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The impact of changes in the geometry of a radial microturbine stage on the efficiency of the micro CHP plant based on ORC

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Presentation outline

1. Introduction
2. Research object
3. Modernization of the microturbine flow system
4. Measurement results
5. Summary and conclusions

1. Introduction

Why build a micro-cogeneration plant? (plant using combined heat and power (CHP) system for energy production on a small-scale, which can satisfy both individual and industrial needs).

- implementation of energy related EU Directives,
- reducing the consumption of fossil fuels and CO_2 emissions into the atmosphere,
- increasing efficiency in electricity generation,
- local production of electric power and heat/cold,
- increasing energy security,
- increasing the share of RES in total energy production.

2. Research object

(ORC system equipped with a radial microturbine)

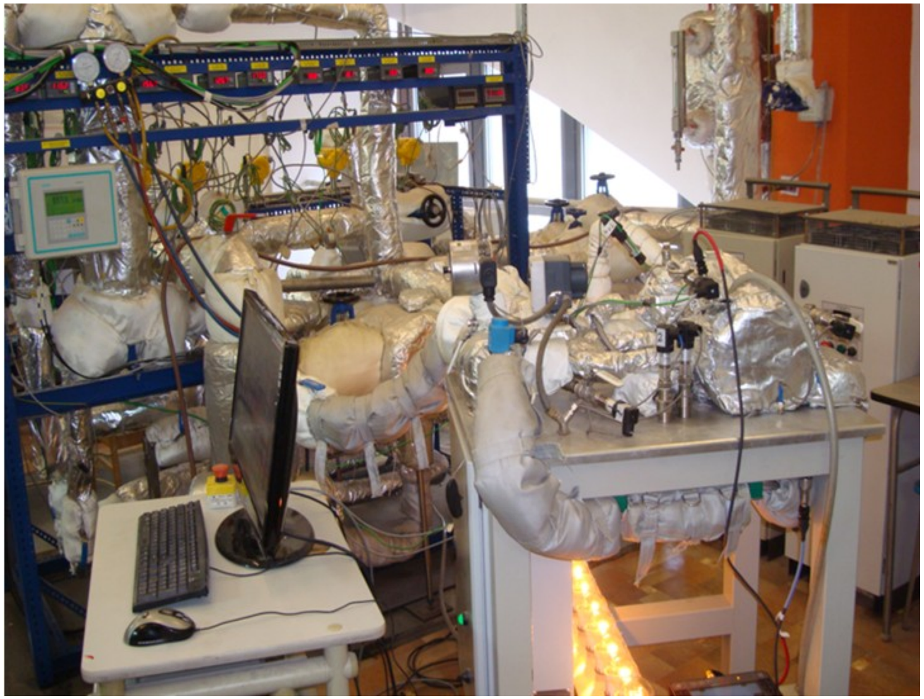


Fig. 1. Photo of the ORC installation operating with a radial microturbine [1]

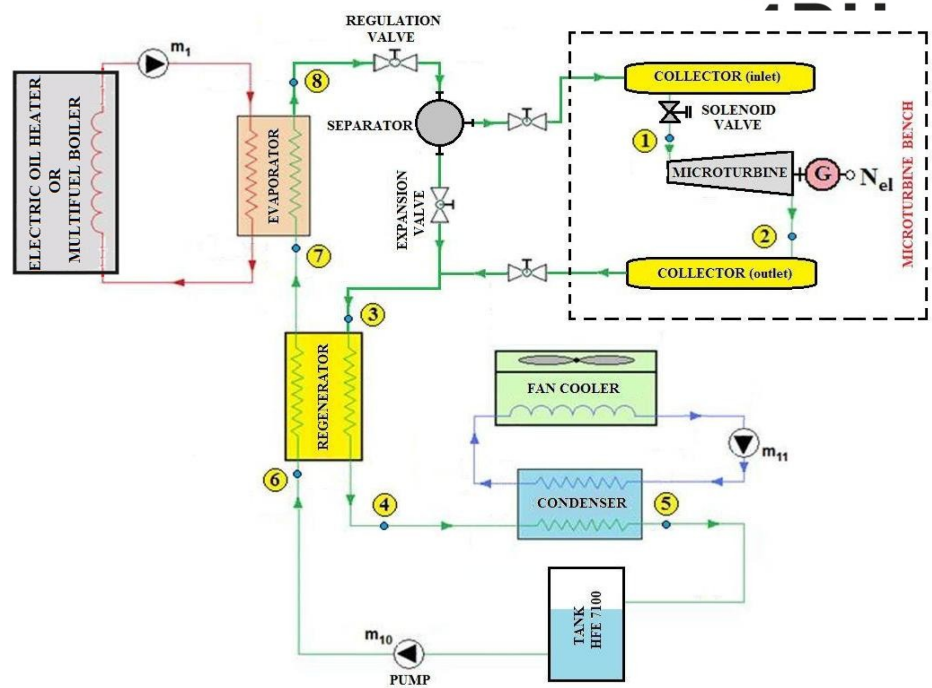
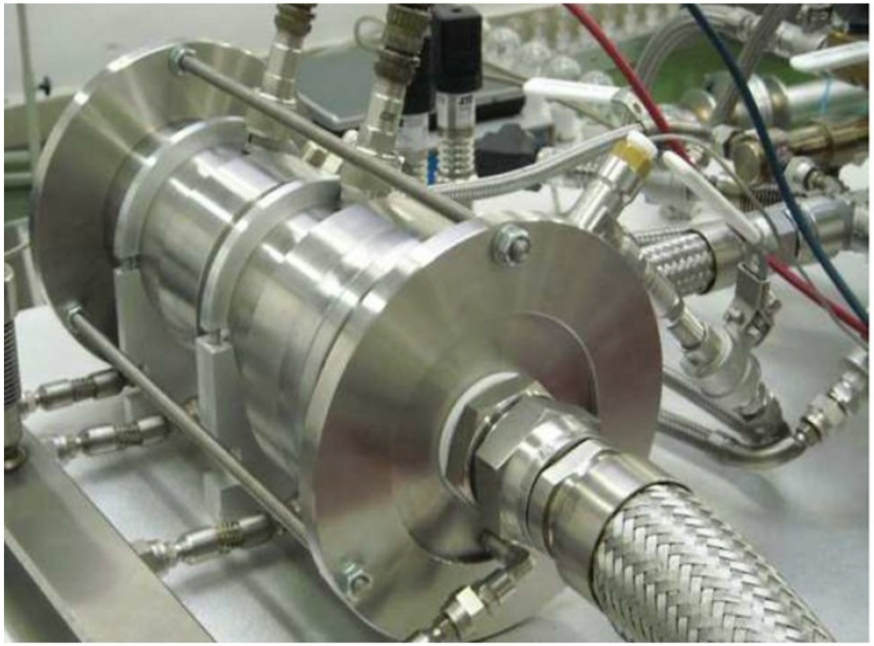


Fig. 2. Diagram of the ORC installation equipped with a radial microturbine [1]

[1] Tomasz Z. Kaczmarczyk, Grzegorz Żywica, Eugeniusz Ihnatowicz.: The experimental investigation of the biomass-fired ORC system with a radial microturbine, *Applied Mechanics and Materials, Advances in Mechanical and Energy Engineering*, Vol. 831, pp. 235-244, 2016

2. Research object

(operating parameters of the radial microturbine)



Microturbine type	radial
Number of stages	4
Nominal power	2 - 3 kW_e
Maximum pressure	14 bar
Maximum rotational speed	25000 rpm
Maximum operating temperature	180 °C
Maximum flow rate	0.17 kg/s
Working fluid	HFE7100
Noise level	43 dB(A)
Weight	10 kg

Fig. 3. Basic technical parameters of the radial microturbine [2]

[2] Tomasz Z. Kaczmarczyk, Grzegorz Żywica, Eugeniusz Ihnatowicz.: Experimental investigation of a radial microturbine in Organic Rankine Cycle system with HFE7100 as working fluid, Paper ID: 13, 3rd International Seminar on ORC Power Systems, October 12-14, 2015, Brussels, Belgium

3. Modernization of the microturbine

(radial microturbine wheels)

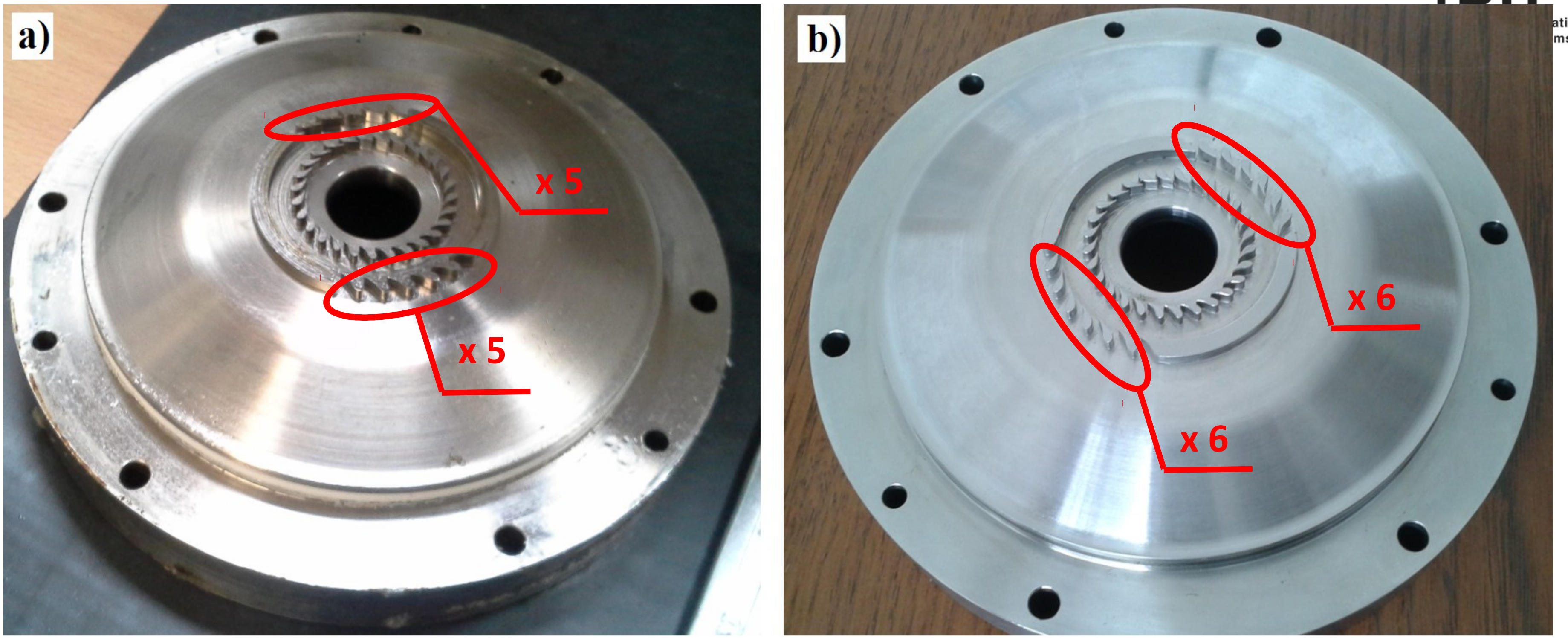


Fig. 4. Photo of the microturbine wheel: a) before and b) after the modernization

