Institute of Fluid Flow Machinery, Polish Academy of Sciences
Centre of Mechanics of Machines
Department of Turbine Dynamics and Diagnostics

Badania i rozwój mikroturbin energetycznych

Research and development of microturbines

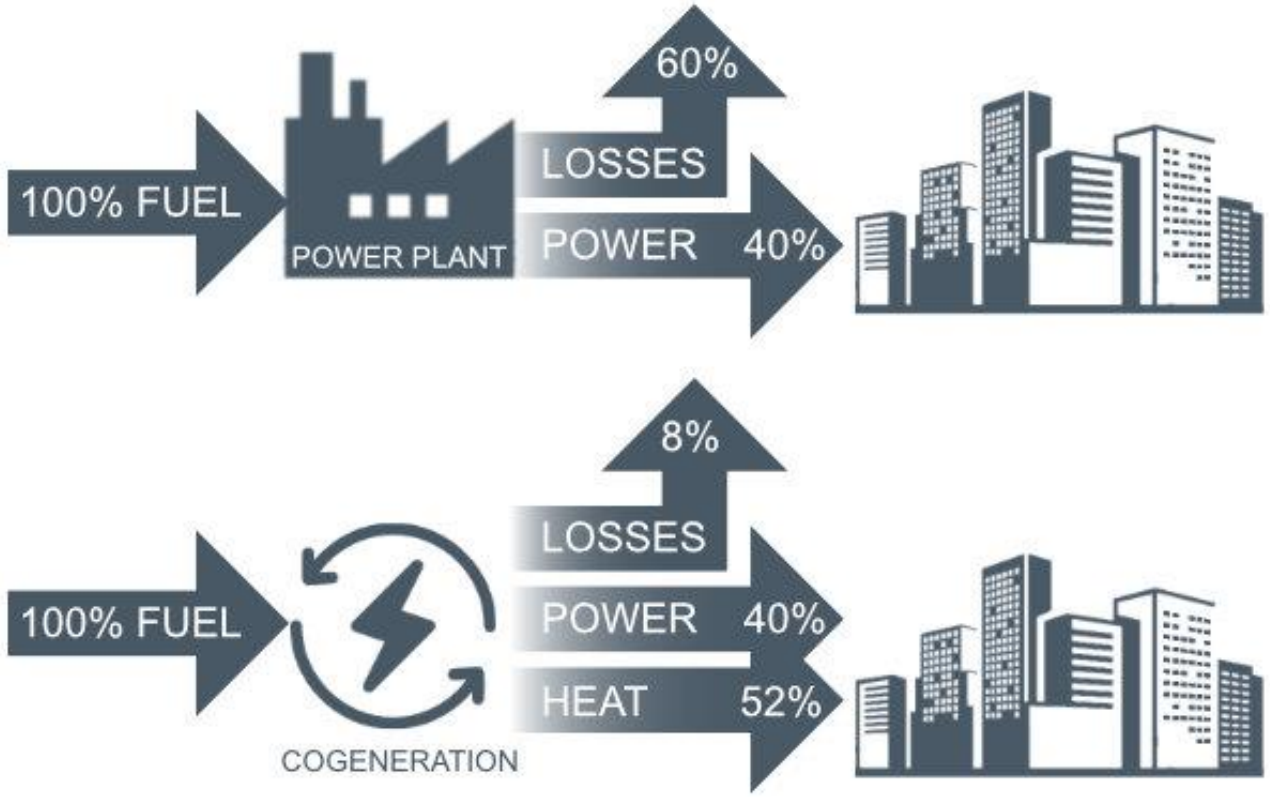
Grzegorz Żywica, Assoc. Prof., PhD.

Opole 8-9.12.2021

Content of presentation

- Introduction
  - Combined heat and power (CHP) system
  - Microturbines
- ORC technology
  - Microturbine with a capacity of 1 kW
  - Microturbine with a capacity of 3 kW
  - Microturbine with a capacity of 10 kW
- Gas microturbines
- Conclusions

Cogeneration efficiency (combined heat and power system)



www.inoplex.com.au

Advantages:

