ID #419 # Experimental characterization of a compact centrifugal pump for liquid helium transfer

Johannes Doll[1], Christoph Haberstroh[1], Nico Steinert[2]

[1]TUD Dresden University of Technology, Schaufler Chair of Refrigeration, Cryogenics and Compressor Technology

[2]maxon international ag

Contact:
johannes.doll@tu-dresden.de

ICEC/ICMC
29th International Cryogenic Engineering Conference
International Cryogenic Material Conference 2024
July 22-26, 2024, Geneva, Switzerland

Motivation

- Conventional decanting of liquid helium is associated with high evaporation losses
- A pump can speed up the transfer rate and lower the evaporation losses significantly [1]

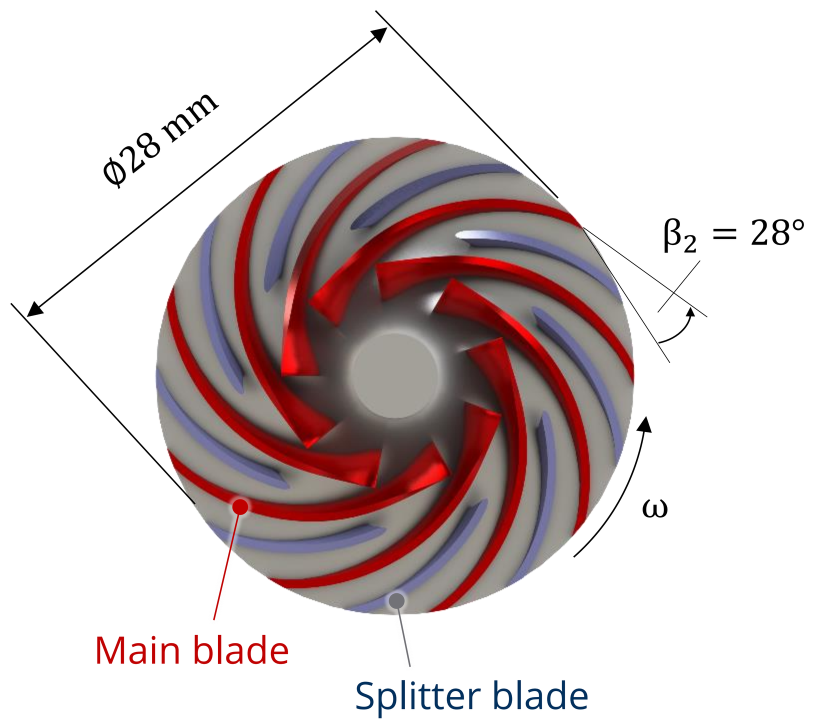
Goal: Development of a simple and efficient pump for transfer operations

