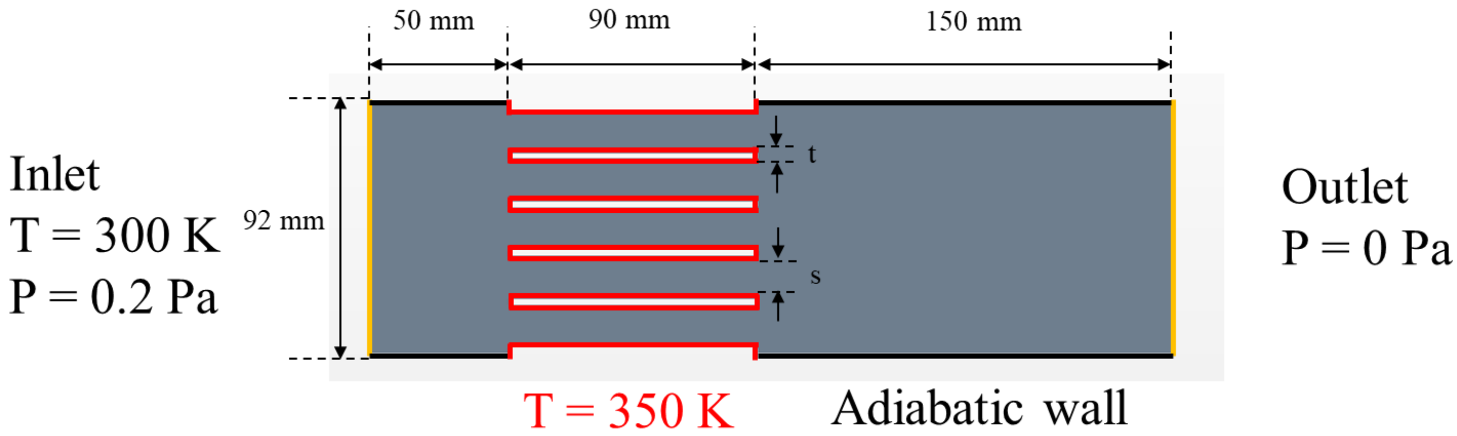
Heat Transfer

Convection Computational Assignment



The goal of this assignment is to computationally model the flow between straight fins and find a (near) optimum arrangement to achieve the maximum heat transfer from the fins while maintaining a fixed inlet pressure. For fins of finite length, the flow will be three-dimensional. However, for the purpose of this assignment, we will consider a simplified two-dimensional geometry as shown on the attached sheet. Also, we will consider all fin surfaces to be uniformly at a fixed temperature (350 K).

For your analytical calculations, please assume a 3D simulation with fin height of 1m (The 2D fins in the figure above have a hypothetical height of 1m).

During the lab session you used Star-CCM+ to computationally model the flow and heat transfer with 6 fins. Now increase the number of fins with fixed inlet and outlet ducts, and for each case tabulate the following information:

a) The number of fins
b) Mass flow rate
c) Bulk temperature at the exit of the domain
d) Total amount of heat transfer (Use formulation below)

$$q_{total} = \dot{m} c_p \left(T_{b,out} - T_{b,in}\right) \qquad \text{(use Cp value of ambient air)}$$

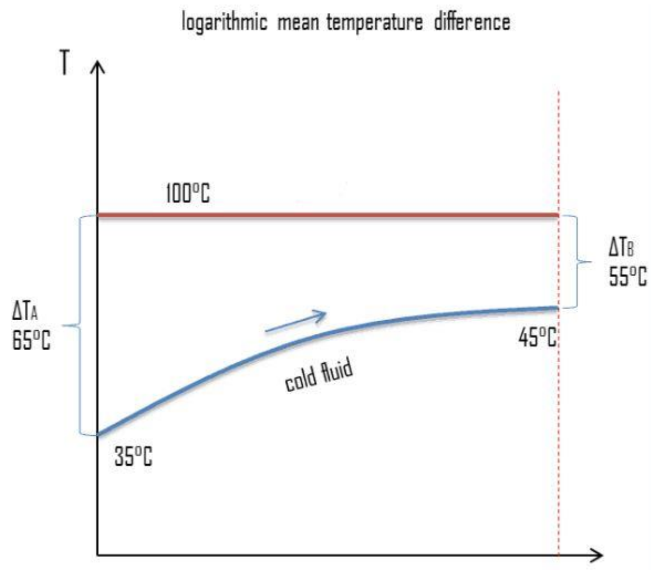
e) Average heat transfer coefficient (Use formulation below)

$$q_{total} = \bar{h} A_{surface} (LMTD)$$

Where,

-LMTD is the Logarithmic mean temperature difference the flow inlet and outlet points (see example below)

-$A_{surface}$ is the total heat transfer area (total fin area in contact with flowing air)



$$LMTD = \frac{65 - 55}{ln\,65 - ln\,55} = 59.9°C$$

At least three cases except for the original case should be run and shown the results. Also for each case, provide an image showing the final temperature contours.

*After checking the table , the value of ambient air in 300K is **cp=1.005kJ/(kg*K)**, which has been used for the calculation.

