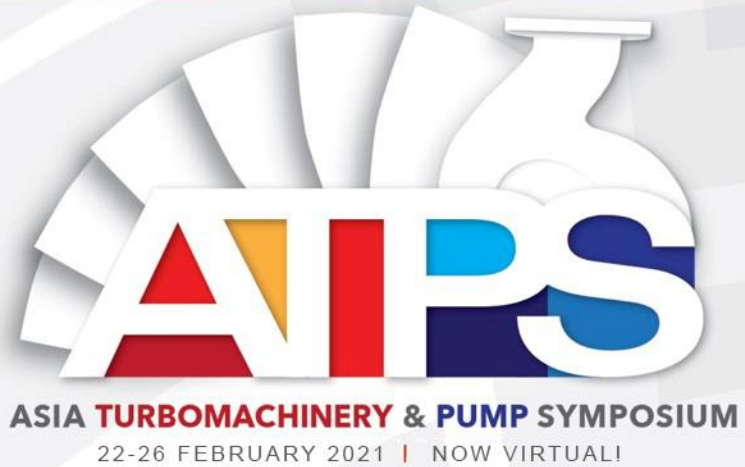

Mechanical validation of axial impellers with plastic blades in genset applications

Technical Brief TB19

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Author Bio

Nicolas Geiger leads the Innovation Team Engine Cooling at Multi-Wing International, a solution provider for axial impellers based in Denmark. His team is responsible for the development of new products, as well as support to the QA department for product validation in machine environment. Nicolas has extensive experience in mechanical design, vibration assessment and finite element analysis.

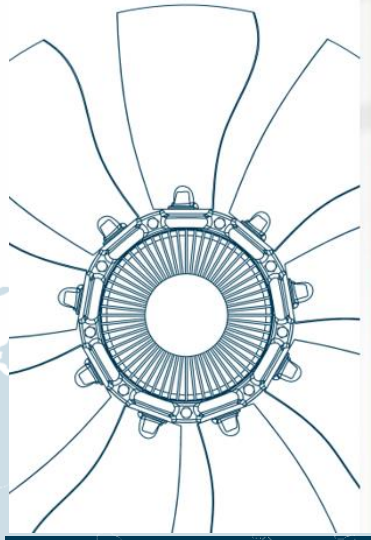
Prior to joining Multi-Wing, he worked as a consultant providing engineering services in the automotive sector. He worked on various projects for major clients located in France, Austria and Germany, with a focus on validation methods combining simulation and physical tests. He graduated in 2005 with a Master's degree in Mechanical Engineering from Ecole des Mines de Douai in France.

Multi-Wing at a glance

Founded 1938 in Denmark

Tailor made axial impeller solutions for

Engine Cooling and HVAC/R



Abstract

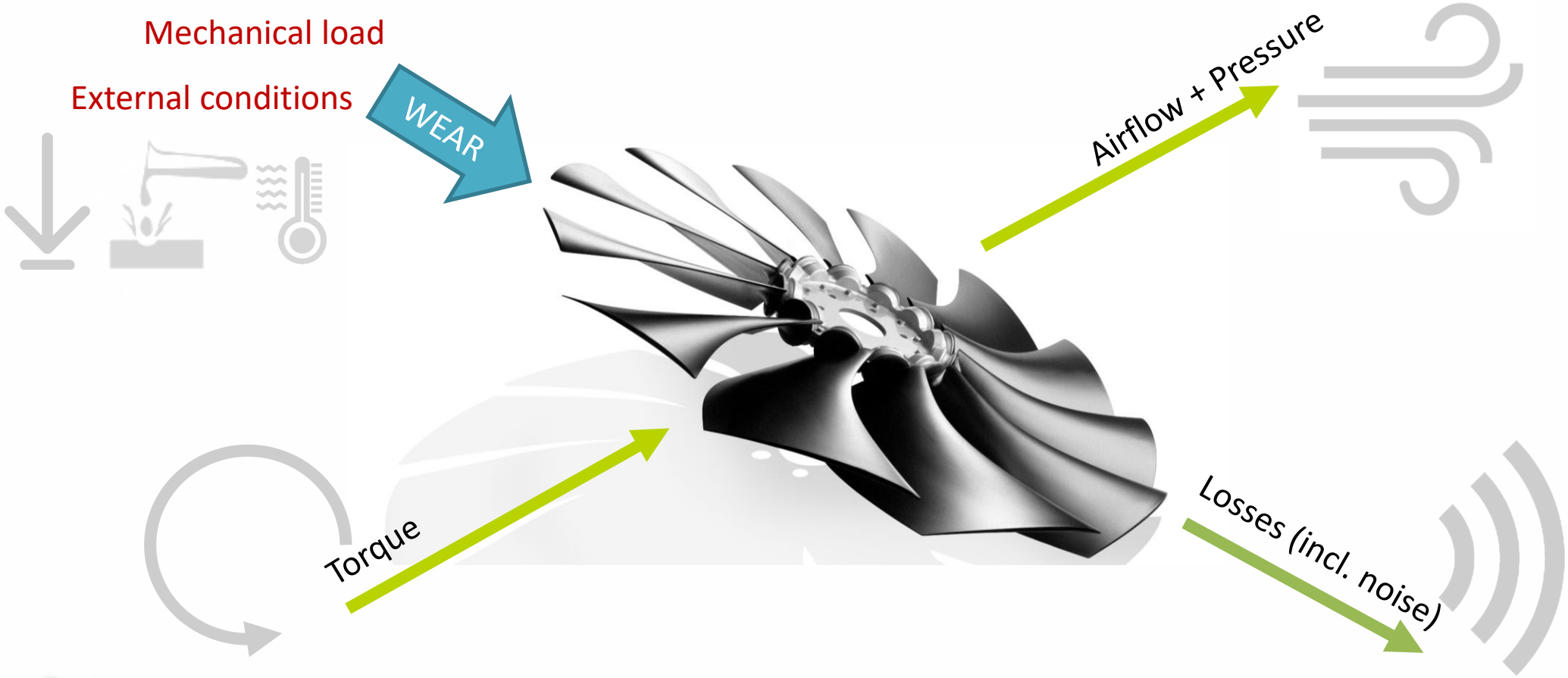
Hybrid axial impellers with a hub made of aluminum and blades of engineering plastics are commonly used as part of cooling packages for industrial applications. The use of plastics opens for a larger design flexibility in terms of blade shapes, allowing optimized profiles for higher efficiency, lower noise and/or higher pressure depending on the application requirements. Additionally, the component weight and cost are lower than their fully metallic counterparts. In environments where spark ignition is not permitted (ATEX), the use of antistatic, reinforced plastics is mandated in some cases.