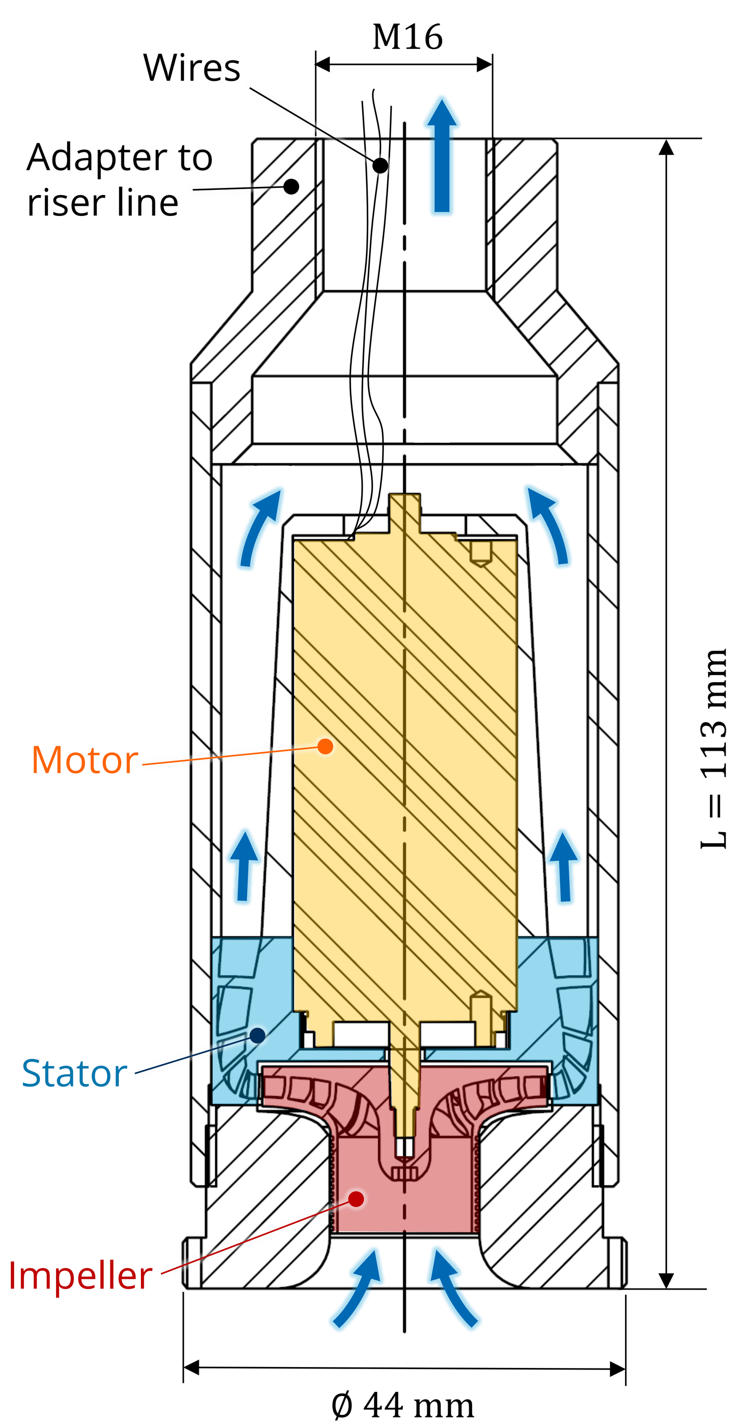
Pump design

Submersible radial centrifugal pump

- Design adapted from first TU Dresden prototype [2]:
  - Shrouded radial impeller with 18 blades (including 9 splitter blades) and labyrinth seal
  - Stator with 22 blades and radial axial deflection allows compact radial design
- All parts made of stainless steel (AISI 316L)
- Impeller and stator additively fabricated (binder jetting method)