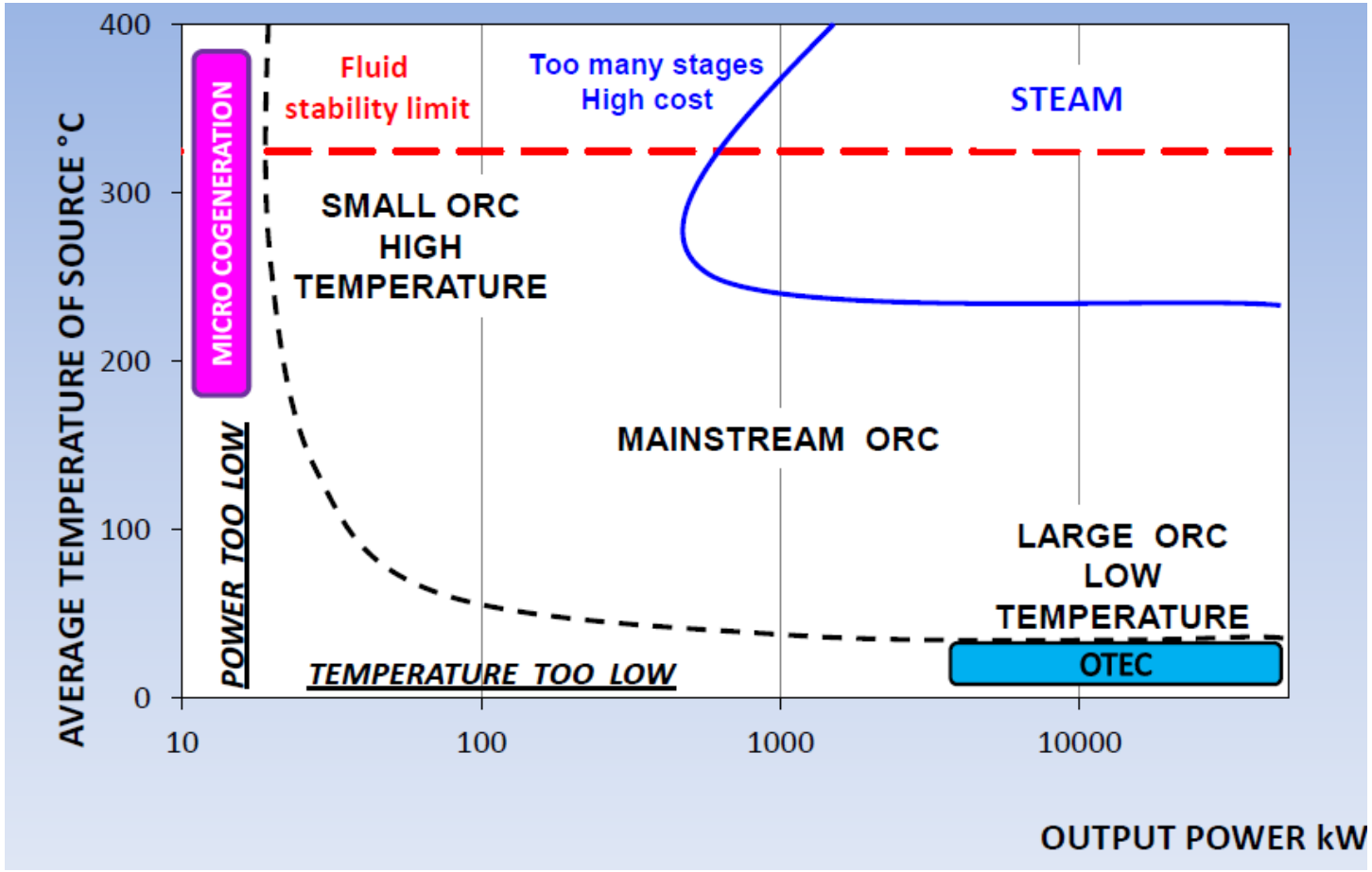
- Output power can be tailored to user's needs
- Use of locally available energy sources (e.g. biomass or gas)
- High efficiency
- Power network load reduction
- No transmission losses
- Minimum impact on the environment

Disadvantages:

- High investment costs
- Constant heat demand is required

Basics of an ORC technology

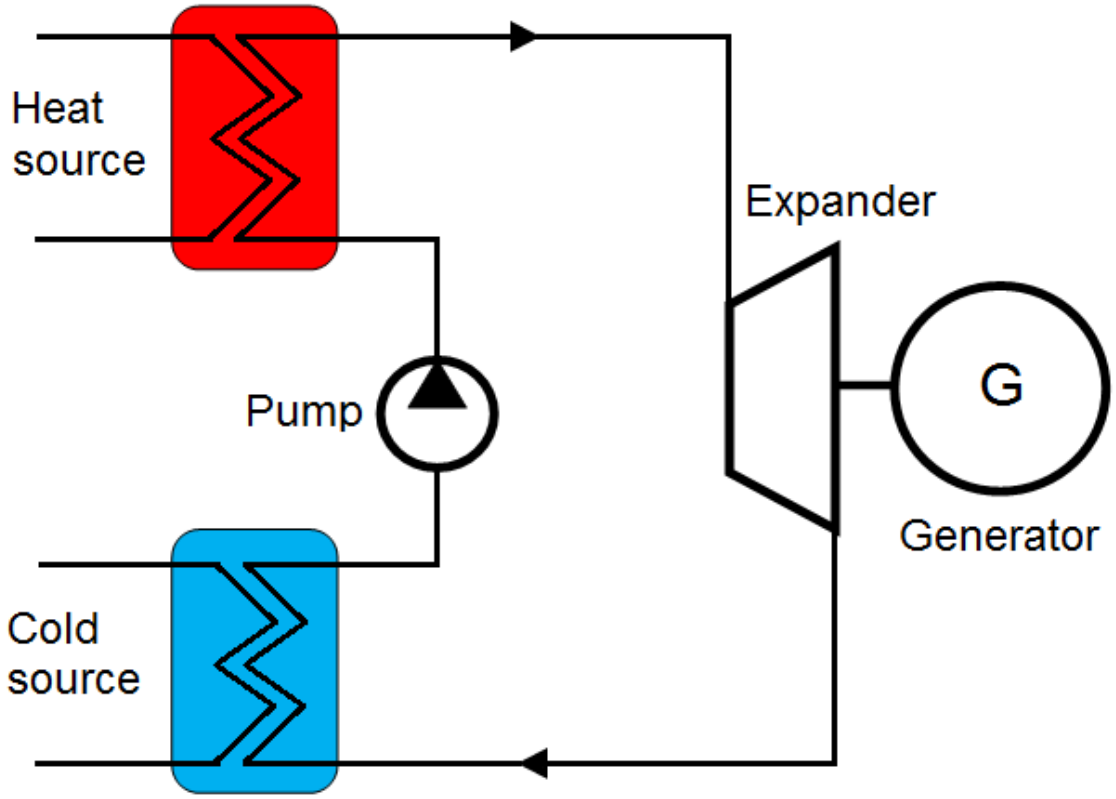
Typical power and temperature ranges of ORC systems



Gaia M.: *30 Years of Organic Rankine Cycle Development*, First International Seminar on ORC Power Systems, ORC 2011, 22-23 September 2011, TU Delft.

