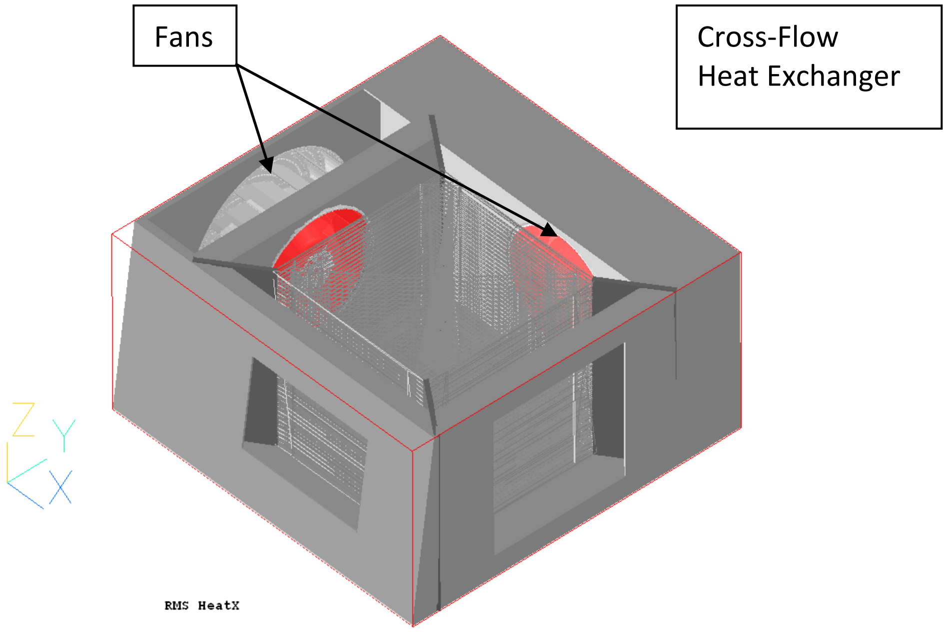
CHAM Limited
Pioneering CFD Software for Education & Industry

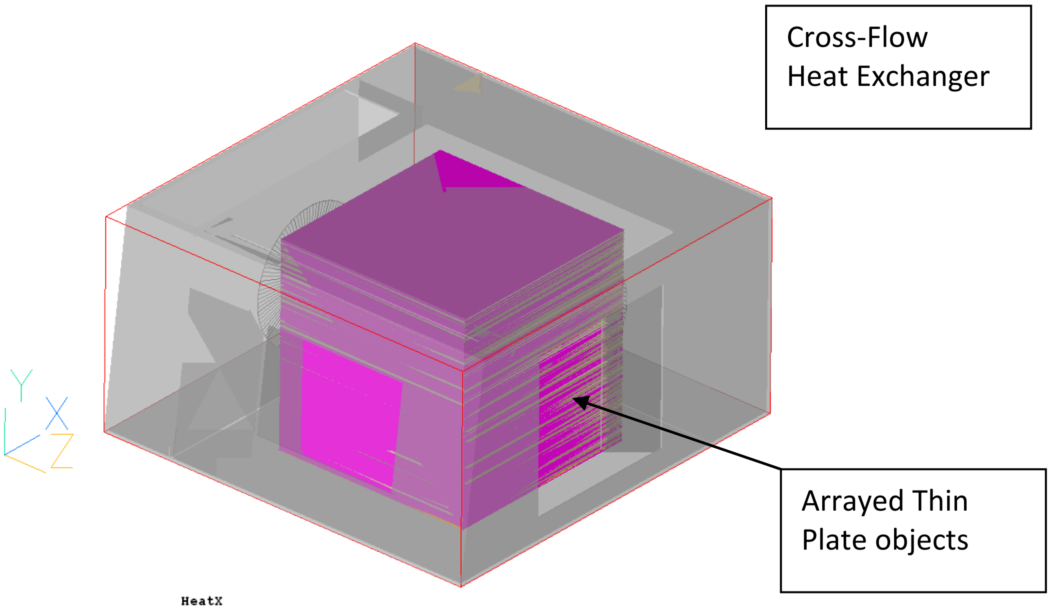
CHAM Case Study – Numerical Simulation of a Air-to-air Cross-flow Heat Exchanger

