Development of a rotary pneumatic transformer

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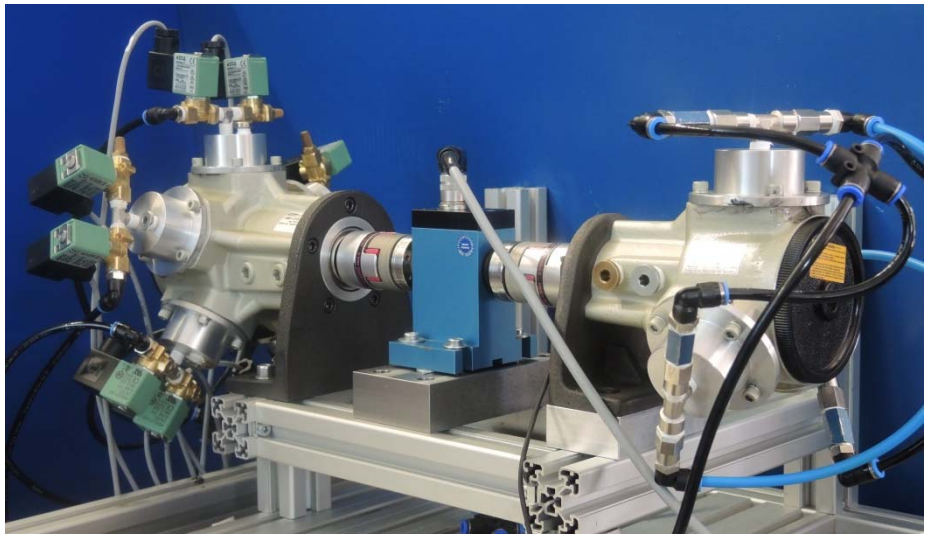
Reinertz, Olivier
Murrenhoff, Hubertus



