CFD Analysis of Fins

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Synopsis

The aim of this project is to analyse the effect of different types of fins and compare their temperature profile, heat loss and effectiveness. The solver used is chtMultiRegionFoam.

Introduction

Fins are used extensively in many areas to increase the heat loss. They are used in radiators in cars, computer CPU heat-sinks, heat-exchangers in power plants, etc. An important parameter of a fin is its effectiveness. Effectiveness is the ratio of heat transfer from fin to heat transfer without fin. Fins with higher effectiveness is preferred. In this project two different cross sections of fins, namely square and rectangle is compared keeping the total volume same.

Governing Equations

The equation solved is the Naiver-Strokes Equation with required simplifications..

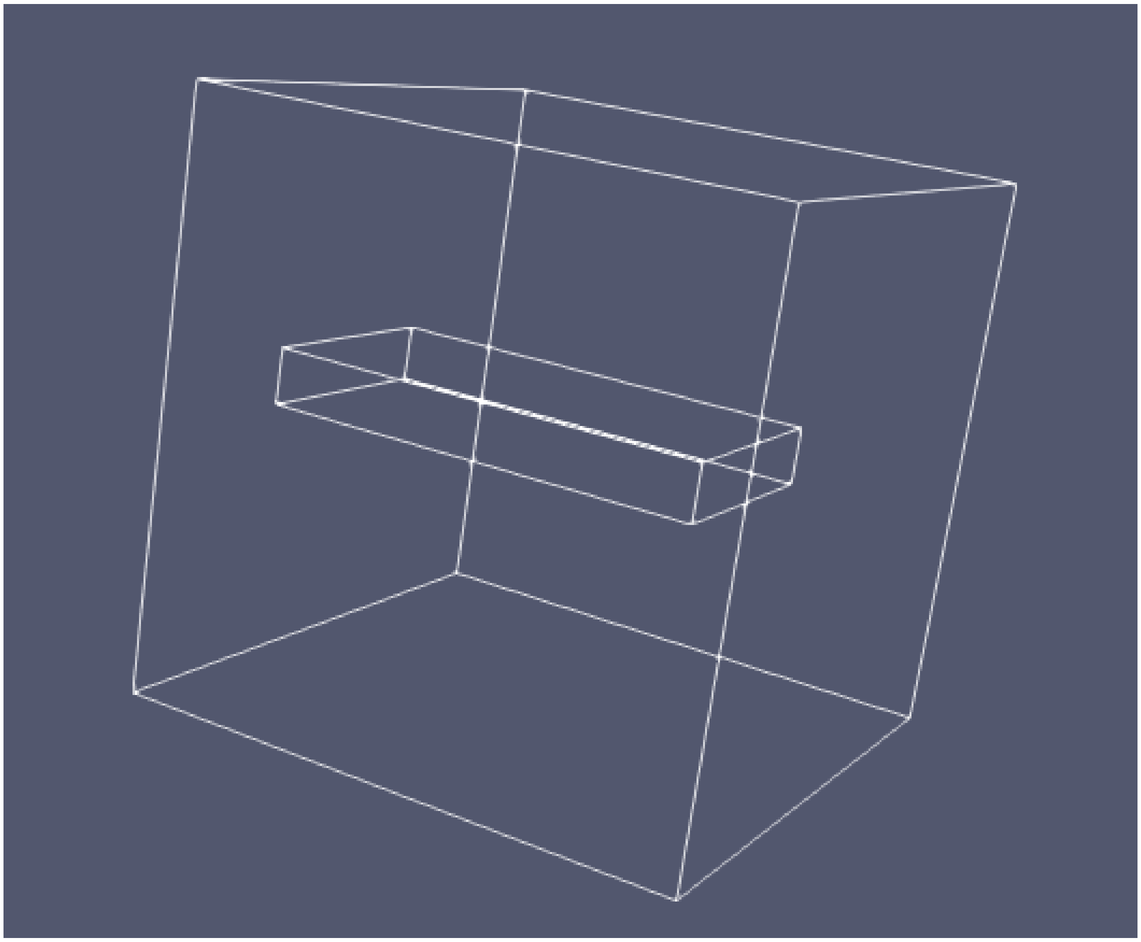
$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u_i)}{\partial x_i} = 0 \tag{1}$$

$$\frac{\partial(\rho u_i)}{\partial t} + \frac{\partial[\rho u_i u_j]}{\partial x_j} = -\frac{\partial p}{\partial x_i} + \frac{\partial \tau_{ij}}{\partial x_j} + \rho f_i \tag{2}$$

$$\frac{\partial(\rho e)}{\partial t} + (\rho e + p)\frac{\partial u_i}{\partial x_i} = \frac{\partial(\tau_{ij} u_j)}{\partial x_i} + \rho f_i u_i + \frac{\partial(\dot{q}_i)}{\partial x_i} + r \tag{3}$$

