A Note on the Identification of Material Properties using INTEMP

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One of the more common problems in model identification is to estimate the material properties using measurements. In this brief note it will be demonstrated how INTEMP[1] can be used to determine the thermal conductivity of a model using temperature measurements. The simplest case, an unknown constant conductivity, has been chosen in order to focus on how INTEMP can be used to determine this unknown. The more complex cases, where both thermal conductivity and specific heat vary with temperature and/or location will require more effort.

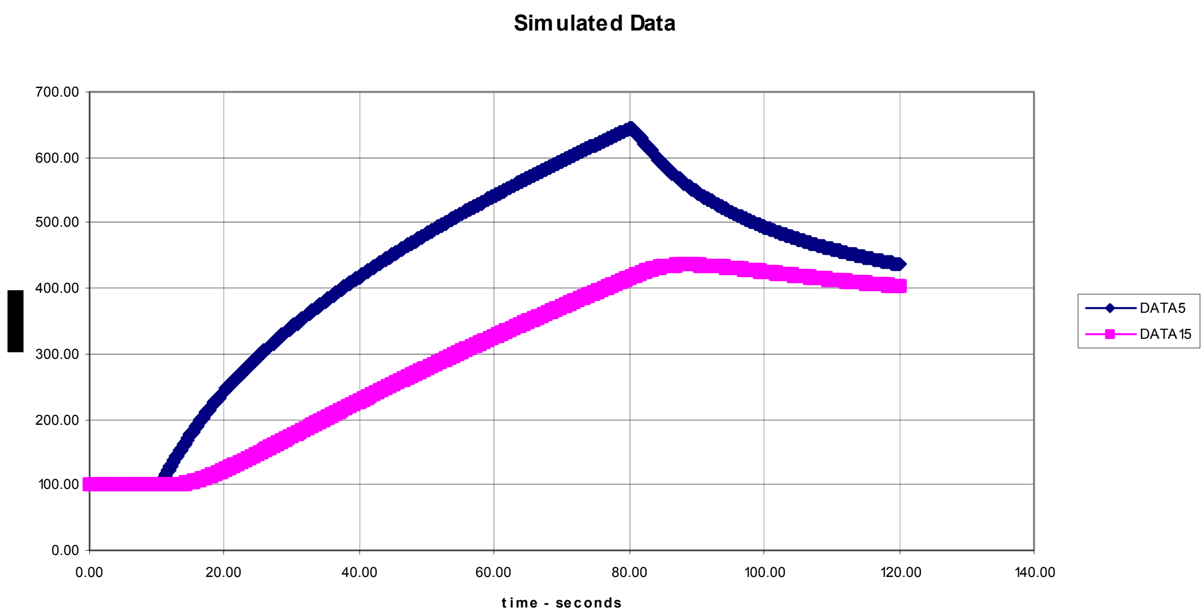
A common experiment used to determine material properties consists of observing a model during a transient and recording temperatures at a small number of locations. These recordings are then used to estimate the material properties. However, this leads to a more difficult problem of **estimating the heat flux** that that is driving the transient as well as the **unknown material property**. In other words, the material identification problem usually requires not only the estimation of constants but the **estimation of unknown functions of time**.

The main reason for requiring a program like INTEMP is that the material identification problem is usually a case of determining an unknown constant or a small number of unknown constants whereas INTEMP solves for unknown functions of time, a much more difficult problem. The approach investigated in this note is to use one temperature measurement to optimally estimate the unknown heat flux and another measurement to estimate the unknown material property.

The case study in this note represents a one dimensional model 10 cm in length. The data were numerically simulated with a finite element code. A heat flux was applied at one end and two temperature histories were recorded every 0.1 seconds, one at 1.0 cm from the heated end and the other at 3.5 cm. The material properties were constant with temperature and are

thermal conductivity	80.E-2 W/cm/C
specific heat	1045. J/kg/C
density	2445.E-6 kg/cm^3

