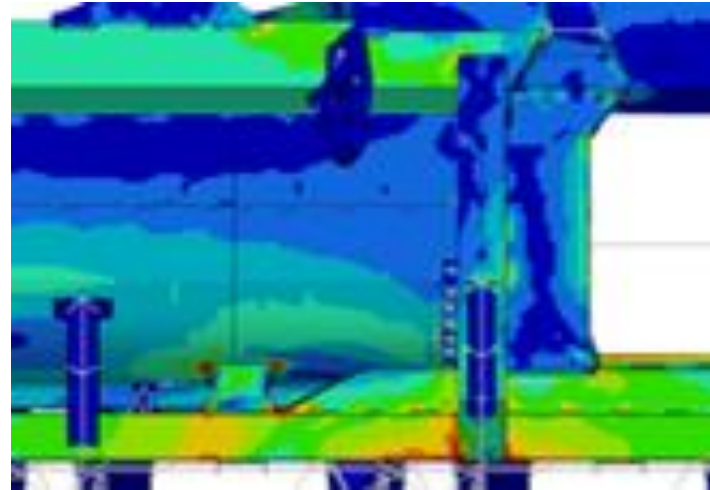


Evaluate
effect

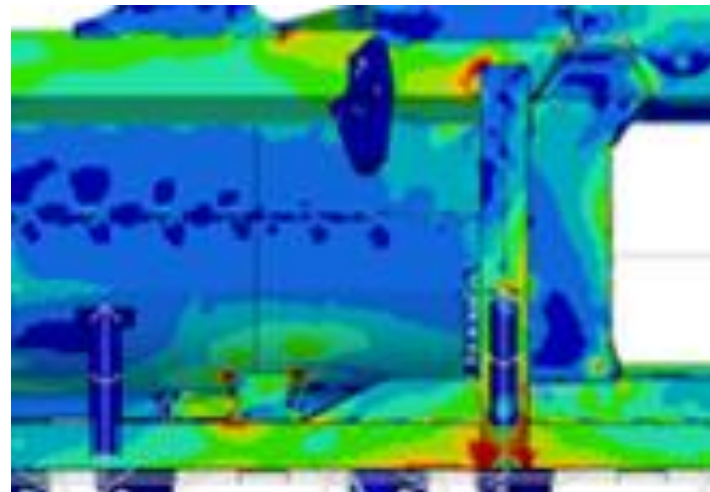
Goal



Result 1



Result 2



Example I – feeder housing



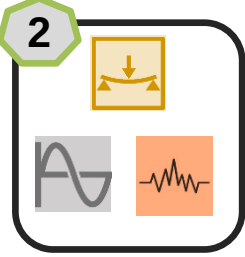
Example I – feeder housing



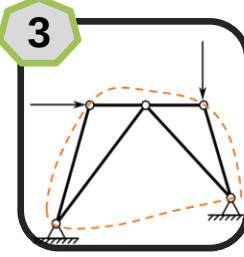
Validation order



Static / dynamic



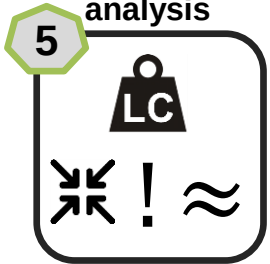
Cut free



