AERZEN
EXPECT PERFORMANCE

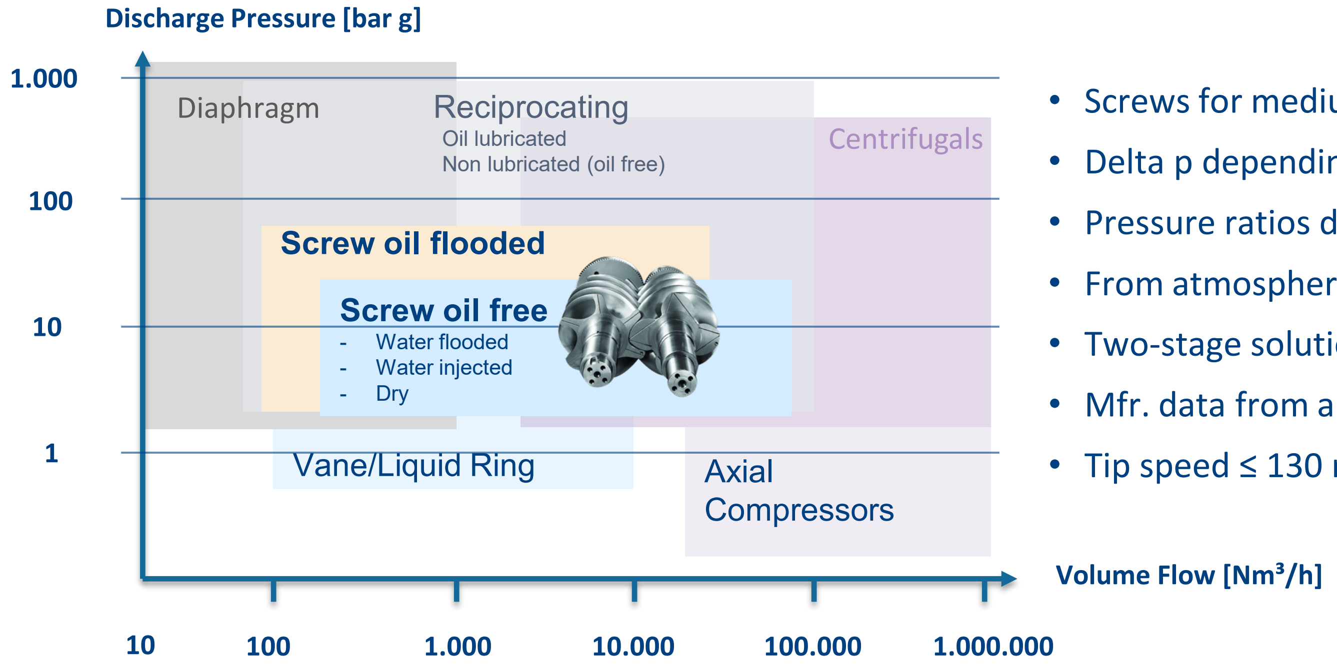
Screw Compressors for Green Hydrogen

TNO Netherlands, Workshop hydrogen compression: synergies between traditional and novel techniques

Jan Gehrmann, October 4th 2023

Agenda

Compressor Map



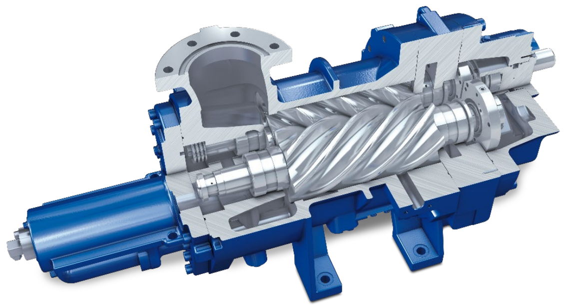
- Screws for medium/large volume flows and medium pressures
- Delta p depending on suction pressure
- Pressure ratios depending on gas/fluid injection
- From atmosphere → 10 bar a (oil free, single-stage)
- Two-stage solutions for higher pressures
- Mfr. data from approx. 500 – 50.000 Nm^3/h H2
- Tip speed ≤ 130 m/s (oil free), 90 m/s (oil flooded)

