THE FLEXPERTS

Flexible Heater Temperature Limits

Heat dissipation varies with installation orientation and ambient conditions.

MARK FINSTAD

WHAT ARE THE upper temperature limits for a flexible heater?

Depending on the material selection, flexible heaters can conservatively run at temperatures exceeding 200°C. Many variables must be considered when pushing the upper limits, however. The main variables are power (watt) density, ambient temp, heatsink type and heatsink bonding method.

To start, assume the heater is polyimide-based and adhered to a rigid heat sink of some type, where no heating area of the flexible heater is permitted to bend or flex after installation. Also, assume that a control system will reduce power to the heating element as the heater approaches the desired temperature, so that no power is supplied to the element at peak temperature.

Adhesive systems. The least expensive option when building a flexible heater is to build a standard flex circuit, with the heating element the only variable. The heating element will usually be a resistive foil such as CuNi or Inconel, instead of copper (although copper *can* be used in certain applications). The adhesive system to bond everything together is a standard epoxy or acrylic thermosetting film. We typically limit the max temp of this type of heater to about 125°C at zero power. This assumes the heater has a void-free bond to a metallic heatsink and a low watt density (<10W per sq. in.).

Some newer thermosetting adhesive films process and cure at the same parameters as the standard thermosetting films described above but maintain a good bond up to 150°C at zero power (again, assuming a good bond to a metallic heat sink). These adhesive systems are more expensive than standard adhesives, so expect a noticeable bump in price.

The next step up in temperature rating is to use a thermoplastic polyimide (TPI) to bond everything together. This material requires high-temperature lamination equipment (>300°C) to bond the resistive foil to the base and cover films. Many manufacturers lack high-temp lamination equipment, so this requirement will limit the number of vendors able to support the project. A final product built with thermoplastic polyimide can operate continuously at temperatures over 200°C at zero power.

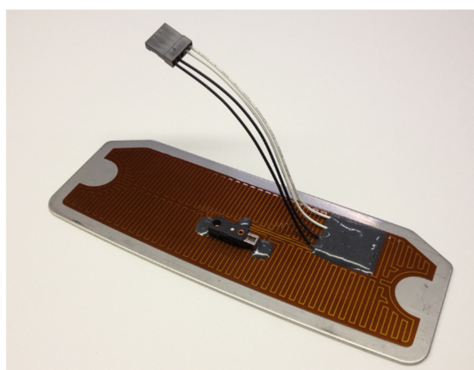

Figure 1. Flexible heater bonded to a heavy stainless steel heatsink with onboard temp sensor and thermostat controller.

Power (watt) density. Power or watt density is the amount of power generated in a given area. The maximum power density limit is primarily driven by ambient temperature, and the mass and conductivity of the heat sink. For example, consider a heater the size of a credit card (~6 sq. in.) with a power output of 120W (20W per sq. in.). That heater, bonded to the hood of a pickup truck in Minnesota in January, would be barely warm to the touch. That same heater bonded to human skin indoors would almost immediately leave burns and blisters. The heater bonded to the truck hood can have a much higher power density than the one bonded to skin. This is due to the truck hood's ability to conduct the generated heat away from the heater rapidly.

It is also important to understand that the heating element in a flexible heater typically has a trace-to-space ratio of 40% to 60% to provide optimal heat transfer characteristics. This means that if the mean temperature of the heating area is, let's say 100°C, the temperature of the element *traces* can be significantly higher when under power. If the element trace temperature exceeds the adhesive's maximum temperature, the heater can delaminate, even though the mean temperature of the heating area is still under the maximum temperature. This is why it is necessary to have a control system that will scale back, or cut out, the power supplied to the element as the mean temperature approaches.

For a variable control system, power supplied to the heater will gradually reduce as the temperature increases and will reach zero power at the target temperature. If a thermostat controls the temperature, the "power off" setting must be lower than the target temperature. In a thermostat-controlled system, the heater is either on or off. Since the temperature of the heatsink will lag that of the heating element, some overshoot will occur after power cuts to the element. Ensure the thermostat shuts off well before the maximum temperature is achieved.

Heat loss. The heat generated by a flexible heater dissipates through conduction, convection and radiation. In a perfect system, 100% of the heat generated goes directly into the heatsink. In reality, no perfect system exists, and some of the generated heat will be lost to convection, and, to a lesser extent, radiation. In the case, for example, of two identical heaters, one mounted on the horizontal plane and the other on a vertical plane, the heater mounted on the vertical plane will run noticeably cooler than the horizontal-plane-mounted heater. Why? Convection. On the horizontal heater, heated air on the bottom side can only escape around the perimeter of the heater as it rises. On the vertical heater, heated air can freely escape directly upwards along the heated surface, which in turn pulls in cooler air behind.

If your heating application may be pushing the upper limits, consider consulting a flexible heater supplier for direction. As discussed in the example above, variables that may seem inconsequential – such as mounting position – can have a big impact on performance. Flexible heater suppliers have seen the good, the bad, the burnt and the ugly, and can keep you on the “good” path.

MARK FINSTAD is director of engineering at Flexible Circuit Technologies (flexiblecircuit.com); mark.finstad@flexiblecircuit.com. He and co-“Flexpert” NICK KOOP (nick.koop@ttmtech.com) welcome your suggestions. They will speak at PCB West at the Santa Clara Convention Center in October.

BACK TO ISSUE