Fluid-Thermal Analysis of an Air-Cooled Inverter with Laminar Flow

Rao Arimilli , arimilli@utk.edu
Ali Nejad, ali@utk.edu
Kivanc Ekici, ekici@utk.edu
Mechanical, Aerospace and Biomedical Engineering Department
University of Tennessee, Knoxville, TN 37996-2210

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The Problem

To design alternate configurations for a 55 kW inverter heat sink with laminar flow, utilizing the module designed for a cylindrical inverter with turbulent flow by Tawfik [5,6].

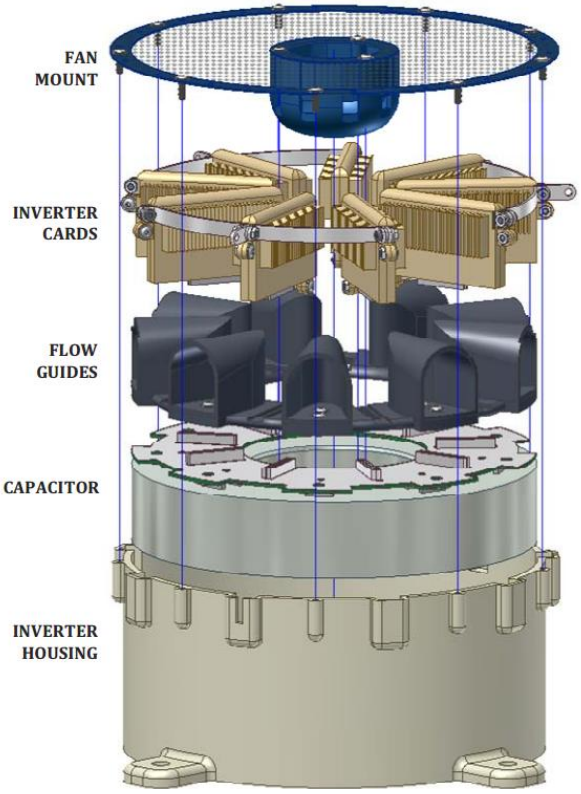
The alternate configurations should satisfy the same maximum temperature limit of 200 °C.

Differences:

- Modules are in linear Configuration
- Laminar Flow

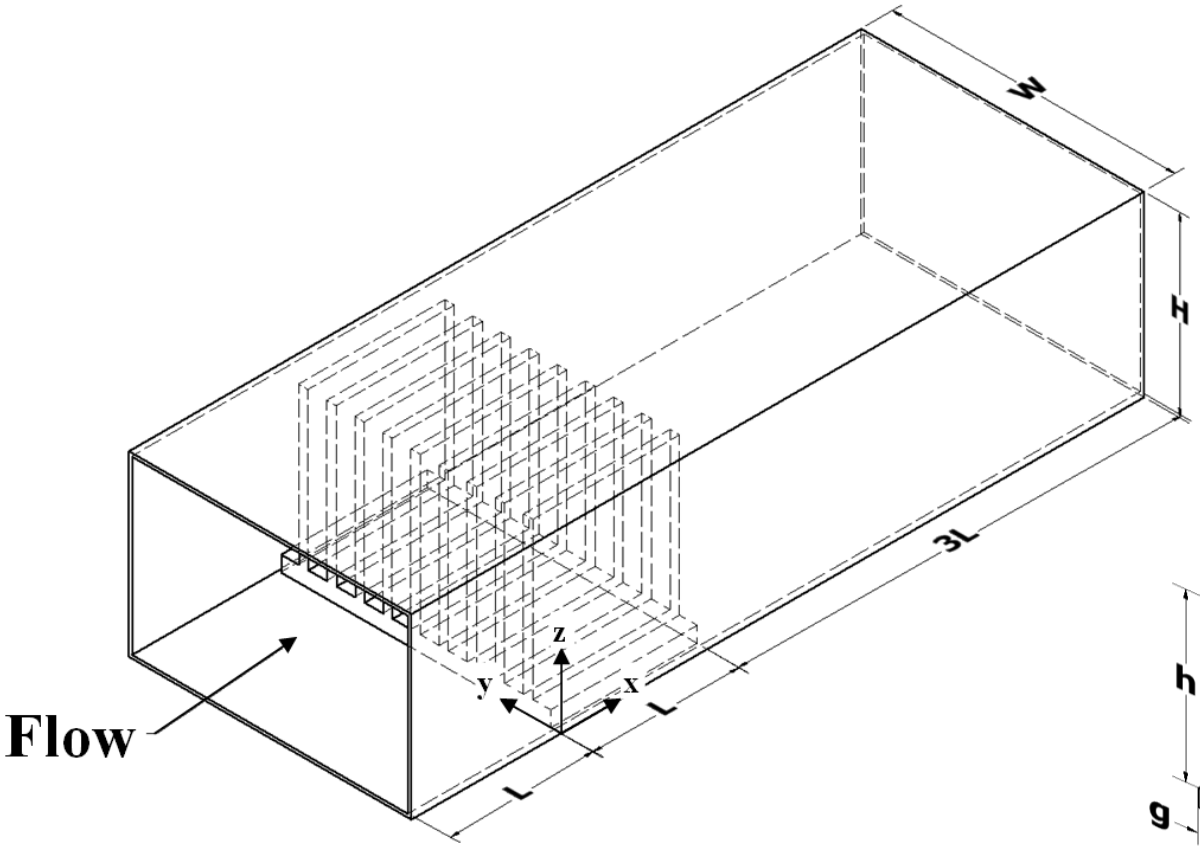
Similarities:

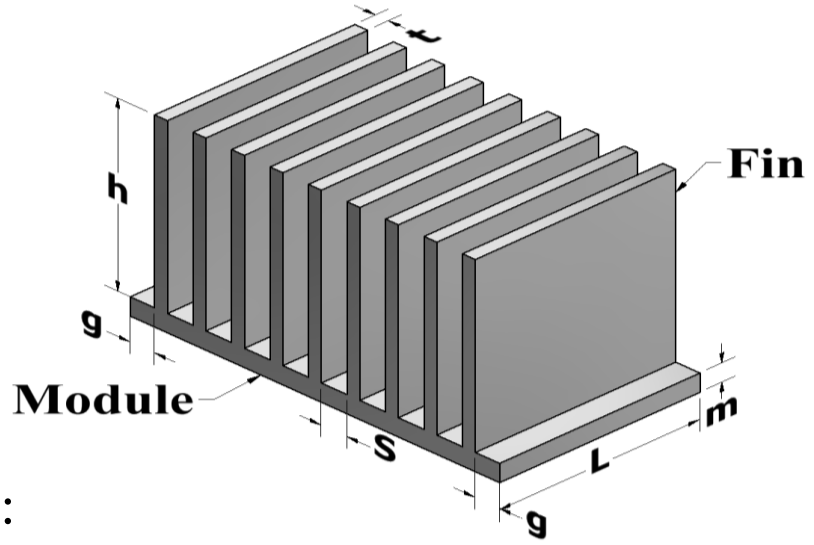
- Same Module size
- Same Generation Rate of 170 W



Tawfik [5,6]

The Configuration





Half Module Dimensions:
W = 86.36 mm; L = 46.84 mm; m = 5 mm

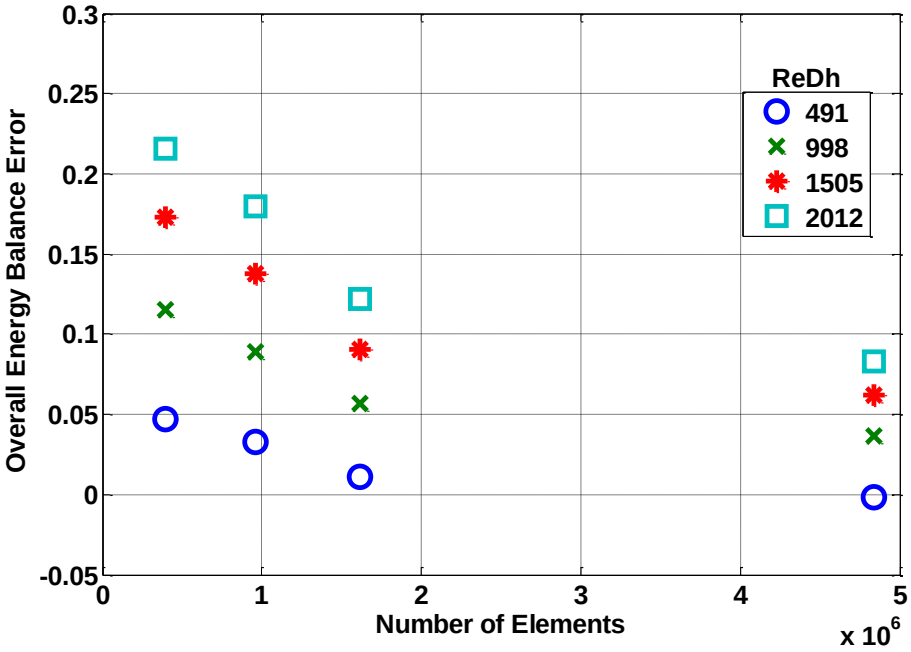
Model Assumptions

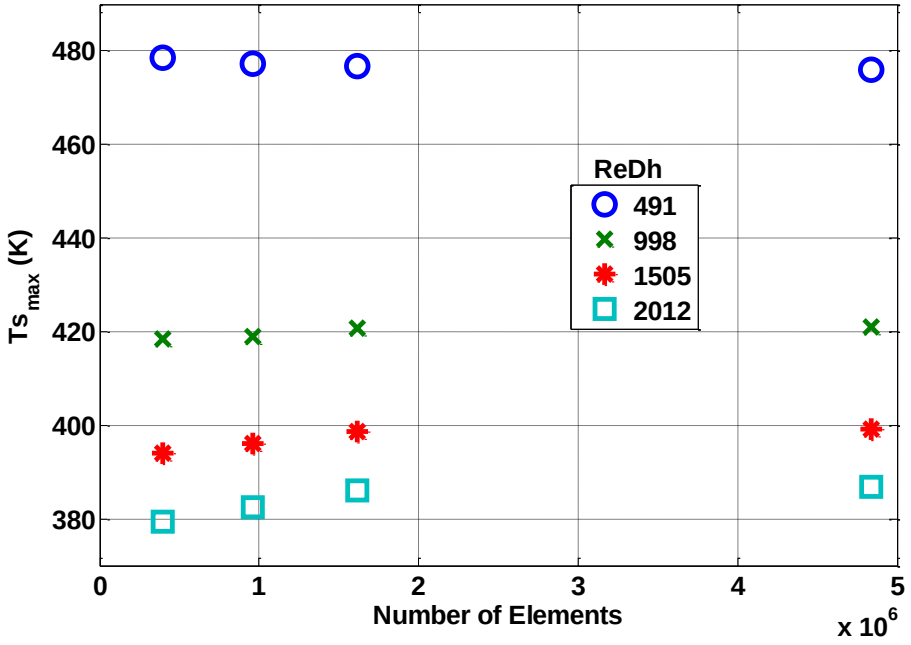
- Variable fluid properties for air from COMSOL material data base
- Constant aluminum properties from COMSOL material data base
- Half module internal generation rate 85.5 W
- Fin and module material: aluminum
- Inlet velocity calculated from specified inlet ReDh

