Large measurement errors with hand-held surface temperature sensors

Questions should be of general interest and be about temperature measurement techniques and/or heat transfer.

QUESTIONS? ANSWERS!

QUESTION: We have to measure the surface temperature of a workpiece during part of the machining process and we use a hand-held sensor to do this. During the brief time we are taking the readings it sometimes seems as if the temperature varies over time even though the values should remain fairly constant. Is there any explanation for this?

Johan H

ANSWER: Measuring surface temperature is always complicated and the difficulty increases if you have to use hand-held sensors. Let us assume that the undisturbed temperature of the workpiece is T_A. In theory, when the sensor comes into physical contact with the workpiece, the temperature of the point of contact changes according to Curve B in the diagram. This temperature change normally occurs very rapidly. Heat is transported from the workpiece to the sensor by thermal conduction and from the sensor to the surroundings by convection and radiation. Within the workpiece and the sensor the heat is transported by thermal conduction.

The temperature reduction of the workpiece's surface is caused by the thermal load resulting from the sensor. The change is due to the geometry and thermal properties of both the workpiece and the sensor. Curves C and D in the diagram show the temperature at the corresponding points in the sensor. Accordingly, which temperature is measured by the sensor depends on where the temperature resistor is located inside the sensor body and what the physical contact is like between the sensor and the measurement object. The measurement error resulting from Pos 2 is greater than that from Pos 1.

In some cases there is a contact resistance, for example an oxide layer, between the sensor and the workpiece. The contact resistance influences the heat flow to the sensor and thereby the surface temperature reading. The contact resistance depends on such factors as how you hold the sensor and the pressure between the sensor and the workpiece. If the pressure and point of contact vary then the temperature will also vary. The reason for the temperature variations you mention can therefore depend on both the measurement method used and the person taking the readings.

If it were possible to mount a fixed sensor on the measurement object then this would considerably reduce the measurement error. In this particular case it is presumably not possible to mount a fixed sensor on the workpiece. To avoid the thermal load which always results from a sensor, it is possible to use a contact-less measurement method by using an IR pyrometer, for instance. Unfortunately this method is not problem free either. The emission coefficient on the surface of the workpiece can vary and thereby so can the temperature that is measured. Another problem is the existence of undesirable radiation from nearby objects and light sources. [Ref 1]

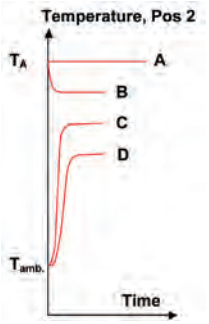

Figure 1. The temperature as a function of time at the different positions shown in Figure 2. Note that initially the sensor's point of contact (B) very briefly adopts the surface temperature T_A.

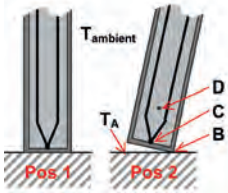

Figure 2. Pos 1. The correct perpendicular application of the surface temperature sensor. Pos 2. Other angles than the perpendicular cause the sensor's point of contact (B) to briefly adopt the surface temperature T_A. The measuring junction (C) remains colder than (B).

If you have comments or questions, contact Professor Dan Loyd at the Institute of Technology at Linköping University: dan.loyd@liu.se

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