Basics of an ORC technology

Simplified organic Rankine cycle system



Expansion devices used in ORC systems

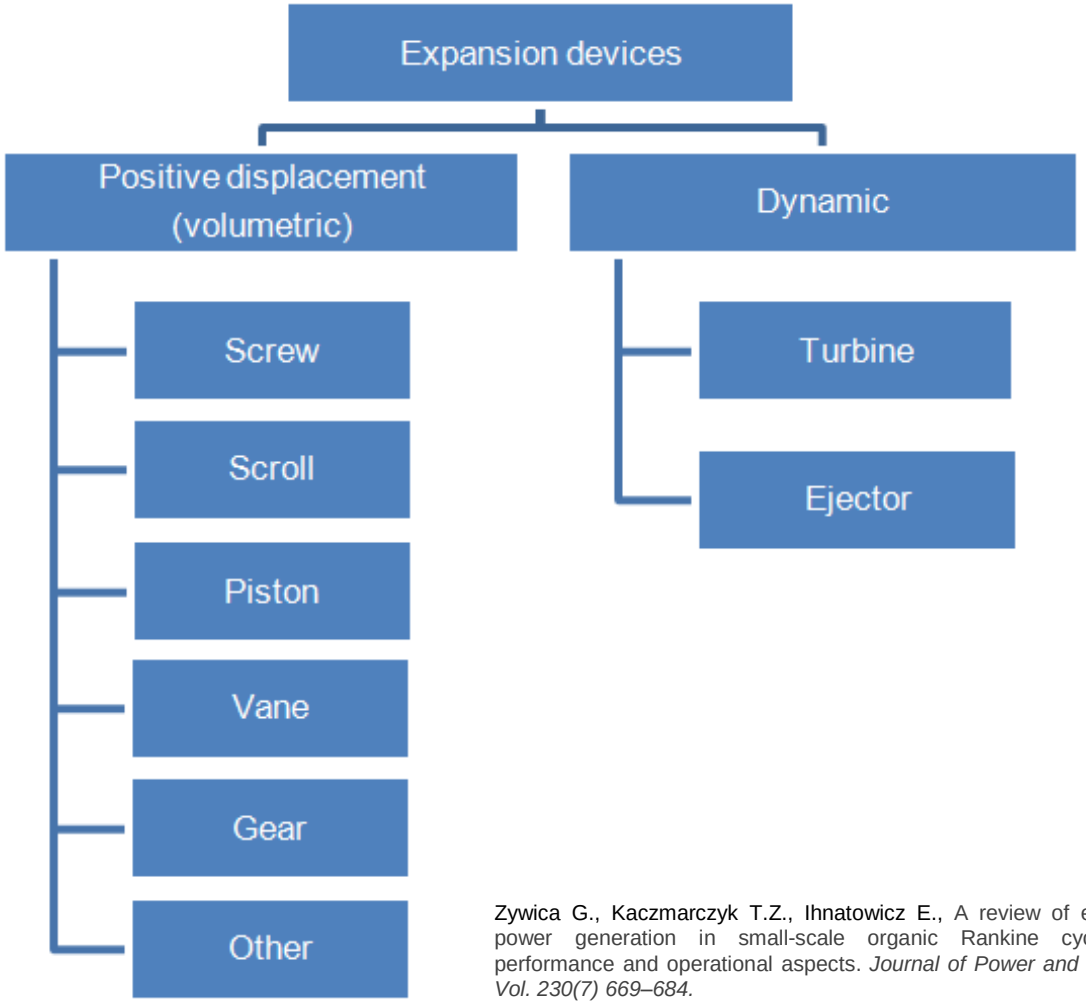
Screw expander

Vanslambrouck B, Vankeirsbilck I, Gusev S, et al. Turn waste heat into electricity by using an Organic Rankine Cycle. *2nd European Conference on Polygeneration*, Tarragona (Spain) 2011

Scroll expander

Vanslambrouck B, Vankeirsbilck I, Gusev S, et al. Turn waste heat into electricity by using an Organic Rankine Cycle. *2nd European Conference on Polygeneration*, Tarragona (Spain) 2011

Classification of expansion devices

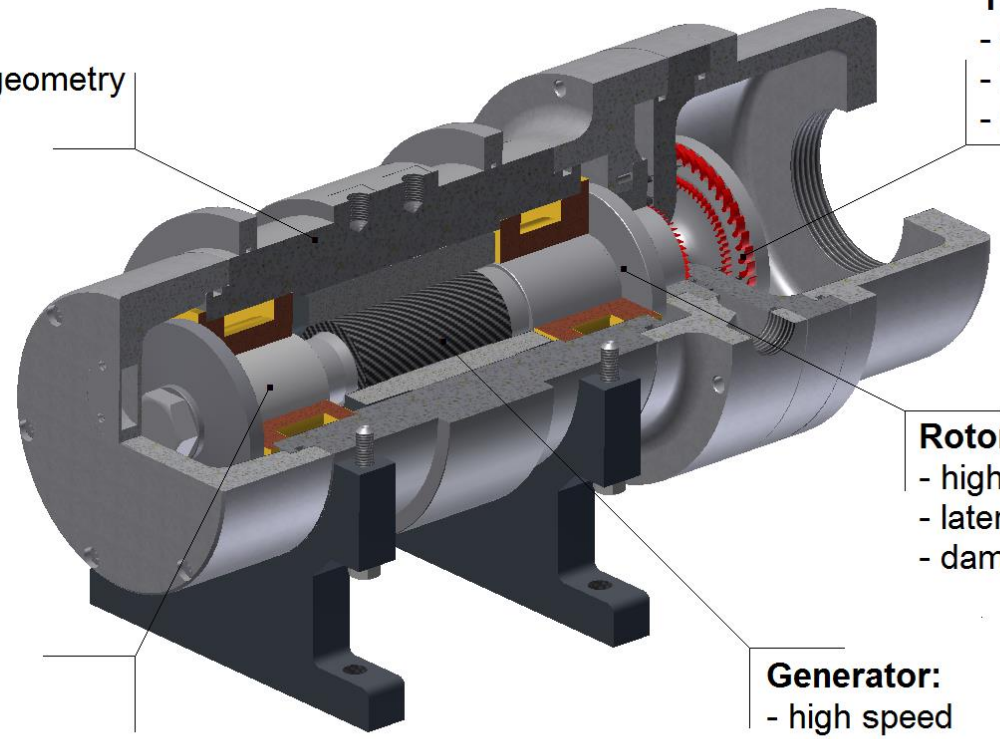


Zywica G., Kaczmarczyk T.Z., Ihnatowicz E., A review of expanders for power generation in small-scale organic Rankine cycle systems: performance and operational aspects. *Journal of Power and Energy 2016, Vol. 230(7) 669–684.*

