NON-CONSTANT WALL THICKNESS SCROLL EXPANDER INVESTIGATION FOR A MICRO SOLAR ORC PLANT

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ABSTRACT

Scroll machines, commonly used as compressors, present relevant advantages working in reverse as expanders in small scale ORCs. While most scroll geometries in industrial applications exhibit a constant wall thickness profile, the purpose of this work is to investigate non-constant wall thickness geometries for scroll expanders (especially geometries with a decreasing wall thickness profile) and design an optimal geometry prototype for use in a micro solar ORC plant. The benefits of tapering wall thickness (in proportion to the internal forces during expansion) include higher isentropic efficiency and increasing compactness [1].

Non-constant wall thickness geometries are generated using an 8-dimensionnal planar curve frame developed by Gravensen and Henriksen [2]. From Cartesian coordinates of the scrolls, a geometric model in Matlab [3] computes all geometric features required during a complete rotation of the orbiting scroll. Once these geometric data are computed, a thermodynamic code in Matlab [3] models deterministically the expansion during a full rotation of the orbiting scroll. This thermodynamic model explicitly treats the following phenomena:

- Mechanical losses into thrust and journal bearings and friction losses between scrolls.
- Ambiance heat losses (lumped model)
- Flank and radial leakages inside the expander
- Under and over expansion as a function of the operating conditions

The deterministic thermodynamic model represents the working fluid enthalpy, pressure, entropy and temperature profiles for each expansion pocket during a full rotation of the orbiting scroll, from which the isentropic and volumetric efficiency of the expander can be known.

As described in [1], the isentropic efficiency of a scroll expander can be related to the compactness factor (defined as the volumetric ratio divided by the scroll diameter). In order to evaluate the minimum acceptable thickness profile for a viable scroll geometry, the thermodynamic model compares the maximum pressure difference profile along the scroll wrap to a constraint defined as the maximum permissible deflection of the wall (5µm, computed from beam theory).

To select a scroll geometry for an ORC expander prototype, we treated a database of several hundreds of thousands geometries and selected those that best meet the following criteria: correct volumetric ratio, high compactness factor and a thickness profile as close as possible of the minimum one required. This process produced thirteen geometries including

decreasing, constant and increasing wall thickness geometries. Our comparison study reveals a higher isentropic efficiency for decreasing wall thickness geometries.

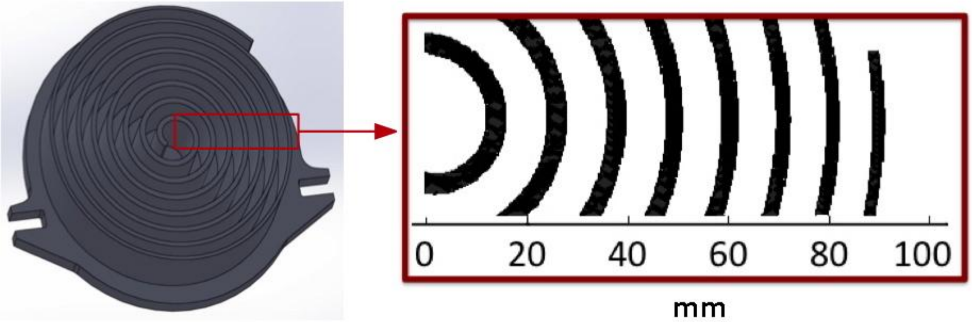

Fig 1. Example of a decreasing wall thickness scroll geometry

The highest performing scroll geometry is developed into a CAD model within Solidworks. Prototype efforts underway include 3D printing the scroll expander to check viability of the architecture, while components will be CNC machined from P20 tool steel to obtain a full scale scroll expander of 3-5kWe nominal output with working fluid R245fa and vaporization at 135°C. This expander can be tested on a micro-concentrating solar power (CSP) ORC facility (100m^2 parabolic trough collector) at Eckerd College in St. Petersburg FL.

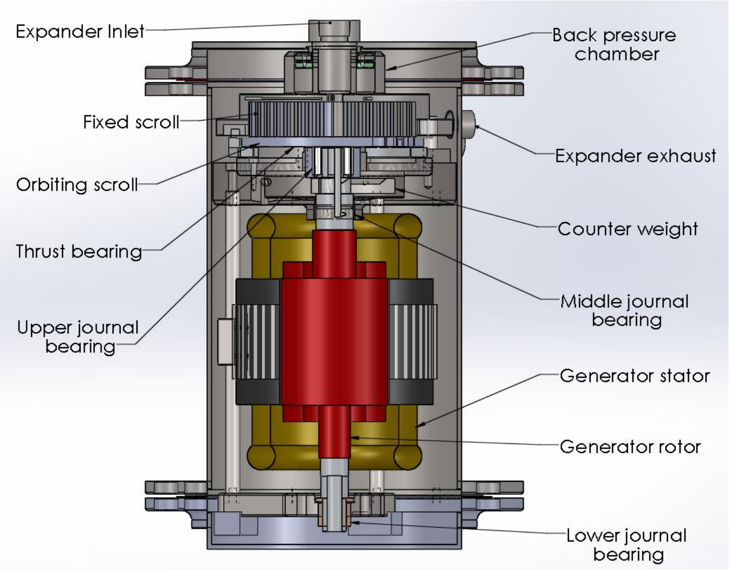

Fig 2. Overall architecture of the prototype

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[1] Matthew S.Orosz, Amy V. Mueller, Bertrand J.Dechesne, and Harold F. Hemond. “Geometric design of scroll expanders optimized for small organic rankine cycles”

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[3] Bertrand Dechesne, 2012, “Designing a Scroll Expander for a Micro-Solar PowerPlant” S.M. thesis, University of Liege, Belgium.