VOLUMETRIC EXPANDER VERSUS TURBINE – WHICH IS THE BETTER CHOICE FOR SMALL ORC PLANTS?

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Andreas P. Weiß

Competence Center for CHP Systems

University of Applied Sciences Amberg-Weiden

Kaiser-Wilhelm-Ring 23, 92224 Amberg, Germany
a.weiss@oth-aw.de

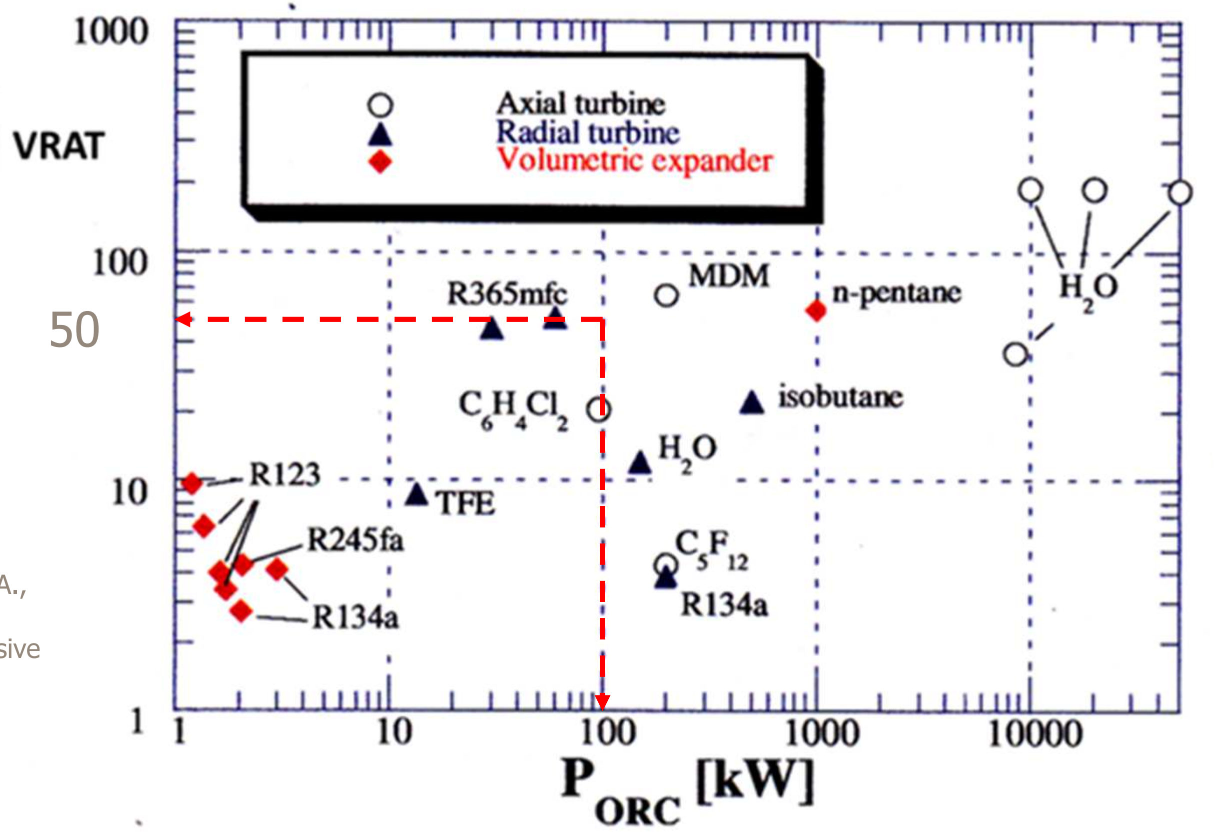
KWK

Kompetenzzentrum für Kraft - Wärme - Kopplung

Ostbayerische Technische Hochschule
Amberg-Weiden

Motivation

Volume Flow Ratio



(Branchini, L., De Pascale, A., Peretto, A., 2013, Systematic comparison of ORC configurations by means of comprehensive performance indexes, *Applied Thermal Engineering 61*, p 129-140)

Which expander concept is the best compromise, aiming for a „micro expander construction kit" which enables the designer to implement an appropriate expander for any given application out of a wide range of boundary conditions and working fluids (3- 100 kW_{el})?

