Dynamic Torsional Loads on Wheelsets - Recent Findings for the Assessment

DB Systemtechnik GmbH

Fatigue Strength and Simulation, T.TVI 24

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Situation

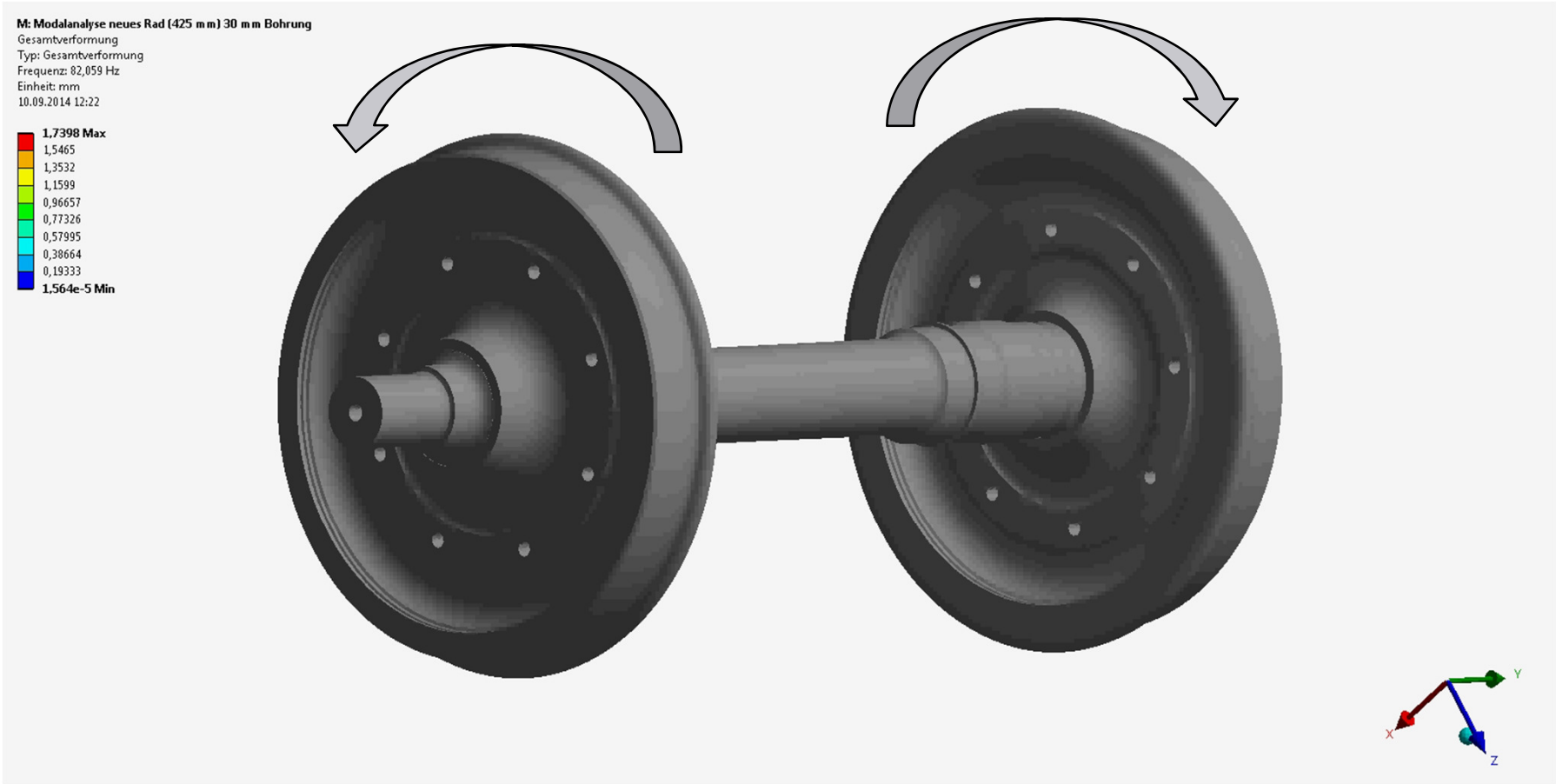
- Physical background
- Normative statements
- In-service loads
- Experience from service

Assessment

- To derive the highest momentum possible
- Assessment of the press fit
- Defining the state of stress
- Assessment levels of the axles fatigue strength

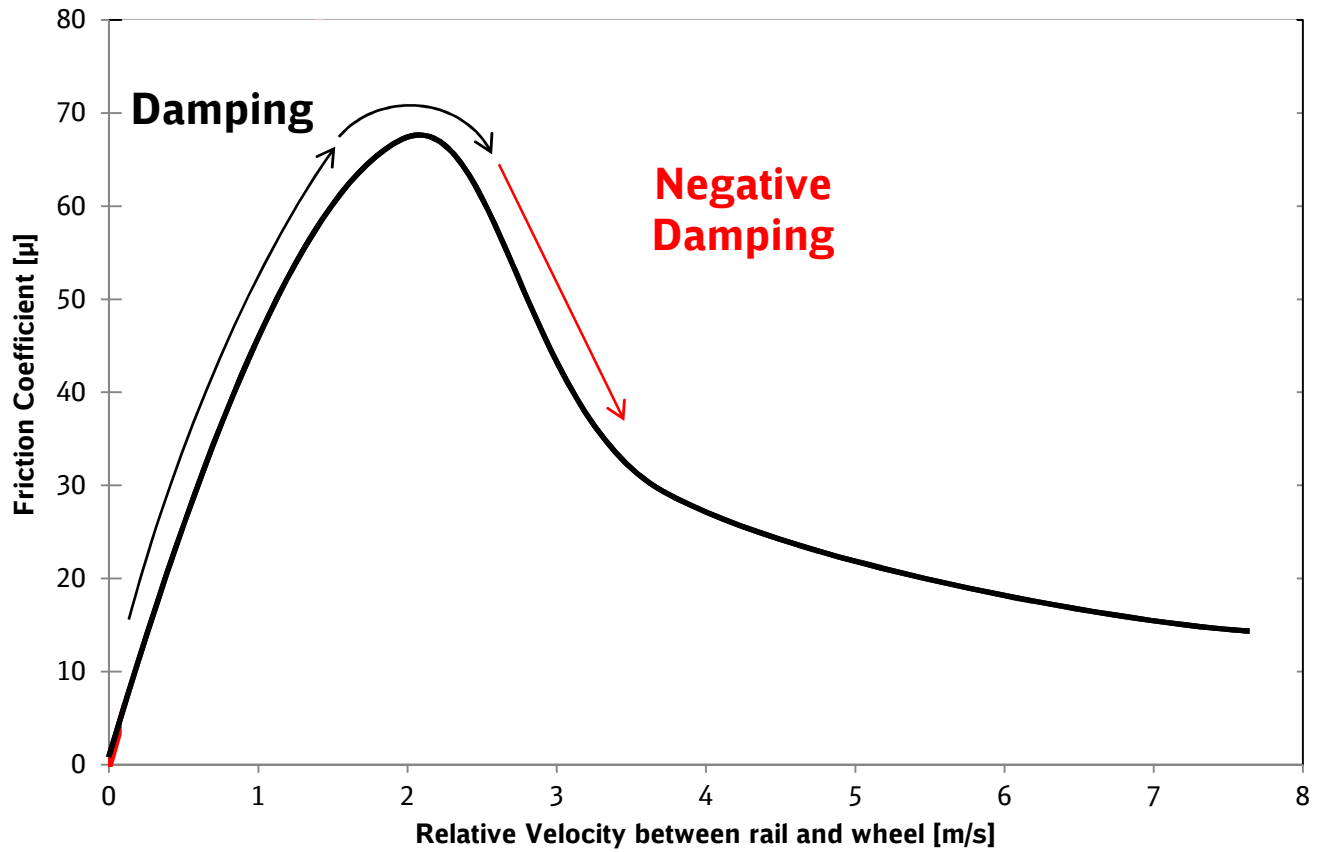
Physical Background (1/2)