→ Customizable design with few constructional parts

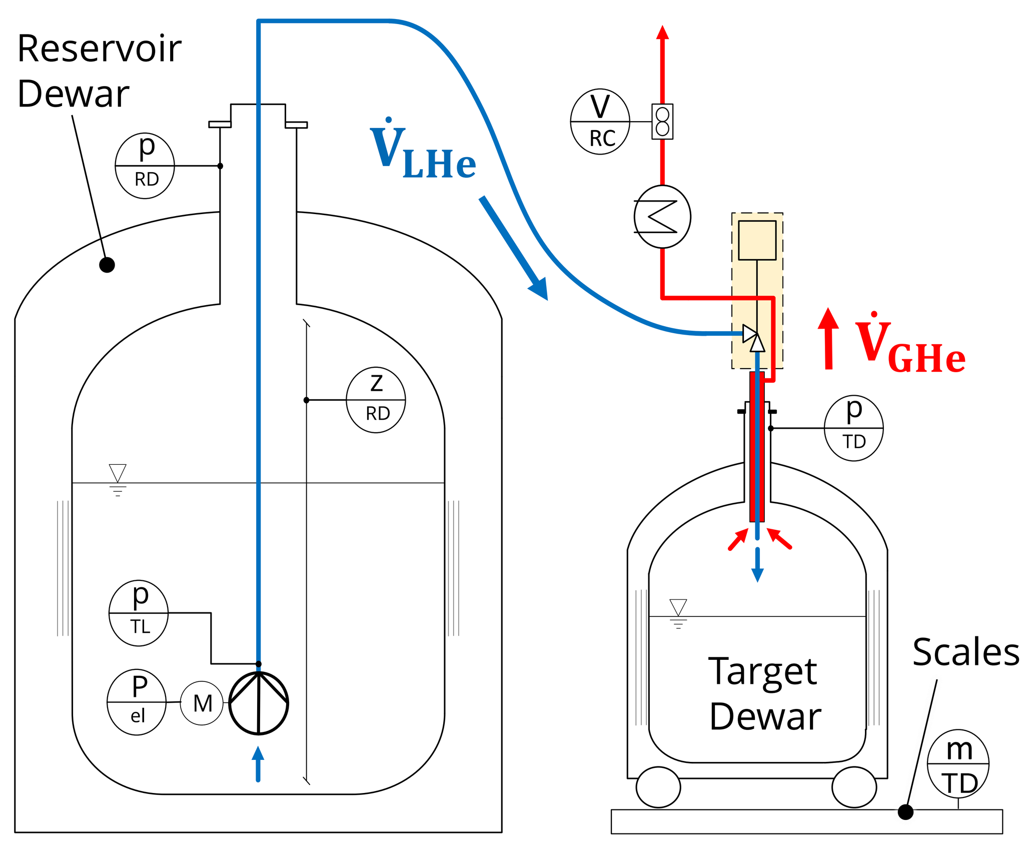




Cold drive

- Modified maxon EC4-pole22 90 W BLDC motor
- Two dry running hybrid ball bearings optimized for space applications:
  - 8 Si_3N_4 balls, stainless steel races and cage (both gold coating for solid lubrication), preloaded
- Sensorless commutation
- AWG 28 copper wires in riser line