Outline

1. Motivation

2. **Volumetric Versus Dynamic Expander**

3. Comparison and Assessment of Different Turbines
    - Impulse Versus Reaction Turbines
    - Axial Versus Radial Turbines

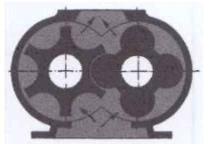
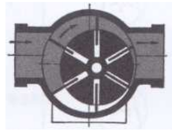
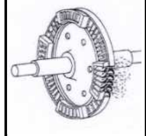
4. The Micro Turbo Generator Construction Kit

5. Conclusions

Volumetric Versus Dynamic Expander
Selection Criteria for Small ORC Expanders (3-100 kW_{el})

Economic Criteria	Technical Criteria
costs	efficiency
availability on market	rotational speed
reliability	lubrication
maintainability	sealing
	power level
	working fluid
	wear
	complexity
	adaptability

Volumetric Versus Dynamic Expander -Pro & Cons

	volumetric expanders				dynamic expanders		
	$work = \int v dp$				$work \sim u^2$		
							
criterion	piston	screw	scroll	vane	axial	cantilever	radial
efficiency	2	1	1	0	1		
VRAT	1	0	0	0	2		
rotational speed	2	1	2	2	0		
part load	2	2	2	2	1		
size	0	0	1	1	2		
adaptability	0	0	2	1	2		
lubrication	0	0	0	0	2		
wear	1	2	1	0	2		
wetness	1	2	2	2	1		
vibration	0	2	2	2	2		
complexity	0	0	2	1	2		
Σ	**9**	**10**	**15**	**11**	**17**		

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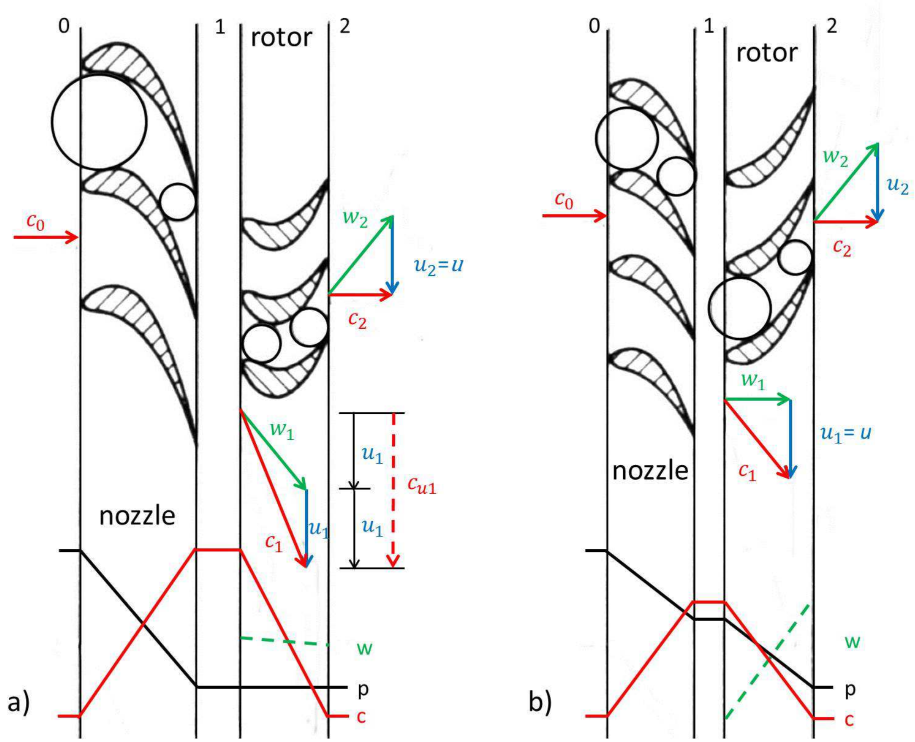
Comparison and Assessment of Different Turbines
Impulse Versus **Reaction** Stage



$$\Delta h_{blading,impulse} = 2 * u^2$$

$$\Delta h_{blading,reaction} = 1 * u^2$$

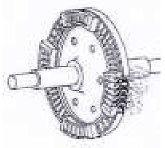
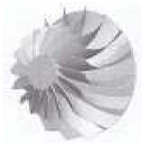
$$\Delta h_{Blading} = c_{u1} * u_1 - c_{u2} * u_2$$

$$u_{opt,impulse} = \frac{1}{\sqrt{2}} * \sqrt{\Delta h_{is}}$$

$$u_{opt,reaction} = 1 * \sqrt{\Delta h_{is}}$$

$$u_{opt,impulse} = u_{opt,reaction} / \sqrt{2}$$

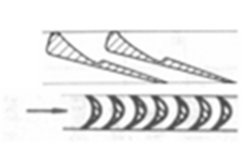
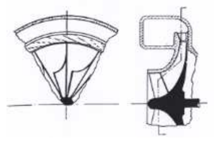
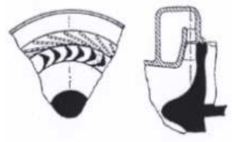
Comparison and Assessment of Different Turbines
Impulse Versus **Reaction** Turbine

