EXPERIMENTAL CHALLENGES AND LESSONS LEARNED

TAČR KAPPA DEXPAND – FINAL MEETING

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07/03/2024

OUTLINE

1. Manufacturing challenges
2. Post processing and dynamic balancing
3. Assembly challenges
4. Commissioning
5. Experience from expanders operation
6. Summary

1. MANUFACTURING CHALLENGES

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- **Rotary vane expander**:
  - eccentric cavities and unconventional geometry needs **specific manufacturing methods** like electrical discharge machining
  - vanes and stator have to sustain **cyclic loading**, careful attention to material and semi-finished product has to be given
  - diamond-like-carbon (**DLC**) coating may bring significant benefits to reduce vane-stator friction, improve lifetime and protect the vane surface
  - **manufacturing precision** affects leakages and eventually volumetric efficiency of the machine – a challenge is to find a manufacturer capable of achieving tight tolerances with a sufficient lead time and costs

1. MANUFACTURING CHALLENGES

- **Turboexpanders**:
  - **manufacturing limits** have severe impact on the stator and rotor design
    - minimum nozzle throat diameter, minimum thickness of leading/trailing edges
  - precision, accuracy and surface roughness significantly affect the turbine performance
  - 5-axis milling machines needed for turbine wheels manufacturing – increases lead time and cost
  - turbine wheels need an experienced manufacturer – high speed parts require **high precision and tolerancing**