Influence of Mesh Refinement on OEBE and Ts_{max}

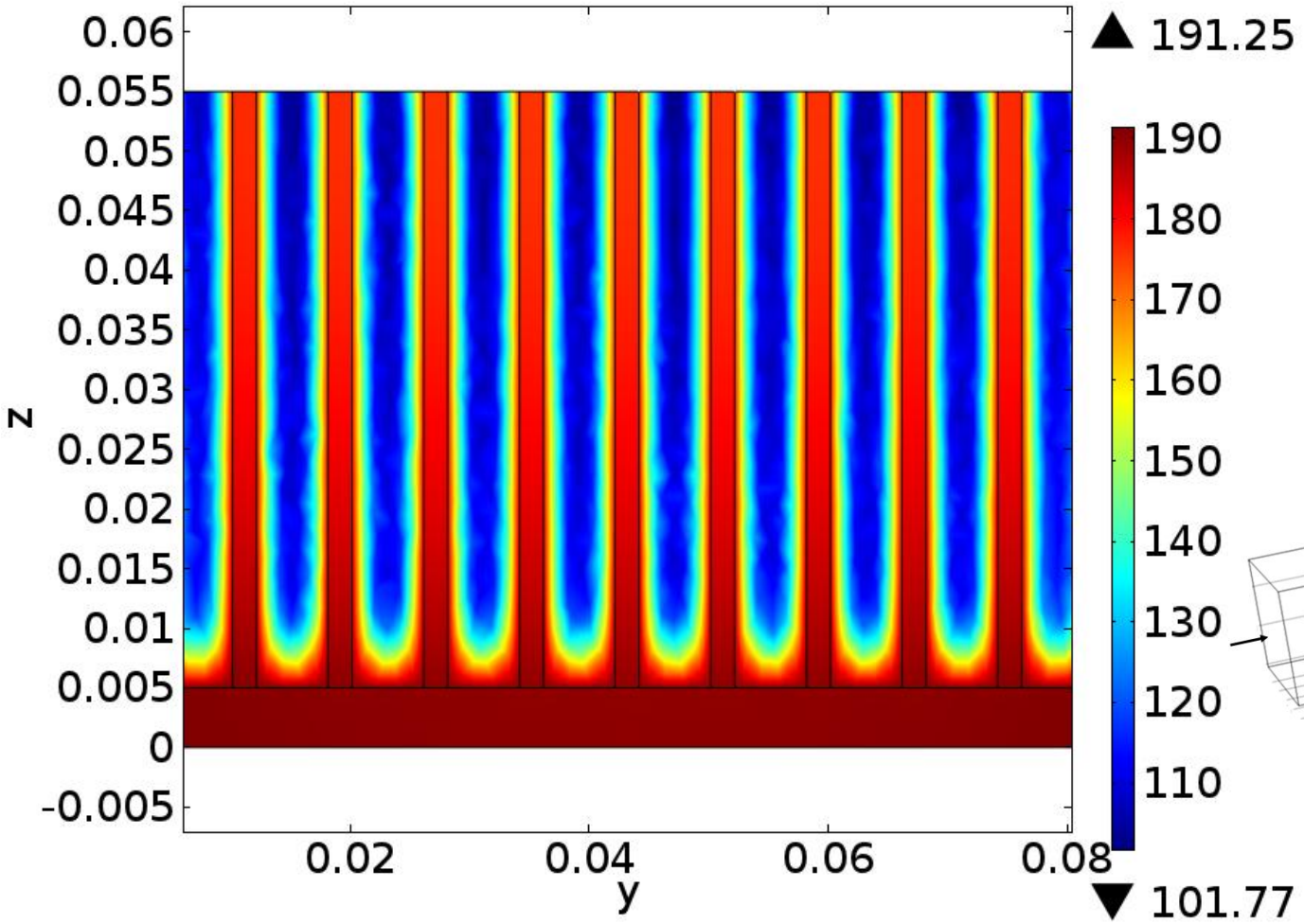
t = 3 mm, h = 50 mm, s = 6 mm, N_{fins} = 9

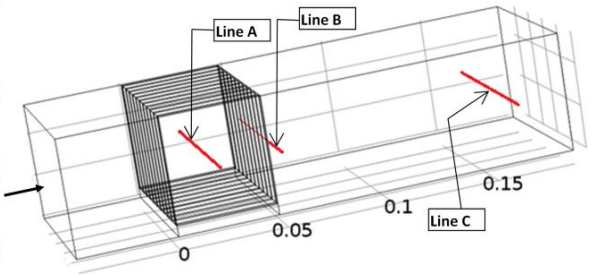
Area (exposed to air) = 47,636 mm^2





Temperature Distribution in Y-Z Plane Through Line A (in °C)



