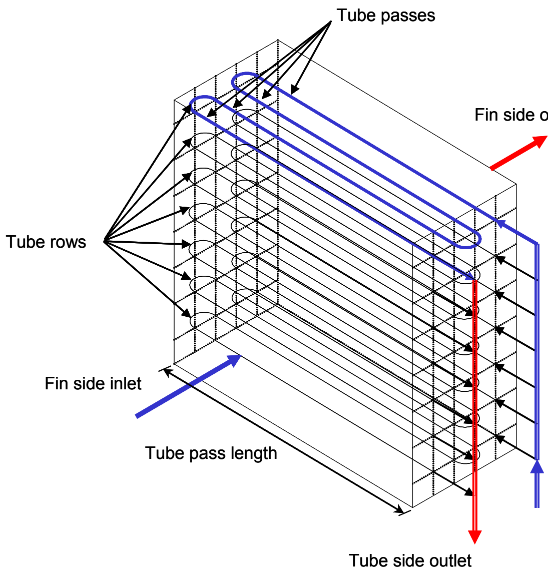
Finned tube heat exchanger Transient

General Industry

Challenge: The objective of the simulation is to simulate the response of a finned tube heat exchanger due to a specified temperature and pressure transient.

Benefits: This case study demonstrates the transient thermal fluid simulation of a finned tube heat exchanger. The finned tube heat exchanger model can also be used in cycle analysis where it is used in conjunction with other models (See “Start-up of two-shaft High-Temperature Gas-Cooled Nuclear Power plant” case study).

Solution: The thermal fluid transient simulation of a finned tube heat exchanger was discussed. The thermal inertia of the finned tube heat exchanger was visible in the temperature results. Depending on the design criteria, different variables can be monitored during the transient event, e.g. velocities, pressure difference between the fin and tube sides. From the temperature graph it can also be determined whether the heat exchanger would provide the design point outlet temperature for the specified transient event.