Case I

a) The number of fins: **7**
b) Mass flow rate: **8.540696e-02 kg/s**
c) Bulk temperature at the exit of the domain: **3.100823e+02 K**
d) Total amount of heat transfer (Use formulation below)

$$q_{total} = \dot{m}c_p\left(T_{b,out} - T_{b,in}\right) = 8.540696\times10^{-2}\,\mathrm{kg/s}\times1.005kj/(\mathrm{kg\cdot K})\times(343.109\mathrm{K} - 312.135\mathrm{K}) = 2658.622\mathrm{J/s}$$

e) Average heat transfer coefficient (Use formulation below)

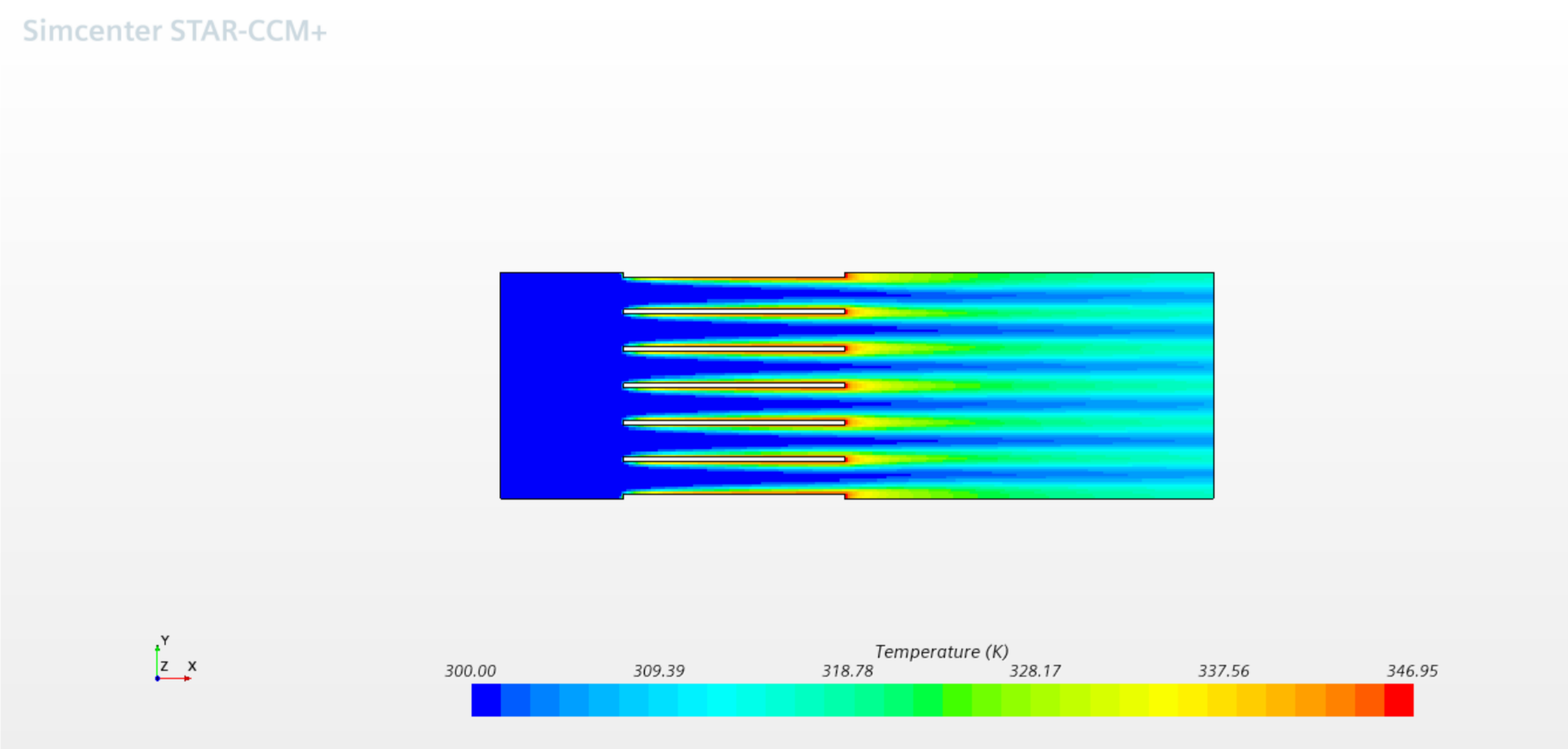
$$\mathrm{A}_{surface} = 12\times(1m\times0.09m) = 1.08m^2$$

$$\mathrm{LMTD} = \frac{(350-312.135)-(350-343.109)}{\log(350-312.135)-\log(350-343.109)} = 41.85926\mathrm{K}$$

