ALBA EXPERIMENTAL SET UP FOR THE EVALUATION OF THERMAL CONTACT CONDUCTANCE UNDER CRYOGENIC AND VACUUM CONDITIONS

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Abstract

The Thermal Contact Conductance (TCC) between two surfaces plays a very important role in the design of components in particle accelerators. The TCC depends on many variables such as surface finish, type of material, pressure, temperature, etc. As a general rule, the TCC comes from experimental results reported in the specialized literature. However, it is not always possible to find this information, especially if components are designed to operate in cryogenic and vacuum conditions, for this reason, assumptions are made that render results with high uncertainty. In this context, ALBA has designed an experimental set up to carry out axial heat flow steady state experiments for the evaluation of TCC under vacuum and cryogenic conditions. The minimum pressure achievable in the set up will be 1e-5 mbar while the temperature may vary between 80 and 300 K. The results will provide inputs to further optimize ALBA designs, including ALBA II, our ongoing fourth-generation synchrotron upgrade project. This paper describes the experimental setup, the thermal and mechanical design considerations and experimental validation tests.

Introduction

Real engineering surfaces exhibit a complex three-dimensional landscape, characterized by peaks and valleys of diverse sizes and shapes. When two surfaces are pressed together, they touch each other at only limited discrete points separated by large gaps filled with an interstitial medium, such as air or a vacuum. Due to this, when heat travels across two surfaces, it encounters resistance in its transmission known as thermal contact and its inverse is known as thermal contact conductance (TCC).

TCC is defined as the ratio of the heat power (Q) per unit area (A) flowing across the interface and the temperature drop (ΔT) at the interface.

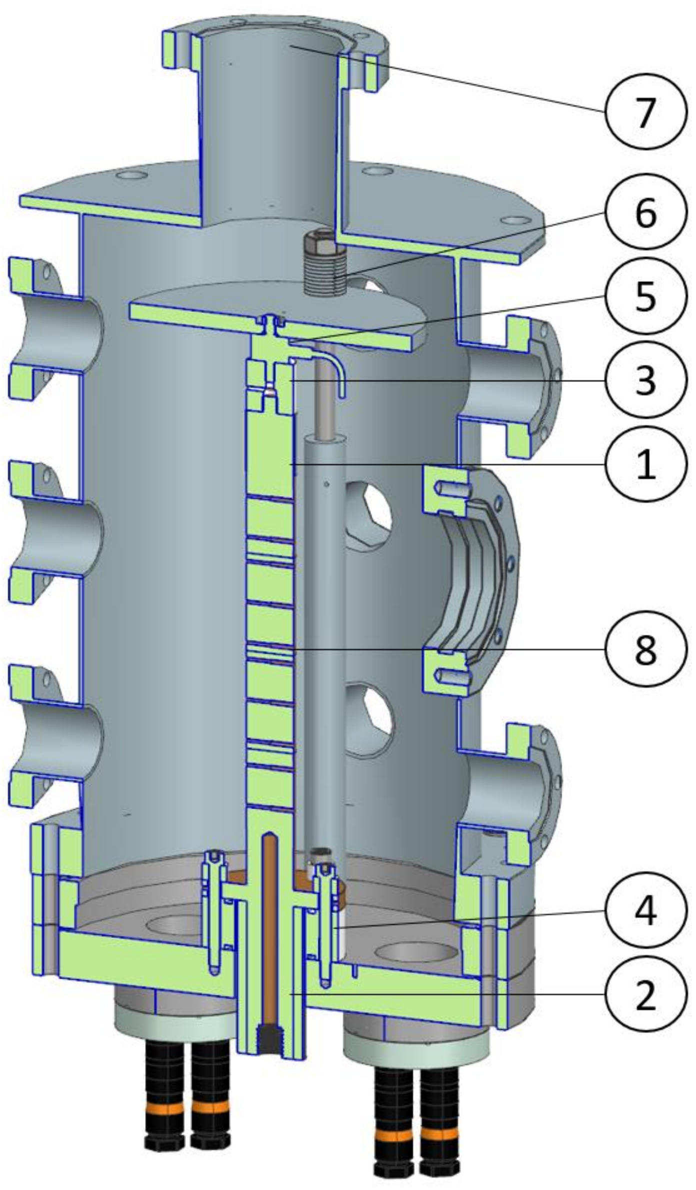
$$TCC = \frac{Q/A}{\Delta T} \qquad (1)$$