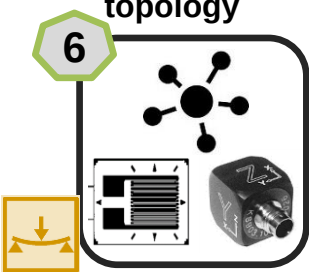
Load range



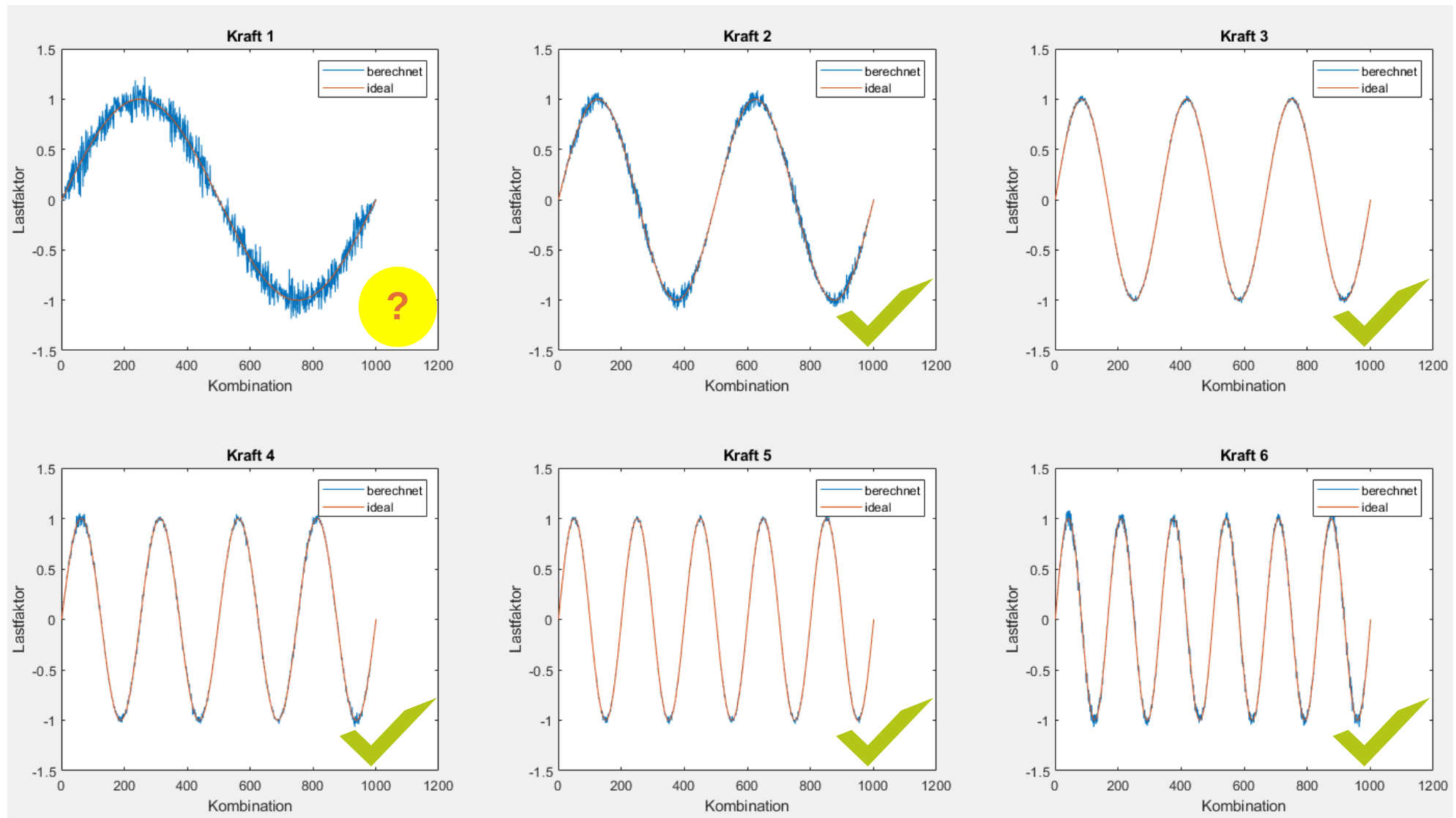
Load analysis



Sensor topology



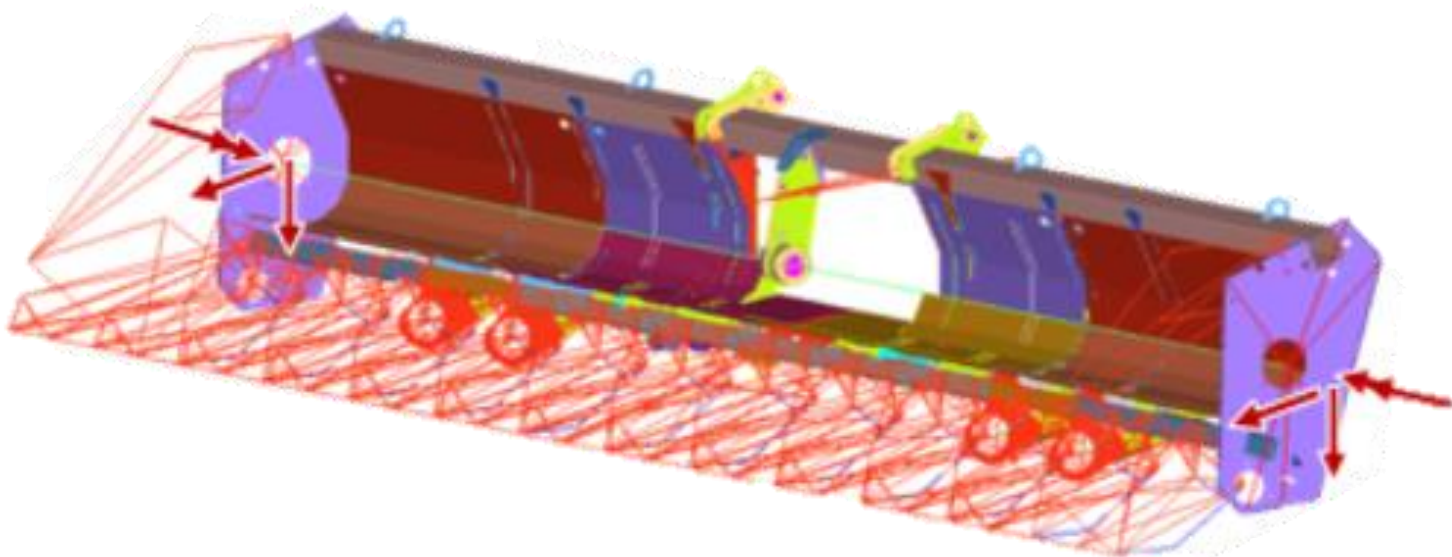
Example I – feeder housing



Example II – Header



Example II – Header static



Validation order

1

VA

Static / dynamic

2

Static / dynamic

Cut free

3

Cut free

Load range

4

[Min, Max]