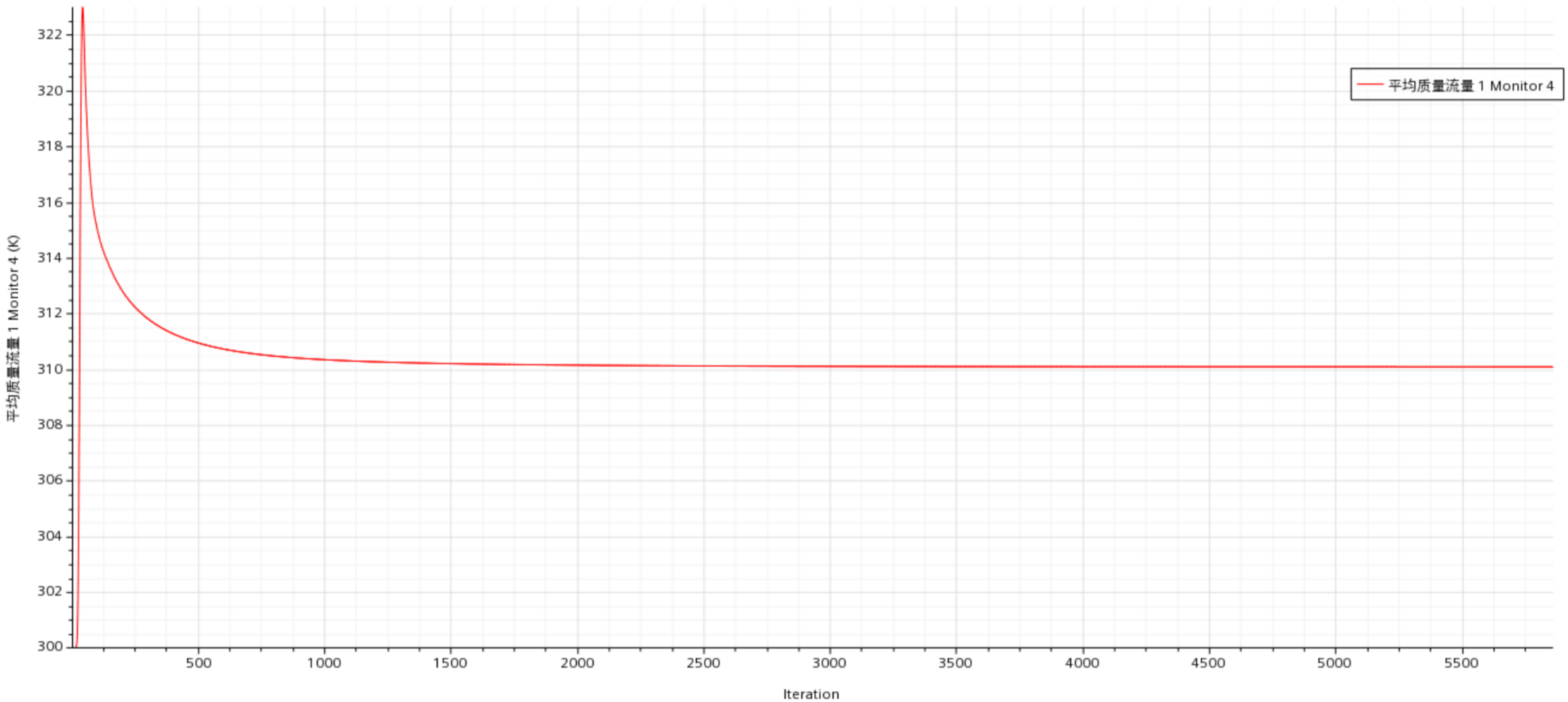
$$q_{total} = \bar{h}A_{surface}(LMTD)$$

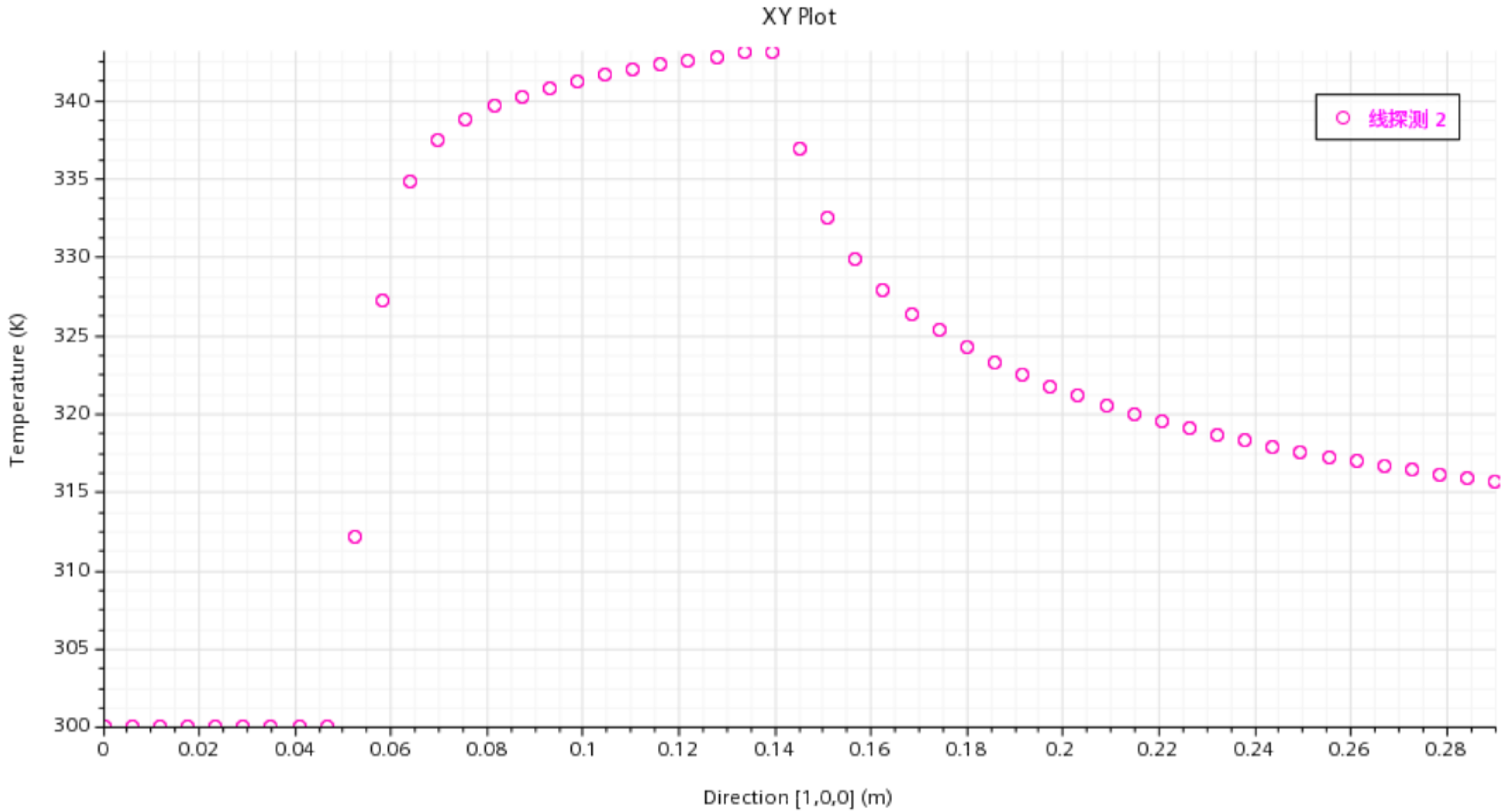
$$\bar{h} = \frac{q_{total}}{\mathrm{A}_{surface}(\mathrm{LMTD})} = \frac{2658.622}{1.08\times41.85926} = 58.809\mathrm{W/m^2K}$$