However, due to lower stiffness of the blades, their natural frequencies are lower than a metal impeller of the same size, but with higher damping. Therefore, special attention must be put into validating the impeller for the application, in order to avoid resonance with vibration inputs coming from the engine and/or from aerodynamic interaction with the shroud and eventual obstacles in the airflow. This article describes the mechanical loads and vibration issues typically encountered in genset applications, as well as the tools used for validation, using numerical simulation as well as physical tests in the machine.

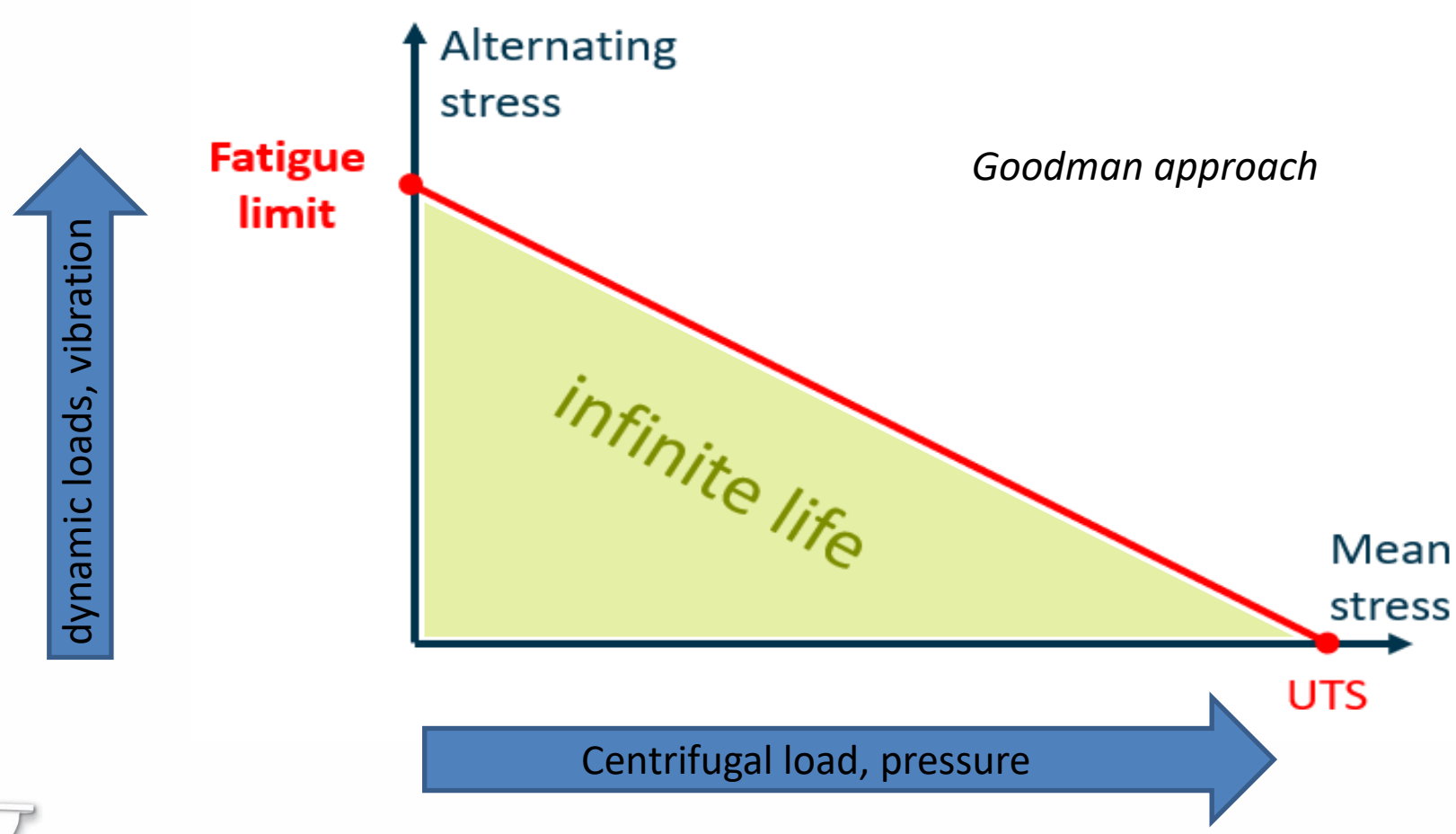
Contents

- Introduction
- Mechanical load on an axial impeller
- Process for a safe impeller selection
- Validation on the machine
- Conclusion and outlook