PH-2011 demonstration case

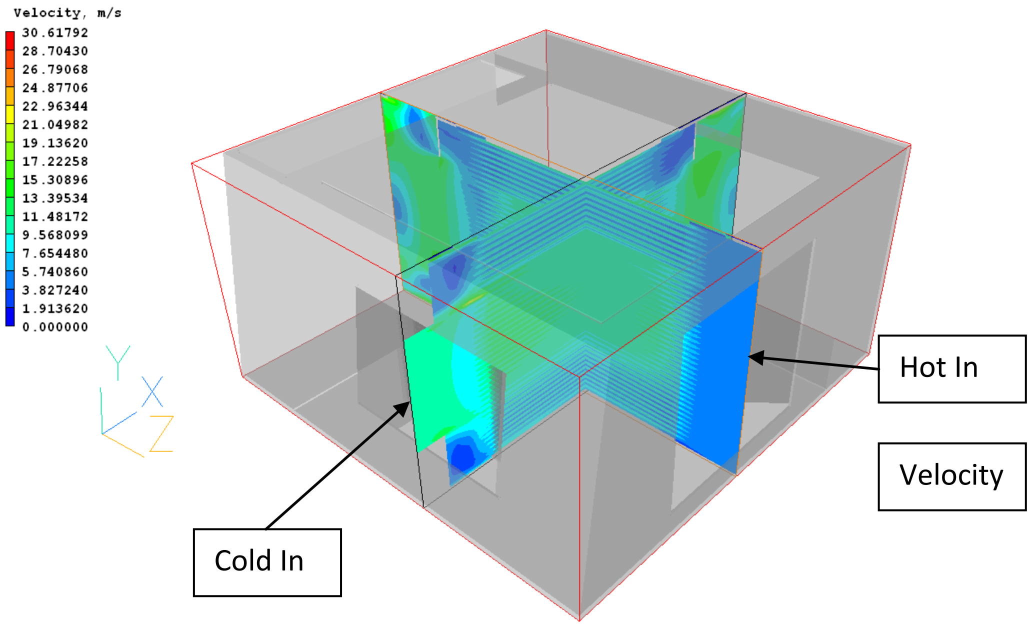
A CFD model of a cross-flow heat exchanger was created following receipt of a specification from the Roads and Maritime Service (RMS) of New South Wales. RMS personnel were carrying out a numerical simulation study to predict the air flow and temperature distribution in the air-to-air type heat exchanger installed in their Variable Message Sign (VMS) system.



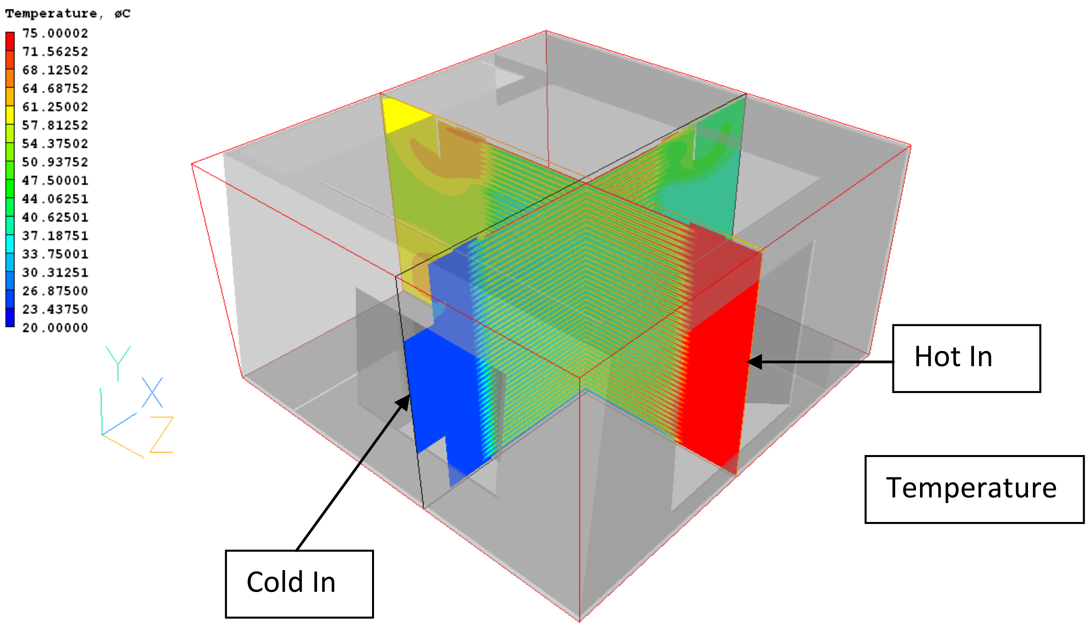
The electronics inside the VMS generate heat due to energy losses under normal operating condition. During the summer time, the temperature inside the VMS can be as high as 75˚C. The internal re-circulating air and the external cooling air are circulated by fan at a flow rate of 600m^3/h. The ambient temperature is 25˚C and the temperature of internal inlet air is 75˚C. A 2% inlet turbulence intensity was specified. The size of the heat exchanger element is 0.2m X 0.2m X 0.2m and it is epoxy coated aluminium. The rest of the enclosure is aluminium alloy grade 5005 H34 with 2.0mm thickness.