Where,
-LMTD is the Logarithmic mean temperature difference the flow inlet and outlet points (see example below)
-$A_{surface}$ is the total heat transfer area (total fin area in contact with flowing air)


Simcenter STAR-CCM+
Temperature (K)
300.00
309.39
318.78
328.17
337.56
346.95
Y
Z
X

平均质量流量 1 Monitor 4 绘图





XY Plot
Temperature (K)
300
305
310
315
320
325
330
335
340
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.22
0.24
0.26
0.28
Direction [1,0,0] (m)
线探测 2

Case II

a) The number of fins: **11**
b) Mass flow rate: **3.285067e-02 kg/s**
c) Bulk temperature at the exit of the domain: **3.300896e+02 K**
d) Total amount of heat transfer (Use formulation below)

$$q_{total} = \dot{m}c_p\left(T_{b,out} - T_{b,in}\right) = 3.28506\times10^{-2}\,\mathrm{kg/s}\times 1.005 kj/(\mathrm{kg\cdot K})\times(344.672\mathrm{K} - 318.165\mathrm{K}) = 875.1247\,\mathrm{J/s}$$

e) Average heat transfer coefficient (Use formulation below)

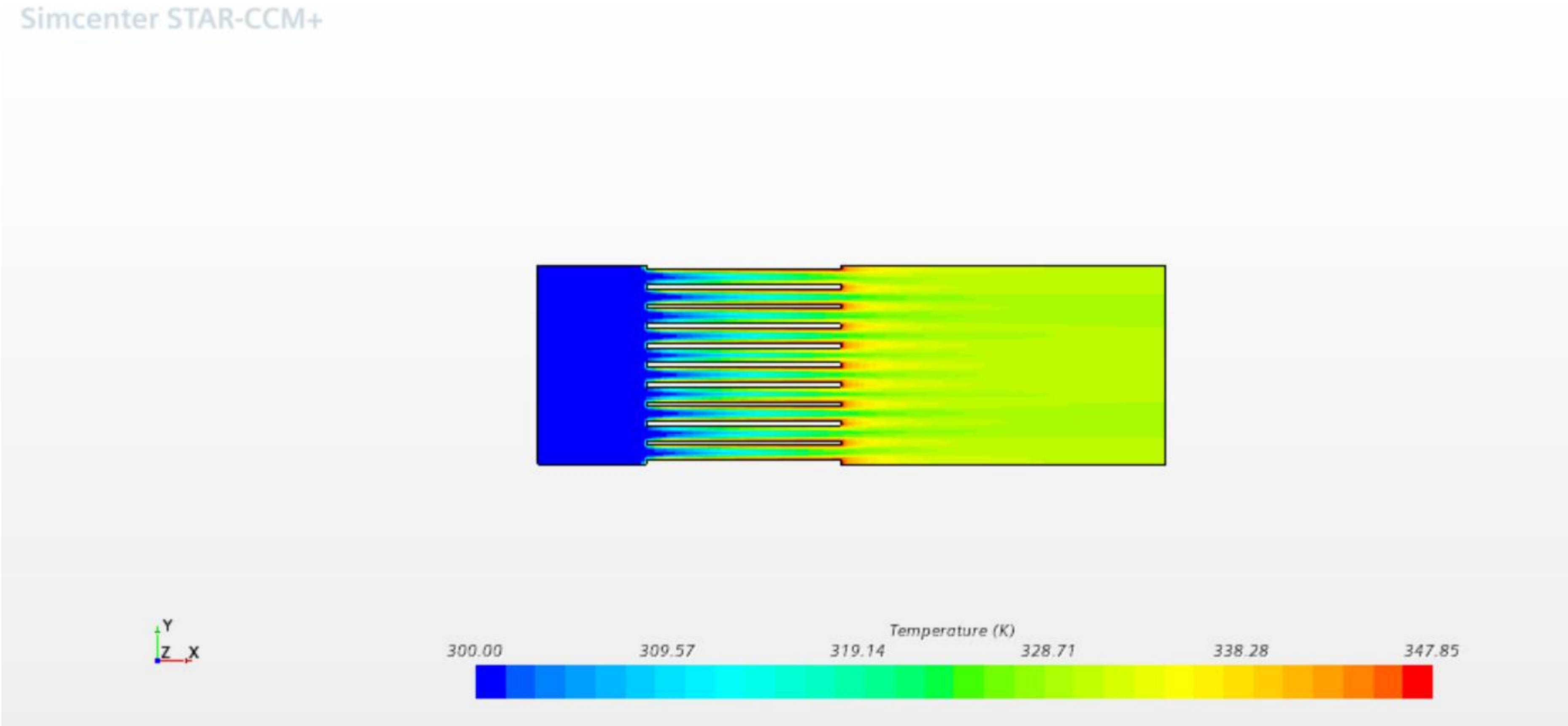
$$\mathrm{A}_{surface} = 20\times(1m\times0.09m) = 1.8m^2$$