Higher Efficiency by lower driving pressure

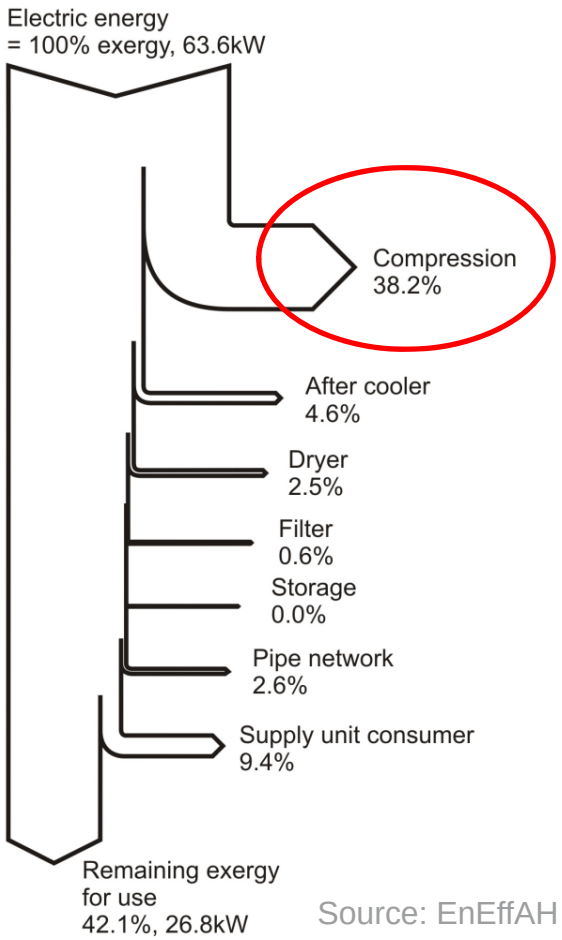
Reduction of System Pressure

- Lower compression losses
- Higher system efficiency

Local Boosting Necessary

- Compact drives
- High power-to-weight ratio

Exergy losses



Source: EnEffAH

State of the Art – Double Piston Booster

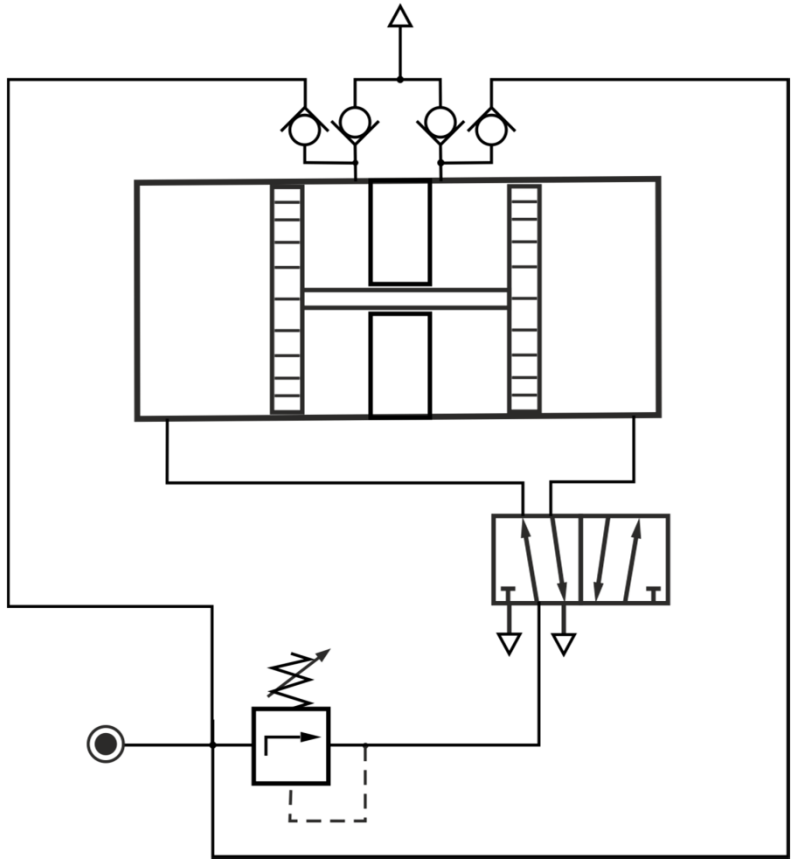
Advantages

- Simple implementation
- Cheap components
- Pressure ratio adaptable through driving pressure in outer chambers

Disadvantages

- Only limited efficiency improvements possible
- High noise emissions

Working Principle

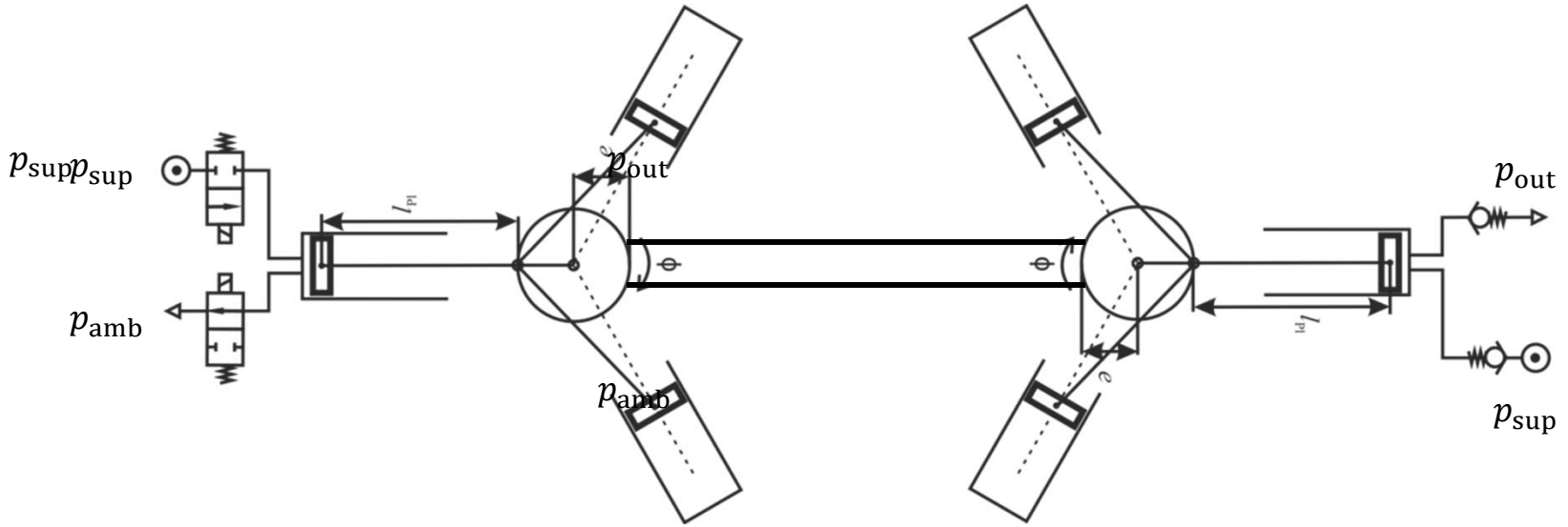


Novel Concept – Rotational Booster

Two Rotational Units

- Motor and compressor mounted on one common shaft
- Based on radial piston units
- Low noise emission because of guided movement