3. Modernization of the microturbine

(geometry of the radial microturbine wheel)

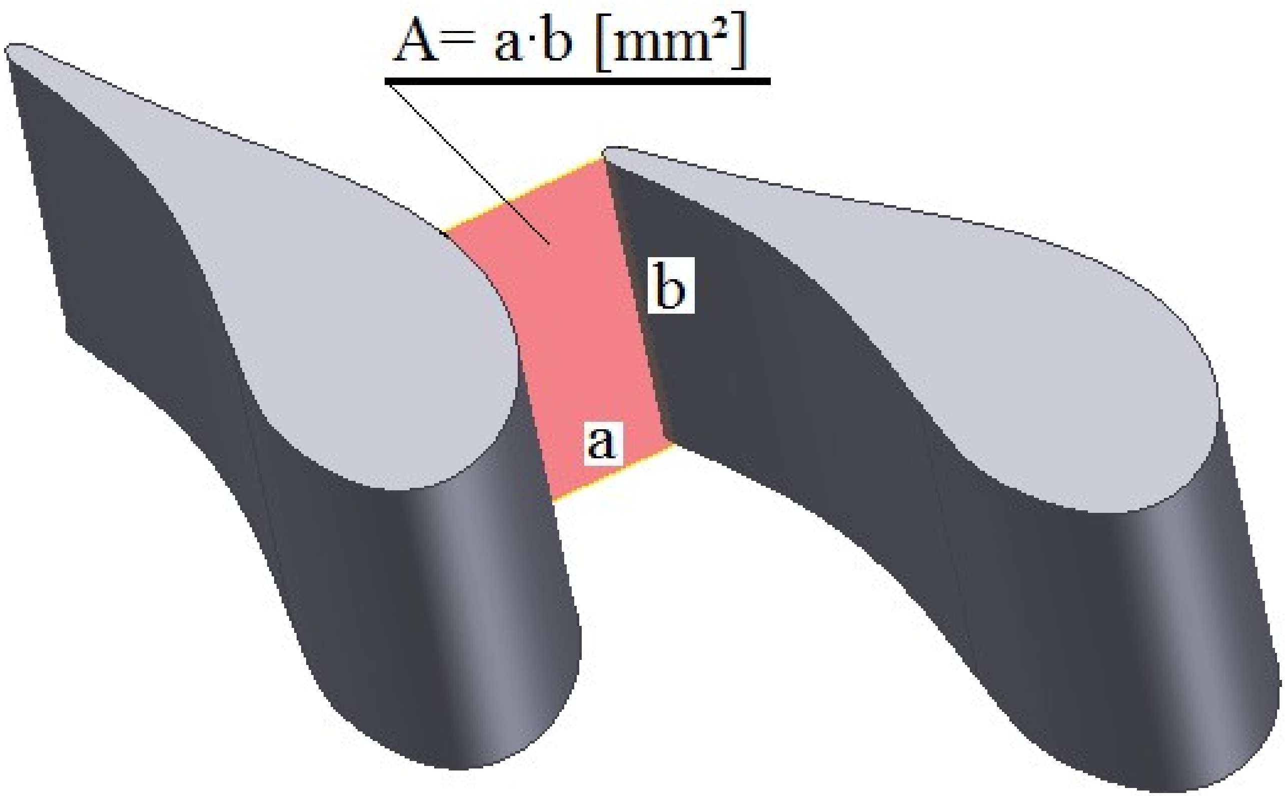


Fig. 5. Geometry of the microturbine wheel vanes and the cross sectional area of the delivery channel

4. Measurement results

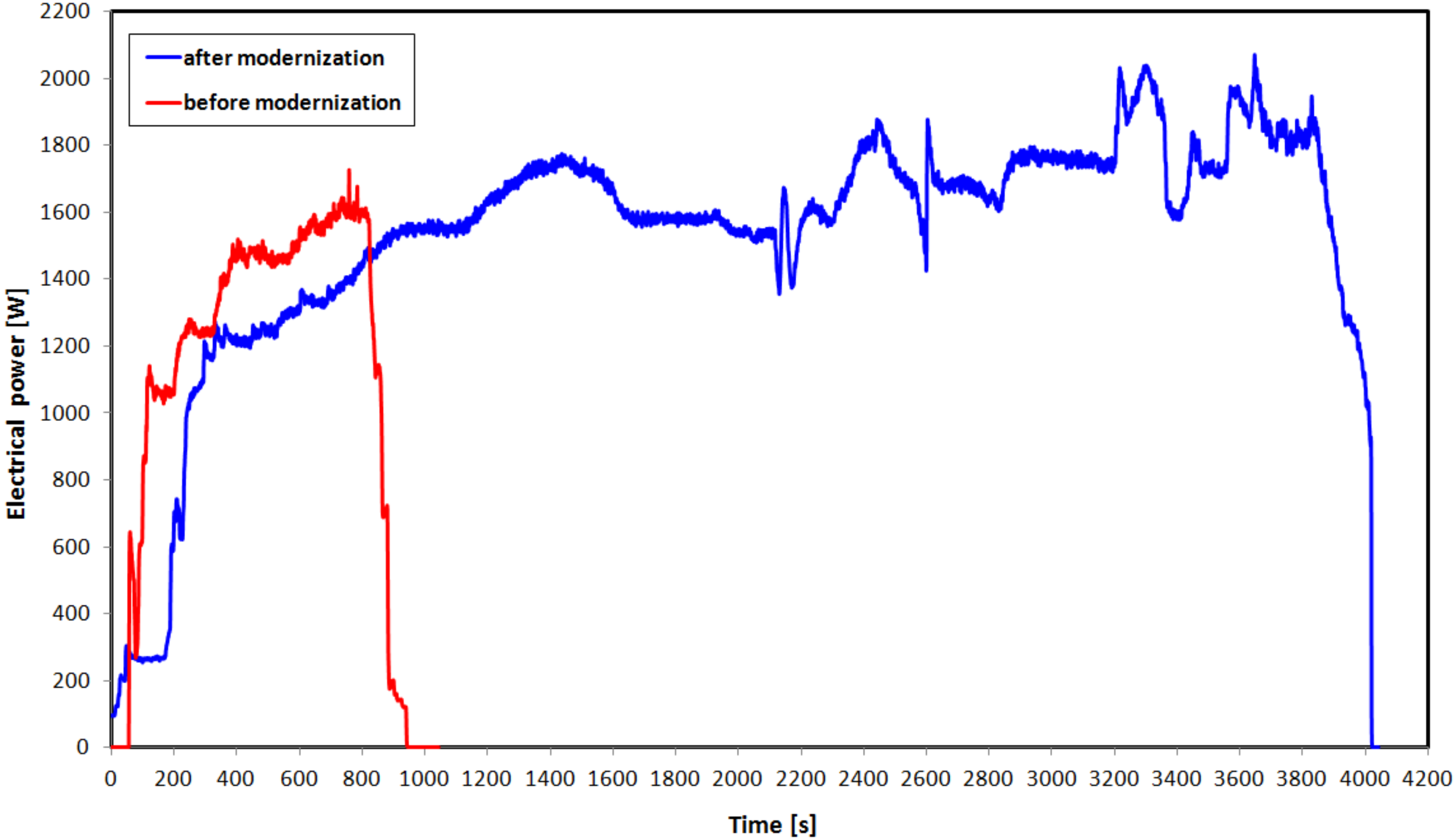


Fig. 6. Electrical power generated by the microturbine (before and after its modernization) vs. time