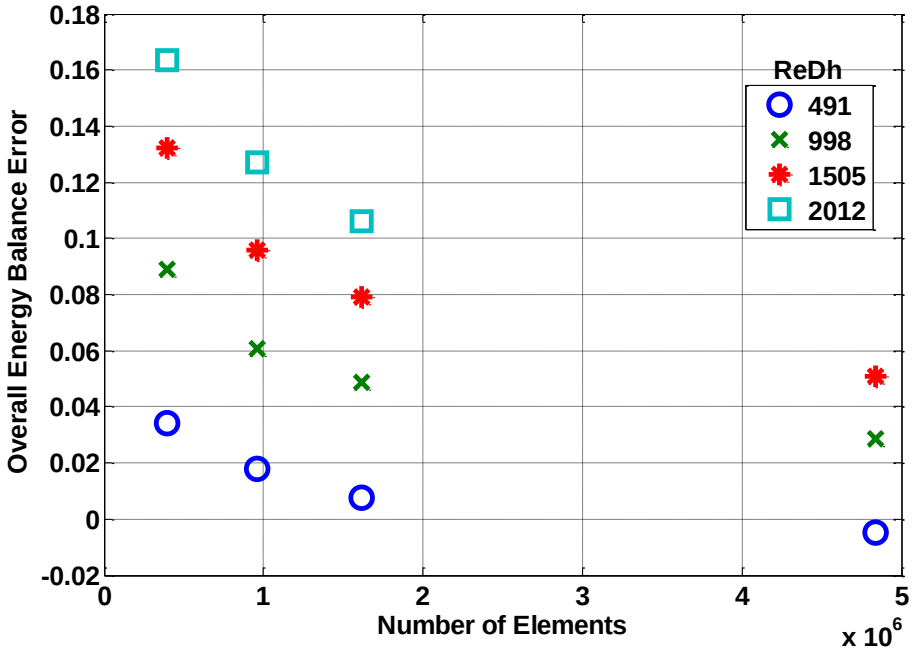


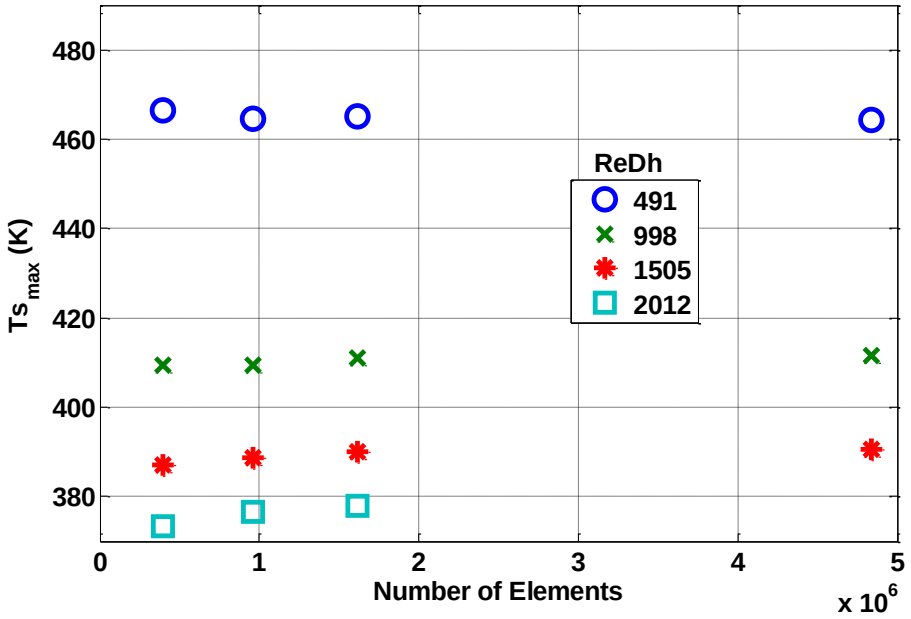
Module, Fins and Air Temperatures

Influence of Mesh Refinement on OEBE and Ts_{max}

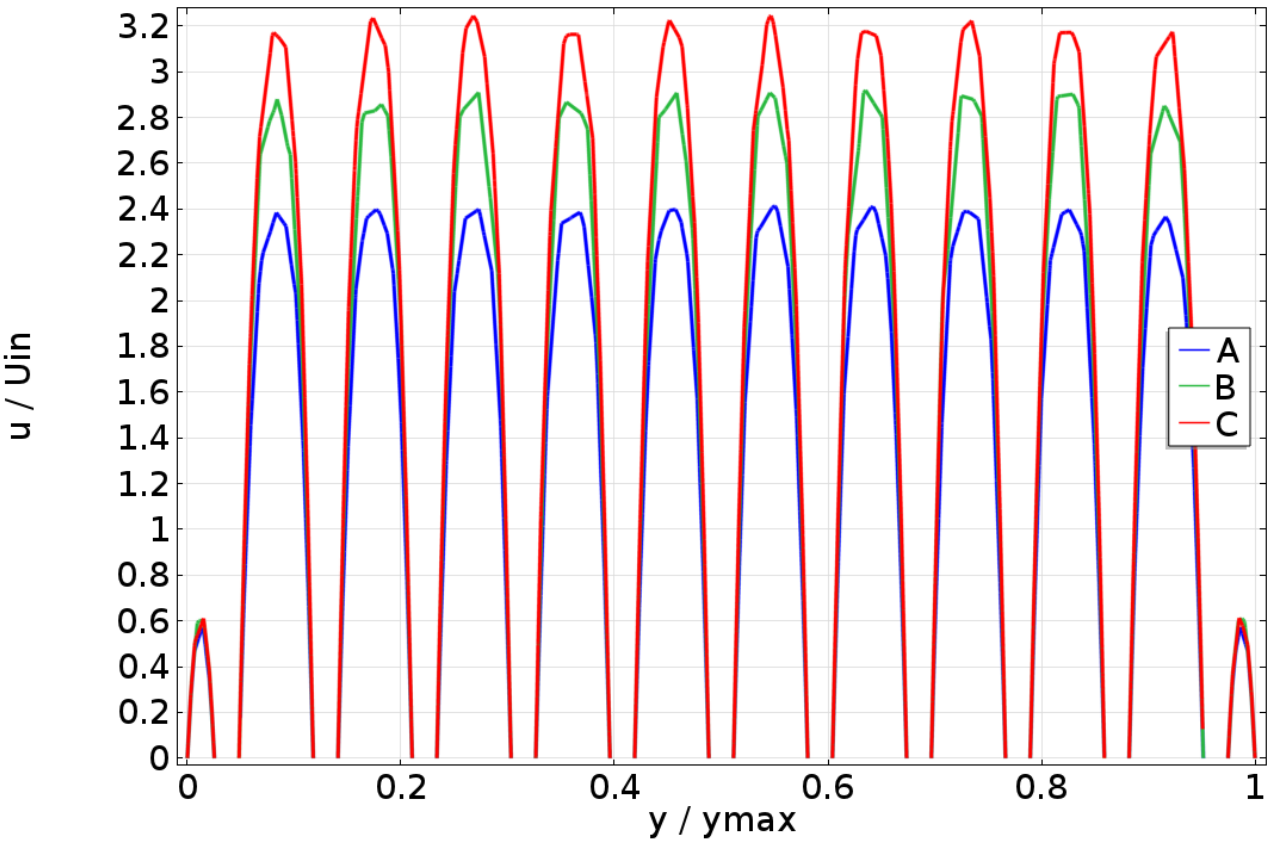
t = 2 mm, h = 50 mm, s = 6 mm, N_{fins} = 11

Area = 56,738 mm^2