General Industry

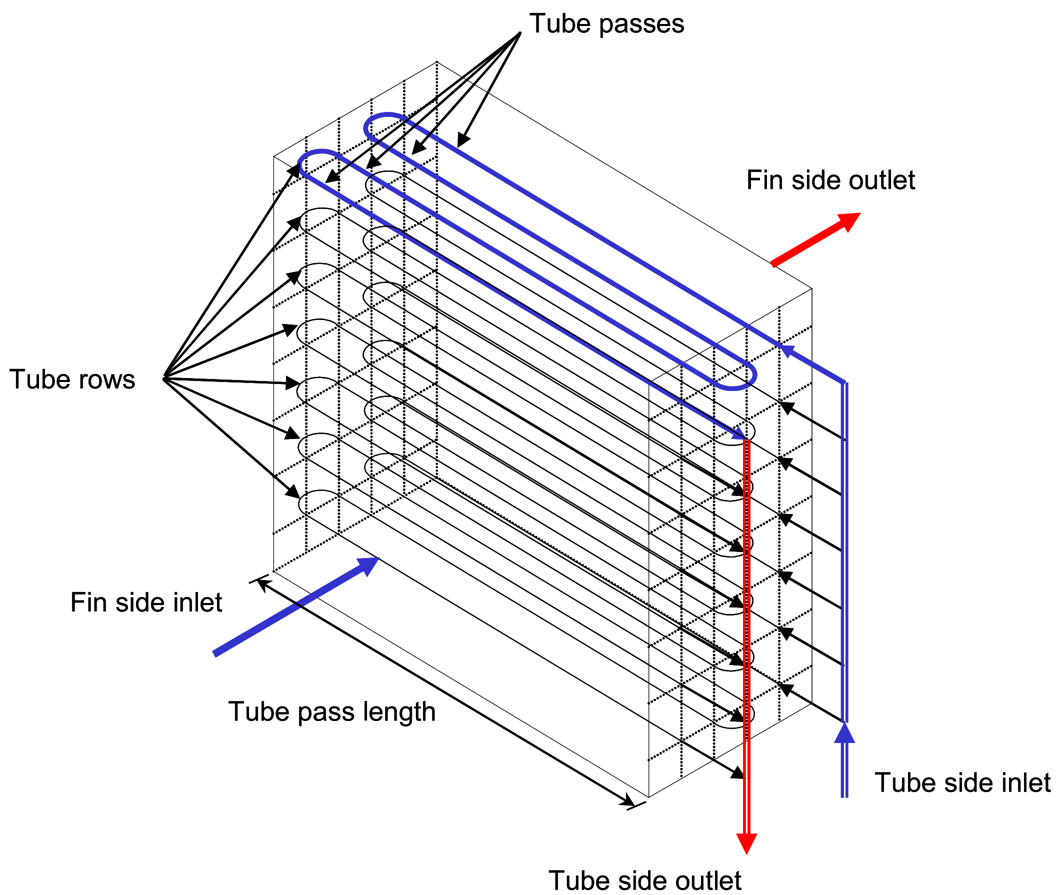
Finned tube heat exchanger – Transient

Introduction

This case study demonstrates the transient thermal fluid simulation of a finned tube heat exchanger. The finned tube heat exchanger model can also be used in cycle analysis where it is used in conjunction with other models (See "Start-up of two-shaft High-Temperature Gas-Cooled Nuclear Power plant" case study).

System Description

The thermal hydraulic conditions of a typical finned tube heat exchanger are simulated. Figure 1



shows a schematic of a typical finned tube heat exchanger.

Figure 1: Schematic layout of a typical finned tube heat exchanger.

Objective of simulation

The objective of the simulation is to simulate the response of a finned tube heat exchanger due to a specified temperature and pressure transient.

Flownex model

The Flownex finned tube heat exchanger model is a distributed model that is build up from an integrated network of one-dimensional elements. These elements represent either the flow paths on the finned or tube sides or they model the heat transfer from the fluid on the tube side, through the tube wall and fins to the fluid on the finned side. In Figure 2 it is shown that each intersection between the finned side fluid path and the tube side fluid path is considered as a control volume and the typical element network of a single control volume is shown. The thermal inertia of the solid tube wall and fin material and the fluid volume are taken into account in the modeling of transient simulations.