50Hz

kg

Load analysis

5

LC

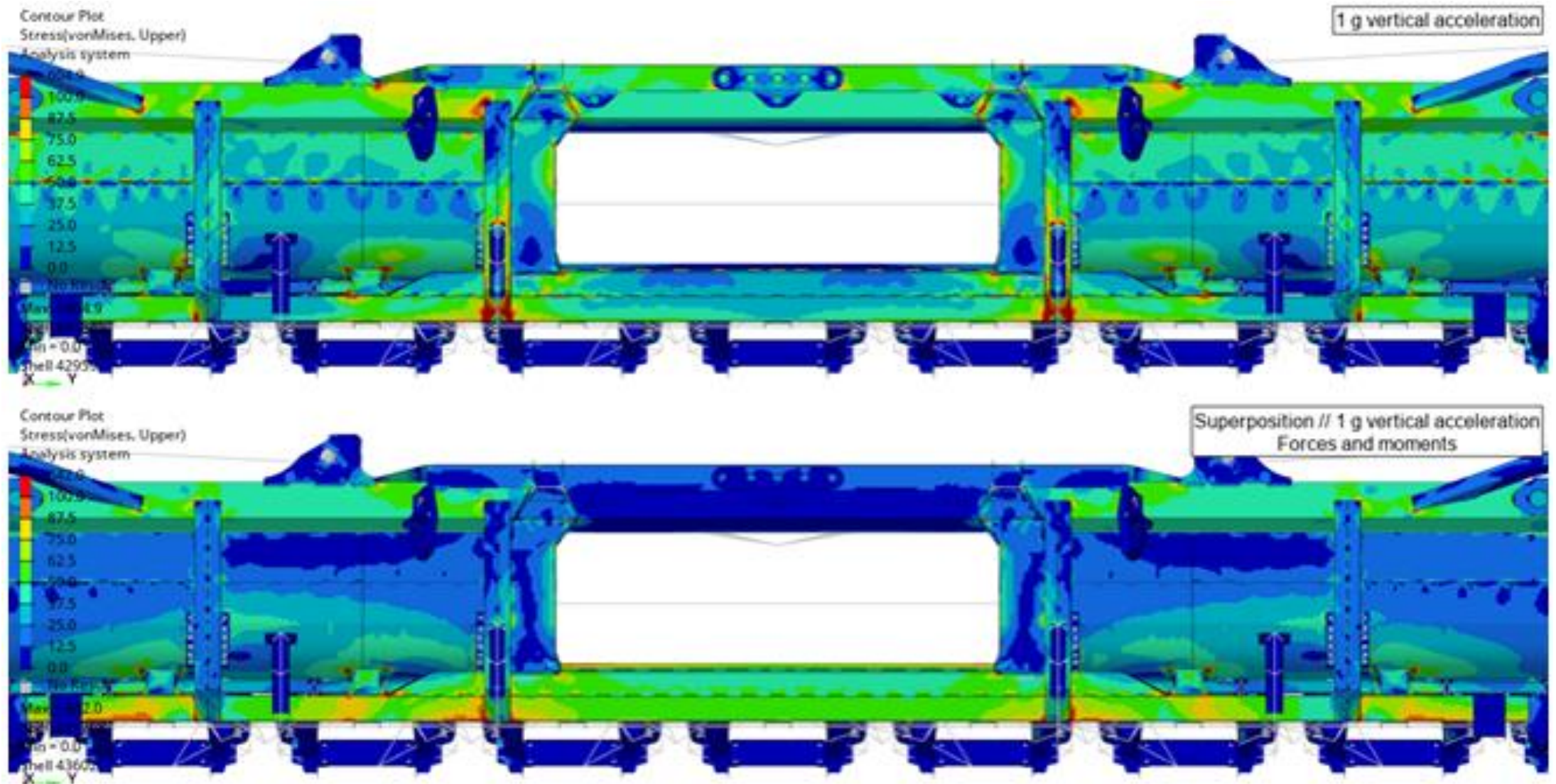
Load analysis

Sensor topology

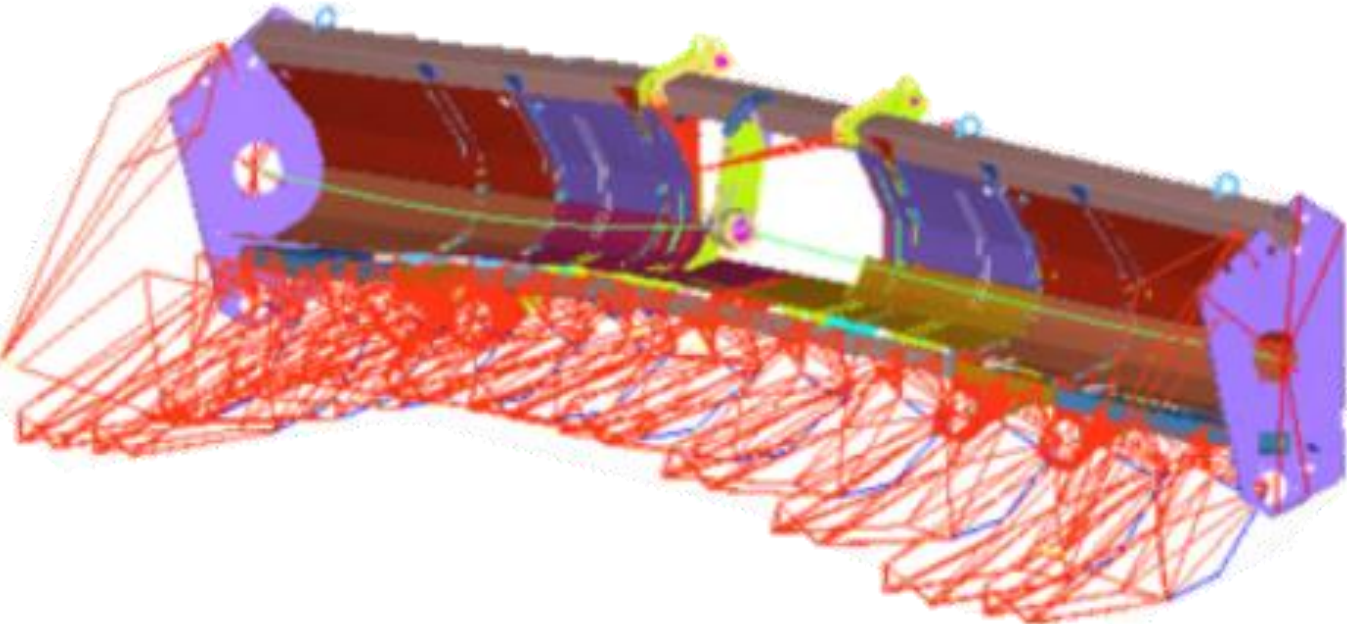
6

Sensor topology

