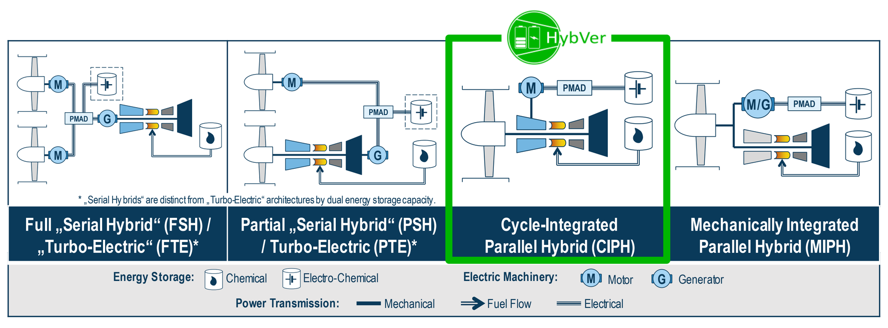
Institute of Turbomachinery and Flight Propulsion
Department of Aerospace and Geodesy
TUM School of Engineering and Design
Technical University of Munich

Hybrid Compressor Concepts – HybVer

Motivation and Technical Concept

Motivation

- Aviation industry aims to reduce emissions and noise levels
- Parallel hybrid aero-engines integrate electric propulsion with gas turbines for fuel burn reductions, efficiency gains, and operational and power flexibility
- Focus on cycle integrated parallel hybrid propulsion concepts



Objective

- Holistic evaluation of turbo compressors featuring hybrid-electric drive
- Multidisciplinary conceptualisation and integrated simulation for selected application cases
- Description of requirements for key technical components and technological development needs

Tab. 1: Performance and emission targets for the HybVer technology study.

Application	Helicopter	Regional turboprop
Design range	up to 200nmi	up to 400nmi
Design payload	up to 19 Pax	up to 50 Pax
Degree of hybridisation	20%	20%
CO_2 reduction (design mission)	>12%	>12%

The Technical Concept

Turbo compressor with partial electric drive

- Individual electric drive of compressor rotor stages

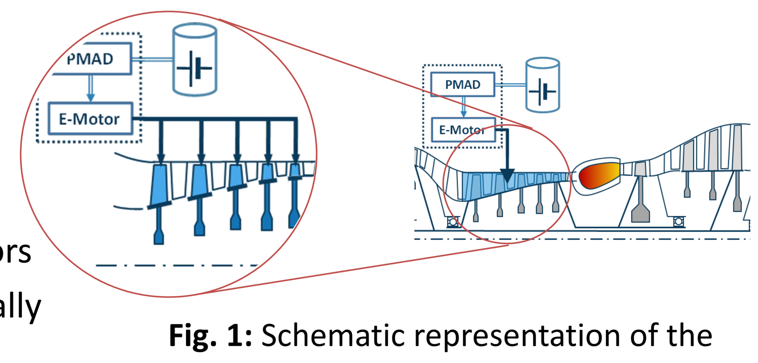


Fig. 1: Schematic representation of the concept.

Advantages

- Compact design integration via counter-rotating rotors
- Enhanced operational flexibility through individually tailored rotor speeds for optimum performance
- Reduction/avoidance of classic variability devices (VSVs)
- Improved cycle variability due to flexible electric energy supply (esp. in part power)

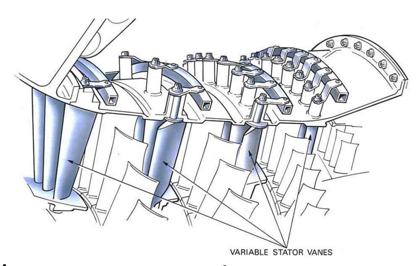


Fig. 2: Variable stator vanes, image courtesy Rolls Royce ltd.

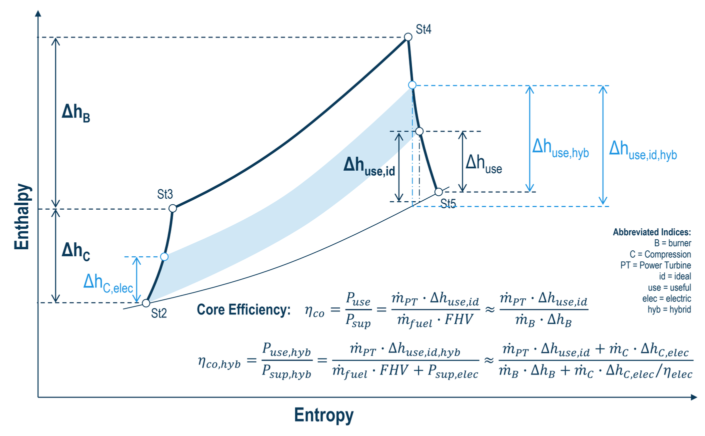


Fig. 3: Thermodynamic benefits.