Geometry

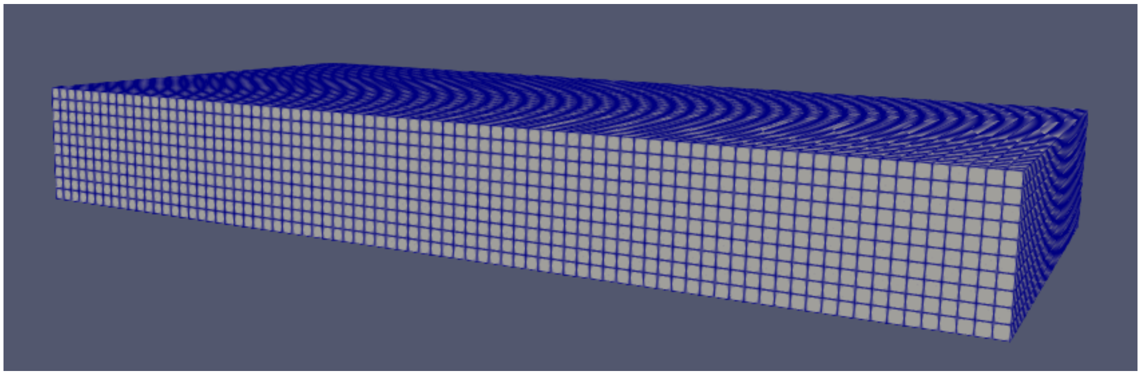
The fin dimensions are 400×10×10 (in mm) for the square fin and 400×20×5 (in mm) for the rectangular fin. The outer domain has dimensions 0.5m×0.5m×0.5m.



Rectangular fin geometry

Mesh

The external domain was made using blockMesh. Metal Fin was added to it using topoSet.



Boundary and initial conditions

The left side of fin is kept at constant temp of 500°C. The fluid is entering the domain at 300°C and at 0.001m/s velocity.

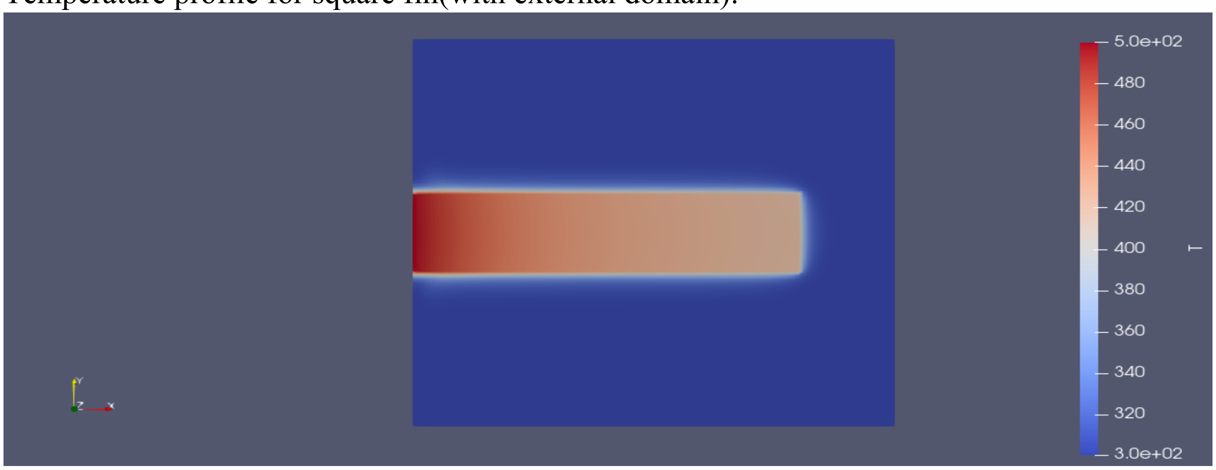
Solver

The solver used is chtMultiRegionFoam. There are two regions namely fluid and metal having different properties.

