Estimation of Temperature Distribution on Inner Surface from Outer Surface Temperature Using Mathematical Analysis-Based Inverse Analysis

Shiro Kubo[1] and Seiji Ioka[2]

[1] Department of Mechanical Engineering, Faculty of Science and Engineering, Setsunan University, 17-8, Ikedanakamachi, Neyagawa, Osaka, 572-8508 Japan,
e-mail: kubo@mech.eng.osaka-u.ac.jp
[2] Department of Mechanical Engineering, Osaka Electro-Communication University,
18-8 Hatsu-cho, Neyagawa, Osaka 572-8530, Japan
e-mail: ioka@isc.osakac.ac.jp ,

Key Words: *Thermal Fatigue, Fluid Temperature, Inverse Analysis.*

It has been recognized that fluctuation of fluid temperature in a pipe may induce high cycle thermal fatigue in the pipe. The knowledge about the temperature distribution is important to prevent the high cycle fatigue [1, 2]. It is, however, difficult to measure the inner surface temperature directly. The monitoring of the temperature distributions by using the outer surface temperature distribution is promising to solve the problem [3-6].

This paper presents an inverse method for estimating the temperature distribution on the two-dimensional inner surface from the measured temperature distribution on the outer surface.

As an extreme of thin pipe, we consider a three-dimensional flat plate shown in Fig. 1. The inner surface, which corresponds to the bottom surface in the figure, is subjected to temperature fluctuation due to cavity flow. The outer surface, which corresponds to the upper surface in the figure, is adiabatically insulated.
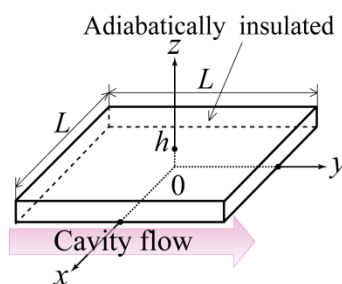

Fig. 1   3-dimensional flat plate

Mathematical analysis was made to investigate the relationship between the temperatures on the inner surface and on the outer surface. Based on the mathematical analysis it was found

that the relationship can be characterized by the reduction ratio in amplitude R and time delay Δt. An inverse analysis method was proposed, in which the inner surface temperature fluctuation is estimated by amplifying the outer surface temperature by 1/R and by advancing by Δt.

Numerical simulations were made to examine the applicability of the proposed method. An example of the inner surface temperature is shown in Fig. 2. It was found that the temperature distribution on the inner surface can be estimated reasonably from that on the outer surface even in the existence of measurement error.
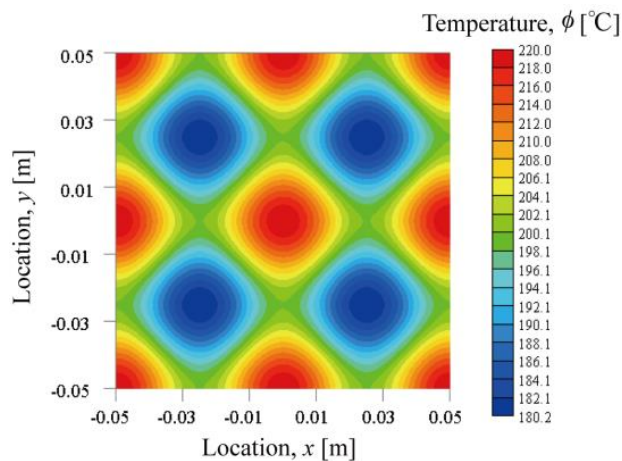

Fig. 2   Inner surface temperature distribution

REFERENCES

[1] Y. J. Yu, S. H. Park, et al., Structural Evaluation of Thermal Stratification for PWR Surge Line, *Nuclear Engineering and Design*, Vol. 178, pp.211-220, 1997.
[2] A. Nakamura, T. Takenaka, et al., Experiments and Numerical Simulations of Fluctuating Thermal Stratification in a Branch Pipe, *INSS Journal*, 9, pp.67-79, 2002, (in Japanese).
[3] T. Ishizaka, S. Kubo and S. Ioka, 2006, "An Inverse Method for Determining Thermal Load History Which Reduces Transient Thermal Stresses", PVP2006-ICPVT-11-93618, *ASME 2006 Pressure Vessels and Piping Conference*, pp. 1-8, 2006.
[4] S. Kubo, S. Ioka, S. Onchi and Y. Matsumoto, Inverse Analysis of Inner Surface Temperature History from Outer Surface Temperature Measurement of a Pipe, *IOP Conf. Series: Materials Science and Engineering*, Vol. 10, 012188, pp. 1-10, 2010.
[5] S. Ioka, S. Kubo, M. Ochi and Kiminobu Hojo, Development of Inverse Analysis of Heat Conduction and Thermal Stress for Elbow (Part I), ASME, *Proceedings of PVP2013*, Paper # PVP2013-97883 , pp.1-9, 2013.
[6] K. Hojo, M. Ochi, S. Ioka and S. Kubo, Development of Inverse Analysis of Heat Conduction and Thermal Stress for Elbow (Part II), ASME, *Proceedings of PVP2013*, Paper # PVP2013- 97620, pp.1-10, 2013.