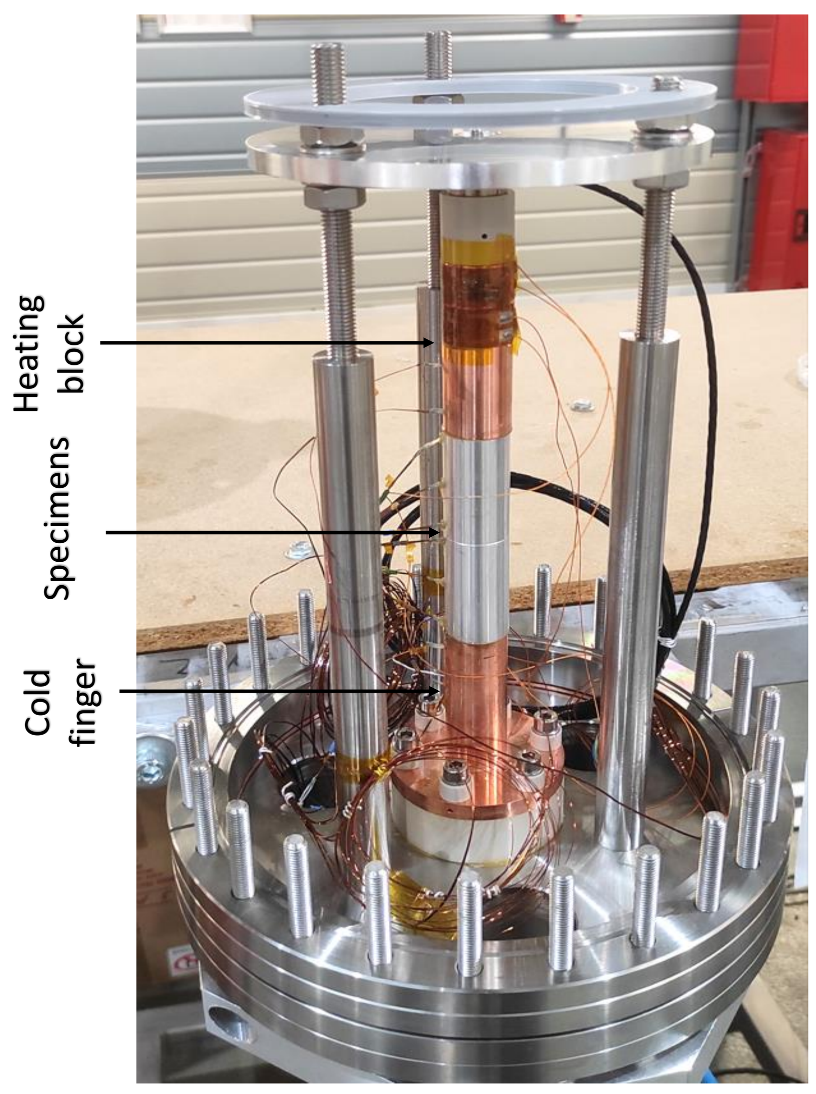
Experimental Set Up

The objective of the experimental unit is to measure the TCC between two samples when different contact pressures and temperatures are applied at the interface.

Description

The experimental setup consists of a heating block (1), a cold finger (2), an insulating block (3) an insulating ring (4), a load cell (5), a mechanical loading system (6), a vacuum system (7) and two specimens (8).