Developing Flow in Channels



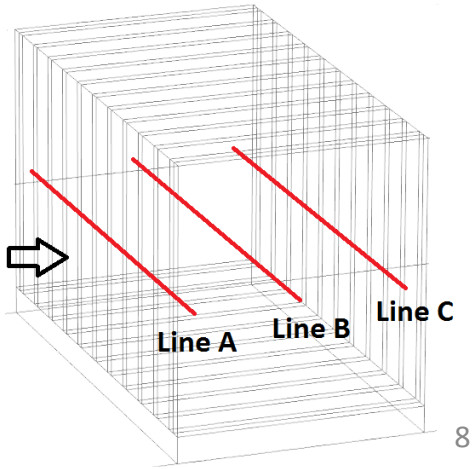
Re = 491

Fine mesh

h = 50 mm

s = 6 mm

t = 2 mm

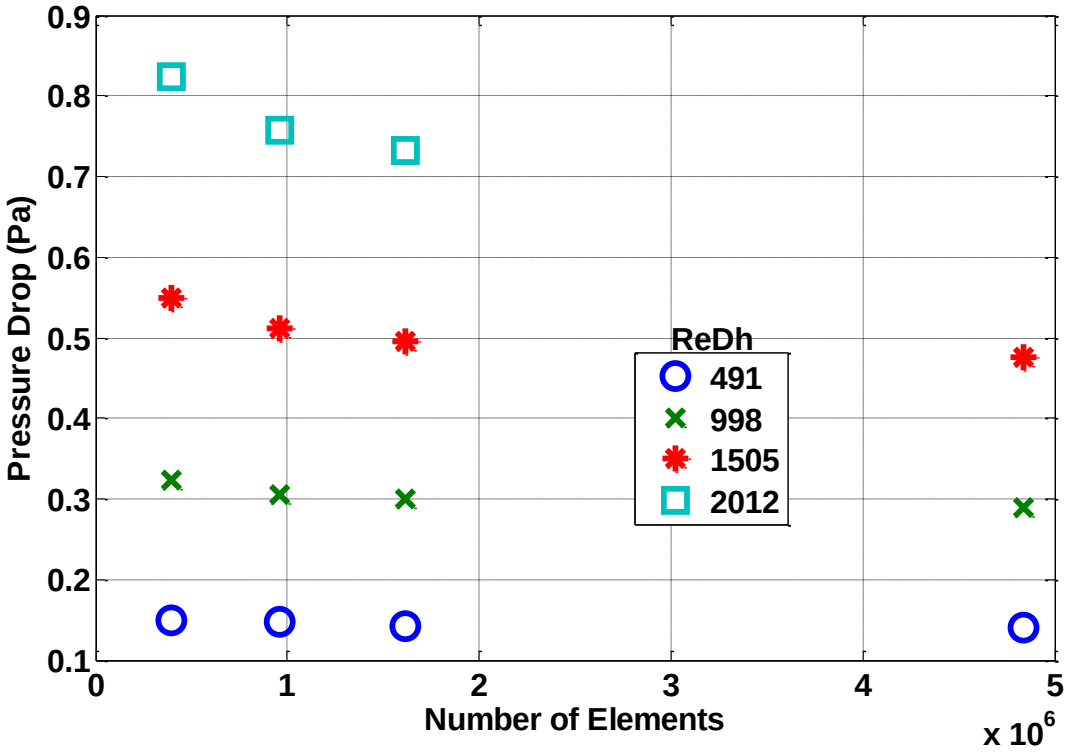


Developing flows have higher heat transfer coefficients relative to fully developed flow.

