EVAPORATOR HEAT-TRANSFER MODEL AND THERMAL DEGRADATION ANALYSIS OF R245FA USED IN A DIRECT VAPORIZATION ARRANGEMENT ORC BASED MICRO-CHP SYSTEM

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ABSTRACT

Combined heat and power systems (CHP) can be implemented within all power scales, even at micro-scale where the most promising target lies in the residential sector given the huge dimension of the potential market. At this scale, and for solutions attempting to retrofit wall-mounted combi-boilers, the Organic Rankine Cycle (ORC) appears to be the most promising technology because of its simplicity and available components. Among those components, the evaporator is the only one that, due to its specificities, cannot be found directly in the market or easily adapted from a mass production part of other appliances. Therefore, almost all industrial or academic researches made are implementing an intermediate circuit between the primary energy source and the ORC. One of the reasons why researchers are using this intermediate circuit, where the heat-exchanger is not directly exposed to hot combustion gases, is connected to the thermal degradation of the organic fluid. Nevertheless, besides the common design features (e.g. efficiency or safety), the residential system should also be small, safe and cheap which appears to be easier achieved using a direct vaporization arrangement.

This work presents a designed ORC-evaporator that uses the high-temperature combustion gases to vaporize an organic fluid – R245fa. The direct ORC-evaporator is integrated into a real ORC based micro-CHP system to analyze the organic fluid regarding its thermal degradation. The operating conditions of the micro-CHP system do not demand higher temperatures than the ones specified in literature for R245fa thermal degradation (≈ 300 ºC). However, the heat-exchanger is submitted to hot combustion gases and so the thermal boundary layer temperature will have higher values. Nonetheless, there is also the possible occurrence of hot spots in the heat-exchanger due to trapped vapor bubbles in its inside, increasing its temperature until the chemical breaking point. Considering both questions, the goal is to recover the organic fluid after several hours of operation at the system's maximum temperature and submitted it to a gas chromatograph analysis. Additionally, a heat-transfer model of the designed ORC-evaporator (experimentally validated) is also described to support the conclusions. Variables like thermal boundary layer temperatures and convection heat-transfer coefficients are key outputs of this model.