ORC turbogenerators

Casing:
- heat load
- accuracy of geometry
- leakage

Turbine disk:
- centrifugal force
- heat load
- natural vibrations



Rotor:
- high speed
- lateral and axial vibrations
- damage (e.g. crack)

Bearings:
- high speed
- lubrication and friction
- vibrations and stability

Generator:
- high speed
- electric load
- cooling

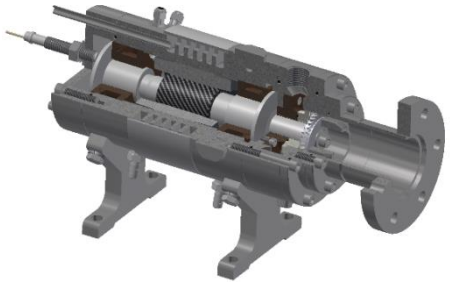
Advantages:

- High efficiency
- Compact size
- Simple structure
- Lubrication is not necessary
- Low or no wear
- Low noise and vibration levels

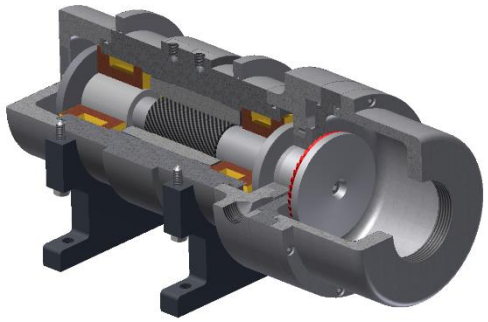
Disadvantages:

- Not resistant to vapour condensation
- High manufacturing precision
- No ready-made solutions on the market

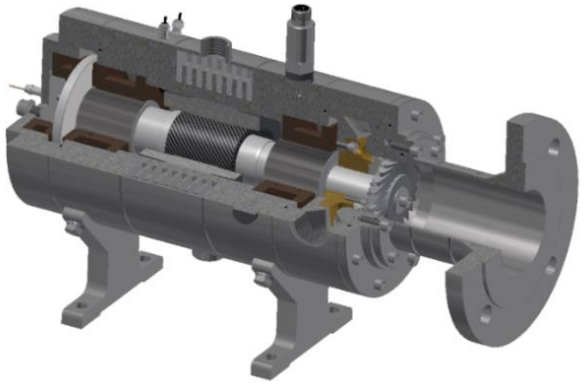
ORC microturbines developed at IMP PAN



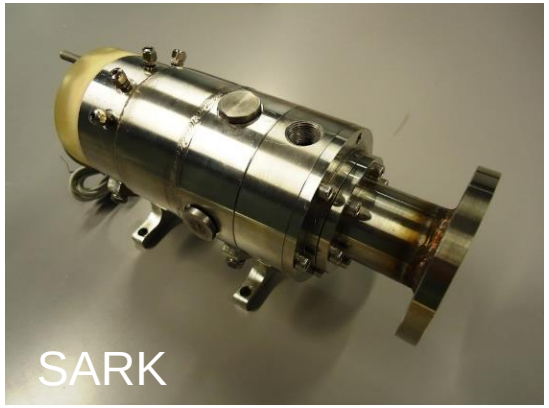
Electric power: **1 kW**
Rotational speed: 100,000 rpm
Weight: 8 kg

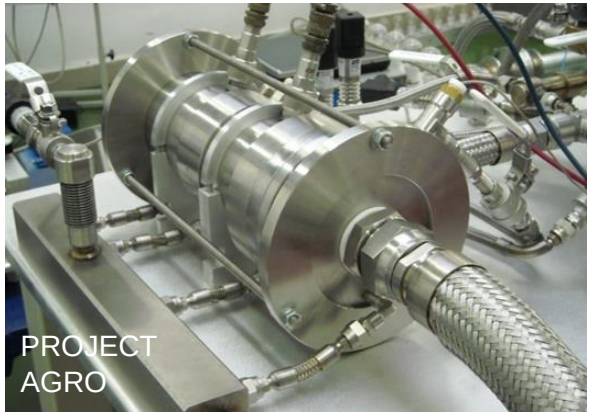


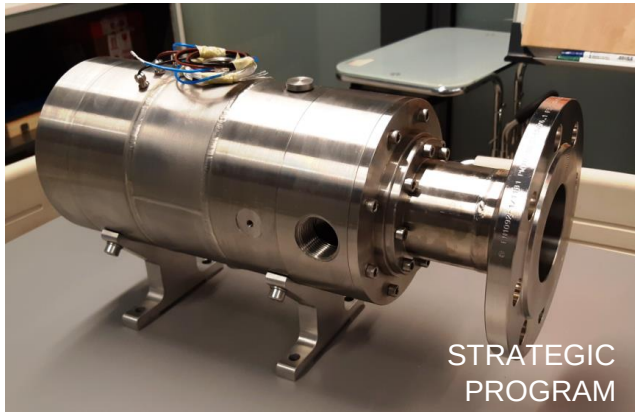
Electric power: **3 kW**
Rotational speed: 24,000 rpm
Weight: 22 kg