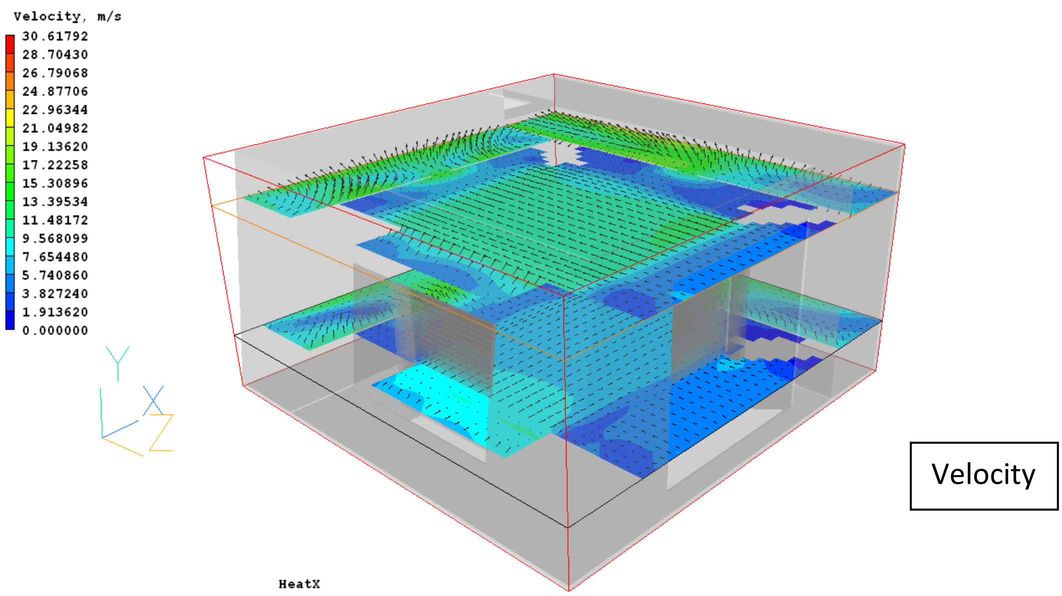
RMS engineers were primarily interested in using the CFD model to calculate and predict the thermal performance and effectiveness of the VMS heat exchanger under different boundary conditions (such as different internal or external inlet temperature, different air flow rate for exhaust fan etc) and how would they affect the results.



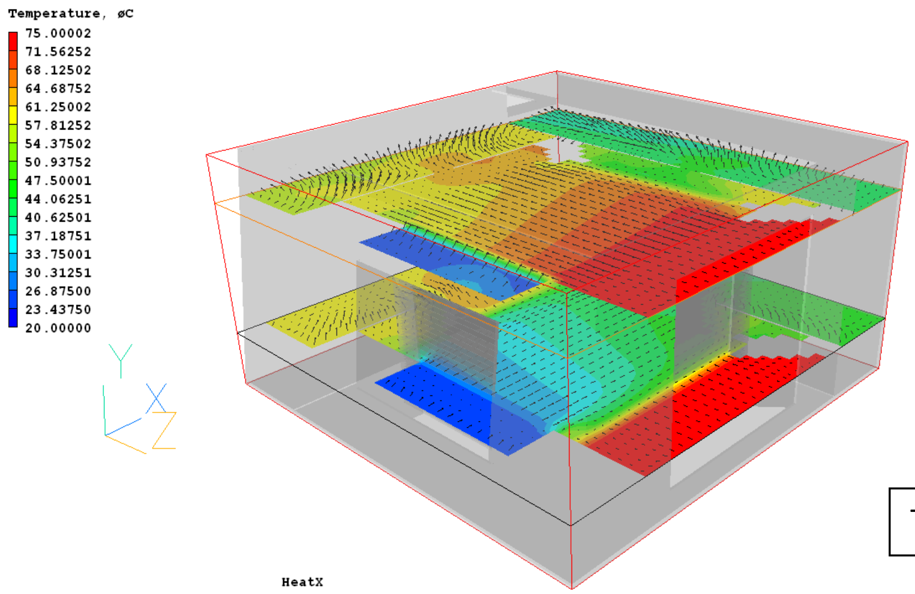
The above plot shows velocity of the hot air (near right to far left) and the cooling air (near left to far right). The next plot shows the temperatures of the two air streams, and shows the heat-exchange mechanism clearly.