4. Measurement results

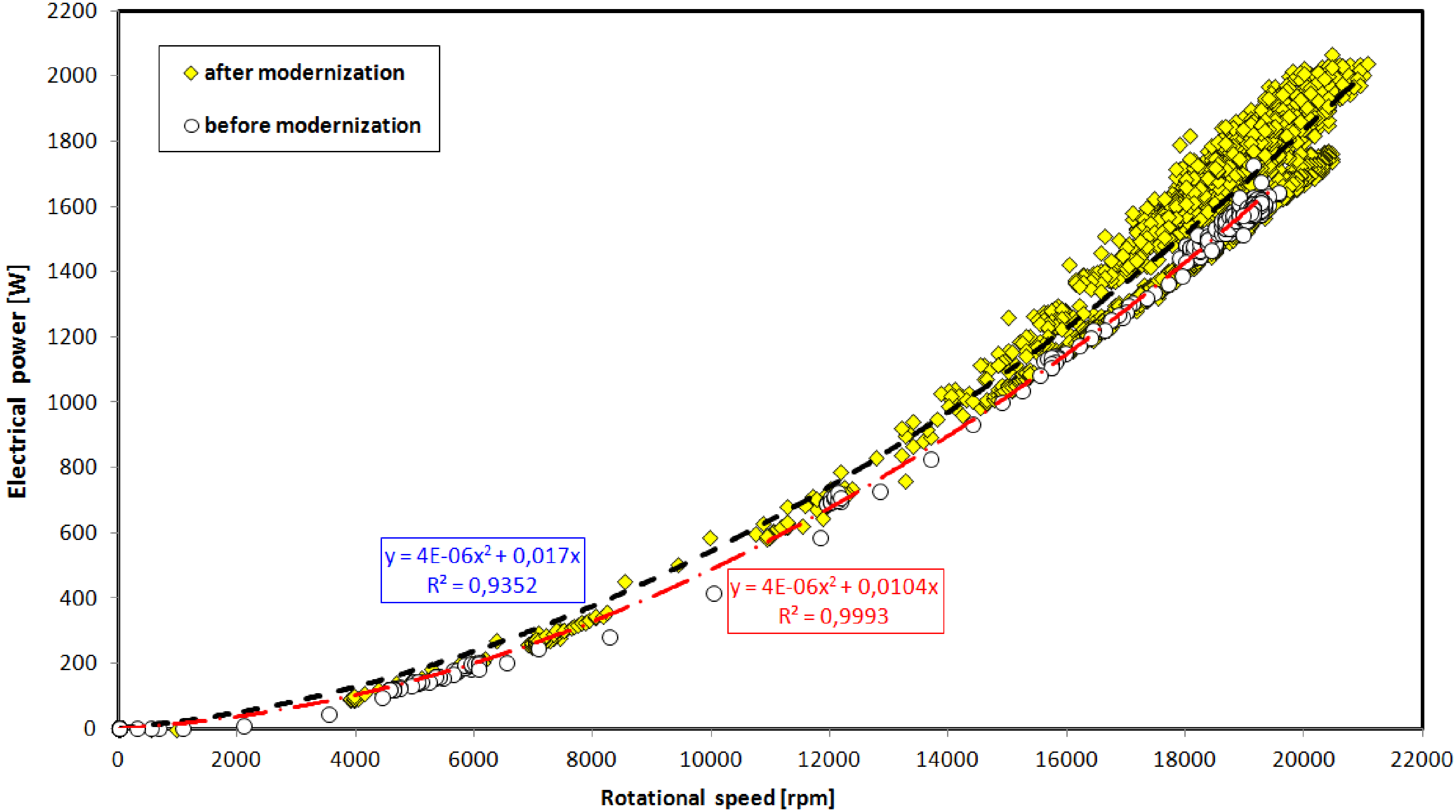


Fig. 7. Electrical power generated by the microturbine (before and after its modernization) vs. rotational speed

4. Measurement results

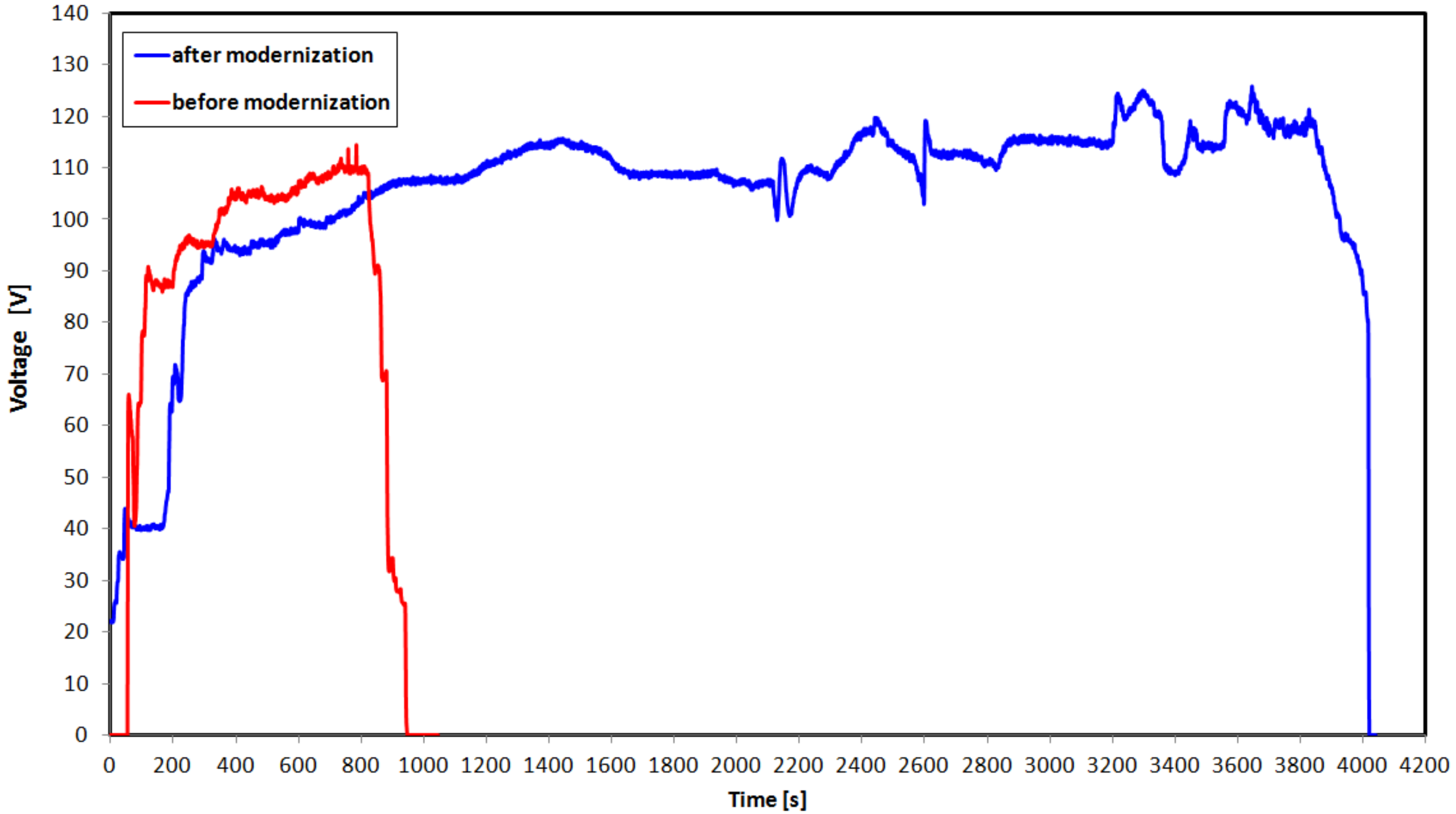


Fig. 8. Voltage generated by the microturbine (before and after its modernization) vs. time

4. Measurement results

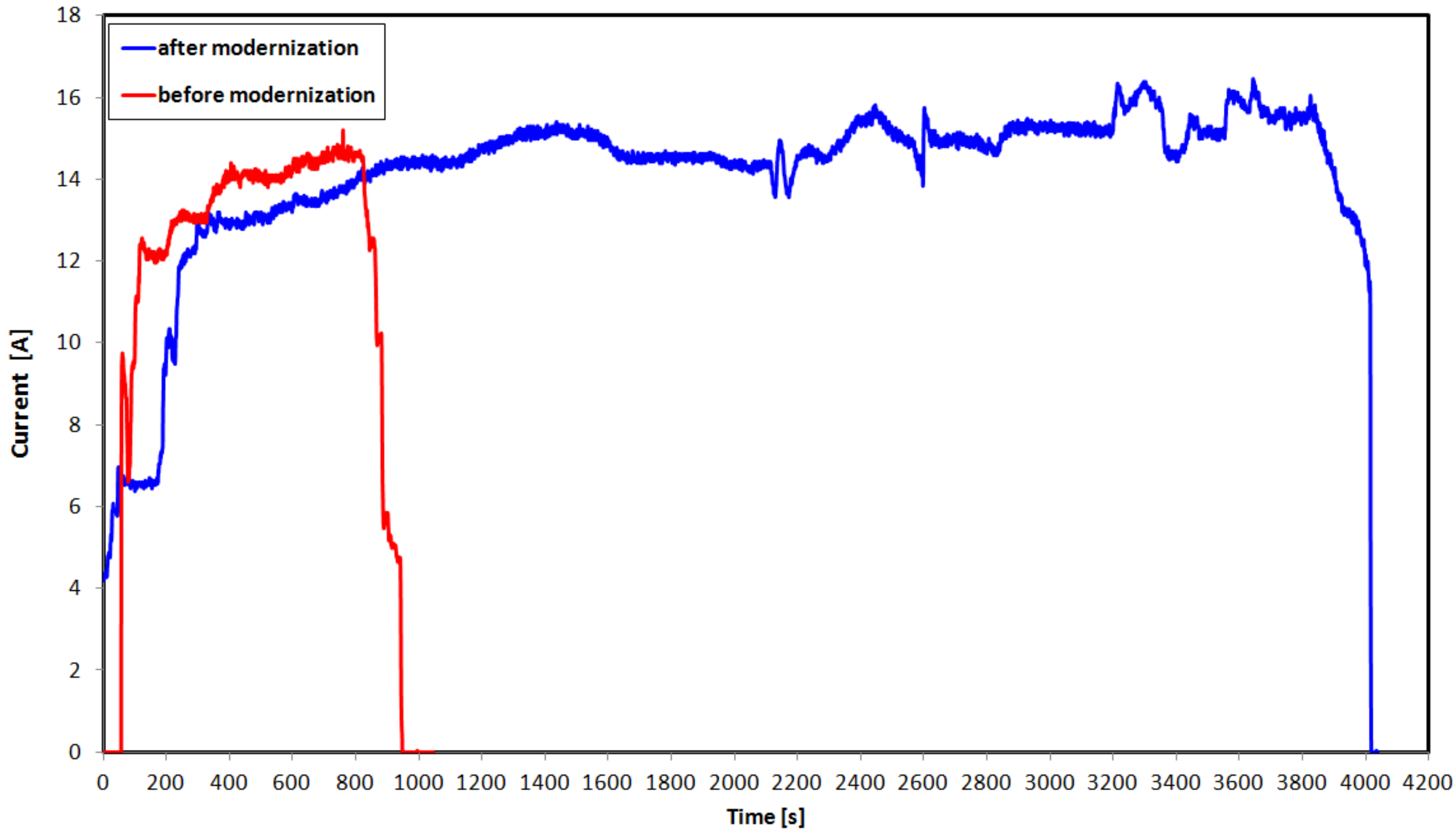


Fig. 9. Load current of the microturbine (before and after its modernization) vs. time

