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Estimation of High Cycle Thermal Fatigue Caused by Mixing Flow at RHR System (II)

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1. Introduction

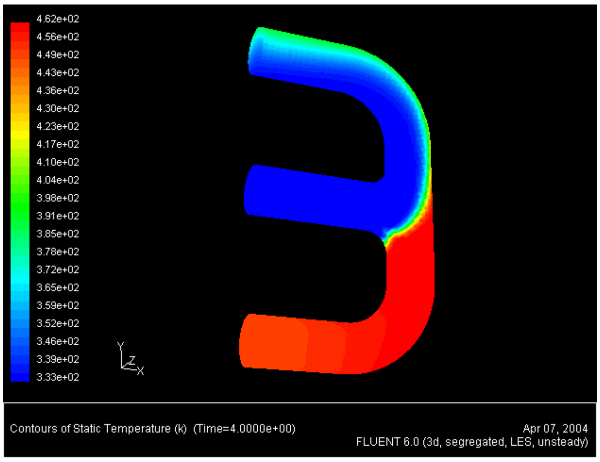
In the case of nuclear power plant, thermal fatigue occurs in the piping system because of temperature change accompanied with plant operations. Therefore pipe and instrument are designed not to exceed fatigue limit. But damage is happening in piping system by thermal fatigue that is not considered at design (for example, abnormal movement at surge line of Torjan, crack at safety injection line of Farley unit 2 and Tihange unit 1, crack at RHR system of Genkai unit 1 and Civaux unit 1 etc).

Root cause of these damages is explained by the thermal stratification and thermal cycling, thermal striping phenomena.

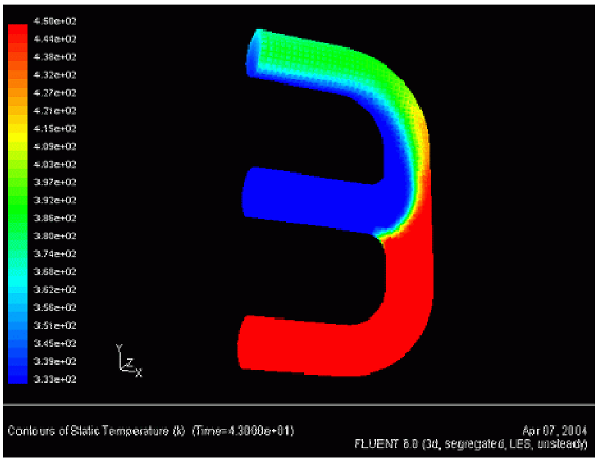
In this paper, integrity assessment of high cycle thermal fatigue were carried out about the heat exchange out let of residual heat removal system (RHR system) of operating domestic PWR nuclear power plants, which is the high temperature – low temperature coolant mixing region.

2. Flow Pattern of high temperature – low temperature coolant mixing

Fig. 1 shows the flow pattern of high temperature (177°C, inlet velocity: 1.0m/s) – low temperature (60°C, inlet velocity: 4.5m/s) coolant mixing. As can know in figure, thermal boundary layer by mixing of high temperature and low temperature coolant is formed, and this thermal boundary layer is made mixing vigorously in downstream and temperature difference is mitigated. In this case, temperature boundary layer is formed because fluid of low temperature meets with fluid of high temperature in municipal narrow place of piping, and this thermal boundary layer changes by fluid own instability. Specially, change of temperature boundary layer is very high speed phenomena and causes thermal fatigue. Change of temperature boundary layer can know according to change of time in Fig.1.



(a) time = 4.0 sec



(b) time = 43 sec

Fig. 1 Temperature distribution of high temperature – low temperature coolant mixing

