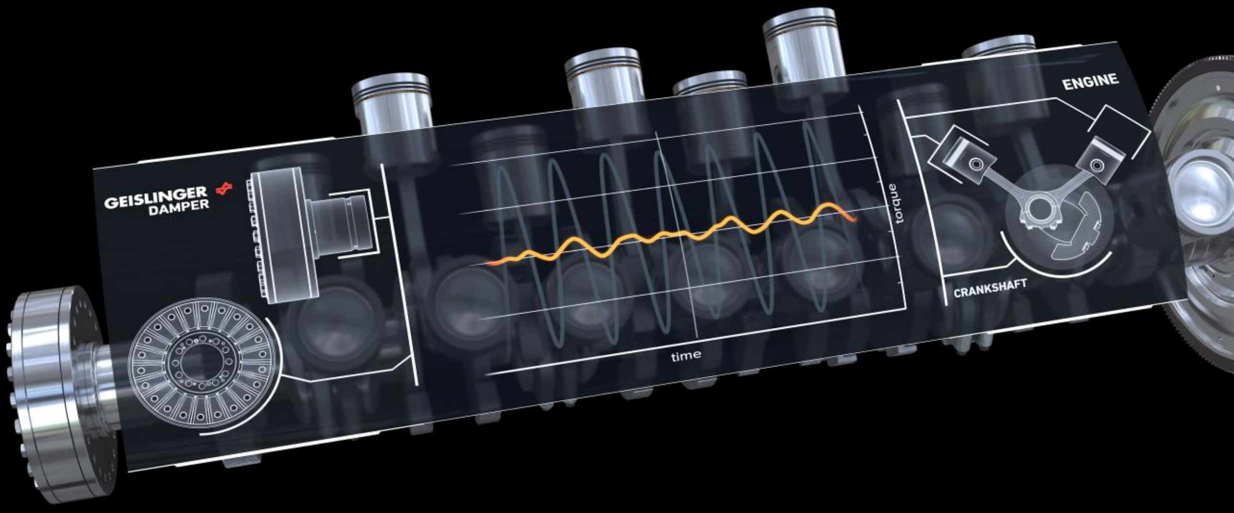
KONSEQUENZ NEUER KRAFTSTOFFE AUF ANTRIEBSSTRANG UND DREHSCHWINGUNG



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Prof. Hinrich Mohr
GasKraft Engineering

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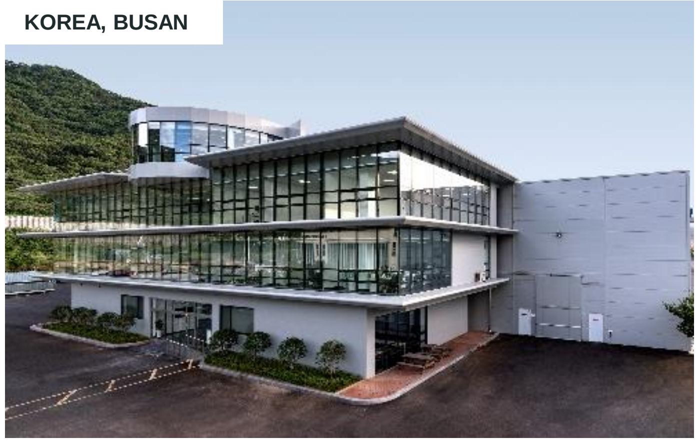
GEISLINGER MISSION

The **family-owned** Geislinger GmbH is a **world market leader** for **innovative powertrain solutions** and **built to last products** for all kinds of **high-performance drivelines.**

GEISLINGER GROUP

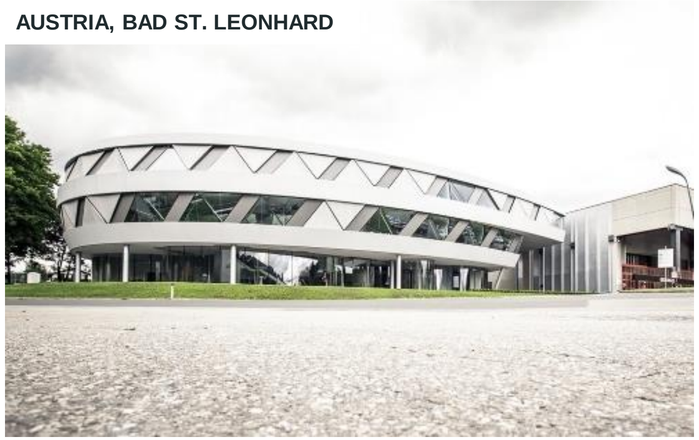
AUSTRIA, SALZBURG

KOREA, BUSAN



JAPAN, KOBE

AUSTRIA, BAD ST. LEONHARD



CHINA, SUZHOU

USA, BATTLE CREEK

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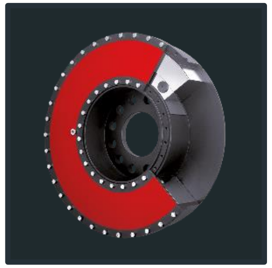
GEISLINGER POWERTRAIN SOLUTIONS

DAMPERS

Damper



Vdamp®

COUPLINGS

SAE Coupling

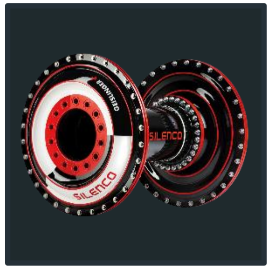
Flexlink

Coupling

Gesilco® Butterfly

Gesilco® Composhaft®

COUPLINGS



Silenco®

Carbotorq®

Compowind®

Disc

SHAFTS

Gesilco® Shaft

DIGITAL SOLUTIONS

Monitoring

Analytics Platform

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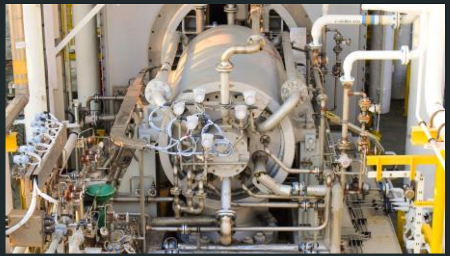
GEISLINGER DAMPER APPLICATION

SHIP PROPULSION

POWERPLANTS & GENSETS

COMPRESSORS & PUMPS



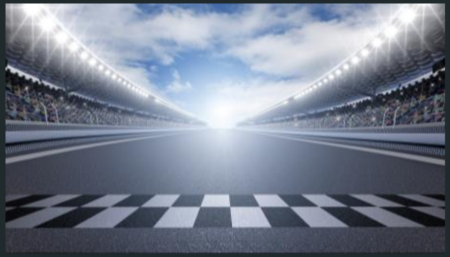
RAIL

OFFROAD VEHICLES & MINING

WINDPOWER

INDUSTRIAL APPLICATIONS

RACING



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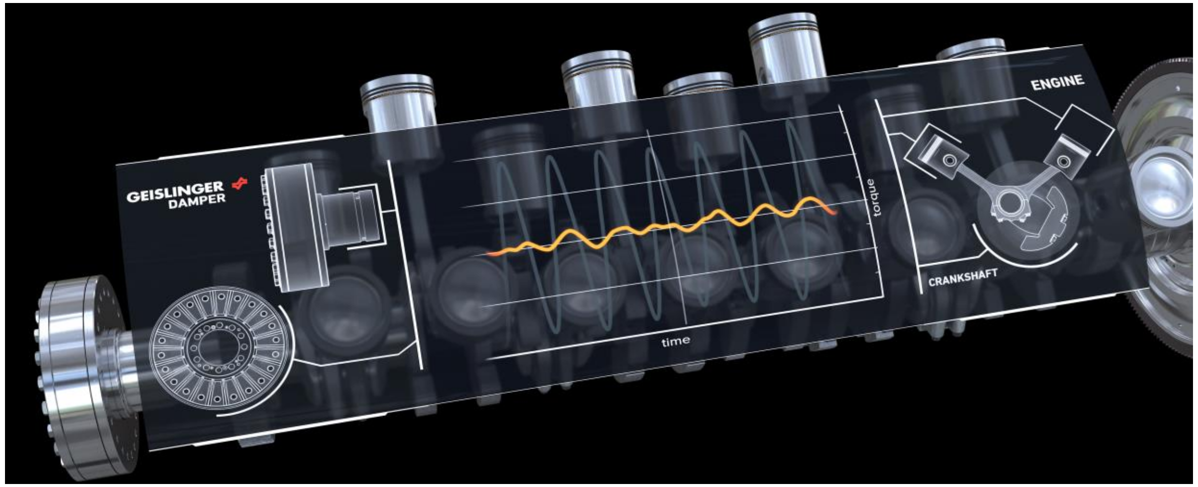
MOTIVATION: NEW FUELS AND VIBRATIONS

Comparison of (torsional) vibrations in the powertrain and music ensembles

- Layout and design
  - *Design* of music instrument = what can generate sounds? Which sounds are possible?
  - *Design* of powertrain = which vibrations might be possible? What might be critical resonance?