Example II – Header static



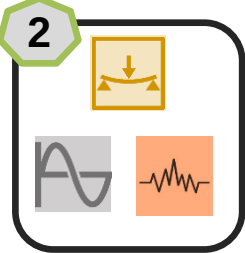
Example II – Header modal



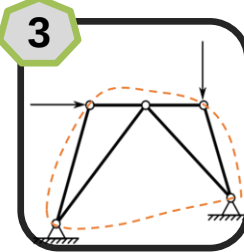
Validation order



Static / dynamic



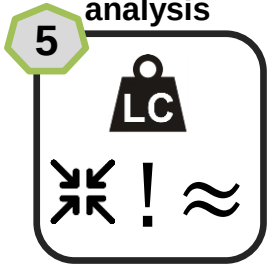
Cut free



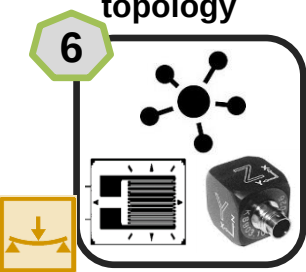
Load range



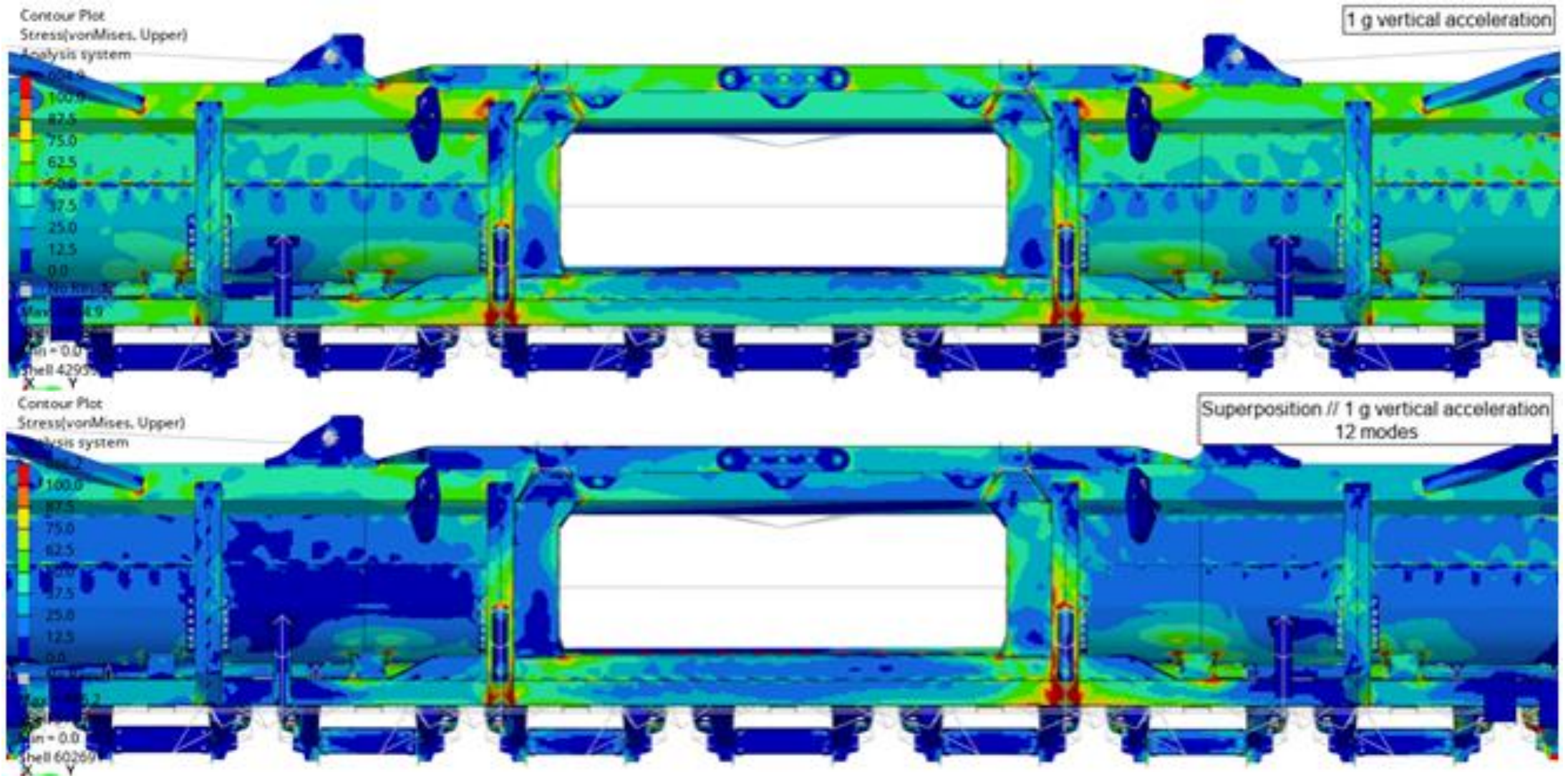
Load analysis



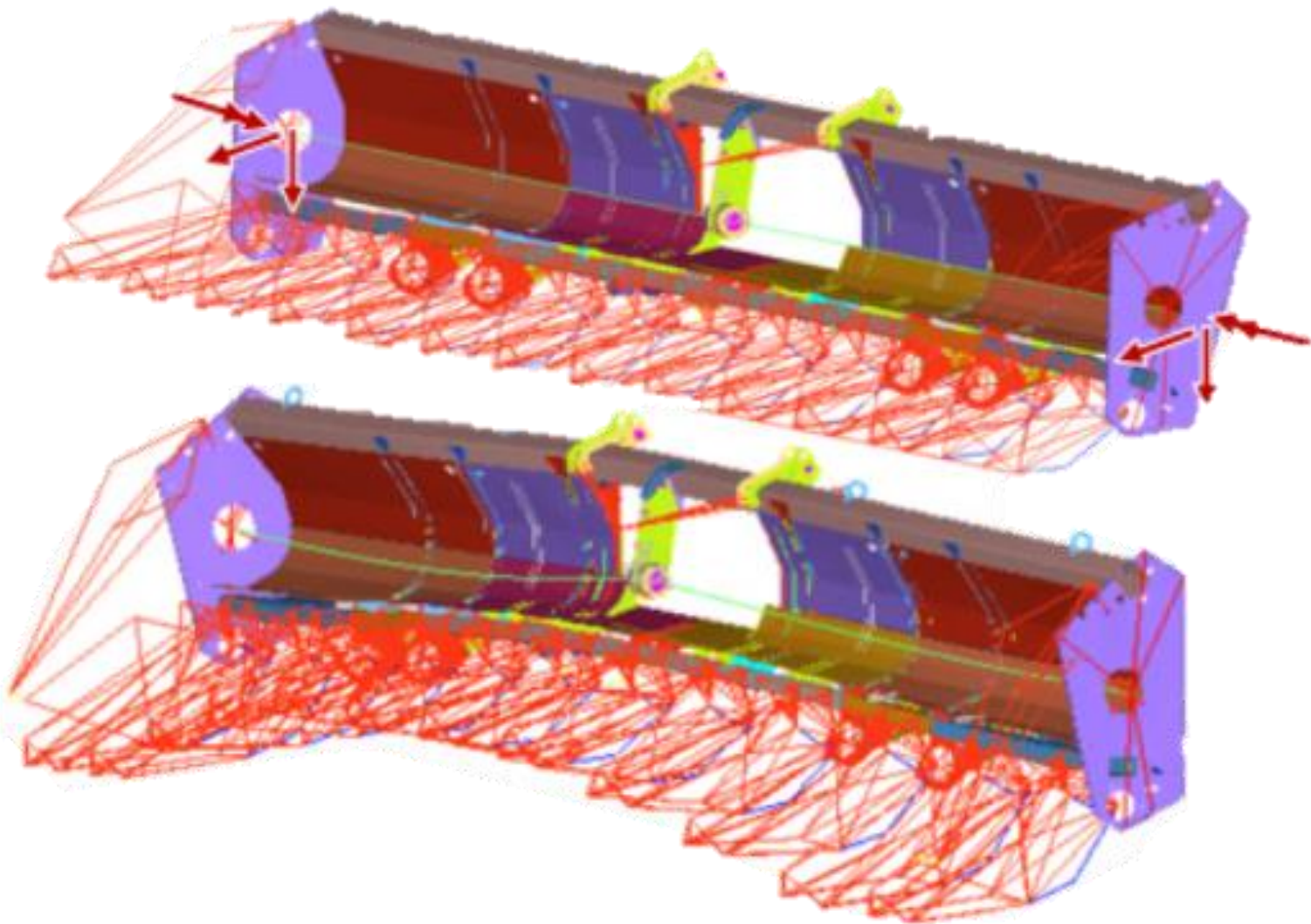
Sensor topology



Example II – Header modal



Example II – Header static+modal



Validation order

1

VA

Static / dynamic

2

Cut free

3

Load range

4

[Min, Max]