Specific challenges in new H2 applications

- Convince decision makers of screws benefits from a product life-cycle view (low maintenance, high reliability)
- Follow the electrolyzer`s dynamics (start/stop, turndown range to 10 %)
- Partial load efficiency vs higher number of stages (OPEX vs CAPEX)
- Bring „standardized/modularized“ H2 solutions into the market, incl. double-stage solutions to ≥ 30 bar a (oil free)
- Fully automated + remote stop/flushing/restart, short stops under operating pressure
- Aligned booster application with downstream reciprocating compressors (managed interfaces, control system)
- General/Light gases with fluid injection:
  - Increase tip speed/capacity
  - Develop rotor profiles for high pressures/delta p and high efficiency
  - Measure/reduce internal clearances during fabrication and operation
  - Use of numerics and CFD modeling in multi-phase simulations (= gas + liquid)

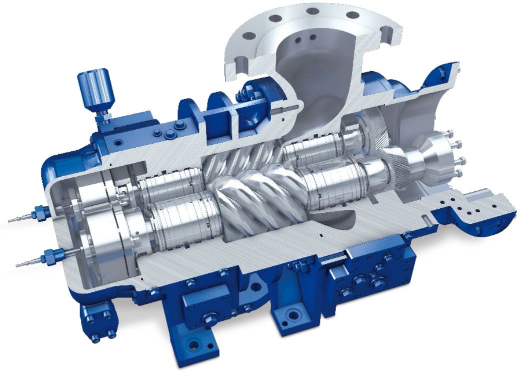
Functional principle screw compressors

Series VMY
Oil flooded



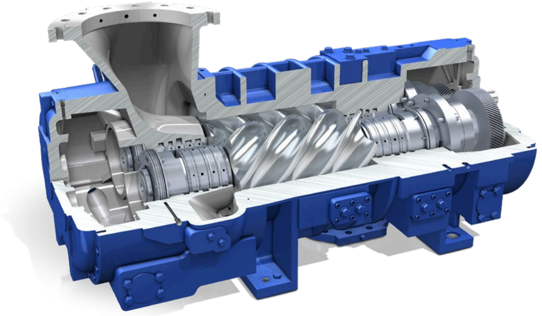
Residual oil aerosols, ≤ 1 ppm (with coalescer)
Capacity control by slide valve (internal bypass)
Adjustable Vi
One mechanical seal for the machine

Series VRA
Oil free, dry or water injected



Injected water usually vaporized (≤ 3 dm³/m³ min)
Capacity control by speed control (VFD)
Diverse sealing systems at conveying chamber

New Series VRW
Oil free, water flooded

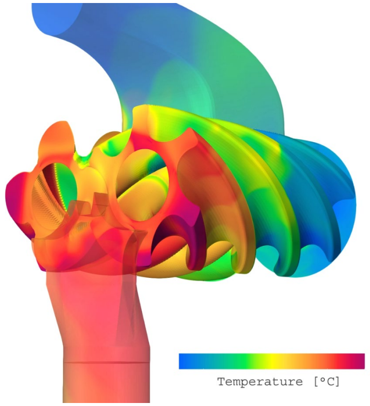


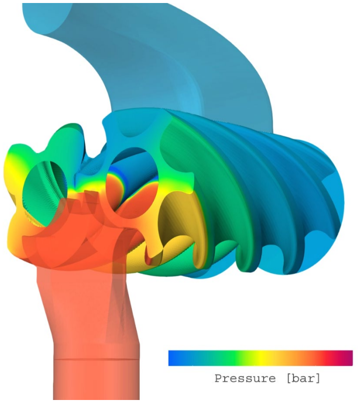
Residual water depends on separators, coalescer
Capacity control by speed control (VFD)
Water-purged mechanical seals at conveying chamber

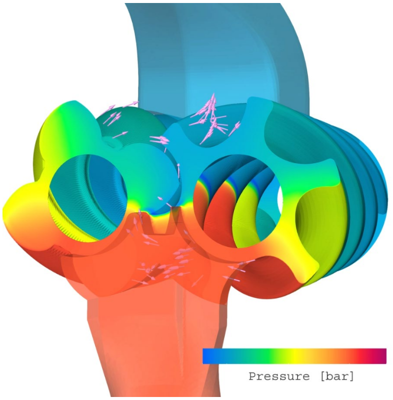
Evolution / H2 Relevance

Functional principle screw compressors

Dry compression







Max. heat losses (no internal cooling)
Max outlet temperature accord. material selection