- The „sound“
  - The way how an instrument is played generates the final sound of an instrument (intensity, forces, …)
  - Combustion process and operating conditions are the key factors for what kind of vibration appears in the powertrain.



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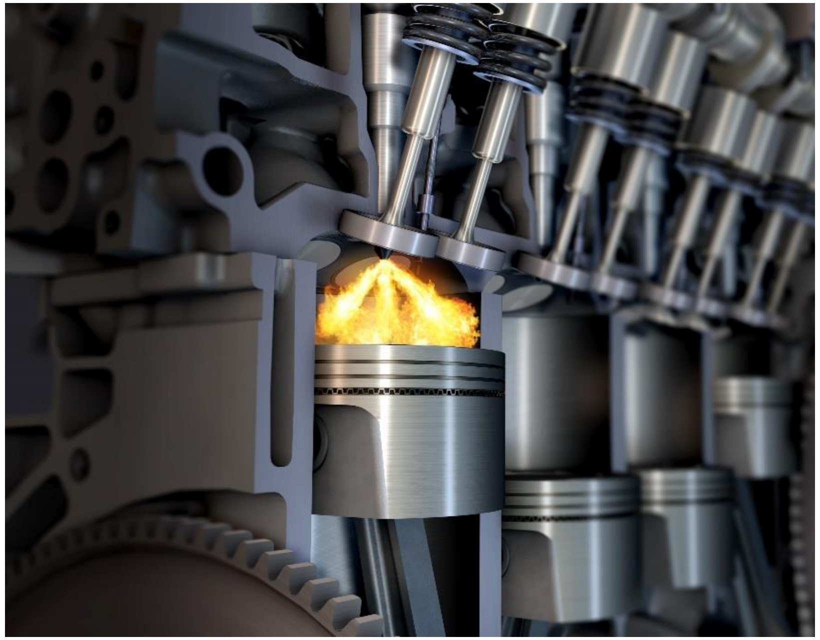
MOTIVATION: NEW FUELS AND VIBRATIONS

- Changing fuels does also mean changing dynamic properties of the system – changing the „how“ the sound is generated.

- Fast advances and reduced development times are needed to meet the market‘s demands. Does this imply also increased risk or less field experience?

- Challenge on multiple levels – not only how the new fuel is burned. Powertrain vibrations and related dynamics are also one key issues to be considered.



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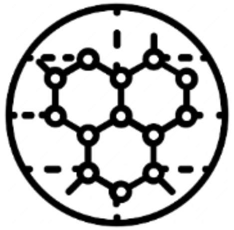
KEY KNOW-HOW FOR FUTURE FUEL-READINESS

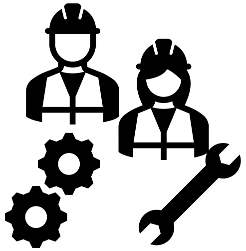
SIMULATION
&
ANALYSIS

PRODUCT
DEVELOPMENT



MATERIAL
SCIENCE

MONITORING
&
TESTING



SERVICES
ALONG THE
PRODUCT
LIFE CYLCLE

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SIMULATION TO PRODUCT SELECTION

1st STEP

- Boundary conditions and restrictions

2nd STEP

- Analysis of the system

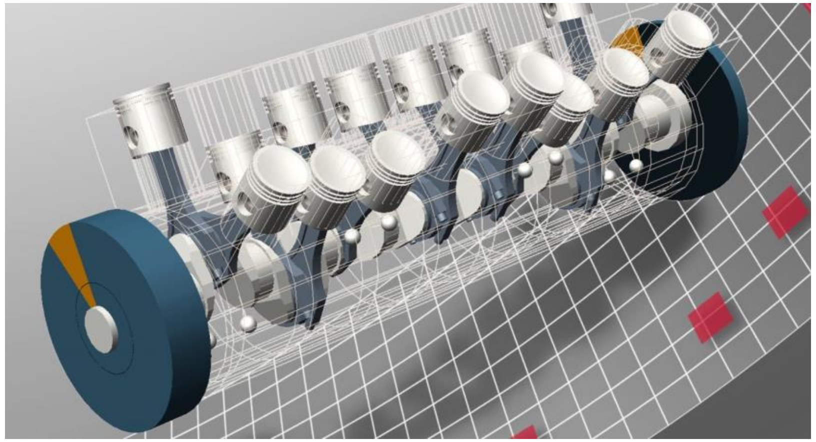
3rd STEP

- System optimization
- Product selection

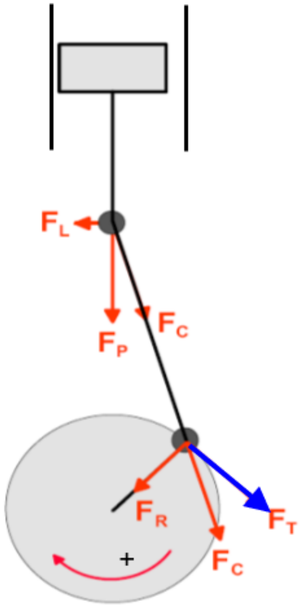
TORSIONAL VIBRATION ANALYSIS

SIMULATION & ANALYSIS

Main sources of excitations in an internal combustion engine is depending on the engine geometry



Engine excitations = tangential forces acting on the crankshaft



1st STEP

- Boundary conditions and restrictions
- Torsional data
- Excitations
- Operating conditions

Mass excitations

- *Due to oscillating masses, tangential forces on crankshaft are generated*
- *Speed-dependent excitations*

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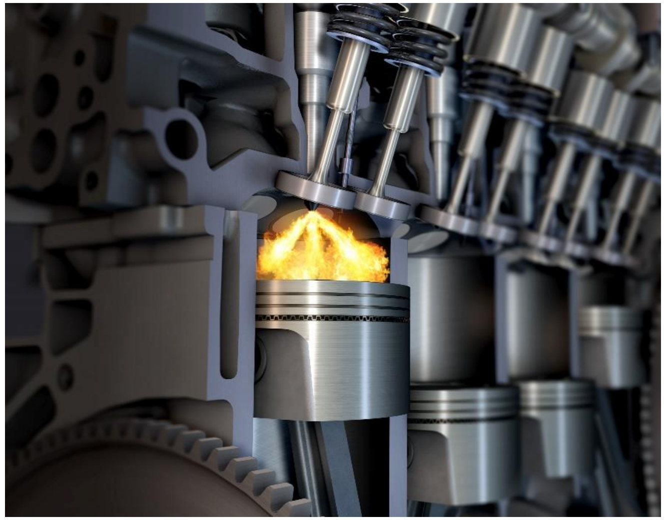
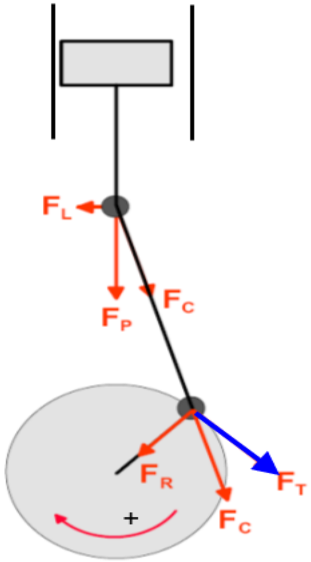
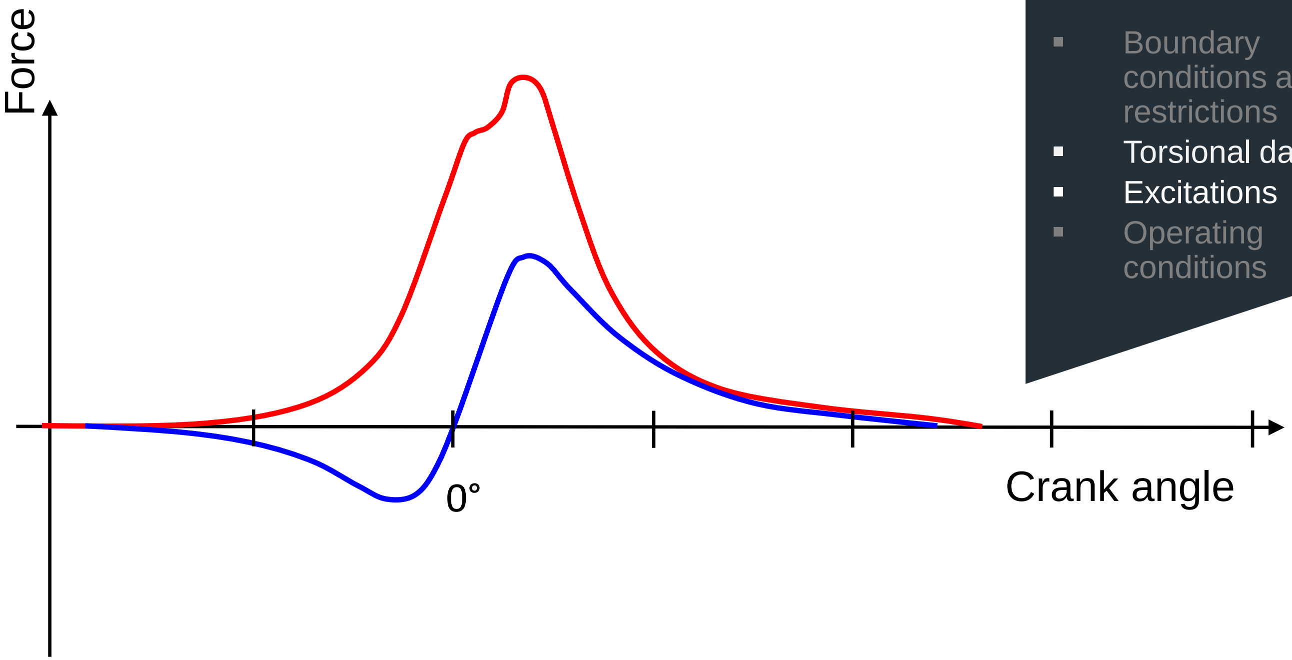
TORSIONAL VIBRATION ANALYSIS