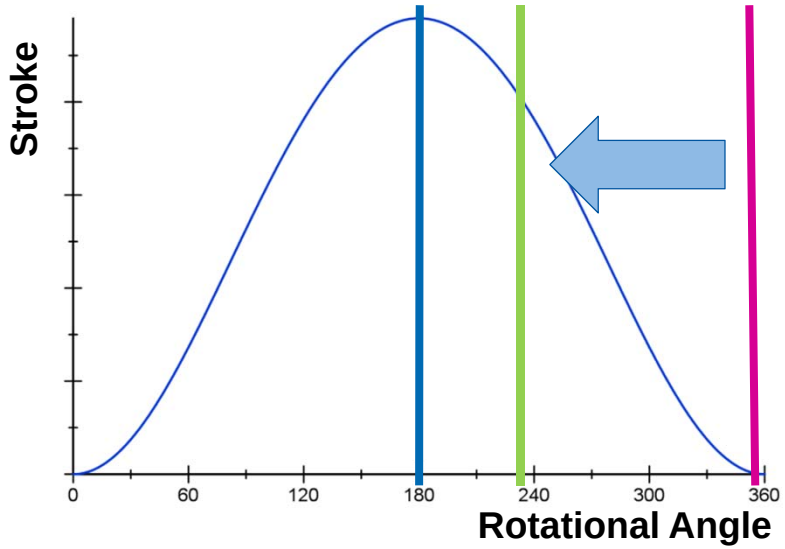
Working principle



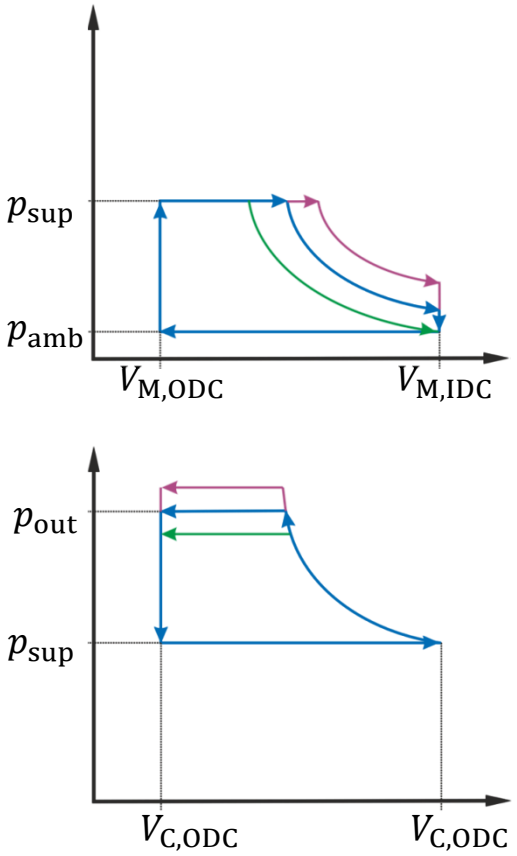
Control Concept

Adaptation of Switching Angles

- Control via motor actuation
- Use of expansion energy
- Control of motor torque



