Analysis of a Twin Screw Expander for ORC Systems using CFD with real gas model

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• Introduction
• CFD methodology
• Results (I) → different designs
• Results (II) → speed change analysis
• Conclusions and future work
MOTIVATION

-Small scale ORC systems \(\rightarrow\) twin screw expander

- Standard technology used in compressors
- Working fluid: R245fa

Outer diameter \(69\) mm
Length of the rotors \(129\) mm
Rotational speed
male \(6000\) rpm
GEOMETRY OF THE TWIN SCREW EXPANDER
PORT AREA AND VOLUME CURVES
LEAKAGE TYPES IN SCREW EXPANDER

End plane (low pressure)

Leading edge

Trailing edge

End plane (high pressure)

Inlet

SEALING

TIP A

TIP B

BLOWHOLE

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GRID GENERATION FOR TWIN SCREW EXPANDER

- B.C: pressure inlet and outlet
- Solver: Coupled, Second Order
- k-ε turbulence model

Handled by an in-house code which generates a block-structured grid
1. **AUNGIER REDLICH-KWONG EOS**

   - Empirical “cubic” equation to relate P to V and T for non-ideal gases

   \[
   p = \frac{RT}{(V - \tilde{b})} - \frac{a(T)}{V(V + b_0)}
   \]

   - The critical temperature and pressure are key parameters for calculating the relationship between P, V, and T for non-ideal fluids using empirical EOS’s

   \[
   V = \frac{1}{\rho}, a(T) = a_0 \left(\frac{T_c}{T}\right)^n, a_0 = 0.42747 \frac{R^2T^2}{p_c}
   \]

   \[
   b_0 = 0.08664 \frac{RT_c}{p_c}, c_0 = \frac{RT_c}{p_c} + b_0 - V_c, \tilde{b} = b_0 - c_0
   \]

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P-V diagram (without additional injection ports)

Inlet closed

Outlet open

Over-expansion!
P-V diagram (with additional injection ports)
POWER

With injection ports

Without injection ports

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FILLING FACTOR AND ISENTROPIC EFFICIENCY

\[ \phi_{ff} = \frac{\dot{m}_{calc, in} \cdot v_{in} (T_{in}, P_{in})}{N \cdot n_{lobes} \cdot V_D} \]  

\[ \eta_{is, exp} = \frac{W_{calc}}{\dot{m}_{calc} \cdot (h(T_{in}, P_{in}) - h(P_{out}, s_{in}))} \]  

\[ \phi_{ff} \eta_{is, exp} = \frac{(\dot{m}_{calc, inj} \cdot v_{inj} (T_{inj}, P_{inj}))}{N \cdot \dot{m}_{inj} \cdot (h(T_{inj}, P_{inj}) - h(P_{inj}, s_{inj}))} \cdot \frac{W_{P_{out, inject}}}{(h(T_{inj}, P_{inj}) - h(P_{out, inject}))} \]
MASS FLOWS THROUGH CLEARANCE BETWEEN ROTOR TIP AND THE HOUSING

Design without additional injection ports

- Leakages increase with the increase of pressure ratio
- Over- and under- expansion → influence on the leakages
MASS FLOWS THROUGH SEALING CLEARANCE BETWEEN THE ROTORS

Design without additional injection ports

Design with additional injection ports
SPEED ANALYSIS

Inlet losses increase with the rotational speed

Injection start

Injection end

Outlet open

Inlet closed
CONCLUSIONS

- CFD tool for the simulation of the twin screw expander with real gas behavior of the working fluid is developed together with the post-processing tools
- Depending on the pressure ratio, under- or over-expansion can occur
- Power increases with both higher rotational speeds and pressure ratios
- Inlet losses increase with the rotational speed.
- This research will be used further to improve the performance and the design of the screw expander

FUTURE WORK
- Oil injection with R245fa
Questions? Comments?

Thank you for your attention!

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