Electric power: **10 kW**
Rotational speed: 40,000 rpm
Weight: 46 kg







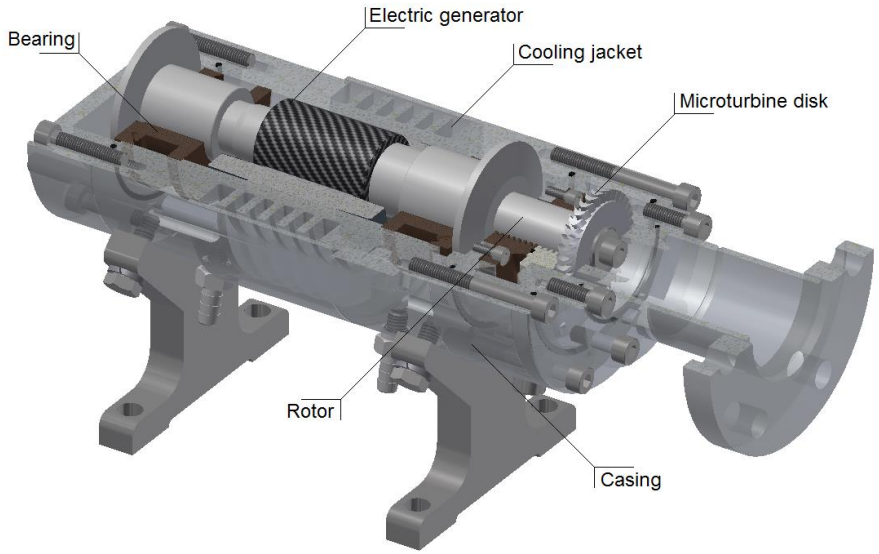
Turbogenerators designed as oil-free units!

SARK

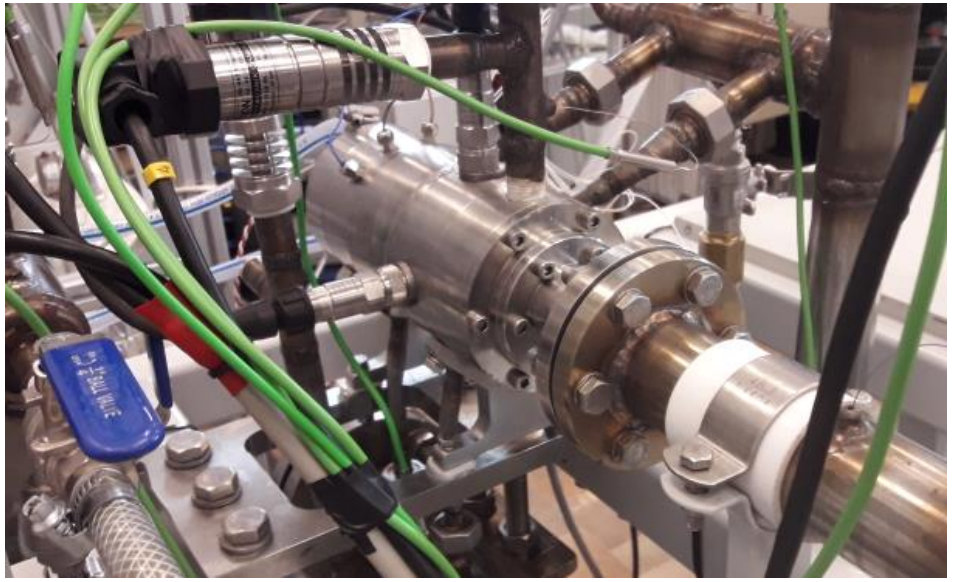
Turbogenerator with a capacity of 1 kW

IMP PAN GDAŃSK

CAD 3D model



Prototype



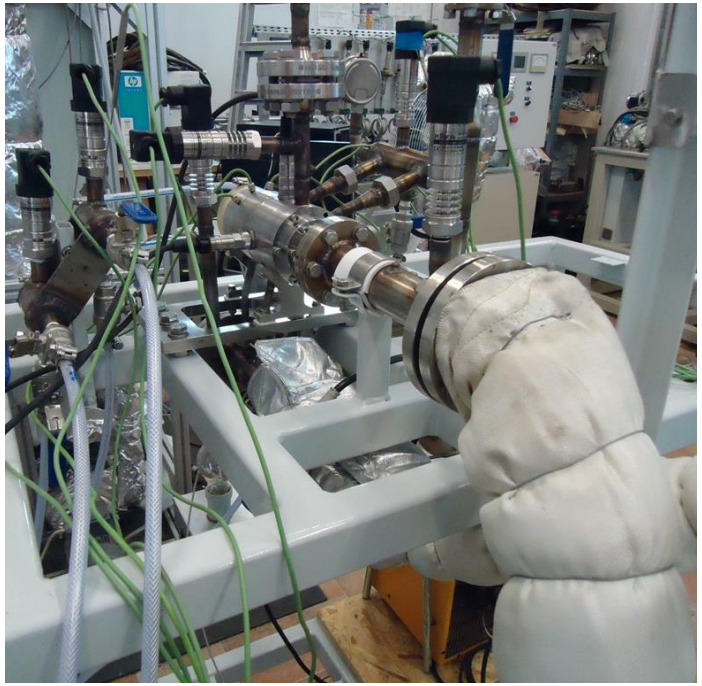
Technical parameters of the turbogenerator

Parameter	Value	Unit
Rated rotational speed	100,000	rpm
Rated electrical power	1.1	kW
Net weight	8.3	kg
Maximum pressure	15	bar
Maximum temperature	200	°C

