Physica Advanced Peltier System PTD 150 (pat. pent.) Making the Temperature Control with a Peltier System Accurate

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Abstract:
A new Peltier system is introduced which offers new dimensions in temperature precision for parallel-plate and cone-and-plate measuring geometries in the temperature range from –30°C to +130°C. The use of an additional actively Peltier controlled hood (pat. pent.) reduces the temperature gradient across the sample to insignificant levels. The design allows easy access for sample loading and trimming as well as the use of inert gas or a solvent trap if necessary.

INTRODUCTION

Temperature control with a high precision is crucial to receive reliable rheological data, since for almost all samples the temperature has a great influence on the rheological behavior. Although this is a commonplace statement, in practical tests inaccurate temperature control is still responsible for a large number of measurement uncertainties and errors. The design of a temperature control unit for rheological tests has to fulfill three main tasks:

- To set and measure the correct absolute temperature,
- To maintain a constant temperature throughout the sample without any or almost no temperature gradient
- To produce no significant temperature overshoot during the control process

For various applications and temperature ranges different principles exist to control the temperature. Electrically heated systems are commonly used for polymer applications in the temperature range from + 50°C to + 400°C. Gas convection ovens cover the broadest temperature range from ambient up to + 600°C using air or nitrogen. The use of liquid nitrogen extends the range down to temperatures of –150°C. By proper engineering the electrically heated systems and the convection chambers can be designed to have a relatively small temperature gradient. However, a purely electrically heated system can not be operated below ambient temperature and has difficulties to work properly without a temperature gradient at temperatures just above the ambient temperature. That leaves the temperature range from - 30°C up to ambient temperature to the gas convection oven which needs liquid nitrogen to cover the lower part of this temperature range. However, a gas convection oven in combination with liquid nitrogen means larger handling efforts and is rather expensive.

Due to price and handling issues, a lot of rheometer users employ Peltier heated systems which consist of a Peltier heated bottom plate and sometimes a passive cover to measure in a temperature range of typically – 30°C to 150°C. However, this setup has the major disadvantage of a temperature gradient across the sample which will occur at temperatures other than room temperature.

The newly developed Physica Advanced Peltier System PTD 150 overcomes this limitation of standard Peltier setups by the additional use of an actively Peltier controlled hood and ensures minimal temperature gradients across the sample within the temperature range of – 30°C up to + 130°C. The PTD 150 combines the ease of use of a Peltier system with unmatched accuracy in temperature control.

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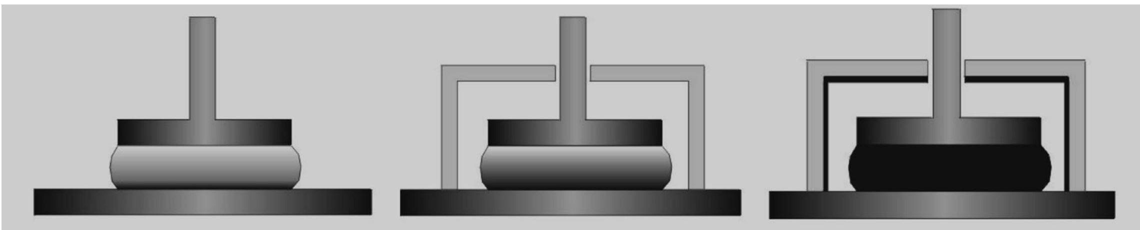
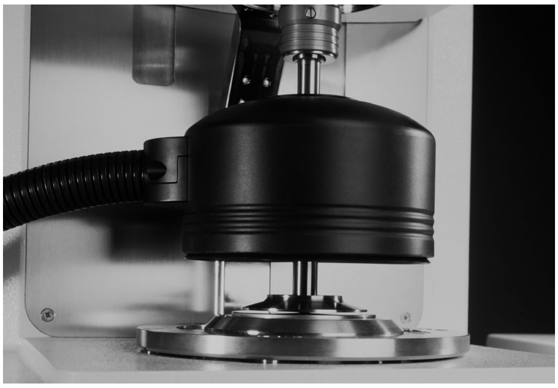
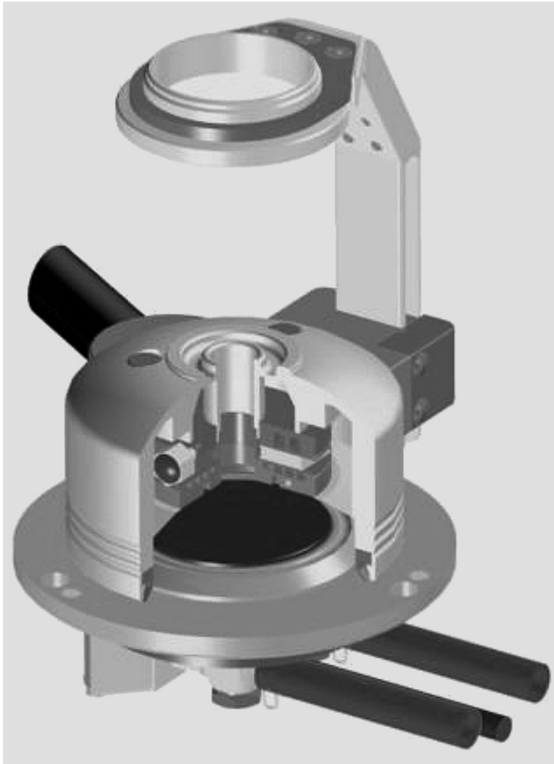
Figure 1 (above): Different setups of a Peltier system lead to differences in the temperature distribution across the sample: a) open system, b) system with insulating cover, c) Advanced Peltier System PTD 150 with an actively controlled hood.

