Applied Thermal Engineering 37 (2012) 249–257

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

# A novel process for engines or heat pumps based on thermal-hydraulic conversion

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ARTICLE INFO

*Article history:*
Received 8 June 2011
Accepted 14 November 2011
Available online 22 November 2011

*Keywords:*
Carnot cycle
Rankine cycle
Liquid piston
Reversible process
CHP
Trigeneration

ABSTRACT

A novel concept for heat engines or heat pumps is presented. The cycle followed by the working fluid is very similar to the Carnot cycle (reverse or engine). However, the isothermal steps of the cycle are achieved by the liquid/vapour phase change of the working fluid, like in the Rankine cycle. The work exchange involved during each step is realised by the alternating movement of an inert liquid, which acts as a liquid piston. This work-transfer liquid flows either through a hydraulic motor (for the engine mode) or through a hydraulic pump (for the heat pump mode). This intermediary hydraulic fluid avoids the main irreversibility inherent to conventional engines or heat pumps. The estimated performances of the engine (efficiency) and heat pump (COP) are very high and close to the corresponding Carnot efficiencies. An example of trigeneration (Combined Cooling, Heating and Power) using thermal solar energy at a low temperature (70 °C) and R-1234yf as a working fluid is given. This scenario requires associations between basic thermal-hydraulic elements (e.g., the engine or heat pump), such as a thermal cascade or mechanical coupling.



## 1. Introduction

In December 2008, the European Union adopted a roadmap to fight against climate change. The objectives for the year 2020 of the "Energy-Climate" package are a 20% reduction in greenhouse gas emissions, a 20% improvement in energy efficiency (in both cases compared with the year 1990) and a 20% share for renewables in the EU energy mix. The residential-tertiary sector is the main consumer of final energy to cover the needs for heating, domestic hot water (DHW), air conditioning and electricity. For example, in France in 2009, this sector represents 44% (156 Mtoe) of the final energy consumption. Of the final energy, 50% is supplied by fossil fuels (oil, gas), 36% is supplied as electricity and 14% is supplied by renewable energy off power (solar thermal, biomass, heat pump) [1]. The combined heat and power (CHP) generation near the location of consumption, particularly in the residential sector (micro-CHP), is relevant compared with that of a centralised system of power production because

- Coproduced resulting heat is recovered.
- Electricity network losses are avoided [2].
- The peak power consumptions, which are particularly disadvantageous and risky for the grid in winter, are attenuated. The effect is positive for $CO_2$ production, even if the primary energy of the CHP is fossil [3], *a fortiori* the effect is positive with renewable energy [4].

Consequently many studies have focused on micro-CHP systems. In particular, they compare the performances of various engines on the market (based on internal combustion, micro-turbine, Stirling cycle or fuel cell) [5,6] to assess the impact of thermal storage and a house type (standard or passive) [7], or they study economic viability based on the varying heating and cooling needs depending on the season [8]. The electrical efficiency is the main performance criterion. It varies between 12% and 27% for electric power between 1 and 10 kW [6].

*A priori*, as the temperature of the hot source increases, the electrical efficiency improves. Moreover, the exergy efficiency depends strongly on the efficiency of heat transfer between the source and heat sink on one side and the working fluid on the other. Thus, the gas cycles (internal combustion, Brayton, Stirling, Ericsson) are favoured on one side because they use heat at high temperature, but they are at a disadvantage on the other side because the heat transfer coefficients with the working fluid are low. Conversely, steam cycles (such Rankine) have excellent heat transfer coefficients (because of the phase change between liquid and vapour) but are limited by the critical temperature of the

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doi:10.1016/j.applthermaleng.2011.11.026