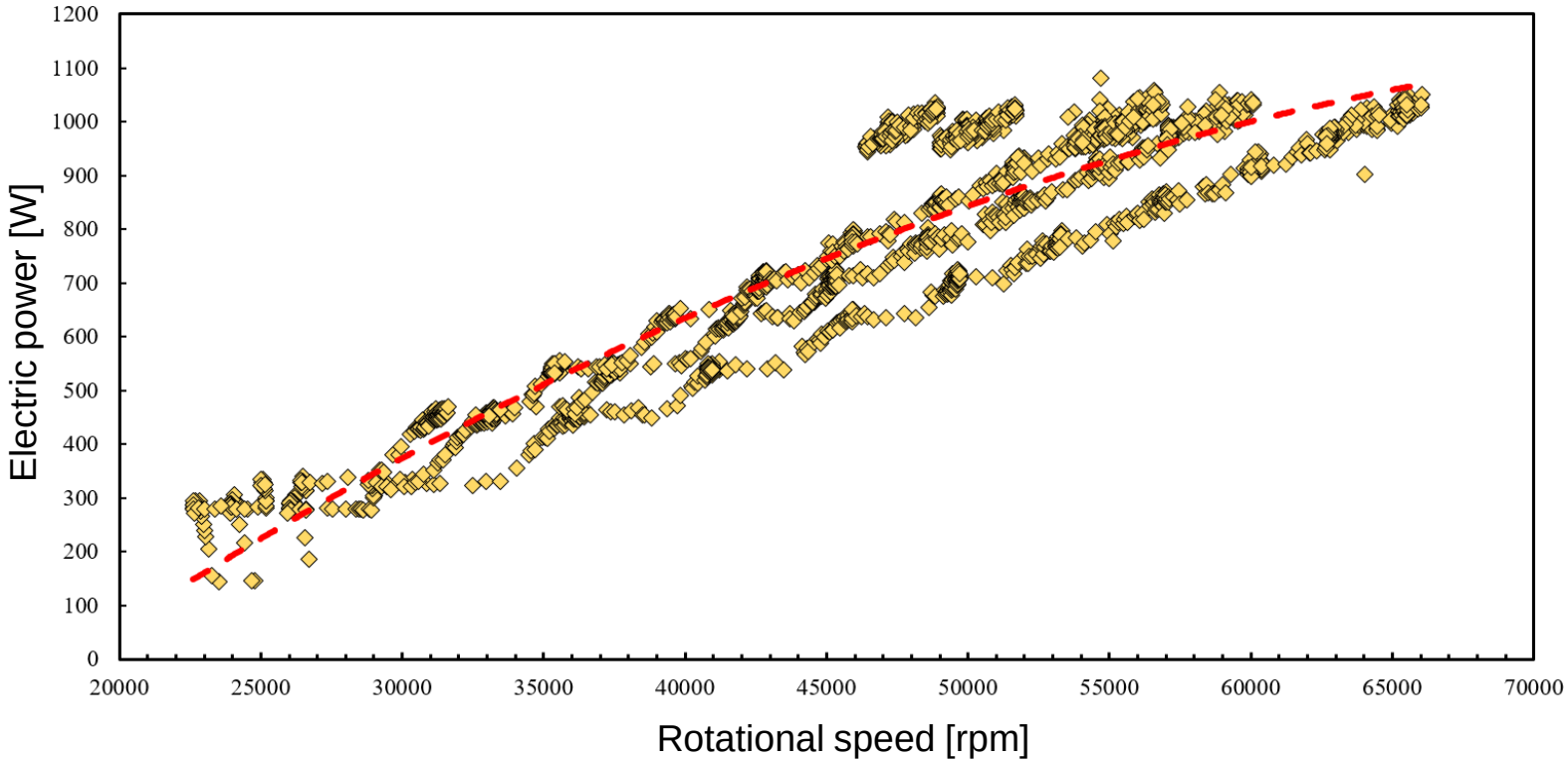
Turbogenerator rotor

Turbogenerator with a capacity of 1 kW

Test rig

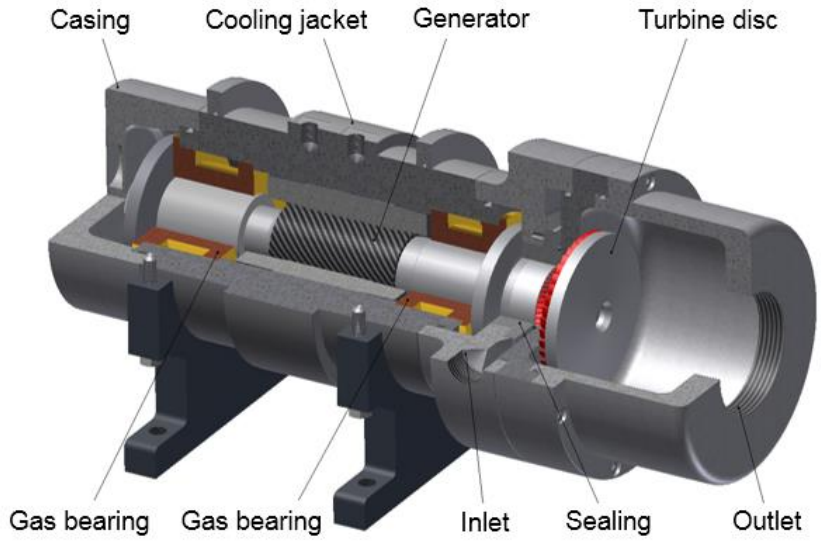


Results of experimental tests

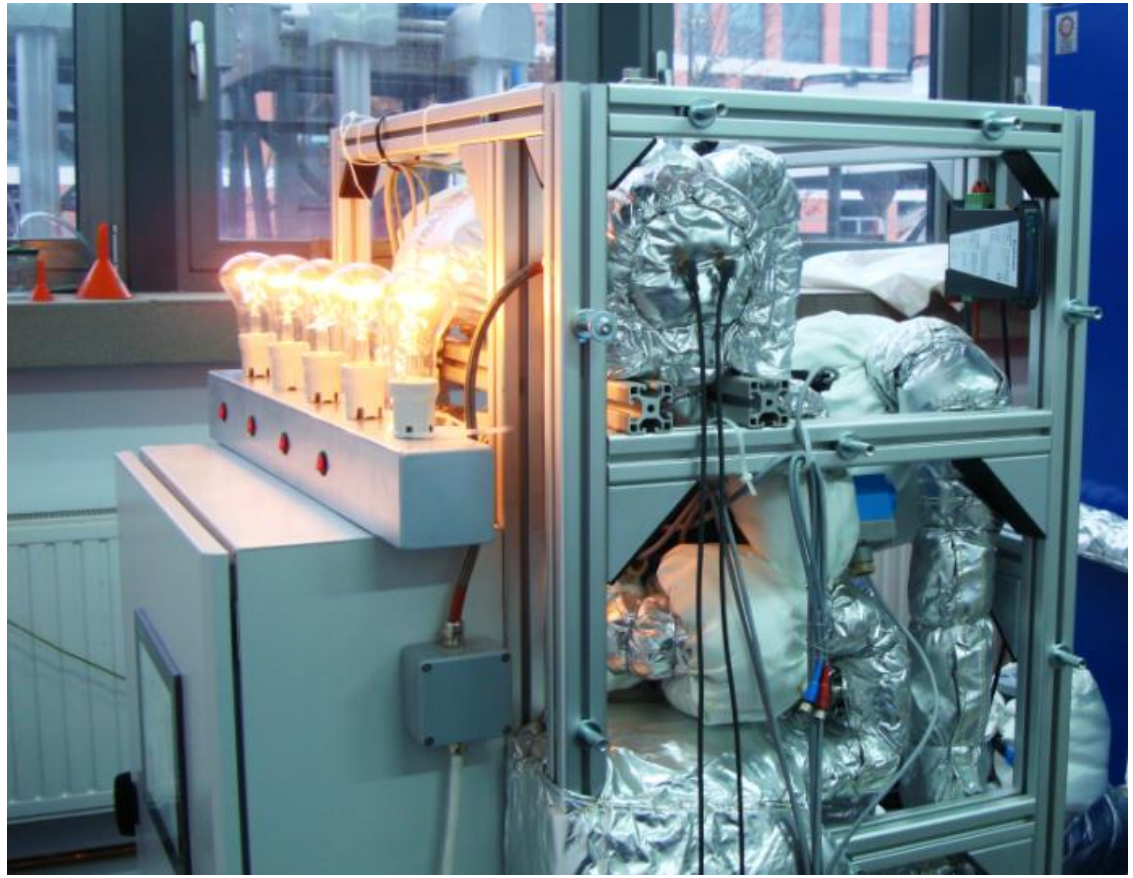


Turbogenerator with a capacity of 3 kW

CAD 3D model



Prototype



Technical parameters of the turbogenerator

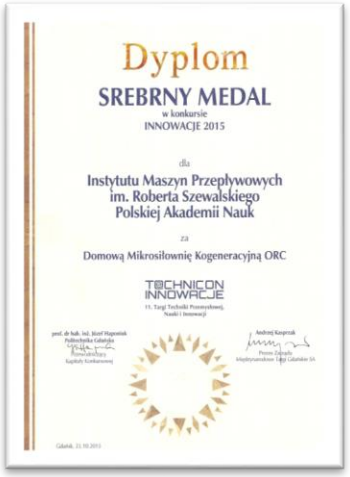
Parameter	Value	Unit
Rated rotational speed	24,000	rpm
Rated electrical power	2.5	kW
Net weight	22	kg
Maximum pressure	12	bar
Maximum temperature	180	°C