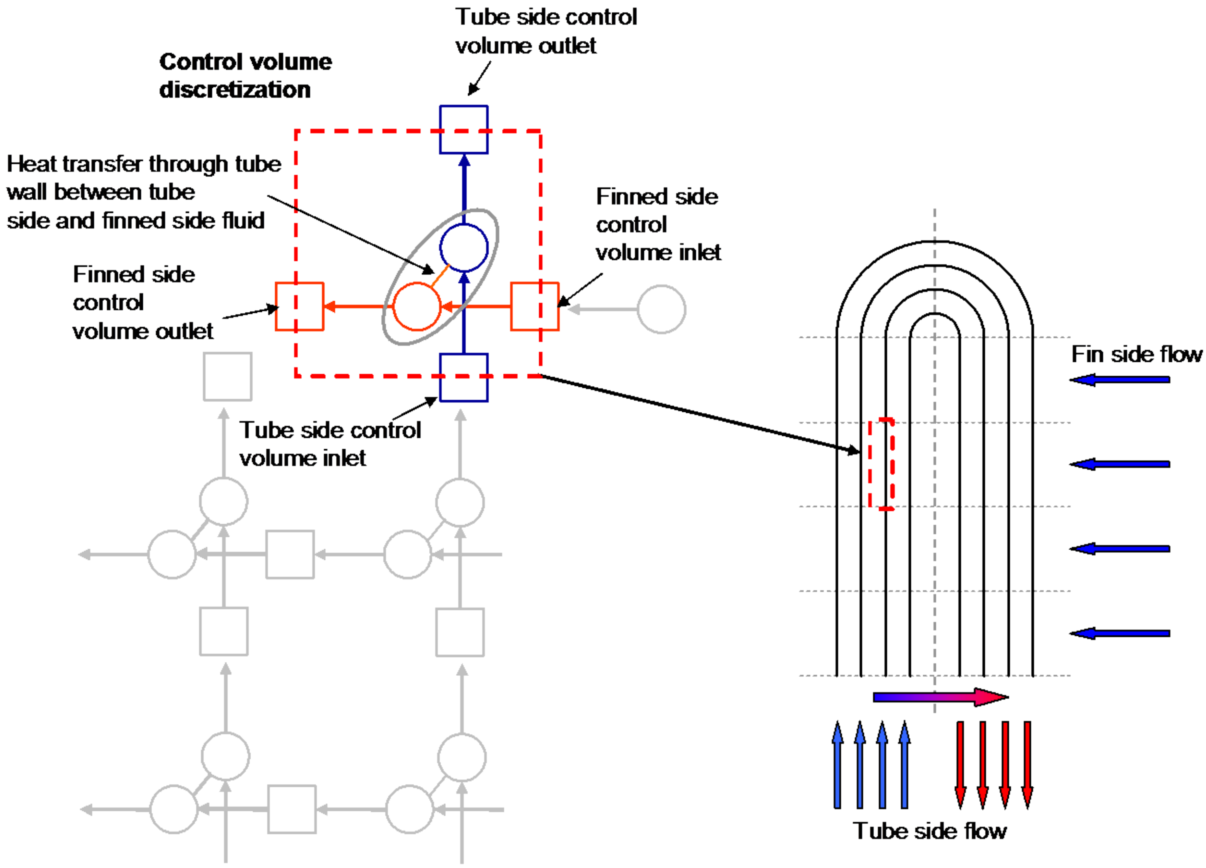


Figure 2: **Discretised Flownex finned tube heat exchanger model.**

Description of simulation

In this case a finned tube heat exchanger with two parallel circuits, ten rows high and five passes are simulated. Both sides use air as working fluid. The inlet temperature and pressure of the air on the finned side is 150 °C and 350 kPa respectively. The inlet temperature and pressure of the air on the tube side is 30 °C and 350 kPa respectively. The finned side has a pressure drop of 1 kPa and the tube side has a pressure drop of 2 kPa. During the transient event the following events were specified:

a) At 1 second the finned side inlet temperature is changed from 150 °C to 300 °C.

b) At 10 seconds the finned side inlet pressure is changed from 350 kPa to 500 kPa.

c) At 20 seconds the tube inlet pressure is changed from 350 kPa to 500 kPa.

d) At 25 seconds the finned side inlet pressure and temperature are changed from 500 kPa and 300 °C to 350 kPa and 200 °C respectively. At the same time the tube side inlet pressure and temperature are changed from 500 kPa and 30 °C to 350 kPa and 25 °C respectively.

During the transient the outlet pressures are kept constant.

Results

The Flownex results are compared to a distributed model in XNet[1]. The comparison between the temperature results are shown in Figure 3. It can be seen that at 1 second when the finned side temperature increases to 300 °C, both the finned side outlet and tube side outlet temperatures increases gradually. At 10 seconds when the finned side inlet pressure is increased, the outlet temperature of both the finned side and tube side increases almost as quick as the specified transient event. This is due to the sudden increase in mass flow on the finned side. At 20 seconds the tube side pressure is also increased and this causes the finned side outlet and tube side outlet temperature to decrease suddenly. This is due to the sudden increase of mass flow on the tube side that is able to remove more heat received from the finned side. At 25 seconds both sides experience a pressure and temperature transient. The quick response of the outlet temperatures are again due to the sudden change in mass flows. Thereafter the gradual decrease of the outlet temperatures is due to the change in inlet temperatures. In both cases where the inlet temperatures were changed the outlet temperature on both sides only changed gradually due to the thermal capacitance of the tube wall solid material. It can be seen that the thermal inertia of the solid material is much larger than the thermal inertia due to the fluid volume by comparing the transient temperature response of the outlet temperatures when a step input was specified at the inlet.

1 XNet is a general thermal-fluid network code, which solves the mass, momentum and energy transfer equations in complex networks. XNet uses an explicit fourth order Runge-Kutta time integration scheme.

