DEVELOPMENT OF A WASTE HEAT RECOVERY ORC PROTOTYPE USING AN OIL-FREE SCROLL EXPANDER

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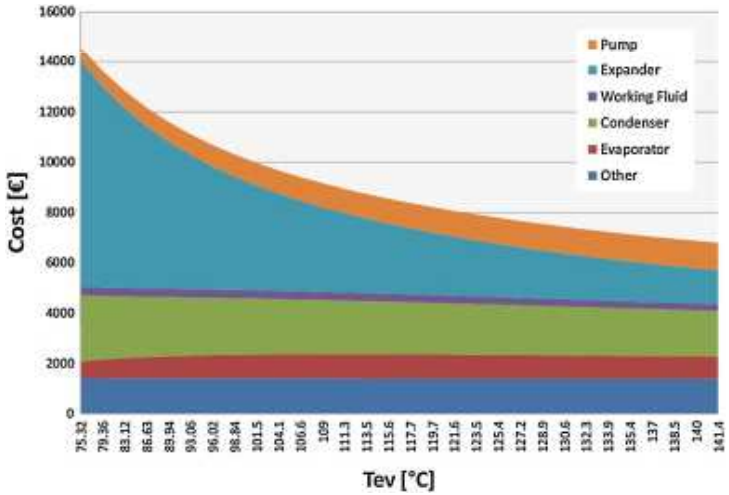
INTRODUCTION

- In small-scale (a few electric kW) ORC, a very important issue is the total installed **cost** of the system.
- S.Quoilin et al. * show that the cost of the system can be dramatically reduced by selecting both appropriate fluid and working conditions
- In the same work it was demonstrated that, depending of working conditions, expander cost can represent more than 50% of total component cost.



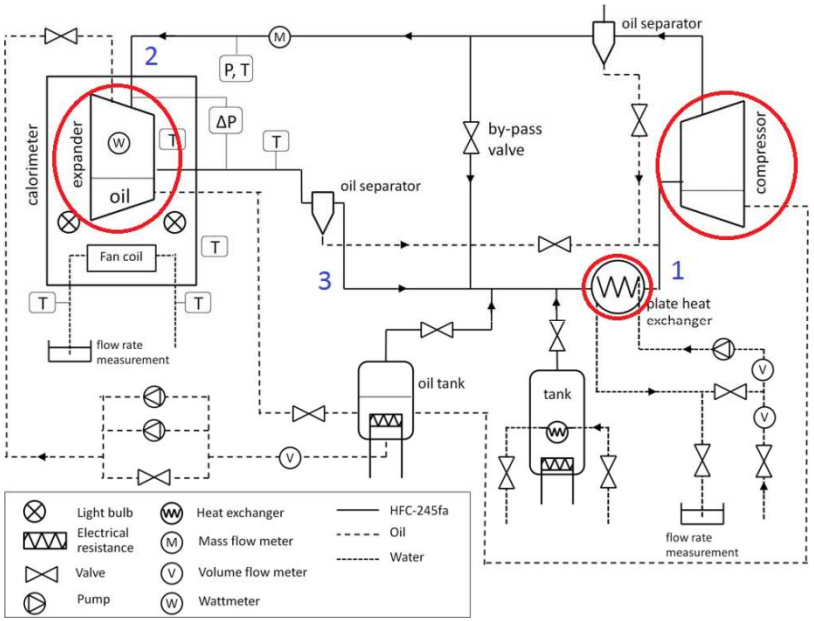
⇨ **Interest in developing low cost expander**

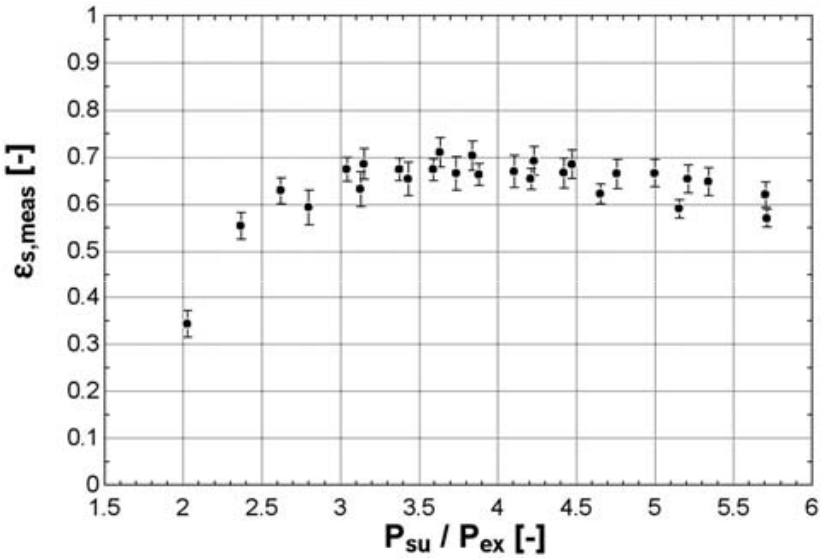
* Thermo-economic optimization of waste heat recovery Organic Rankine Cycles Applied Thermal Engineering, Volume 31, Issues 14-15, October 2011, Pages 2885-2893
Sylvain Quoilin, Sébastien Declaye, Bertrand F. Tchanche, Vincent Lemort

