# Heat transfer simulation Wojciech Dziuba

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clc; close all;

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## Creating matrices that represent the simulation resolution

```
matrix_4x4 = [
1 1 1 1 1 1 1 1;
1 2 2 8 8 2 2 1;
1 1 1 8 8 1 1 1;
0 0 1 2 2 1 0 0;
0 0 1 2 2 1 0 0;
0 0 1 2 2 1 0 0;
0 0 1 2 2 1 0 0;
0 0 1 1 1 1 0 0;
1;
matrix 1x1 = [
```

```
];
matrix 05x05 = repelem(matrix 1x1,2,2);
matrix_02x02 = repelem(matrix_1x1,5,5);
figure('name', 'Resolution Matrices', 'Position', [300 300 1200 500])
subplot(2,2,1)
imagesc(matrix 4x4);
title("Matrix 40 mm x 40 mm")
subplot(2,2,2)
imagesc(matrix_1x1);
title("Matrix 10 mm x 10 mm")
subplot(2,2,3)
imagesc(matrix_05x05);
title("Matrix 5 mm x 5 mm")
subplot(2,2,4)
imagesc(matrix_02x02);
title("Matrix 2 mm x 2 mm")
        Matrix 40 mm x 40 mm
                       Matrix 10 mm x 10 mm
                   15
                   20
        Matrix 5 mm x 5 mm
                       Matrix 2 mm x 2 mm
   20
   30
                  100
```

## Phisical & Simulation parameters of diffrent materials

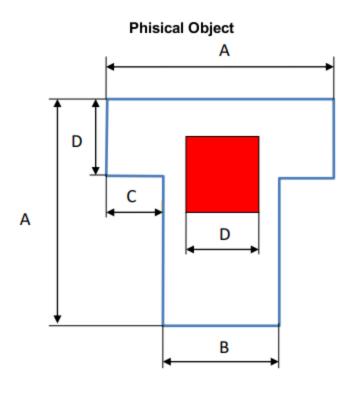
50

30

40

```
% Stainles Steel
ss_K = 58;
ss_Cw = 450;
```

```
ss_ro = 7860;
ss_Epsilon = 0.001;
% Coper
cu_K = 401;
cu_Cw = 380;
cu_ro = 8920;
cu_Epsilon = 0.001;
% Aluminum
al_K = 237;
al_Cw = 900;
al_ro = 2700;
al_Epsilon = 0.001;
figure('name', 'Object', 'Position', [300 300 1200 500])
imshow("Przechwytywanie.PNG")
title("Phisical Object")
A = 0.3;
N = 0.2;
C = 0.05;
D = 0.1;
h = 0.005;
P = 100;
dt = 0.01;
sim_duration = 10000;
```



### **Running the simulation**

```
% Stainless Steel
fprintf("steel...");
[ss 4x4 out, ss 4x4 H,
                           ss 4x4 T e,
                                         ss max 4x4 dT]
sim_board(matrix_4x4,
                           sim_duration, ss_K, ss_Cw, ss_ro, A, D, h,
P, dt, ss Epsilon, 0);
[ss_lxl_out,
              ss_1x1_H,
                           ss_1x1_T_e,
                                         ss_max_1x1_dT]
sim_board(matrix_1x1,
                           sim_duration, ss_K, ss_Cw, ss_ro, A, D, h,
P, dt, ss_Epsilon, 0);
[ss 05x05 out, ss 05x05 H, ss 05x05 T e, ss max 05x05 dT] =
sim_board(matrix_05x05,
                           sim_duration, ss_K, ss_Cw, ss_ro, A, D, h,
P, dt, ss_Epsilon, 0);
[ss_02x02_out, ss_02x02_H, ss_02x02_T_e, ss_max_02x02_dT]
                           sim_duration, ss_K, ss_Cw, ss_ro, A, D, h,
sim_board(matrix_02x02,
P, dt, ss Epsilon, 0);
fprintf("done\n");
% Cooper
fprintf("cooper...");
[cu_4x4_out,
                           cu_4x4_T_e,
                                         cu_max_4x4_dT]
             cu_4x4_H,
sim board(matrix 4x4,
                           sim_duration, cu_K, cu_Cw, cu_ro, A, D, h,
P, dt, cu_Epsilon, 0);
```

