Recuperator with transient pressure and temperature boundary variation

Introduction

For this validation case study the transient simulation of the Flownex recuperator element involves the variation of the pressure and temperature boundaries.

Validation specification

A schematic representation of the counterflow air tube in tube recuperator is shown Figure 1.

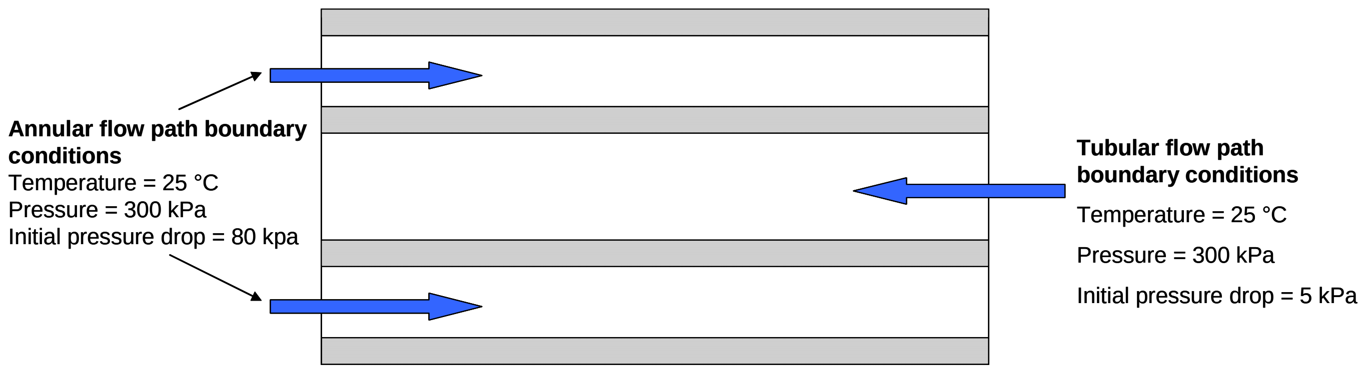

Figure 1: *Schematic representation of counterflow tube in tube heat exchanger.*

The objective of this case is to validate the ability of the Flownex recuperator element to model the thermal inertia of the fluid and the thermal capacitance of the solid material associated with a transient simulation of a heat exchanger. An initial pressure drop of 80 [kPa] was specified for the primary side and an initial pressure drop of 5 [kPa] was specified for the secondary side. The recuperator was solved for steady-state conditions where after the following transient events will be applied while keeping the outlet pressures constant:

a) At 8 seconds the tube inlet temperature is changed to 60 °C.

b) At 252 seconds the tube inlet pressure is changed to 250 kPa. At the same time the annular side inlet temperature and pressure changes to 35 °C and 380 kPa respectively.

Flownex model

The Flownex model of the system is shown in Figure 2. The Flownex model is a discretised model that, depending on user inputs, can be incremented and refined to enable the modeling of a vast range of heat exchangers. By specifying the number of increments, the user actually specifies the number of control volumes that will be used to model the recuperator. In each increment the flow on the annular and tube side is modeled. In addition to flow, the heat transfer from the fluid on the annular side to the solid wall (convection), through the tube wall (conduction) and to the fluid on the tube side (convection) is also modeled. The discretised model layout is very similar to the benchmark network shown in Figure 3, where one-dimensional elements are used in an integrated network.