Influence of Mesh Refinement on Pressure Drop

t = 2 mm, h = 50 mm, s = 6 mm, N_{fins} = 11

Area = 56,738 mm^2



Unlike Ts_{max} , the pressure drop is more sensitive to mesh refinement at higher ReDh.

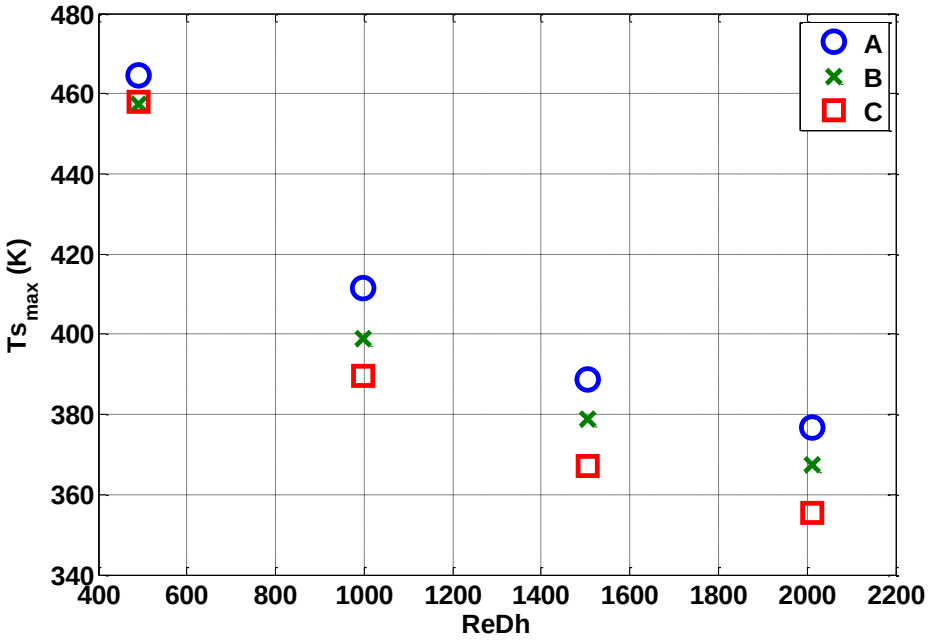
Selected Configurations for Further Study

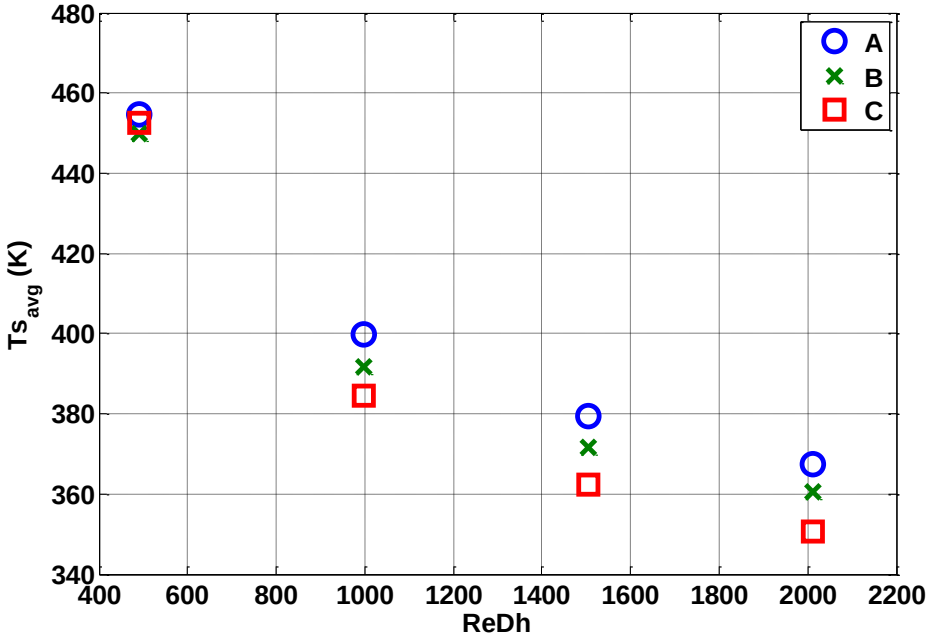
To reduce overall volume, the fin height needs to be reduced while keeping the exposed area for heat transfer and Ts_{max} relatively unchanged.

This can be achieved by increasing the number of fins and reducing the spacing between them.