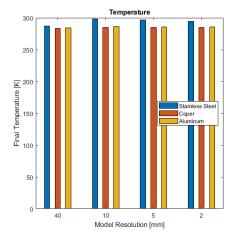
```
[cu_1x1_out, cu_1x1_H,
                           cu_1x1_T_e,
                                         cu_max_1x1_dT]
 sim board(matrix 1x1,
                           sim duration, cu K, cu Cw, cu ro, A, D, h,
P, dt, cu_Epsilon, 0);
[cu 05x05 out, cu 05x05 H, cu 05x05 T e, cu max 05x05 dT] =
 sim_board(matrix_05x05,
                           sim_duration, cu_K, cu_Cw, cu_ro, A, D, h,
P, dt, cu Epsilon, 0);
[cu_02x02_out, cu_02x02_H, cu_02x02_T_e, cu_max_02x02_dT] =
 sim board(matrix 02x02,
                           sim_duration, cu_K, cu_Cw, cu_ro, A, D, h,
 P, dt/10, cu Epsilon, 0);
fprintf("done\n");
% Aluminum
fprintf("aluminum...");
[al_4x4_out,
              al_4x4_H,
                           al_4x4_T_e,
                                         al_max_4x4_dT
sim board(matrix 4x4,
                           sim_duration, al_K, al_Cw, al_ro, A, D, h,
P, dt, al_Epsilon, 0);
[al_1x1_out,
              al_1xl_H,
                           al 1x1 Te,
                                         al max 1x1 dT]
 sim_board(matrix_1x1,
                           sim_duration, al_K, al_Cw, al_ro, A, D, h,
P, dt, al Epsilon, 0);
[al_05x05_out, al_05x05_H, al_05x05_T_e, al_max_05x05_dT] =
 sim_board(matrix_05x05,
                           sim_duration, al_K, al_Cw, al_ro, A, D, h,
 P, dt, al_Epsilon, 0);
[al_02x02_out, al_02x02_H, al_02x02_T_e, al_max_02x02_dT] =
 sim board(matrix 02x02,
                           sim duration, al K, al Cw, al ro, A, D, h,
P, dt/10, al_Epsilon, 0);
fprintf("done\n");
steel...done
cooper...done
aluminum...done
```

