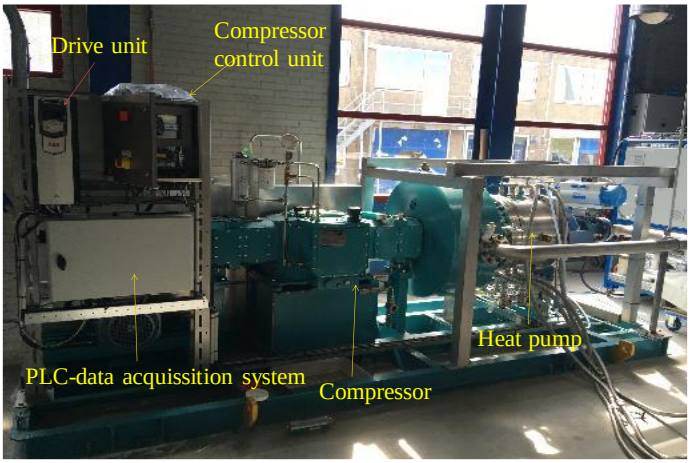
# HEAT PUMP Project I

## Experimental characterisation and constitutive modelling of 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

Understanding the constitutive behaviour of the elastomer that the membrane is made of is the basis to evaluate its mechanical response during service. In this assignment, you are required to select a suitable elastomer material for the membrane, and experimentally characterize its

constitutive behaviour. Also, you need to find out a suitable constitutive model that can accurately describe the elastomer's behaviour while accounting for mechanical losses during oscillation and dynamic response, and the final outcomes will serve as an input for the ***HEAT PUMP Project II***.

**Assignment**

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

1. Conduct a comprehensive literature review to specify suitable materials (preferably relative high temperature resistant, 150 - 200 $^{o}$C, negligible relaxation, negligible fatigue)
2. Perform a series of experiments to characterise the constitutive behaviour of the most suitable elastomer you selected in task one. Experiments include but are not limited to quasi-static and dynamic tensile tests, DMA tests and so on. The experimental data will be processed to derive the representative mechanical properties, such as tanδ and Young's modulus.
3. Search for a suitable constitutive model (such as hyper-elastic model, hyper-visco-elastic model) to describe the mechanical behaviour of the chosen elastomer. MATLAB codes may be needed to realise the computation of the constitutive model.

**Report**

The graduation report consists of literature review, experimental characterisation and analysis, discussion about constitutive models and numerical implementation of the chosen constitutive model.

**Partners**

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

**Pre-requisite:**

Experience of mechanical characterisation on elastomer materials.

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

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