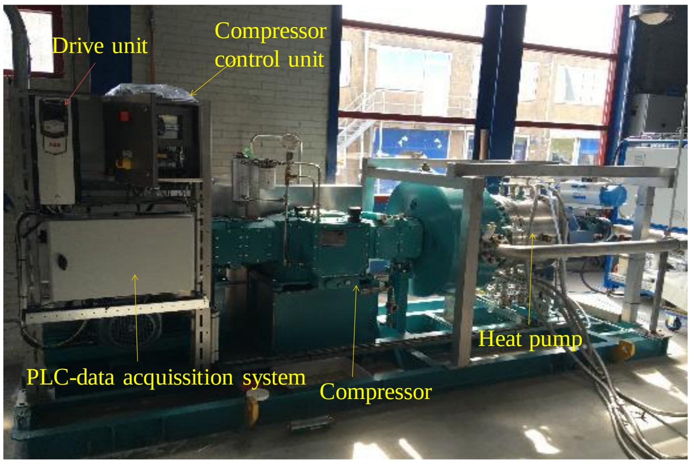
HEAT PUMP Project II

Dynamic Modelling of oscillating elastomer membrane

Heat is the predominant final energy carrier in industry, representing about 2/3 of final energy consumption. Process heat is currently produced by burning (natural) gas. Alternative carbon free heating systems are required to meet the industrial contribution to the climate objectives. This can be realized by high temperature heat pumps. However, these heat pumps are commercially not available. An electrically driven thermoacoustic heat pump can fill this gap. The reason is that a thermoacoustic heat pump can deliver heat up to a very high temperature (>200°C) and over a very wide range of temperatures with a fixed standardized design. A thermoacoustic heat pump uses a high intensity acoustic wave to pump heat. Carbon free industrial heating can be realized with application of the thermoacoustic heat pump when the future electricity supply is fully renewable. A project consortium (TNO, BHT, HTC, DOW, and ISPT) is currently further developing the compact thermoacoustic heat pump (COMTA concept). One crucial component in the heat pump is an oscillating (20 Hz) elastomer membrane.



COMTA thermoacoustic heat pump installed at TNO in Petten

In a thermoacoustic heat pump, this membrane improves the efficiency of the heat pump by suppressing the acoustic circulation of helium (DC flow). However, large membrane oscillations (much larger than average helium displacement) are likely to occur. This could result in unwanted contact with internal structures and the rupture of the membrane and/or high dissipation of mechanical energy and lower performance of the heat pump. A less elastic (or pretensioned) membrane could lower the unwanted oscillation; however, the acoustic losses could increase too much. BHT (Bronswerk Heat Transfer) is optimizing the membrane and looking for options to scale-up the membrane to larger dimensions for a full-scale heat pump.

Objective

A promising approach to optimising the elastomer membrane is to simulate its behaviour during service. This essentially requires dynamic modelling of the elastomer membrane under oscillation. Aiming at this, this assignment will focus on finite element modelling of the dynamic response of oscillating elastomer membrane, and the final simulation results will be used to provide an optimal design of the membrane. The outcomes from ***HEAT PUMP Project I*** may be used in this project as an input.

Assignment

To achieve the final objectives of this project, you are required to finish following tasks:

1. Conduct a comprehensive literature review on existing concepts and associating numerical models.
2. Establish a finite element model for the elastomer membrane to simulate its dynamic response under oscillation. Mesh sensitivity of the model should be minimised, and the accuracy of the model will be verified by comparison between the simulation results and experimental observations.
3. Use the model established in task 2 to simulate the behaviour of higher modes of oscillation, and to predict the amplitude.
4. Based on the finite element model, you will conduct a series of FE simulations to analyse the effect of thickness and diameter of the membrane on its dynamic response, and to evaluate the energy dissipation in the elastomer.

Report

The graduation report consists of literature review, finite element modelling, simulation of higher modes of oscillation, and analysis of the effect of membrane's thickness and diameter.

Partners

This project will be technically supported by Bronswerk. They will share experimental data, some details of current design, and so on.

Pre-requisite:

Finite element modelling (using ABAQUS).

Fundamental mechanics of elastomers and elastomeric composites (ESE and PEE course).

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