EXPERIENCES FROM OPERATION OF DIFFERENT EXPANSION DEVICES IN DOMESTIC MICRO ORC

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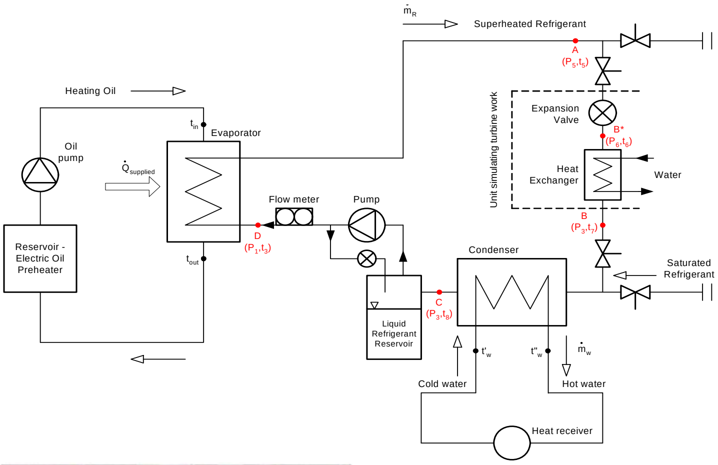
1. INTRODUCTION

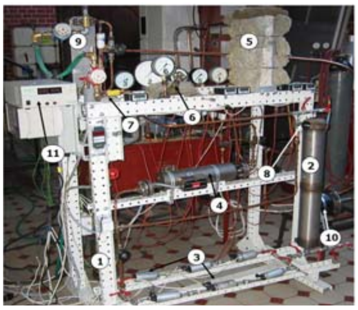
Design and manufacture of a small size turbine (expansion machine) featuring the effective power of the order of few kilowatts, high internal efficiency and ensuring the full air-tightness in the presence of the low boiling-point fluid as a working fluid is a formidable engineering challenge. The smaller the turbine capacity the higher is the nominal speed of the turbine. Ensuring of a requested power implies the rotational velocities exceeding 100 thousands rev/min. For such range of velocities of significant importance are issues of manufacturing, dynamical balancing of rotating elements as well as coupling of turbine with the electricity generator.

The parallel path for searching of the expansion device to operate within the domestic micro heat and power plant encompasses activities related to adaptation and modification of existing devices available on the market to adjust them to operate as expansion machines.

2. EXPERIMENTAL FACILITY

The experimental rig has schematically been presented below. The flow of the working fluid (R123, ethanol) is induced by a system of six pumps with a possibility of maximum flow of 0.1 kg/s and pumping pressure of 24 bar assemblied in a parallel fashion from two series of three pumps. The working fluid flowing through the heat exchanger takes up heat from the heating oil having temperature of about 170°C and changes from liquid state to the superheated state. The state of vapour at outlet from the heat exchanger is controlled by measurement of temperature and pressure. Produced in such way vapour is further directed to the system simulating operation of a turbine (consisting of a plate heat exchanger and a throttling valve) or expansion device. Subsequently in the condenser the working fluid removes heat to the water installation and is directed to the tank. In the oil loop the heating oil Mobiltherm 603 has been used.





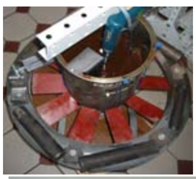
Working fluid: R123
ethanol

1 – supporting structure
2 – reservoir of liquid refrigerant
3 – pumps
4 – flowmeter
5 – evaporator
6 – throttle valve
7 – heat exchanger
8 – by-pass valve
9 – condenser
10 – expander
11 – power supply

3. EXPANSION DEVICES

Rotating Plate Expander

Adapted device was the BOSCH pneumatic drill, appropriately modified to fulfill the specific needs of experiment. The basic parameters of the drill were: rotational velocity 1800/3000 rev/min, power 180 W, feeding pressure 6.3 bar, weight 0.96 kg. The body of the drill was made of steel. In experiments the machine was coupled with the hydraulic brake which enabled determination of effective power.

