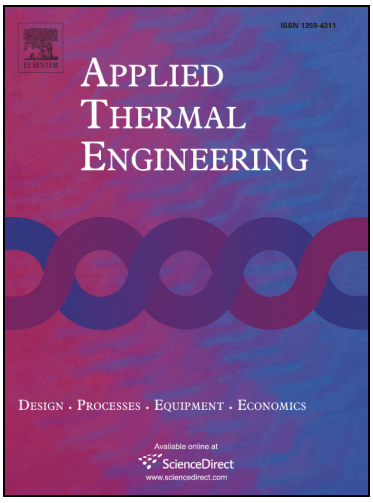

Research Paper

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PII: S1359-4311(17)37866-3
DOI: https://doi.org/10.1016/j.applthermaleng.2018.04.009
Reference: ATE 12006

To appear in: *Applied Thermal Engineering*

Received Date: 11 December 2017
Revised Date: 10 March 2018
Accepted Date: 2 April 2018

Please cite this article as: M. Santos, J. André, S. Francisco, R. Mendes, J. Ribeiro, Off-design modelling of an Organic Rankine Cycle micro-CHP: Modular Framework, Calibration and Validation, *Applied Thermal Engineering* (2018), doi: https://doi.org/10.1016/j.applthermaleng.2018.04.009

Off-design modelling of an Organic Rankine Cycle micro-CHP: Modular Framework, Calibration and Validation

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KEYWORDS
micro-CHP; Organic Rankine Cycle; Model; Off-design

ABSTRACT

A modular framework to model the steady off-design behavior of micro-CHP natural gas boilers based on Rankine technology is presented. The system charge integration into the model eliminates the use of any assumptions (i.e. subcooling, superheating, condensing pressure,…) which makes the presented model completely predictive. It is illustrated in the modelling a micro-CHP that satisfies the hot waters and central heating domestic needs (35 kW_t) and produces electricity (≤1.5 kW_e). A library of sub models of components with empirical (rotary vane pump and vapor scroll expander), semi-empirical (compact plates condenser) and spatially detailed physical (gas burner and evaporator) models is used to construct a model, using R-245fa as thermal fluid.

The model is calibrated and validated in tests in which 0.1 kg/s of water was heated from 20 °C to 30–36 °C, and 80–500 W mechanical power was delivered at the expander shaft, sweeping restrict ranges of three control variables: burner thermal power of combustion (10–14.5 kW_t), pump (500–740 rpm) and expander (2500–2750 rpm) rotation speeds. The model predicts most output variables with acceptable errors, e.g., less than ±10% for the expander outlet pressure (190–220 kPa,abs) or the temperatures at the outlet of the evaporator (80–150 °C) or the expander (60–120 °C).

NOMENCLATURE:

Symbols:

A	Area (m^2)
C	Heat capacity rate (W/K)
c_p	Specific heat (J/kg·K)
D	Diameter (m)
F	F Factor
f	Friction factor
g	Constant gravity acceleration (m/s^2)
G	Mass velocity ($kg/s \cdot m^2$)
h	Specific enthalpy, (kJ/kg)
K	Thermal conductivity (W/m·K)
L_p	Length of plates of the CHE (m)
M	Molar mass (kg/kmol)
$\dot{m}$	Mass flow rate (kg/s)
N	Rotational Speed (rpm)
N_p	Number of plates of the CHE
Nu	Nusselt Number
p	Pressure (kPa, abs.)
P	Power (W)
p_{co}	Wavelets step distance of CHE plates (m)
Pr	Prandtl Number

Greek Letters:

α	Pump displacement (m^3)
β	Chevron angle of the plates of the CHE
δ	Excess air ratio of combustion
ε	Heat exchanger efficiency
η	Efficiency (various types)
ρ	Density (kg/m^3)
μ	Dynamic viscosity (Pa·s)

Subscripts:

a	ambient
ad	adiabatic
b	burner
c	combustion
e	electric
f	thermal fluid
g	natural gas
gq	burnt gases
h	hydraulic
in	inlet