Wheelset oscillates according to the 1st torsional Eigenmode at appr. 50 - 100 Hz



Physical Background (2/2)

Due to a negative damping a self-excited oscillation occurs



Physical Background (2/2)

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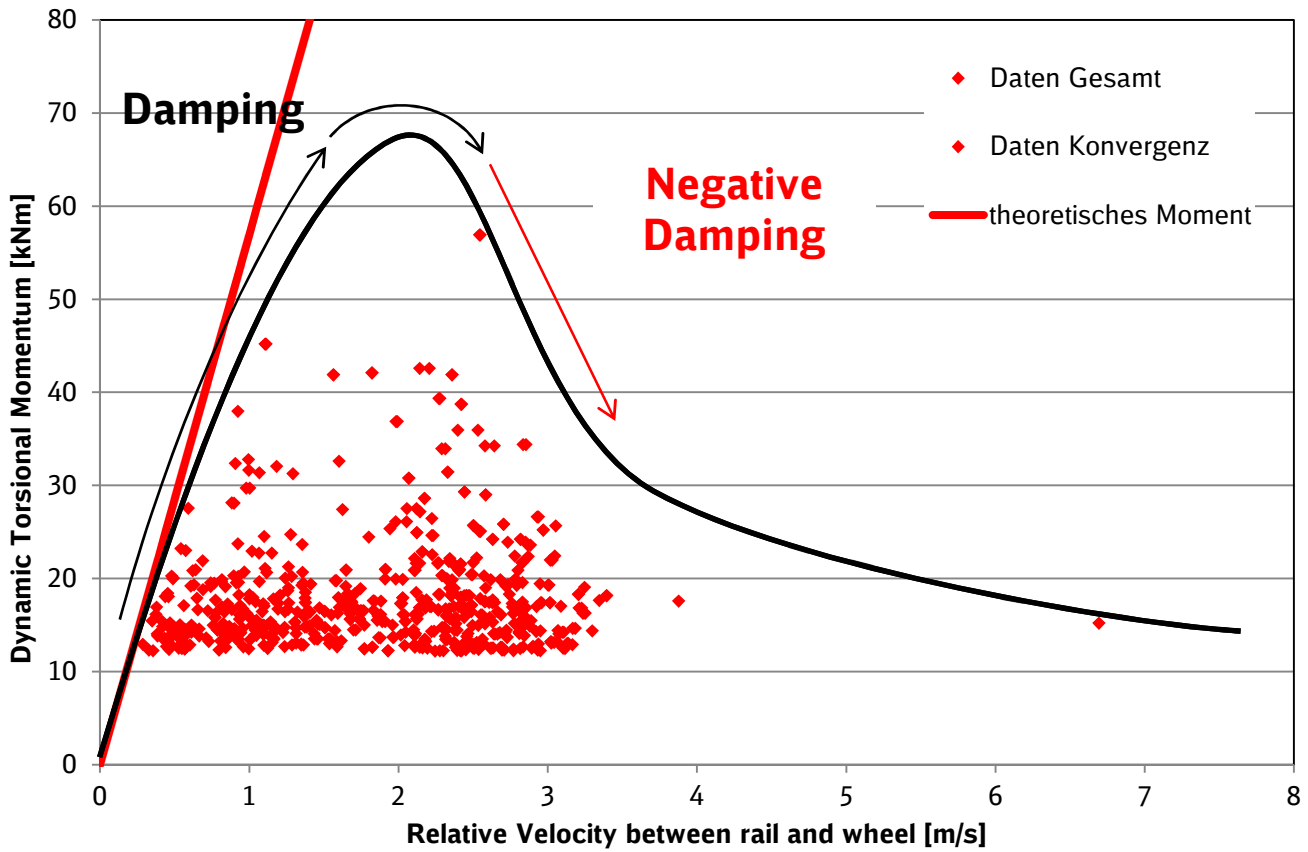
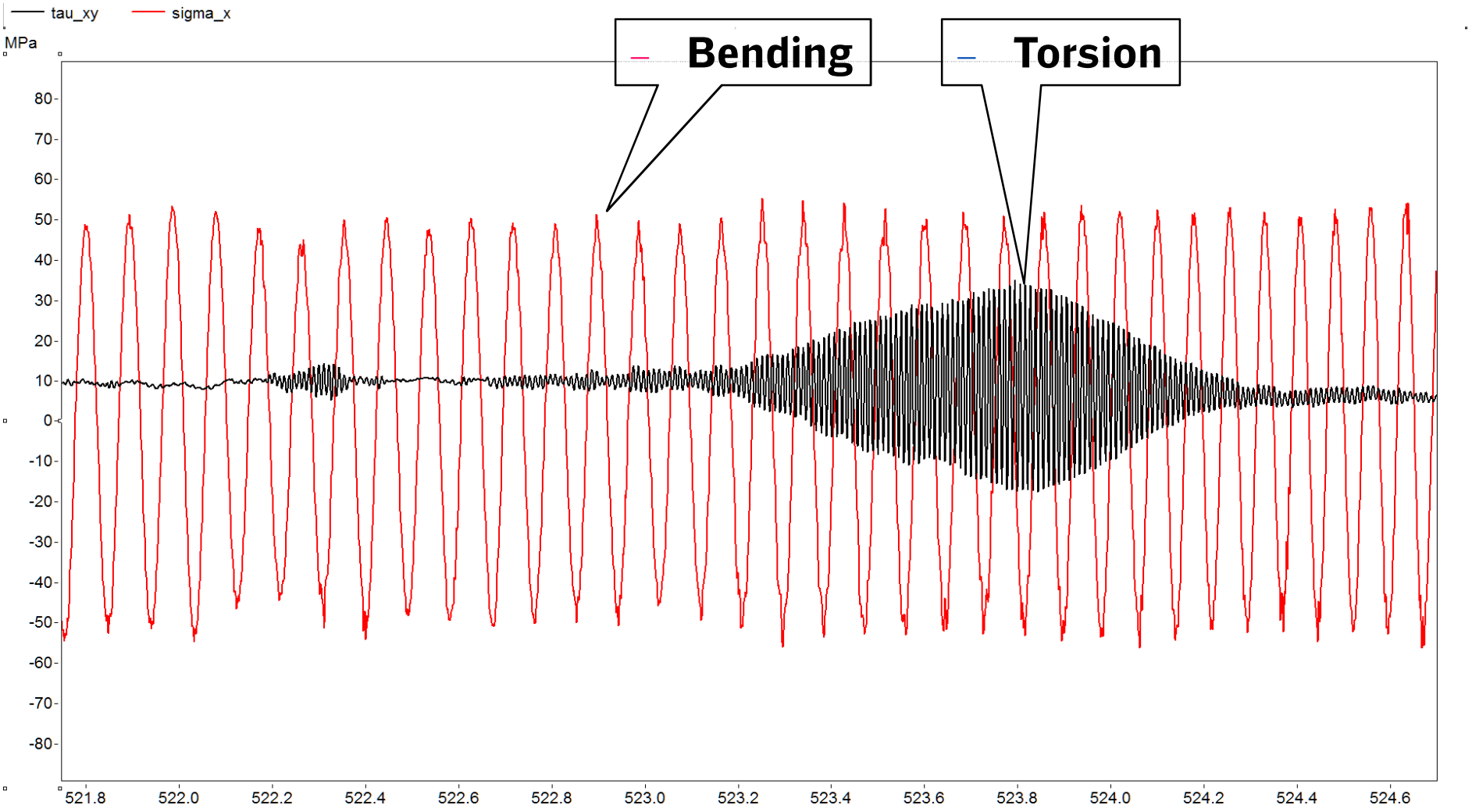


