REVIEW OF THE POLISH RESEARCH WORKS ON APPLICABILITY OF THE ORC POWER PLANTS

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Poland, like many other countries around the world, has recently deveoped a great interest in the ORC systems. This poster presents a review of the scientific work on the ORC power plants carried out in five Polish scientific centres located in four cities: Institute of Fluid-Flow Machinery in Gdańsk (IFFM Gdańsk) and Gdańsk University of Technology (Gdansk UT), Łódź University of Technology (Łódz UT), West Pomeranian University of Technology in Szczecin (WPUT Szczecin), Wrocław University of Technology (Wrocław UT). It should be stressed that this review refers to the papers and articles published within the last 10 years. The review process is based on analysis of the following publications: IFFM Gdańsk and Gdańsk UT [16,22,24-30,38-40,42], Łódz UT [1, 7, 8,15,20,21,32], WPUT Szczecin [2-6,17,31-36] and Wrocław UT[9-14,18,19,23].

WROCŁAW UNIVERSITY OF TECHNOLOGY (WROCŁAW UT)

- the first in Poland research work related to the experimental micro-ORC system - a prototype installation with R11 used the thermal oil evaporator and the process of expansion was based on volumetric machines, [11]

Figure 1. View of the test ORC installation in Wrocław TU [19]

- the second prototype was built only of serial components available on the market (two expansion volumetric machines, spiral and screw ones, with the power of 2kW each, a hermetic seal installation with a magnetic clutch to drive generators without need to directly connect the shafts, the working fluid R123) [19]
- analysis of systems with heat accumulator for aligning the variable thermal characteristics of heat sources [18]
- research on modular systems by using energy from many sources [19]

INSTITUTE OF FLUID-FLOW MACHINERY IN GDAŃSK & GDAŃSK UNIVERSITY OF TECHNOLOGY

- the concept of cogeneration micro-ORC power plant with thermal power from 25 to 199 kW and electric power from 2 to 12 kW [16,25,26,29,42] - key project no. POIG.01.01.02-00-016/08
- a new criterion for the selection of the working fluid [27]

$$\eta = 1 - \frac{\frac{\Delta H(T_2)}{h_{iv_1}}}{\frac{c_p T_1}{h_{iv_1}}\eta_c + 1} = 1 - \frac{\frac{\Delta H(T_2)}{h_{iv_1}}}{Ja(T_1)\eta_c + 1}$$

- heat exchangers with micro-channels [27]
- the prototype of micro-power plant with R123 as working fluid built in Department of Heat Engineering of Gdańsk University of Technology with the cooperation of Institute of Fluid-Flow Machinery PAN in Gdańsk [39] (as the expansion machine a reversed refrigeration spiral compressor was used)
- comparative analysis of the axial single and multi-stage turbines, radial and–axial- radial turbines [28]

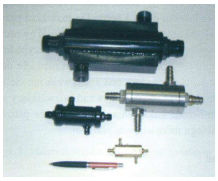


Figure 2 Micro heat exchanger

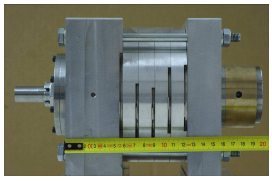


Figure 3 Microturbine

ŁÓDŹ UNIVERSITY OF TECHNOLOGY (ŁÓDZ UT)

- analysis of application of the ORC technology for geothermal energy utilization [8, 15, 20]
- numerical calculation and experimental study of small power turbines [1]

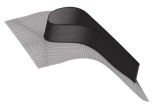


Figure. 4. The grid for the second channel of nozzles

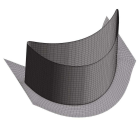
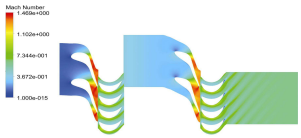


Figure. 5. The grid for the second channel impeller



Figuer 6. Distribution of the Mach number at 50% of the flow-through channel

WEST POMERANIAN UNIVERSITY OF TECHNOLOGY IN SZCZECIN

- thermodynamic analysis of the ORC system and the possibility of improving the efficiency of the work of this type of systems [2, 3]
- use of low-temperature heat sources to supplying bottoming cycle in hybrid -dual-fluid power plant [6]
- evaporation of a working fluid in the near critical region
- effectiveness of supercritical organic power plant [4, 5]
- single cycle power plant supplied by heat sources of different temperature
- utilization of waste heat from industrial processes, e.g. from the firing of cement clinker, by using sub and supercritical ORC system [5],
- utilization of heat from engine cooling (engines fuelled by gas and biogas) [4]