4. Measurement results

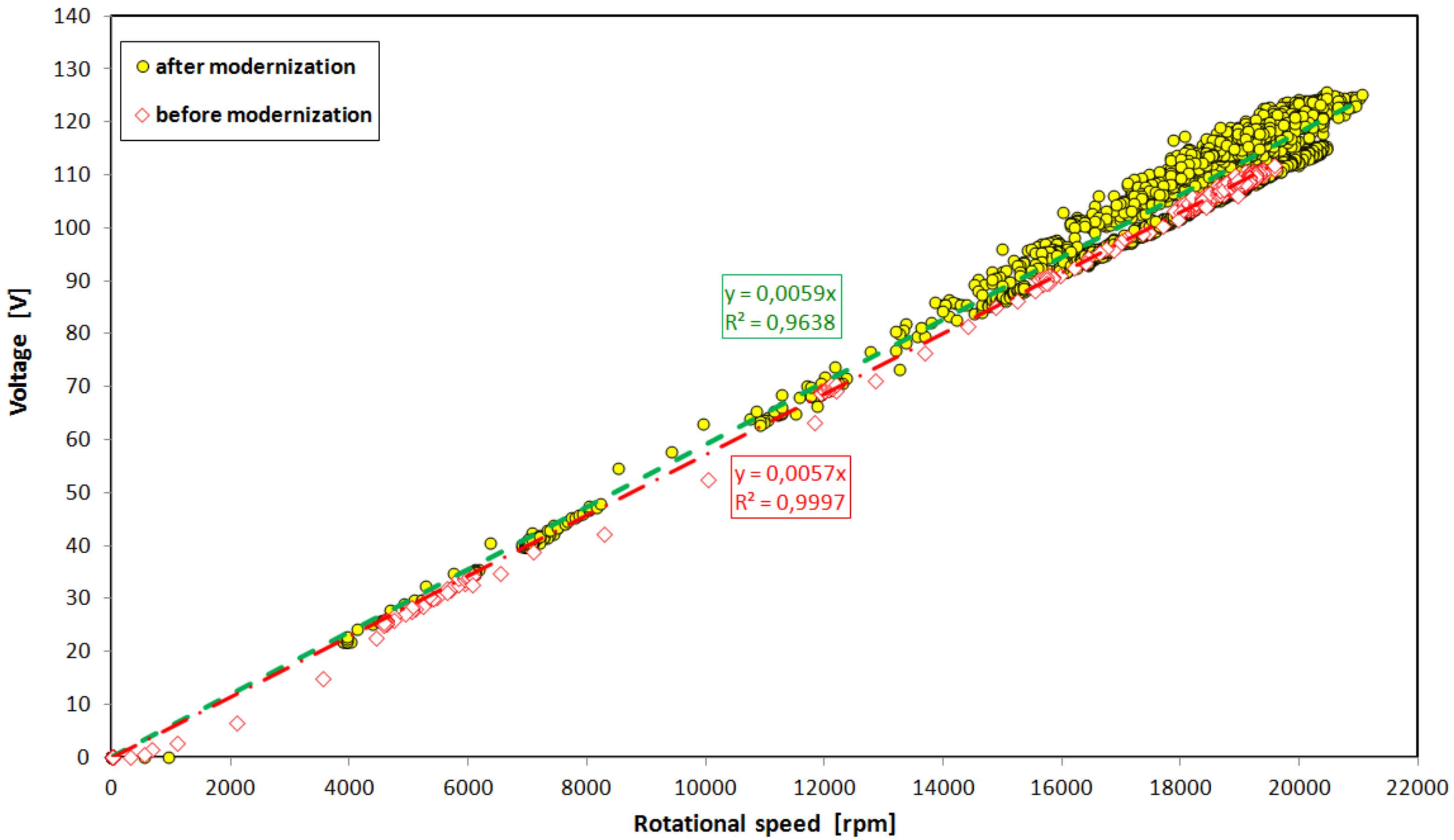


Fig. 10. Voltage generated by the microturbine (before and after its modernization) vs. rotational speed

4. Measurement results

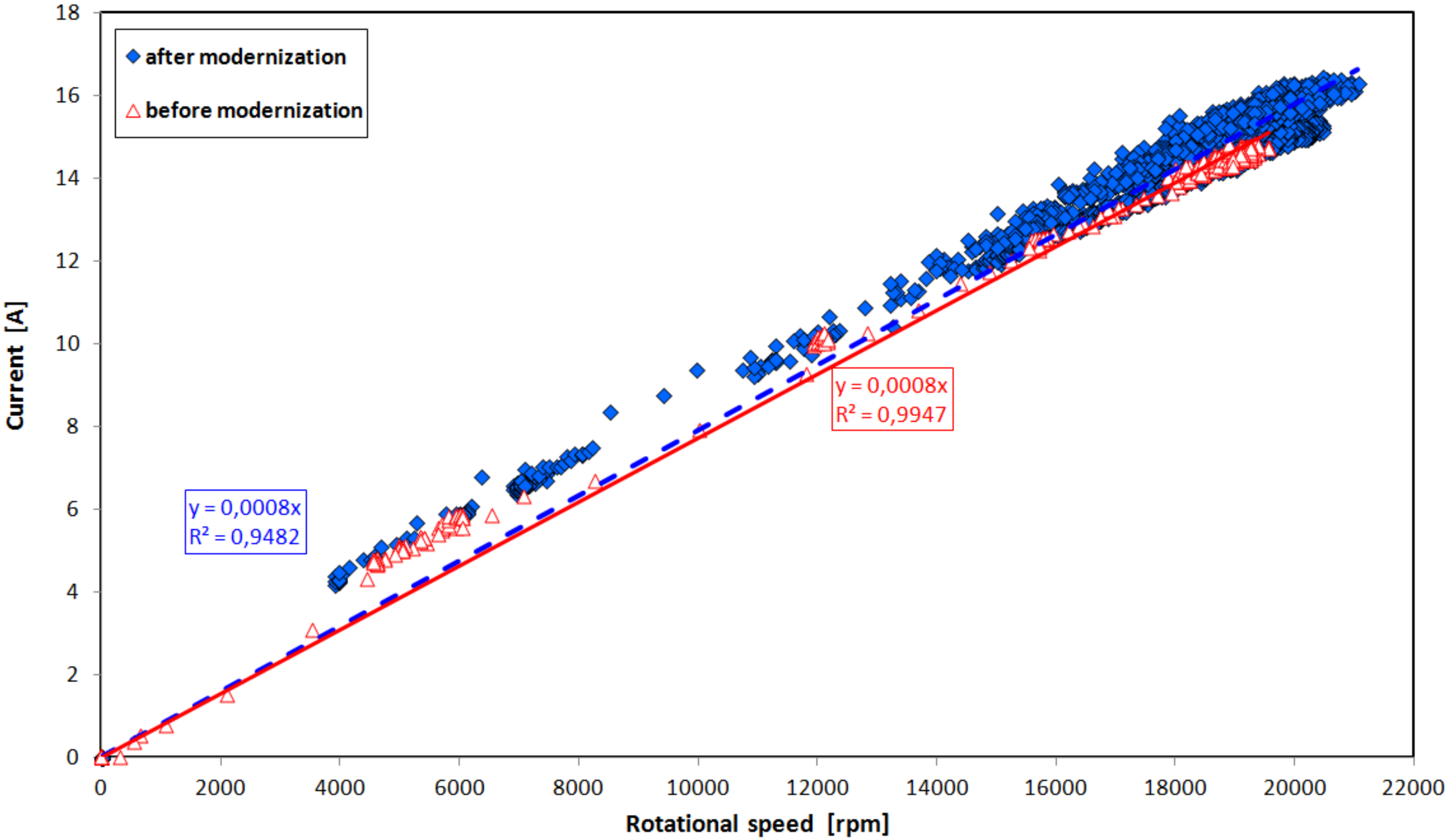
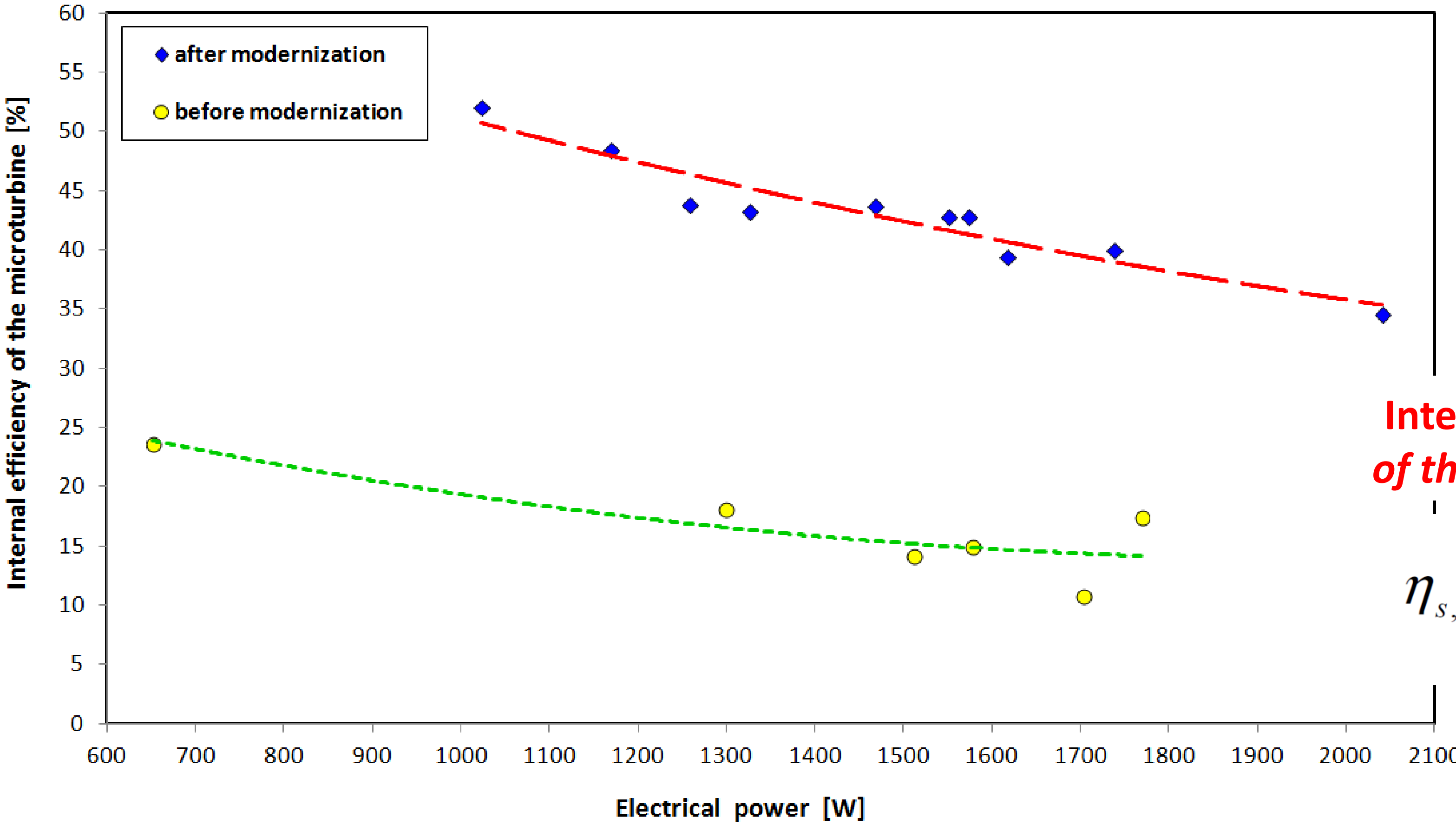