In-Service Loads

Stresses due to torsion and bending are not correlated



In-Service Loads

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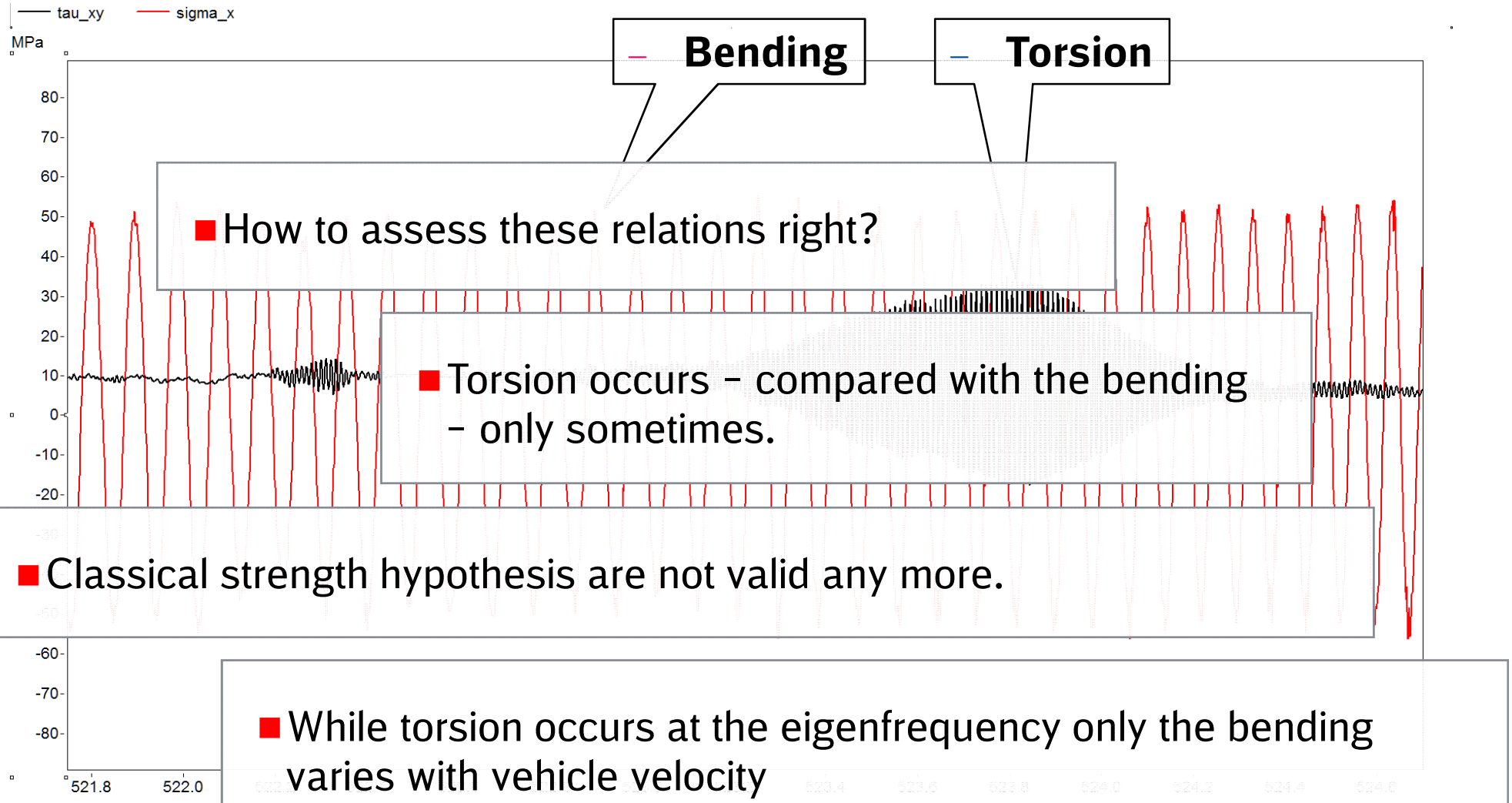


Normative Statements (1/2)

A Hint at torsional oscillation is given even in EN13104

- EN13104 (Design method for powered axles):

> […] Where traction control systems adopt a technique to maintain the tractive effort at the limit of adhesion, any resultant controlled oscillations about the mean driving torque shall be considered in determining the magnitude of the torsional moment My´´.
> […]

- EN13103 (Design method for non-powered axles) does not contain this requirement.