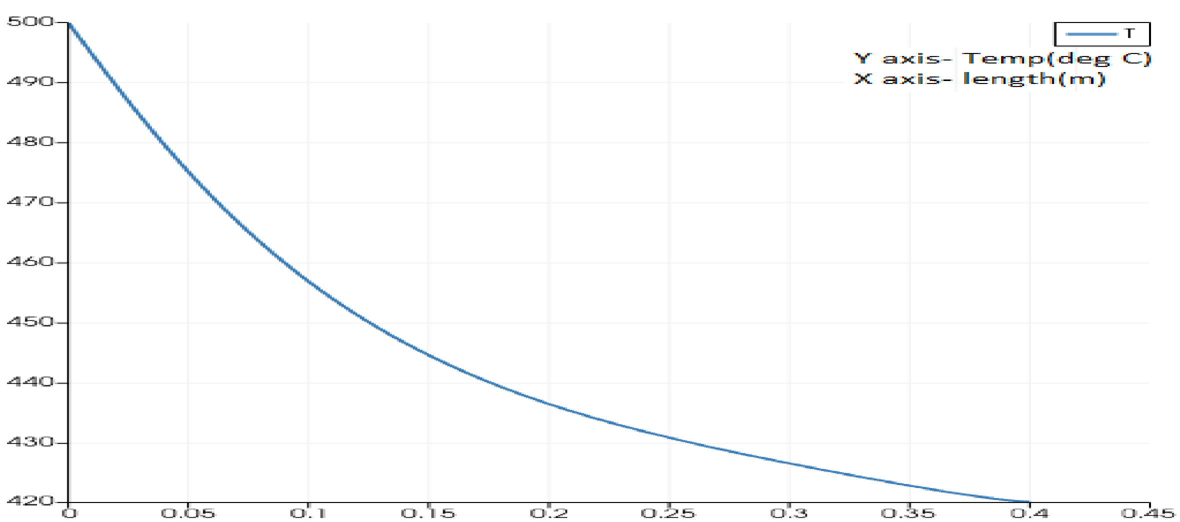
Results and Discussions

The simulation was run till steady state was achieved and no further change in temperature profile was observed. The final temperature velocity profiles are shown below.

Temperature profile for square fin(with external domain):

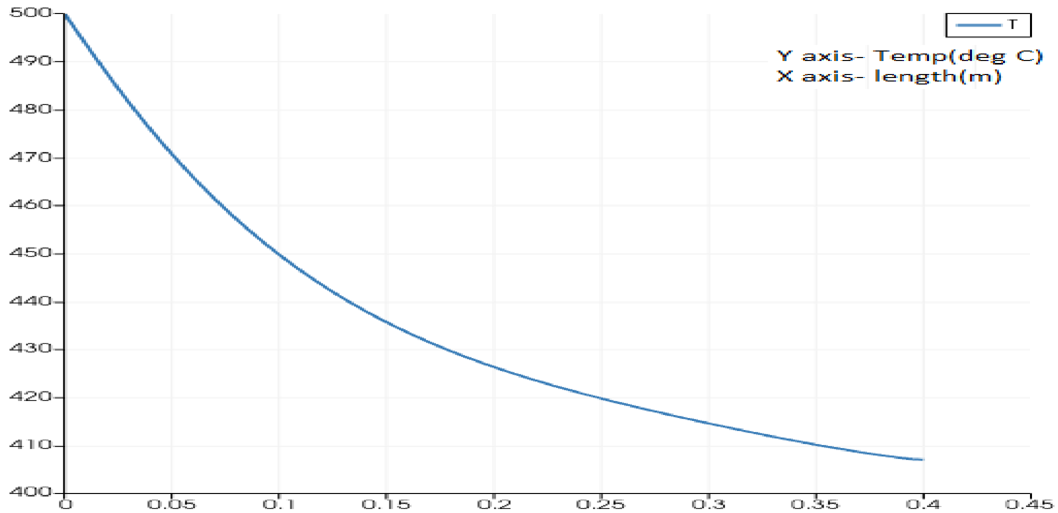


Variation of temperature along length for square fin:

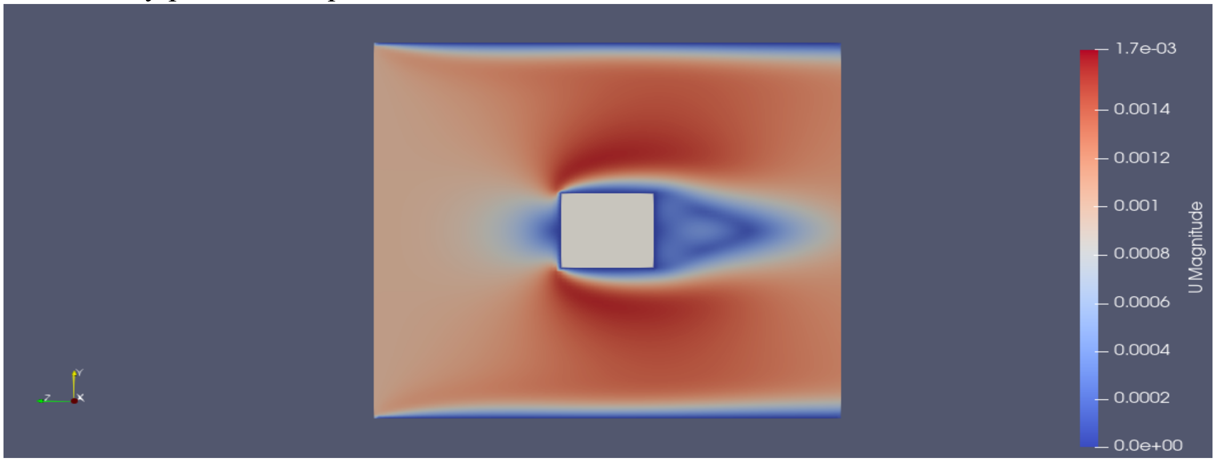


Temperature profile for rectangular fin(hiding the external domain):

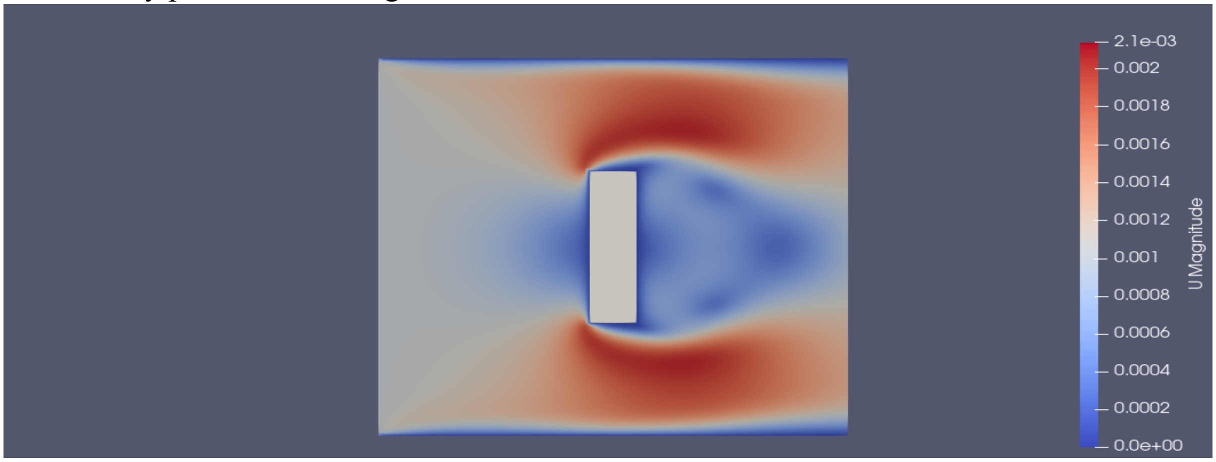
Variation of temperature along length for rectangular fin:



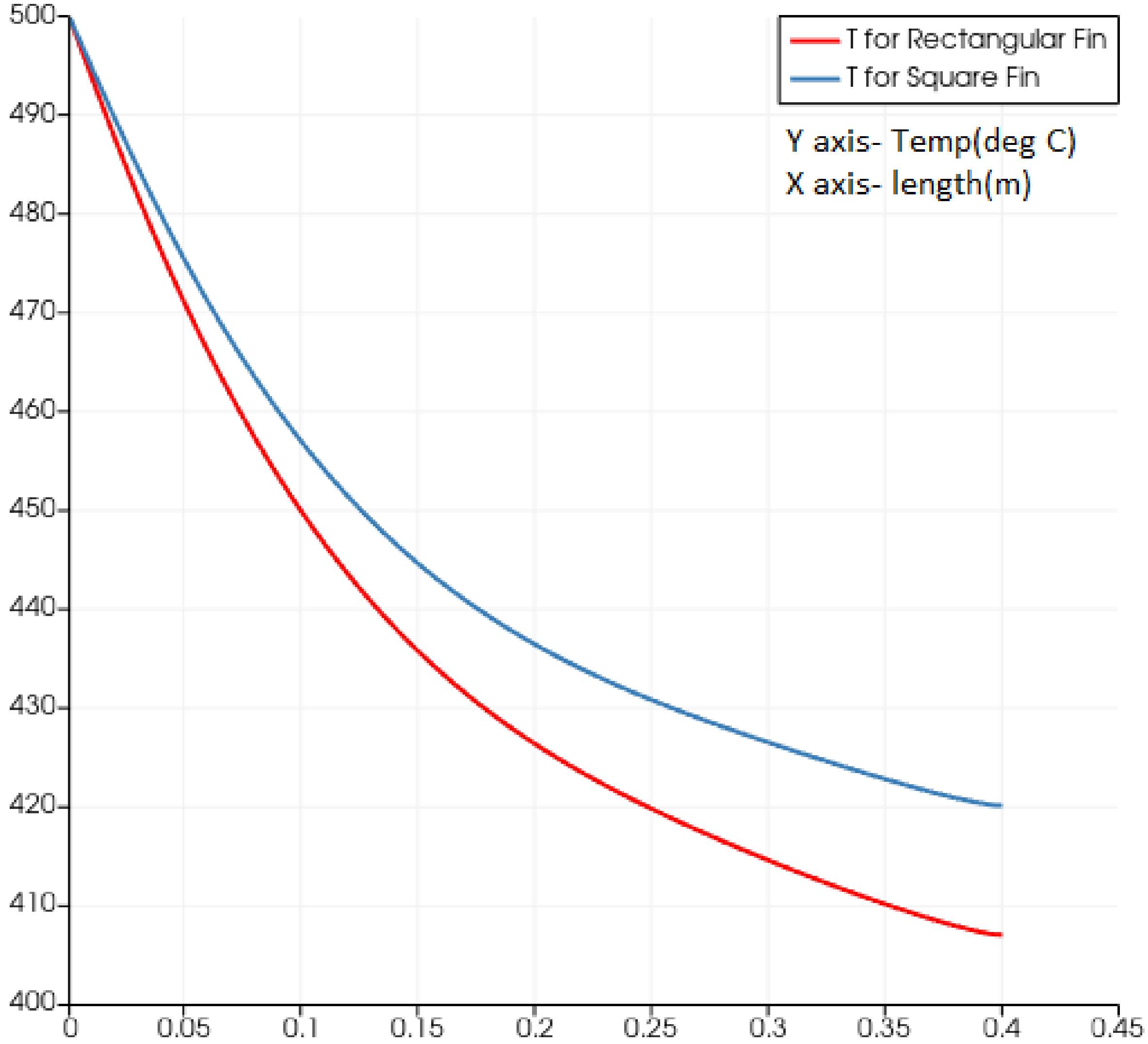
Velocity profile for square fin



Velocity profile for rectangular fin



Comparison of the variation of temperature along length for rectangular and square fin in a single figure is as follows:



Heat transfer from a fin is given by:

$$Q = \sqrt{hPkA_c}\theta_b \frac{\sinh mL + \frac{h}{mk}\cosh mL}{\cosh mL + \frac{h}{mk}\sinh mL} \tag{4}$$

and Effectiveness,

$$\epsilon = \frac{Q}{hA_c\theta_b} \tag{5}$$

where,
h - convective heat transfer coefficient
P - perimeter of the fin
k - conduction coefficient
L - length of fin
A_c - Area of cross section
θ_b - Temp difference from base($T_b - T_{\text{inf}}$)
m - $\sqrt{\frac{hP}{kA_c}}$

Table 1: Calculated Fin parameters.

Fin Parameter	Square Fin	Rectangular Fin
Heat Transfer(KW)	1.07	1.285
Effectiveness	15.07	15.56

Conclusion

The temperature profile of the fins match the theoretical expected temperature profile. The rectangular fin has less tip temperature compared to square fin. Also the rectangular fin has more effectiveness. It is also true logically as a rectangular fin has more surface area than square fin for the same volume.