RETROFIT OF COMPRESSORS

- Low cost expander can be obtained by modifying existing compressor
- Scope of modifications required depends on both compressor type and original application.
- Due to high volume production of these machines, prices are competitive
- Both scroll air compressors and refrigeration scroll compressors can be converted to expander

PREVIOUS SCROLL EXPANDER TEST RESULT





- **Refrigeration scroll** compressor tested in expander mode in a gas cycle with **R245fa**
- Several pressure ratio and oil fraction investigated
- Maximum isentropic efficiency : **71%**

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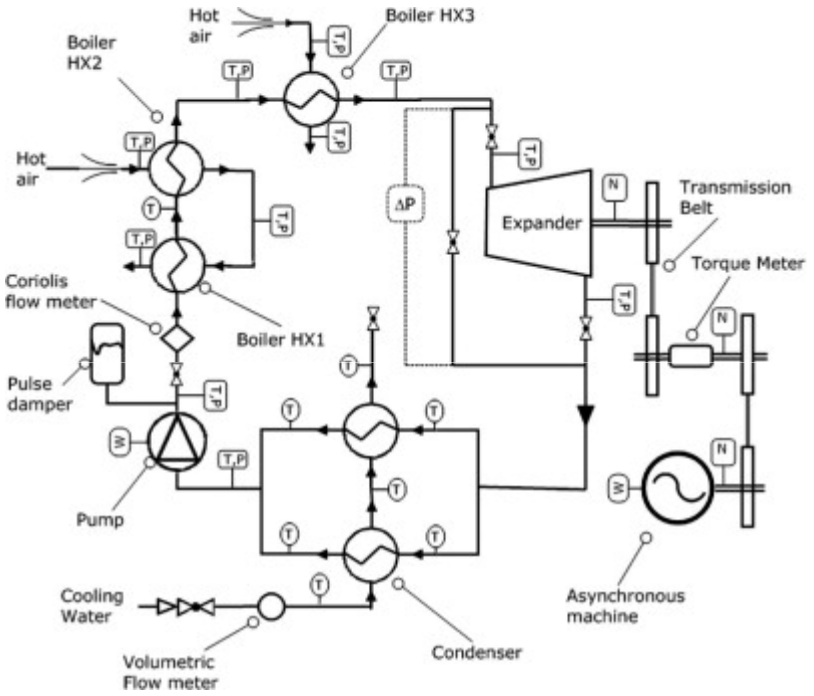
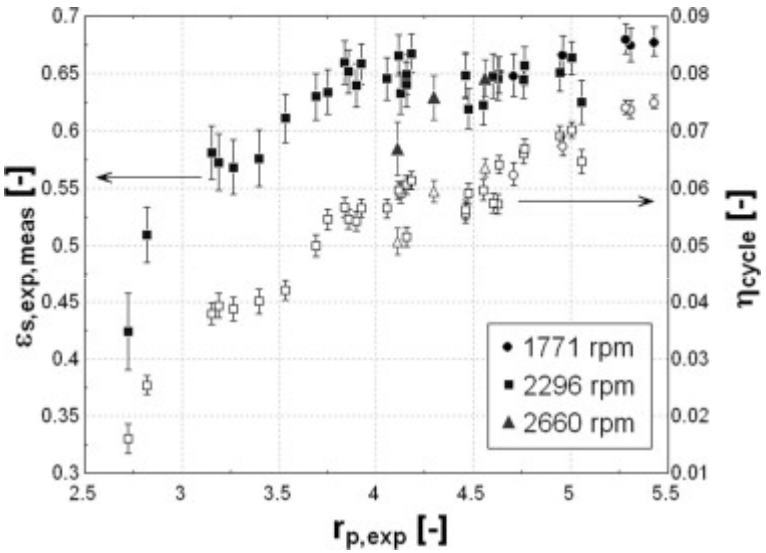
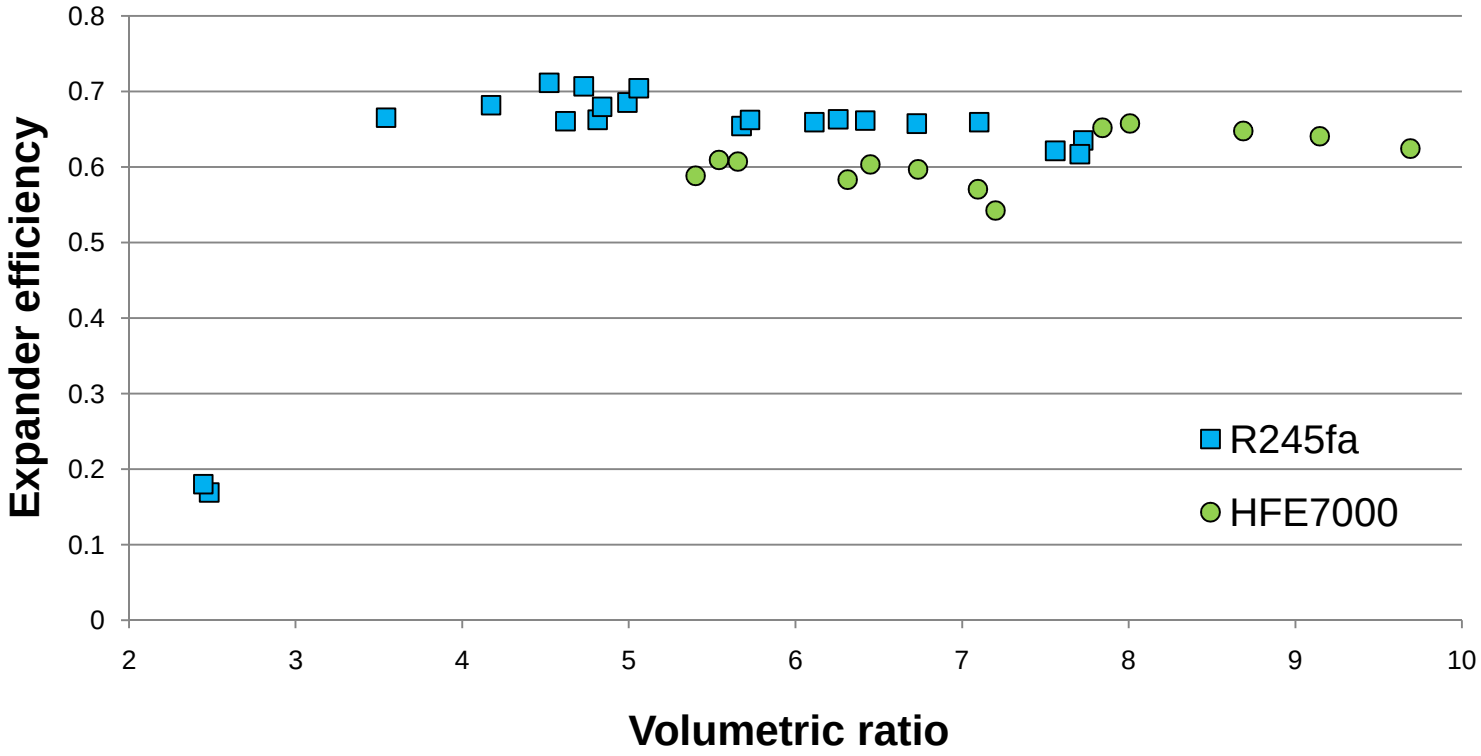




- **Air scroll** compressor tested in expander mode in an ORC loop with **R123**
- Several speed and pressure ratio investigated
- Maximum isentropic efficiency : **68%**

PREVIOUS SCROLL EXPANDER TEST RESULT



- **Air scroll** compressor tested in expander mode in an ORC loop with **R245fa** and **HFE7000**
- Several speed and pressure ratio investigated
- Maximum isentropic efficiency : **71%**