Normative Statements (2/2)

NF F 01-118 explains the origin of different safety factors

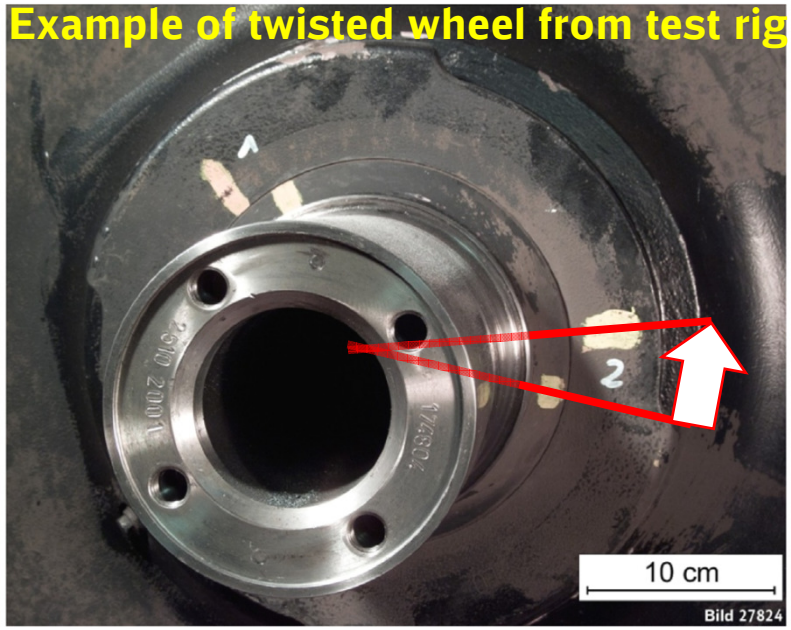
- NF F 01-118 (= origin of EN13103/4) about the selection of safety factor 1,3 or 1,5.

> […] elle est plus élevée pour les essieux moteur, sur lesquels sont calés pont moteur ou pignon, que pour les autres essieux moteurs parce que des surcharges de fonctionnement mal connues, dues à la transmission directe du couple moteur, peuvent exister pour des essieux du premier type.
> […]

- The explanation is not comprehensive because also powered wheelsets with 1,3 might oscillate.

Experience from Service

- In Germany quite a significant number of wheel twists occurred on locomotives and locomotive like vehicles.
- But the wheels did not move laterally (the flange distance did not change).
- A few wheels of locomotives with laterally pre-loaded engines acting on the wheels showed lateral movement by some few millimeters.



- Up to now fatigue no cracks or serious incident (with damage to persons or the infrastructure) happened.
- Some few classes do not tend to oscillations at all.

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To derive the highest Momentum possible (1/2)

Dedicated measurements are necessary

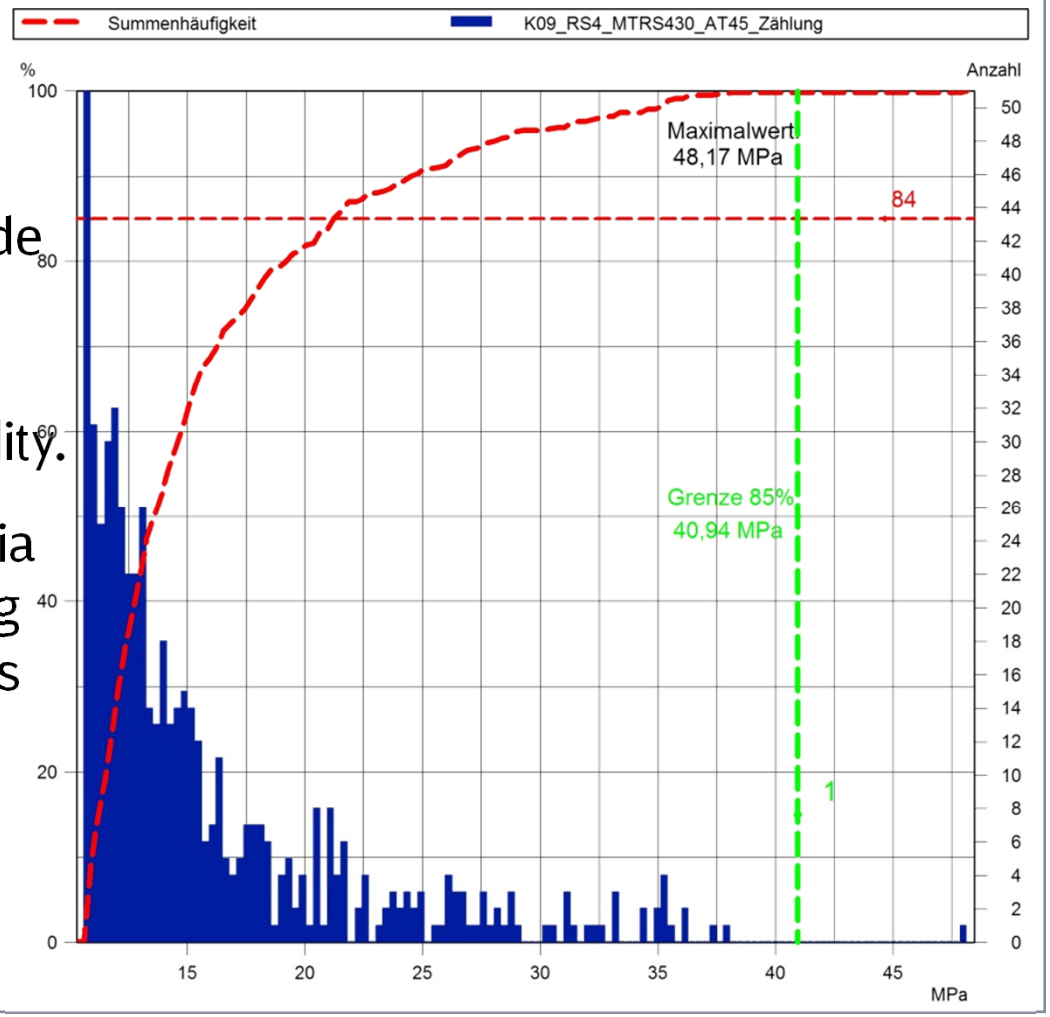
- The momentum to be assessed has to be verified by measurements dedicated to this purpose.
- The main problem is to set and verify conditions that lead to high dynamic torsional loads.
- Because randomness has a very big influence usually a large number of tests has to be conducted to achieve sufficient results.
- These points make it quite difficult to perform measurements in a successful way. It is necessary to have an experienced team for the measurements, that has performed those measurements and assessments before.