Experimental setup



Calculus

$$\Delta p_P = p_{TL} - p_S$$

$$\dot{V}_{LHe} = \frac{dm_{ZK}}{dt} \cdot \frac{1}{(\rho' - \rho'')}$$

$$P_{el} = \sqrt{3} \cdot u \cdot i$$

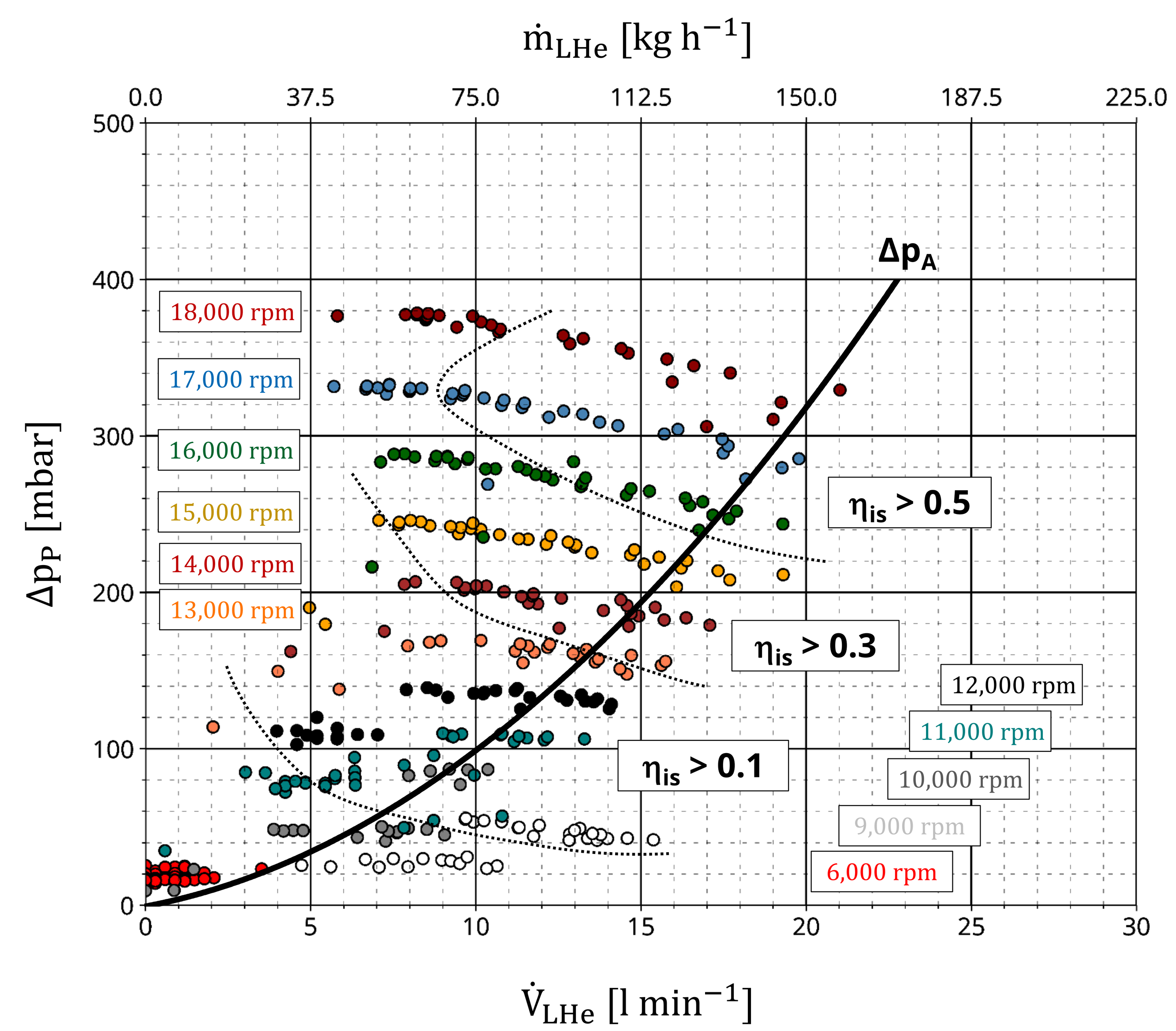
$$P_{L,\Omega} = 3 \cdot R_L(T) \cdot I_L^2$$

