HSLU Lucerne University of Applied Sciences and Arts

Engineering and Architecture
BSc. Energy and Environmental Systems Engineering
Bachelor-Thesis

Modern Vane Design for Real Gas Centrifugal Compressor

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Industry Partner: Teqtoniq GmbH

1. Background, Challenge & Objectives

Background
The project focuses on analyzing a tandem vane design for the return channel of a real gas centrifugal compressor using R1234ze refrigerant. Switzerland's aim to achieve zero greenhouse gas emissions by 2050 necessitates the transition to CO2 neutral heat production, such as heat pumps. The industry partner has developed a two-stage centrifugal compressor for refrigeration systems and heat pump applications. Ensuring the precise alignment of flow between stages is crucial, highlighting the necessity of this project.

Challenge
The vanes in the return channel play a significant role in removing swirl and improving efficiency. Previous simulations identified flow separation and suboptimal flow before the second stage, highlighting the need for a new vane design, making this project essential.

Objectives

1. Provide quantitative results of a tandem design of the vanes
2. Reduce flow separation in the return channel of the centrifugal compressor
3. Perform an Adjoint optimization of the return channel

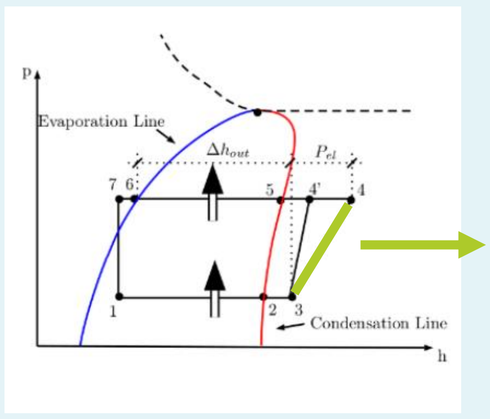

Figure 1: Heat pump p-h diagram

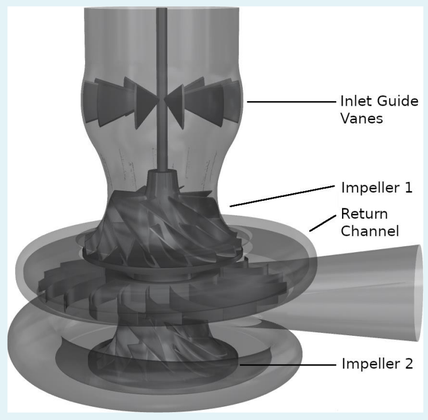

Figure 2: Centrifugal compressor

2. Methodology

Methodology

- An in-house computational fluid dynamics (CFD) software is used for the simulations.
- An adapted and improved existing Python script is used for the post-processing of the results.
- An in-house developed Adjoint optimizer is used for improving the flow

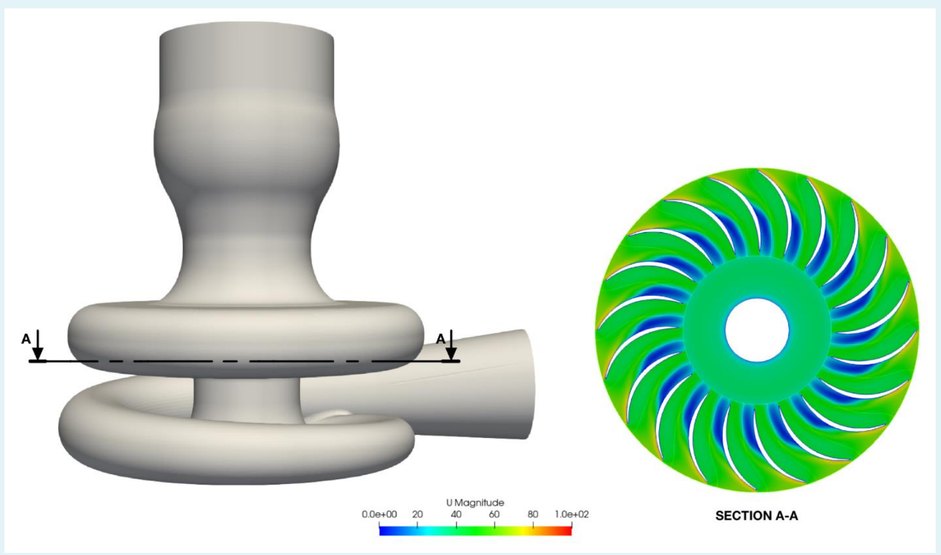

Figure 3: Flow separation in the return channel of the compressor

3. Results

Tandem Vane Results
The results of CFD performed on the initial tandem vane design show reduced flow separation, but it is not completely removed.

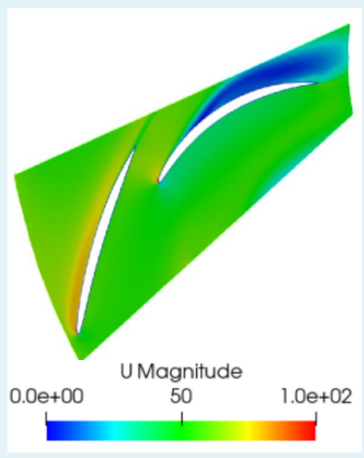

Figure 4: CFD results of the tandem vane design

Optimized Tandem Vane Results
The results from the Adjoint optimization performed on the tandem vane design shows further significant reduction in the flow separation.

Figure 5: CFD results after performing an Adjoint optimization

4. Discussion, Conclusions & Future Research

Discussion
The analysis of the initial tandem vane design revealed reduced flow separation, but it was not completely eliminated. However, through Adjoint optimization, the tandem vane design showed a significant further reduction in flow separation, indicating a potential for higher efficiency.

Conclusions
In conclusion, the analysis and optimization of the tandem vane design for the return channel of the centrifugal compressor demonstrated successful reduction of flow separation. Further refinements can be made to enhance the design and achieve an even greater reduction in flow separation.

Future Research

- Compare the results of this project to measurements on manufactured compressor

Literature

Hanimann, L., Mangani, L., Casartelli, E., Vogt, D., Darwish, M. (2020). Real Gas Models in Coupled Algorithms Numerical Recipes and Thermophysical Relations. International Journal of Turbomachinery, Propulsion and Power, 5(3), 20. https://doi.org/10.3390/ijtpp5030020

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