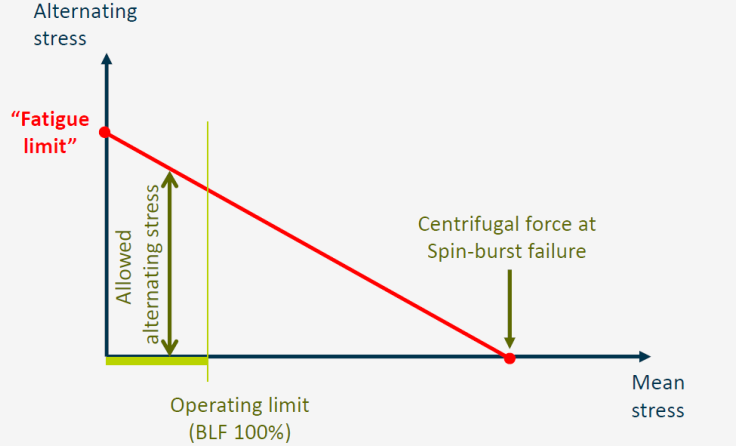
Function of an impeller



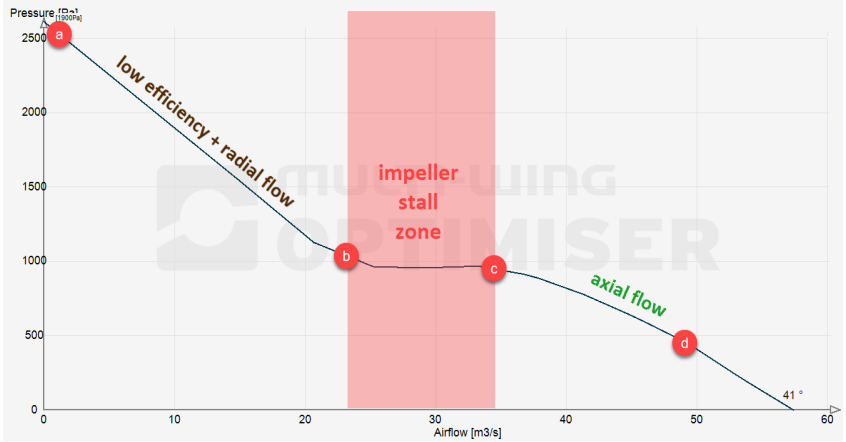
Stress on rotating impeller blades



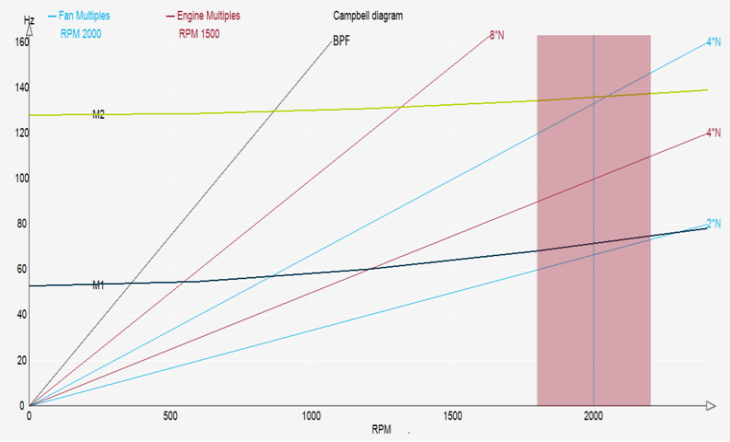
Safe impeller selection process