Motor Torque Determines Pressure Ratio



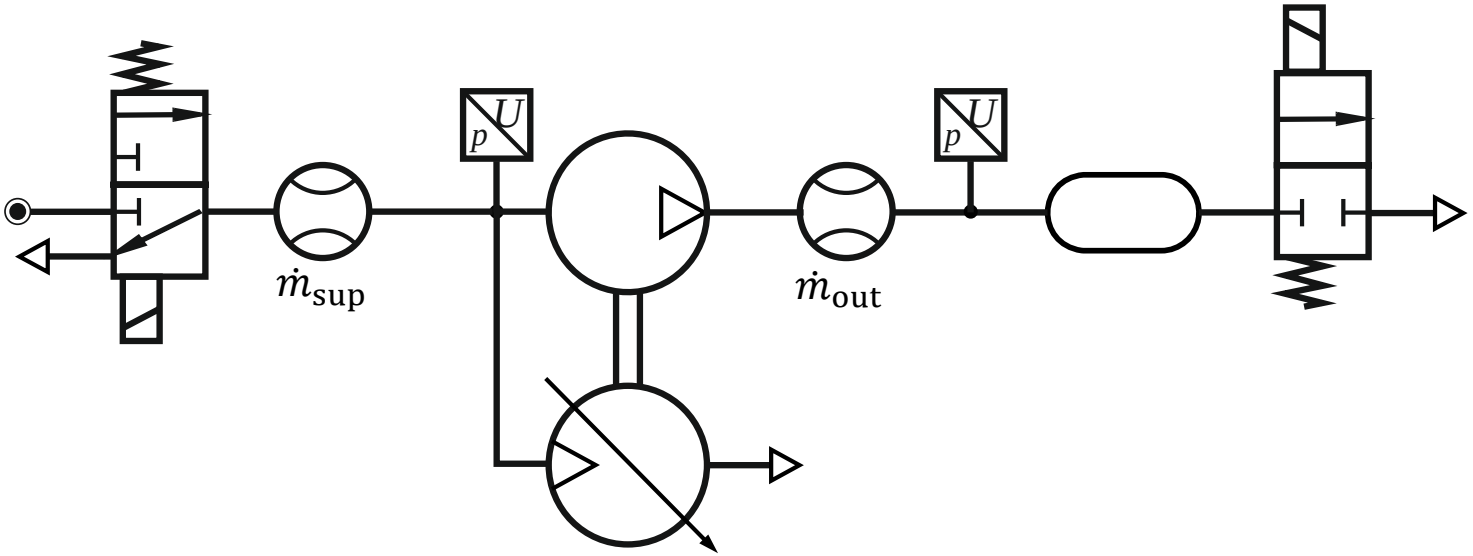
Test Rig Design

Measurement System

- Supply & output pressure
- Supply & output massflow
- Delivery to 5 litre accumulator volume
- Process considered isothermal
  - Cooling of air inside accumulator

Exergy Efficiency

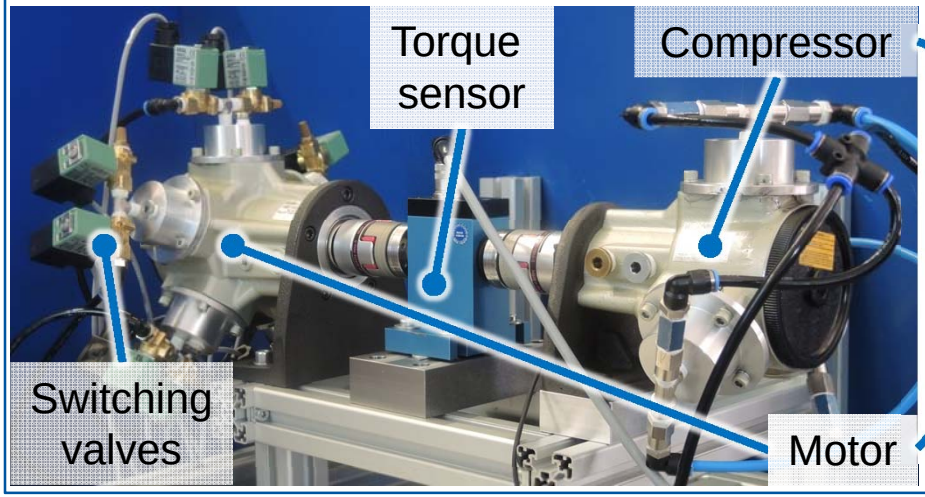
$$\zeta = \frac{\Delta E_{\text{out}}}{\Delta E_{\text{in}}} = \frac{\Delta m_{\text{out}} \cdot \ln\left(\frac{p_{\text{out}}}{p_{\text{amb}}}\right)}{\Delta m_{in} \cdot \ln\left(\frac{p_{\text{in}}}{p_{\text{amb}}}\right)}$$

