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Comparison of Modeling Techniques for Simulating Contact Between Steam Generator Tubes and Supports

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1. Introduction

Both nuclear power plants and thermal power plants are types of steam power plants. In these plants, thermal energy is used to produce electricity by burning fuel, including coal, gas, or nuclear fuel. This thermal energy is then converted into mechanical energy with the help of steam, which acts as the medium for transferring the thermal energy into mechanical energy.

Therefore, a steam generator is a critical facility in power plants using thermal resources. Especially in nuclear power plants, two major systems, the primary and secondary systems, are separated for nuclear safety [1]. Heat is transferred from the primary to the secondary system, generating steam. Therefore, it is important to maintain the integrity of the steam generator tubes not only for safety but also for the efficient operation of the nuclear power plant [2].

Hot steam flows through tubes and transfers thermal energy to the cooling water around them. The flow through and around the tubes induces vibration, which may cause them to wear out or damage. Therefore, investigation of the vibration of the steam generator tube is critical to estimating and predicting its wear, and various experimental and numerical studies have been conducted.

Steam generator tube bundles are supported by supporting structures including eggcrates, bat wing strips, vertical strips, and horizontal strips. A finite element analysis has been used to predict the wear of the steam generator tubes [3]. In the analysis, contact behaviors of tubes are critical in predicting tube wear because they are estimated based on the work rate on the contact surface. In this study, contact behaviors of a tube in three different modeling methods to simulate contact in Abaqus were compared with each other.

2. Materials and Methods

A single tube with length of 2,000 mm, its inner and outer diameters are 16.916 mm and 19.05 mm respectively, was modeled. A diamond shaped support was put at the middle of the tube. The height of the support was assumed to be 50.8 mm (Fig. 1). Elastic modulus of 200 GPa, and Poisson's ratio of 0.3 were assumed for the material properties for the tube and supports.

The tube and support were modeled using beam and shell elements, respectively. Three different contact modeling methods, self-contact, contact pair, and gap element, were applied for simulating contact between a tube and support. Each method was applied accordingly (Fig. 2). Then, 0.1 N of the force was applied on all nodes of the tube for 5 seconds and the direction was varied to make contact the tube on all support surfaces (Fig. 3).

Behaviors of a node on the tube in the contact region were predicted in three models using a commercial finite element analysis software Abaqus and compared with each other.

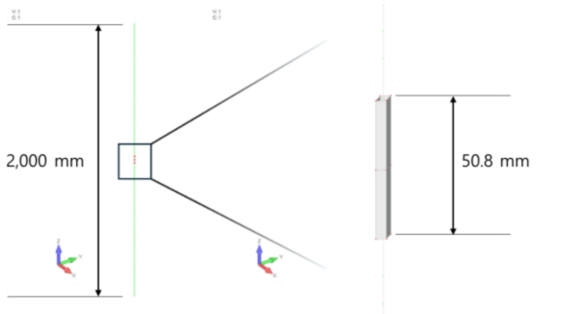
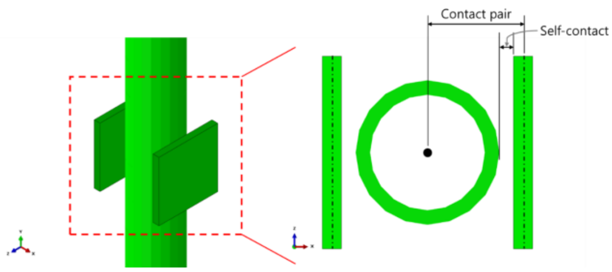
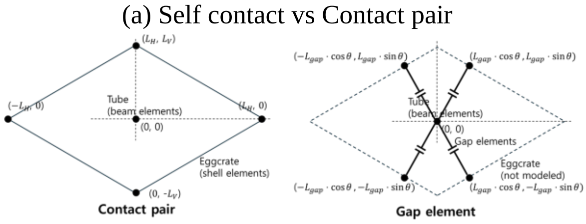