Combustion / compression / gas excitations
Load-dependent excitations





F_P: Piston rod force
F_C: Connecting rod force
F_T: Tangential force



1st STEP

- Boundary conditions and restrictions
- Torsional data
- Excitations
- Operating conditions

R&D FOCUS: FUTURE FUELS

Different Fuels → Different combustion properties → Different dynamics

In other words …

Different fuels → Different cylinder pressure traces → Different tangential excitation forces → Different vibration characteristics

R&D FOCUS: FUTURE FUELS

SIMULATION & ANALYSIS

Fuel Types		Torsional Vibration Impact
Fossil Diesel Fuel	DI	0
Natural Gas, LNG, CNG	DI	↗
	Pre-mixed	↗
LPG	DI	↗
	Pre-mixed	↑
Methanol	DI	↗
Ammonia	DI	↗
H2: Ottocycle		↑

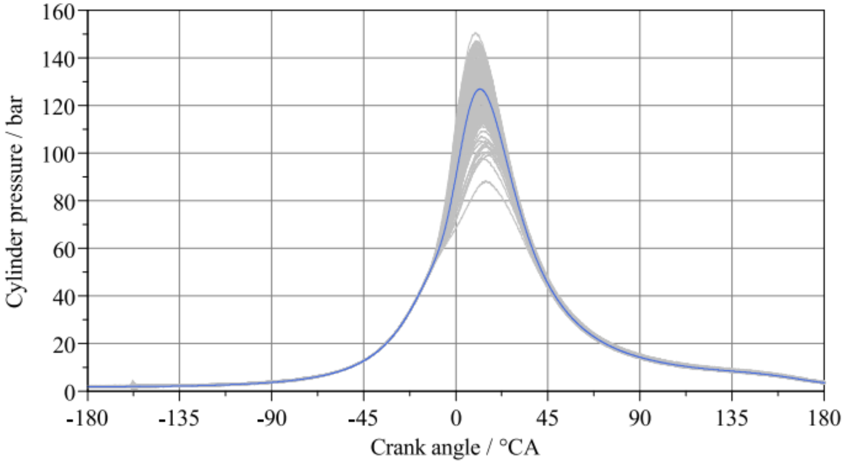
Effect Legend	
↑	Strong impact
↗	Impact
→	Unchanged
0	Reference

Fuel Properties	Torsional Vibration Impact
Power Density	↗
Ignition Energy Request	→
Ignition Stability	↗
Combustion Stability	↑
Peak Pressure Level	↑
Temperature Level	→
Knocking Sensitivity	↗
Mechanics & Tribology	↗

- Traditionally strong focus on new technologies and development partner of gas, hydrogen and methanol engines.
- On-going 3rd party collaborations with focus on fuel consumption & emission reductions and maintenance savings

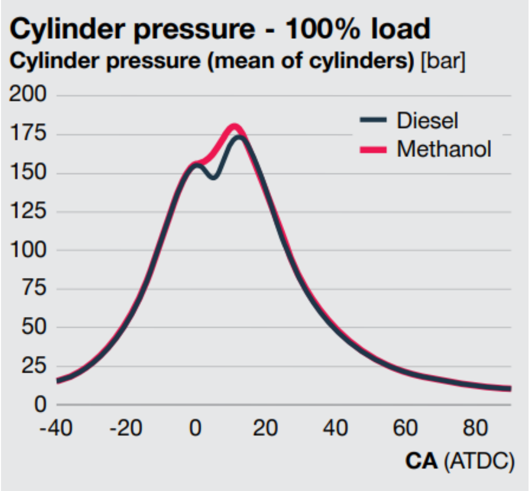
EXAMPLES

SIMULATION & ANALYSIS



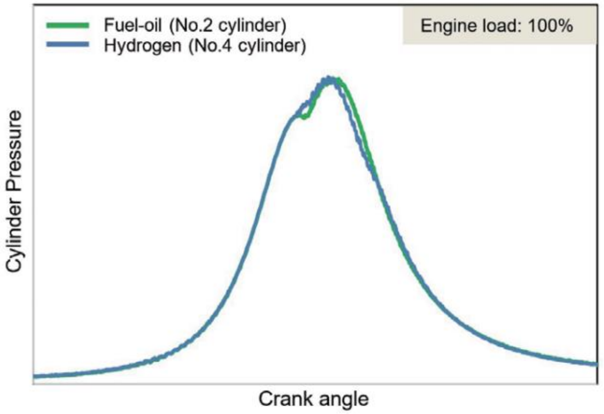
Examples with Ammonia

Hinrich Mohr: CAMPFIRE Ammonia-fueled Cracker-Engine-Propulsion System for Inland Waterway Vessels – actual Development Status and Safety Considerations, 3rd Rostock Ship Machinery Conference, 2023.



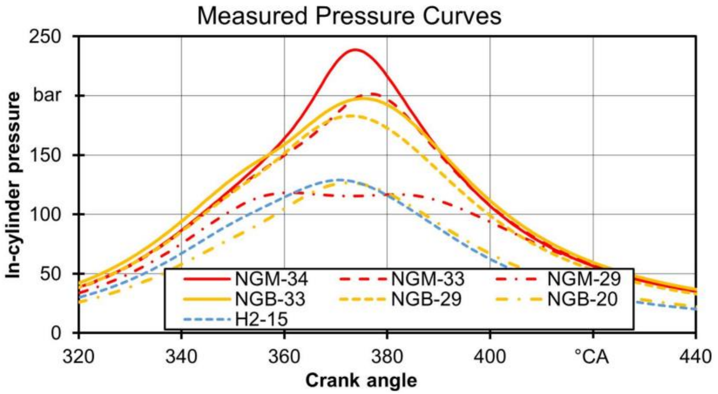
Examples with Methanol

https://www.man-es.com/marine/strategic-expertise/future-fuels/methanol



Examples with H_2 (2-stroke)

Sea Japan Newsletter No.425, June 2024



Examples with CNG & H_2 (4-stroke)

Klaus Prenninger, Claudia Mühlberger, Stefan Eicheldinger, Georg Wachtmeister: IMPACT OF EMISSION REDUCTION STRATEGIES ON TORSIONAL VIBRATIONS, Torsional Vibration Symposium, 2021.

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TORSIONAL VIBRATION ISSUES

SIMULATION & ANALYSIS

What are the limits for torsional vibrations that must be fulfilled?

Type of Torsional load	Failure mode
Vibratory torque / stress in the crankshaft	crankshaft failure
Vibratory torque / stress in the shaftline	shaftline failure
Vibratory torque at the gearbox input shaft	Gear hammering, noise emission, gearbox failure
Vibratory acceleration at camdrive / chaindrive	Timing issues, cam/push rod contact
Vibratory angle / velocity at alternator	Flickering, synchronization

What are the additional requirements that must be fulfilled?