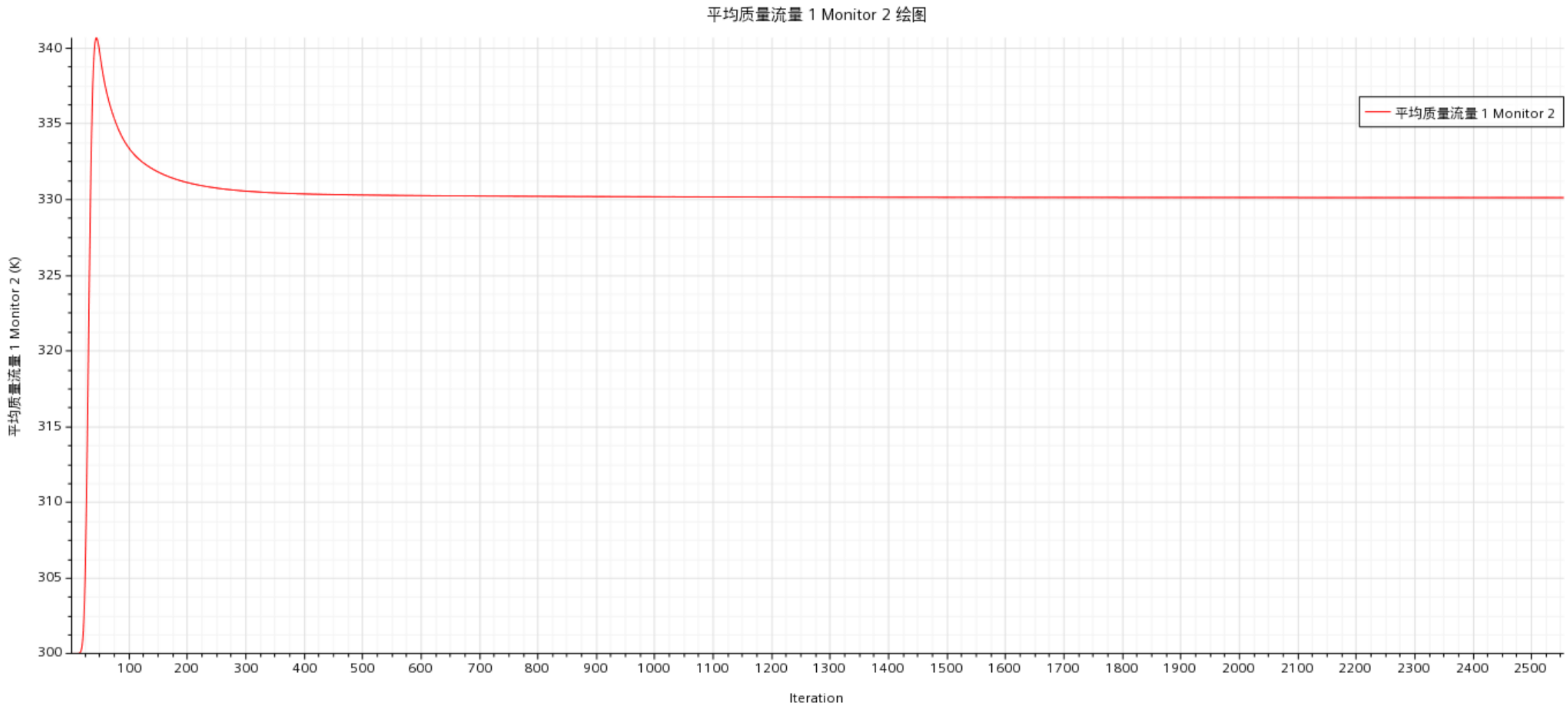
$$\mathrm{LMTD} = \frac{(350-318.165)-(350-344.672)}{\log(350-318.165)-\log(350-344.672)} = 34.14352$$