Two methods of modelling the heat exchanger were considered. The first option was to simply import the geometry from CAD and then apply a sufficiently fine mesh to capture the 80 x 2mm cross-sectional slots in the heat exchanger. A second, more pragmatic, method was adopted involving the replacement of this section with an array of "thin plate" objects using the same dimensions. The advantage of doing so is to remove the possibility of incorrectly defined geometry and to ensure that the heat transfer is based on the correct plate thickness, whilst using a much smaller computational mesh.



Velocity vectors and contours



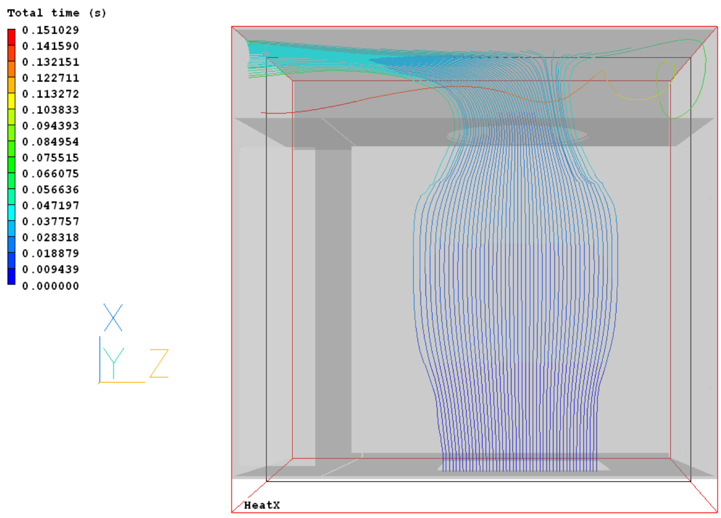
Temperature

Velocity vectors and temperature contours

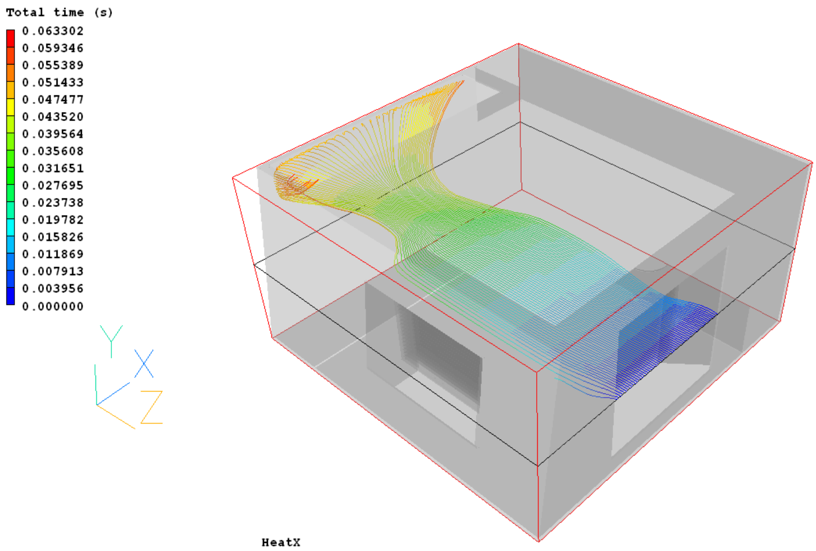
The above two plots show velocity and temperature respectively, in a hot-air channel (above) and a cooling-air channel below. The cooling of the hot air and the warming of the cold air within the heat exchanger are clearly shown.