Type of Requirements	Actions to be considered
Classification society	Class-dependent rules for dimensioning and design
Ice class requirements or generator short circuit	Time-domain simulation of ice impact or short-circuit
Barred speed range free operation	Increased demands on Torsional vibrations
Installation limits of a torsional vibration limits	Max. dimensions, max. weight and max. allowable bearing load

1st STEP

- Boundary conditions and restrictions
- Torsional data
- Excitations
- Operating conditions

BASIC DESIGN GEISLINGER DAMPER

- **Basic parts of a steel spring damper**
- **Stiffness**

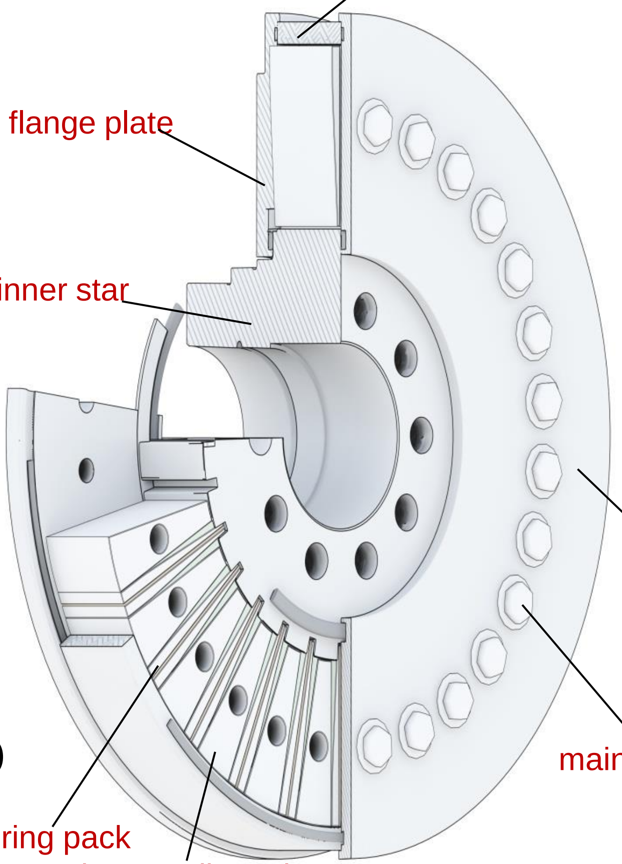
Steel spring packs

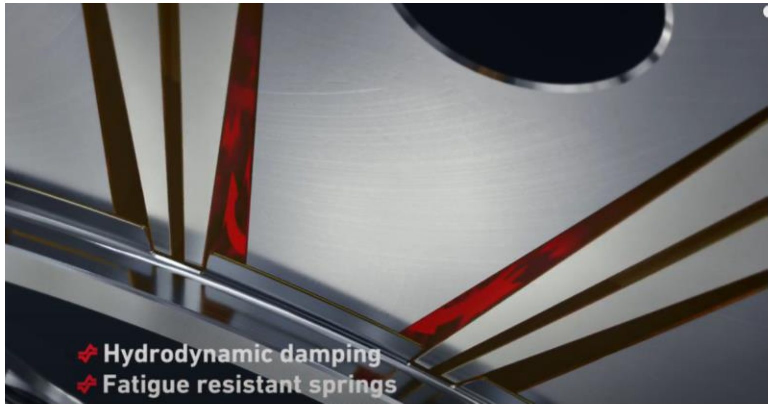
- Any desired degree of stiffness available
- No progression steps
- Independent of the required damping
- Inner part small (lower inertia)
- Outer part large (higher / more efficient inertia

- **Damping**

Hydrodynamic oil damping

- Using engine oil, leads to no wear
- Oscillation of the outer part causes a pumping of oil between chambers (A & B)
- Oil flow through damping gap
- Design of damping gap influences the damping properties





Link:
Product video
Geislinger Damper

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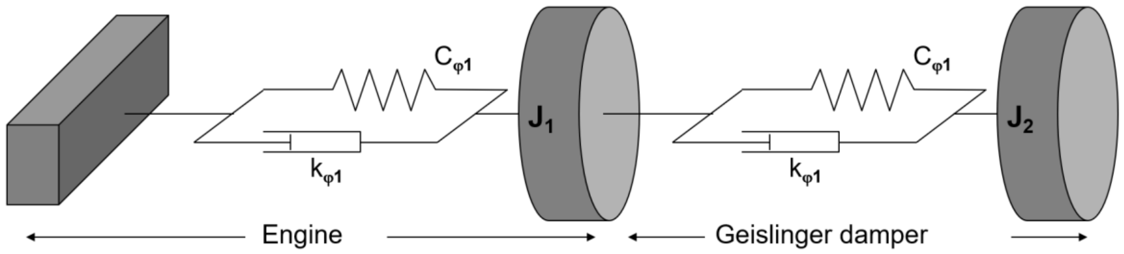
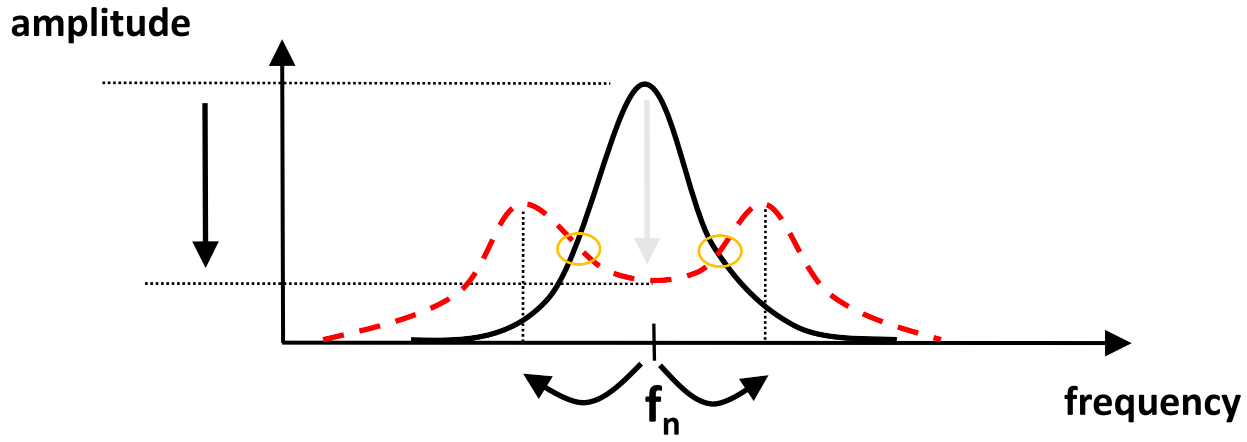
DAMPER SELECTION

SIMULATION
&
ANALYSIS

Working principle of Geislinger Dampers:



- Elasticity of damper springs split resonance
- Damper mass moves resonance
- High damping of pressurized oil reduces resonance



3rd STEP

- System optimization
- Damper selection

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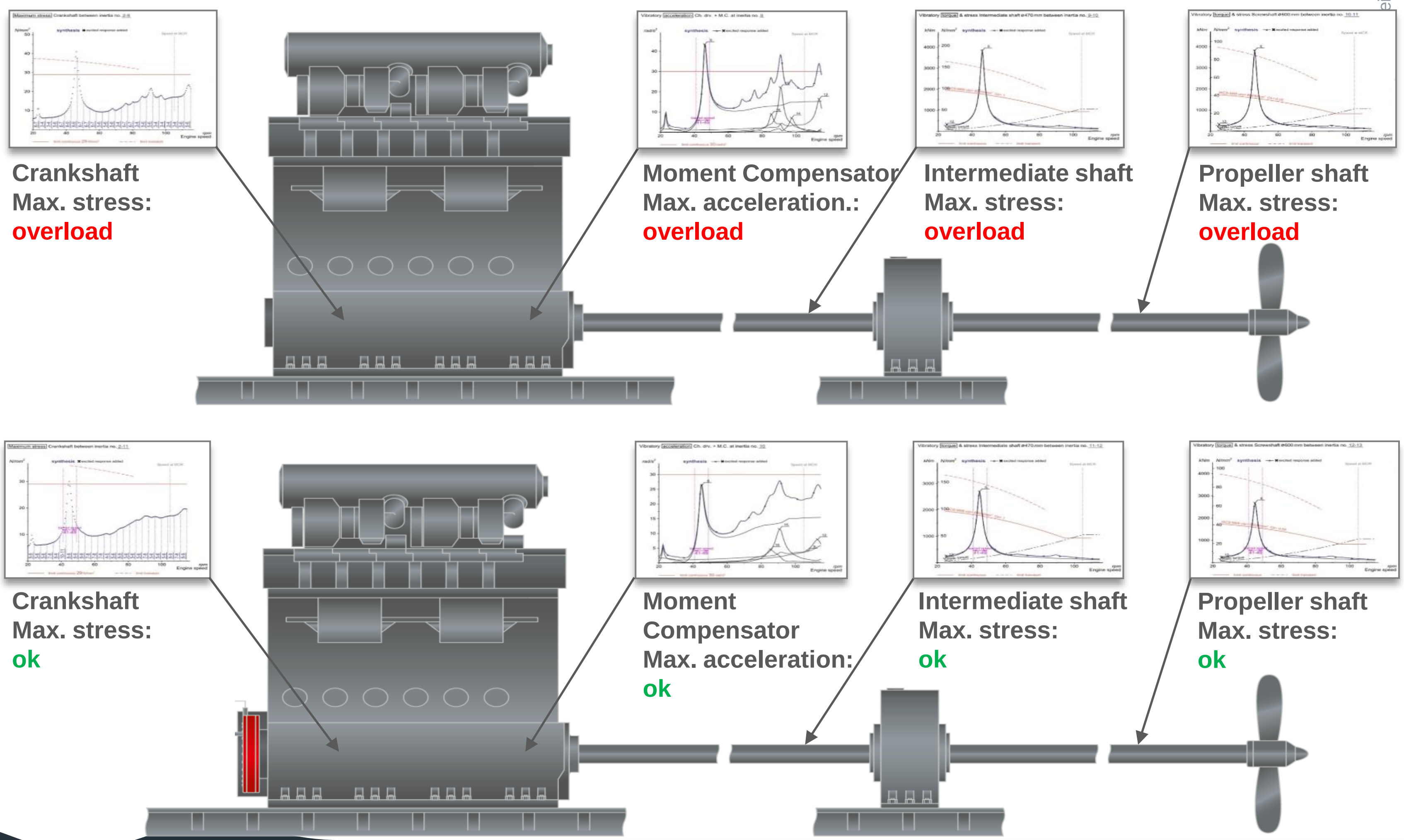
APPLICATION OVERVIEW