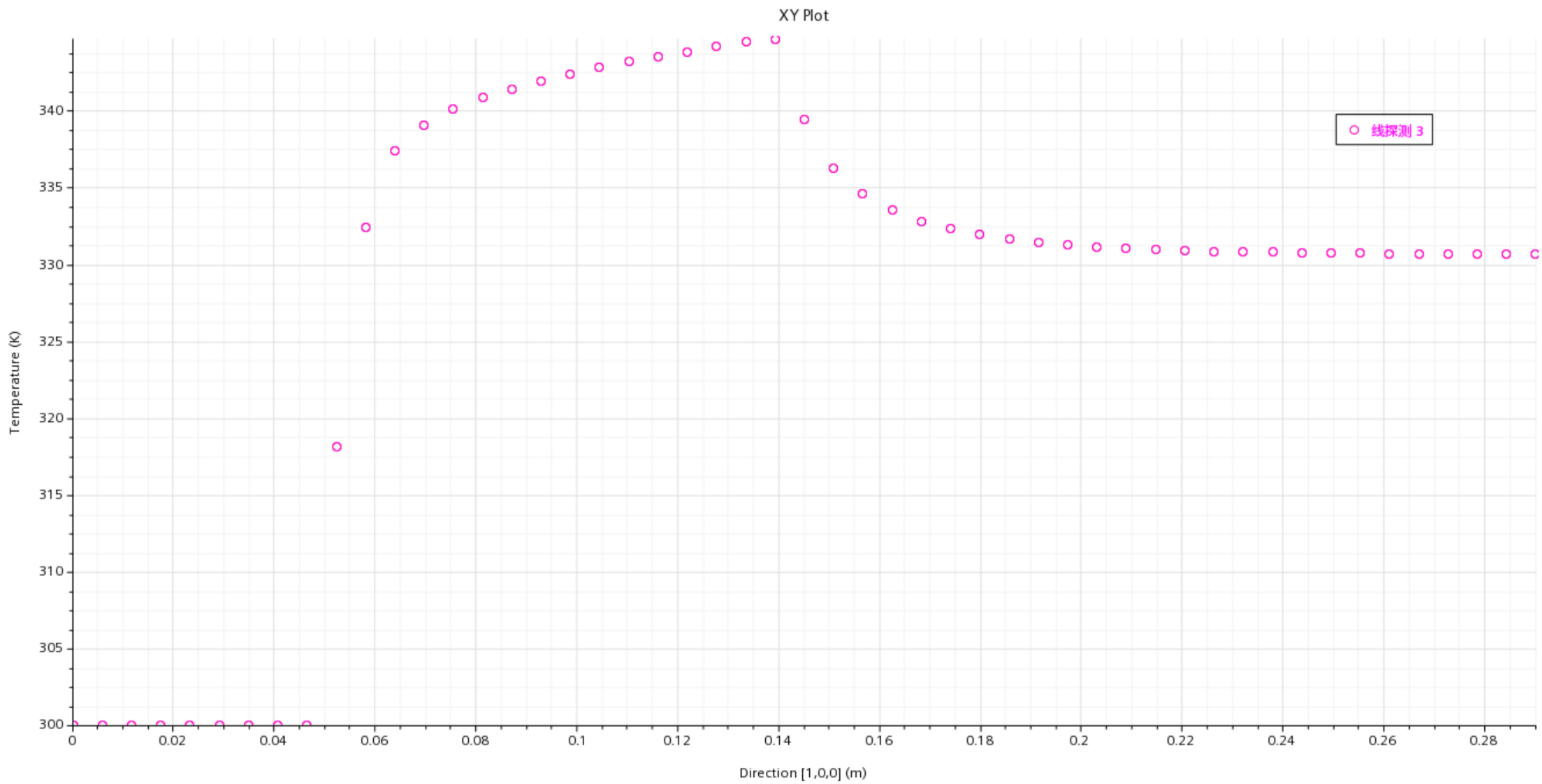
$$q_{total} = \bar{h}A_{surface}(LMTD)$$

$$\bar{h} = \frac{q_{total}}{\mathrm{A}_{surface}(\mathrm{LMTD})} = \frac{875.1247}{1.8\times34.14352} = 14.2393\,\mathrm{W/m^2K}$$

Where,
-LMTD is the Logarithmic mean temperature difference the flow inlet and outlet points (see example below)
-$A_{surface}$ is the total heat transfer area (total fin area in contact with flowing air)


Simcenter STAR-CCM+
Y
Z
X
Temperature (K)
300.00
309.57
319.14
328.71
338.28
347.85


平均质量流量 1 Monitor 2 绘图
平均质量流量 1 Monitor 2
平均质量流量 1 Monitor 2 (K)
Iteration
340
335
330
325
320
315
310
305
300
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500


XY Plot
线探测 3
Temperature (K)
340
335
330
325
320
315
310
305
300
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.22
0.24
0.26
0.28
Direction [1,0,0] (m)

Case III

a) The number of fins: **16**
b) Mass flow rate: **1.198155e-02**
c) Bulk temperature at the exit of the domain: **3.498231e+02**
d)
e)
f) Total amount of heat transfer (Use formulation below)

$$q_{total} = \dot{m}c_p\left(T_{b,out} - T_{b,in}\right) = 1.198155\times10^{-2}\,\mathrm{kg/s}\times1.005\,kj/(\mathrm{kg}\cdot\mathrm{K})\times(349.912\mathrm{K} - 327.483\mathrm{K}) = 270.0779\,\mathrm{J/s}$$

