Hot Disk®

APPLICATION NOTE

Thermal Conductivity of Silicone Oil – Polydimethylsiloxane

Testing the intrinsic thermal conductivity of liquids can be a challenge compared to testing solids. The reason for this is that convective heat transfer in the fluid during the measurement. However, the Hot Disk method can be utilized to test liquid samples with relative ease. The keys to success are small volumes, closed sample cells and short measurement times.

In this example, a commercial silicone oil has been tested to demonstrate the robustness of Hot Disk results when measuring on liquids.

Thermal Conductivity of SIL 180 silicon oil, including related properties, as measured with a Hot Disk TPS 2500 S.

Measurement time	λ [W/m/K]	Std.	κ [mm²/s]	Std.	ρC_p [MJ/m³K]	Std.
3 s	0.156	0.003	0.127	0.008	1.23	0.05
4 s	0.157	0.003	0.121	0.010	1.30	0.08
5 s	0.157	0.001	0.129	0.004	1.22	0.03

Sample

SIL 180 silicone oil (polydimethylsiloxane)
Viscosity: 11 mPas (20 °C)
Density: 0.93 g/cm3 (20 °C)
Specific heat: 1.51 J/g K (20 °C)
Brand: Fisher Scientific

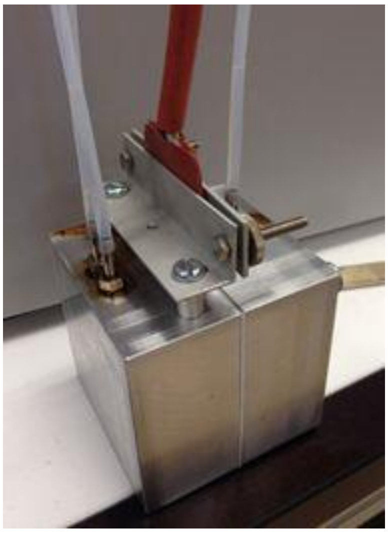
Silicon oil is commercially available, chemically stable and does not evaporate under ambient conditions. It is therefore an excellent demonstration sample. The viscosity of SIL 180 is about 10 times higher than water, which limits the convection. The thermal conductivity of silicon oil is typically lower than most common organic compounds (but close to the values of benzene and toluene) and it has roughly on quarter of water's conductivity (ca 0.6 W/m/K @ 20 °C). The specific heat of silicone fluids varies somewhat depending on the length or the silicone chains, but is generally about one-third of water's specific heat (ca 4.18 J/gK @ 20 °C).

Preparations

A small amount, ca. one tablespoon, of SIL 180 was poured into the Hot Disk sample holder for liquids (cf. Fig. 1) and kept under controlled ambient temperature of 21 ˚C. The sensor was placed in a vertical position to minimize the risk of trapping air pockets. The oil was then gently pumped back and forth through the chamber of the sample holder, making sure that all potential air bubbles left the system.

Kapton sensor 7577 was selected to perform the measurements on this small volume sample. This sensor model is usually the recommended choice when testing fluids, as the measurement times are kept short and liquids generally have a low diffusivity.

The standard isotropic measurement module was then utilized to perform the tests. Liquids are, with very few exceptions, isotropic and this measurement module should always be employed for testing such as this.



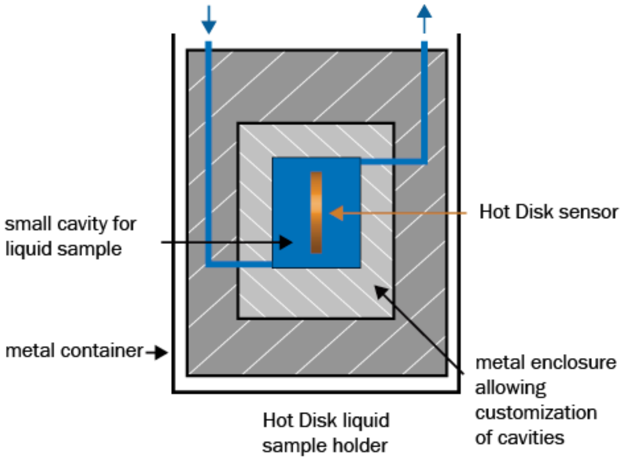


Fig. 1. Sample holder (picture and schematic drawing) for liquids, with mounted Hot Disk sensor.

Parameters

Three sets of experiments with different measurement times were conducted on the silicon oil sample. Each set of measurements consists of three repetitions for statistics. Measurement times here used were 3 s, 4 s, and 5 s. Heating power was 15 mW for all experiments. In general, short measurement times and low heating powers are used to minimizes the evolution of convection when testing fluids. Minimum waiting time between measurements was 15 minutes to make sure that thermal equilibrium had been re-established from measurement to measurement.

Results

In the table at the beginning of this article the final results are presented. Each set of measurements were calculated separately and the data point selection was made to achieve a randomly distributed residual plot, while only removing the final data point from each experiment.[1] Thus, the results will correspond to the full measurement time of each set of experiments. Independent of measurement time, all tests show similar results. It is therefore possible to conclude that the results are stable and no convection has evolved. If convection evolves, the measured thermal conductivity increases with increasing measurement time. This is a result of convective heat transfer entering the equation.

More on testing the thermal conductivity of liquids

It is very important to avoid convection during measurements of thermal conductivity as the convection will inflate the measured values. Liquids with high viscosity are easier to test as convection will be limited in a thick fluid. When testing low viscosity liquids, such as water, it is crucial to use short measurement times and a confined measurement cell. Proximity to solid surfaces will help suppressing convection, and if the cell is closed, convection due to evaporation can be avoided.

Recommended is also to de-gas liquids prior to testing. This is best done by eg. boiling the liquid and then cooling it in a closed cell. Gas content will affect the results, often seen as a lower than expected specific heat capacity per unit volume.

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