3. High cycle thermal fatigue analysis method

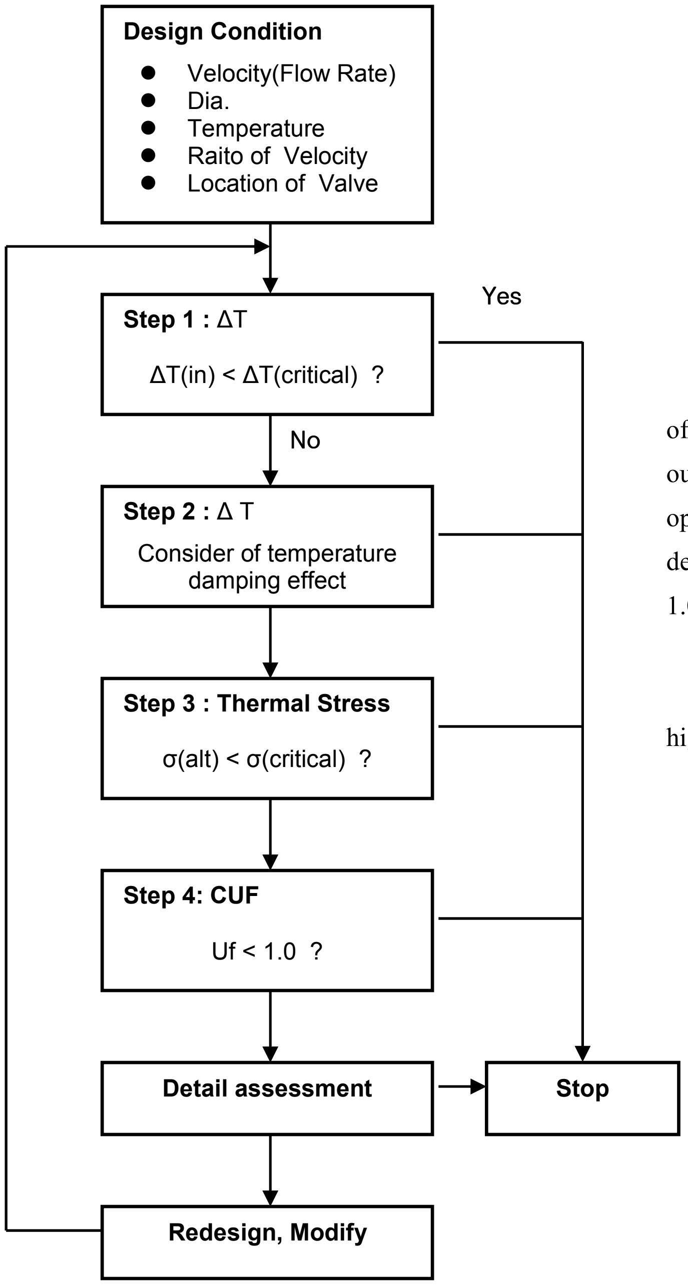


Fig. 2 High cycle thermal fatigue analysis method

Fig.2 shows the method of high cycle thermal fatigue analysis according to high temperature – low temperature coolant mixing case.

1) Step 1: Consider of temperature difference

Temperature difference of high temperature flow (T hot) and lo temperature flow (T cold) compares with the maximum allowable cyclic range of temperature.

2) Step 2: Consider of temperature damping effect

At high and low temperature fluid mixing, consider damping effect of temperature changing width.

3) Step 3: Thermal stress analysis

Estimates thermal stress amplitudes of structure by temperature change that consider heat transfer coefficient between fluid and structure surfaces.

4) Step 4: Fatigue analysis

Calculates cumulate fatigue factor (CUF) and compare with fatigue limit 1.0.

4. Results and conclusion

Table 1 shows the results of the integrity assessment of high cycle thermal fatigue about the heat exchange out let of residual heat removal system (RHR system) of operating domestic PWR nuclear power plants. During design life time, cumulate fatigue factor do not exceed 1.0.

Table 1 Results of the integrity assessment of high cycle thermal fatigue

Unit	CUF
Kori #1	0.71
Kori #2	0.71
Kori #3, 4	0.58
Yungkwang #1, 2	0.58
Yungkwang #3, 4	0.30
Yungkwang #5, 6	0.90
Ulchin #1, 2	0.53
Ulchin #3, 4	0.88
Ulchin #5, 6	0.90

REFERENCES

1) Operating Experience Regarding Thermal Fatigue of Un-isolable Piping Connected to PWR Reactor, MRP-25, 2000/12.

2) High Cycle Thermal Fatigue Estimation Guideline in Piping System, JSME S017, 2003