To derive the highest Momentum possible (2/2)

The highest Momentum has to fullfill some simplified statistical criteria

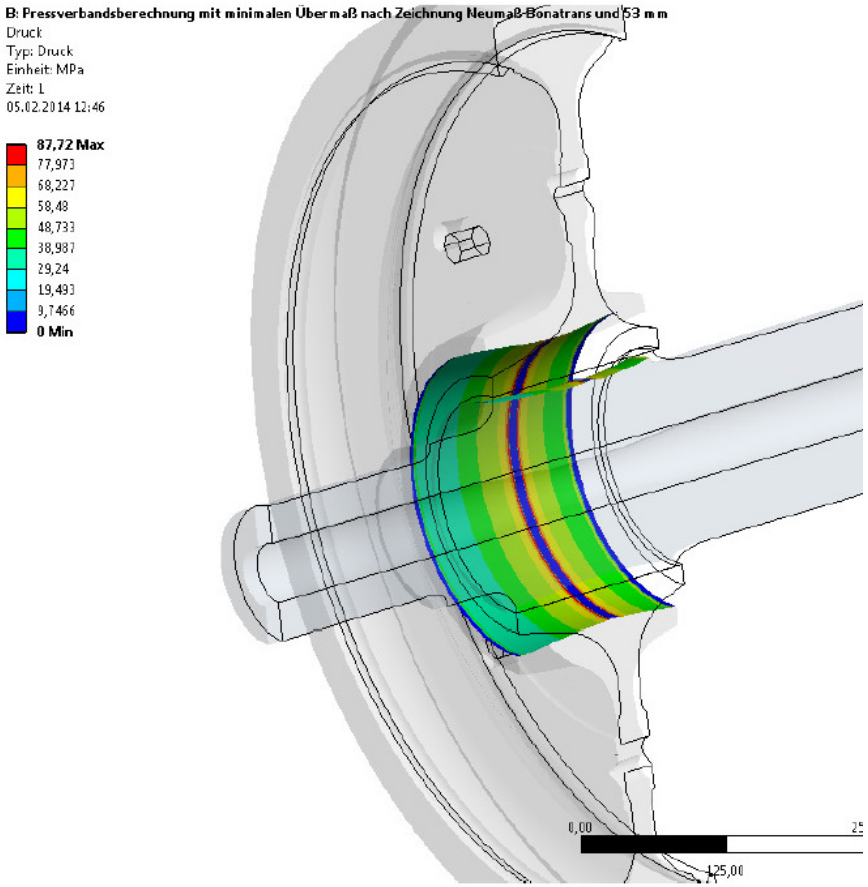
- So called convergence diagram (see left).
- 10 occurrences > 85% amplitude

  or
- 20 occurrences > 85% probability.
- To recognize whether the criteria is fulfilled or not before stopping the measurement campaign it is vital to conduct a detailed analysis along the complete measurement.

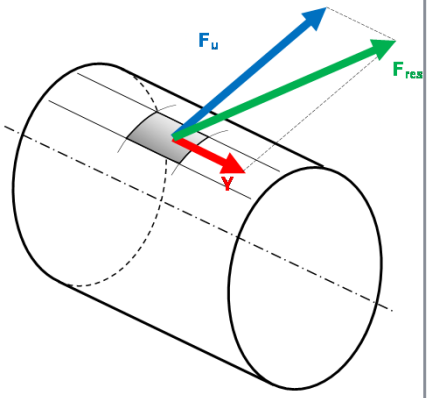


Assessment of the press-fit

The Press Fit is assessed in a quasi-static way



- The assessment is done following DIN7190.
- The pressure distribution and the resulting contact force is derived by FEA (see picture).
- The transmissble force is: contact force x friction coefficient.
- The press fit has to withstand the maximum torque and the lateral force Y1 from EN13104.



Assessment levels of the axle‘s fatigue strength (1/4)

Assessment level A: simple but very pessimistic

- Applying assessment level A means to use the highest measured torque within the calculation according to EN13104 and to combine it with the bending from running and accelerating/breaking.
- This assessment level supposes both load components acting simultaneously.
- Because of the limits to adhesion the maximum of both load components will never occur simultaneously.
- Due to this fact the assessment level A can be judged as simple but very pessimistic.

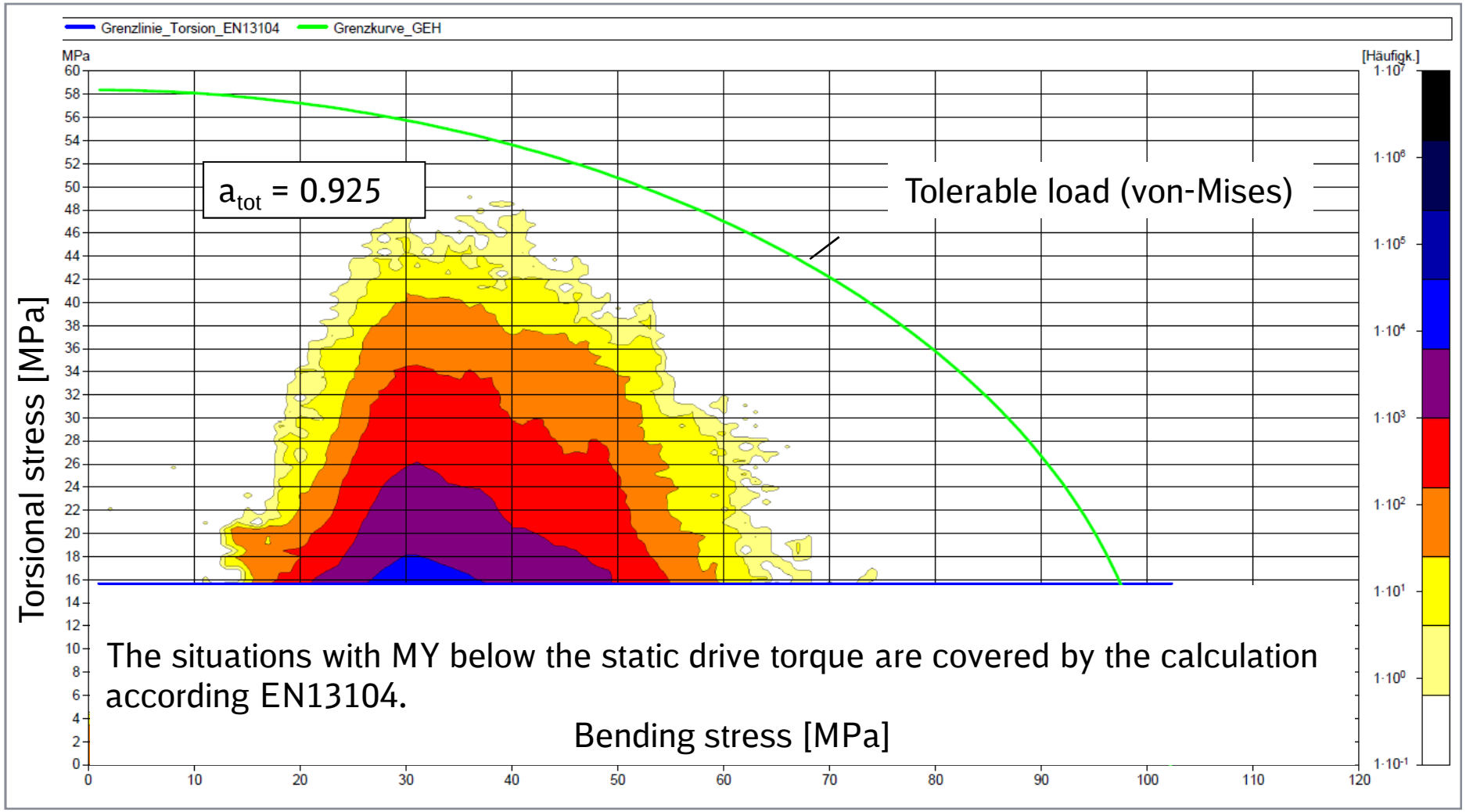
Assessment levels of the axle‘s fatigue strength (2/4)