Figure 2a (left below): Image of the Physica Advanced Peltier System PTD 150.

Figure 2b (right below): Sketch of the Physica Advanced Peltier System PTD 150.







PRINCIPLE

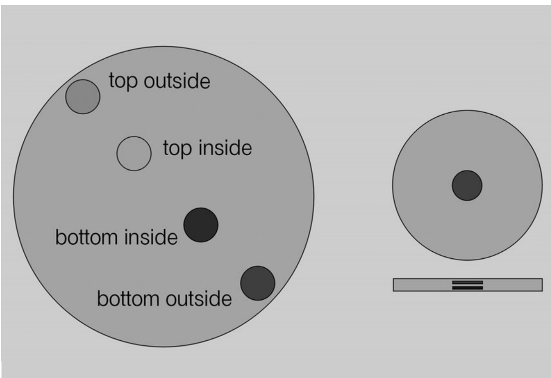
The Physica Advanced Peltier System PTD 150 consists of a Peltier controlled bottom plate and an actively Peltier controlled hood (pat. pent.). The patented technology of the use of an actively controlled hood together with a small gas flow in the chamber (either dry air or inert gas) results in an extremely small temperature gradient across the sample. Fig. 1 displays the differences between the various setups. Fig. 1a represents a system with controlled bottom plate and no protection, i.e. an open system, Fig. 1b shows the setup with controlled bottom plate and a passive insulation cover, whereas in Fig. 1c the principle of the Physica Advanced Peltier System PTD 150 with the actively controlled bottom plate and the additional actively controlled hood is displayed, respectively. The design of the PTD 150 is shown in Fig. 2. The actively controlled hood can be moved on the guiding rail thus giving easy access for sample loading and trimming.

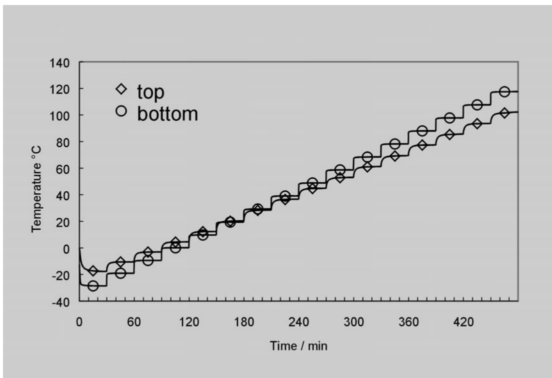
In order to quantify the effect of the Peltier controlled hood the temperature gradients have been measured with specially developed sensor tools as indicated in Fig. 3. One version consists of a 25 mm diameter, 2 mm thick plastic disc with two temperature sensors, one in the upper and one in the lower part, respectively. The second tool is a 50 mm diameter, 2 mm thick plastic disc with four temperature sensors at different positions (see Fig. 3) which allow the determination of the temperature gradients in the vertical and horizontal direction. All temperature sensors have been calibrated with respect to certified calibration standards.

Fig. 4 shows the results obtained with the 25 mm sensor disc in the temperature range – 30°C to + 120°C using a conventional Peltier system with a passive insulation cover. A standard stainless steel parallel-plate geometry with 25 mm

Figure 3 (left): Sensor tools for the design and evaluation of the new Advanced Peltier System PTD 150 (see text).

Figure 4 (right): Temperature gradients with a conventional Peltier system with a passive cover. Huge temperature gradients up to 15 K occur.