Case	t (mm)	h (mm)	s (mm)	N_{fins}	Area **Exposed to Air (mm^2)**
A	2	50	6	11	56,738
B	2	42	4.5	13	56,160
C	2	33	3	17	57,251

Ts_{max} and Ts_{avg} for Configurations A, B and C

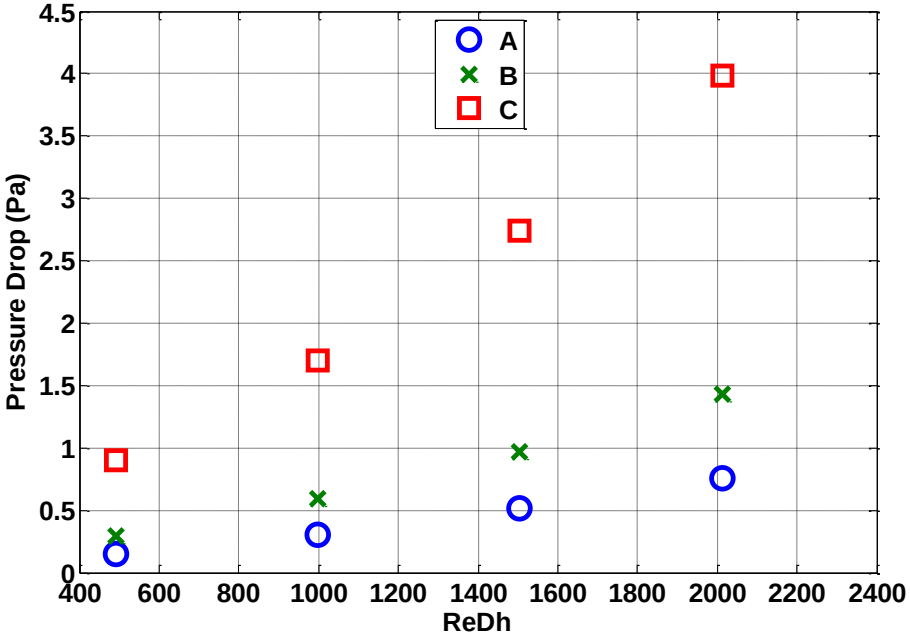




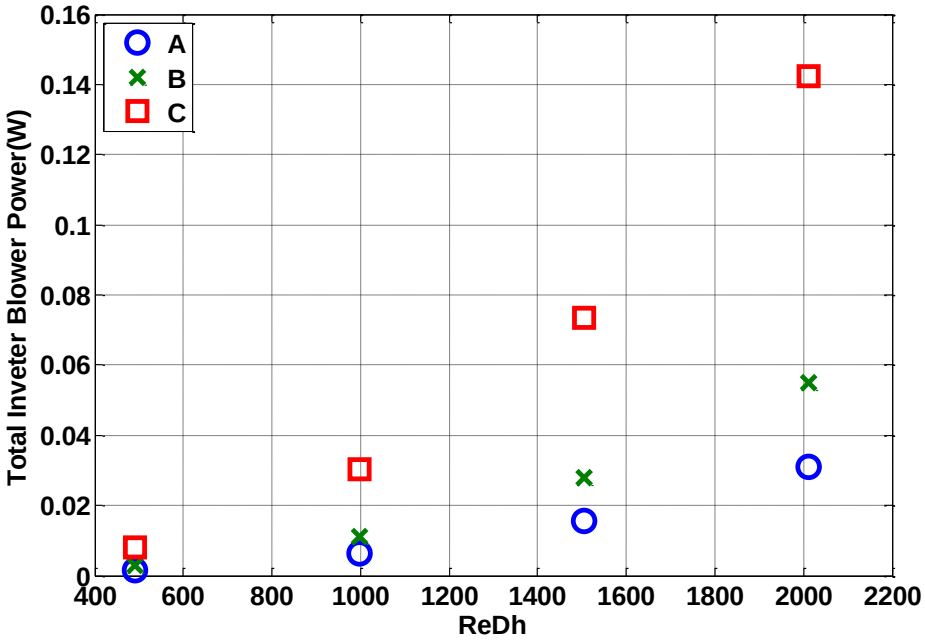
At any given ReDh, inlet velocity is increasing from A to C because of a decrease in hydraulic diameter.