PRODUCT DEVELOPMENT

- 2 stroke engine
  - System is torsionally excited by the combustion and mass forces
  - Continuous increase of engine power results in higher exciting torques
  - Leads to increased torsional vibrations
  - Damper on the crankshaft can protect the intermediate- and propeller shaft
  - Geislinger steel spring damper can avoid barred speed ranges



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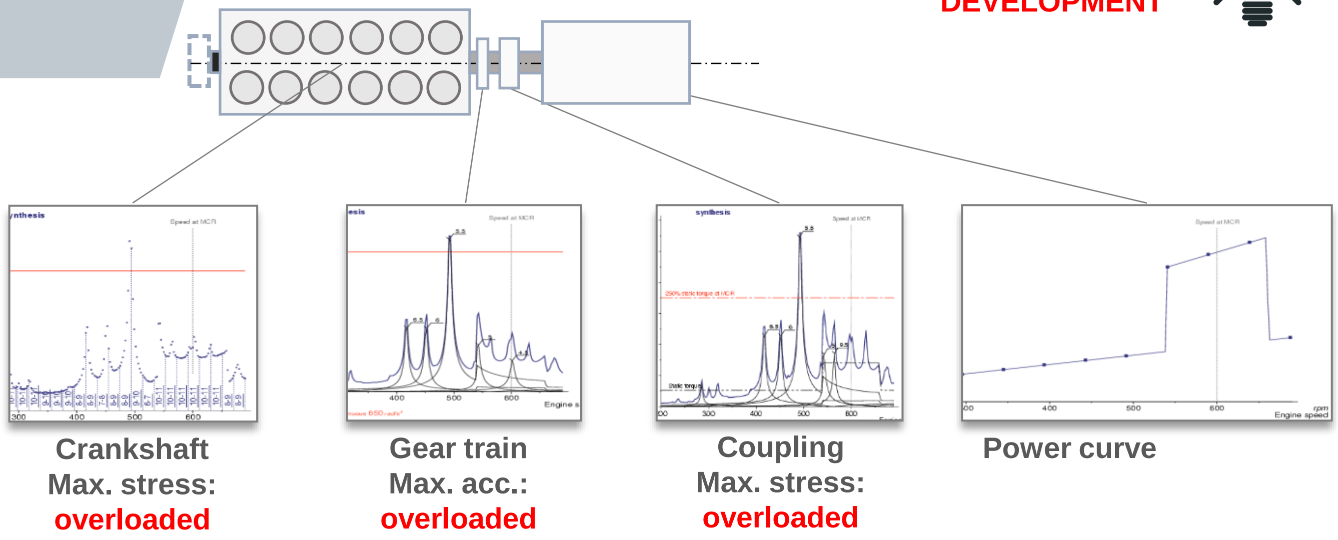
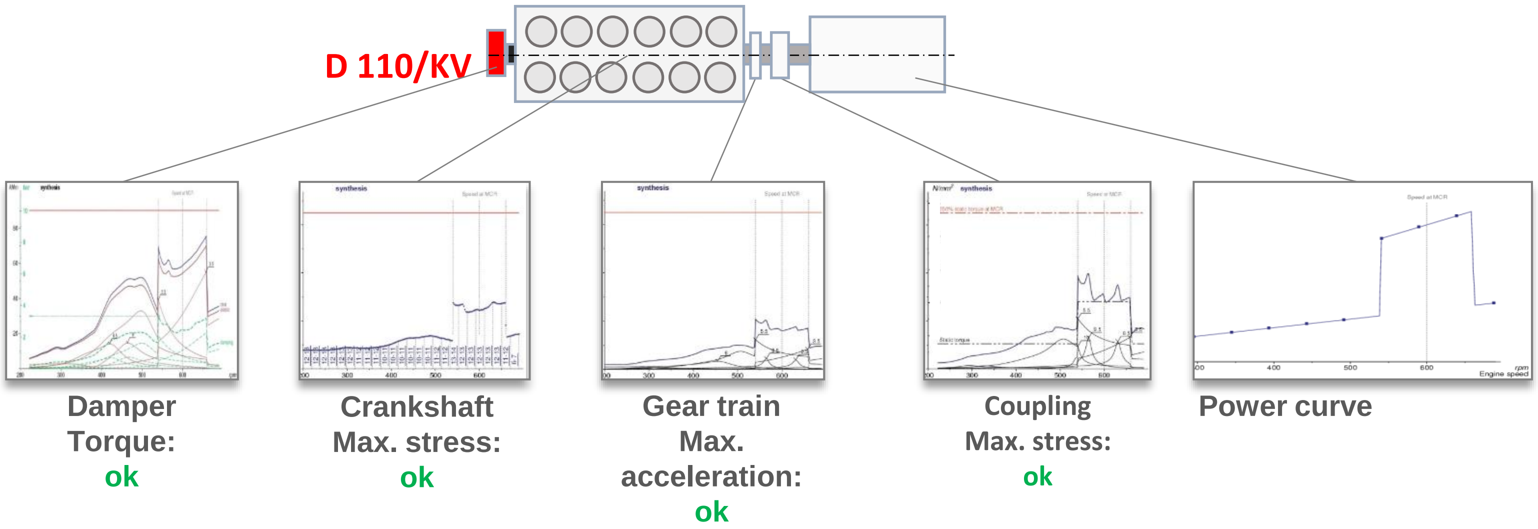
APPLICATION OVERVIEW

PRODUCT DEVELOPMENT

- 4 stroke engine
  - Due to continuing progress in engine design, attention must be paid on torsional vibration problems
  - Vibration must be reduced by detuning and damping
  - Combination of high elastic of the spring leaves together shift critical speeds out of the engines operating speed range
  - Damper lowers vibratory torque of the crankshaft





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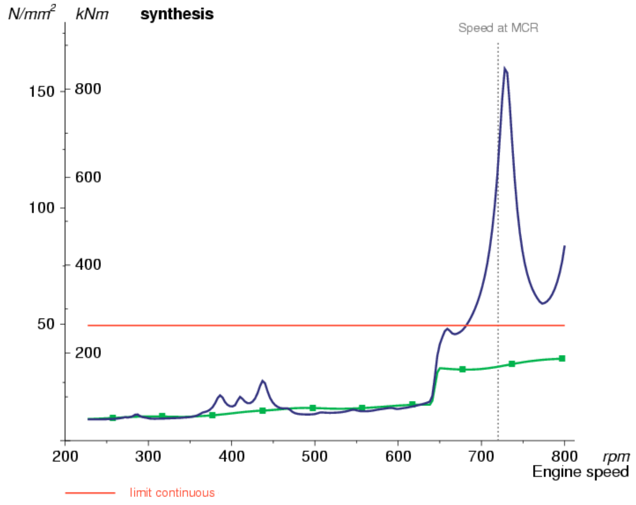
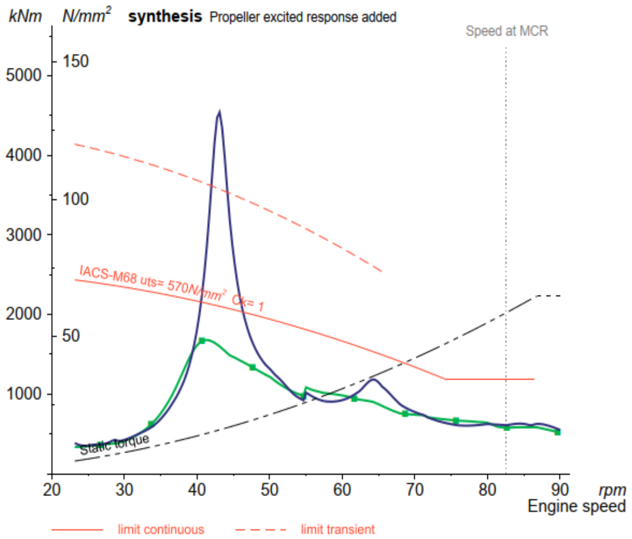
TORSIONAL VIBRATION ISSUES

PRODUCT DEVELOPMENT

- Torsional Vibration Dampers protect essential powertrain components (crankshaft, shaftline, alternators, …)
- A failure of the Torsional Vibration Damper increases risk of failures of protected components.