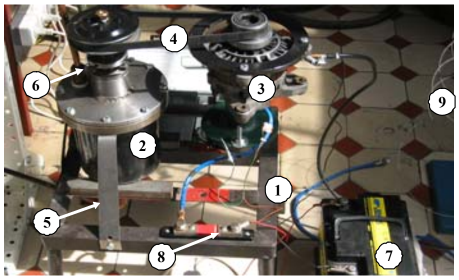


$\dot{m}_{R123}$	$\dot{Q}_{evap}$	N_i	N_{eff}	η_t	η_C	η_i	η_b
kg/s	kW	kW	kW	%	%	%	%
0.025	6.41	0.820	0.127	12.8	32.5	81.4	39.4
0.031	8.23	0.713	0.153	8.9	32.9	60.8	27.1
0.029	7.39	0.703	0.138	9.5	31.2	57.5	30.5
0.028	7.13	0.771	0.106	10.8	31.9	68.8	33.9
0.021	5.44	0.626	0.102	11.5	32.1	75.3	35.8

Scroll Expander

Experiments have been accomplished with the inverted scroll compressor LG ELECTRONICS model HQ028P featuring the nominal capacity of 6.974 kW. The optimum parameters determined by the producer for operation with R407C are T_{evap}/T_{cond} = 7.2/54.4 ^{0}C. The dimensions of the scroll were: width/depth/height equal to 235/235/374 mm.

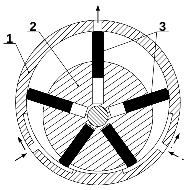
$\dot{m}_{R123}$	$\dot{Q}_{evap}$	$\dot{Q}_{cond}$	N_i	η_t	η_C	η_i	η_b
kg/s	kW	kW	kW	%	%	%	%
0.034	8.14	7.69	0.473	5.8	29.2	29.0	19.9
0.040	9.12	8.70	0.456	5.0	26.2	25.2	19.1
0.041	9.01	8.12	1.050	11.7	28.1	52.1	41.6
0.043	10.13	9.22	0.959	9.5	30.6	42.9	31.0



View of the scroll expander connected with the car alternator: 1- supporting structure, 2- expander, 3- alternator, 4- transmission belt, 5- steam inlet to the expander, 6- steam outlet, 7- accumulator (battery), 8- shunt, 9- variable resistor

Pneumatic Engine

The third examined device was the adapted pneumatic wrench (model VS02YU1260T). Its basic technical parameters are: rotational speed 6500 rev/min, torque 813 Nm at the supply pressure of 7 bar (air), air flow rate demand of 0.36 m3/min, weight 2.8 kg. Such nominal parameters of operation made a very attractive option for implementation in the ORC. The body of the device was made of steel. The pneumatic engine is governed by the same principles as the pneumatic drill. In that case much higher power of the device was expected than in the case of the pneumatic drill.



1 – cylinder
2 – rotor
3 – blades

	$\dot{m}_{ethanol}$	Q_{par}	N_t	N_{el}	η_t	η_c	η_i	η_b
	kg/s	kW	kW	kW	%	%	%	%
first adaptation	0,013	14,79	0,759	0,121	5,13	30,01	67,10	17,09
	0,014	15,96	0,769	0,130	4,82	30,32	73,68	15,90
	0,014	16,01	0,907	0,085	5,66	32,61	82,35	17,37
	0,014	15,84	0,881	0,057	5,56	33,50	78,52	16,59
second adaptation	0,018	20,91	2,000	0,146	17,5	30,50	82,30	57,40
	0,020	21,75	1,710	0,145	13,7	26,10	81,50	52,40
	0,018	19,69	1,530	0,142	17,0	26,50	82,70	64,20
	0,015	17,72	1,930	0,170	17,9	31,60	83,60	56,50

4. CONCLUSIONS

Experiments showed the superiority of both “pneumatic devices” over the scroll expander, indicating the possible internal efficiencies in the range of 61÷82%. Such efficiencies are very attractive, especially at the higher end of that range. The volume of these devices is much smaller than the scroll expander which makes it again more suitable for a domestic micro CHP. Small rotational velocities enable to conclude that connection to electricity grid will also be simpler in the case of “pneumatic devices”. The “pneumatic devices” under scrutiny here could be an alternative to the typical vapour turbine in the ORC cycle, which is in the process of development at the IFFM.

It should be mentioned that the nominal range of rotational speed of investigated pneumatic devices (about 3000 rpm) is advantageous from the electricity generator point of view. These parameters can be obtained by the presented solution after increasing the steam pressure supplying the turbine.

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