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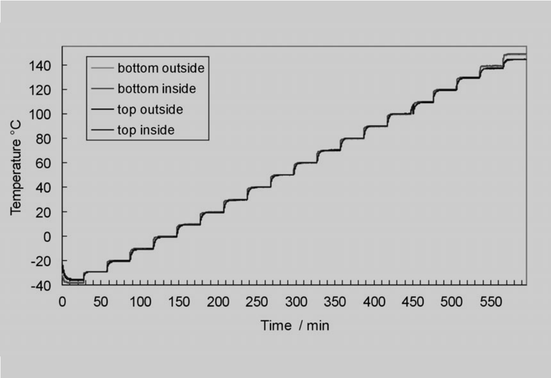

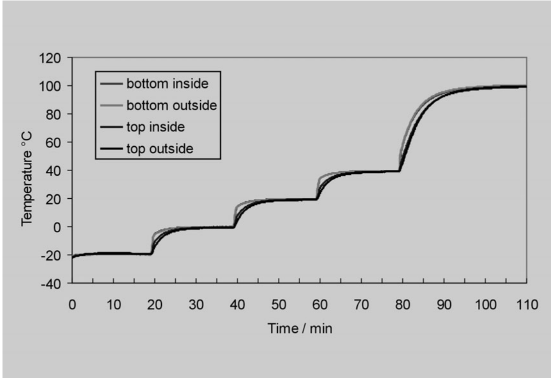

Figure 5 (left): Temperature gradients for the Advanced Peltier System PTD 150. Virtually no significant gradients are existing across the sample in the temperature range from – 30°C to + 130°C.

Figure 6 (right): Temperature gradients with the 50 mm sensor tool for the Advanced Peltier System PTD 150

diameter was used. As can be seen the temperature in the sample is different from the set temperature and large temperature gradients occur. The difference between the set temperature and the sample temperature might be adjusted by a temperature calibration for a given setup, but the temperature gradients can not be corrected. At – 30°C and + 120°C temperature gradients as large as about 12 K and 16 K occur, respectively. This setup with the 2 mm thick plastic material and the stainless steel geometry represents almost the worst case. Even though the temperature gradients can be reduced somewhat by using a geometry made out of plastic material or glass or by trying to reduce the heat flow through the shaft with the use of insulating materials in the shaft there will be still a rather large and significant temperature gradient across the sample.

The huge improvement the new Physica Advanced Peltier System PTD 150 offers is shown in Fig. 5. This measurement was performed with the 50 mm diameter sensor tool in the temperature range from – 40°C to + 150°C. The use of the actively Peltier controlled hood results in an absolute temperature setting which is exactly the sample temperature and in an elimination of virtually any significant temperature gradients. Fig. 6 shows a similar measurement for five different temperatures. A closer examination of the data in Figs. 5 and 6 gives an average sample temperature which only has a maximum deviation of ± 0.2 K from the set temperature. The temperature gradients in horizontal and vertical direction are lower than ± 0.3 K (deviation from the average temperature) across the sample in the entire temperature range from – 30°C to + 130°C even for the plastic tools with 2 mm thickness. To our knowledge such small gradients have never been reported before in Peltier based temperature control devices for cone-and-plate and parallel-plate geometries.

The small deviation of the absolute sample temperature to the set temperature is achieved because the temperature probe of the PTD 150 is located directly beneath the sample, therefore giving the real sample temperature.

APPLICATIONS

Typical applications for the Physica PTD 150 are measurements on all samples which require an exact temperature control in the temperature range from – 30°C to + 130°C. The excellent temperature characteristics combined with easy handling and the relatively low costs of this system makes the PTD 150 the preferred temperature control system for a variety of applications. For example tests on lubrication grease at low temperatures, food samples like ice cream or sorbets at low temperatures or chocolate at +40°C, asphalt, surfactants, the exact temperature dependence and temperature stability of cosmetics or pharmaceuticals, the gelling behavior of PVC pastes and many more. The exact temperature throughout the sample allows in particular investigations of crystallization processes or phase transitions of complex fluids.

CONCLUSIONS

The new designed Physica Advanced Peltier System PTD 150 (pat. pent.) offers new dimensions in temperature accuracy for parallel-plate and cone-and-plate measuring geometries in the temperature range from – 30°C to + 130°C. The deviation of the absolute sample temperature from the set temperature as well as the temperature gradient across the sample are reduced to levels which have been never attained before for a Peltier based temperature control unit. The unique design allows easy access for sample loading and trimming as well as the use of inert gas or a solvent trap if required.

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