Methodology

Overall Workflow

Phase 1

General conditions and broad design space study (BHL, BTU, TUM, TUM)

Pre-selected concepts & defined use cases ✓

Phase 2

- Overall conceptual integration (BHL)
- Compressor aerodynamics & operating behaviour (TUB)
- Electrical system components and drive train (BTU)
- Overall conceptual integration (TUM)

System performance & overall design · Electrical design · Aerodynamic design · Mechanical design

HybVer: Detailed model development & iterative concept development

Holistic technical design of pre-selected concepts

Initial design results

Phase 3

Final concept evaluation (BHL, BTU, TUB, TUM)

Evaluation of performance, emissions, regulatory implications, key technology requirements

TRL 2 demonstrated & technology development plan for EIS in 2035 developed

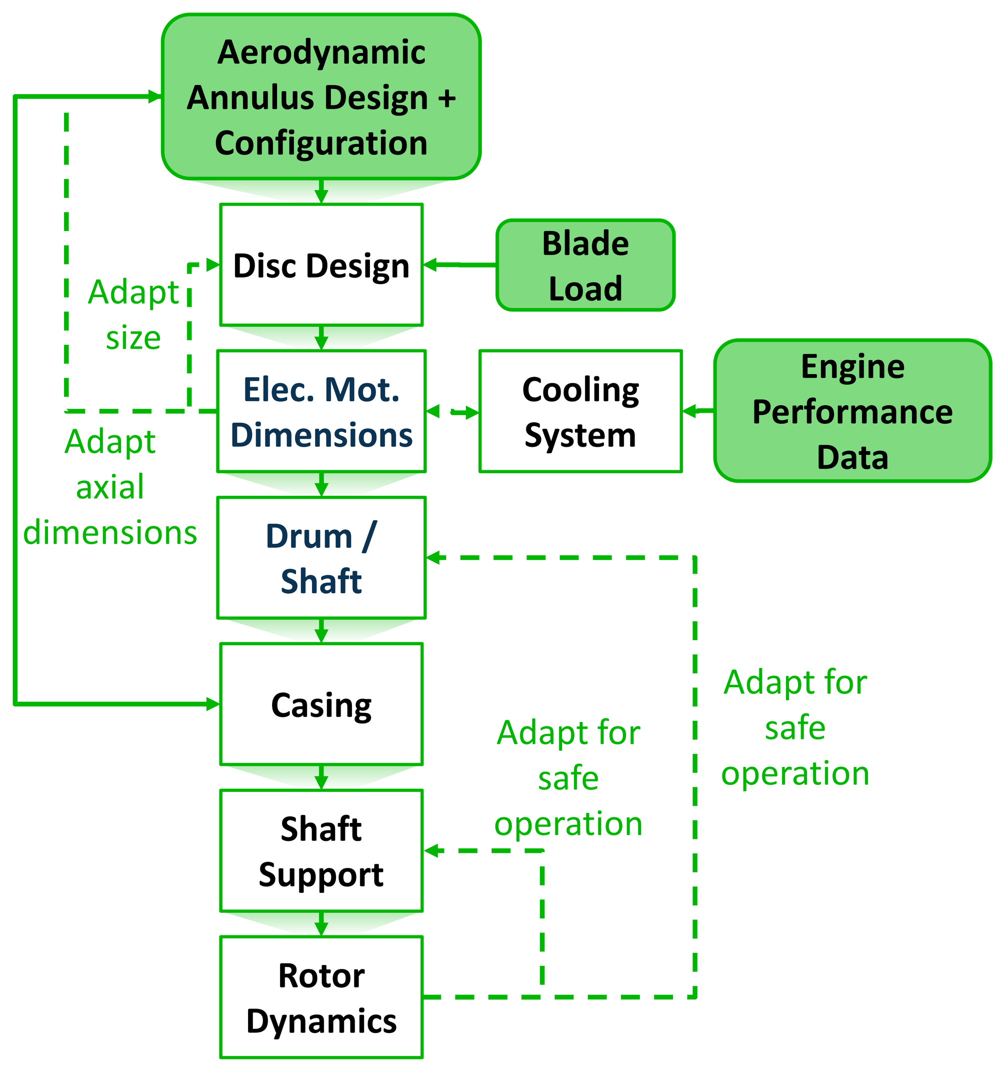
TUM Contribution

Responsibilities

1. Compressor architecture and interfaces
2. Component cooling and thermal management
3. Mechanical design of compressor components
4. Confirm feasibility through rotor dynamics and failure mode analysis

