ME 3345 Computational Project

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Problem Overview –

3 Rectangular bars in contact aligned in the y direction. Size of bars given. 2D conduction and convection assumed. Constant Properties. k for the upper and lower bars is given along with fixed temperatures for both bars. Heat flux from upper towards lower bar due to $T_{upper} > T_{lower}$. Perfect insulation at lower bar. Heat loss @ h = 3 W/m^2K for upper bar. Heat loss @ h = 10 W/m^2K for ends of bars and through material.

Part 1:

The problem is divided into three surfaces – Upper Reference Bar, Lower Reference Bar and Material. For each surface, nodes are specified at a distance of 1mm for both dx and dy. The finite difference method narrows down the partial differential equations required for a perfect solution to solvable matrices.

The nodal equations for all interior nodes are :-

$$T_{m,n+1} + T_{m,n-1} + T_{m+1,n} + T_{m-1,n} - 4T_{m,n} = 0$$

The nodal equations for exterior nodes along side walls for Upper Reference Bar are : -

$$T_{m,n+1} + T_{m,n-1} + 2T_{m-1,n} - 2(h_{ins}dx/k + 2)T_{m,n} + 2h_{ins}dxT_{inf}/k = 0$$

The nodal equations for exterior nodes along side walls for Lower Reference Bar are : -

$$T_{m,n+1} + T_{m,n-1} + 2T_{m-1,n} - 4T_{m,n} = 0$$

The nodal equations for exterior nodes where bars are in contact are :-

$$T_{m,n+1} + ksam*T_{m,n-1}/kbar + T_{m+1,n} + T_{m-1,n} - (3+ksam/kbar)T_{m,n} = 0$$

The nodal equations for exterior nodes with no insulation are: -

$$T_{m,n+1} + T_{m,n-1} + 2T_{m-1,n} - 2(h_{air}dx/k + 2)T_{m,n} + 2h_{air}dxT_{inf}/k = 0$$

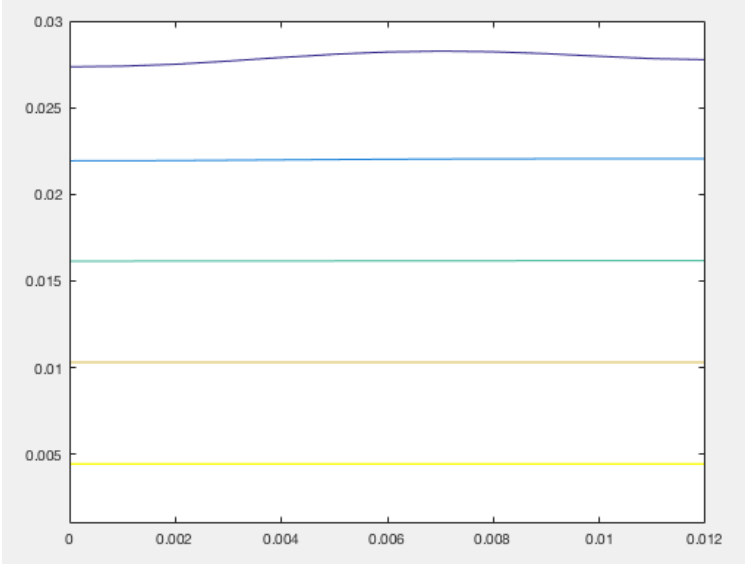
The above equations are solved in Matlab to get the following results for Part 1 –

Thermocouples
296.37 258.20 220.28 164.67 146.82 129.59 113.22 98.00 51.03 117.13 185.47 219.65
Th - 84.21; Tl - 37.69
Heat Loss - 0.30