Verification of the centrifugal load w.r.t. operating limit

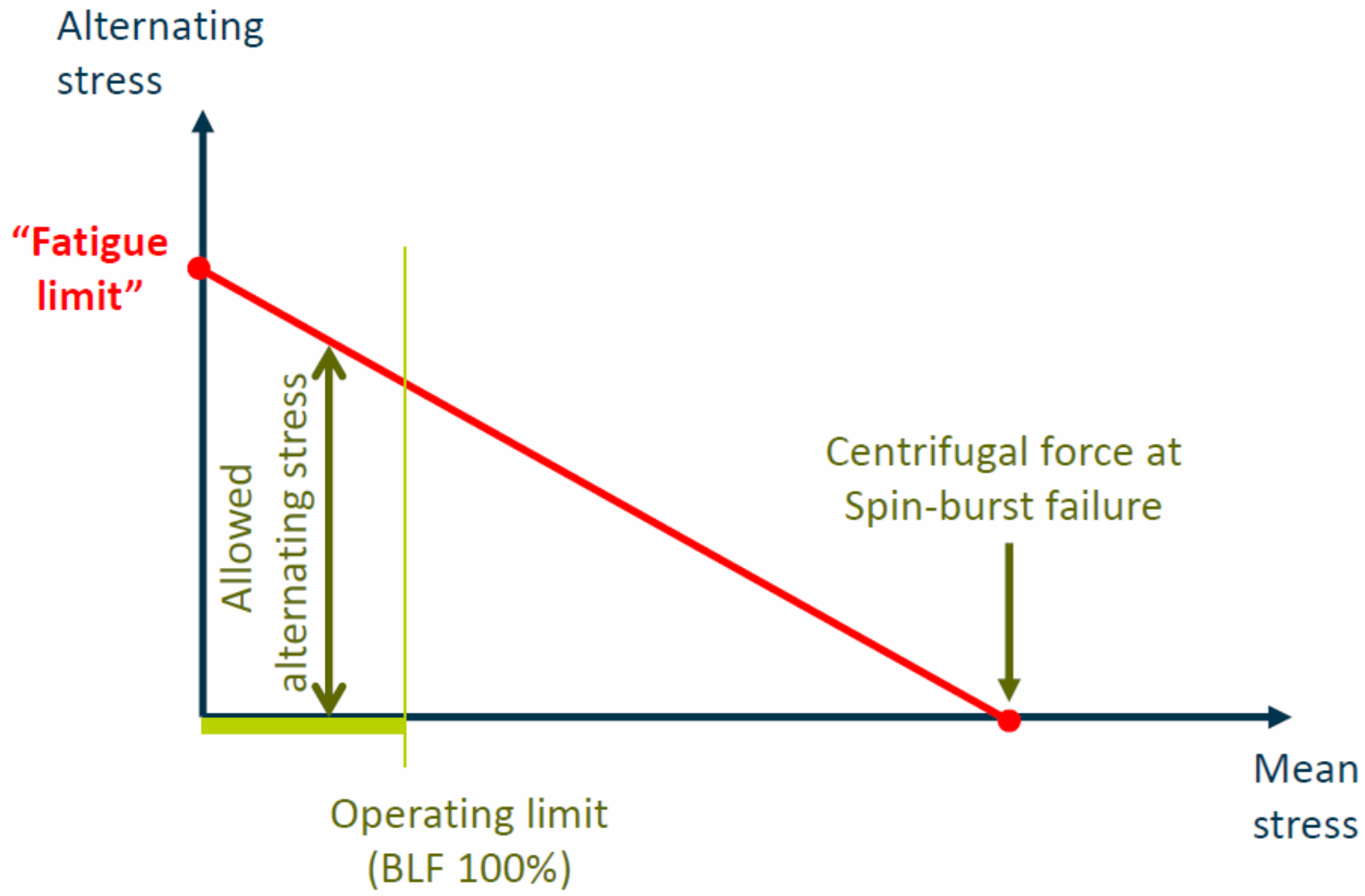


Verification of the impeller duty point w.r.t. stall region

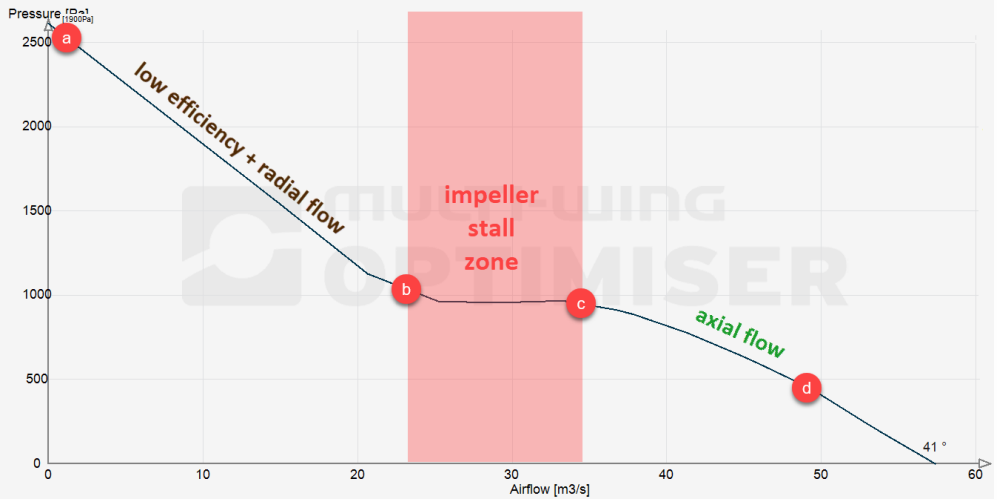


Identification of potential resonances (Campbell diagram)