Limited delta p
Max pressure ratio approx. 3

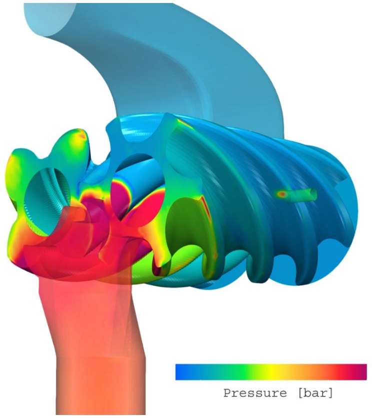
Max. gas velocity, backflow
Limited volumetric efficiency

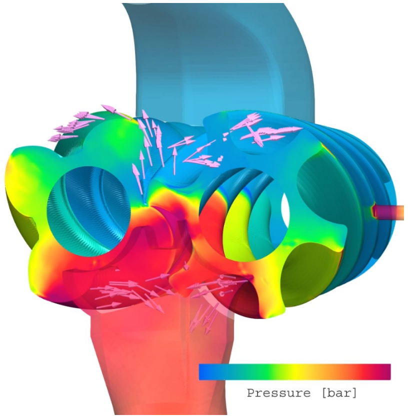
Functional principle screw compressors

Fluid injected compression

CFX BERLIN

Ansys TwinMesh FLOWMEX





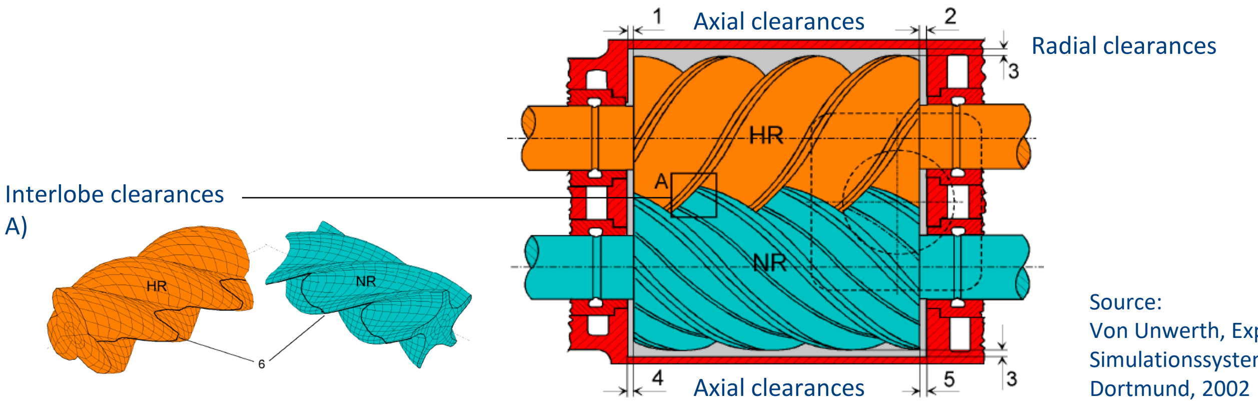
Fluid phase for cooling and gap sealing
Fluid phase enters downstream piping/vessels

Higher pressure by cooling/gap sealing
Delta p max approx. 9 bar

Limited gas velocity, less backflow
Higher volumetric efficiency
“More” isothermal compression

Internal clearances drive efficiency

How to reduce the internal clearances in a screw compressor?