<u>Details of the model set-up</u>

A 3D Cartesian mesh was employed with 40 x 168 x 40 cells. PARSOL was not activated, as it is not required for the rectangular geometry of the heat exchanger. The LVEL turbulence model was used because of its suitability for flows through narrow channels, with a sparse grid resolution across the channels. The runs were reasonably converged after 1000 sweeps; this required a 75 minute run time on a single-processor 3GHz system.



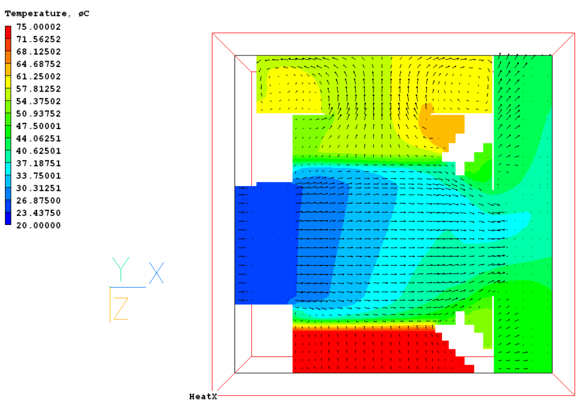
Streamlines X

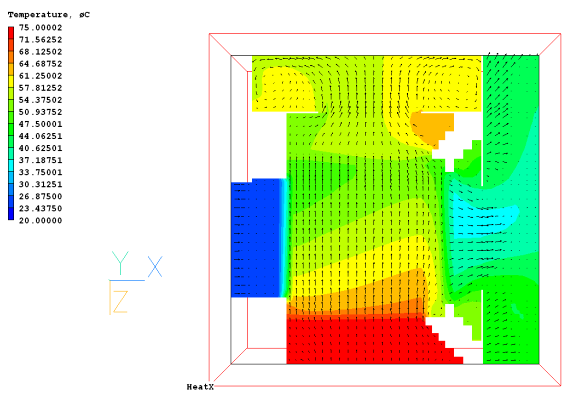


Streamlines -Z

Conclusions

The model provides a good representation of the heat transfer processes in the heat exchanger. Close examination of the model predictions reveal non-uniformities within the heat exchanger. Air from the inlet plena impinges straight onto the central channels, while the outer channels receive air via a more circuitous trajectory. This means that the air velocities in the central channels are somewhat higher, giving better heat transfer. This can be observed directly in the temperature plots. If it were possible to spread the air more uniformly, the overall heat transfer efficiency might be improved. The CFD model can therefore function as a design testbed, which engineers can use to improve the performance of the unit.