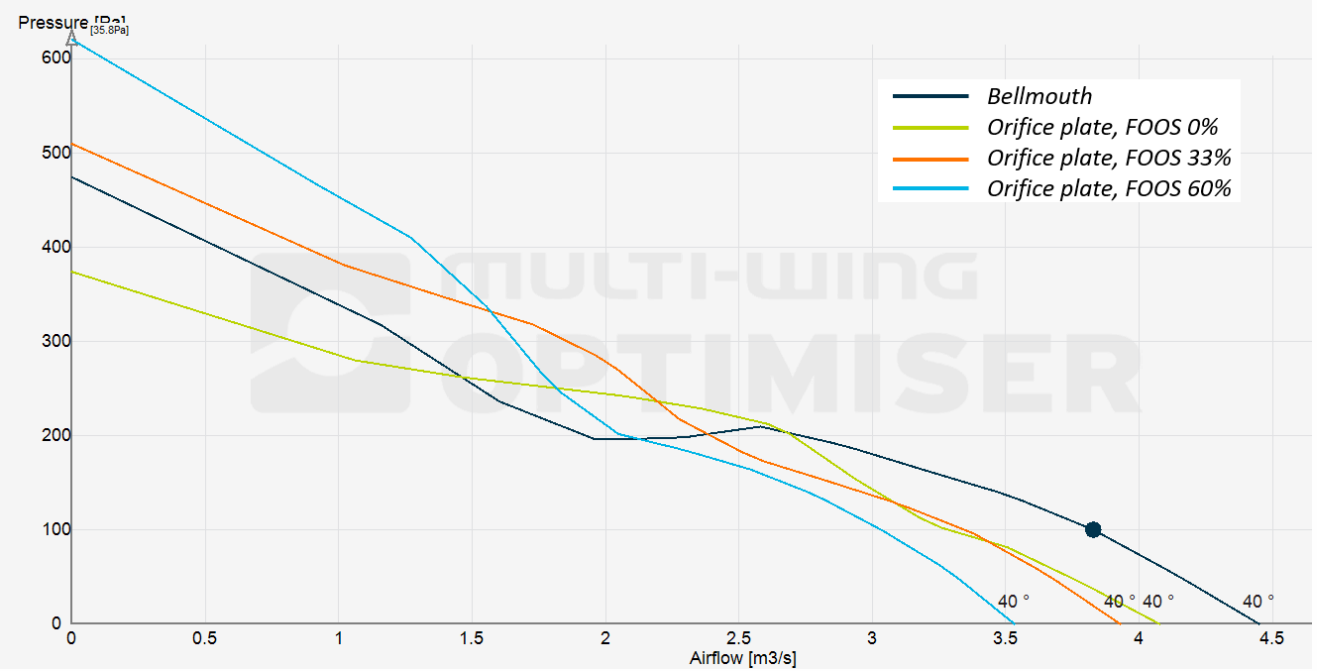
Operating limit



Stall region

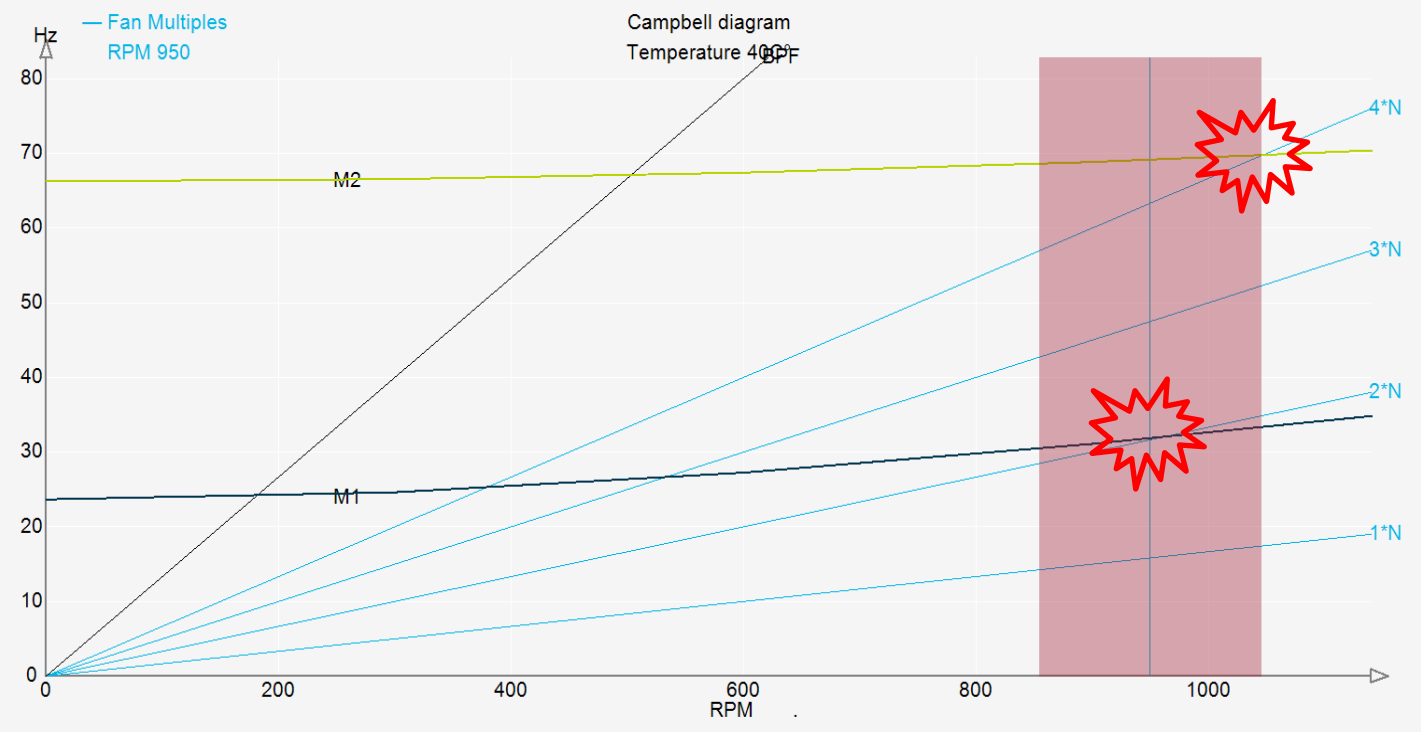


Performance and stall highly influenced by impeller environment



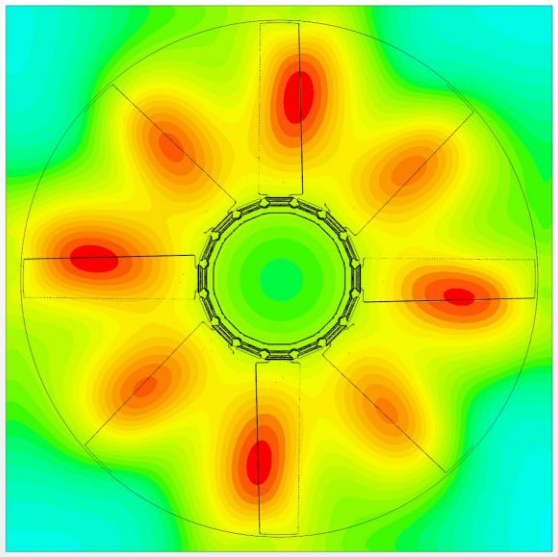
Identification of potential resonance

Example: 1550/8-8/27°/PAG/9W2R – 950 RPM

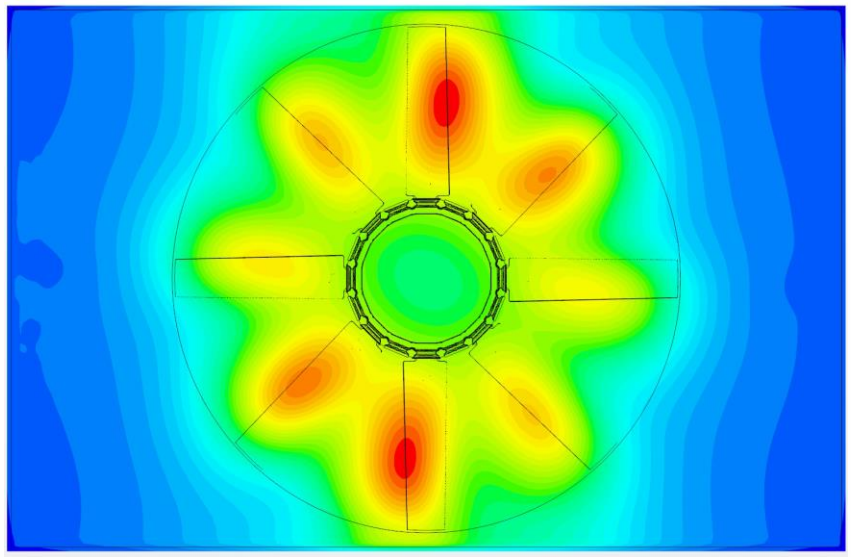


Question: is 2*N at 950RPM an issue in the application?