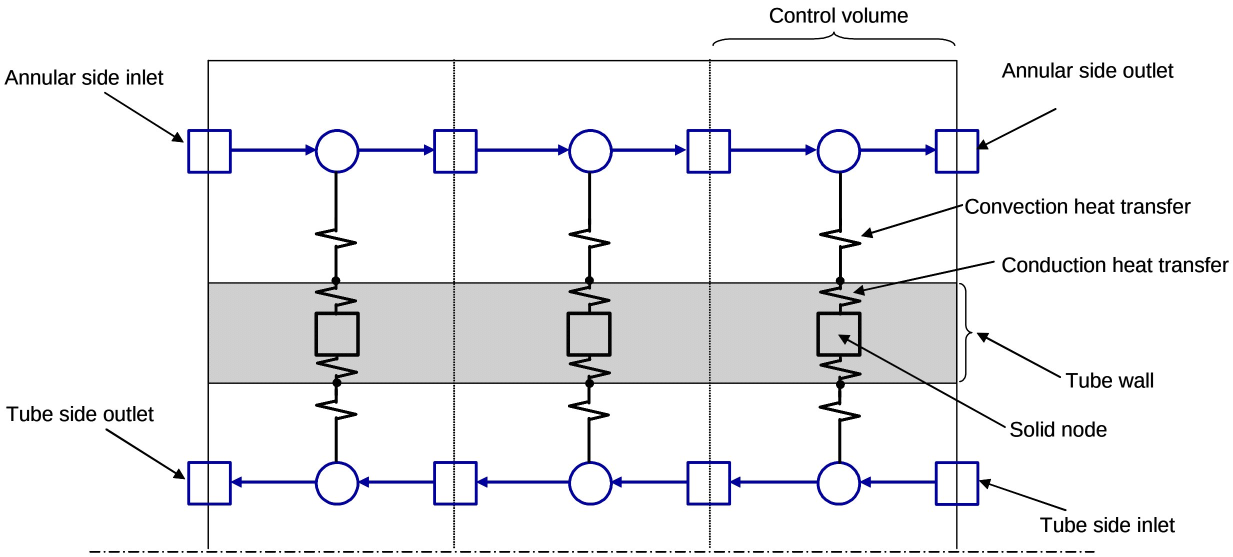

Figure 2: *Flownex network discretization.*

Benchmark

XNet is a general thermal-fluid network code, which is capable of solving complex thermal-fluid networks. XNet solves the mass, momentum and energy conservation equations in complex networks and can deal with both steady-state and transient problems. XNet uses an explicit fourth order Runge-Kutta time integration scheme with trapezoidal damping to solve the one-dimensional governing equations. XNet has a range of primitive elements that enables the user to build and model complex thermal-fluid networks. These elements are the fundamental building blocks for the construction of more complex models. An example of the XNet network for the validation case is shown in Figure 3. The primitive components model/represent the flow in the flow paths (P_DW), the convection heat transfer between the flow paths and the solid tube wall between the flow paths (P_CONVEC) and the conduction heat transfer through the solid tube wall (P_CHT).

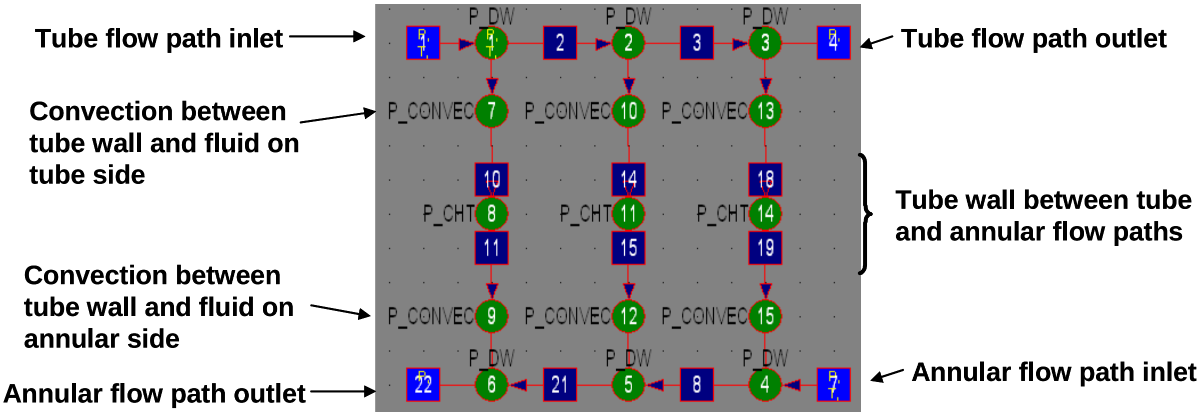

Figure 3: *Typical XNet network layout comprising of the primitive components.*

Results

The comparison between the benchmark code XNet and Flownex for the temperature and heat transfer are shown in Figure 4 and Figure 5. From the results it can be seen that the differences were negligible.