Fig. 11. Load current of the microturbine (before and after its modernization) vs. rotational speed

4. Measurement results

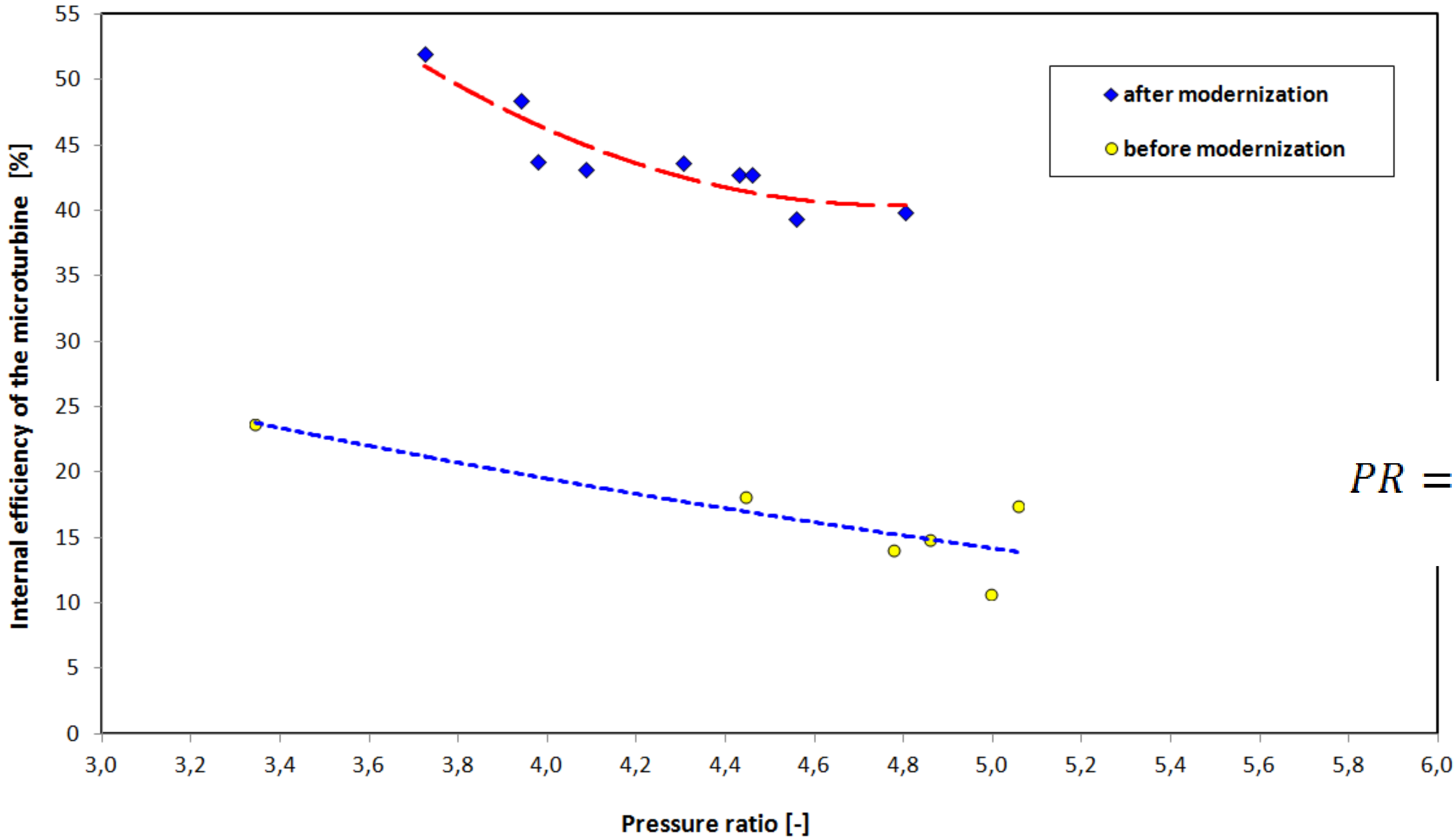


Internal efficiency
of the microturbine

$$\eta_{s,turb} = \frac{h_1 - h_2}{h_1 - h_{2s}}$$

Fig. 12. Internal efficiency of the microturbine (before and after its modernization) vs. electrical power

4. Measurement results

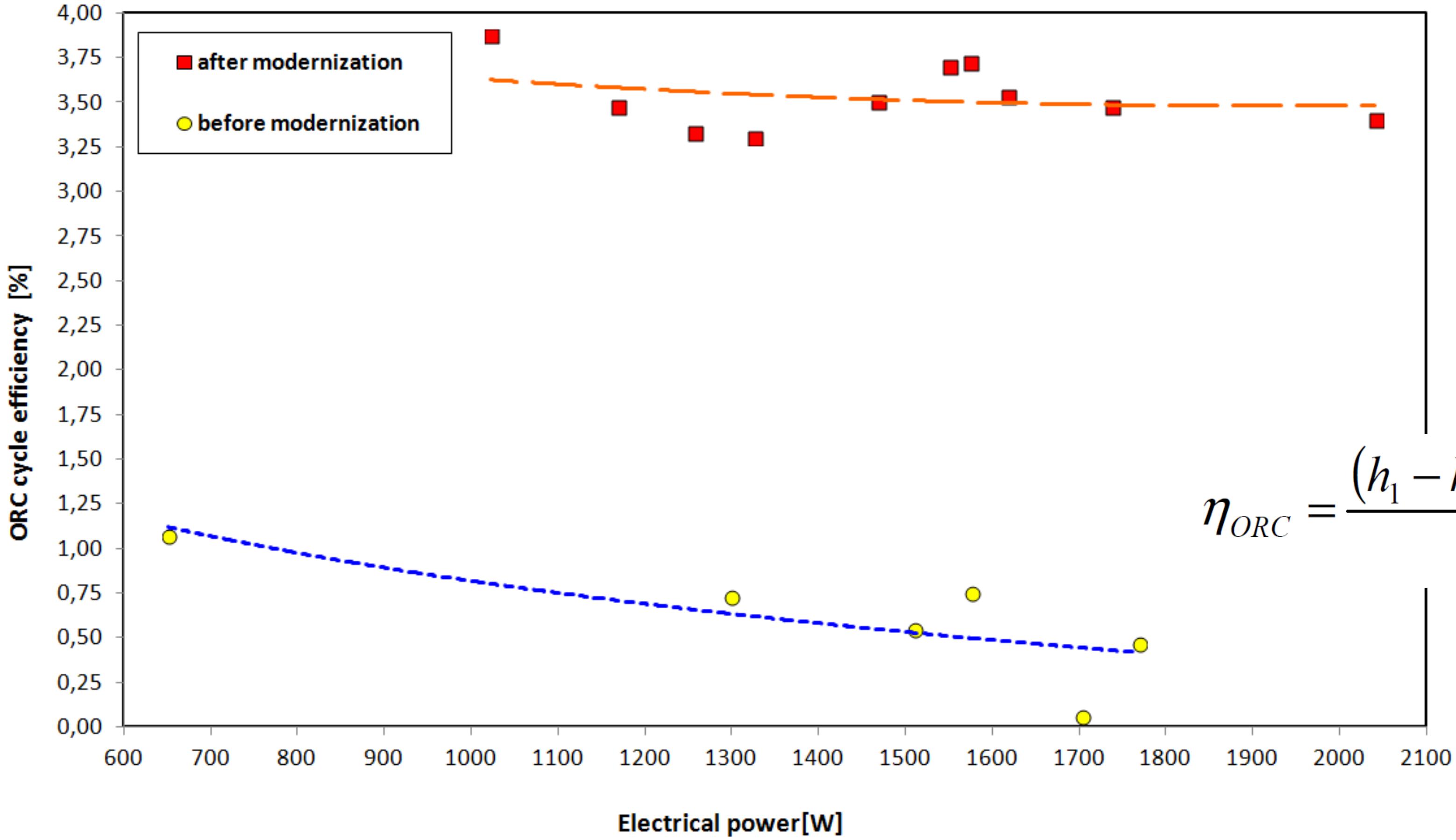


Pressure ratio

$$PR = \frac{P_{inlet\ (turbine)}}{P_{outlet\ (turbine)}}$$

Fig. 13. Internal efficiency of the microturbine (before and after its modernization) vs. pressure ratio