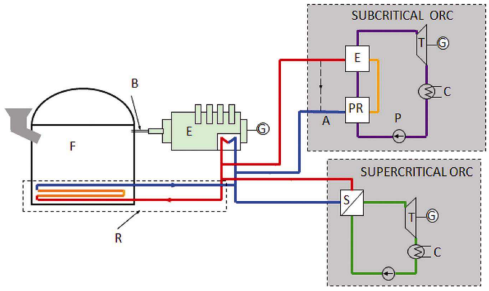
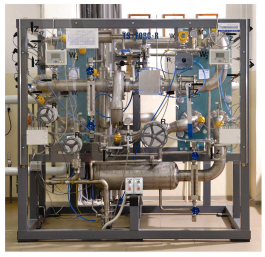


Figure 7. Simplified diagram of the biogas generator and ORC [2] or S-ORC [3] modules; A – node, B – biogas, C – condenser, E – gas engine, F – fermentation chamber, G – generator, P – preheater, R – periodic reheating of the digester at the initial stage of fermentation process, S – supercritical heat exchange, T – turbine, V – vaporizer.

EXPERIMENTAL WORKS WEST POMERANIAN UNIVERSITY OF TECHNOLOGY, Szczecin & TUBOSERVICE SP. z o.o. Łódź

- experimental study of subcritical ORC with R227ea as working fluid – simulating operation of geothermal power plant [32]
- researching in the direction of hermetic turbogenerators



Rys. 8 Small ORC Power Plant with R227ea

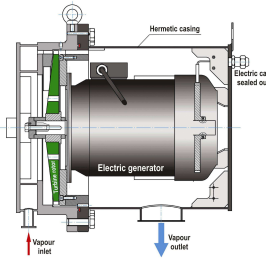


Fig 9. Cross-section of the hermetic turbogenerator design

At the moment the research project R06 0020 06/2009 is realised. Supercritical power plant with R227ea supplied by raw biomass fired in boiler is under construction.

SUMMARY

Review of available literature that has been published by the Polish researchers allows to conclude that the themes associated with the ORC systems and with possibilities of their application are present at the Polish universities and are implemented not only in theoretical terms but in experimental studies, too. Some trends are visible: IFFM i Gdańsk UT concentrate their research on micro systems, researchers from Wroclaw UT push their interests towards volumetric expansion machines and towards the possibility of acquisition and transportation of waste heat for its agglomeration. However, researchers employed in WPUT together with the Turboservice Sp. z o.o. focused their research on the possibility of converting energy from low and medium temperature sources in small and medium-size ORC systems. Authors of this poster would also like to mention works of Prof. B. Zaporowski from the Poznań University of Technology that are devoted to a comparative analysis of efficiency of various types of energy systems supplied with different types of fuels (conventional, renewable). Prof. Zaporowski was the first in Poland who promoted the ORC systems as those being equivalent to other more popular and better known energy systems [41].