Assessment level B & C consider the simultaneous occurrence of bending & torsion

- Besides the torsional stresses also the bending stresses have to be measured.
- The assessment is possible by calculating the equivalent stresses for each measured time sample and compare it with the allowable value or to plot the torsional stress versus the bending stress. In the latter case no point is allowed to be outside the limiting curve (see next chart).
- For assessment level B the measurements have to be performed intentionally in narrow curves coincidentally inducing torsional oscillations. The measurement may be relatively short.
- For assessment level C the measurement is done over a longer distance under service-like conditions.
- In both cases the maximum torsional momentum shall reach 80% of the maximum value.

Assessment levels of the axle‘s fatigue strength (3/4)

Assessment level B and C



Assessment levels of the axle‘s fatigue strength (4/4)

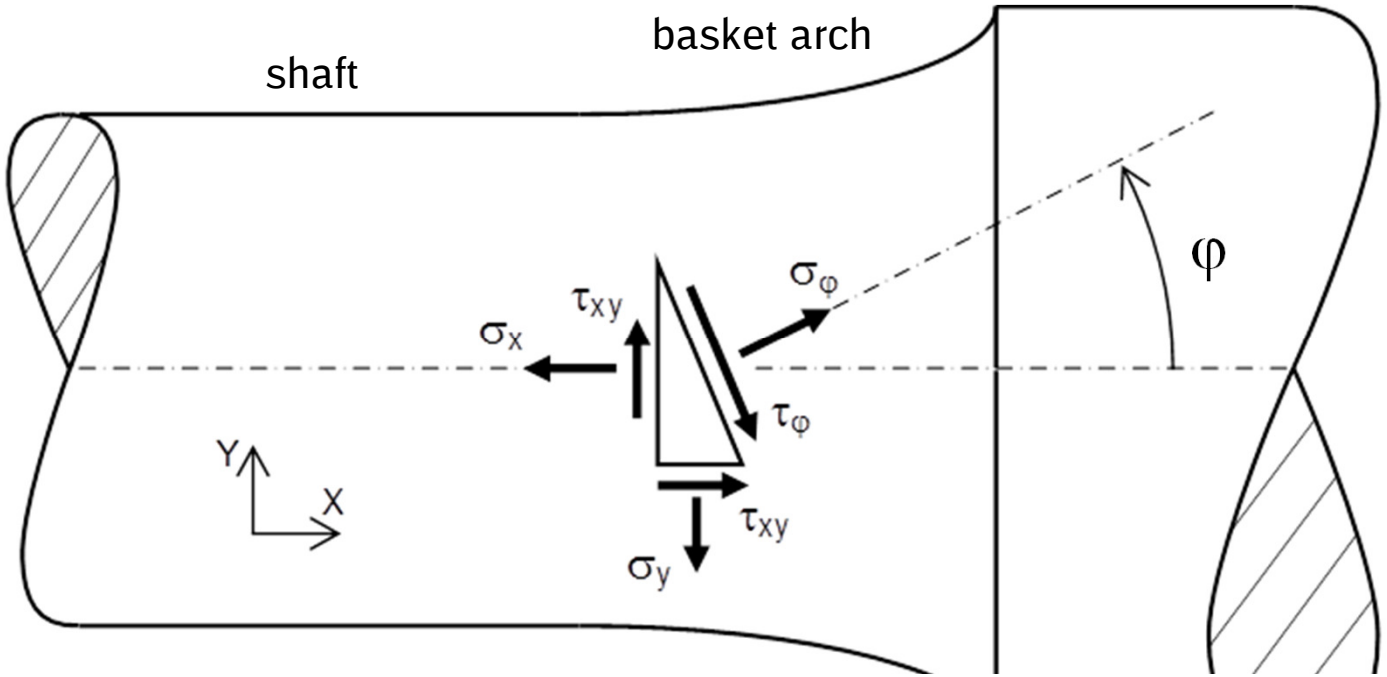
Assessment level D – Assessment of variable amplitudes is not defined

- No definition in the specification yet.
- An experts group is set up to evaluate level D.
- Simple as well as more complex methods are used for calculating examples of real load-time-functions as well as artificial tests from test rigs.
- First results are:
  - A relation between the endurance limits of shear and tension of $1/\sqrt{3} = 0{,}577$ can be used.
  - The circumferential stress should be assessed as proportional even when torsional loads are acting.
- The aim is to verify a simple calculation method for the assessment of railway axles.