4. Measurement results



ORC cycle efficiency

$$\eta_{ORC} = \frac{(h_1 - h_2) - (h_6 - h_5)}{h_8 - h_6}$$

Fig. 14. ORC cycle efficiency vs. electrical power generated by the radial microturbine (before and after the turbine modernization)

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4. Measurement results

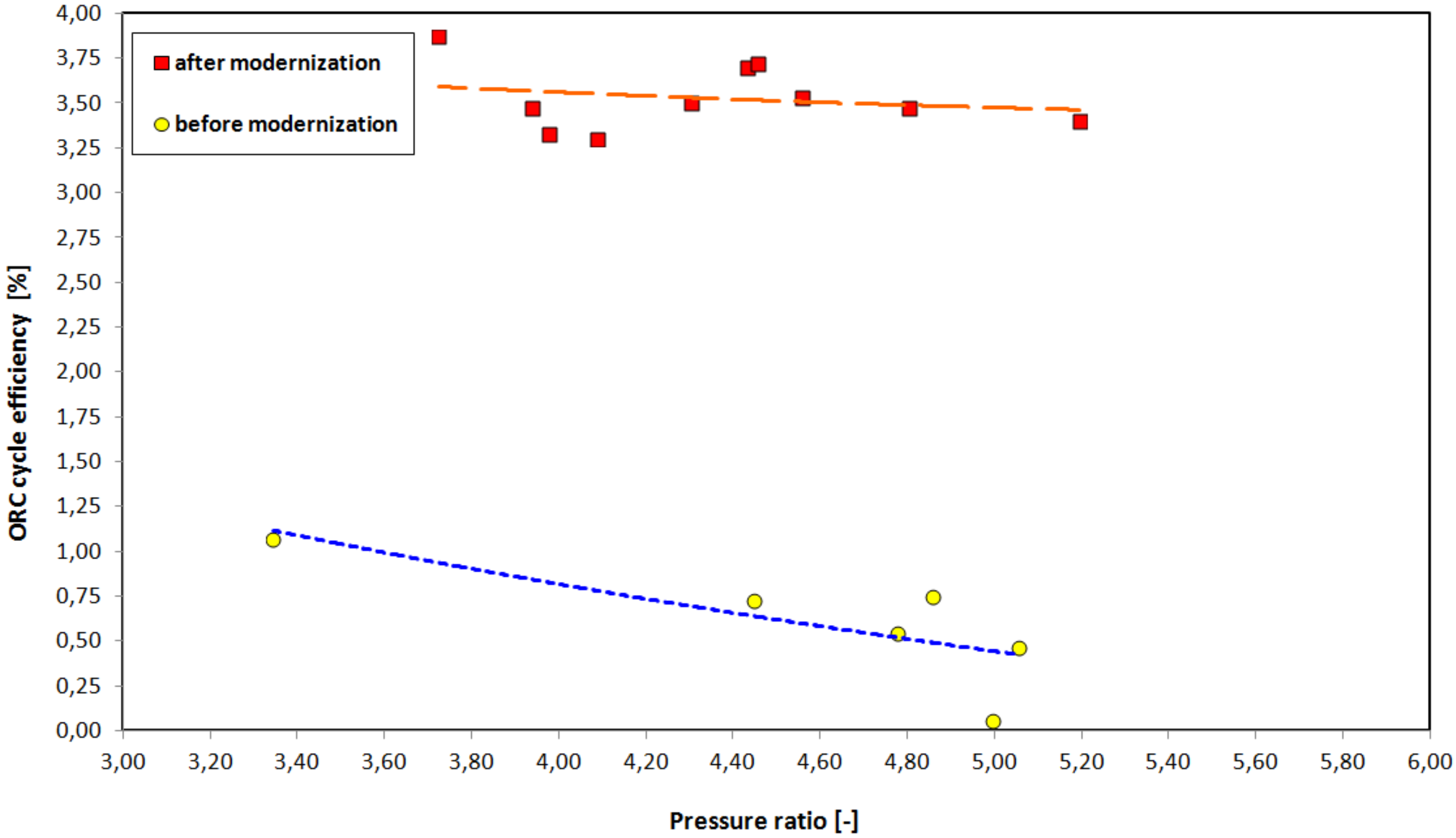

Fig. 15. ORC cycle efficiency vs. pressure ratio (before and after the microturbine modernization)

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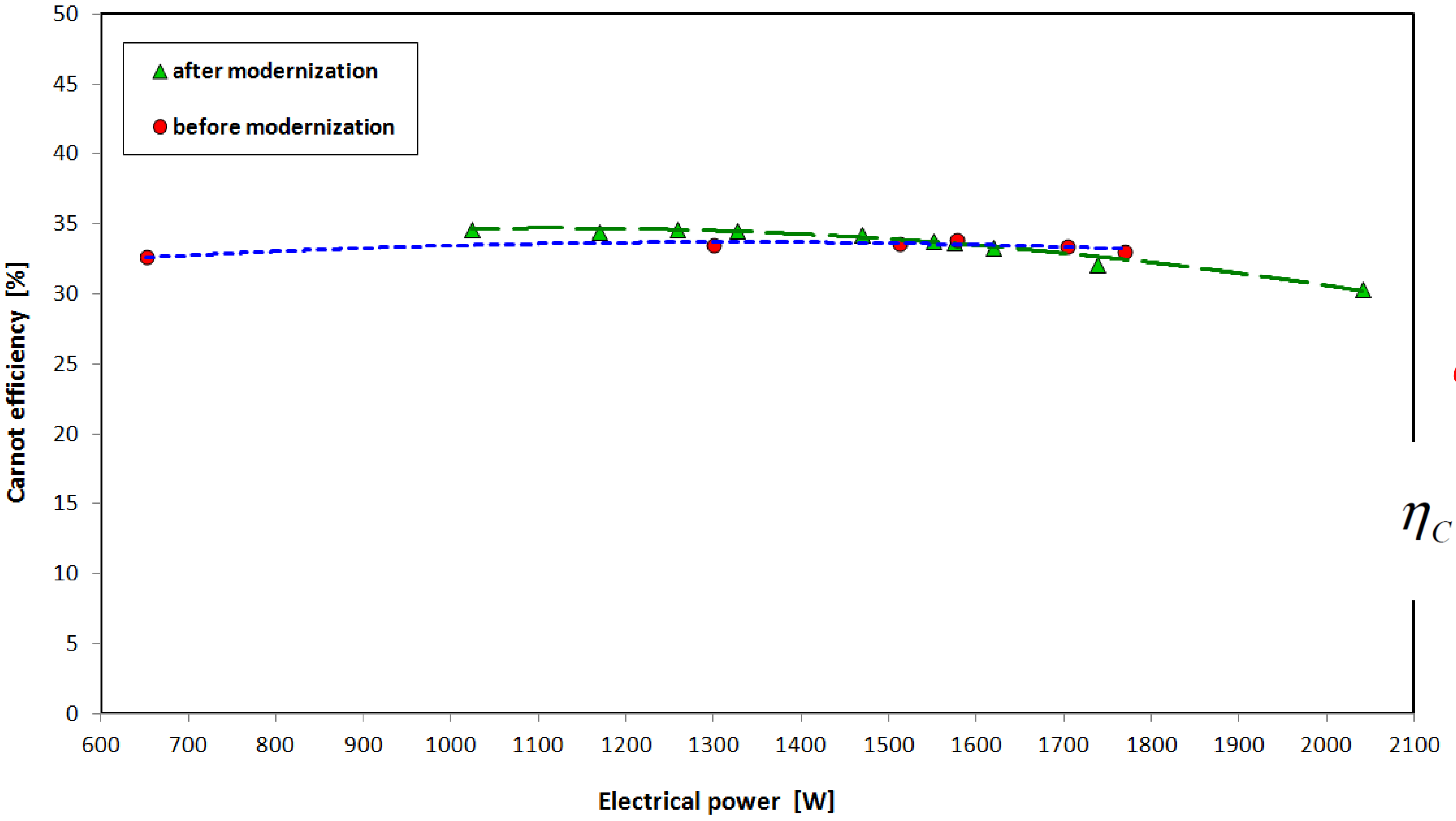
4. Measurement results



Carnot efficiency

$$\eta_C = 1 - \frac{T_{\min}}{T_{\max}}$$

Fig. 16. Carnot efficiency vs. electrical power generated by the microturbine (before and after its modernization)