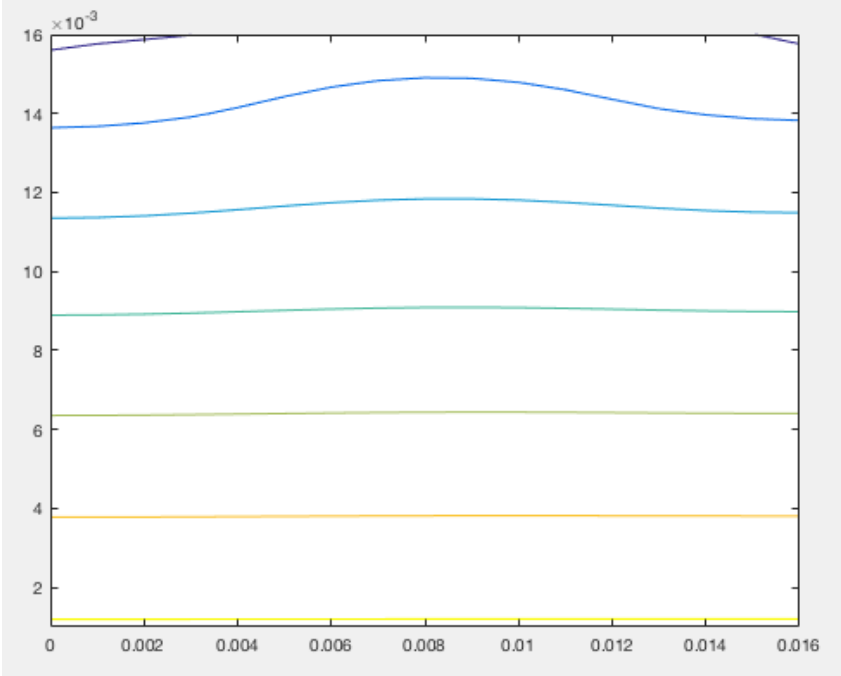
Plot of Temperature distribution along centerline

Contour Plots for each bar

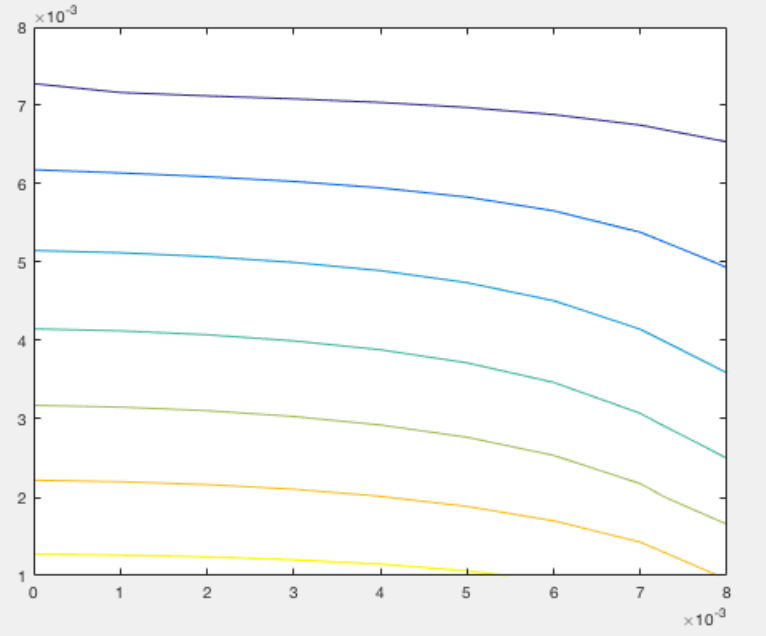
LRB



URB



Material



Part 2 :
The analysis is narrowed down to a 1D problem with q'' coming from a linear fit through Thermocouples 1-4 (values known from part 1) or coming from a linear fit through Thermocouples 9-12. TH and TL are also approximated using known values of the Thermocouples. The measured values of k and associated errors are calculated through Matlab and given below.

Part 2 Results

Th - 83.43; Tl - 33.62
Errors are:
Error 1 - 21.85 for kmeas1 - -416.98 from qflux from URB - -2596149.80
Error 2 - 8.35 for kmeas2 - 187.04 from qflux from LRB - 1164541.66
Error 3 - 6.75 for kmeas3 - -114.97 from qflux from Average - -715804.07

Part 3 :

