Development of a rotary chamber compressor for use in the air cooling process

Further development of a rotary chamber machine based on Schukey technology

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In Short

- Development of a novel rotary chamber machine based on Schukey technology.
- Transient CFD simulations
- Moving and highly deformed meshes

Climate change and the associated higher peak temperatures, especially in Europe, increasingly require the air conditioning of workspaces, homes and houses. As already decreed by the European Commission in EU Regulation No. 517/2014 (F-Gas-V) [1] "on the regulation of fluorinated greenhouse gases", the use of air-conditioning systems containing CFCs or other refrigerants with a greenhouse effect is to be dispensed in the future. For this purpose, other environmentally friendly alternatives, e.g. the use of natural refrigerants, must be investigated.

The objective of this project is the development of a compact and economically efficient air conditioning system for room air conditioning using the natural refrigerants air and water. The use of air or water as a working medium represents a non-toxic and environmentally friendly alternative that can sustainably protect the ozone layer. The project thus contributes to the reduction of fluorinated greenhouse gas emissions and to climate protection. The project also investigates the suitability of the technology described below for generating energy from residual renewable energy sources.

As a basis for this application, the Schukey technology further developed at the Institute for Process Engineering, Energy Technology and Climate Protection (IVEK) was modified for the demanding application and a compact new cooling machine was set up on the laboratory scale and tested under real conditions. The technology is a compressor/expander system, hereafter referred to as a rotary chamber machine, in which the working medium can be compressed and expanded for the process-related steps of the refrigeration machine.

The rotary chamber machine is based on two intermeshing rotors, each with four blades, which perform a phase-shifted motion relative to each other by means of special toothed or eccentric gears (see Fig.1). Both rotors rotate in the same direction and are driven by a common main shaft. While one rotor accelerates, the other rotor decelerates and vice versa. This results in volume pulsation between the vanes, which form the working chambers of the machine where the suction and compression of the working fluid takes place. The changing angular velocities of the rotors and the working chambers are shown over one main shaft revolution in Fig.2.

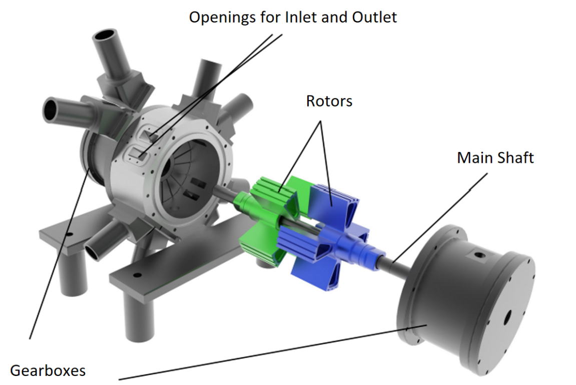

***Figure 1:** Structure of the rotary chamber machine with its main components*

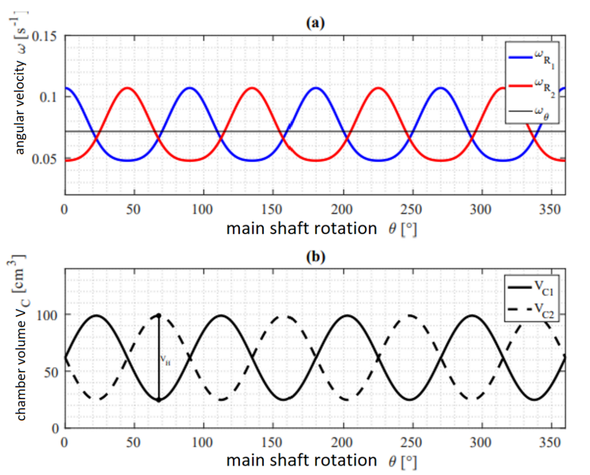

***Figure 2:** (a) Angular velocities of rotors $\omega_{R1,R2}$ and main shaft ω_N=const., (b) chamber volume profile V_C during one main shaft revolution.*

A total of 32 working cycles take place in one main shaft revolution. These ensure a high volume throughput, which is necessary for the circulation with natural refrigerants. The machine continues to operate oil-free and without valve mechanisms according to the slide-valve principle, and is thus characterized by low-maintenance operation over the long term. The operational requirements and optimization potentials of the machine are supported by numerical calculations and simulations with a commercial CFD solver (Computational Fluid Dynamics) (cf. figure 3) in order to obtain more detailed knowledge of the physical phenomena taking place and to optimize the machine according to its key performance indicators.