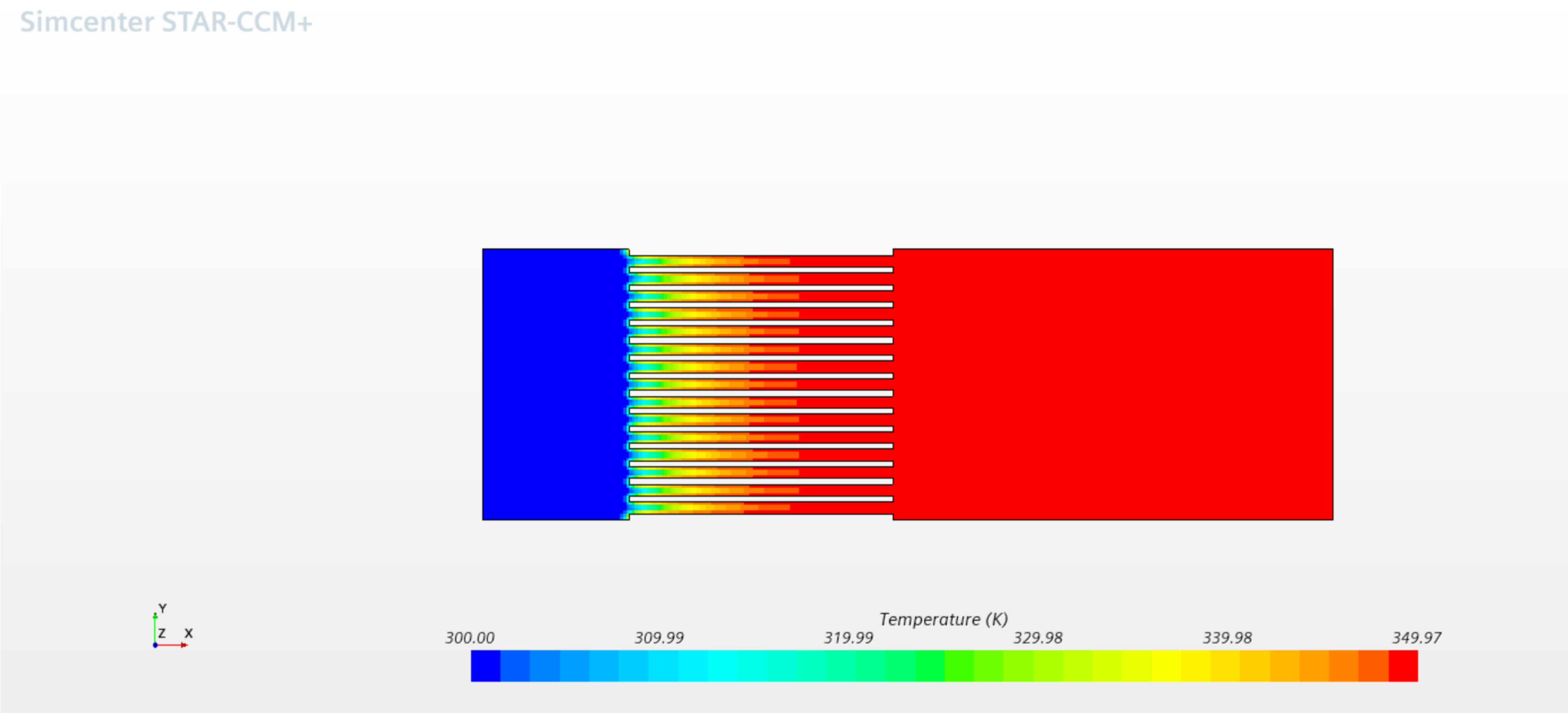
g) Average heat transfer coefficient (Use formulation below)

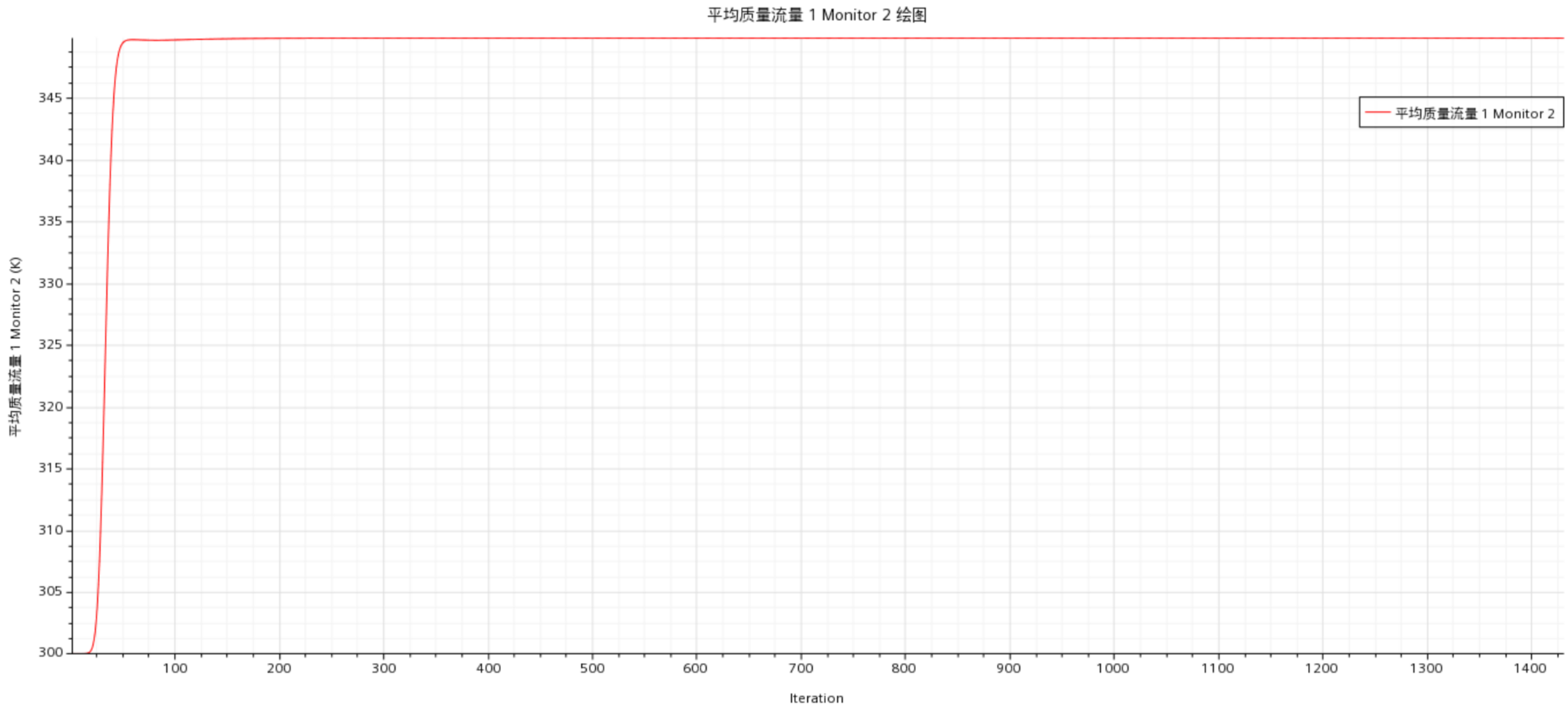
$$\mathrm{A}_{surface} = 30\times(1m\times0.09m) = 2.7m^2$$

$$\mathrm{LMTD} = \frac{(350-327.483)-(350-349.912)}{\log(350-327.483)-\log(350-349.912)} = 9.31426$$

