Proceedings of the 9th World Congress on Mechanical, Chemical, and Material Engineering (MCM'23)
Brunel University, London, United Kingdom –August 06-08, 2023
Paper No. HTFF 116
DOI: 10.11159/htff23.116

The Effect Of The Thermal Boundary Layer Over The Organic Fluid Chemical Integrity In Micro-Scale ORC-Evaporators

João S. Pereira, Joel Morgado, José B. Ribeiro
Univ Coimbra, ADAI, Department of Mechanical Engineering, Coimbra, Portugal
joao.pereira@dem.uc.pt

Extended Abstract

Organic Rankine cycles have the potential to be implemented at a micro-scale and to fulfil the technological gap that is preventing the retrofit of the wall-hang residential combi-boilers by cogeneration systems. Such ability requires the use of high-temperature combustion gases to vaporize the organic fluid and needs to deal with the risk of its thermal degradation. Limits to the fluid bulk temperatures are well known and easily controllable, nevertheless, the relevance of the thermal boundary layer and the temperature of the heat-transfer surfaces over the thermal degradation must be considered and deeply analyzed because of the significant temperature differences between the combustion gases and the organic fluid.

Starting by understanding the thermal degradation temperature limits presented in the literature, an extensive and updated review of the most relevant works were presented in this work. The review allows identifying that i) most of the thermal degradation temperature values were determined using static tests (which represent operating conditions that are far from reality) and ii) the existence of a significant discrepancy in the degradation temperature values presented for the same working fluid. There is no specific justification in the literature for these differences but is believed that those are associated with two factors: the actual time and the effective temperature that a molecule of the fluid is retained in a specific condition above its stability limit. This means that the fluid is above the degradation limit for only a reduced part of the test duration, as well as only a fraction of it will probably be above that threshold (due to the existence of a thermal boundary layer). Therefore, the thermal degradation analysis made must be carefully defined because it should be also associated with the time that the fluid is kept above the degradation limit, especially in dynamic tests (which represent operating conditions close to reality) from which the fluid circulates between the different components of the cycle. Because of thermal degradation uncertainties, the ORC cycles with direct vaporization have been disregarded since the maximum temperatures reached in the evaporator, which limits the whole operation, are also being unsubstantiated limited by the organic fluid degradation temperature found in the literature (that was obtained for situations far from the reality). Taking this into account, one of the main objectives of this work is to quantify the thermal boundary layer of a real direct vaporization ORC-evaporator in order to understand the distribution of temperatures inside it and identify the amount of fluid subject to temperatures higher than those defined in the literature as being safe in terms of the risk of degradation. Additionally, this analysis is coupled with the realization of dynamic thermal stress tests that include the experimental evaluation of the organic fluid thermal degradation in an attempt to offer a first insight into the study of the effect of the thermal boundary layer on the organic fluid chemical integrity.

Acknowledgements

In association with the authors' host institutions, this research was also supported by the Portuguese Recovery and Resilience Plan (PRR) and Next Generation European Funds EU through the project Transform nº 34 of the agenda n.º 02/C05-i01/2022 under the work package 2 "Green Operations and Logistics". The financial support is gratefully acknowledged.

PRR Plano de Recuperação e Resiliência
REPÚBLICA PORTUGUESA
Financiado pela União Europeia NextGenerationEU