Fig. 1 A finite element model of single tube and eggcrate support



(a) Self contact vs Contact pair



(b) Contact pair vs Gap element

Fig. 2 Application of three contact methods

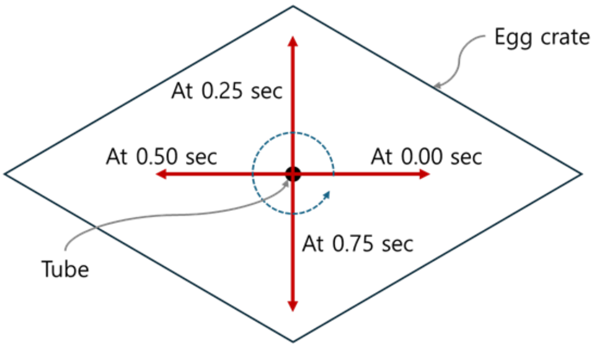
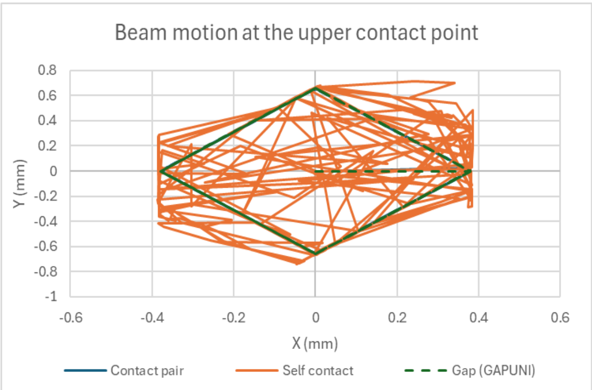
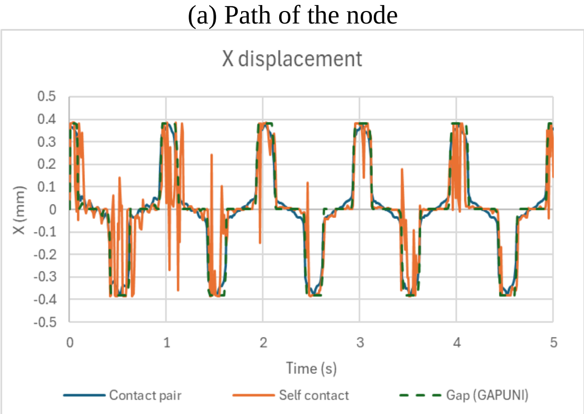


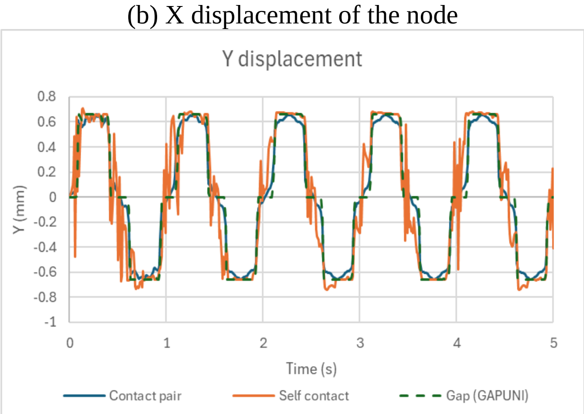
Fig. 3 Force to simulate contact between a tube and support



(a) Path of the node



(b) X displacement of the node



(c) Y displacement of the node

Fig. 4 Contact behaviors of the node on the tube in the contact region during 5 seconds

3. Results

If the contact correctly applied, the node on the tube should behave in the region of the support. However, motion of the node in the self-contact used model exceeded the range of the support.

The node behaved in the region of support when the contact pair and gap element were applied. However, the instantaneous velocities in the gap element model showed greater than those in the contact pair used model. Thus, the nodes showed impulse like behaviors of X and Y displacement in the gap element used model.

4. Discussion

Modeling using self-contact is intuitive, because it considers the thickness of the shell thickness. However, it requires more attention to simulate exact contact motion compared to other method. Attention to choose the right gap size is necessary to use the contact pair and gap element method. However, the method showed more reliable results compared to the self-contact method model.

Because the wear of the steam generator tube is estimated using the work rate in the contact region between tubes and supports. Thus, the exact estimation of contact motion is critical to predicting the wear of the steam generator tubes. The results of this study should be helpful for estimating tube wear using finite element analysis. In the future, the authors will estimate the tube wear using the contact modeling method investigated in this study.

ACKNOWLEDGEMENT

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