

# DEVELOPMENT OVERVIEW

All development activities at Pankl Turbosystems are driven by systems engineering principles. This enables the integration of a wide range of subject areas such as bearing systems, aerodynamic components, and electric drives. Based on this holistic approach, Pankl Turbosystems offers services to develop components and complete systems:

Requirements management, risk analysis, FMEA, DVP creation

Simulation, including CFD, FEA and modal analysis

Development of bearing systems

Rotordynamics and NVH

Integration of E/E systems

Design

Validation



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## Contact

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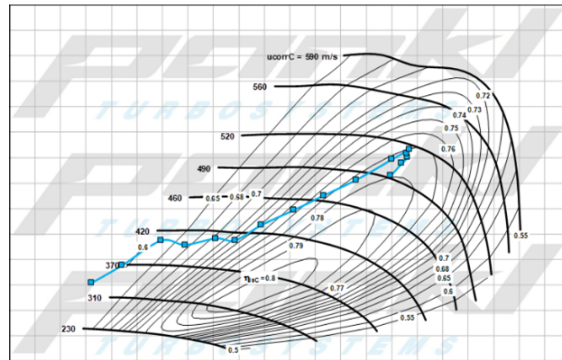
### Web

www.pankl.com/en

# SYSTEMS ENGINEERING

Development of complex system require central control of the different subject areas and permanent monitoring of compliance with the requirements. In this respect, Pankl Turbosystems offers a full spectrum of methods and processes from systems engineering:

- Requirements management, including change management and tracking
- System matching, to optimize component interaction, e.g., compressor to turbine
- Risk analysis, e.g., in the form of DFMEA, PFMEA
- Design Verification Plan



Matching: Compressor map with operating points

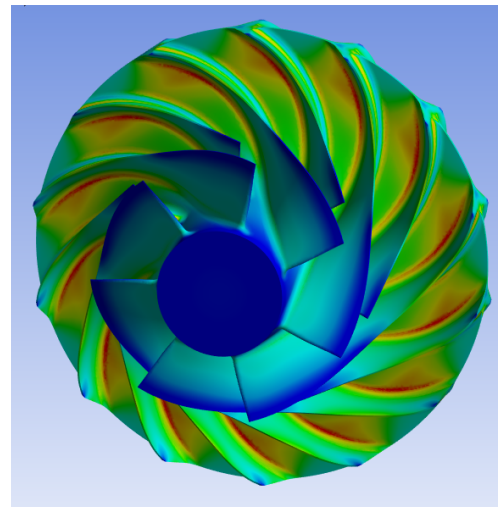
# SIMULATION

The in-house development of our turbosystems is based on the so-called inverse design, optimally matching individual components and subsystems to one another, achieving the highest levels of performance and efficiency, even for single-stage applications at very high boost pressures and with industry-leading power densities / installation space requirements.

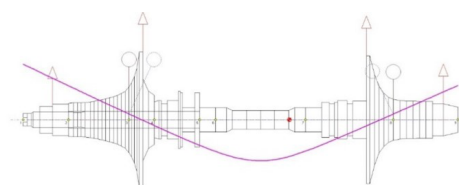
Complete transparency of the development process enables a comprehensible and well-founded basis for decision-making of the best variant tailored to the respective customer application.

Our numerical simulation capabilities cover the diverse disciplines of fluid dynamics, rotordynamics and (thermo-) structural mechanics, including:

- 1D engine simulation
- CFD optimization of aerodynamic systems and cooling circuits
- Generation of compressor and turbine maps
- Multi-body simulation of rotating systems
- Calculation of bearing life expectancy
- Low- and high-cycle fatigue (LCF/HCF) of rotating components, modal analysis
- Thermomechanical fatigue (TMF) with considerations of fluid-structural interaction (CHT)



Compressor wheel FEA



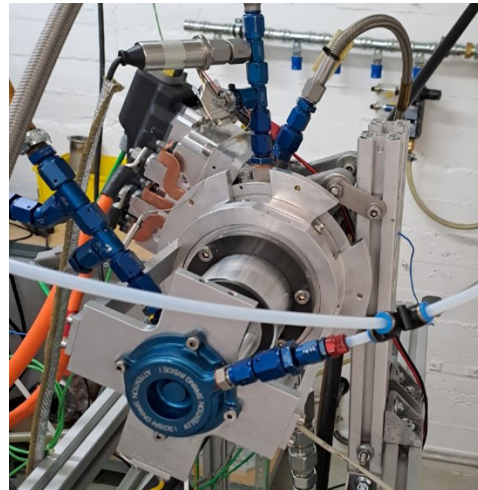
Rotordynamics: 1D simulation of a rotating system

# BEARING SYSTEMS DEVELOPMENT

Pankl Turbosystems draws on many years of experience with calculation methods in the development of high-speed and highly dynamic bearing systems.