SCROLL EXPANDER COMPARISON

	Refrigeration Scroll	Air Scroll
Lubrication	Yes	No
Hermetic	Yes, both compressor elements and electrical motor are enclosed in a tight container	No, the machine is open drive
Built-in volumetric ratio	Around 3	Around 4
Maximum pressure	Up to 30 bars	Up to 10 bars
Maximum temperature	Up to 150 °C	Up to 200 °C
Conversion to expander	Some key internal elements of the compressor such as valves or springs has to be removed or modified	The only required modification is the removing of the external cooling fan
Generator	Included	Freely sized
Isentropic efficiency	Around 70%	Around 70%

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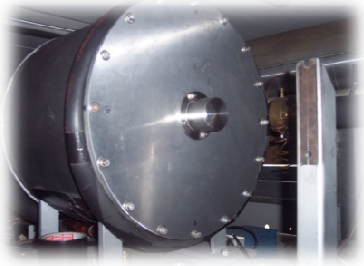
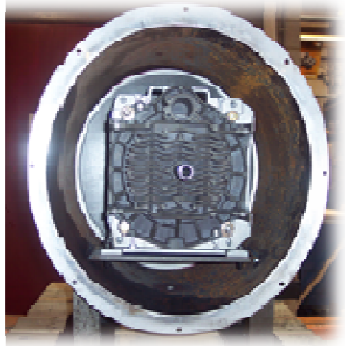
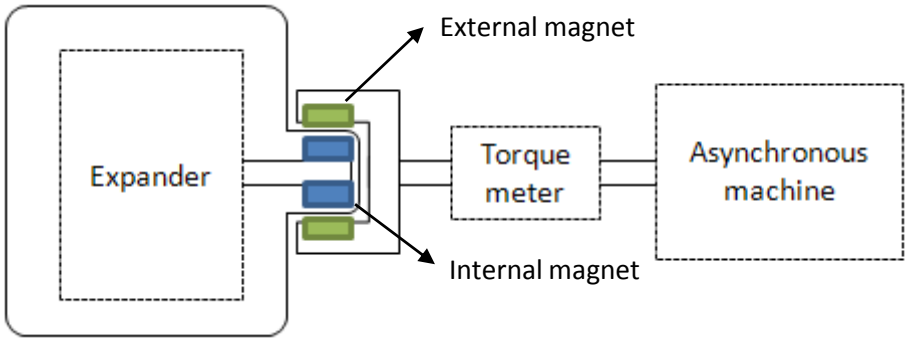
ZERO LEAKAGE OIL FREE SCROLL EXPANDER





- Expander enclosed in a steel container.
- No moving part through the container
- Power transmitted through the wall by means of a magnetic coupling

⇨ No external leakages
⇨ No friction



OTHER COMPONENTS OF THE CYCLE

Fluids

- Working fluid : R245fa
- Heat source : hot gas ranging from 150 and 200 °C
- Cooling medium : water ranging form 10 to 17°C