Case study 4-stroke: Genset application
Crankshaft stress for partly failure of TVD



Case study 2-stroke: bulk carrier with shaft generator
Intermediate shaft stress for partly failure of TVD

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TRENDS AND REGULATIONS

- Future targets need to be considered for new-builts
- Decarbonization process will be accompanied with other emission reduction strategies that also have impact on Torsional Vibrations
- Retrofit solutions will be necessary
  Powertrain changes over lifetime multiple times

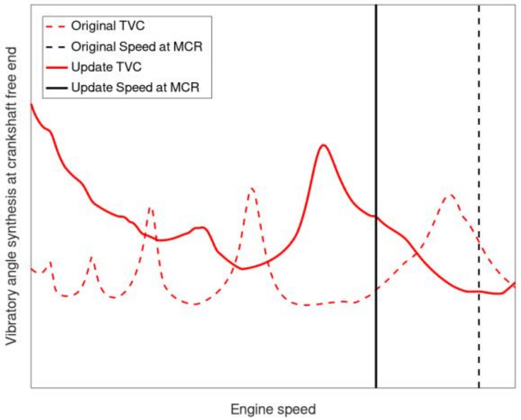
Improving GHG Emissions	
	Operational optimization
	Engine Power Limitation (EPL) or Shaft Power Limitation (ShaPoLi)
	Optimizing hull and hull resistance
	Carbon capture technologies
	Exhaust Gas Treatment
	Alternative fuels for M/E and A/E

TODAY FOR TOMORROW's POWERTRAIN

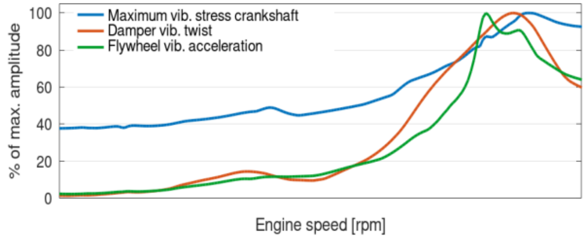
PRODUCT DEVELOPMENT

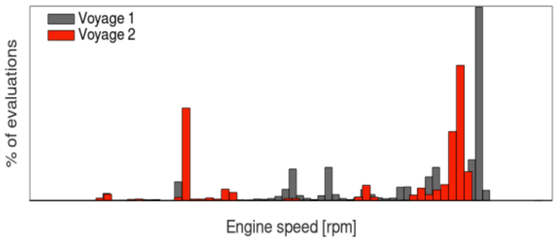
Product development: Ready for powertrain modifications

CPO Containerschiffreederei
HAMBURG



Propeller retrofit
Changed Torsional Vibration situation
Propeller size has significant impact on torsional vibrations

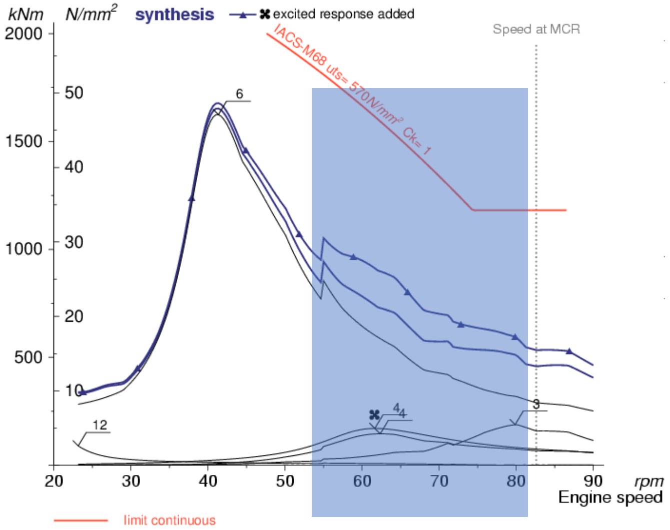




Changed operational profile
Speed up ageing of powertrain components possible due shift to different vibration load conditions.

Shaft generator retrofit
6-cylinder 2-stroke engine
Geislinger Damper initially installed - application without Barred Speed Range

Torsional stress on intermediate shaft



Generator operation range

[Wärtsilä and Berge Bulk complete maritime industry's first inline shaft generator retrofit (wartsila.com)]

NEW FUELS AND MATERIALS

MATERIAL SCIENCE

- Additional challenges arise by the use of new fuels
- Possible direct and indirect effects such as emulsification, corrosion and direct reactions
- Combustion main/by-products
  - Interaction of fuel and by-products with surfaces
  - Ingress of fuel into lubricating oil
- Intensive research needed on materials needed

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NEW FUELS AND TORSIONAL VIBRATIONS

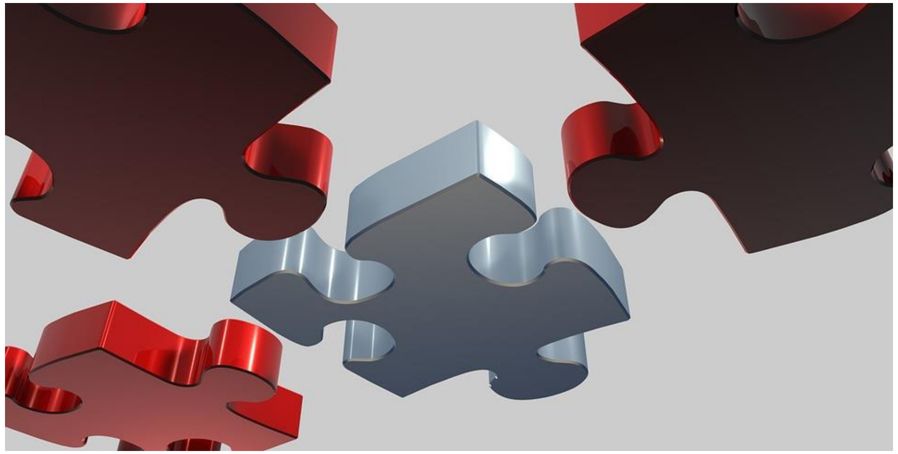
- Alternative fuels will change torsional vibrations depending on their combustion properties.
- Beyond the use of different fuels, other countermeasures will be necessary and will affect Torsional Vibrations.
- Systems will get more complex and various aspects concerning Torsional Vibrations in the powertrain need to be considered for design new propulsion systems.

TODAY FOR TOMORROW’s POWERTRAIN

MONITORING

Monitoring & Digitalization: GMS & Geislinger Digital Solutions from the perspective of future powertrain development

- Continuous monitoring of Torsional loads for new-builts as well as conversion projects
  - Detect at an early stage: increased component wear, fast ageing & failures on the Powertrain
- Long term monitoring and Data Science support (data-based risk assessment)
- Continuous data analysis of new technologies to gain field experience
  - On-going 3rd party collaborations with focus on fuel consumption & emission reductions and maintenance savings
  - Data exchange with other platforms



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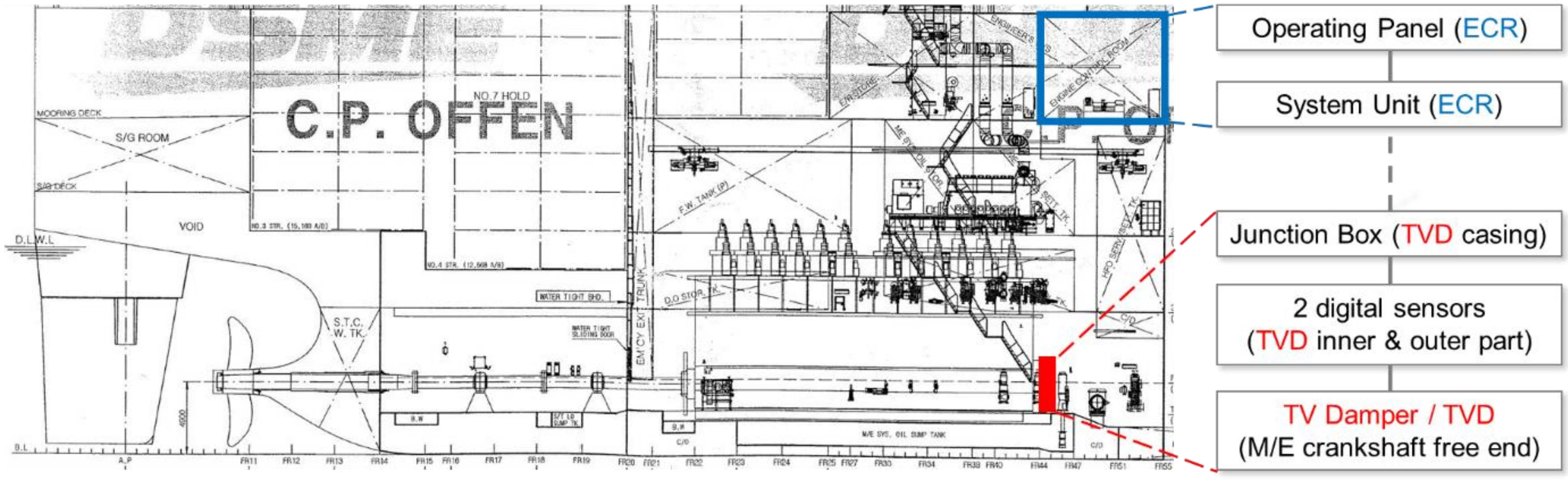
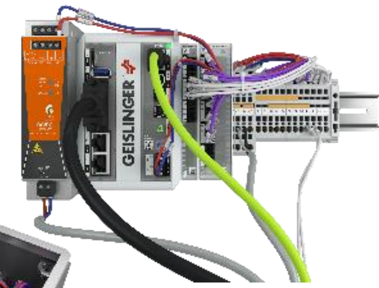
GEISLINGER MONITORING SYSTEM