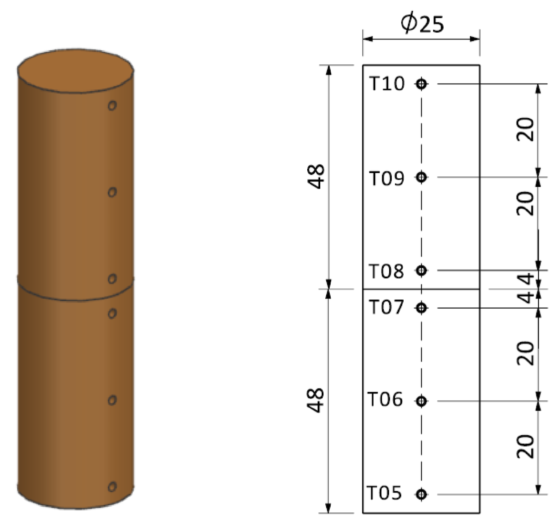
The upper specimen is heated from the top by the heating block, the lower specimen is cooled from the bottom by the cold finger. This arrangement generates a downward axial heating flow and a temperature gradient along the column with a drop at the specimens interface.

Evaluation test

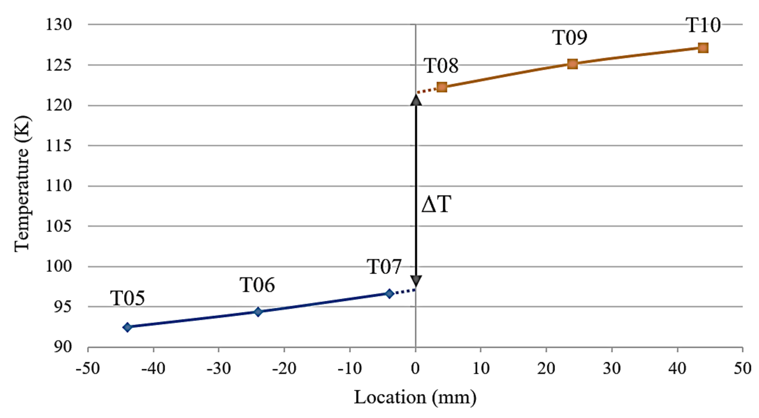
The experimental setup has been validated through the experimental study of a pair of specimens made of copper, at a vacuum level of 1·10-5 mbar.

Specimens

A pair of specimens has been fabricated in copper. Three holes have been drilled into each specimen at 20 mm intervals, but 4 mm away from the specimen ends.



Data acquisition



The temperature distribution along the length of the specimens is observed to follow a linear dependence with a drop at the interface (ΔT). By knowing heat flow across it (Q) and the interface area (A), the thermal contact conductance (TCC) can be calculated using the Eq. (1).

Results

Experiments were conducted varying the interface temperatures and pressure. It is observed that TCC increases with increasing temperature and pressure.

Pressure [Bar]	Cu-Cu TCC [W/m²·K]
0.2	1582
0.4	2618

Temperature [K]	Cu-Cu TCC [W/m²·K]
110	2422
147	2576
170	2674

Set-up evaluation

Steady-state heat flow was reached after 45 minutes of machine running. It was at this stage that the temperature variation in the sensors remained below 0.5 K every 10 minutes while a vacuum level of 1·10-5 mbar was reached after 15 minutes of operation and remained stable throughout the entire experiment.

Further development

The liquid nitrogen flow is controlled using a manual valve, leading to challenges in achieving and maintaining precise temperatures in the cold finger. To address this, a PDI-controlled liquid nitrogen flow system is planned to be installed. To identify and measure heat losses, we plan to install temperature sensors on the inner surface of the vacuum chamber to monitor temperature variations. Currently, data recording is done manually. We aim to automate this process; recording more data will enable us to assess uncertainties effectively.

Conclusions

An experimental set up for the evaluation of thermal contact conductance under cryogenic and vacuum conditions have been fabricated at ALBA. Test with pairs of copper specimens under different interface pressure and temperature had been carried out. The TCC at the interface of the specimens has been estimated by measuring the temperature across the specimen and the heat flux.
The experimental setup is prepared to evaluate the contact of new materials interfaces, of interest for our current designs, and especially for the new components of the ALBA II upgraded project.