greenTEG

Convective heat flux explained

Theory

Thermal convection is one of the three mechanisms of heat transfer, besides conduction and thermal radiation. The heat is transferred by a moving fluid (e.g. wind or water), and is usually the dominant form of heat transfer in liquids and gases. Convection can be divided into natural convection and forced convection.

Generally, when a hot body is placed in a cold environment, the heat will flow from the hot body to the cold surrounding until an equilibrium is reached. Close to the surface of the hot body, the surrounding air will expand due to the higher temperature. Therefore, the hot air is lighter than the cold air and moves upwards. These differences in density create a flow, which transports the heat away from the hot surface to the cold environment. This process is called natural convection.
When the movement of the fluid is enhanced, we talk about forced convection: An example is the cooling of a hot body with a fan: The fluid velocity is increased and thus the device is cooled faster, because the heat transfer is higher.

Mathematically, the heat flux q is given by the following formula:

$$q=A*ð*(T_1 - T_2)$$

Where A is the surface area, ð the heat transfer coefficient and T_1 and T_2 are the temperatures of the surface and the environment, respectively.

To illustrate this formula, consider the following scenario: You have boiled some water and fill it into a tea cup. The water and the cup have now a temperature of T_1=100°C, while the air in the environment has the temperature T_2=25°C. The heat flux q out of the tea cup to the surrounding is highest at the beginning and decreases with time. This is due to the fact that the temperature of the water in the cup (T_1) decreases. Finally, when the water has reached room temperature, there will be no more heat flux because the water is in thermal equilibrium with the environment.
The heat flux can also be increased by changing the heat transfer coefficient. ð depends on various parameters like velocity of the fluid, material properties etc. For example, if one blows air over the tea cup, the speed of the fluid is increased and thus the heat transfer coefficient becomes larger. This means, that the water cools down faster.

Application

To demonstrate the phenomenon of convection, the heat flux of a tea cup with hot water was measured with the gSKIN® heat flux sensor. In one case, air was blown towards the cup by a fan. The profile of the heat flux shows an exponential decay, as the ΔT between the water and the surrounding is decreasing. With natural convection, it takes about 180 minutes until the heat flux drops to zero. In comparison, in the case of forced convection, where the cup is cooled with wind from a fan, the water temperature has reached equilibrium after less than 60 minutes.