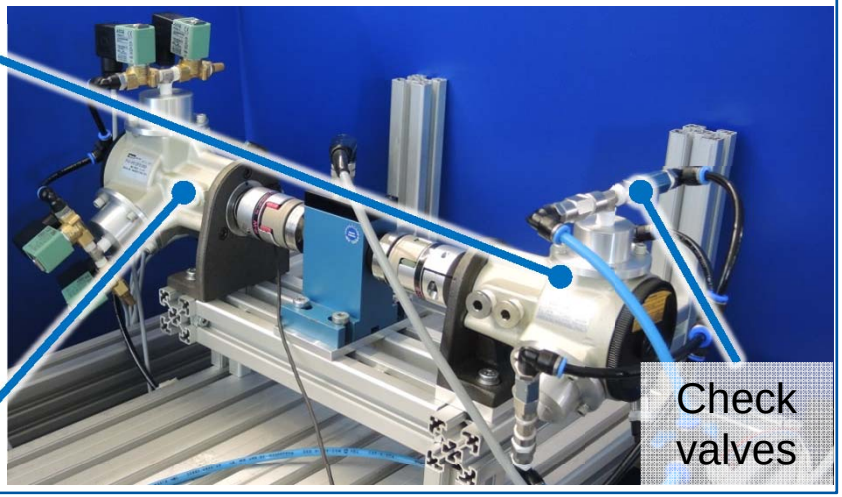


Functional model

Two Configurations

- Built from „off the shelf“-components
- 5-cylinder-motor (75 cm³), 3-cylinder-compressor (45 cm³)
- 3-cylinder motor (45 cm³), 3-cylinder compressor (16 cm³)
- Electronic control in dependency of the rotational position
  - Actuation of motor via switching valves
  - Actuation of compressor via check valves



