Heat Mass Transfer
DOI 10.1007/s00231-014-1375-4

ORIGINAL

Thermodynamic and heat transfer analysis of heat recovery from engine test cell by Organic Rankine Cycle

Naser Shokati · Farzad Mohammadkhani ·
Navid Farrokhi · Faramarz Ranjbar

Received: 18 April 2013 / Accepted: 5 May 2014

Abstract During manufacture of engines, evaluation of engine performance is essential. This is accomplished in test cells. During the test, a significant portion of heat energy released by the fuel is wasted. In this study, in order to recover these heat losses, Organic Rankine Cycle (ORC) is recommended. The study has been conducted assuming the diesel oil to be composed of a single hydrocarbon such as $C_{12}H_{26}$. The composition of exhaust gases (products of combustion) have been computed (and not determined experimentally) from the stoichiometric equation representing the combustion reaction. The test cell heat losses are recovered in three separate heat exchangers (preheater, evaporator and superheater). These heat exchangers are separately designed, and the whole system is analyzed from energy and exergy viewpoints. Finally, a parametric study is performed to investigate the effect of different variables on the system performance characteristics such as the ORC net power, heat exchangers effectiveness, the first law efficiency, exergy destruction and heat transfer surfaces. The results of the study show that by utilizing ORC, heat recovery equivalent to 8.85 % of the engine power is possible. The evaporator has the highest exergy destruction rate, while the pump has the lowest among the system components. Heat transfer surfaces are calculated to be 173.6, 58.7, and 11.87 m^2 for the preheater, evaporator and superheater, respectively.

List of symbols

A_{fr}	Frontal surface (m^2) (Eq. 7)
A_i	Inner surface (m^2)
A_o	Outer surface (m^2)
A_{op}	Heat transfer surface for each pass (m^2) (Eq. 16)
A_{ph}	Preheater heat transfer surface (m^2)
A_{tp}	Evaporator heat transfer surface (m^2)
A_{sh}	Superheater heat transfer surface (m^2)
A_w	Wall surface (m^2) (Eq. 20)
C	Heat capacity ratio (Eq. 32)
C_{min}	The smaller value of heat capacity rate for hot and cold fluids (kW/K)
C_{max}	The larger value of heat capacity rate for hot and cold fluids (kW/K)
c_p	Specific heat at constant pressure (kJ/kg K)
D_h	Flow passage hydraulic diameter (m) (Eq. 9)
D_i	Inner diameter of tubes (m)
EPC	Exergy performance coefficient
E, S, F	Correction factor (Eqs. 17, 29)
$\dot{Ex}_D$	Exergy destruction rate (kW)
$\dot{Ex}_{D,tot}$	Total exergy destruction rate (kW)
$\dot{Ex}_{in}$	Rate of exergy transfer into a control volume (kW)
$\dot{Ex}_{out}$	Rate of exergy transfer out of control volume (kW)
$\dot{Ex}_{ch}$	Chemical exergy rate (kW)
$\dot{Ex}_{ph}$	Physical exergy rate (kW)
G	Mass flux (kg/m^2 s) (Eq. 9)
h	Enthalpy (kJ/kg)
h_0	Enthalpy at dead (environmental) state (kJ/kg)
H	Convective heat transfer coefficient (W/m^2 K)
H_i	Convective heat transfer coefficient at the inner surface (W/m^2 K)

N. Shokati (✉) · F. Mohammadkhani · F. Ranjbar
Faculty of Mechanical Engineering, University of Tabriz,
Tabriz, Iran
e-mail: N_shokati@tabrizu.ac.ir

N. Farrokhi
Department of Mechanical Engineering, Ilkhchi Branch, Islamic
Azad University, Ilkhchi, Iran