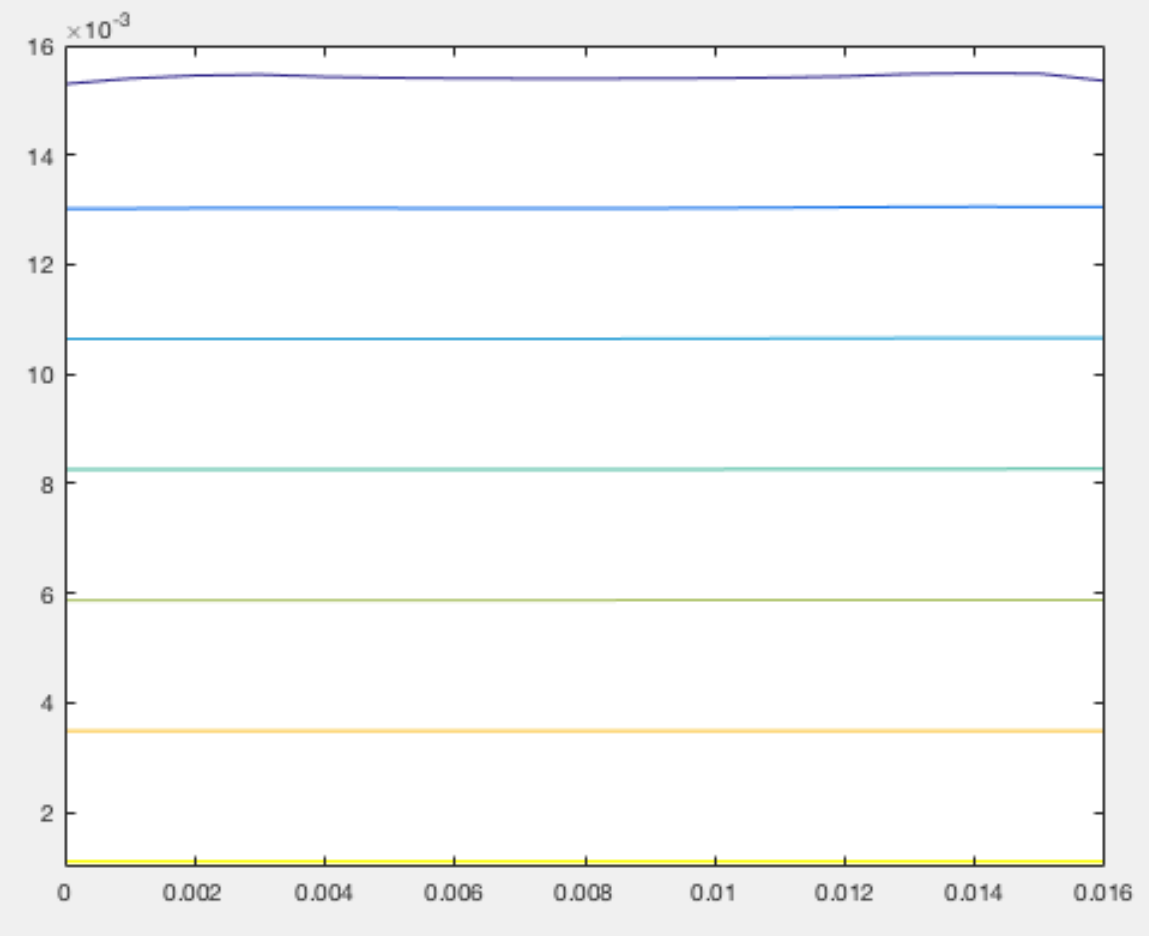
The value of k is changed from 138 W/m-K to 35 W/m-K (material for bars changed from Al to carbon steel). Updated results for parts 1 and 2 are as follows:

Part 1 Results
Thermocouples
289.23 247.34 205.43 142.54 121.55 100.53 79.48 58.37 35.49 107.51 179.71 215.81
Th - 37.19; Tl - 17.68

Heat Loss - 0.34

Part 2 Results

Th - 37.23; Tl - 17.42
Errors are:
Error 1 - 15.81 for kmeas1 - -296.19 from qflux from URB - -733440.52
Error 2 - 5.37 for kmeas2 - 127.44 from qflux from LRB - 315565.97
Error 3 - 5.22 for kmeas3 - -84.38 from qflux from Average - -208937.28



Contour plot lines are straighter for smaller k – meaning less heat loss at edges. Smaller k also has lower error. This configuration would be better than Aluminum.