Temperature Distribution in the Thermal Mixing Tee of Shutdown Cooling System

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1. Introduction

In 1998, a leakage through a cracked pipe in the Residual Heat Removal (RHR) system at Civaux plant in France has been found. The crack occurred in the elbow at downstream of the RHR mixing tee between the line through RHR heat exchanger and the bypass line. As a result of this failure, the utility and the plant designer have recognized it as an important issue in nuclear power plant to clarify a thermal fatigue phenomenon in a region where two fluids of different temperatures mix together. However, the mixed fluid condition will have different temperature distribution with different pipe configuration and operating conditions [1][2].

The purpose of this paper is to evaluate the mixed fluid temperature distributions in the mixing tee at downstream of the Shutdown Cooling System (SCS) heat exchangers for the future plant design with two different configurations applied for KSNP. For this evaluation, a numerical analysis has been performed with a commercial CFD code of FLUENT[3].

2. Methodology

To analyze the temperature distributions in the mixing tee at downstream of SCS heat exchanger, the computational fluid dynamics code, FLUENT V.6.1 with SIMPLE algorithm, is used. The standard κ-ε turbulent model, which is widely used for engineering purposes, is utilized in the analysis. Here κ stands for the turbulent kinetic energy and ε the dissipation rate. The governing equations for the 3-dimensional unsteady state incompressible flow include the conservation of mass, momentum and energy. In the momentum equation, the Boussinesq approximation is used, which models the buoyancy force in terms of the temperature instead of the density variation, and which treats the density as a constant value in all solved equations except for the buoyancy term in the momentum equation. First order upwind scheme based on control volume is also adopted.

2.1 Analysis model and boundary condition

Fig. 1 depicts the simplified analysis models both of which have about 900,000 meshes. For configuration 1, the two different temperature fluids from opposite direction at horizontal pipe are mixed at the T-junction, and then flow through the vertical outlet pipe line. For configuration 2, all piping layouts are located at the same horizontal plane with T-junction of main and branch pipe.

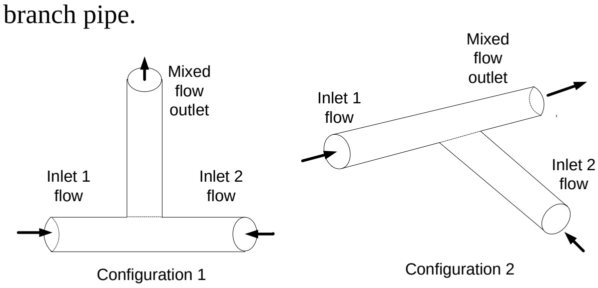

Fig.1 Simplified analyzed models

Table 1 shows the applied boundary conditions and analysis cases. The boundary conditions are from the representative operating conditions of KSNP.

Table 1. Evaluation cases

			Inlet 1	Inlet 2
Config. 1	Case 1		3922 gpm / 450K	878 gpm / 330K
	Case 2		2947 gpm / 380K	1853 gpm / 329K
Config. 2	Case 1	Cond.1	878 gpm / 330K	3922 gpm / 450K
		Cond.2	3922 gpm / 450K	878 gpm / 330K
	Case 2	Cond.1	1853 gpm / 329K	2947 gpm / 380K
		Cond.2	2947 gpm / 380K	1853 gpm / 329K

3. Computational Results

The temperature distribution in the mixing tee at downstream of SCS heat exchanger are analyzed with CFD code for two different configurations with two different cases.

The overall temperature distributions in the mixing tee and pipe for case 1 of configuration 1 is shown in Fig. 2. This figure shows the temperature distribution in the cross section of pipe at XY plane. This is a front view of the piping layout. As shown in this figure, with the flowrate ratio of case 1, the mixed fluids show well mixed temperature distribution in the vertical pipe after mixing at the T-junction. The stratified temperature distribution only can be seen around the T-junction after mixing.

The overall temperature distribution in the mixing tee and pipe for case 1 of configuration 2 are shown in

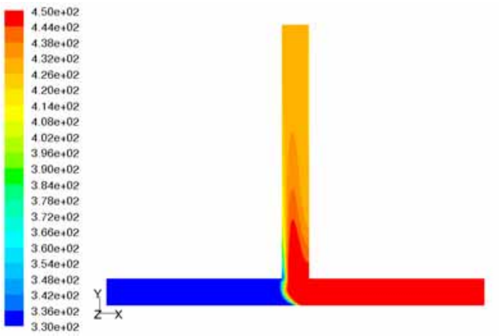

Fig.2 Case1 of Configuration 1

Fig. 3 and Fig. 4.