modelowe kompleksy agroenergetyczne

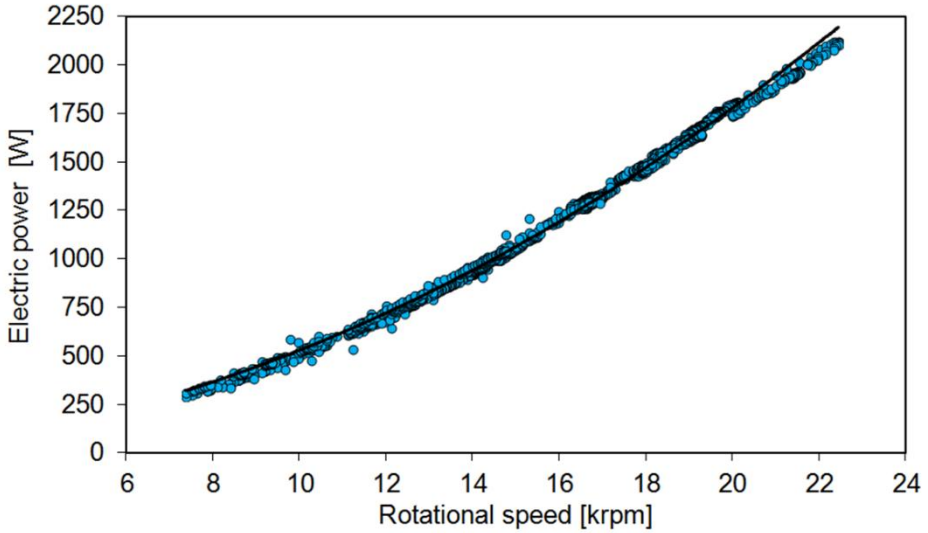
Turbogenerator with a capacity of 3 kW

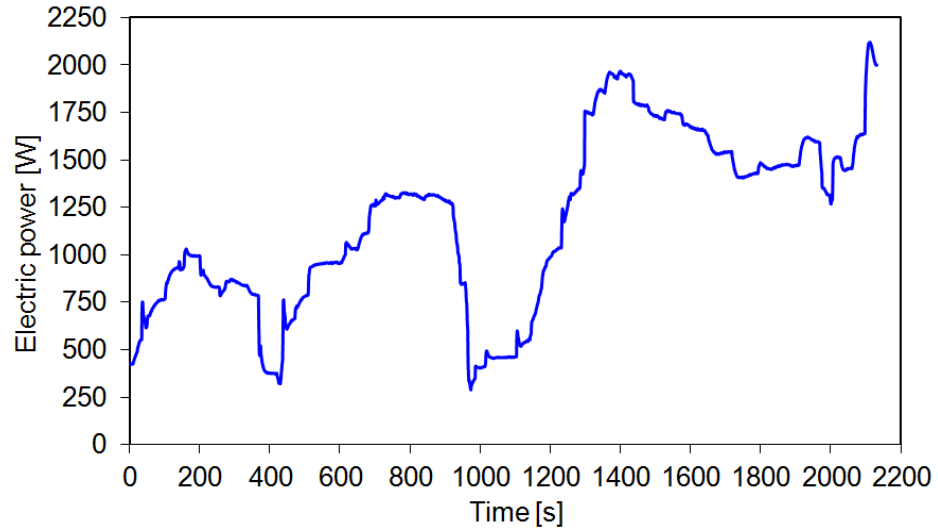
IMP PAN GDAŃSK

Domestic micro-power plant



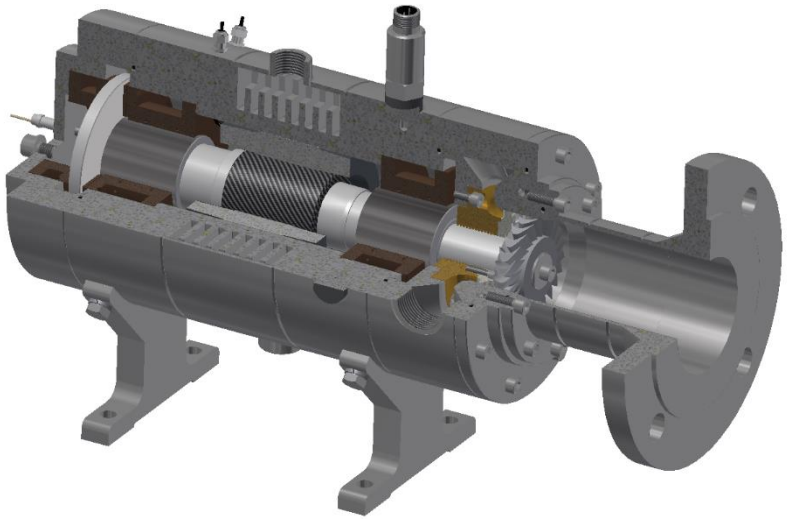
Results of experimental tests





Turbogenerator with a capacity of 10 kW

CAD 3D model



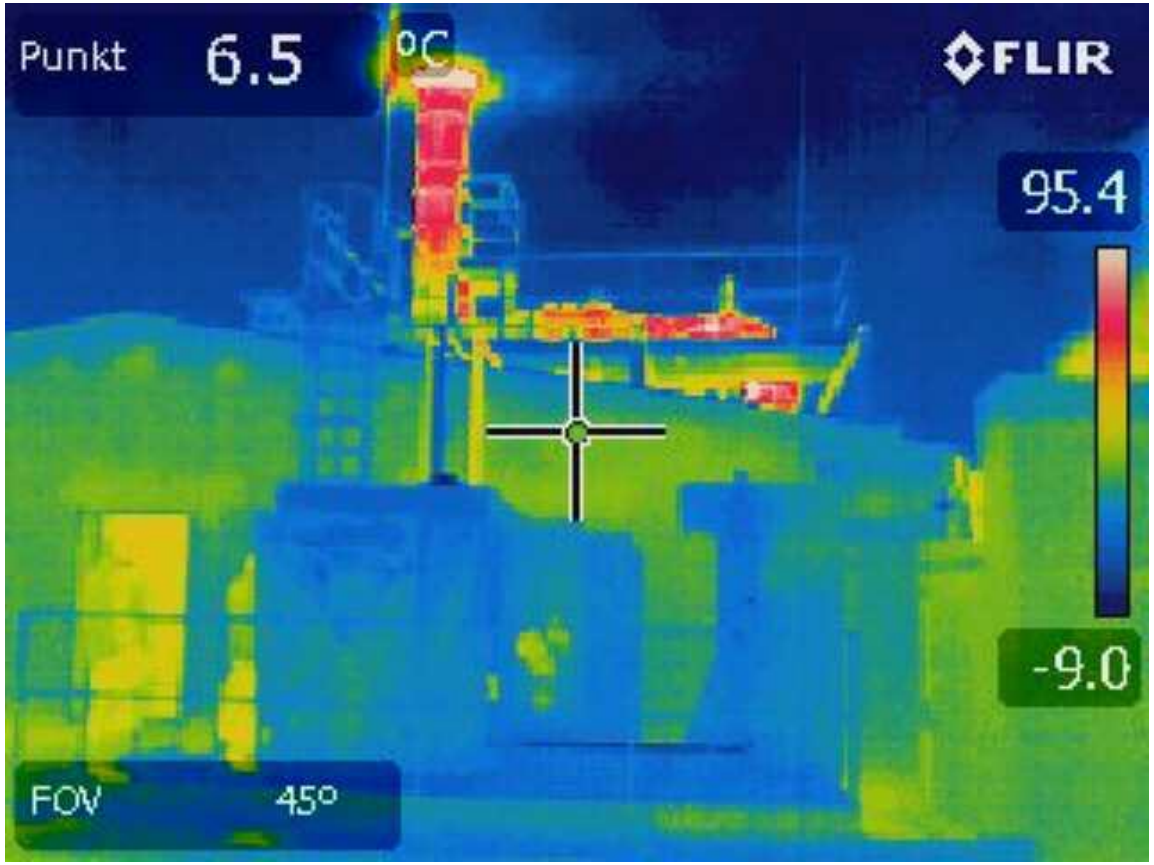
Prototype on the test stand at the IMP PAN

Technical parameters of the turbogenerator

Parameter	Value	Unit
Rated rotational speed	40,000	rpm
Rated electrical power	10	kW
Net weight	46	kg
Maximum pressure	12	bar
Maximum temperature	180	°C

Turbogenerator with a capacity of 10 kW

Experimental tests carried out under operating conditions



Conclusions

- ORC microturbines with a low capacity of up to 100 kW can achieve an efficiency of up to 80%.
- ORC systems can achieve electrical efficiencies of 5-20% (depending on the size of the system and temperature).
- Systems with a gas microturbine are more efficient than ORC systems, but they require the use of more advanced materials due to the higher temperature level.
- In order to develop commercial products, further development of mCHP systems is necessary. In particular, it is necessary to carry out experimental studies under operating conditions.

Contact

Institute of Fluid Flow Machinery, Polish Academy of Sciences
Department of Turbine Dynamics and Diagnostics
Fiszera 14 str., 80-231 Gdańsk (Poland)
www.imp.gda.pl, gzywica@imp.gda.pl