turbine axial – cantilever - radial	impulse	reaction
  		
efficiency potential (ts) ≈	80 %	90 %

criterion	impulse	reaction
efficiency	0	2
VRAT	2	0
rotational speed	2	0
axial thrust	2	0
partial admission	2	0
minimal power (size)	2	0
Σ	**10**	**2**

Comparison and Assessment of Different Turbines
Axial Versus **Radial** Turbine

$$\Delta h_{Blading} = c_{u1}*u_1 - c_{u2}*u_2 = \frac{1}{2}*[(c_1^2 - c_2^2) - (w_1^2 - w_2^2) + (u_1^2 - u_2^2)]$$

	turbine type		
			
criterion	axial (r=0)	radial inflow (r ≈0,5)	cantilever inflow (r>0)
efficiency	1	2	2
VRAT	2	0	1
rotational speed	2	0	1
axial thrust	2	0	1
partial admission	2	0	2
multi stage	2	0	0
complexity	2	1	2
Σ	**13**	**3**	**9**

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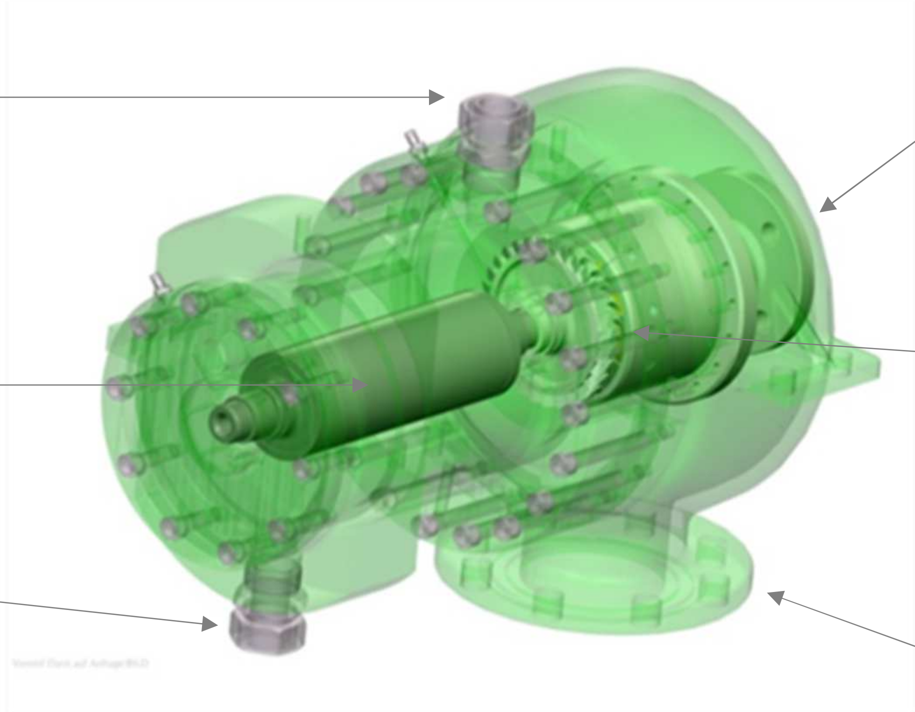
The Micro Turbo Generator Construction Kit (3–100kW$_{el}$)

generator cooling inlet

turbine inlet



permanent magnet rotor

turbine axial impulse wheel

generator cooling outlet

turbine outlet

Several small turbo generators applying small impulse turbines have already been built and successfully tested for various fluids (steam, air, r245fa, SES36, cyclopentane, CO_2 etc.) in the range 1 to 120 kW. Measured efficiencies are in the expected range of 60-70% (is, ts).

Conclusions

- The motivation and goal of this work have been to identify the most suitable expander type for a „micro expander construction kit" which enables the designer to implement an appropriate expander for any given application out of a wide range of boundary conditions and working fluids (3- 100 kW_{el}).

- The comparison of various volumetric and dynamic expanders types showed, that a turbine is the more flexible concept.

- The evaluation of the pro and cons of impulse versus reaction turbines and an axial versus a radial design led to the conclusion that the simple axial impulse turbine is the best compromise. Therefore, it has been choosen for the „micro expander construction kit".