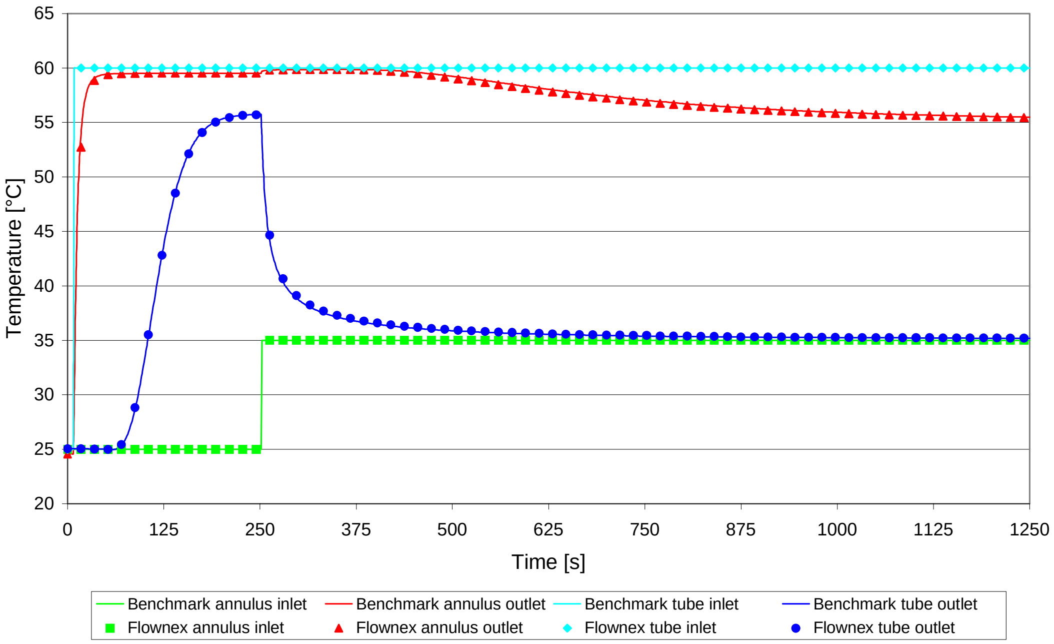

Figure 4: *Primary side and secondary side temperatures for Flownex and the benchmark code XNet for the transient event.*

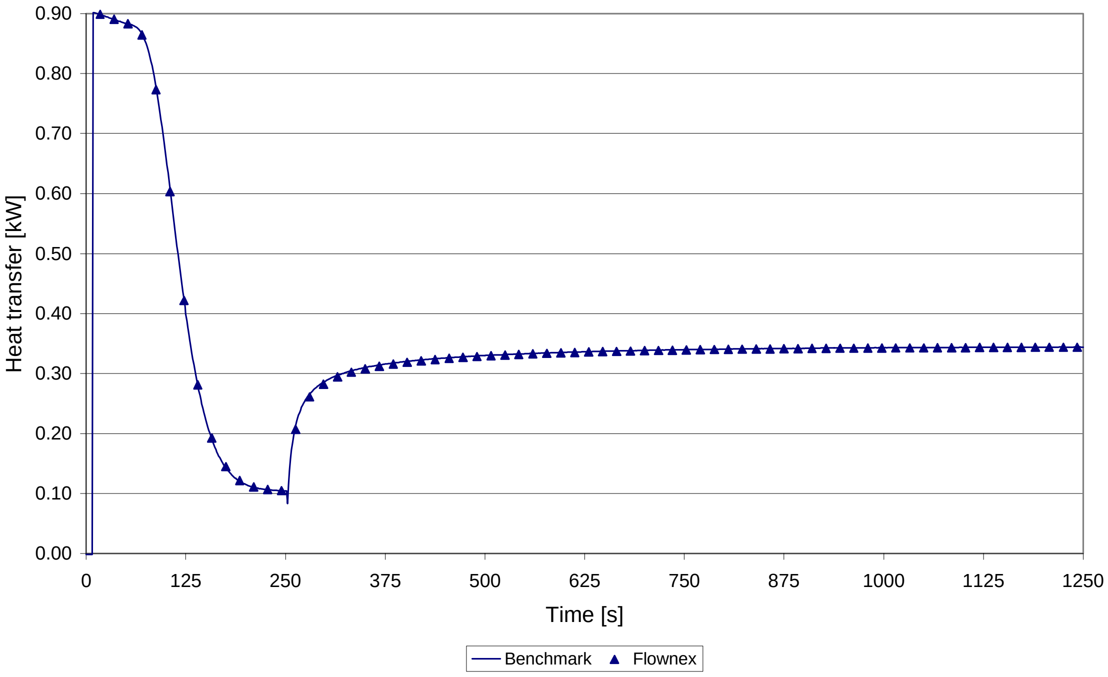

Figure 5: *Total heat transfer for Flownex and the benchmark code XNet for the transient event.*

Conclusion

In this validation case the recuperator Flownex model was validated against a model generated in an explicit code. From the comparison it was seen that Flownex and the explicit code produced the same results. Furthermore the introduction of a temperature step on the tube side only became apparent on the annular side after a time delay, indicating that the thermal inertia of the recuperator wall is taken into account.