Goals

- Developing an object-oriented preliminary design routine in Python
- Enabling the rapid mechanical design of hybrid compressors with individual electric drive of rotor stages
- Developing the evaluation capability of hybrid electrical concepts regarding implications on installation space, assemblability, and weight compared to conventional compressor designs

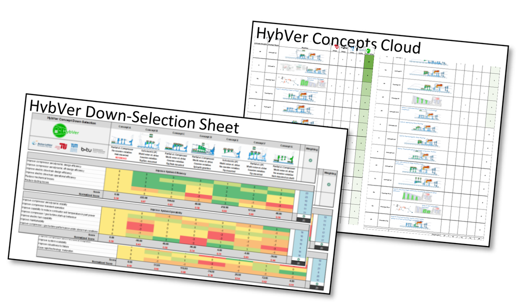


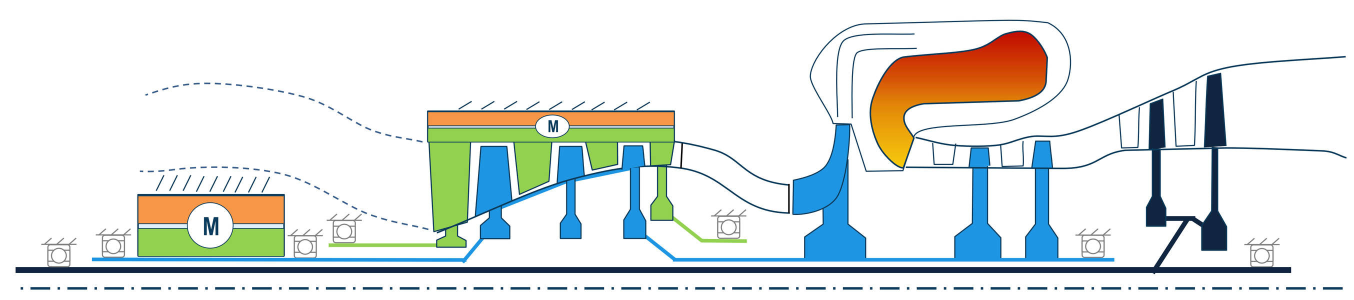
Results

Selected Concept

Concept selection based on 37 rating criteria in six main categories and reference to reference engine:

1. Improve compressor design
2. Improve overall power plant design integration
3. Improve system efficiency
4. Improve system operability
5. Reduce system weight





The Concept

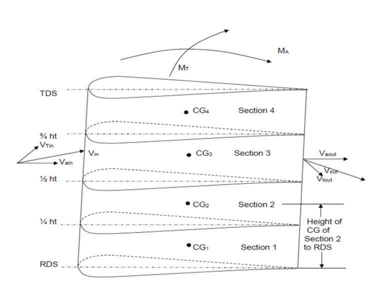
- Axial centrifugal compressor with contra-rotating axial section
- Contra-rotating rotor mounted on rolling element bearings in the hub section
- Electrically assisted-high pressure spool by hub-mounted motor

Future Steps

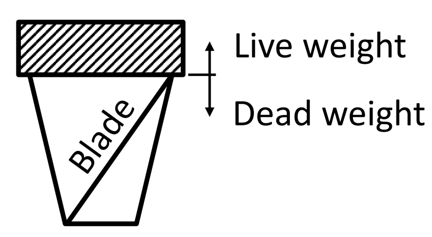
The next steps are investigating the mechanical integrity of the chosen concept including:

- Performing a preliminary mechanical design of the compressor components
- Assessing the rotor dynamical behaviour and failure modes
- Extending existing preliminary design routines to the new operating conditions

Blades:

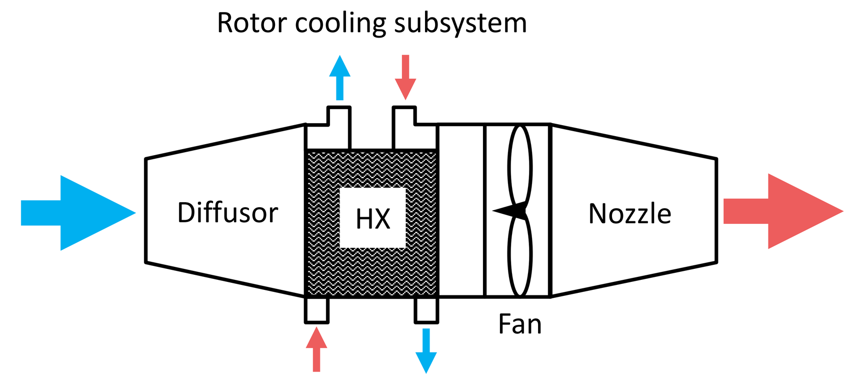


Discs:



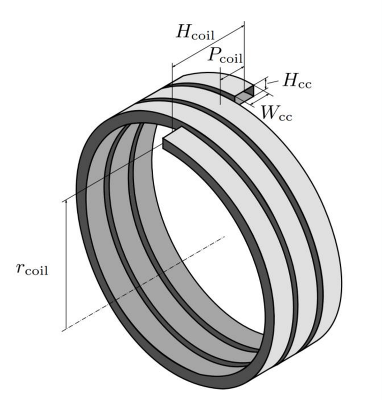
Thermal Management System

- Electric motors thermally critical, permanent magnets in danger of demagnetisation
- Two cooling subsystems:
  1. Liquid cooling subsystem for the stators
  2. Air cooling subsystem for the rotor to avoid potential leakage of cooling liquids into the gas path
- Release of waste heat to the environment via a ram air system



Stator Cooling Subsystem

- Liquid jacket cooling in a helical shape
- Only copper and winding losses in the stator
- Losses transformed directly into waste heat
- Cooling system design separate from electric machine



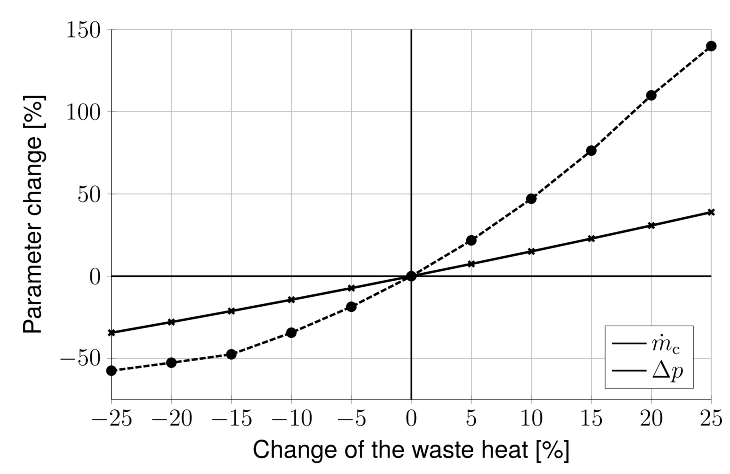
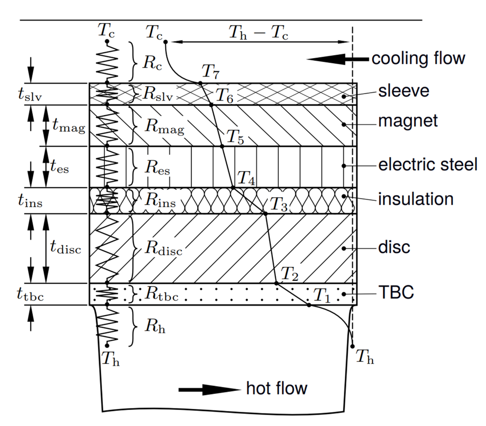


Fig 4: Cooling mass flow requirement and pressure losses with respect to the waste heat

Rotor Cooling Subsystem

- Heat conduction from gas path to the permanent magnets
- Air cooling flow through the air gap of the electric motor



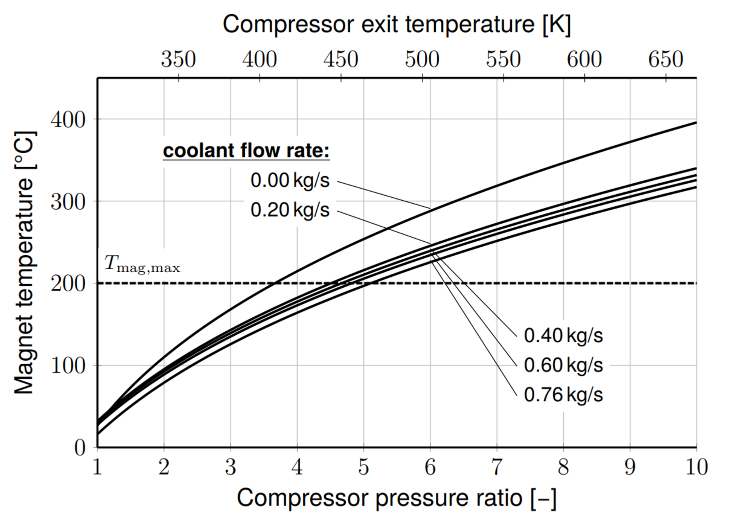


Fig 5: Magnet temperature for different cooling flow rates.

Lucas Schreer, M. Sc. | Feb. 2025
Lucas.Schreer@tum.de