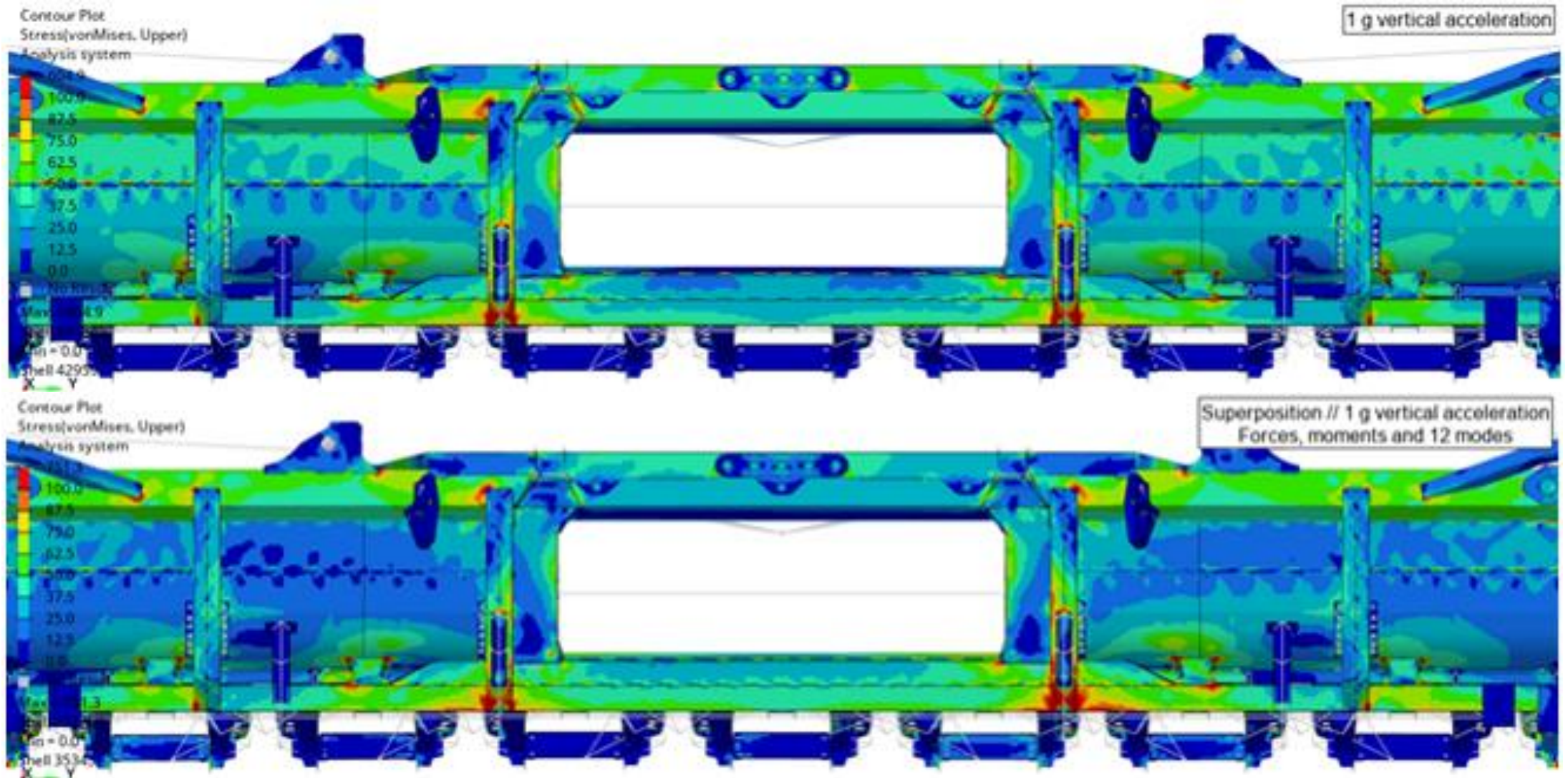
Load analysis

5

Sensor topology

6

Example II – Header static+modal



Conclusion

- We can convert local strain gauge measurement to external loads.
- It is not about hotspots, but about the entire structure.
- The basic principle is the inversion of superposition.
- Understanding the structure, loads and load paths is key.
- The process is semi-automated.
- Don't be afraid to take a step back and change an assumption



Thank you for your attention!

CLAAS