The transient data are shown below

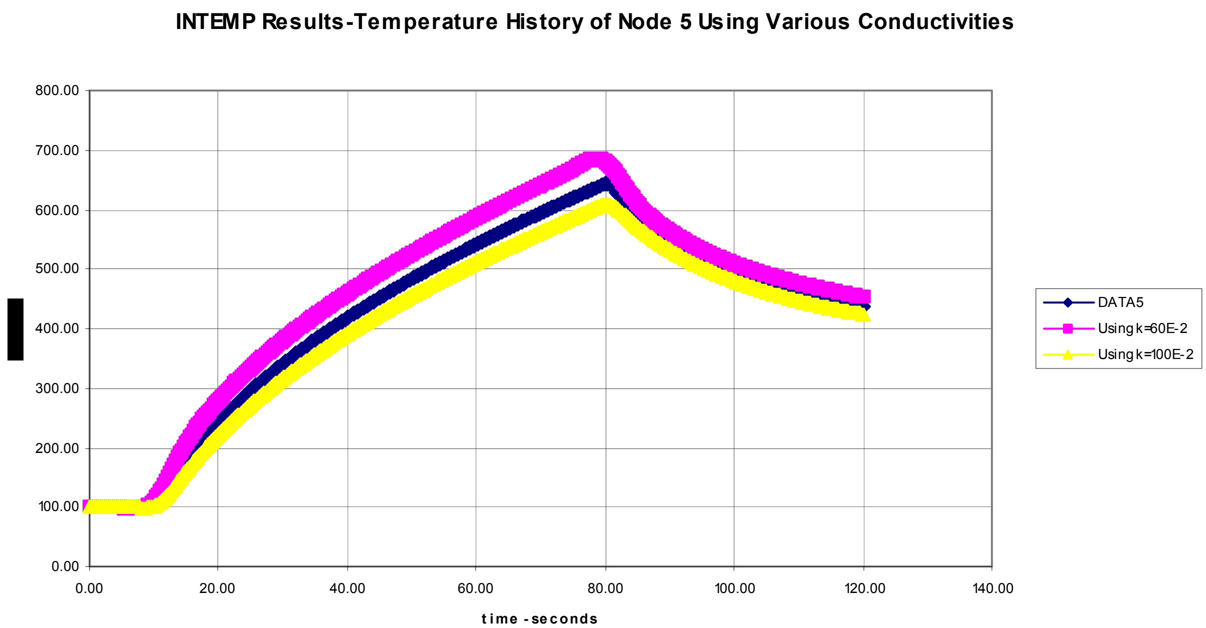


Data5 represents the temperature history at node 5 (1.0 cm) and Data15 the temperature at node 15 (3.5cm).

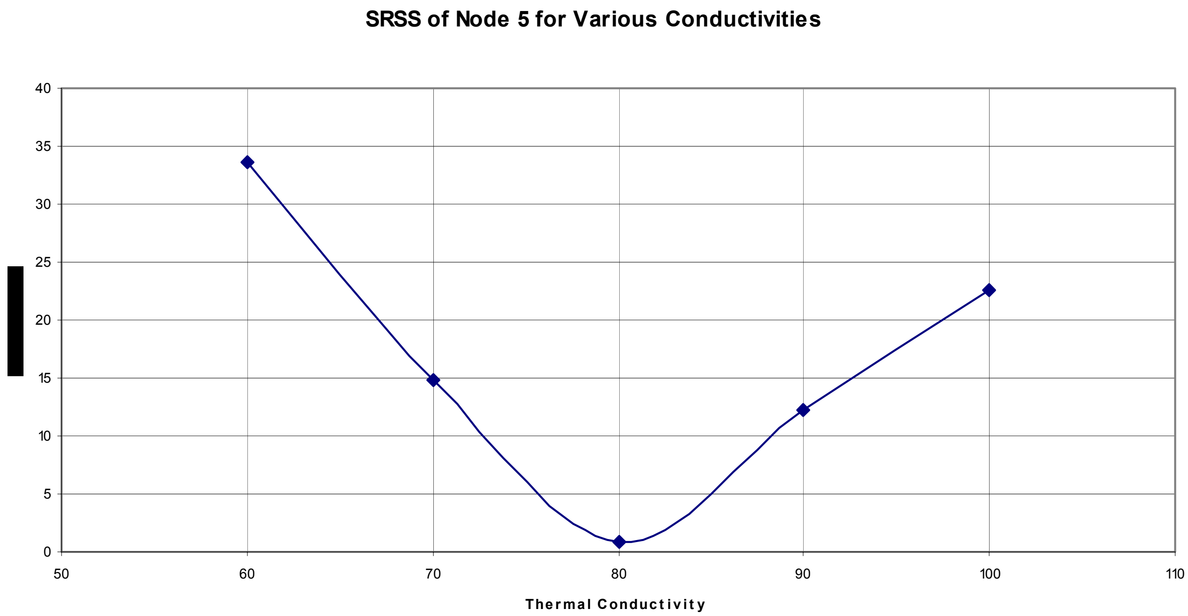
The idea is to use one of the measurements , Data15, to estimate the unknown heat flux and the other, Data5, to estimate the thermal conductivity. This is usually an iterative process and requires guessing a thermal conductivity and running INTEMP which finds a heat flux that will best match Data15. If the thermal conductivity is incorrect, then there will be discrepancy between the Data5 and the estimated temperature produced by INTEMP. This leads to choosing another value for the thermal conductivity. There are many iterative procedures available for selecting these values, such as the Marquart method. The key to the success of this process is that