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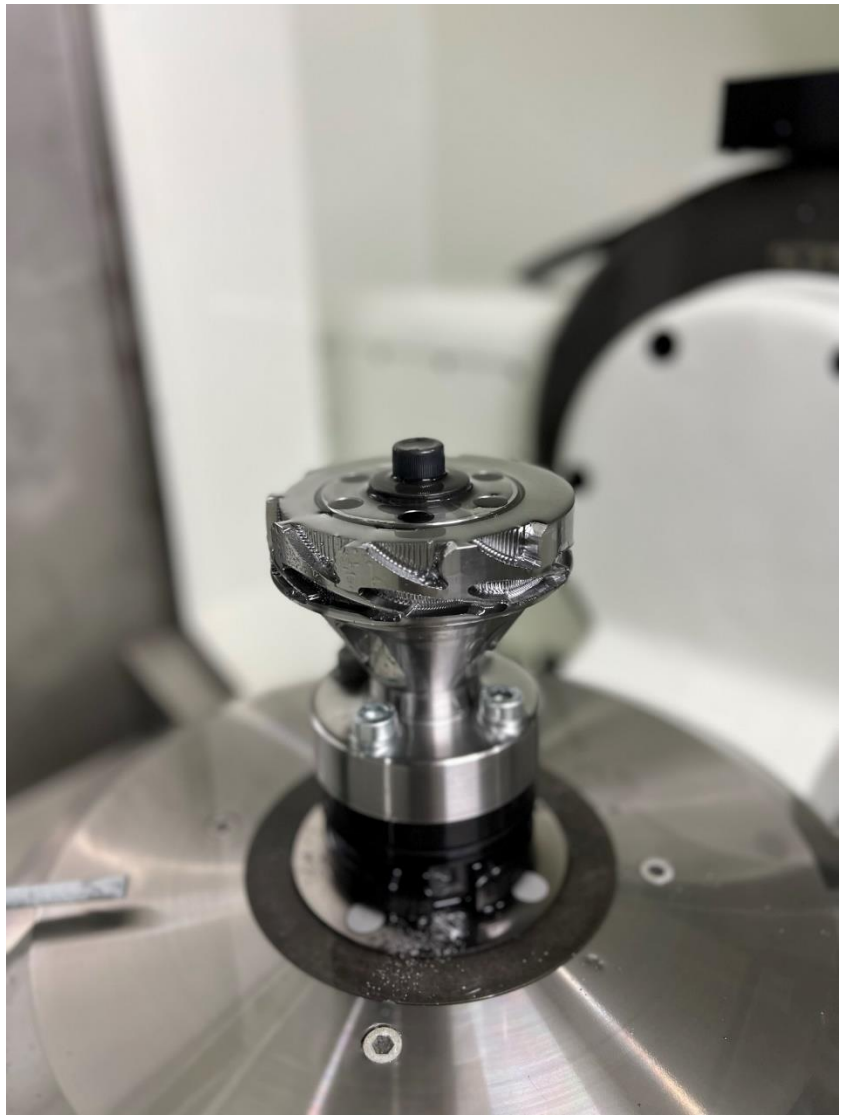
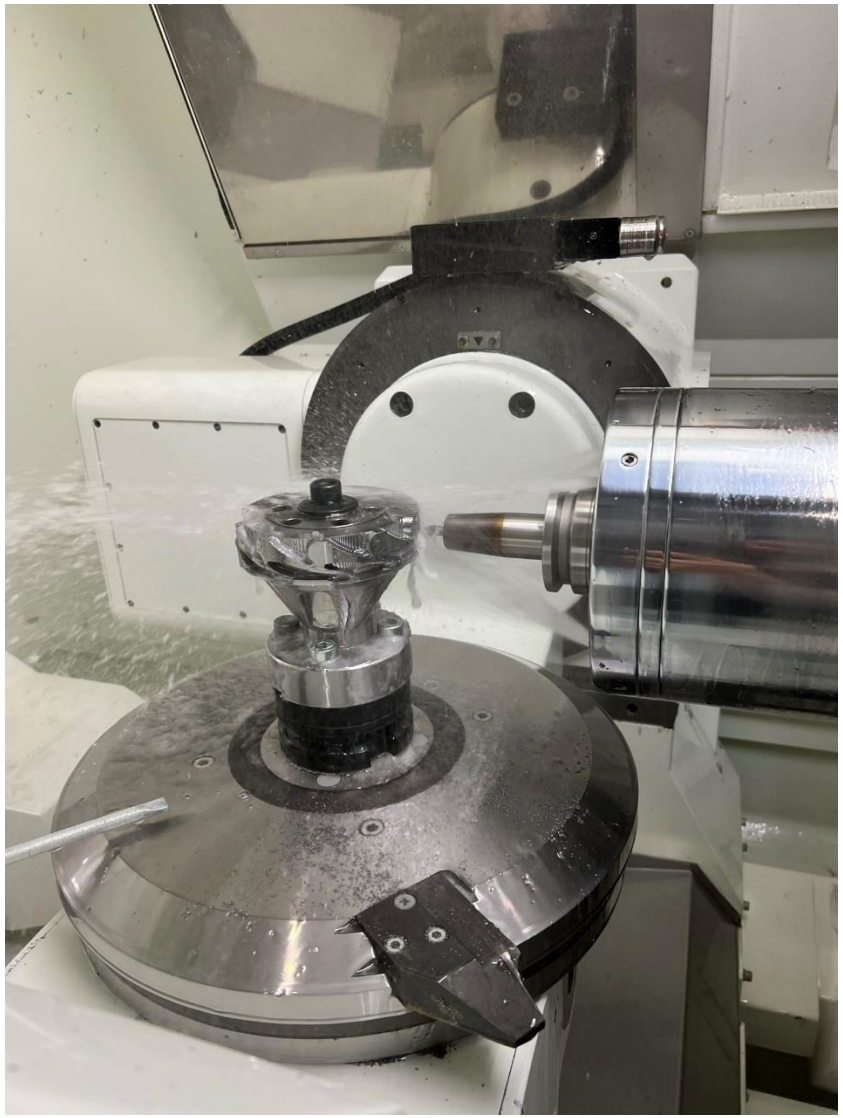
1. MANUFACTURING CHALLENGES





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2. POST PROCESSING AND DYNAMIC BALANCING

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- turbine **shaft assembly to be dynamically balanced as a whole** instead of single rotor
- Expander housing has to allow for inserting the shaft assembly after balancing without disassembling it
- turbine shaft assembly **design has to account for mounting to the dynamic balancing** rig and for the belt drive
- hot black oxide **coating** process not a suitable post-processing technology for turbine housings
    - => Arcor (thermochemical treatment which combines salt bath nitriding with a passivation stage in an oxidizing bath)