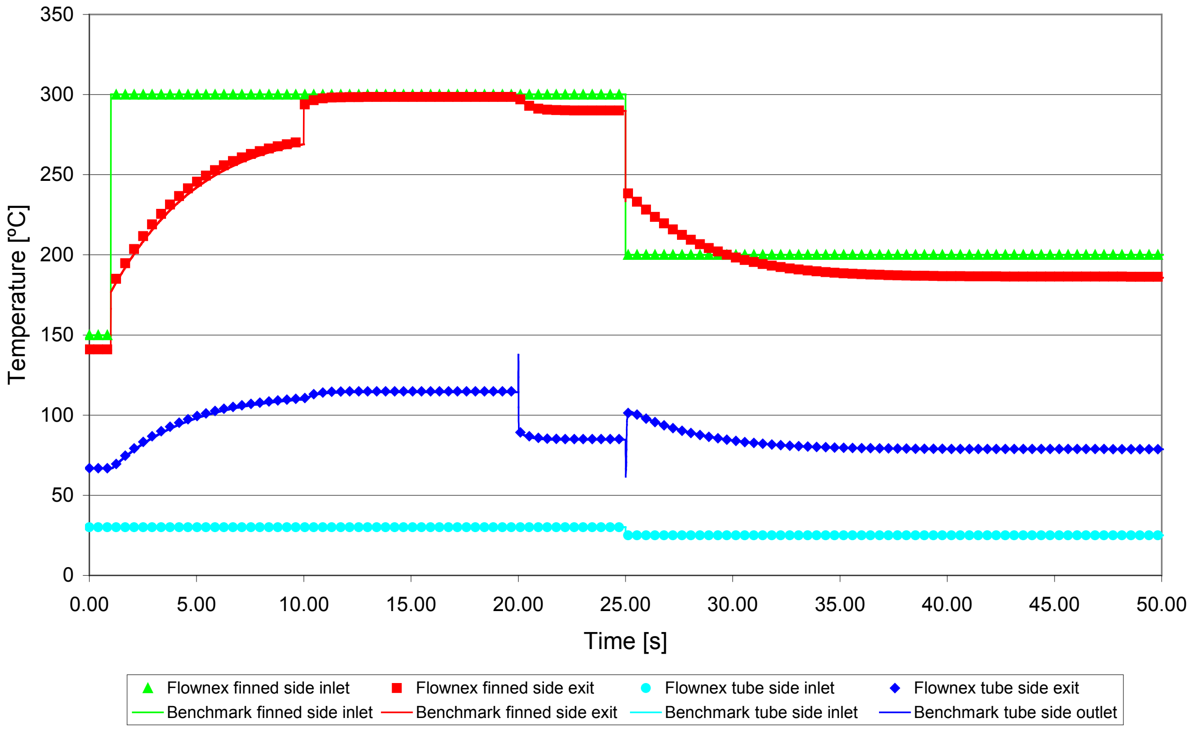


Figure 3: **Finned side and tube side temperatures for Flownex and the code XNet for the transient event.**

