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Eigenvalue analysis on fluidelastic instability of a rotated triangular tube array considering the effects of two-phase flow

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Abstract

Fluidelastic instability is a key issue in steam generator tube arrays subjected in two-phase flow. Lots of experimental analyses were conducted on fluidelastic instability of a tube array subjected to air-water cross-flow. However, there is seldom theoretical analysis to calculate the critical velocity. Therefore, considering the effect of two-phase flow, the fluidelastic instability of a rotated triangular tube array was studied in this paper. A mathematical model of a tube array with unsteady fluid force model was set up. A program based on the model was written, and an experiment was carried out to verify the correctness of the program. The results of this program were in good agreement with the experimental data. Using this program, the critical velocity of fluid-elastic instability considering the effect of two-phase flow was determined by the eigenvalue analysis. This paper investigated the critical velocities of fluid-elastic instability for void fraction ranging from 0% to 90% with five tube natural frequencies, respectively. The results show that void fraction and tube natural frequency are the key factors in fluidelastic instability, which have an obvious effect on the critical velocity of fluidelastic instability.

Keyword: fluidelastic instability; tube array; two-phase flow; critical velocity; void fraction

1 Introduction

The tube bundles of steam generators are subjected to several types of flow-induced vibrations. Especially, when the cross-flow reaches a certain critical velocity, the fluidelastic forces may result in fluidelastic instability. Since the first report on fluidelastic instability of circular cylinders by Roberts in 1962[1], a great effort has been dedicated to this flow-induced instability of heat exchangers. In 1970, a quasi-steady theoretical model was developed by Connors. Based on “quasi-steady” assumption, Connors[2] found the stability curve, which has been extensively used as a design guideline for the prevention of fluidelastic instability of heat exchanger tube arrays. But, this linear quasi-steady model cannot predict the dynamic instability of a single flexible tube in a rigid array without somehow introducing unsteady forces. Chen[3] developed the semi-empirical unsteady models to account for unsteady fluid forces. All the relevant fluid force coefficients must be measured for each array pattern and pitch, which is the major drawback associated with this semi-empirical model. In order to overcome this problem, a series of studies were conducted by

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