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CFD Analysis of a Lab-Scale Prototype Two-Phase Fluid Flow Scroll Expander

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Extended Abstract

The main target of the project REGEN-BY-2 Horizon 2020 is to develop a lab-scale prototype of a plant for the exploitation of renewable thermal energy sources. The lab-scale plant prototype exploits a highly efficient thermodynamic cycle that integrates Carnot cycles working with fluid in two-phase flow conditions. The objective of this work is to numerically investigate the two-phase fluid flow in a newly designed two-phase scroll expander operating in the plant. Numerical simulations provide a solid and reliable tool for the design of Positive Displacement (PD) machines. In the REGEN-BY-2 Horizon 2020 project, the company EXOES initially designed a two-phase scroll expander, and the design was later improved by the National Technical University of Athens (NTUA) based on the results of numerical simulations that were carried out utilizing a deterministic model (DM) available in the literature [1]. Since the DM relies on several simplifying assumptions, such as homogeneous flow and property distribution of the working fluid in the expansion chambers, detailed numerical investigations of a two-phase scroll expander are still necessary for an accurate analysis of the multiphase flow phenomena that occur while the machine is operating and for the realization of the final design of the machine. To this end, we developed an in-house Cavitating Dynamic Mesh Solver (CDMS) that can predict the multiphase flow phenomena inside the working chambers of the expander. The solver is based on the Homogeneous Equilibrium Model (HEM) [2] with barotropic closure [3] and considers mesh motion and mesh topology changes. On the one hand, we generated dynamic grids of the orbiting turbomachine using the OpenFOAM® utility *blockMesh* which allows for creating meshes with multiple blocks. On the other hand, we utilized the Arbitrary Coupling Mesh Interface (ACMI) to connect adjacent mesh domains, since this OpenFOAM® utility is particularly suitable for rotating geometries. The key numerical assessments of the two-phase scroll expander in the present investigation are the velocity and the pressure distribution, vapor condensation, and liquid evaporation phenomena, the average inlet and outlet mass flow rates, and the isentropic and volumetric efficiencies. Those are crucial to identify whether the machine is working under overloaded conditions, or the working fluid causes severe vibrations. The average inlet and outlet mass flow rates, the volumetric efficiency, and to a lesser extent the adiabatic efficiency obtained numerically, are in very good agreement with the results of the DM employed by NTUA, especially considering the simplifications and assumptions used to develop the DM. In addition, the distribution of pressure and velocity inside the chambers of the expander is qualitatively in good concordance with the outcomes of similar numerical studies of single-phase scroll expanders available in the literature [4-6]. The obtained results indicate that the expander prototype has a significantly high adiabatic efficiency, while there is a small potential for improving the volumetric efficiency.

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