INTEMP will **always** find a heat flux history that will **optimally match Data15**. If the thermal conductivity is incorrect, then so will be the estimate of the heat flux. The iterative process is then reduced to varying the thermal conductivity until Data5 is closely matched. Each iteration requires the operation of INTEMP.

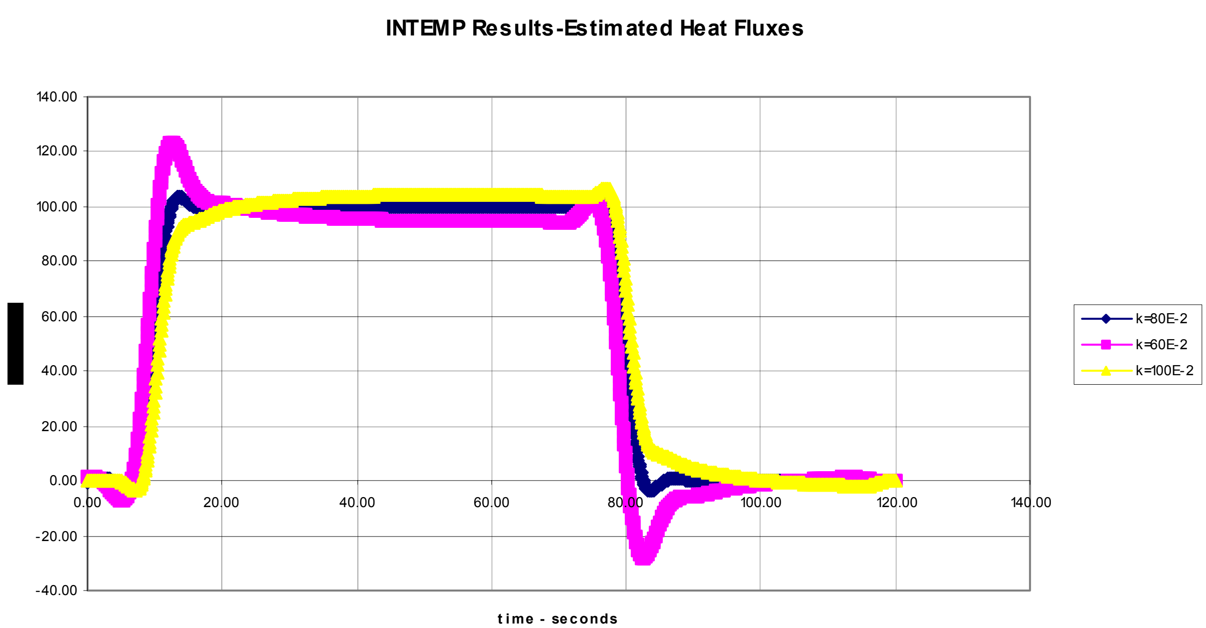
For example, the temperature history of node 5 for incorrect thermal conductivities of 60.E-2 and 100.E-2 are shown below together with Data5.



A measure of the difference between each estimate of node 5 and the data can be expressed as the square root of the sum of the squares. The plot below shows this measure for various thermal conductivities. The correct value, 80E-2, is clearly evident.



As a further point of interest, the estimated heat fluxes computed by INTEMP for different thermal conductivities are shown below. Recall that the temperature history for Data15 is always matched by INTEMP.



Discussion

A similar experiment could be made for determining an unknown specific heat. It appears that the more difficult case of determining both the thermal conductivity and the specific heat would require a different approach than the one outlined here. The reason for this is that the ratio of the thermal conductivity to the specific heat times the density is a scale factor for the model (i.e.,the thermal diffusivity). This means that the heat flux determined by INTEMP would also be scaled. The result would be a non unique estimation of the properties. Perhaps an experiment with three or more measurements would allow the determination of both the properties. This is for the future.

References

1 INTEMP – Inverse Heat Transfer Analysis – TRUCOMP. See http://home.earthlink.net/~trucomp