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Energy and exergy assessment of an ORC power plant with geothermal hot water and wood biomass-Serbian case

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In this study it has been presented performance analysis, from the point of First and Second Law of Thermodynamic, of an ORC for working fluids: R113, R245fa and R600a. Two heat sources were used- geothermal hot water from Vranjska Banja and wood biomass. Properties of the working fluids were obtained from Reference Fluid Properties (Refprop) and simulation was made with our own code. R600a showed better performance than R245fa with turbine power output 3.39 MW *, thermal efficiency* $\eta = 14.01\%$ *and exergy efficiency of 33.3%.*

Keywords: ORC, working fluid selection, biomass, geothermal energy,

INTRODUCTION

This research is meant to present a performance analysis of a power plant in ORC (Organic Rankine Cycle) with geothermal hot water from Vranjska Banja and wood biomass, and compare the results for working fluids: R113, R245fa and R600a. R600a is environmentally acceptable fluid because of low GWP=3 and ODP=0, R113 is banned from use [1] and R245fa has very high GWP=1030 [2]. ORC is highly recommended for low-temperature heat sources [3] since the use of a steam is unsatisfactory here due to low thermal efficiency and excessive plant costs [4]. Working fluids are selected by recommended criteria of evaporation temperature of a working fluid [5].

ORC SYSTEM DESCRIPTION

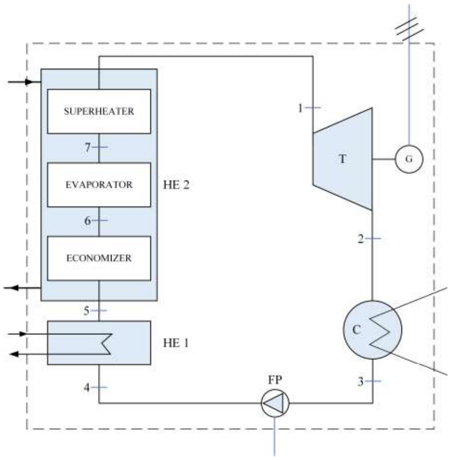


Fig.1. Scheme of the ORC system: turbine (T), generator (G), condenser (C), feed pump (FP), heat exchanger 1 (HE1) and heat exchanger 2 (HE2)

In Fig.1. is shown scheme of the analyzed ORC system where in HE 1 geothermal hot water is used in an economizer. Flue gases are made by biomass combustion in HE 2 which consists of an economizer, evaporator and superheater.

MATHEMATICAL MODEL

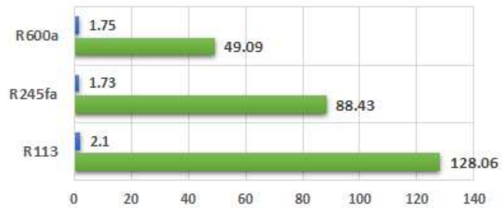
Set parameters and most important correlations for the ORC system are given in Tab.1.

Table 1. Set parameters for the simulation of ORC system

Component	Parameters	
Evaporating	$T_6 = T_e = 120°C$, $p_6 = p_e = p_{sat}(T_e)$	
Condensing	$T_2 = T_c = 35°C, p_c = p_{sat}(T_c)$	
Turbine	Inlet	$T_1 = 130°C, p_1 = p_e$
	Outlet	$p_2 = p_c$
Condenser	Inlet	$T_c = 35°C, p_2 = p_c$
	Outlet	$p_3 = p_c$
Feed Pump	Inlet	$p_3 = p_c,\ h_3 = h'(p_c)$
	Outlet	$p_4 = p_e$
Heat Exchanger 1	Inlet	$T_{gw_{out}} = 60°C$ $m_{gw} = 46 kg/s$
	Outlet	$T_{gw_{in}} = 85°C$ $T_5 = T_{gw_{in}} - 10K$
Heat Exchanger 2	Inlet	$p_5 = p_e$ $T_5 = T_{gw_{in}} - 10K$
	Outlet	$p_1 = p_e,\ T_1 = 130°C$

RESULTS

Energy and exergy assessment has been carried out from the point of First and Second Law of Thermodynamic which showed following results (Figs.2, 3 and 4):



	R113	R245fa	R600a
Mass flow rate of biomass [kg/s]	2.1	1.73	1.75
Mass flow rate of working fluid [kg/s]	128.06	88.43	49.09

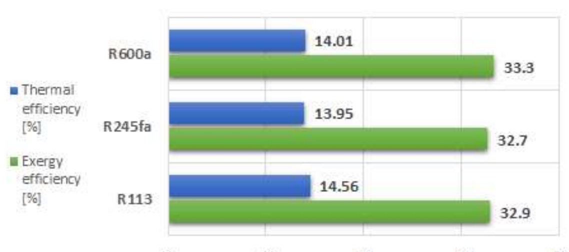
Fig.2. Mass flow rate of biomass and working fluid: R113, R245fa and R600a, [kg/s]

R113 needs 160.87% bigger mass flow rate of working fluid and 20% bigger mass flow rate of biomass than R600a.

	R113	R245fa	R600a
Power input [MW]	0.06	0.14	0.22
Power output [MW]	3.93	3.25	3.39

Fig.3. Turbine power output and feed pump power input for R113, R245fa and R600a, [MW]

Compared to R113, R600a showed slightly better performance than R245fa regarding turbine power output. R600a needs 266.7% more power input than R113, while R245fa only 133.3%.



	R113	R245fa	R600a
Thermal efficiency [%]	14.56	13.95	14.01
Exergy efficiency [%]	32.9	32.7	33.3

Fig.4. Thermal and exergy efficiency for R113, R245fa and R600a, [%]

R113 showed the best thermal efficiency. R600a is slightly better solution compared to R245fa with increase of 0.43%. The biggest exergy efficiency with 33.3% achieved R600a and biggest exergy losses were noted in HE 2 followed by condenser.

CONCLUSION

The results showed that R600a needs 61.7% less of a mass flow rate of working fluid than R113. It is necessary to provide 16.7% less mass flow rate of biomass which is fed to boiler for R600a compared to R113 while cycle efficiency is 14.01%. On the other hand, feed pump power input is 266.7% bigger than for R113. R600a showed highest exergy efficiency among all the other fluids with 33.3%. It is believed that optimization of ORC should follow two directions, one regarding the finding the adequate working fluid for certain application and other in reducing the necessary power input.

ACKNOWLEDGEMENTS

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