Pressure Drop and Blower Power for Configurations A, B and C

Pressure Drop



Blower Power

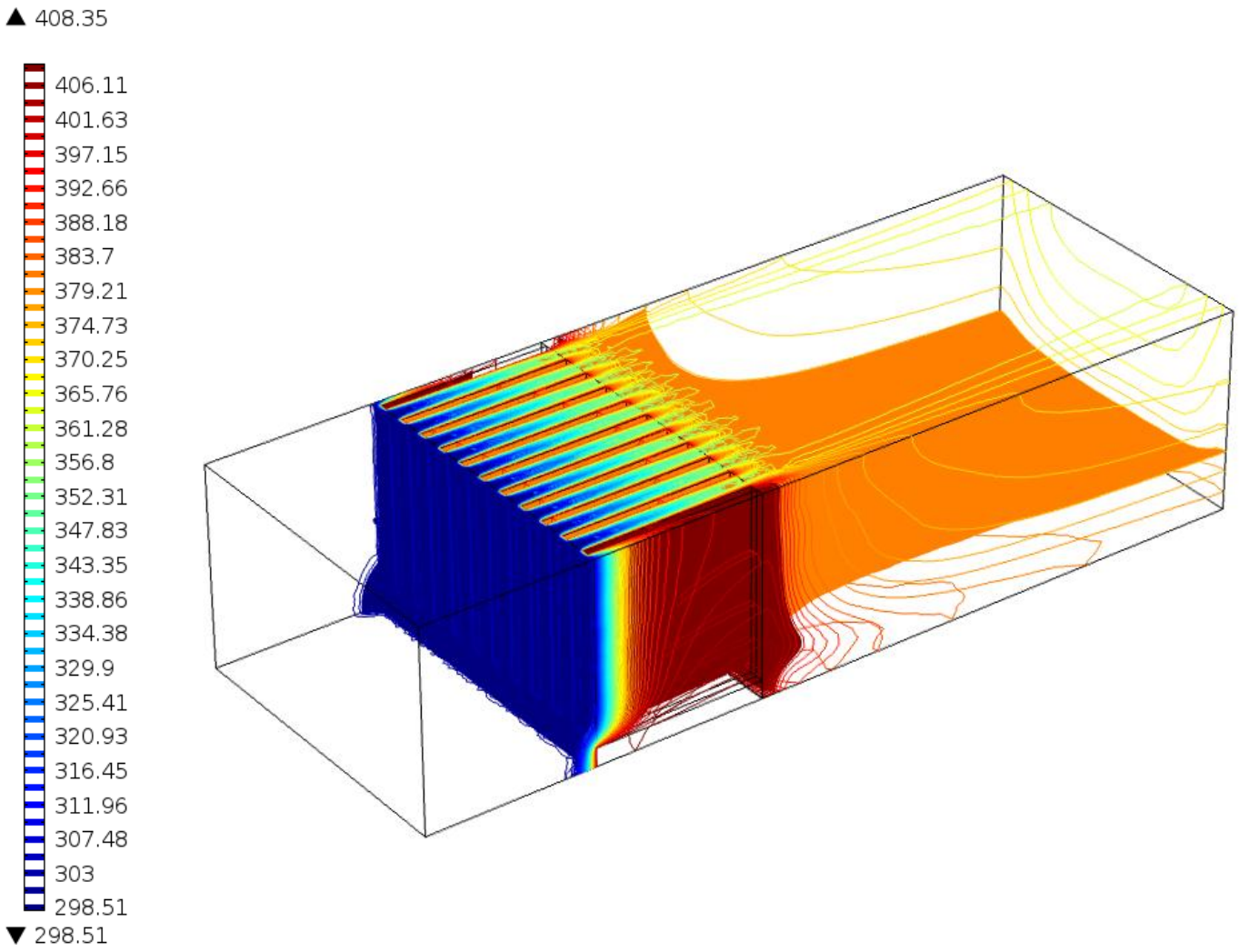


Conclusions

With laminar flow conditions it is shown that acceptable Ts_{max} values are achievable.

- Ts_{max} is less sensitive to mesh refinement.
- OEBE and pressure drop are much more sensitive to mesh refinement.
- Flow in the channels between fins is in the developing state for all ReDh considered.
- The overall volume was successfully reduced, while keeping the exposed area for heat transfer and Ts_{max} relatively unchanged.

Temperature Contours and Isosurfaces



Re = 998

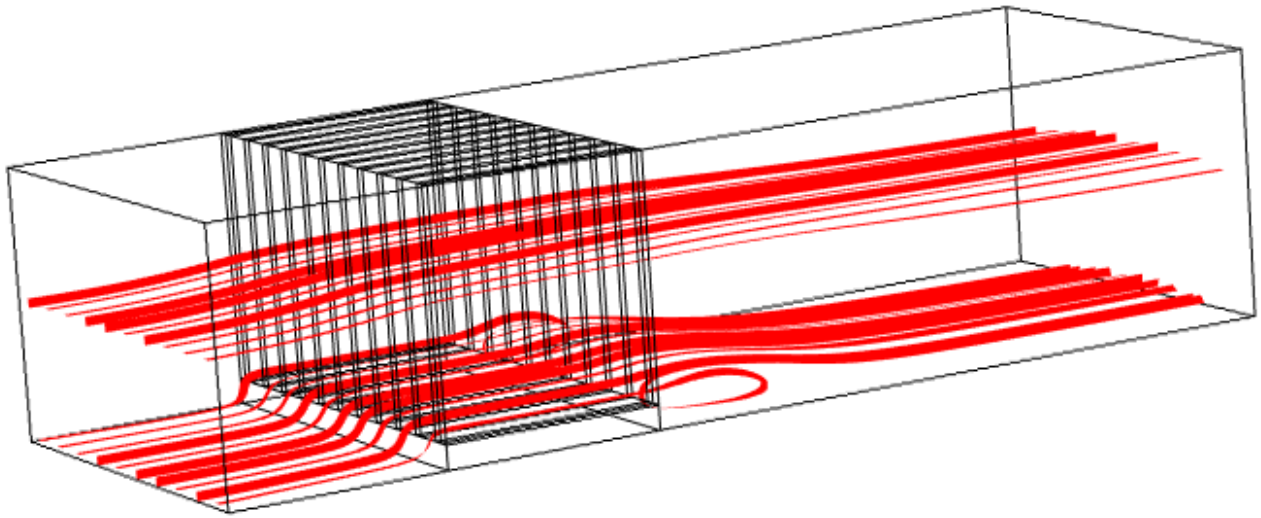
Normal mesh

h = 50 mm

s = 6 mm

t = 2 mm

Streamlines



Re = 491

Fine mesh

h = 50 mm

s = 6 mm

t = 2 mm