These figures show the temperature distributions in the cross section of pipe at XY plane. This is the top view of the piping layout. In these figures, the temperature of mixed pipe is very different with each other flow direction. The lower flowrate in the branch pipe line of case 1(cond.1) shows the rather stratified temperature distribution. However, the higher flowrate in the branch pipe line of case 1(cond.2) shows the well mixed fluid flow in the mixed pipe. With this configuration, it can be realized that the mixed fluid condition is strongly dependent on the flowrate in the branch line.

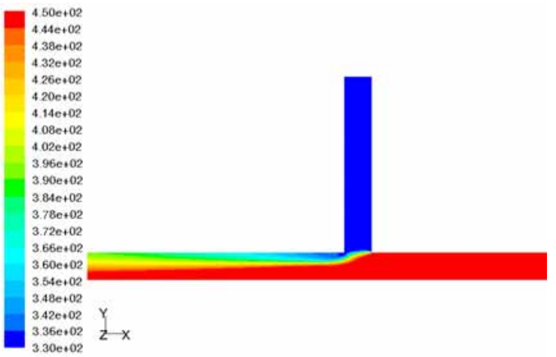

Fig.3. Case 1(cond.1) of Configuration 2

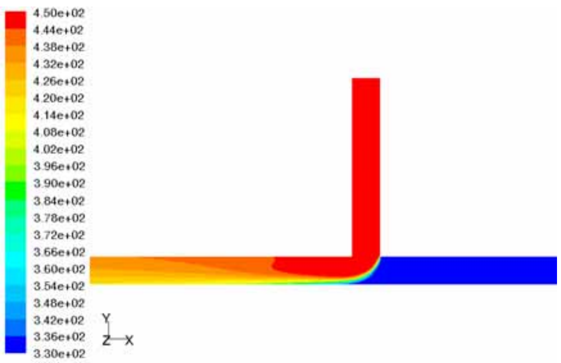

Fig.4. Case 1(cond.2) of Configuration 2

Fig.5 shows the temperature difference along the circle of the cross section of mixed pipe for the three conditions with the same flow ratio of case 1. As shown in this figure, the case 1 of configuration 1 has the least temperature difference along the wall circle at cross section.

Fig. 6 shows another temperature difference along the circle of the cross section of mixed pipe for the three different conditions with same flow ratio of case 2. The case 2 of configuration 1 has the least temperature distribution. But for these three cases, the two different temperature fluids are flowing rather separately in the mixed pipe after mixing.

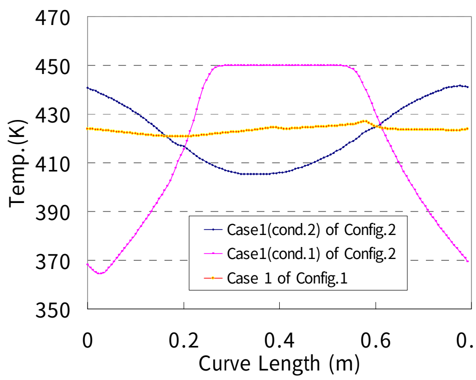

Fig.5. Temperature distribution along the circle at cross section of mixed pipe(at 5D distant from the T-junction center) for case 1.

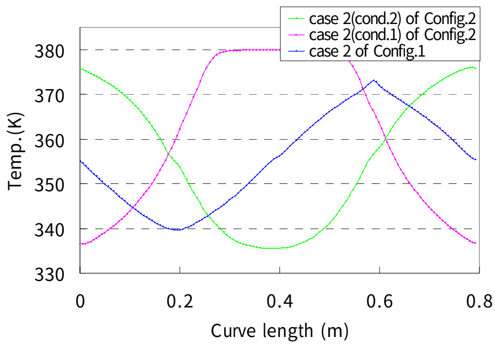

Fig.6. Temperature distribution along the circle at cross section of mixed pipe(at 5D distant from the T-junction center) for case 2.

4. Conclusions

Temperature distributions in the mixed T-junction are evaluated and compared for the two different piping configurations. The mixed flow temperature distribution is strongly dependent on the piping configuration and the flow ratio. With the same flow ratio, configuration 1 shows better mixed temperature distribution in the mixed fluid.

REFERENCES

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[2] T.Muramatsu, " Numerical Investigations of Thermal Striping Characteristics in the Use of Various Coolants" , NUTHOS-6, Nara, Japan, October 4-8, 2004.
[3] FLUENT user's guide.