2. POST PROCESSING AND DYNAMIC BALANCING

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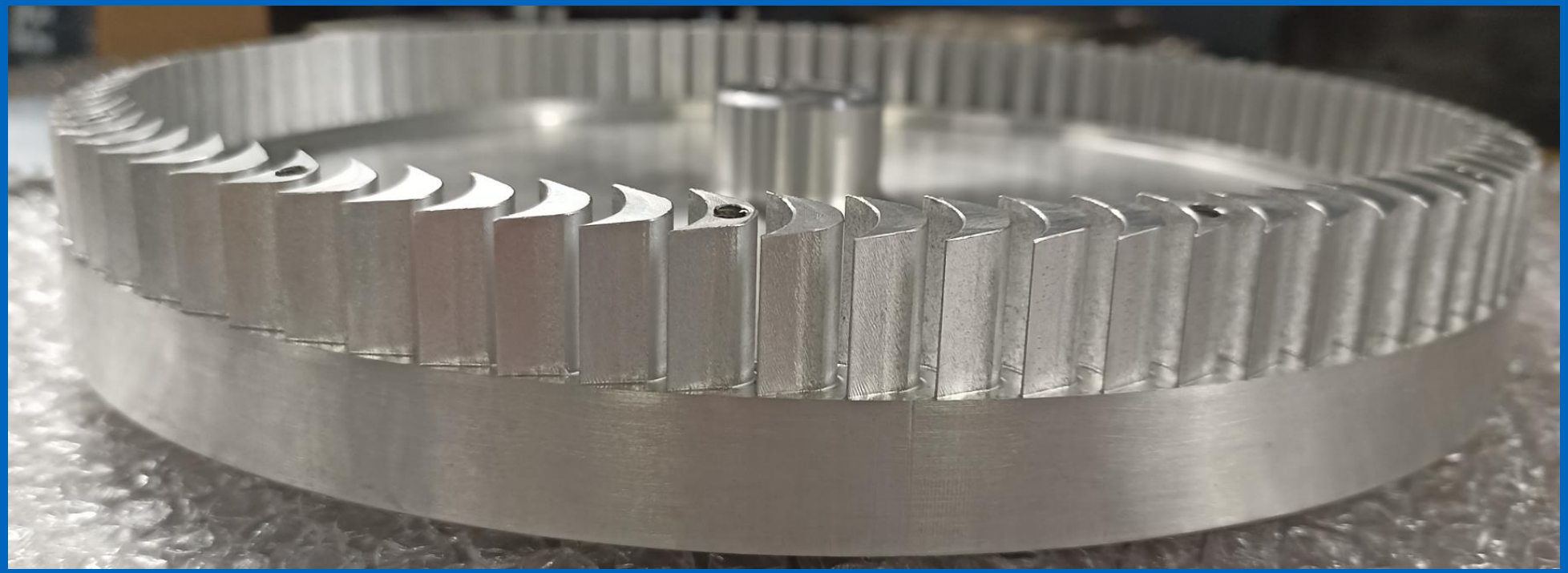
3. ASSEMBLY CHALLENGES



3. ASSEMBLY CHALLENGES

- hot-pressing of the turbine stator into the turbine housing proved to be a tedious and imprecise process
- turbine rotor shroud assembly with hot-pressing and secured with screws – screws can not withstand the centrifugal stresses -> **shroud spot welded**
- rotor-shaft torque transmission only by pressing the hub on the shaft (low torque)
- axial gaps and radial clearances of 0.5 mm are attainable
- **center positioning** of the magnetic coupling sealing cylinder **is crucial** to avoid the contact of the coupling inner rotor with the cylinder

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4. COMMISSIONING

4. COMMISSIONING

- **pressurized air tests of turbines are irreplaceable** for commissioning and ensuring correct turbine assembly
- **pressure testing** of the expanders for both over and underpressure is crucial to avoid either working fluid leakages during operation or air and humidity leaking in when in shut off/stand by
- clear **operational protocols**, start-up checklists and emergency shutdown procedure has to be in place
- standard **pressure probes have difficulties** to capture transient effects in the expanders, whereas aerodynamic tunnel Pitot probes for organic vapors are not yet existant
- **vibration sensors** can be helpful to understand the rotordynamics of the turbine in the real test environment
- **noise analysis** using an acoustic camera may help to identify major noise sources and prevent mechanical failure