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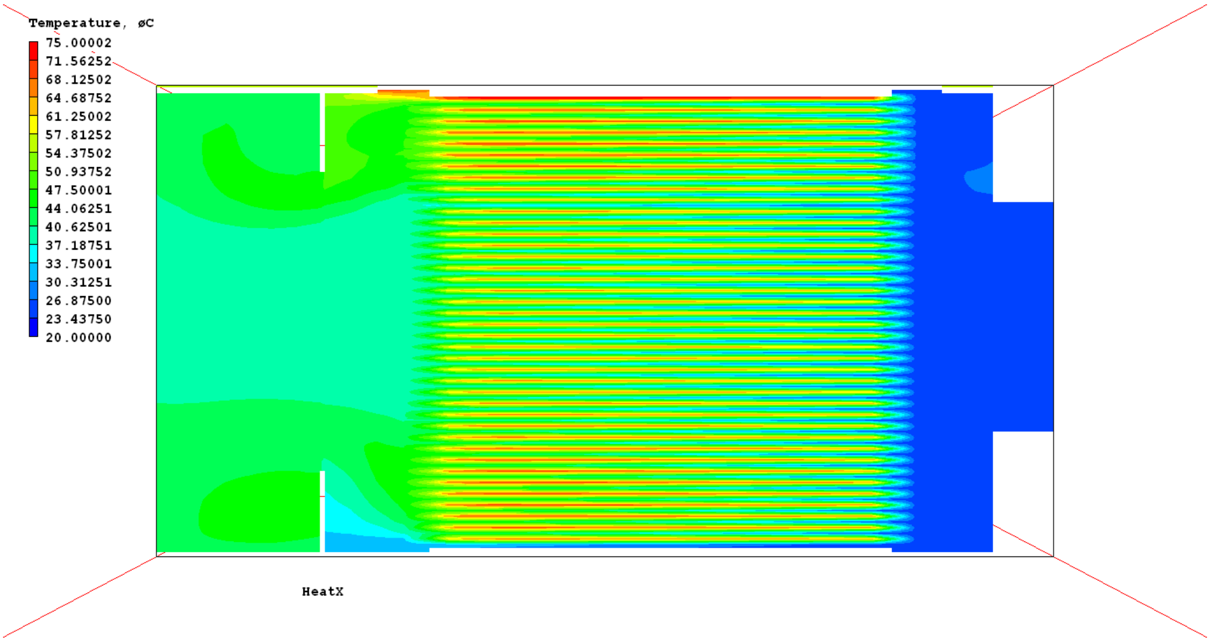
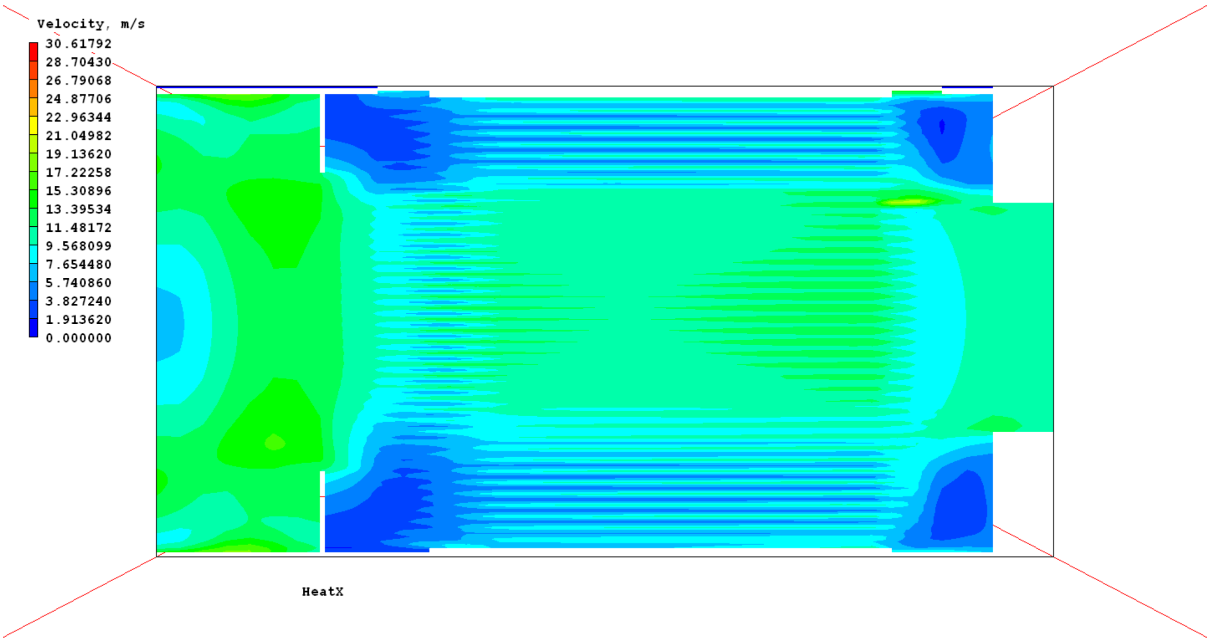
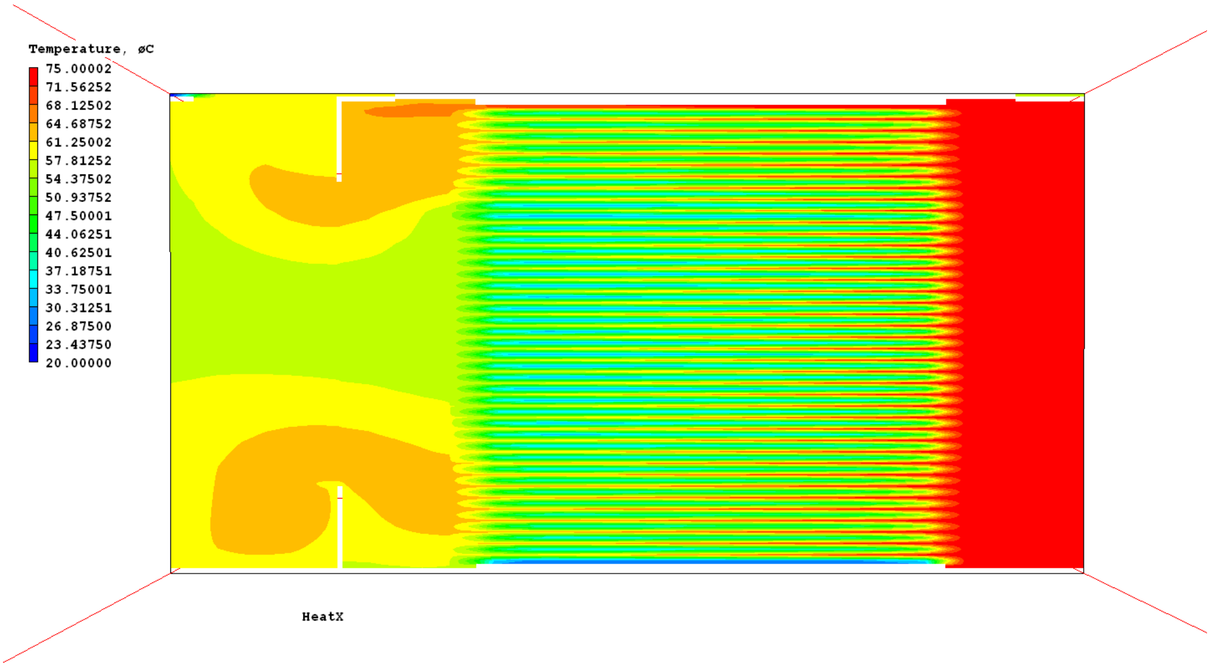
