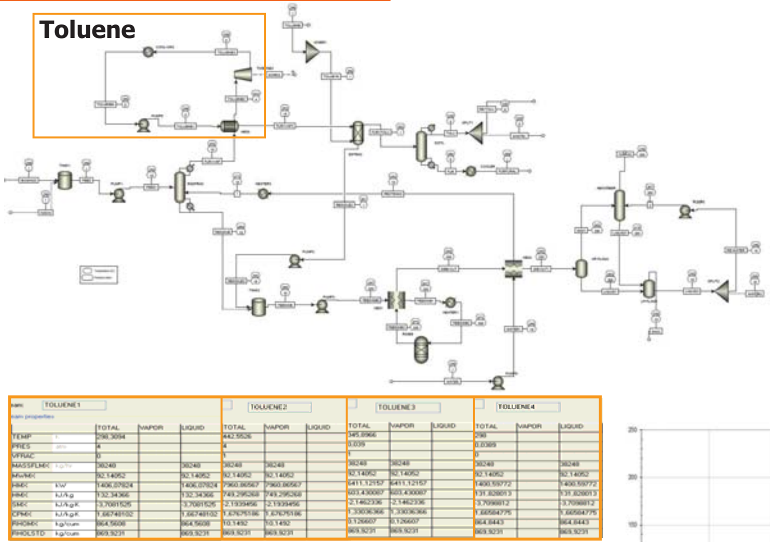
ORC 2011
First International Seminar on ORC Power Systems
In memory of Prof. G. Angelino

APPLICATION OF AN ORGANIC RANKINE CYCLE FOR RECOVERY OF LOW-GRADE WASTE HEAT IN A (WET) BIOMASS SUPERCRITICAL WATER GASIFICATION SYSTEM

SUMMARY: Green platform chemicals and biofuels(s) can be produced from wet biomass pretreatment integrated with supercritical water gasification. This is a novel biorefinery concept. However, the utilization of low grade heat to improve economics has been a challenge. This article describes a process model and simulations in which an Organic Rankine Cycle (ORC) was combined with Supercritical water gasification (SCWG) system. The working fluid used in this study is CO_2. It has many advantages, low cost, low toxicity, is nonflammable and has no environmental impact. In this modeling, water temperature in the range of 170 – 200 ºC and a flow of 7200 kg/hr was used as the low-grade heat source. CO_2 is biomass derived in the same process which can be produced about 1300 kg/hr. Aspen Plus^{TM} process modeling software is used to model this system. The efficiency of the process is evaluated.

PROCESS DESCRIPTION



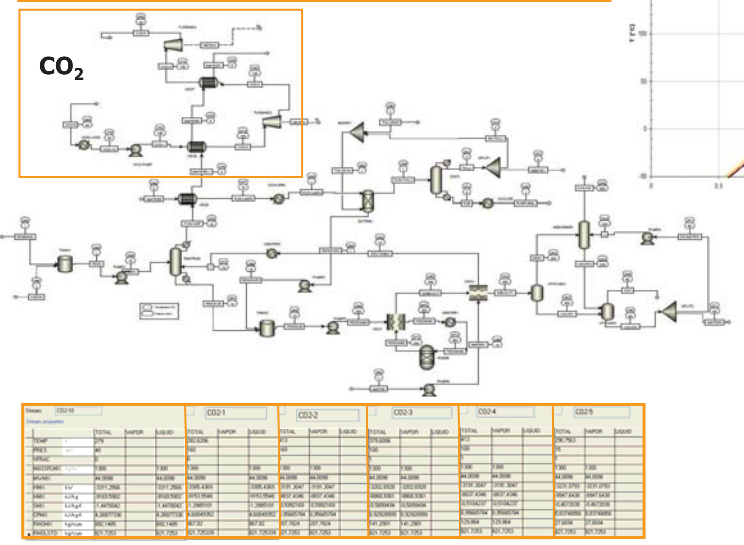


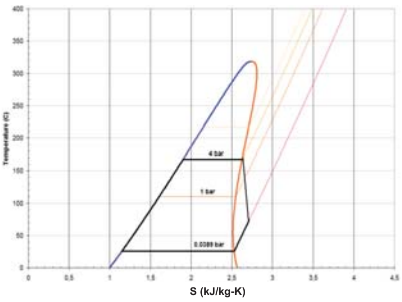
Table I : Cycle data

Cycle data	
Isentropic efficiency turbine	80 %
Pump efficiency	90 %
Inlet turbine (CO_2)	Superheat
Inlet turbine (Toluene)	Saturated
Flow rate (CO_2)	1300 -36000 kg/h
Flow rate (Toluene)	38248 kg/h
Temperature (High)	180 °C
Water flow rate	7200 kg/h
Temperature (Low)	25 °C

Table II : Thermo-physical properties of working fluids

Working fluid properties		
Properties	Carbon dioxide	Toluene
Formula	CO_2	C_7H_8
MW (g/mol)	44.01	92.14
T critical (°C)	31.06	318.6
P critical (bar)	73.84	41.06
Boiling point (°C)	-57	110.6

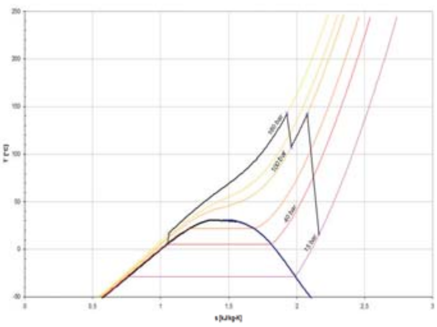
RESULTS



Toluene organic rankine cycle T-S chart

Table III : Result Toluene ORC

Toluene organic rankine cycle	
Component	Work (kW)
Pump (Toluene)	5.48
Turbine	1377.54
Q in (turbine,hp)	6554.76
Efficiency (%)	20.93



CO_2 power cycle T-S chart

Table IV : Result CO2 power cycle

Carbon dioxide power cycle					
Component (kW) / CO_2 flow rate (kg/h)	1300	3600	5400	7200	36000
Pump (CO_2)	5.79	16	24	32	160
Turbine (HP)	11.376	31.50	47.25	63	315
Turbine (LP)	21.21	58.75	88.13	117.5	587.5
Q_{in} (turbine,hp)	114.15	316.12	474.18	632.24	3161.2
Q_{in} (turbine,lp)	11.376	31.5	47.25	63.00	315
Efficiency $_{th}$ (%)	21.346	21.359	21.361	21.359	21.359

CONCLUSIONS

- Organic rankine cycle can be operated on low temperature heat source in a (wet) biomass supercritical water gasification (SCWG) system. The applications can be divided into two difference working fluids, were operating on the same heat source.
- Toluene has been chosen as the step in an extraction unit in the same process. The working fluid used as Toluene in ORC, can be operated on low temperature heat source in a (wet) biomass SCWG system and the result show relatively high power output .
- The working fluid used as CO_2 in power cycle, is biomass derived in the same process. It has many advantages, low cost, low toxicity, nonflammable and no environmental impact.
- Work net of CO_2 flow rate at 1300 kg/h in CO_2 power cycle is relatively low, therefore limiting the CO_2 production in this process. However, the increasing of work net can be increased by employing CO_2 flow rate.

This research was supported by Faculty of Engineering
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