Torsional vibration damper monitoring
Installation on a 14k TEU container vessel



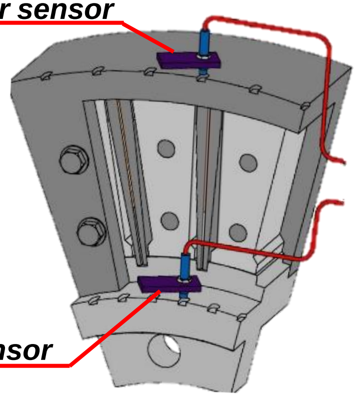
Panel



System Unit

Junction Box

Outer sensor



Inner sensor

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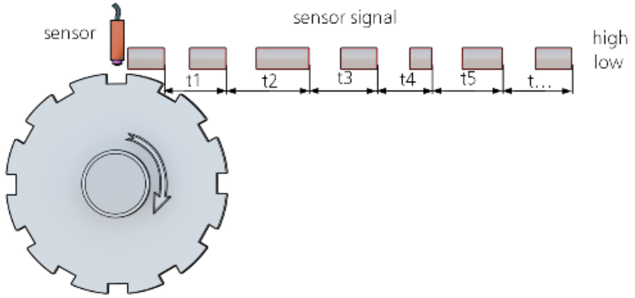
TORSIONAL VIBRATION MONITORING

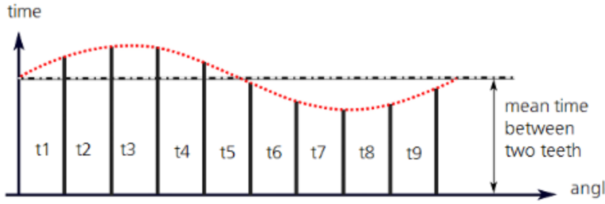
MONITORING

Measurement principle & signal processing

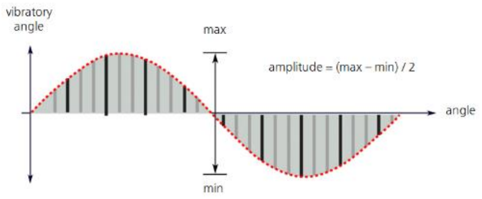
- Digital sensors are mounted against gear patterns
- Time differences between passing flanks are measured



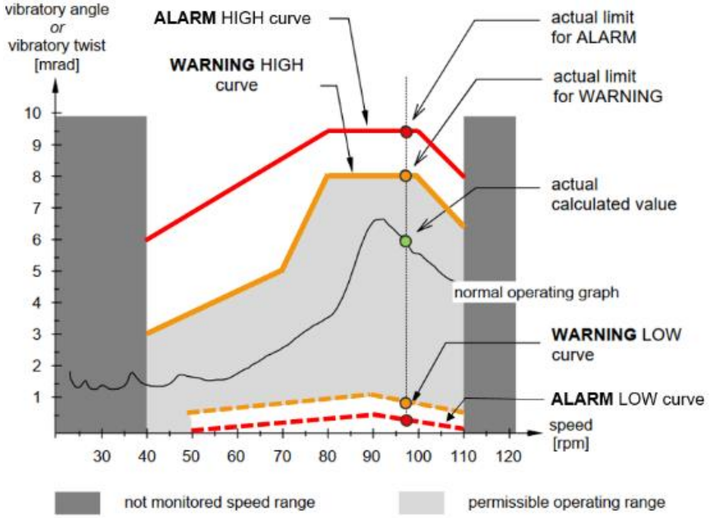
- Based on time differences the angular displacement can be calculated



- By applying bandpass filters, critical frequency ranges can be extracted
- Result = Vibration amplitude (angle or twist) in critical frequency range.



- Based on TVC results, normal operation ranges are defined
- By exceeding critical thresholds, the system provides information on warnings and alarms to the local technical staff / crew.



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BENEFITS OF TORSIONAL VIBRATION MONITORING

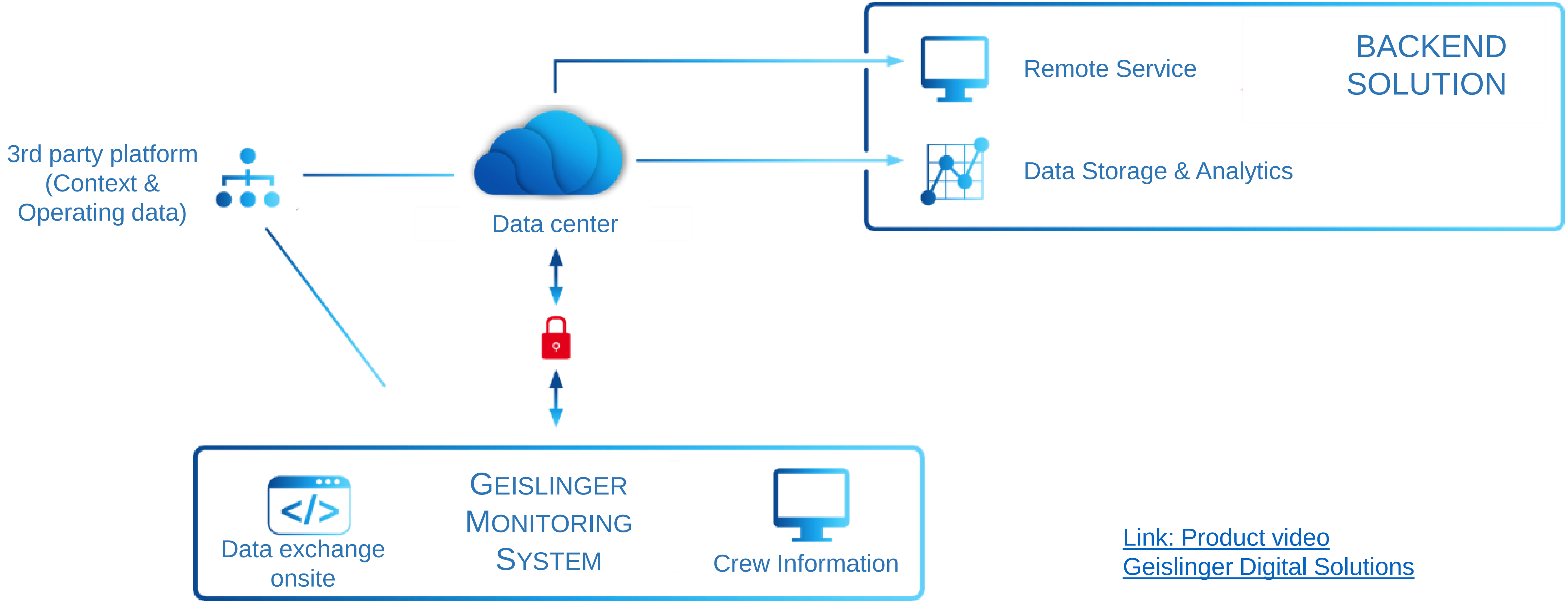
- Guarantees a simple way to perform Torsional Vibration measurements
  - Verification of calculation results

- Data is tailored for detailed system analysis
  - Damper and coupling performance evaluation and system validation

- In case of necessary troubleshooting,
  - Fast feedback to crew / technical staff,
  - indication of critical or abnormal system conditions (e.g. misfiring),
  - provides information about the status of the powertrain when it is needed most,
  - a reliable source of information,
  - indication of normal operation conditions.