Defining the State of local Stress

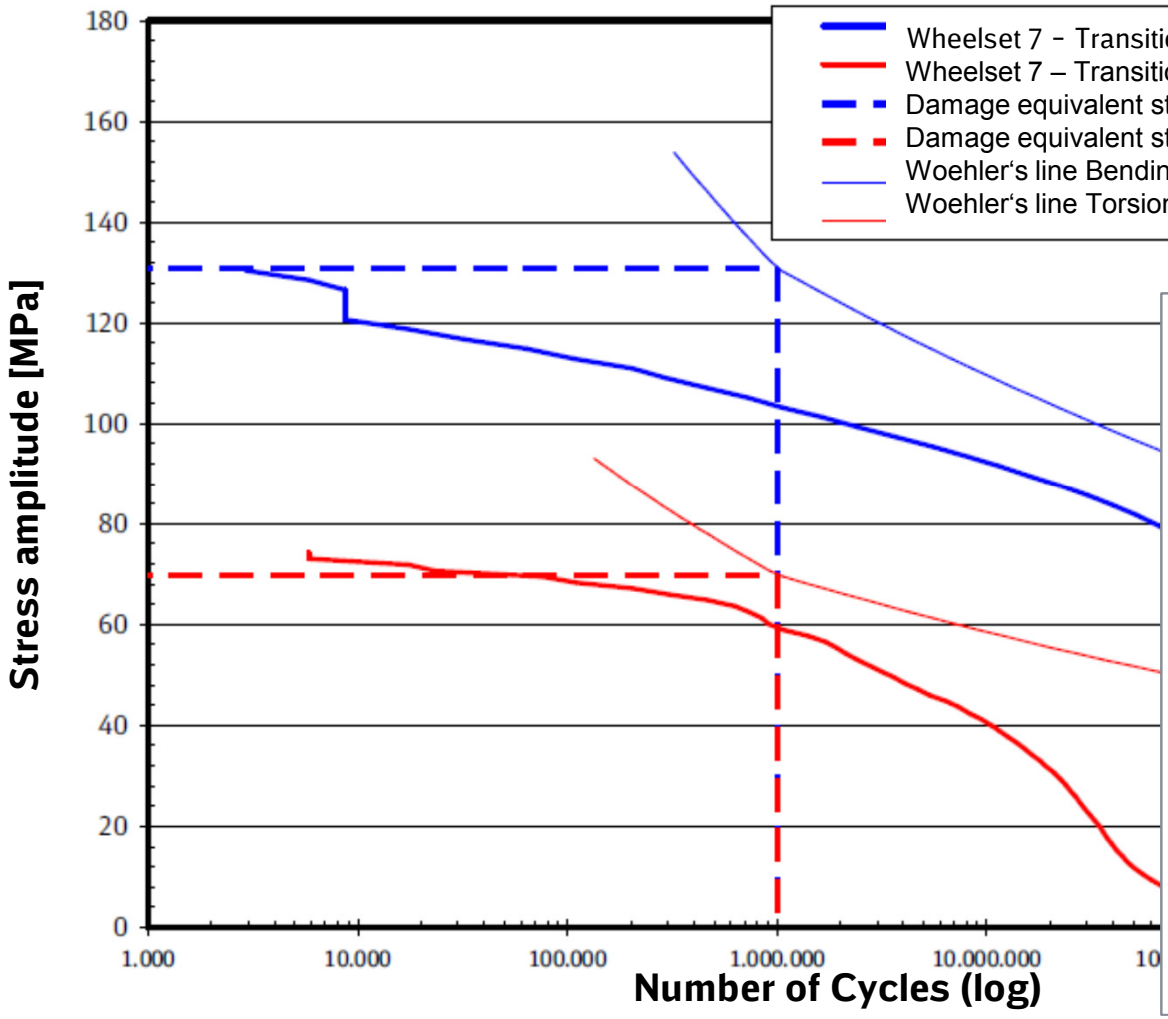
There is proportional and non-proportional biaxiality

- Primary biaxiality (non-proportional) between τ_{xy} and the normal stresses σ due to non-proportional acting forces
- Secondary biaxiality (proportional) between σ_x and σ_y caused by the geometry



Assessment Level D (1/3)

One Possibility is the Combination of componentwise Utilization



Utilization bending

$$a_\sigma = \frac{\sigma_{equiv}}{\sigma_{allow}}$$

Utilization torsion

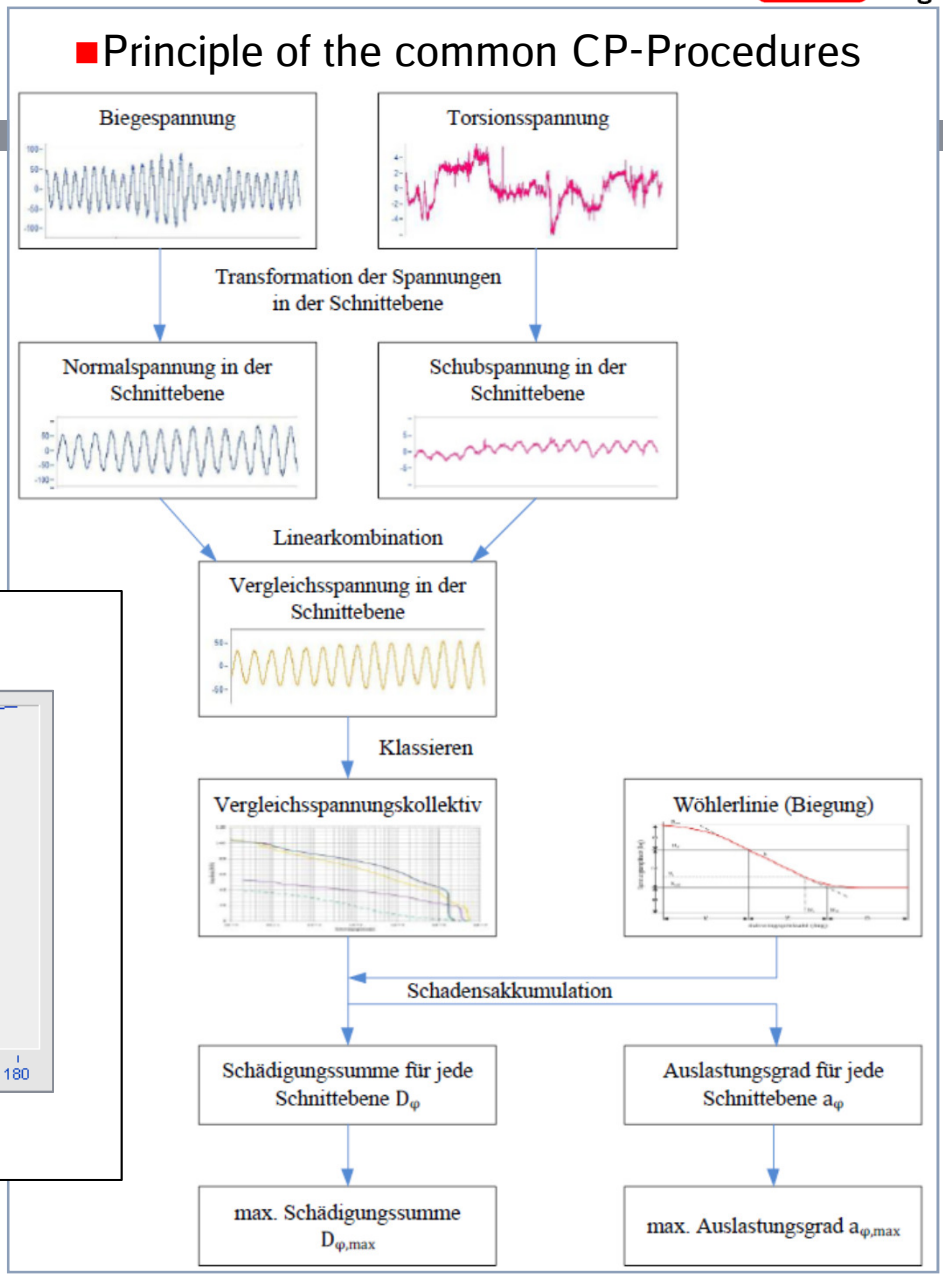
$$a_\tau = \frac{\tau_{equiv}}{\tau_{allow}}$$