4. Measurement results

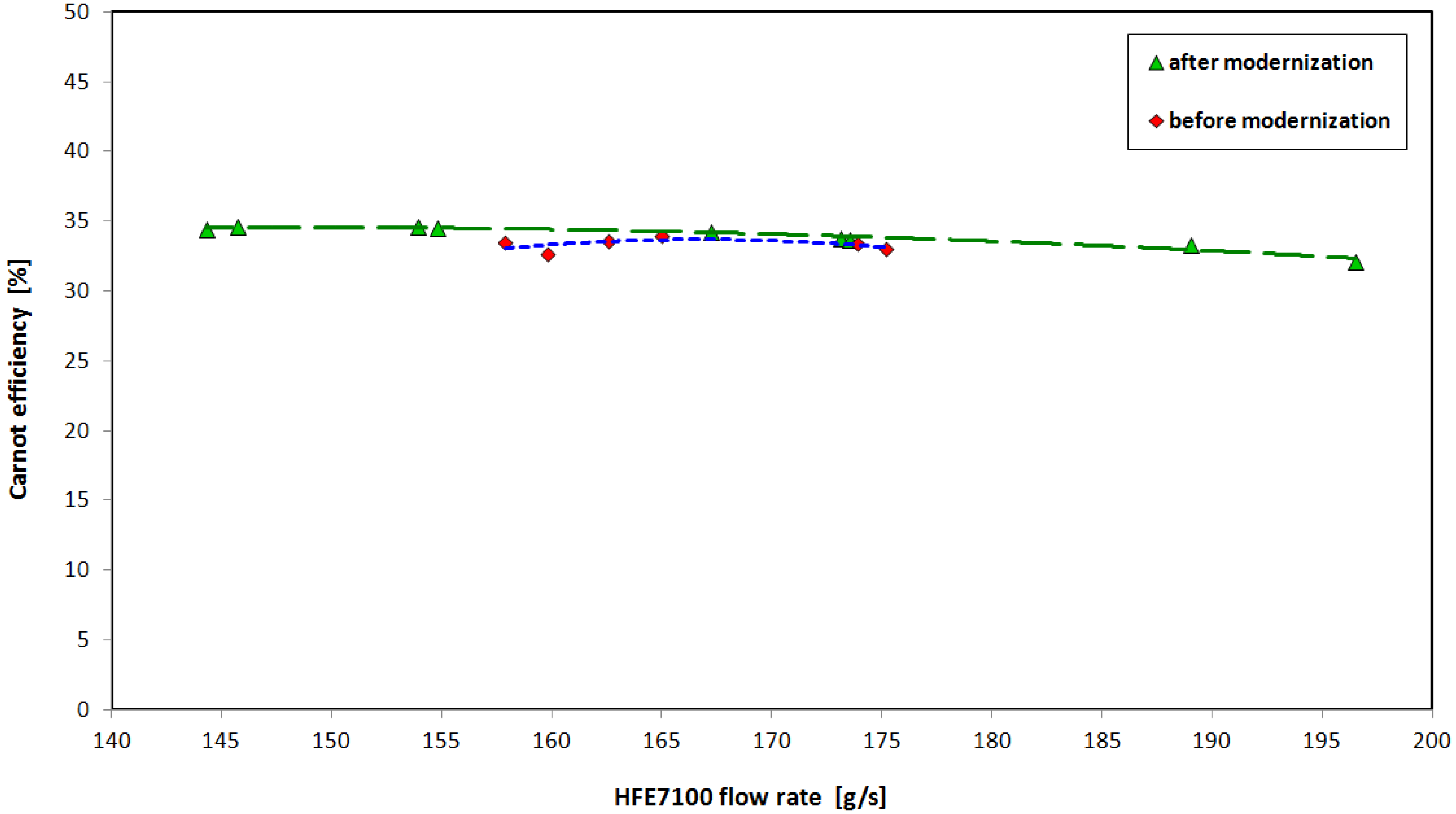


Fig. 17. Carnot efficiency vs. HFE7100 flow rate (before and after the microturbine modernization)

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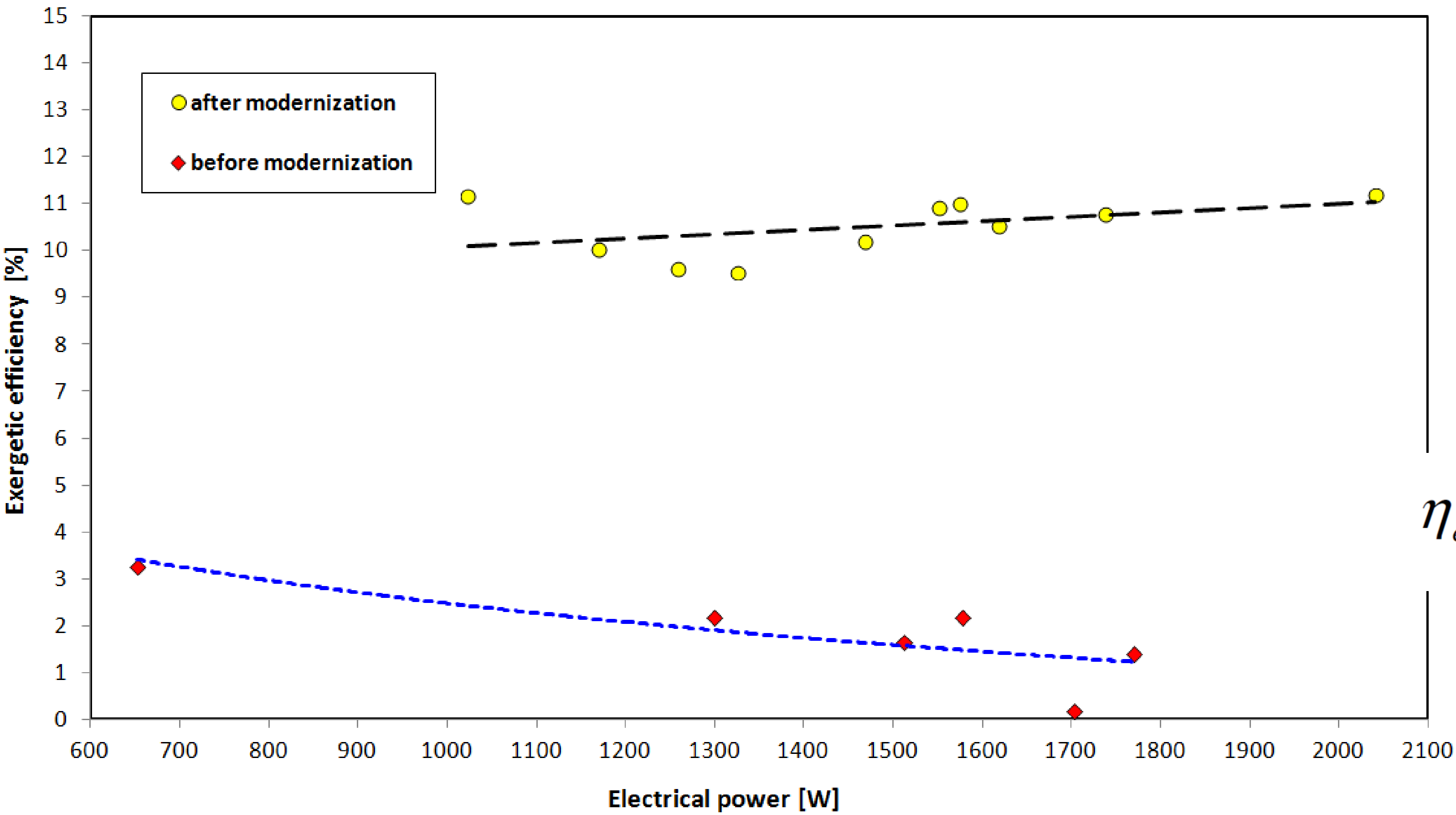
4. Measurement results



Exergetic *efficiency*

$$\eta_{exerg} = \frac{\eta_{ORC}}{\eta_C}$$

Fig. 18. Exergetic efficiency vs. electrical power generated by the microturbine (before and after its modernization)

4. Measurement results

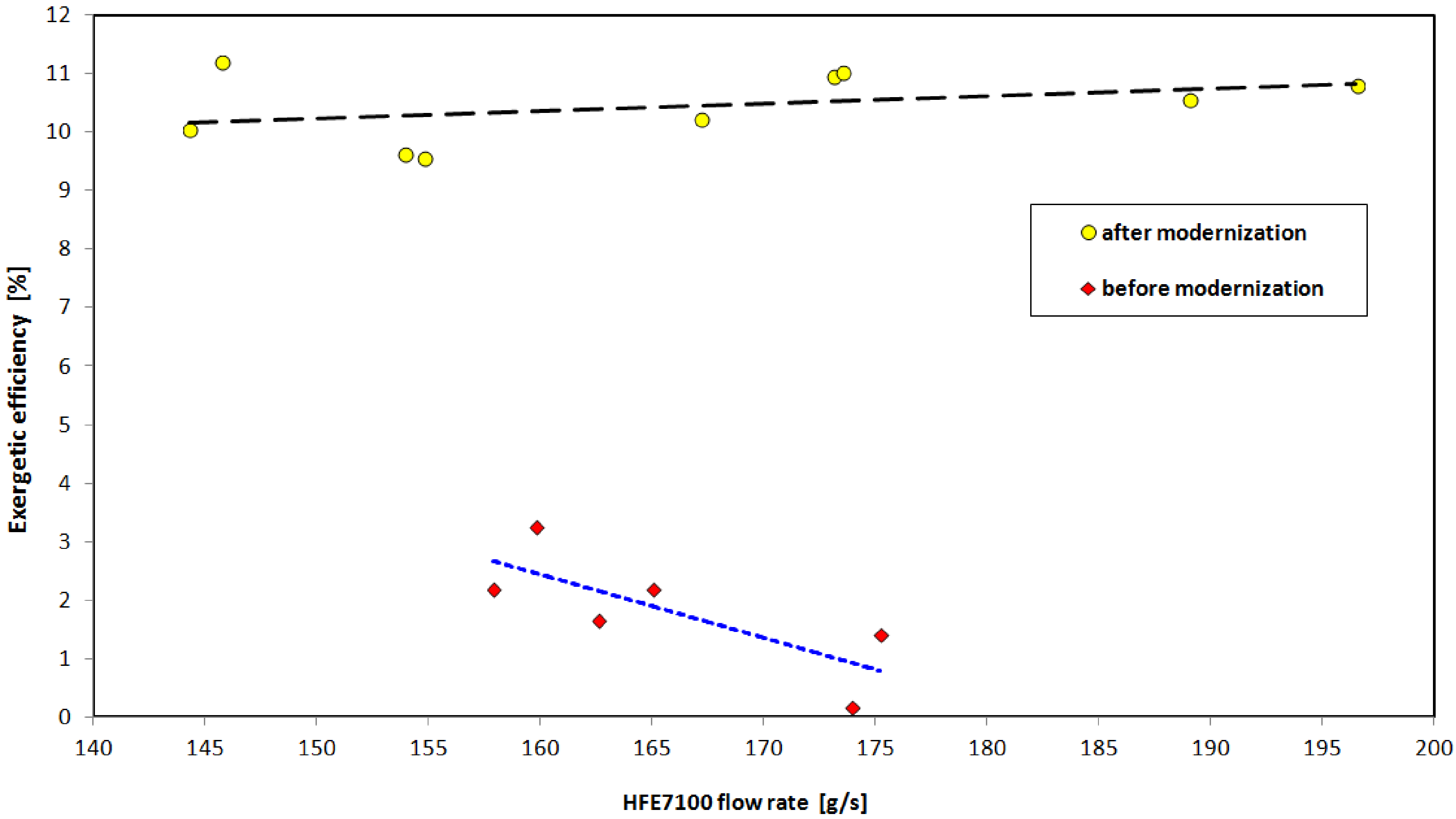


Fig. 19. Exergetic efficiency vs. HFE7100 flow rate (before and after the microturbine modernization)