BIBLIOGRAPHY

1 Antczak Ł, Fijalkowski T, Klonowicz P. Turbiny małej mocy dla potrzeb doświadczalnej mikrosiłowni hybrydowej. Low-power turbines for the experimental micro-hybrid power plant. Turbomachinery, 138, 15-20, 2010. **2** Borsukiewicz-Gozdur A.: Efektywność pracy elektrowni geotermalnej z organicznym czynnikiem roboczym. Praca doktorska. Politechnika Szczecińska,2008. **3** Borsukiewicz-Gozdur A., Nowak W.: Comparative analysis of natural and synthetic refrigerants in application to low temperature Clausius-Rankine Cycle, Energy 32 (2007), pp. 344-352. **4** Borsukiewicz-Gozdur A., Nowak W.: Increasing of electricity generation capacity of biogas power generator by application of sub- and supercritical modules of Organic Rankine Cycle. Arch of Thermod, Vol. 30(2009), No. 4, pp. 175-188 **5** Borsukiewicz-Gozdur A., Nowak W.: Utylizacja ciepła odpadowego z procesu wypalania klinkieru cementowego w elektrowni z nadkrytyczną siłownią organiczną, Rynek Energii 6(85), 2009. **6** Nowak W., Stachel A.A., Borsukiewicz-Gozdur A.: Comparison of the effectiveness of geothermal energy utilisation in the case of a power plant with organic Rankine cycle and a hybrid binary plant, Arch of Thermod, Vol. 29(2008), No. 4, pp. 133-140. **7** Chodkiewicz R., Hanausek P., Krysiński J.: Externally biofuelled gas turbine coupled with a geothermal energy source, Arch of Energetics, vol. XXXVI (2006), pp. 37-46. **8** Chodkiewicz R., Hanausek P., Porochnicki J.: Pozyskiwanie energii elektrycznej ze źródła geotermalnego,2001.CMP nr120,s.19-37. **9** Gnutek Z., Biernacki S.: Warunki efektywnego wykorzystania ciepła odpadowego w mikrosiłowni C-R z czynnikiem niskowrzącym, Gospodarka Paliwami i Energią 12/1996. **10** Gnutek Z., Bryszewska -Mazurek A.. The thermodynamic analysis of multicycle ORC engine.Energy.Vol.26,nr 12,s.1075-1082. **11** Gnutek Z., Kolasinski P., Pomorski M.: Prototypowa mikrosiłownia parowa zasilana energią odpadową, Termodynamika w nauce i gospodarce.T.1.Oficyna Wyd. Politechniki Wrocławskiej, 2008. **12**. Gnutek Z., Kolasiński P. Application of volumetric machines in micro steam power plants. Arch Energetyki.2010.t.40,nr ½,s.63-74 **13** Gnutek Z., Kolasiński P., Pomorski M.: Influence of the type of working substance and its thermodynamic parameters for selection of sliding vane expanders, Arch of Thermod 2009.Vol.30 nr 4 s.163-173. **14** Gnutek Z., Kolasiński P.: Silownie parowe o zmiennej ilości czynnika roboczego. Współczesne technologie i urządzenia energetyczne, WTiUE. Kraków 2007,s.157-165. **15** Hanausek P, Klonowicz P, Krysiński J, Koncepcja hybrydowej siłowni geotermalnej w Uniejowie. Materiały II Ogólnopolski Kongres Geotermalny, 2009, s.1-11 **16** Ihnatowicz E., Żywica G: Kompleksy agroenergetyczne jako przykład kogeneracji rozproszonej. Czysta Energia, 6(118)2011. **17** Kaczmarek R.: Analiza i ocena efektywności pozyskiwania i wykorzystania energii Ziemi do zasilania elektrowni/elektrociepłowni geotermicznej. Praca doktorska 2010. ZUT w Szczecinie. **18** Kolasiński P., Gnutek Z.: Możliwości i korzyści wynikające z zastosowania akumulatorów ciepła w obiegach mikrosiłowni. Termodynaamika w nauce i gospodarce.T.1.Oficyna Wyd. Politechniki Wrocławskiej, s.542-549,2008. **19** Kolasiński P.: Termodynamika układów konwersji energii o zmiennej ilości czynnika roboczego. Praca doktorska 2010. Politechnika Wrocławska. **20** Kryllowicz W, Piotrowska D, Hanausek P, Klonowicz P. The Uniejów project - an example how geothermal energy is used in Poland. Procedings of 8th Conference on Power System Engineering, Thermodynamics and Fluid pp.123-157, 2009. **21** Krysiński J., Chodkiewicz R., Hanausek P., Porochnicki J., Sadowski J.: Możliwości efektywnego