Combined utilization

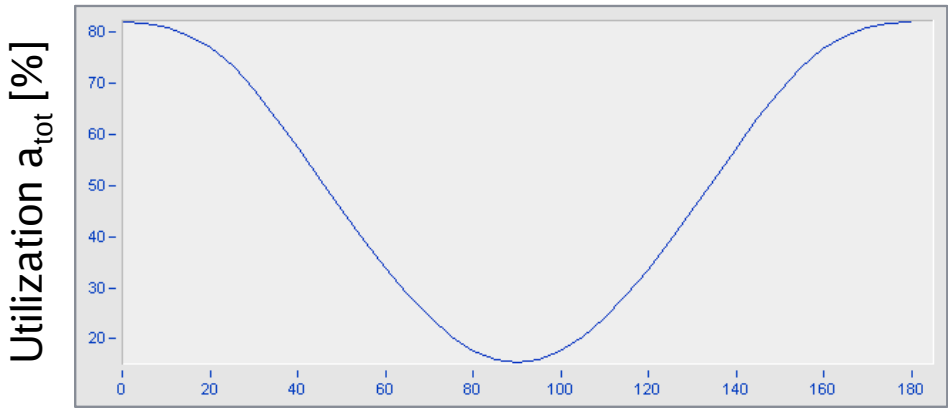
$$a_{com} = \sqrt{{a_\sigma}^2 + {a_\tau}^2}$$

Assessment Level D (2/3)
CP-Procedures

■Principle of the common CP-Procedures

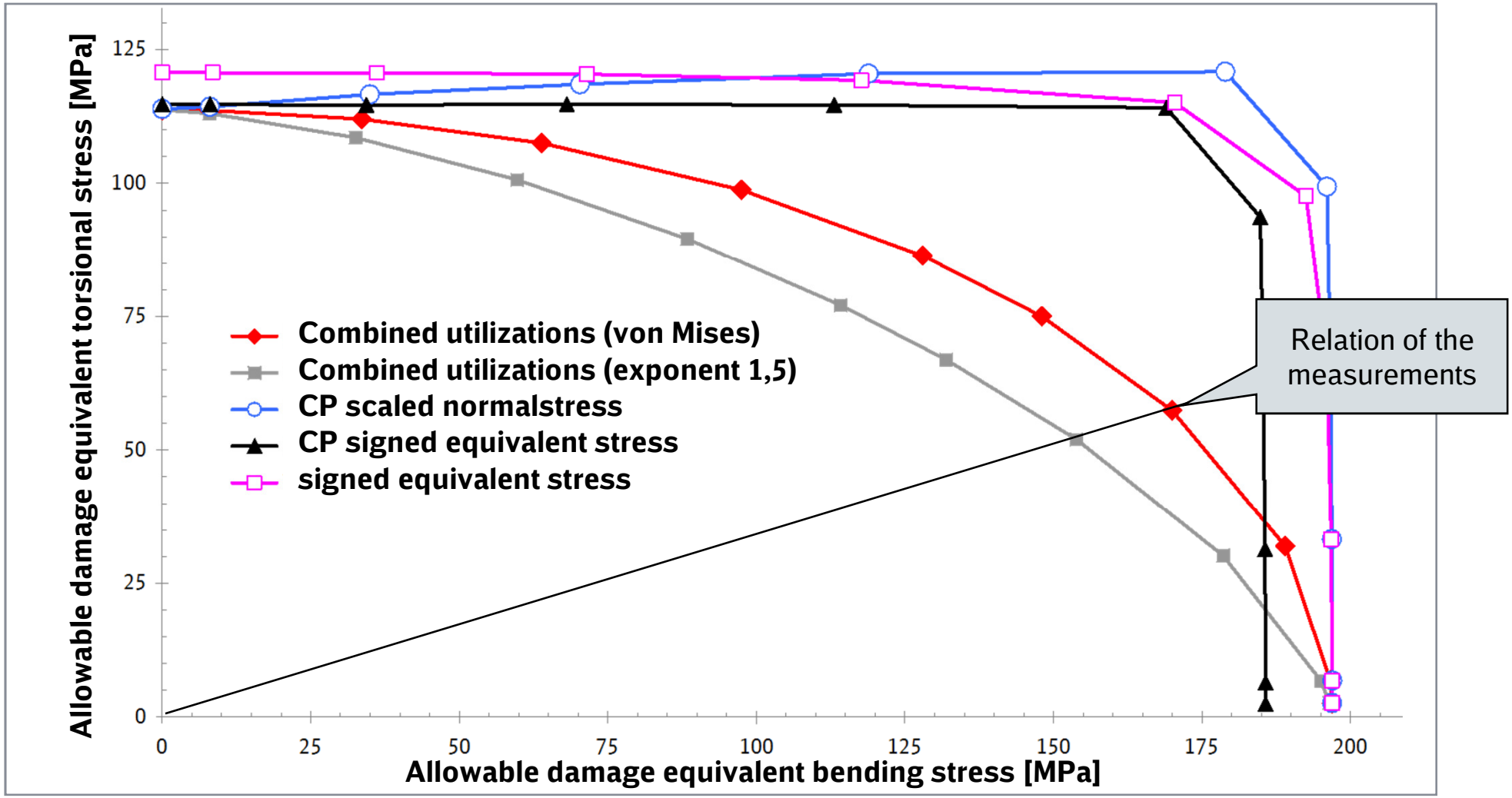


■Utilization depending on the Cutting Angle



Assessment Level D (3/3)

Depending on the method the results can differ quite much



Conclusions

- Though no serious accidents due to torsional oscillations have happened in the last decades this topic is one of the most challenging in homologation in Germany right now.
- The momentum to be assessed has to be verified by measurements dedicated especially to this purpose. Because randomness has a great influence the tests that have to be conducted are very extensive. A large number of oscillations have to measured for a valid result. A well planned measurement campaign and an experienced team is needed.
- Besides the press fit the fatigue strength of the axle has to be assessed. Depending on the magnitude of the torsional stresses four assessment levels regarding different safety margins are defined.

Thank you for your attention!

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