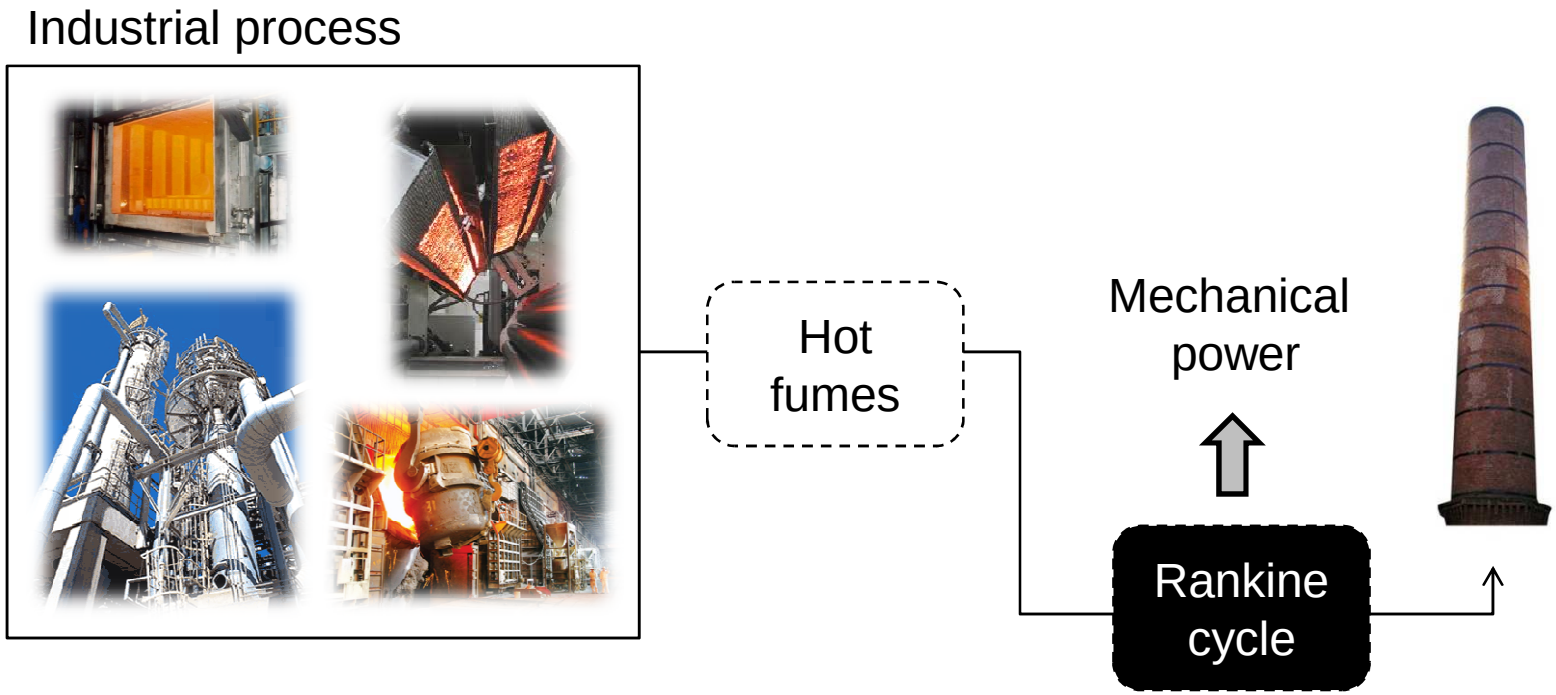
Components

- Condenser : brazed plate heat exchanger
- Evaporator : brazed plate heat exchanger
- Pump : diaphragm pump

Main measurement devices

- Type T thermocouples
- Torque meter on expander shaft
- Coriolis effect flow meter for R245fa flow measurement
- …

OPEN LOOP WASTE HEAT RECOVERY CYCLE



The heat that is not transferred to the ORC is released to the atmosphere.

In this case, the parameter to maximize during cycle design is **not** the cycle efficiency. Maximizing the cycle efficiency can lead to waste a large fraction of the available heat

