Temperature Control on a Combined Motor and Transducer Rheometer: a New Solution

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ABSTRACT

Temperature control on a combined motor and transducer (CMT) rheometer has always been problematical, and none of the solutions offered in the past has been entirely satisfactory. Here we introduce a patented, low cost, solution, that ensures that the upper and lower platens are at the same temperature.

INTRODUCTION

For various reasons, two fundamentally different types of design are now in use for rotational rheometers. In one case, the drive system and sensor are on separate axes: we can call this the separate motor and transducer (SMT) design. In the other, combined motor and transducer (CMT), case, the drive system and sensor are on the same axis. SMT and CMT rheometers are often referred to as controlled strain and controlled stress respectively, although with modern electronics both can normally operate efficiently in either mode. TA Instruments' ARES series are examples of SMT rheometers; for the same companies AR series, the CMT design is used.

Accurate and precise temperature control presents engineering difficulties whichever design is used. On the CMT type, the lower platen is fixed, the upper must rotate freely without significant drag. Temperature control of the lower platen is therefore relatively straightforward, but control of the upper is more difficult, since there must be no physical contact between the rotating components, and the heater or temperature probe. Several methods of control have been used, for example inductive heating of both platens, or thermally conducting covers, but although most of these operate reasonably well under some conditions, none of them provides a complete solution. The importance of temperature on the rheological properties of materials is well attested in the scientific literature[1], and TA Instruments have now developed a patented non-contact method of heating the upper platen, which provides rapid and precise heating, with minimal temperature difference between the upper and lower platens.

DESCRIPTION

The lower platen is heated using Peltier elements in the way traditionally used by TA Instruments. Several methods of heating the upper platen were considered, including the use of a heated cover, but were rejected because of the differential thermal coupling between the heaters and upper platen that would occur when the geometry gap was changed. A solution was preferred in which the thermal coupling was independent of the gap width, and could therefore easily be calibrated.

TA Instruments have therefore developed a patented non-contact method of heating the upper platen, which provides rapid and precise heating, with minimal temperature difference between the upper and lower platens. Resistance elements are used to heat a cylindrical heat spreader, of high thermal conductivity and large internal surface area, fixed to the instrument stator. Concentrically placed within this cylinder, but fixed to the instrument rotor, is a second cylindrical heat spreader, in this case with large external surface area. The annular gap between the two cylinders is of the order of a few tenths of a millimeter, so that there is rapid heat transfer across the gap, with extremely low heat loss. The temperature probe is placed within the stator heat spreader, close to the inner surface (see Fig. 1).

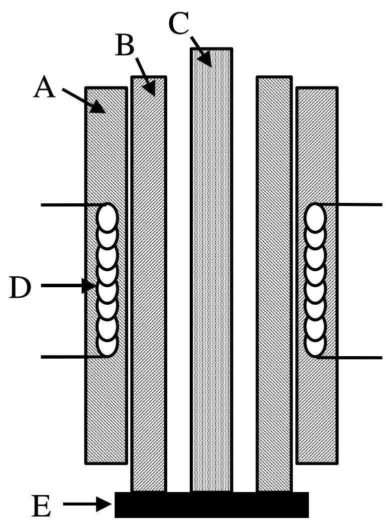

Figure 1. Cross section of the Upper Heated Plate (schematic). A is the stator heat spreader, B the rotor heat spreader, C the rheometer spindle, D the heating elements, and E the rheometer upper platen

This arrangement ensures that the thermal coupling between the stator and rotor heat spreader, and therefore between the heating elements and the upper platen, is indepedent of the sample thickness.

Because of the excellent thermal coupling between the two heat spreaders, and therefore between the upper platen and the temperature probe, any slight temperature difference between the probe and the platen can be allowed for by calibration. Cooling of the upper platen is by a fluid circulating in channels within the stator heat spreader. This fluid can be air, water or a low viscosity silicone based material. At high tempatures, air is used to expel the circulating fluid from the coolant channel.

CALIBRATION AND MODELLING

Calibration of the upper platen is easily effected. A heat flow detector is held between the upper and lower platens, and the temperature of the upper platen is adjusted until the heat flow is zero. The temperature of the upper and lower temperature probes is then compared, and a calibration offset is introduced to the upper probe to allow for any difference. This calibration can be performed incrementally across the full operating temperature range of the upper platen.

Because the temperature response of the Peltier controlled lower platen is more rapid than that of the upper platen, the lower platen temperature can then be constrained to a model of the upper platen, to ensure that the two platens are at the same temperature both during isothermal operation and during temperature ramping. For more rapid temperature ramping this modelling can switched off.

RESULTS

The minimum temperature achievable will depend on the circulating fluid used, and will usually be about 1 to 5°C above that of the circulating fluid. The maximum temperature is in independent of the circulating fluid, although the suppliers recommendations for the maximum usable temperature should be adhered to. The coolant used for the Peltier can either be from the same source as used for the upper platen, or from a separate source.

Fig 2 shows the performance of the upper heated plate with a high viscosity silicone oil used as circulating fluid.

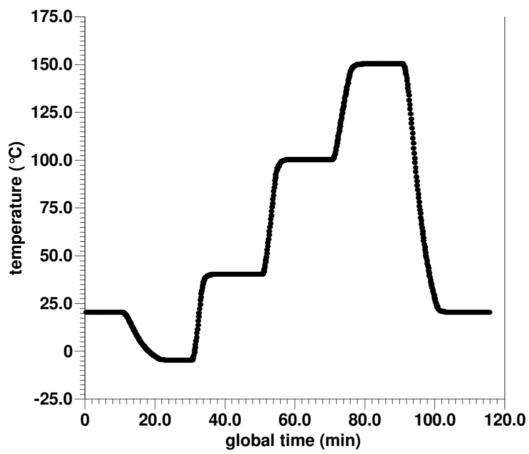

Figure 2. Performance of the Upper Heated Plate with high viscosity silicone oil

SPECIFICATIONS

Temperature range -30°C to 150° (the lower temperature is only achievable using low viscosity circulating fluid at -40°C).

Temperature heating rate: 15°C with modelling on.

Maximum temperature difference between platens: 0.1°C during isothermal operation or temperature ramping.

SUMMARY

A new solution to the problem of temperature on combined motor and transducer rheometer has been developed. This limits the thermal difference between the upper and lower platens to 0.1°C, over the temperature range -30°C to 150°, during isothermal operation or temperature ramping.

ACKNOWLEDGMENTS

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REFERENCES

1. Macosko, C.W. (1994), "Rheology: principles, measurements and applications", VCH, New York, pp 352-356.