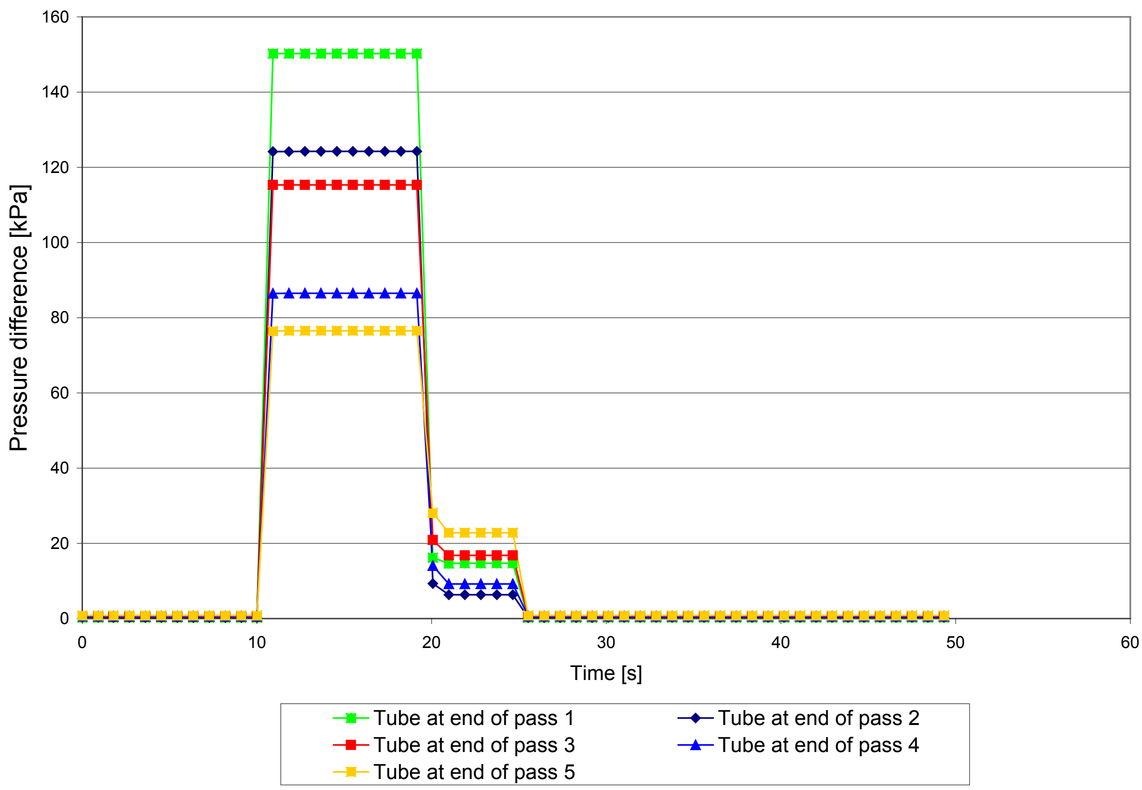


Figure 4: **Pressure difference across tube wall during transient.**

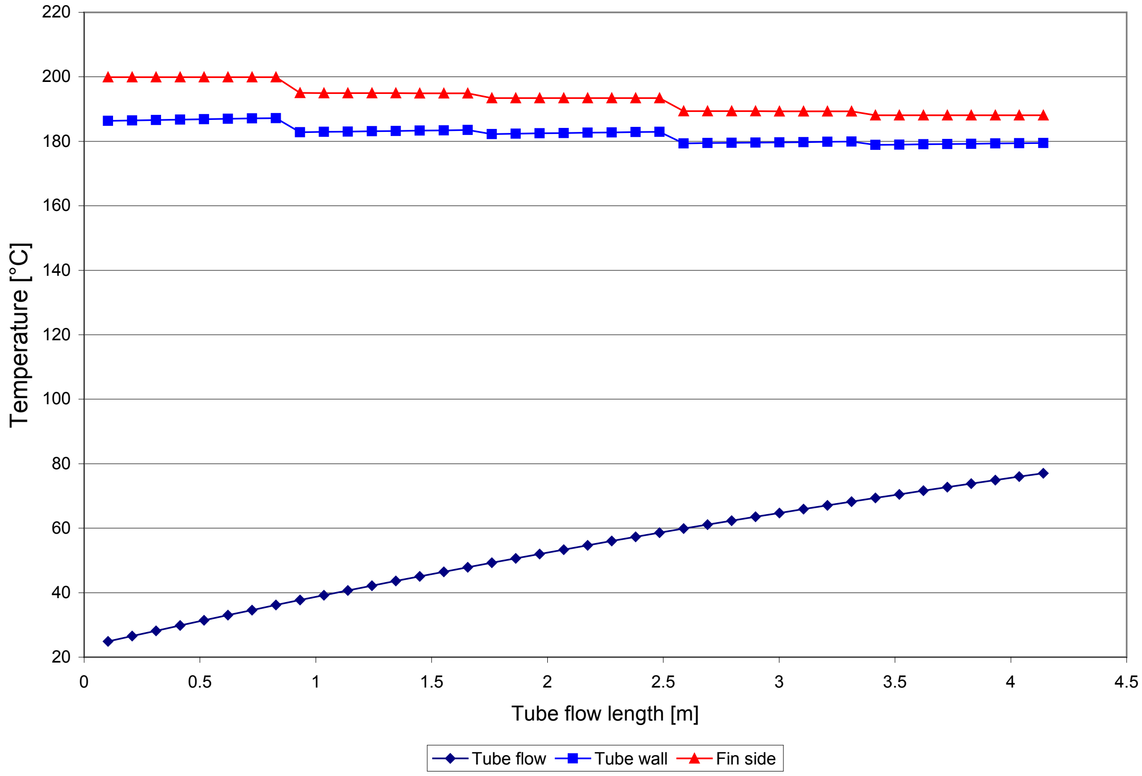


Figure 5: **Temperature distribution along tube flow length.**

The pressure difference across the tube wall, at the bends at the end of each pass through the heat exchanger, during the transient event is shown in Figure 4. The largest pressure difference across the tube wall is between 10 and 20 seconds and has a value of 150 kPa. The fluid temperature distribution on the fin and tube sides of the heat exchanger and the tube wall temperature for the last time step of the transient is shown in Figure 5. It can be seen that the tube wall temperature and the finned side air temperature stays constant for each tube pass through the heat exchanger. The tube side temperature however, increases gradually along the tube length.

Conclusion

The thermal fluid transient simulation of a finned tube heat exchanger was discussed. The thermal inertia of the finned tube heat exchanger was visible in the temperature results. Depending on the design criteria, different variables can be monitored during the transient event, e.g. velocities, pressure difference between the fin and tube sides. From the temperature graph it can also be determined whether the heat exchanger would provide the design point outlet temperature for the specified transient event.

Flownex® International,
Global Headquarters
+27 (0) 18 297 0326/7
www.flownex.com

Australia	+61 3 8790 1087	Poland	+27 11 782 3895
China	2 164 821 011	Singapore	+65 67 32 9818
Greece	+30 231 0 251 731	South Africa	+27 12 809 9500
India	+91 08 042 151 310	Turkey	+90 312 432 37 85
Israel	+972 3 920 6303	United Kingdom & Europe	+44 08 450 772 810
Japan	+81 44 230 5121	United States & Canada	+11 (781) 993-9003
Korea	+82 22 051 2305		