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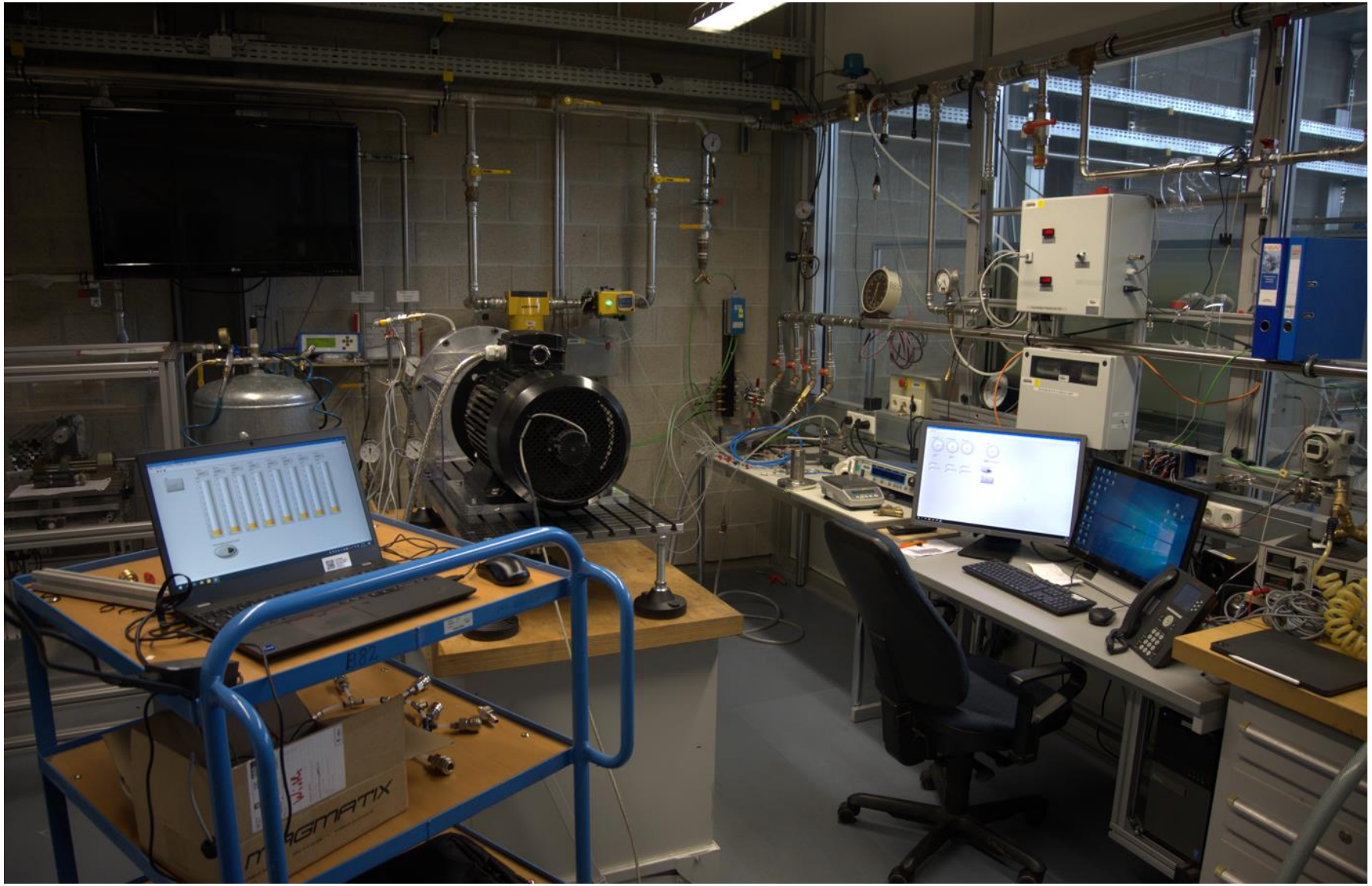
4. COMMISSIONING



4. COMMISSIONING

In experimental research, not everything goes according to your plan all the time…

5. EXPERIENCE FROM EXPANDERS OPERATION

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- **fittings** for compressed air pressure sensors **not suitable** to seal the organic fluid properly + act as an lubrication oil separator
- high temperature bearing **lubricants capable of operation** within the harsh environment of the superheated organic vapor
- **DLC coatings** of sliding surfaces proved to be **a good approach** towards increasing the maintanance period of the rotary vane expander
- **surface roughness** of the turbine nozzle segments **plays a significant role** in loss generation during the expansion (more than expected)
- for high speed turbogenerators - rotation speed control using a high frequency VFD is a viable option

5. EXPERIENCE FROM EXPANDERS OPERATION

6. SUMMARY

- Developing good design models and optimizations are just a start
- Many issues handled in experimental design, but some always come during
  - Manufacturing
  - Assembly
  - Balancing
  - Commissioning
  - After xx hours of operation
- Iterative experimental design
- All results successfully achieved thanks to a perfect and experienced project team

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THE PROJECT „OPTIMISED EXPANDERS FOR SMALL-SCALE DISTRIBUTED ENERGY SYSTEMS“ BENEFITS FROM A € 1,469,700 GRANT FROM ICELAND, LIECHTENSTEIN AND NORWAY THROUGH THE EEA GRANTS AND THE TECHNOLOGY AGENCY OF THE CZECH REPUBLIC.

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