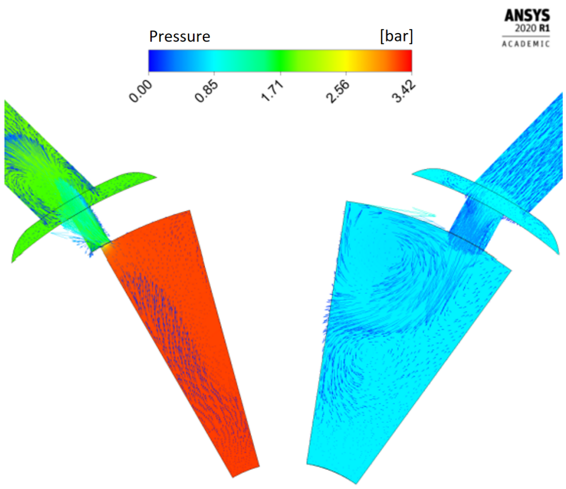

Figure 3: *Simulated pressure and velocity distribution during the inlet and outlet process in the working chambers (left outlet, right inlet).*

For the calculation of the highly transient flow behaviour occurring in the machine, high spatial and temporal resolutions are necessary. In addition, the description of the pulsating working chambers according to the function in Fig.2, which are described by moving meshes, is required. The distortions of the moving meshes cause a difficult convergence behaviour, which makes a high resolution indispensable for the compliance with the topology. Therefore, meaningful parameter studies can only be computed on clusters due to the high computational capacity required.

In previous work [2], extensive CFD parameter studies have been successfully implemented using the computational capabilities of HLRN. More than 50 design points with a computing time of 11 hours each were computed in parallel on several nodes in a few days.

A PhD thesis [3] prepared as part of the project provided data on efficient operating parameters, key performance indicators and the main optimization variables. The study showed that the delivery efficiency of the present prototype is strongly speed dependent, with a local maximum of 86.8% at a speed of 1200 rpm. The numerical investigations also show that increasing the blade widths and thus reducing the dead space has a positive effect on the above-mentioned key parameters. Employing the CFD calculations for guidance, experimental measurements for operation as a compressor were successfully collected, validated and presented [4].

To achieve higher efficiencies and fluidic optimizations within the inlet and outlet ducts, further development of the compressor is necessary. Currently, due to increased compactness, the outlet and inlet pipes are to be combined into one outlet and one inlet pipe. This requires geometric changes that preclude periodicity of the model, necessitating simulation of a full-circle model, which requires four times the computational capacity.

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More Information

[1] Regulation (EU) No 517/2014 of the European Parliament and of the Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006,OJ L 150, 2014, S. 195-230. http://data.europa.eu/eli/reg/2014/517/oj

[2] B. Cui, et al., *Parametric Studies On A New Schukey Type Rotary Compressor*, 25th International Compressor Engineering Conference at Purdue, Purdue, 2021. https://docs.lib.purdue.edu/icec/2675/

[3] B. Cui, *Experimentelle und numerische Analyse eines Rotationskammer (RC) - Verdichters zur Anwendung im Luftkälteprozess* , TEWISS, 2022 https://www.isbn.de/buch/9783959007566

[4] M. Gottschlich *Parametric Studies On A New Schukey Type Rotary Compressor @CADFEM Conference 2024* , Darmstadt, 2024. https://www.cadfem.net/de/de/cadfem-informiert/veranstaltungen/cadfem-conference-2024

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