Four essential technologies are implemented in our systems:

- Roller bearings: the first choice for high requirements in efficiency, load capacity and transient behaviour, both for conventional and electrically assisted turbochargers. Several bearing sizes for various speed and load ranges are available.
- Plain bearings: characterized by robust and rotor-dynamically-stable operation, used particularly for conventional turbochargers.
- Air bearings: developed in-house, our aerodynamic foil bearings allow for oil-free operation of fuel cell compressors (FCAS). Several sizes in our portfolio cover diverse performance, speed and load ranges.
- Hybrid bearings: Pankl Turbosystems also has experience in combining bearing technologies, merging their advantages to optimize customer solutions.



*Testing of aerodynamic foil bearings*

# ROTOR DYNAMICS AND NVH

Pankl Turbosystems has many years of experience in the fields of rotordynamic, acoustic, and vibration testing. The focus of our services and consulting is:

## **Acoustics / Vibration:**

- Frequency analyses, operational vibration analyses, determination of modal parameters
- Natural frequency measurements, Campbell diagrams, SAFE / ZZENF diagrams
- Vibration analyses in connection with engines and turbomachinery
- Measurement and assessment of unbalance on turbomachinery
- Measurements of airborne and structure-borne sound (sound pressure, sound level, sound power)

## **Rotordynamics:**

- Non-contact shaft vibration measurements on rotors
- Determination of critical speeds, rotor stability
- Vehicle acoustics
- Transmission path
- Sound source localization and diagnosis
- Run-up and run-down analyses

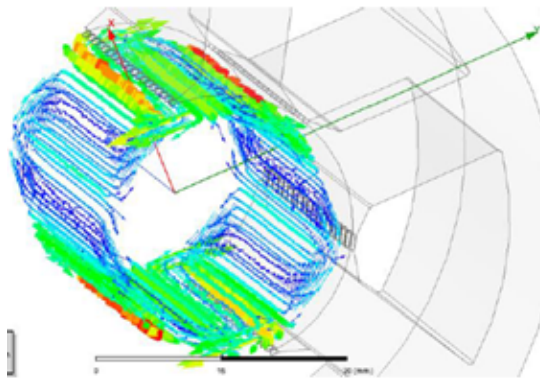
# INTEGRATION E/E

Pankl Turbosystems uses bespoke high-speed permanent magnet synchronous motors and SiC-MOSFET inverters to achieve maximum efficiency and performance with industry-leading compact dimensions. The focus on seamless integration into the turbosystems ensures a robust and virtually maintenance-free operation.

All systems are subjected to demanding in-house tests to ensure our high standards of quality, continuous improvement, and HV safety. All Pankl Turbosystems inverters are optimized for the trouble-free application of each electric motor, pushing the limits of development.

Consequently, we offer a diverse range of turn-key systems:

- Electric motors in the 22 kW, 37 kW and 60 kW power classes, with speeds of up to 150,000 rpm
- Tailored electric motors for special applications with outputs of up to 90 kW
- Accompanying power electronics based on SiC-MOSFETs for precise control of the motors



Calculation of the current density in an MGU stator.

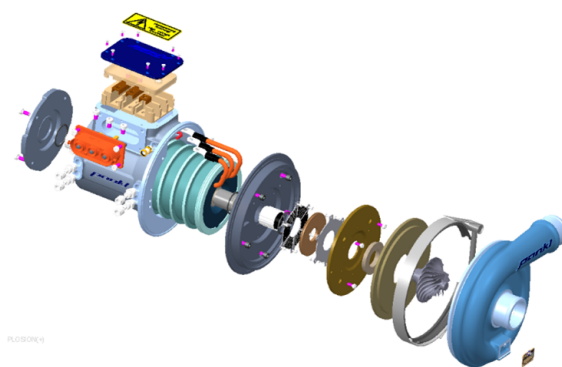
# DESIGN

Pankl Turbosystem's design scope starts with concept definition and continues through detailed development up to close-to-production support during manufacturing.

We offer comprehensive engineering and design services in the following product areas:

- Electrically assisted turbochargers (Power range of the e-motors up to 90 kW; speeds of the systems up to 150,000 1/min)
- Electrically driven oil-free compressors for fuel cell power requirements from 80 to over 700 kW
- Conventional turbochargers
- External Wastegates

In addition, Pankl Turbosystems has a large network of suppliers to manufacture components for prototypes based on the models and drawings generated.



Exploded view of a fuel cell air supply (FCAS) system.

# VALIDATION

All numerical results are measured and validated on state-of-the-art test stands to verify function, feasibility and durability. The validation of systems follows the design verification plan to test all functions and requirements of the systems in hardware in a structured way.

Pankl Turbosystems has several of its own test benches for this purpose, which are designed for different areas of application:

- Hot gas stand with battery simulator – enables testing of exhaust gas turbochargers and electrically driven turbochargers
- Two test stands for electric compressors
- Component test rigs, including for air bearings

Validation rounds off Pankl Turbosystems' portfolio of development services. Customers thus receive a fully developed product, ready for use in the target application.



*Pankl Turbosystems test stand for electric compressors*