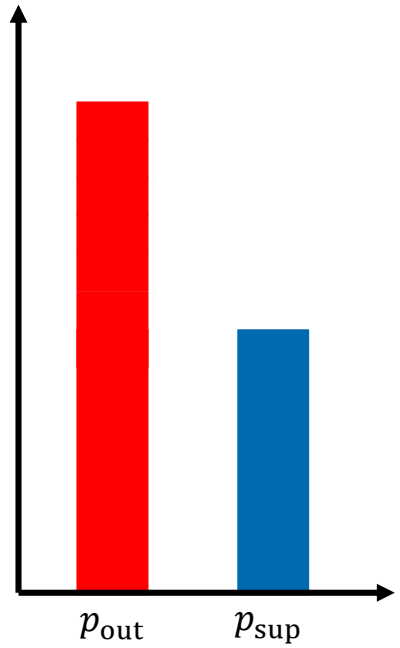


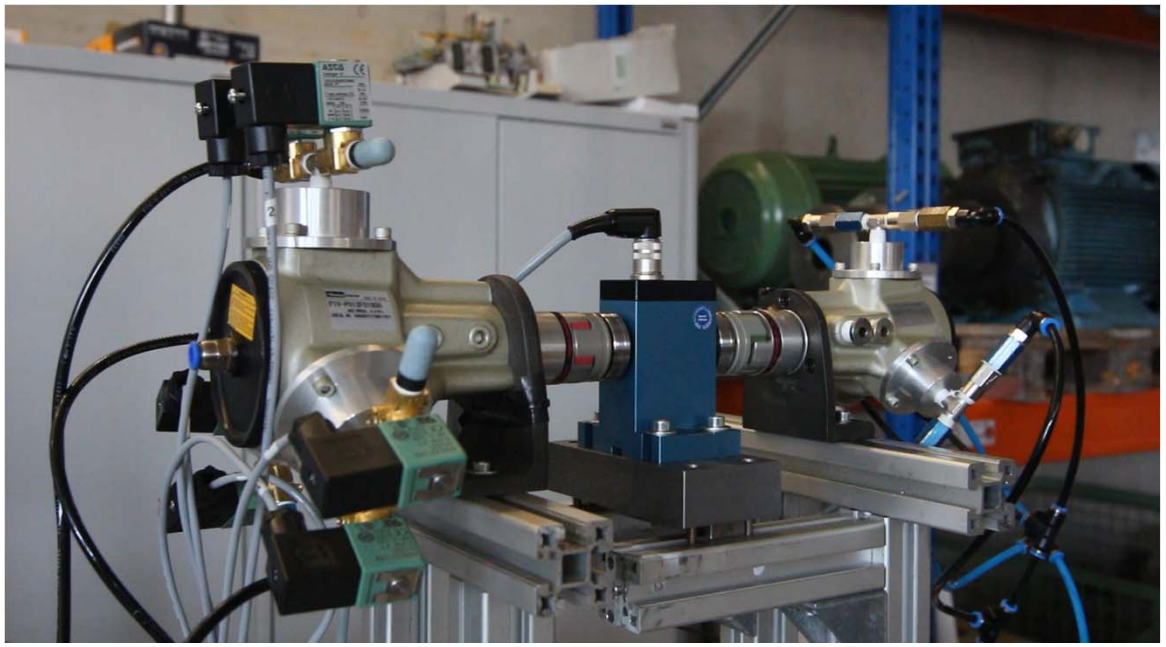
First working example

Small Configuration

- Good dynamic behaviour
- Booster restarts automatically
- Maximum pressure ratio about 2

Pressure build-up





Experimental Results

Efficiency

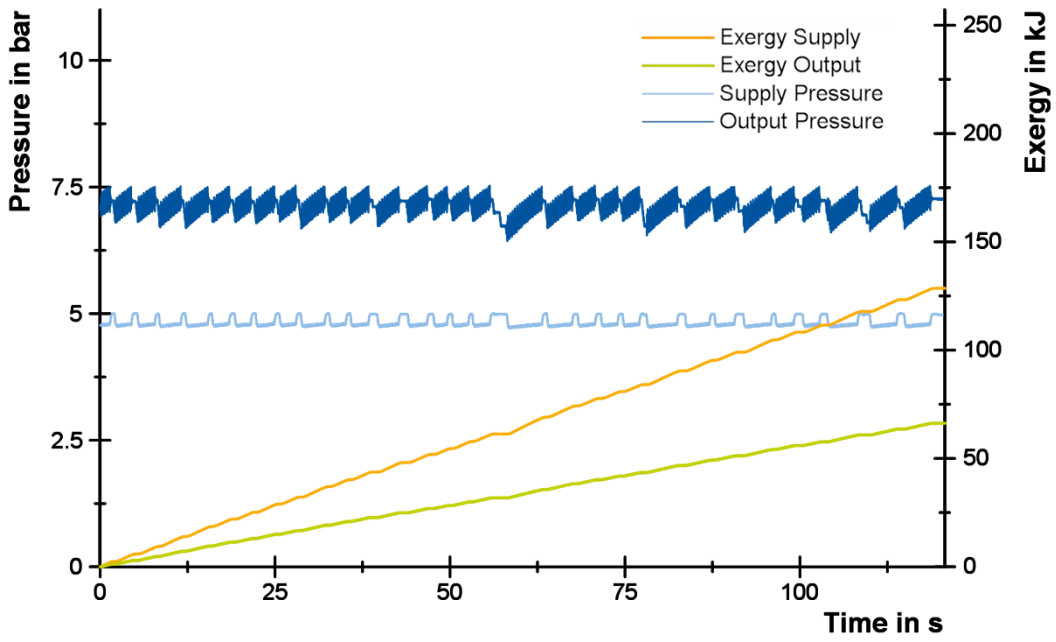
Small Configuration

- Exergy efficiency 23 – 36 %
- Large influence of dead volume

Large configuration

- Exergy efficiency 45 – 59 %
- Smaller influence of dead volume

Results



Standard double piston booster

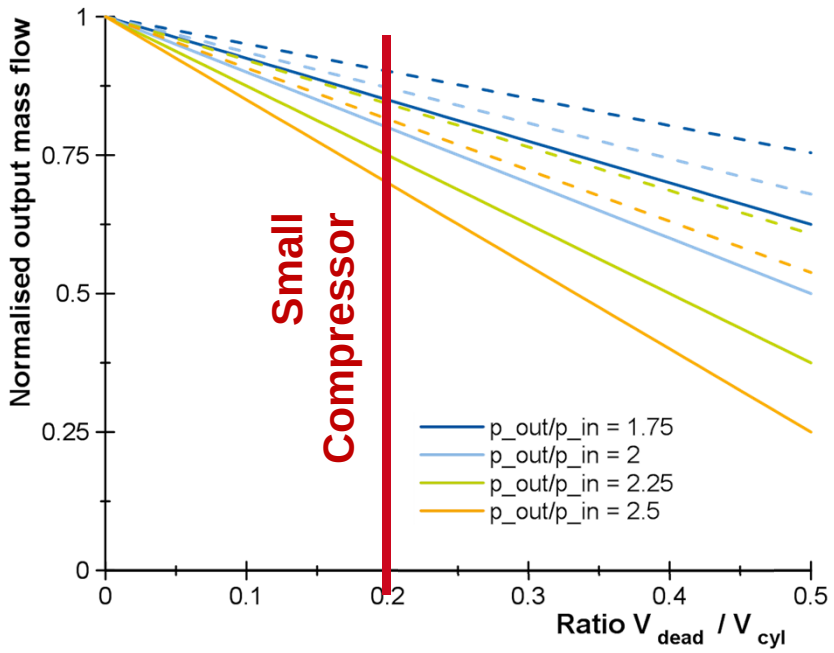
- Exergy efficiency 46 – 49 %
- Only small potential for efficiency improvements