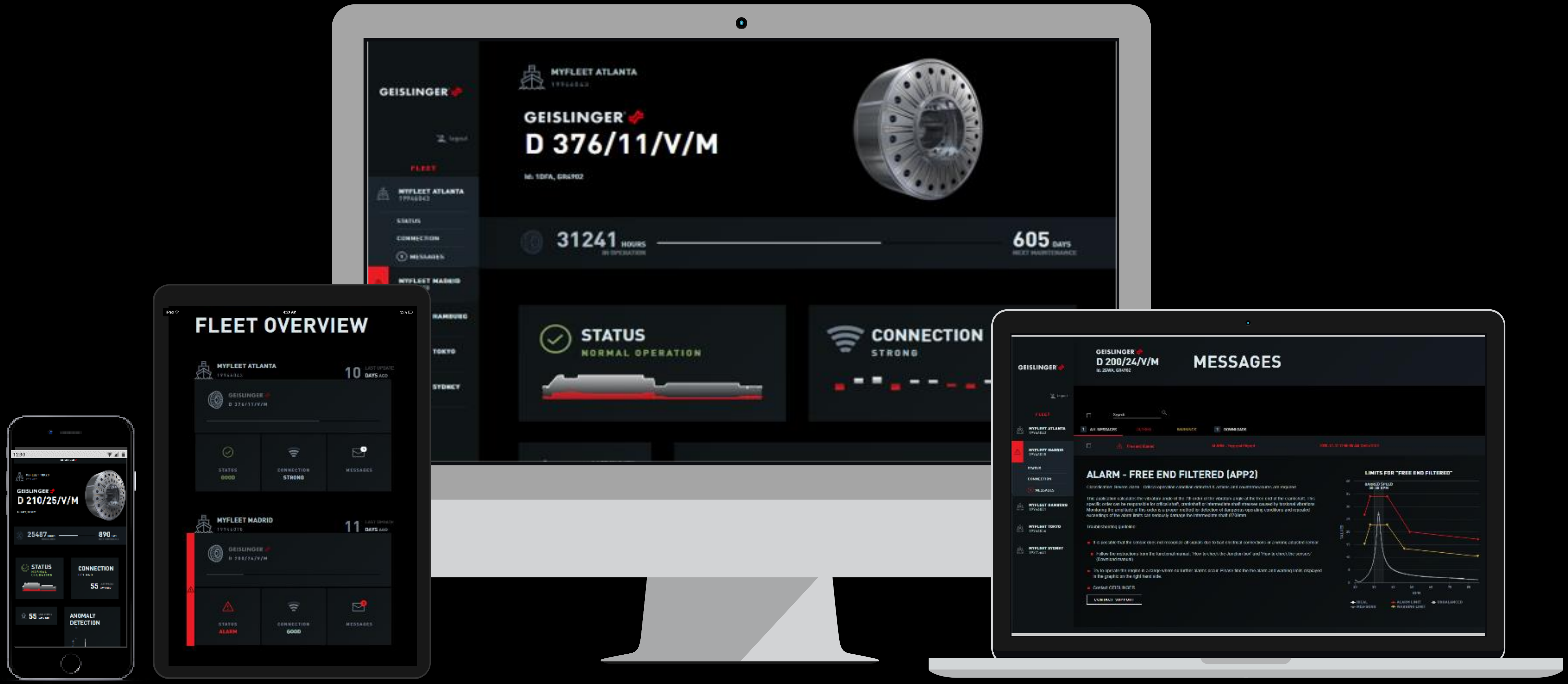
- Enabling **Geislinger Digital Solutions**

DIGITAL ECOSYSTEM



[Link: Product video
Geislinger Digital Solutions]

GEISLINGER ANALYTICS PLATFORM



analytics.geislinger.com

WHAT CAN BE DONE WITH THE DATA…

MONITORING

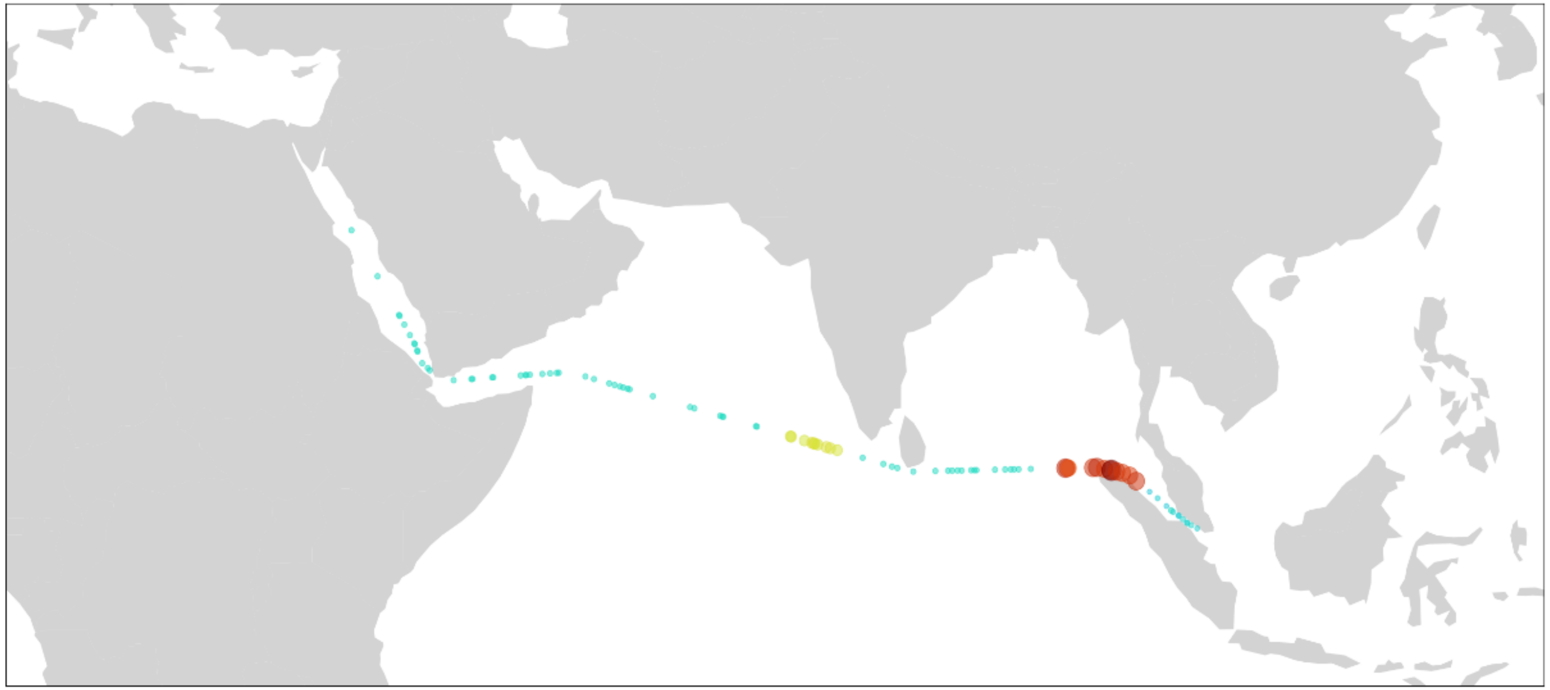
Anomaly detection

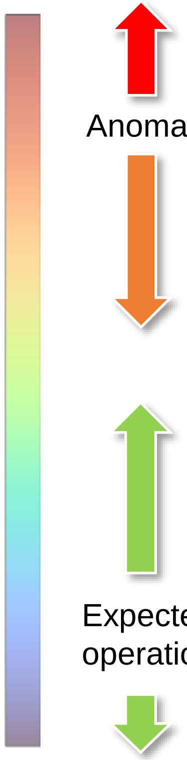
Data models are trained to compare measurement results with model predictions

- Anomaly if difference gets larger (out of expected operation range)

Vessel:
14k TEU container vessel

Context information:
Improved results and interpretability, if torsional vibration data are combined with e.g. operational, GPS- and/or weather data.





Example of Anomaly detection for a power monitoring based on torsional vibration data.

red and yellow areas show operational anomalies due to e.g. bad weather conditions, measurement errors or unexpected high power demand.

WHITEPAPER

MONITORING

For more insight in our data-driven approach to torsional vibration data please check out our latest Whitepaper

„Data-driven approach to Torsional Vibration Analysis“

ABOUT THE AUTHORS

DIPL.-ING. KAI BERGMANN, MSC

Kai Bergmann is an accomplished data scientist with a background in telematics and data science. He has extensive experience in software development and knowledge management in the banking sector and was a pioneer in video data acquisition and analysis in the automotive industry.

In his current position, Kai Bergmann works in Data Science for damper monitoring at Geislinger and is a true pioneer in using data for transformative outcomes in various fields.

DR. ANDREAS THALHAMMER

Dr. Andreas Thalhammer earned an MSc. and PhD in computational mathematics at JKU Linz. His focus on statistics and numerical simulations was the cornerstone of an innovative career.

At Geislinger GmbH, he developed high-performance powertrain simulations and is now responsible for the further development of Geislinger's innovative solutions as manager for digital development. As an advisory board member of the Vibration Association and co-organizer of the Torsional Vibration Symposium, Andreas Thalhammer is driving advances in torsional vibration analysis and shaping the landscape of industrial progress.

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Solution Provider – Adaptations, i.e. due to operational changes

Lifespan “companion“ – Geislinger and its network

Repairs & Maintenance – “Built to last“ ensurance

KEY TAKE AWAYS

With the Geislinger Engineering Competence we:

- Select a tailor-made product which best fits to each application
- Optimize the propulsion system
- Increase the lifetime of the system
- Support powertrain readiness for new IMO regulations (CII, EEXI) by Engineering, Products and Services

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