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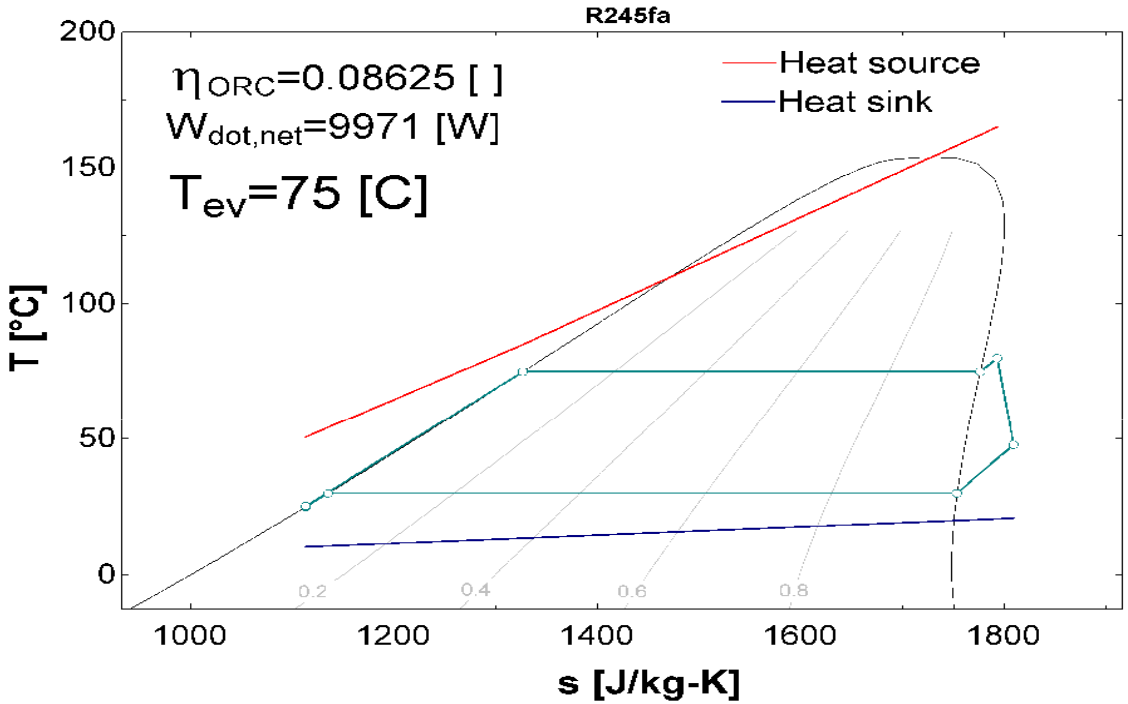
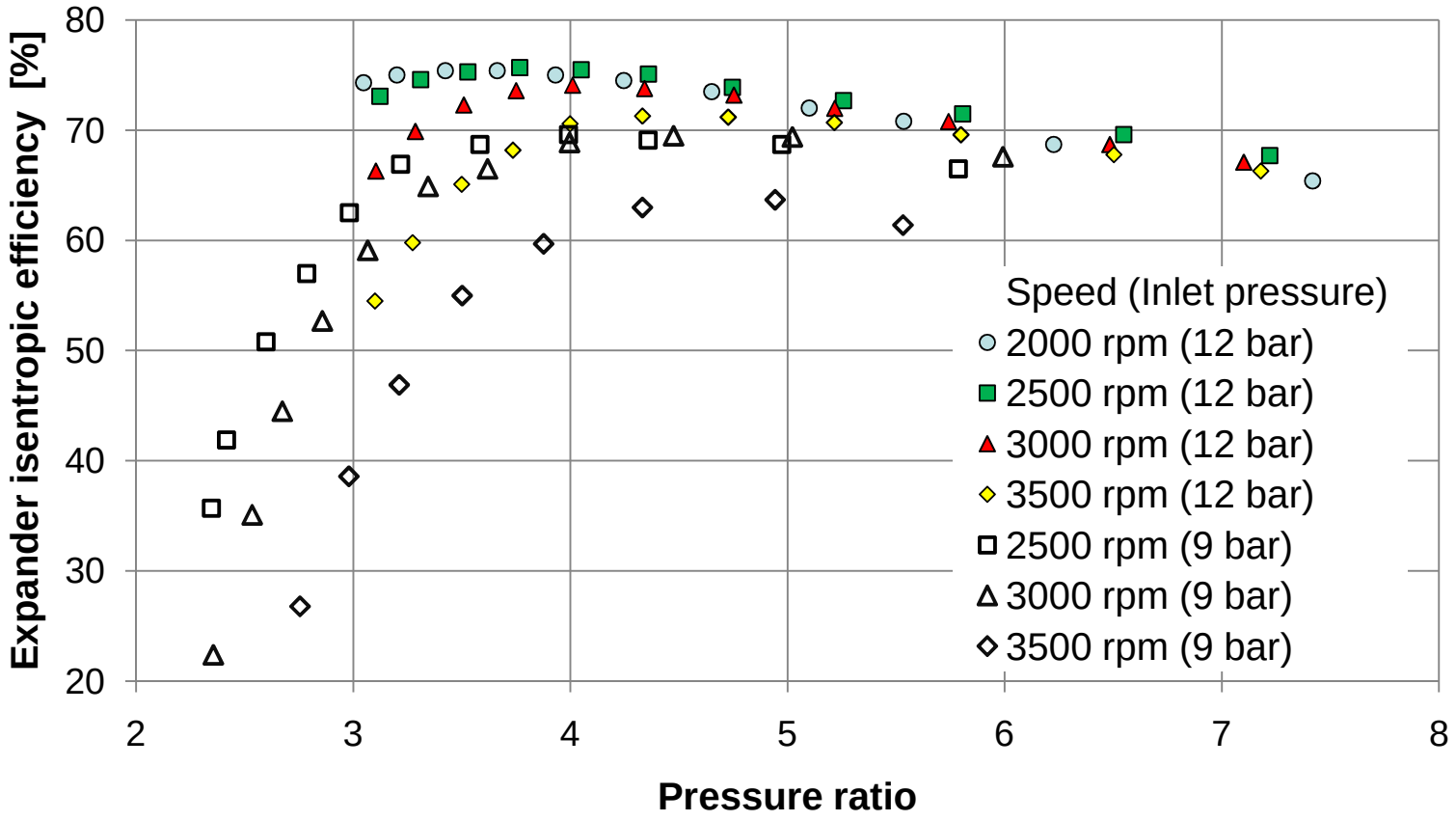


- Low evaporating temperature : large fraction of available heat recovered but poor conversion efficiency.
- High evaporation temperature : low fraction of available heat recovered but high conversion efficiency.

