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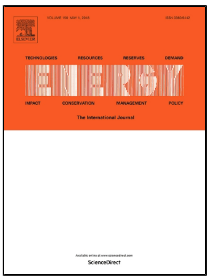

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Dimensionless correlations and performance maps of scroll expanders for micro-scale Organic Rankine Cycles

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In the endeavor towards distributed power systems, not seasonal-dependent micro-power generation technologies are expected to integrate the energy scenario in the years to come. In this context, the Organic Rankine Cycle (ORC) in the (1-10) KWe scale has chronically lacked a suitable expansion device, hindering its market attractiveness. As scroll expanders have been pointed out as strong potential candidates, performance correlations and pre-design maps based on a review and analysis of published experimental data are presented. A dimensionless approach based on the traditional Ns, Ds dimensionless numbers stemming from turbomachinery has been chosen for greater generality. In addition, the lubricating oil mass fraction effect on the scroll expander performance has been included. The generated maps contribute to accelerating the pre-design phases at the system and component level with beneficial effects for the overall development process. Basic geometry and size characteristics are considered as well, acknowledging their importance in micro-power embedded applications; these considerations are illustrated in a passenger car waste-heat recovery case study. Findings suggest that optimized scroll expanders may potentially reach very interesting nominal electric isentropic efficiencies (up to 80% for an oil lubricated scroll expander).

Introduction

Decentralized energy conversion is growing more and more since it is needed for transitioning towards low-carbon energy systems [1]. In this context, the significant potential of micro-power generation (<10kWe) based on low-temperature heat sources has been identified by various authors [2–5], while the Organic Rankine Cycle (ORC) has been widely studied and recognized as one of the leading candidates for such tasks [6–9]. Literature considers the expander device as one of the key technologies for both performance and commercial success of micro-scale ORC [10–14]. Hence, considerable attention has been paid to expanders [15,16], in particular to piston, rolling piston and scroll expanders. Piston and rolling piston expanders, although inexpensive, are mainly penalized due to the requirement of check valves and a limited lifetime. The scroll technology has received significant attention in research in recent years, reinforced by its success as a compressor in the refrigeration and air-conditioning industry. Since it is being mass produced already for these markets, this clearly proves its feasibility also in terms of cost [17,18]. Further, the scroll technology offers interesting volume ratios and efficiencies while maintaining acceptable manufacturing complexity [14,16,19].

Scroll systems can be classified according to several criteria. In terms of the relative motion between scroll involutes, the co-rotating and orbiting mechanisms are to be distinguished. In co-rotating scrolls, the two involutes rotate in a carefully synchronized manner. In the orbiting scroll case, one of the scroll plates remains stationary while the other follows an orbital motion. Co-rotating scroll machines have lagged behind orbiting scrolls in the compressor scroll market due to a series of technical difficulties mainly associated with the synchronization of the scroll volutes [20]. However, they are still a subject of research and study, in particular due to their tolerance to liquid injection [21]. In terms of the driving type: direct-