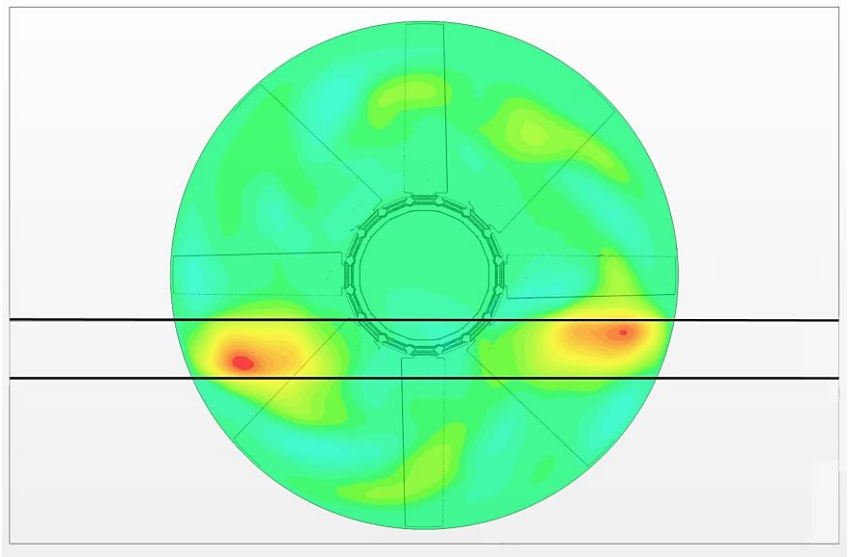
Sources of cyclic loads, aerodynamic



Square shroud
4x rotation frequency



Rectangular shroud
2x rotation frequency



Wide beam-like obstruction
2x rotation frequency

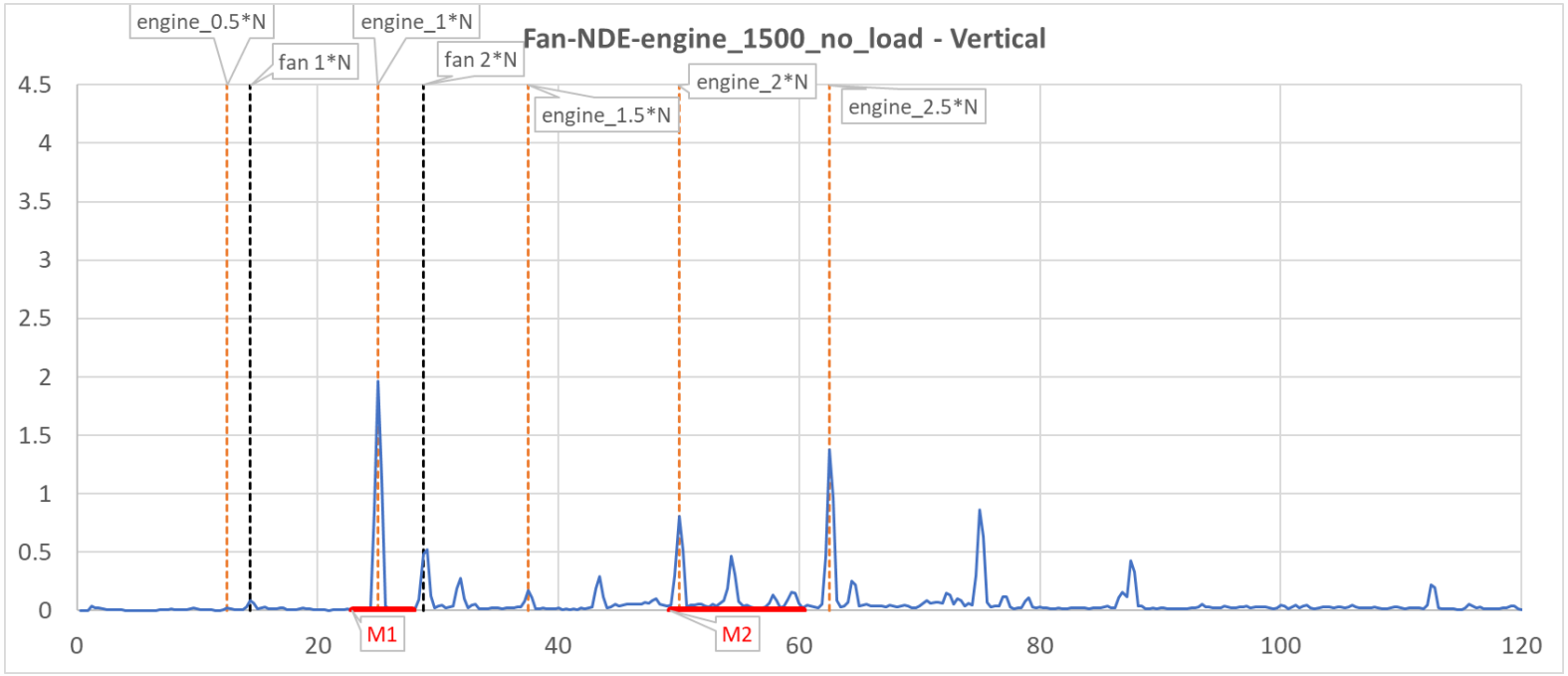
Sources of cyclic loads: combustion engine

Cyclic loads can be transmitted to the impeller, originating from the engine

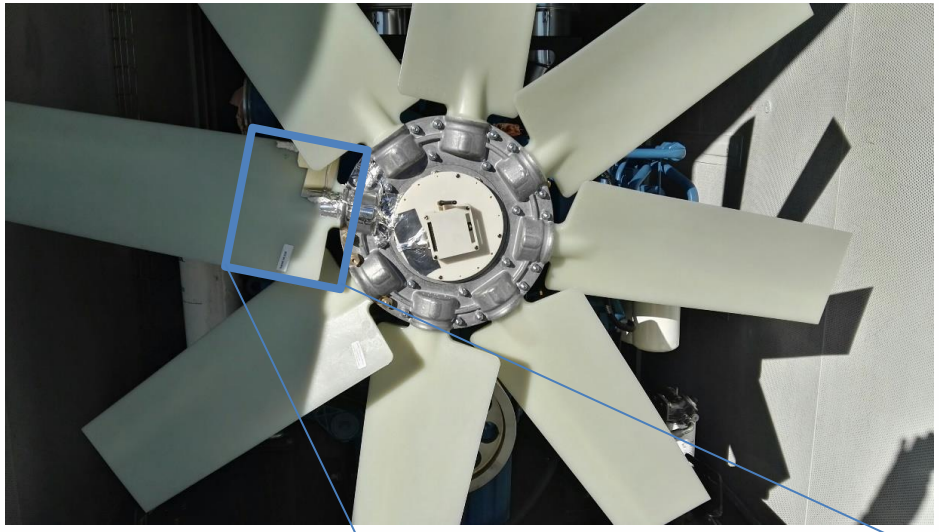
Examples:

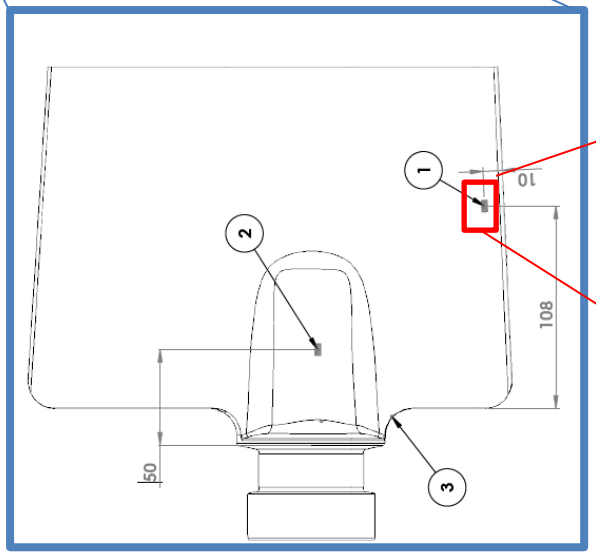
- Torsional vibration of crankshaft
  - Unbalance
  - Oscillating masses
  - Gas forces

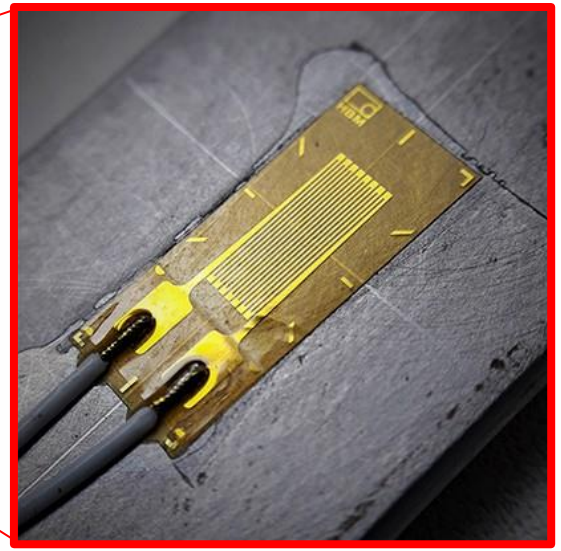
- Rigid body vibrations of engine block



Validation by machine test: strain gauges

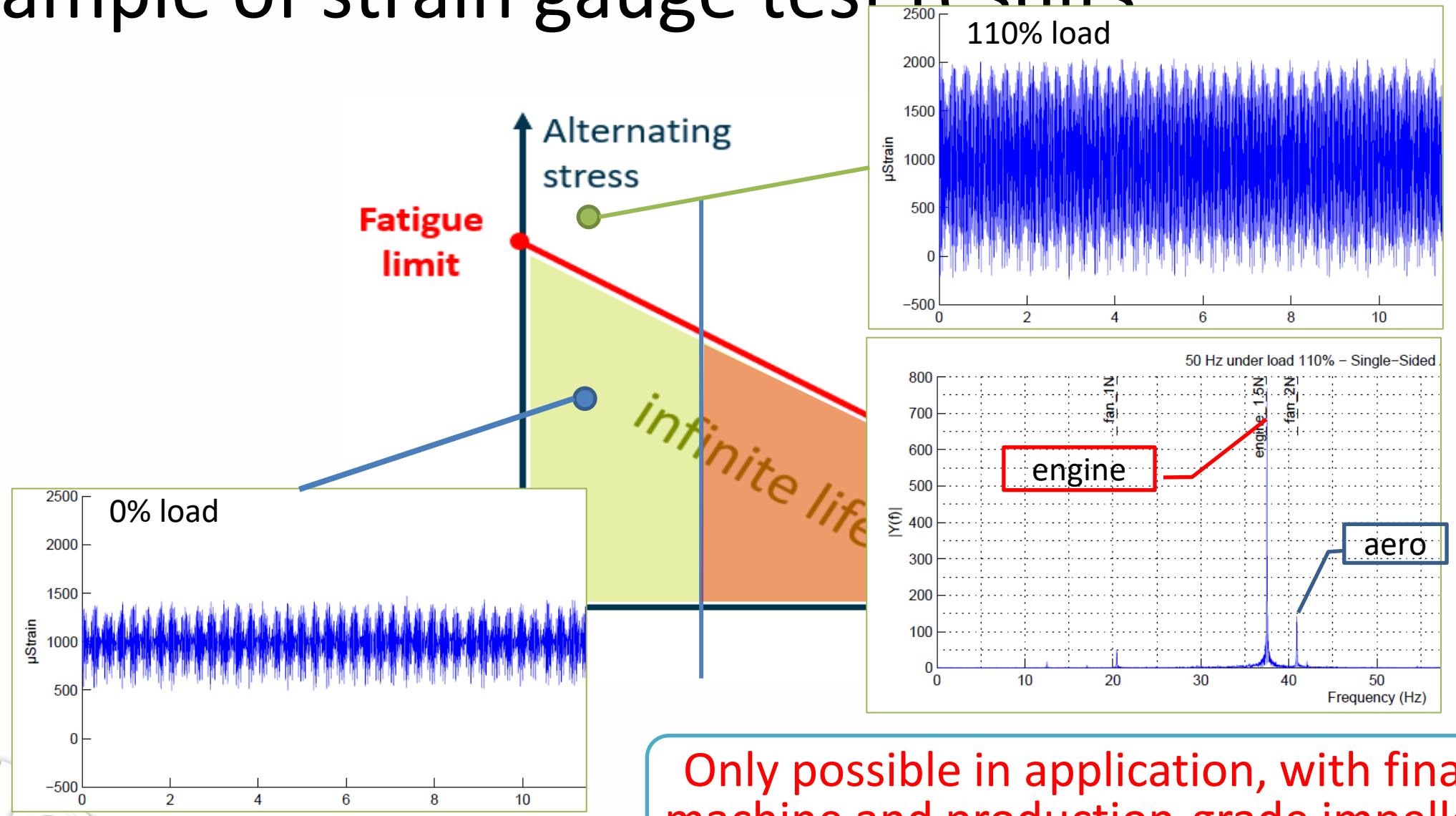






- Strain gauges are sensors used to measure local deformations of a mechanical part
- When applied on a fan blade at proper locations, they can show the level of static and dynamic stress of the impeller. This allows lifetime estimation