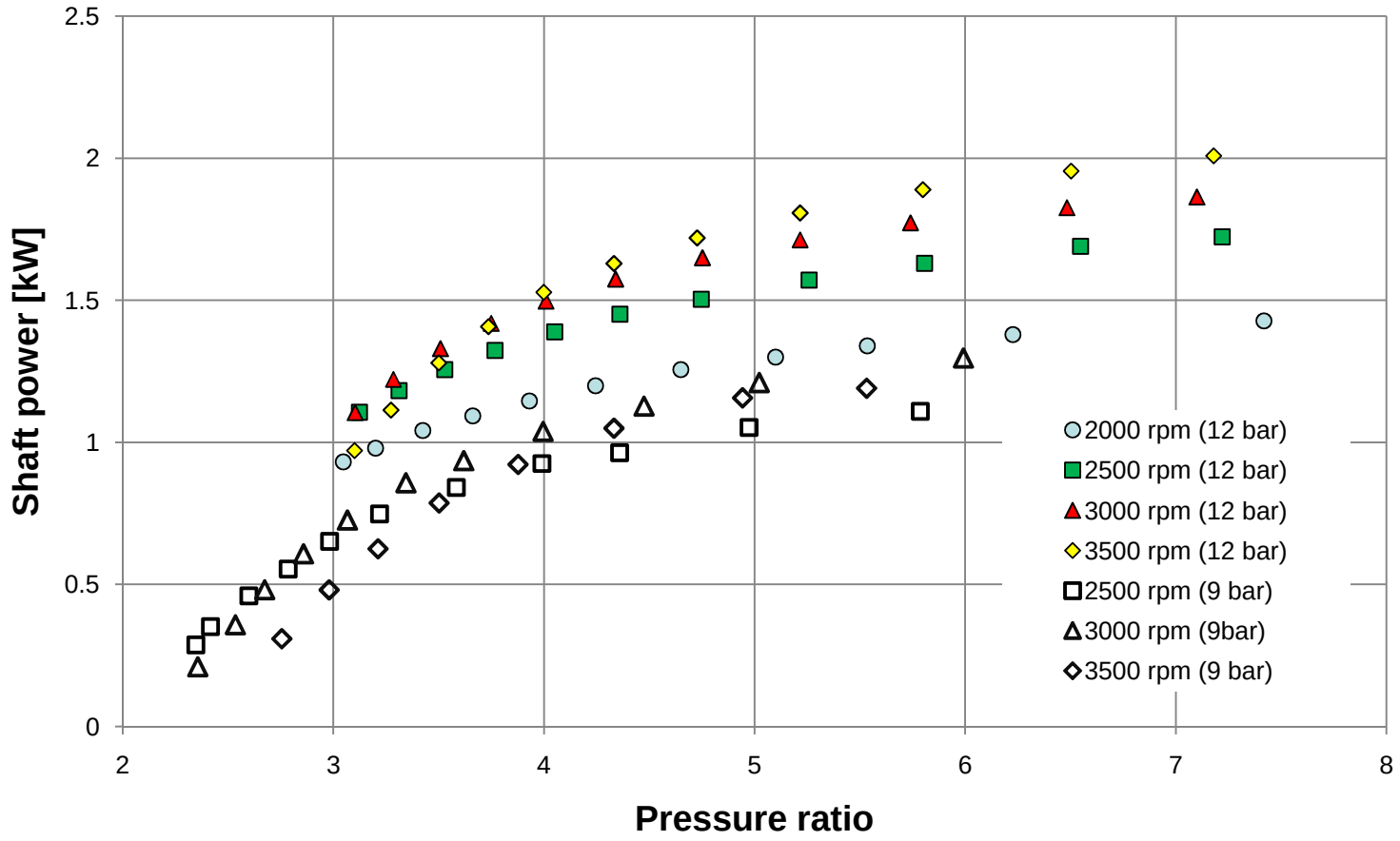
⇨ Trade-off that also depend of economic concern