$$\eta_{tot} = \frac{P_{hydr}}{P_{el}}$$

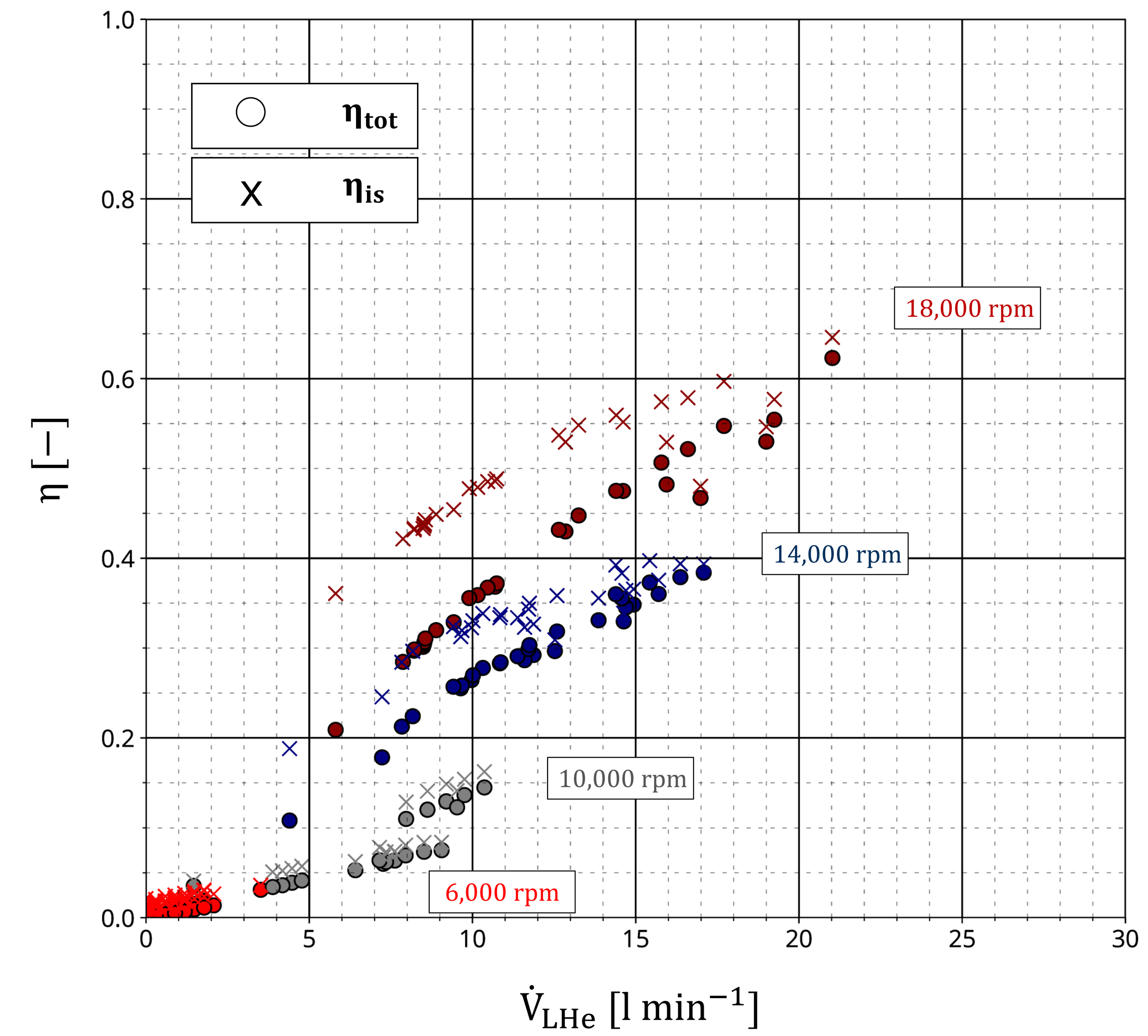
$$\eta_{is} = \frac{P_{Hydr}}{P_{el} - P_{L,\Omega}}$$

- Performance tests were conducted during dewar filling procedures

Transfer Performance



Thermal characteristics



- Adiabatic efficiencies ≥ 0.5 possible at flow rates > 11 l · min^{-1}
- Share of ohmic losses increases at lower flow rates

Summary and Outlook

- Up to now 31 transfer operations were conducted without signs of increased bearing friction
- Sufficient transfer performance and acceptable efficiency

Future work

- Optimization necessary regarding blade numbers due to channel blockage
- Comparison of hydraulic efficiency of milled and 3D printed surfaces
- Investigation of cavitation performance
- Observation of long term stability of bearings

Literature

[1] Berndt, H., Doll, R., Wiedemann, W., 1990. *Two Years' Experience in Liquid Helium Transfer with a Maintenance free Centrifugal Pump*. Advances in Cryogenic Engineering, Volume 35.

[2] Doll, J.; Klöppel, S.; Haberstroh, Ch., 2023. *Development and Characterization of a Centrifugal Pump for Low-loss Liquid Helium Transfer*. 17th Cryogenics 2023, IIR Conference (DOI: 10.18462/iir.cryo.2023.148).

Member of: DRESDEN concept SCIENCE AND INNOVATION CAMPUS