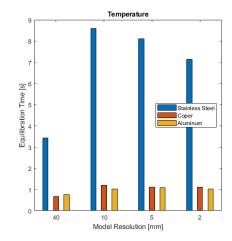
#### **Acquired Data**

```
figure('name', 'Resolution Matrices', 'Position', [300 300 1200 500])
subplot(3,4,1)
imagesc(ss 4x4 out);
title("Stainless Steel 40 mm x 40 mm")
subplot(3,4,2)
imagesc(ss_1x1_out);
title("Stainless Steel 10 mm x 10 mm")
subplot(3,4,3)
imagesc(ss_05x05_out);
title("Stainless Steel5 mm x 5 mm")
subplot(3,4,4)
imagesc(ss 02x02 out);
title("Stainless Steel 2 mm x 2 mm")
subplot(3,4,5)
imagesc(ss_4x4_out);
title("Cooper 40 mm x 40 mm")
subplot(3,4,6)
imagesc(cu_1x1_out);
title("Cooper 10 mm x 10 mm")
```

```
subplot(3,4,7)
imagesc(cu 05x05 out);
title("Cooper 5 mm x 5 mm")
subplot(3,4,8)
imagesc(cu_02x02_out);
title("Cooper 2 mm x 2 mm")
subplot(3,4,9)
imagesc(al_4x4_out);
title("Aluminum 40 mm x 40 mm")
subplot(3,4,10)
imagesc(al_1x1_out);
title("Aluminum 10 mm x 10 mm")
subplot(3,4,11)
imagesc(al_05x05_out);
title("Aluminum 5 mm x 5 mm")
subplot(3,4,12)
imagesc(al_02x02_out);
title("Aluminum 2 mm x 2 mm")
T_e_{data} = [
    ss_4x4_T_e cu_4x4_T_e al_4x4_T_e;
    ss 1x1 T e cu 1x1 T e al 1x1 T e;
    ss_05x05_T_e cu_05x05_T_e al_05x05_T_e;
    ss_02x02_T_e cu_02x02_T_e al_02x02_T_e;
   ];
H_{data} = [
    ss 4x4 H cu 4x4 H al 4x4 H;
    ss_1x1_H cu_1x1_H al_1x1_H;
    ss_05x05_H cu_05x05_H al_05x05_H;
    ss_02x02_H cu_02x02_H al_02x02_H;
   ];
figure('name', 'Simulation Data', 'Position', [300 300 1200 500])
subplot(1,2,1)
bar(T_e_data, 0.5)
ax = qca;
%ax.XTickLabel = {'SS','Cu', 'Al'};
ax.XTickLabel = { '40', '10', '5', '2'};
%xlabel('Plate Material')
xlabel('Model Resolution [mm]')
ylabel('Final Temperature [K]')
title("Temperature")
legend('Stainless Steel', 'Coper', 'Aluminum', 'Location', 'east')
subplot(1,2,2)
bar(H_data.*dt, 0.5)
ax = qca;
%ax.XTickLabel = {'SS','Cu', 'Al'};
ax.XTickLabel = { '40', '10', '5', '2'};
%xlabel('Plate Material')
xlabel('Model Resolution [mm]')
```

```
ylabel('Equilibration Time [s]')
title("Temperature")
legend('Stainless Steel', 'Coper', 'Aluminum', 'Location', 'east')
figure('name', 'Table', 'Position', [300 300 300 100])
resolution = { '40 mm'; '10 mm'; '5 mm'; '2 mm'};
Stainless_Steel =
 [T_e_{data(1,1)}; T_e_{data(2,1)}; T_e_{data(3,1)}; T_e_{data(4,1)}];
Coper = [T_e_{data(1,2)}; T_e_{data(2,2)}; T_e_{data(3,2)}; T_e_{data(4,2)}];
Aluminum = [T_e_data(1,3); T_e_data(2,3); T_e_data(3,3); T_e_data(4,3)];
T = table(Stainless_Steel,Coper,Aluminum,'RowNames',resolution);
uitable('Data',T{:,:},'ColumnName',T.Properties.VariableNames,...
      'RowName', T. Properties. RowNames, 'Units', 'Normalized', 'Position',
[0, 0, 1, 1]);
                      Matrix 40 mm x 40 mm
                                                                 Matrix 10 mm x 10 mm
                                                     10
                                                     15
                                                     20
                                                     25
                       Matrix 5 mm x 5 mm
                                                                 Matrix 2 mm x 2 mm
          10
          20
                                                     50
          30
          40
                                                     100
          50
                 10
                      20
                           30
                                 40
                                      50
                                                              40
                                                                       80
                                                                           100
                                                                               120
            Stainless Steel 40 mm x 40 mm
                                Stainless Steel 10 mm x 10 mm
                                                     Stainless Steel5 mm x 5 mm
                                                                         Stainless Steel 2 mm x 2 mm
                                                                      100
                                  5 10 15 20 25 30
                                                      10 20 30 40 50 60
                                                                                100
              Cooper 40 mm x 40 mm
                                  Cooper 10 mm x 10 mm
                                                      Cooper 5 mm x 5 mm
                                                                          Cooper 2 mm x 2 mm
                                                                      100
                                  5 10 15 20 25 30
                                                      10 20 30 40 50 60
                                                                               100
              Aluminum 40 mm x 40 mm
                                 Aluminum 10 mm x 10 mm
                                                                          Aluminum 2 mm x 2 mm
                                                                      100
```





	Stainless_Steel	Coper	Aluminum
40 mm	286.8484	283.5595	283.9460
10 mm	297.9243	285.0850	286.5514
5 mm	296.7268	284.6650	285.9292
2 mm	294.3228	284.7398	286.0091

### **Summary**

With that we can observe, that the minimum resolution right for the simulation was the  $1 \text{ mm} \times 1 \text{ mm}$ . Any better resolution yealds the same information about the equilibrium temperature of the plate

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