EXPANDER ISENTROPIC EFFICIENCY

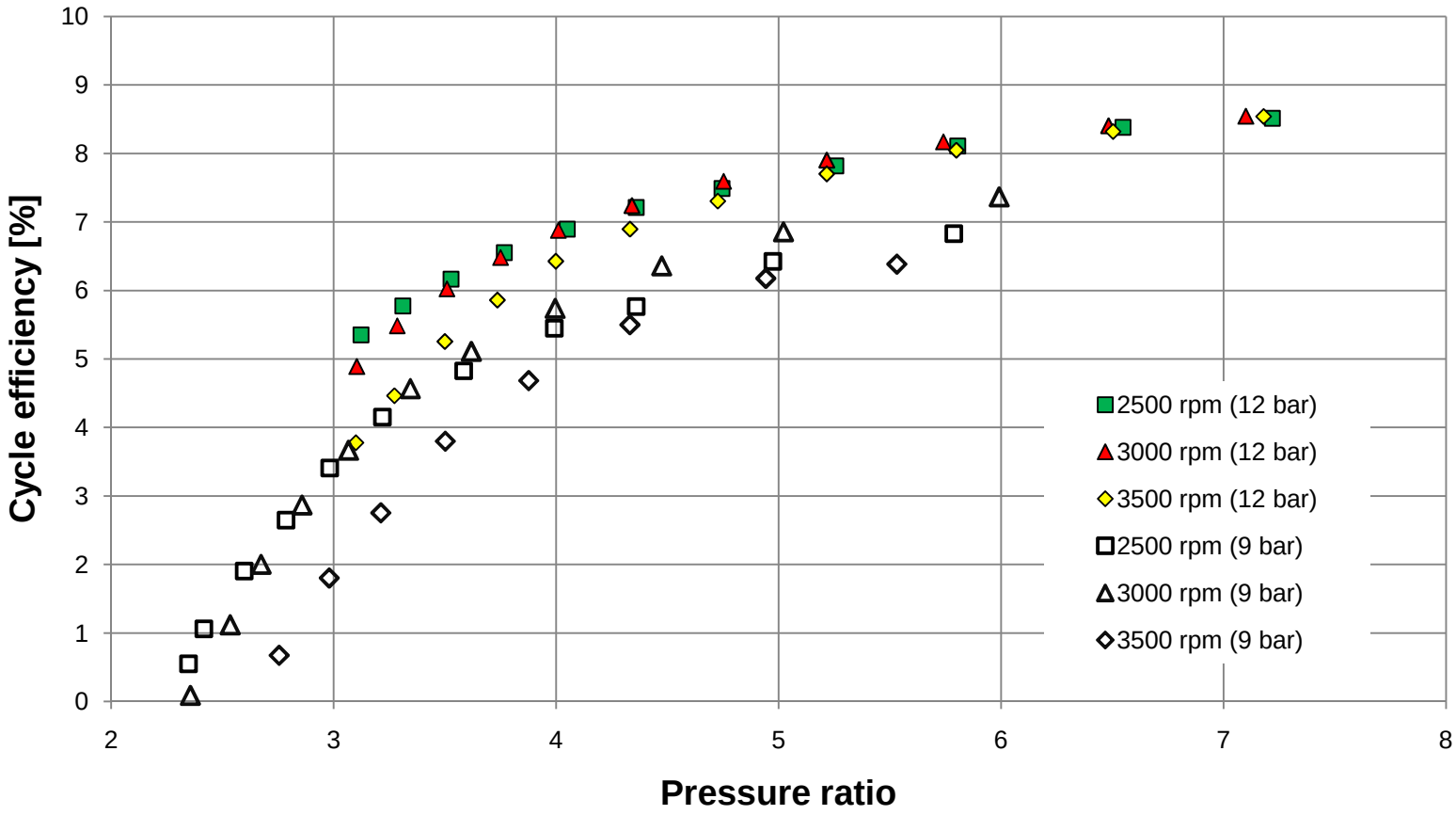


- 76% maximum isentropic efficiency at 2500 RPM
- Flat curve at high pressure ratio
- Sharp decrease for low pressure ratio

EXPANDER SHAFT POWER



CYCLE EFFICIENCY



CONCLUSION

Successful test of an oil-free scroll expander

- External leakages eliminated by magnetic power transmission
- 76% maximum isentropic efficiency
- No oil required
- No modification on the machine it-self
- Generator can be chosen separately

THANK YOU FOR YOUR ATTENTION