4. Measurement results

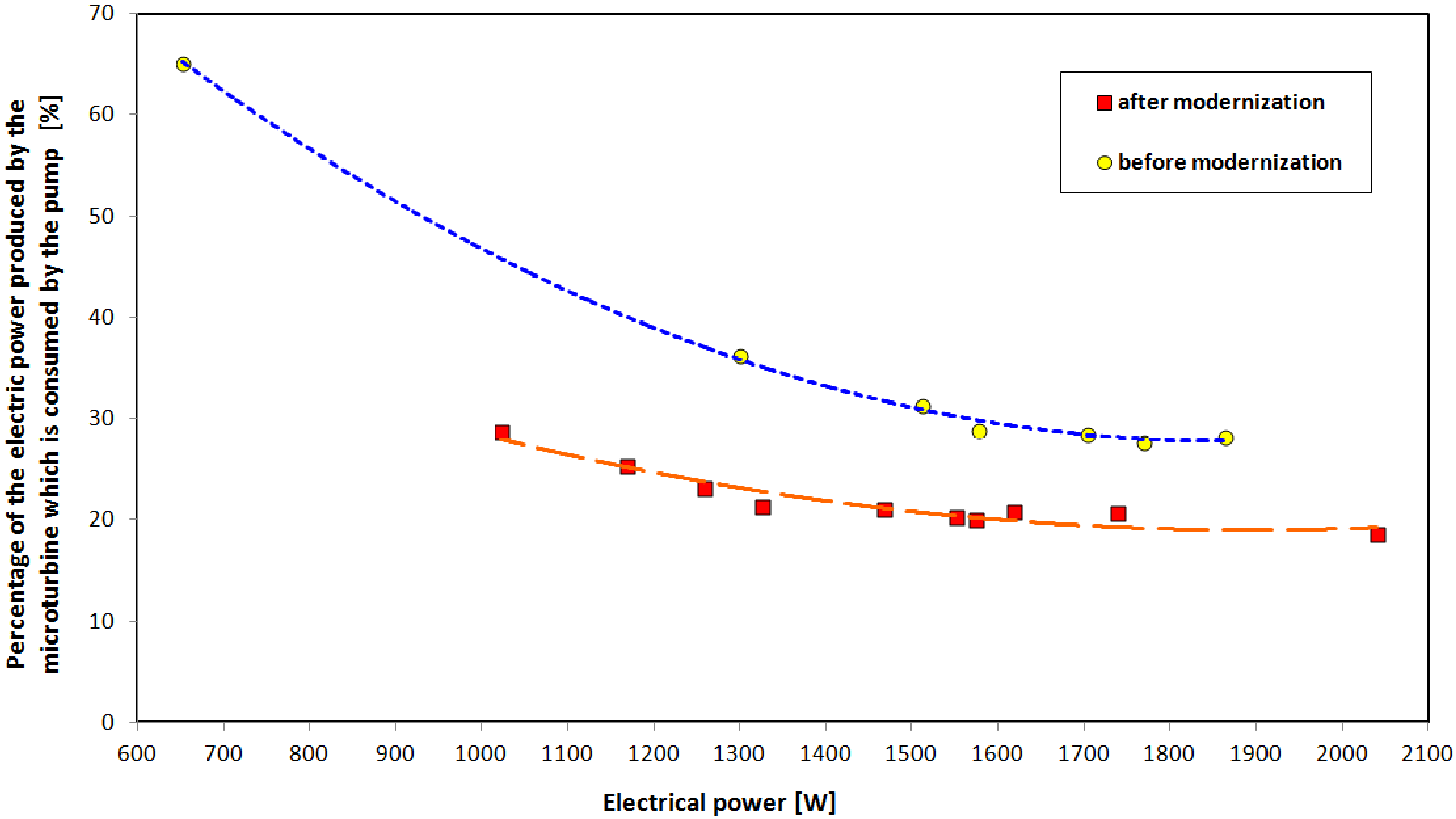


Fig. 20. Percentage of the electric power produced by the radial microturbine which is consumed by the pump vs. electrical power (before and after the microturbine modernization)

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5. Summary and conclusions

The modernization of the microturbine wheel consisted in the increase in the cross sectional area of the delivery channel by around 17%. This constructional change caused:

- increase in electric power generated by the microturbine (from 1740 W to 2050 W);
- increase in the internal efficiency of the microturbine (from 15 % to 42 %);
- increase in the exergetic efficiency (from 3.5 % to 10.5 %);
- increase in the ORC cycle efficiency (from 0.45 % to 3.55 %).
- decrease in the electrical energy consumed by the circulating pump (around 33 %).

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Thank you for your attention

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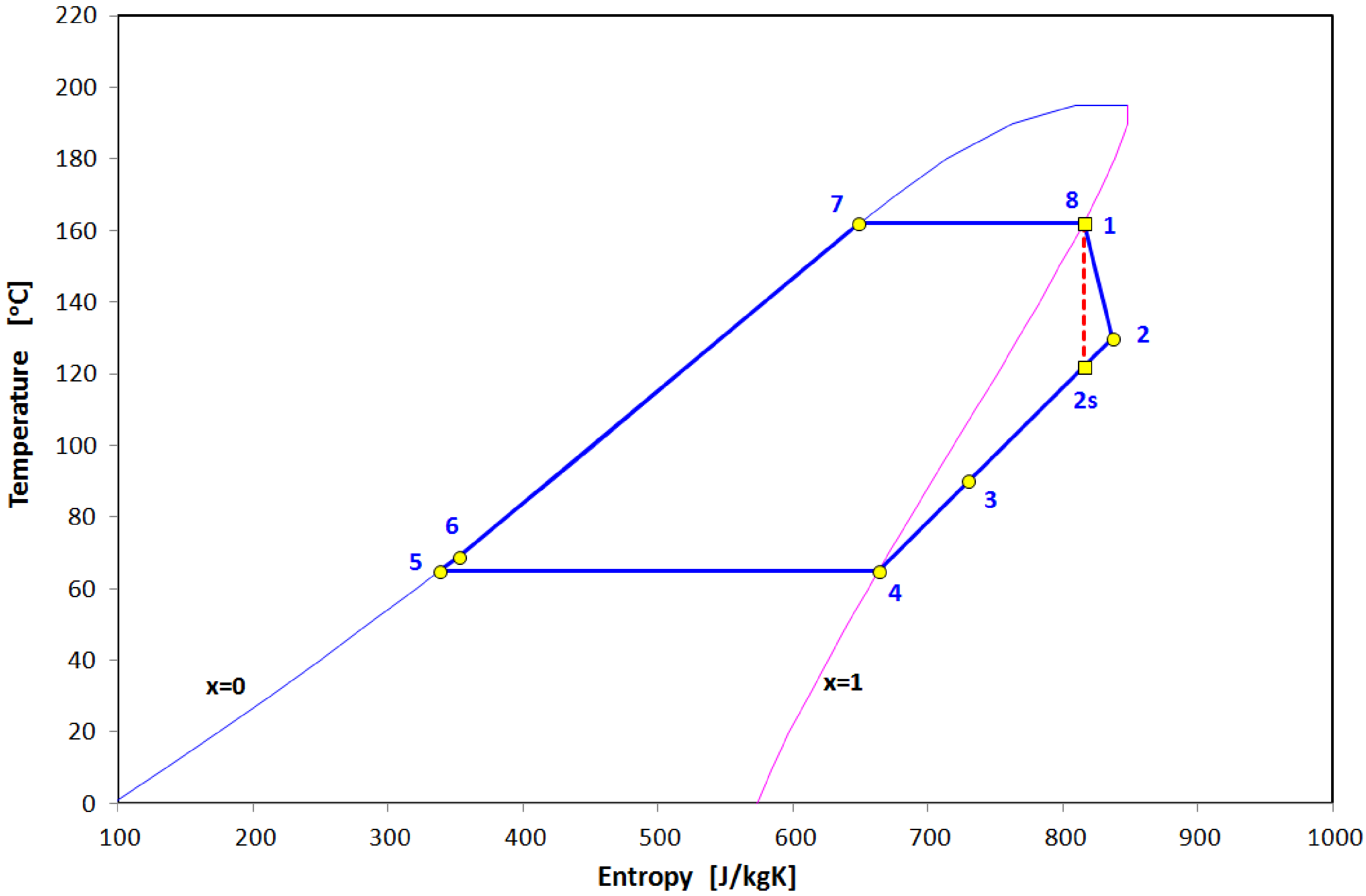

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