wykorzystania energii geotermalnej z odwiertu na terenie campusu Politechniki Łódzkiej. Turbomachinery, nr 123, 2003, s. 53-60. **22** Lewandowski W.M., Kubski P., Ryms M.: Wstępna koncepcja doboru czynnika roboczego obiegu ORC dla określonych źródeł ciepła odpadowego./w/Termodynamika w nauce i gospodarce, red. Gnutek, Gajewski W.,t.1 s.31-36,Wrocław 2008. **23** Mazurek W., Swieboda T., Bryszewska-Mazurek A., Juchim S.: Metody podnoszenia sprawności siłowni ORC. Współczesne technologie i urządzenia energetyczne.WIiUE-2007,Kraków s.384-395. **24** Mikielewicz D., Mikielewicz J., Tesmar J.: Improved semi-empirical method for determination of heat transfer coefficient in flow boiling in conventional and small diameter tubes , Int. Journal of Heat and Mass Transfer,50,3949-3956,2007. **25** Mikielewicz D., Mikielewicz J: Cogenerative micro power plants-a new Direction for development of power engineering?, Arch of Thermod.,29(4),109-132,2008. **26** Mikielewicz D., Wajs J., Mikielewicz J.: Determination of transfer coefficient in evaporator of the organic Rankine cycle using the Wilson method. Szczecin-Międzyzdroje HTRSE 2008. **27** Mikielewicz D.: Wrzenie i kondensacja w przepływie w kanałach i mikrokanałach, Wydawnictwo Politechniki Gdanskiej, 2009. **28** Mikielewicz J., Piwowarski M., Kosowski K.: Design analysis of turbines for co-generating micro-power plant working in accordance with organic Rankine s cycle. Polish Maritime Ressearch.,s1,2009,s.34-38. **29** Mikielewicz J.: Micro Heat and Power Plants Working in Organic Rankine Cycle,Polish J. of Environ Stud.Vol.19 No 3 2010,499-505. **30** Mikielewicz J. Mikielewicz D. Comparative study of selected fluids for use in supercritical Organic Rankine Cycles, Arch of Thermod,30(2), **31** Nowak W, Wiśniewski S.: Koncepcja zasilania siłowni organicznej ORC nisko i średniotemperaturowymi źródłami ciepła. Poznań 2011. **32** Nowak W., Borsukiewicz-Gozdur A., Klonowicz P., Stachel A., Hanausek P., Klonowicz W..: Wstępne wyniki badań prototypowego układu minisiłowni z ORC zasilanej wodą o temperaturze 100°C, Przegląd geologiczny, vol. 58, nr 7, 2010, pp.622-625. **33** Nowak W., Borsukiewicz-Gozdur A., Stachel A. A., Using the low-temperature Clausius-Rankine cycle to cool technical equipment, Applied Energy, No. 85, pp. 585- 588, 2008. **34** Nowak W., Borsukiewicz-Gozdur A., Stachel A.: Ocena efektywności pracy hybrydowej elektrowni z ORC zasilanej parą wodną z kotła opalanego biomasą, Rynek Energii, 5(2008),s.35-40. **35** Nowak Wł., Kaczmarek R.: Utulisation of geothermal energy for supplying CHPs. Arch of Thermod.Vol.28 (2007).No.4, 3-18. **36** Nowak W.: Analitycal calculation model of underground closed geothermal heat exchanger Arch of Thermod.Vol.26 (2005),No.3,49-66. **37** Polecki Z.: Możliwość wykorzystania organicznego obiegu Rankine a dla odzysku ciepła z procesów technologicznych. Rynek Energii, (2)2008,s.50-53. **38** Wajs J., Mikielewicz D., Minikanałowy płaszczowo-rurowy wymiennik ciepła. Technika Chłodnicza i Klimatyzacyjna – R.17,nr.6-7 (172-173) (2010), s.255-259. **39** Wajs J., Mikielewicz D., Mikielewicz J., Sprężarka chłodnicza jako maszyna ekspansyjna w obiegu ORC mikrosiłowni. Technika Chłodnicza i Klimatyzacyjna-R.16 nr 3 (2009),s.101-106. **40** Wajs J., Mikielewicz D., Mikielewicz J., Turbina pneumatyczna jako maszyna ekspansyjna w obiegu ORC. Technika Chłodnicza i Klimatyzacyjna-R.16 (2009)s.312. **41** Zaporowski B., Szczerbowski R., Wróblewski R.: Analiza efektywności energetycznej i ekonomicznej układów skojarzonego wytwarzania energii elektrycznej i ciepła małej mocy wykorzystujących energię biomasy, Arch Energetyki,t.XXXVIII,2(2008),s,215-223. **42** http://www.imp.gda.pl/pkagro/.