Numerical analysis of heat transfer of supercritical water in multiple rod channels

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1. Introduction

Supercritical Water – Cooled Reactors (SCWRs) were proposed as one of the six Generation IV nuclear reactors[1]. During the past few years, several researchers have conducted numerous experimental and numerical studies on the supercritical water in the circular tubes[2 - 5]. The heat transfer mechanism varies with operating conditions and there is no common consensus on the experimental results for the criteria of the heat transfer deterioration. The experimental data for the supercritical water in the fuel rod channel in the open literature are quite limited[6 – 8] and measurement technology changes with cases. Depending on the fluid flow and heat transfer phenomenon in the supercritical water tube flow, computational fluid dynamics (CFD) method has been used for investigating the fluid flow and heat transfer phenomenon in the supercritical water channels for many years. However, there is still lack of the analysis of heat transfer of supercritical water in the heat transfer of supercritical water in the Canadian 64-elelment rod bundle.

2. Materials and Methods

In this work, the supercritical water in the 64-elelment fuel bundle is investigated numerically by the Reynolds – averaged Navier – Stokes (RANS) approach and the detailed fluid flow and heat transfer phenomenon for the supercritical water in the fuel rod channels are presented. Only quarter of the region with fuel rods in the fuel bundle is considered because of the symmetry. The CFD simulations are carried out by the commercial software ANSYS FLUENT.

3. Results and discussion

Figure 1 shows the distribution of the cladding surface temperatures on the fuel rods in the whole domain. Generally, the wall temperatures increase along the axial direction. It seems the circumferential temp gradient is large near the exit.

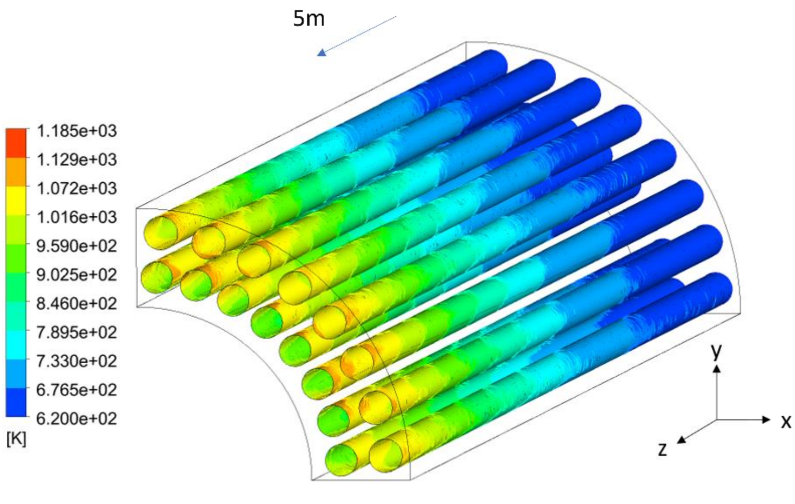
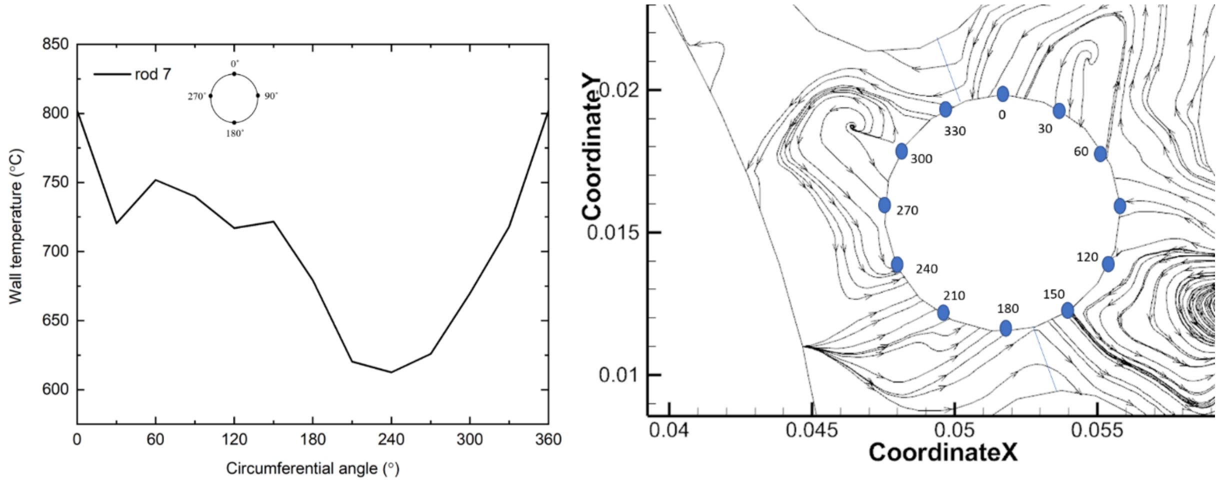


Figure 1. Cladding surface temperature distributions on the fuel rods.

Based on the numerical results, the largest gradient of the circumferential wall temperatures occurs at rod #7 at z = 4.8m, which is shown in Figure 2(a). Figure 2(b) is the zoom-in region around the fuel rod #7 with the streamline. Comparing these two figures, it is observed that for the region around the fuel rod #7, the wall temp is generally lower when the flow is moving towards the rod while higher when the flow is moving away from the rod. However, if we compare the lowest and highest wall temp 0 and 240 degree, we can see the flows are both moving towards the rod while the performance is totally different. This can be because when multiple gaps are present in the rod bundle, the vortex streets from different gaps are coupled with each other. The interactions between the vortex streets with different sizes and shapes could bring the differences of the turbulence of the flow in the edge subchannels compared to the central subchannels.



(a) CWT distributions at z = 4.8m (rod #7) (b) Zoom-in streamline near rod #7 at z = 4.8m

Figure 2. CWT and streamline near rod #7 at z = 4.8m.

4. Conclusions

A sequence of fluid flow and heat transfer phenomena have been clarified, especially the possibility of the existence of the vortex shedding in the edge flow subchannels. This phenomenon can explain the obvious differences of the turbulence of the flow as compared to the central subchannels. The fluid bulk temperature and the wall temperatures of the fuel rods generally increase along the axial flow direction. It is observed that the circumferential wall temperature distribution around the fuel rod surface is extremely non-uniform and the maximum CWT for each fuel rod also shows large differences.

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