Source:
Von Unwerth, Experimentelle Verifikation eines Simulationssystems für eine GASSCREW, Universität Dortmund, 2002

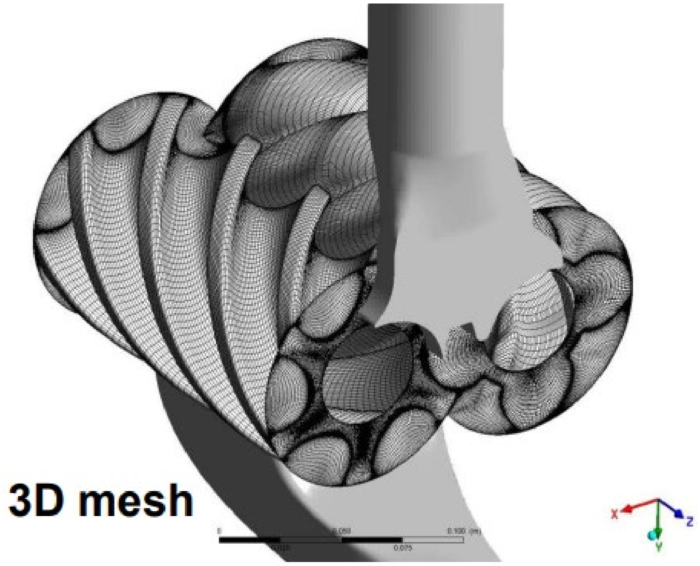
- Minimize rotor and housing tolerances in fabrication (cutting, milling, turning, grinding)
- Minimize thermal expansion by temperature management and material selection
- Minimize rotor deflection caused by pressure difference (-forces) by geometry and bearing selection
- Injection of fluid to seal the internal gaps 1 - 6 (and to cool down the gas)

➢ **Every machine compromizes on gas, use case(s) and guarenteed tolerances!**

CFD simulation to boost product development (?)

➢ **Challenge of high complex calculations in 3D meshes:**
- Transient chambers at high rotor speed
- Deforming rotors and casings (variable clearances), cold start
- Heat exchanges (solid, gas, fluid)
- Phase transition fluid ↔ gas (evaporation, condensation)
- Real gas behaviour in dynamic chambers/small gaps
  (Small clearances radial, axial, intermesh in between the rotors)
- Interaction of transitions with method/meshing conditions
- Instationary + varying local physical geometries (= complex equations!)

➢ **Ultimate target is performance prediction:**
- CFD as enabler for a digital twin
- Calculate gaps in real conditions
- Derive machine geometries, confirm simulation results on test benches!



Source: CFX Berlin

Further optimizations for H2/light gas applications

- Online measurement, calculation of dynamic internal clearances
- Water-lubricated bearings (on suction side) → Remove 50% of sealing system!
- Increase tip speed (capacities) by proper rotor profiles → Trials and studies
- Increase fluid injection → Trials and studies
- Development of Tandem-stages (one housing, two pairs of rotors)
- Public/shared test benches for H2 compressors (real condition H2 in closed loops)

➢ **Shared research results from:**
  - Technische Universität Dortmund, Prof. Brümmer
  - City, University of London, Prof. Kovacevic
  - Leibniz Universität Hannover, Dr. Fleige

➢ **Collaboration with key suppliers/tools ongoing:**
  - ANSYS, StarCCM+, CFX/TwinMesh, OpenFoam (numerics, simulation)
  - SRM Tec, SCORG, BOGE, inhouse tools (rotor geometry)

Future ambitions on Green H2 applications

- Bigger stages of water flooded type up to 25.000 m³/h (equiv. 100 MW atmospheric electrolysis)
- Standardized concepts for large low pressure electrolyzers (redundancy, availability vs CAPEX/OPEX)
- Two-stage concepts for pipeline injection pressure
- Use H2 test bench/closed loop operations for testing (confirming further CFD multi-phase simulations)
- Develop high pressure rotor profile
- Increase tip speed at maximum water injection
- Win projects using low pressure electrolysis

➢ **Provide solutions on short term as standard concepts are shaping now!**

Example case – VRA 336/236 (oil free, two-stage, water-injected)

Project Information	
Installation site	Poland
Year of installation	2015
Suction volume flow Q	2.100 m³/h
Suction pressure p1	1.0 bar a
Discharge pressure p2	3.0 bar a (1st stage) 8.8 bar a (2nd stage)
Suction temperature t1	40 °C
Process Gas	Wet hydrogen
Application	Caprolactam (Chemical)

Thank you for your attention!

LET’S TALK

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