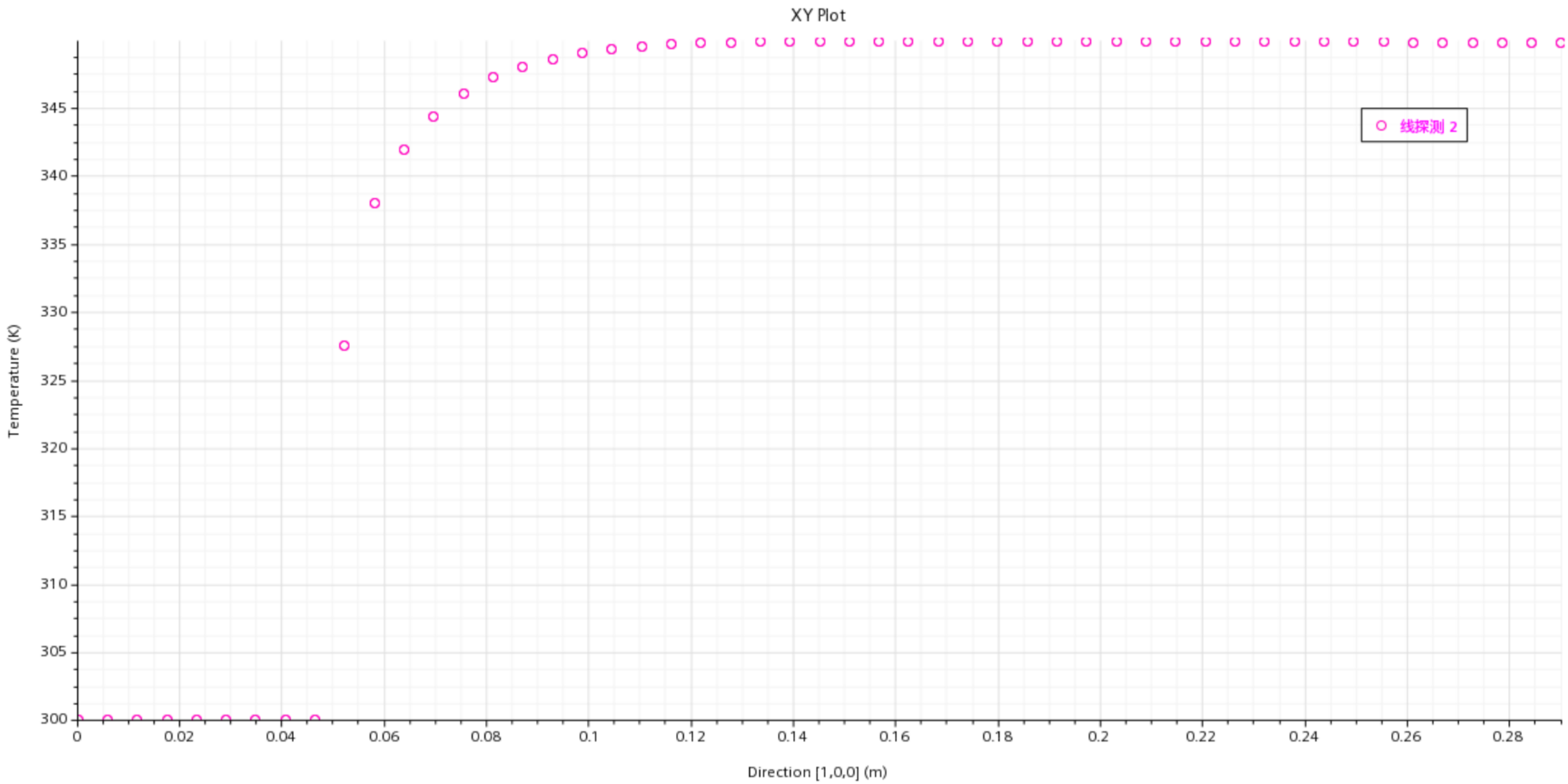
$$q_{total} = \bar{h}A_{surface}(LMTD)$$

$$\bar{h} = \frac{q_{total}}{\mathrm{A}_{surface}(\mathrm{LMTD})} = \frac{270.0779}{2.7\times9.31426} = 10.7393\,\mathrm{W/m^2K}$$


Simcenter STAR-CCM+
Y
Z
X
Temperature (K)
300.00
309.99
319.99
329.98
339.98
349.97



平均质量流量 1 Monitor 2 绘图
平均质量流量 1 Monitor 2
平均质量流量 1 Monitor 2 (K)
Iteration
300
305
310
315
320
325
330
335
340
345
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400



XY Plot
Temperature (K)
345
340
335
330
325
320
315
310
305
300
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.22
0.24
0.26
0.28
Direction [1,0,0] (m)
线探测 2