Optimization

Reduction of losses

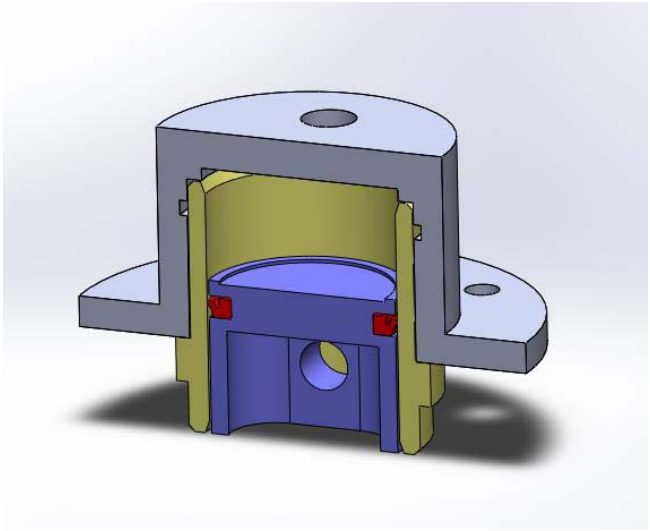
Compression losses

- Large influence on the efficiency
- Reduction of dead volume necessary



Friction losses

- Pistons sealed with O-rings
- Different sealing concepts currently under examination
- Reduction of friction losses by about 75 %



1 Motivation

2 Novel Concept

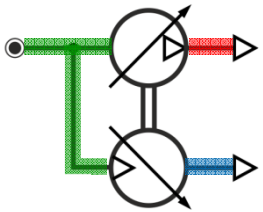
3 Test Rig & Results

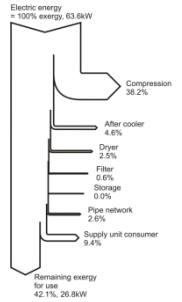
4 Conclusion

Conclusion

Enhancement of energy efficiency

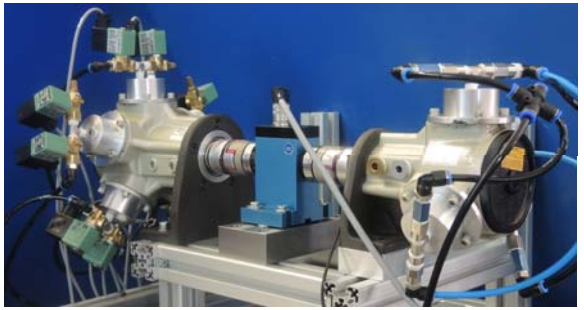
- Reduction of overall system pressure
- Local pressure boosting





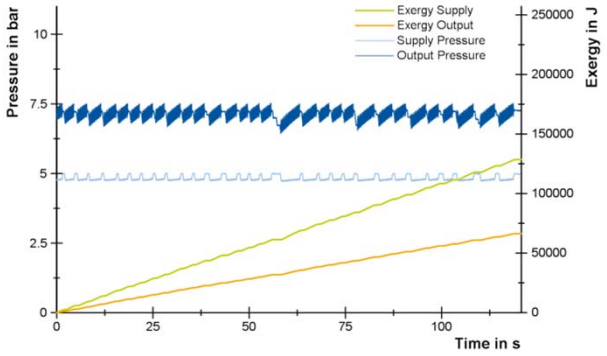
Novel booster concept

- Based on radial piston units
- Motor and compressor mounted on single shaft



Working example

- Different sizes working
- Fast response
- Efficiency of about 45 to 59 % reached
- Low noise emission



Thank you for your attention!

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