Example of strain gauge test results

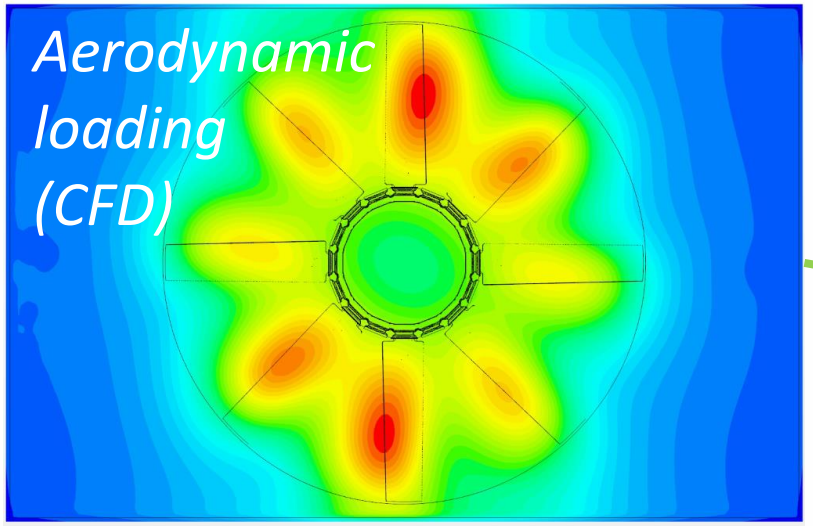


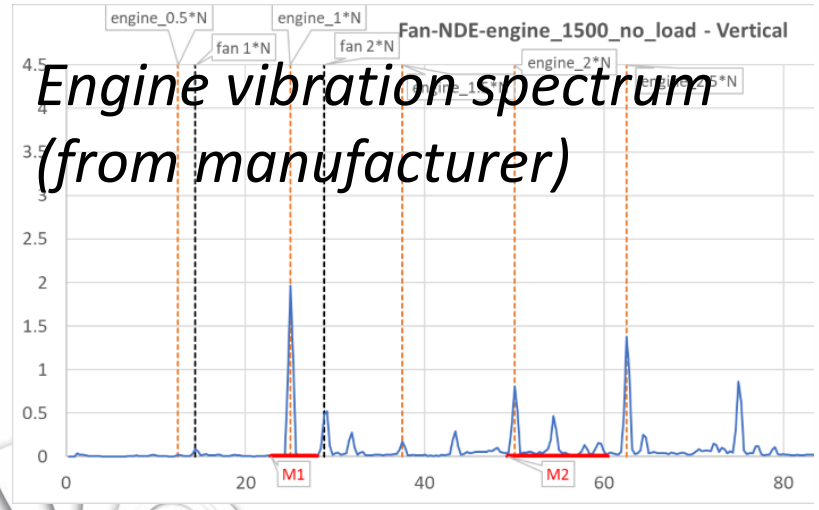
Only possible in application, with final machine and production-grade impeller

Conclusion

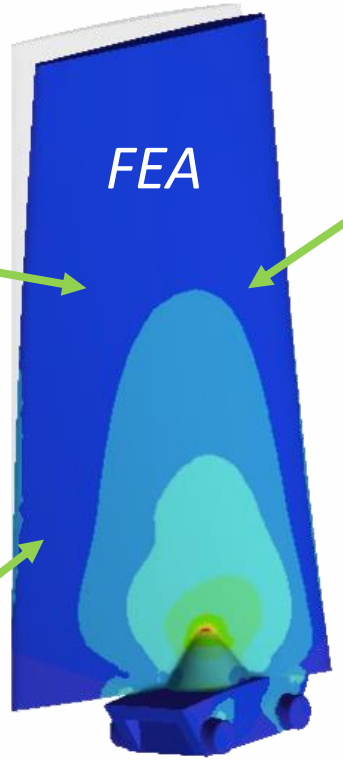
- It’s essential to characterize both the static and dynamic loading to predict impeller lifetime
- Dynamic part of the mechanical load is almost solely dependent on the impeller use environment and type of drive used.
- Both structural vibrations from the system and pulsating aerodynamic loads have to be characterized
- A process for safe impeller selection has been introduced for an early risk assessment
- Machine test using strain gauge testing and spectral analysis remains a must for full confidence
- Target: is to frontload an increasing number of validation steps by means of simulation
  - CFD for the aerodynamic coupling
  - FEA for the structural vibrational load
  - Only possible with involvement of machine manufacturer and transparency on loads

Lifetime prediction - vision

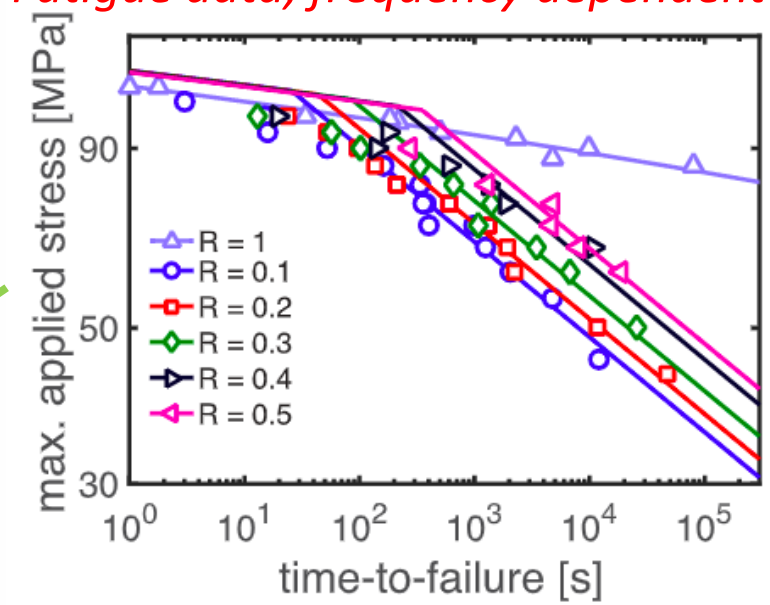




Engine vibration spectrum (from manufacturer)



Fatigue data, frequency dependent



Lifetime in machine (cycles / hours)

Thank You !