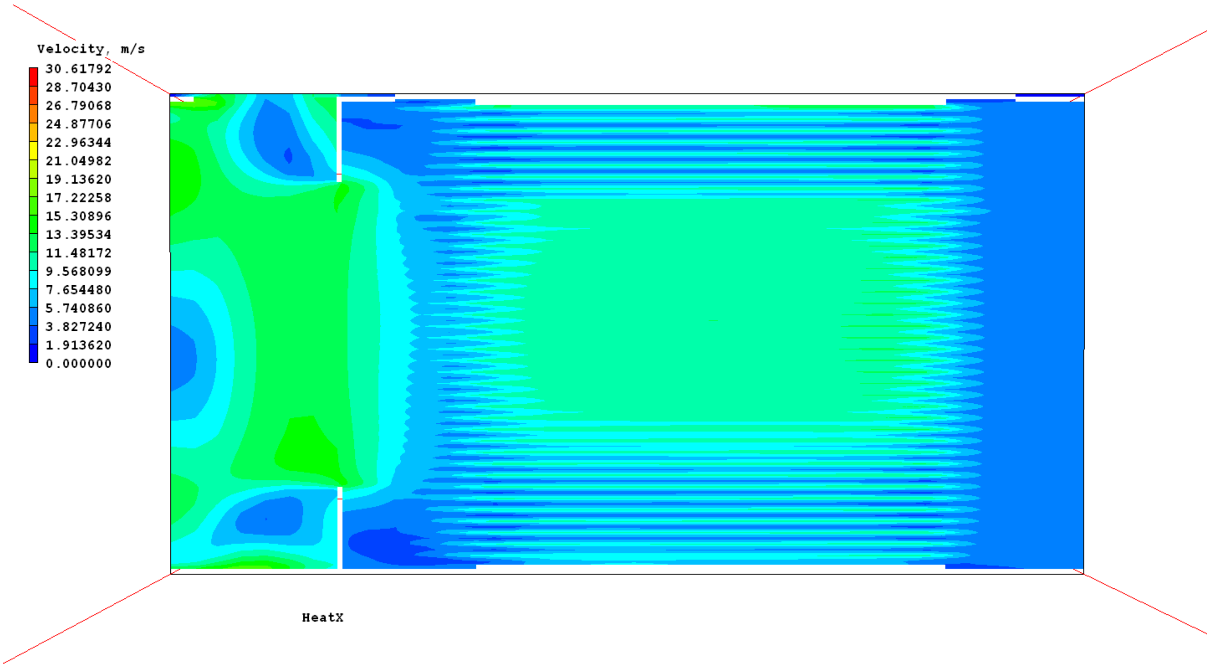
Supplementary images – Temperature & velocity @ Y & Z planes









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