Estimation of Stress Concentration Factor in Guide Tube of PWR Fuel Assembly

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1. Introduction

Some wear of the guide tubes may occur from interaction with core components, especially the flow-induced vibration of the CEAs (Control Element Assemblies). This wear can act as a flaw, and cause integrity deterioration because the guide tubes transmit vertical loads including the load from the fuel assembly holddown springs directly. Therefore, stress concentration factor (SCF) for notched round tubes should be considered to evaluate the structural integrity. As is well-known, the stress field in a structural component depends on the possible presence of a notch, and fatigue life may strongly be affected by geometric discontinuities [1-4].

This paper evaluates the stress concentration factors for a circumferentially notched thin-walled cylinder along its surface.

2. Method and Results

2.1 Test specimen and procedure

The guide tube specimen is shown in Fig. 1. Its length (L), notch depth (d) and width (w) are 200 mm, 0.9 mm and 20mm, respectively. The notch has a rounded geometry with a root radius ρ of 0.1 mm. Four strain gages were attached to the surface of the specimen in the longitudinal direction. The tension rate was controlled by the displacement of 0.02in/min. A mechanical test is performed on an INSTRON™ load frame with a maximum force of 50kN. During the test, a data acquisition device is utilized to collect the strains, displacement and load information, and all data are transmitted to a computer.

2.2 FEM Model

A two-dimensional finite element model has been adopted, and the validity of the FEM results before determining stress concentration factors is verified through the comparison of the test results. Due to the symmetry of the problem, only a quarter of the specimen has been analyzed by employing 8-node structural solid element (plane183) in ANSYS. This model is shown in Fig. 2 and includes a notch radius of 0.1 mm. Submodeling is used to produce satisfactory results in the notch region [5]. In discontinuous region such as notch, crack and hole, generally, coarse mesh may not give sufficient accurate stress results. Therefore, by creating a submodel on that region, more accurate results can be obtained.

FEM has been performed under the displacement control at the end of the unnotched part. The magnitude of the displacement is small enough to provide an elastic behavior.

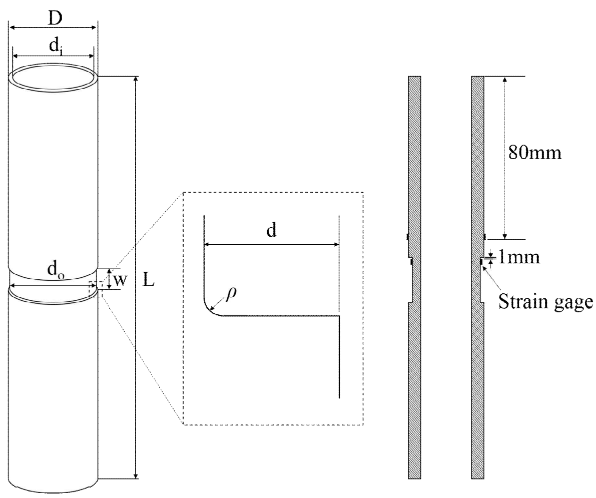

Fig. 1. Geometry of thin-walled guide tube with a circumferential notch.

2.3 Comparison of FEM results with test

To obtain reliable results, a parametric study depending on mesh size has been performed. Fig. 3 presents the value of the axial concentration factor with respect to the mesh size to notch radius ratio ε/ρ. To reach an enough accuracy, 0.01 was used.

Table I shows the longitudinal results of the test and FEM using this ratio. As shown in Table I, each error is very small ranging from 2.12% to 2.99%. Thus, it can be said that the results of the simulation is acceptable.

Table I: Comparison of FEM results with test at both a distance from notch: (a) 1mm, (b) 10mm

		FEM	Test	Error
(a)	Strain	0.000997	0.000968	0.0299
(b)	Strain	0.0001396	0.0001367	0.0212

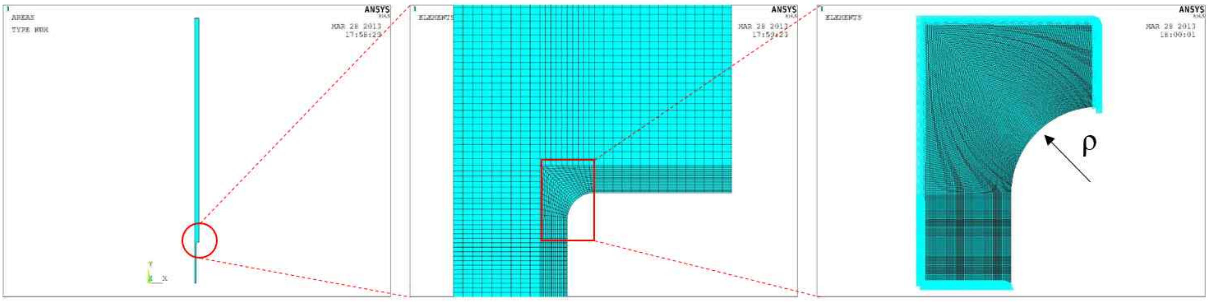

Fig. 2. 2D Finite Element Modeling of Guide tube Specimen.

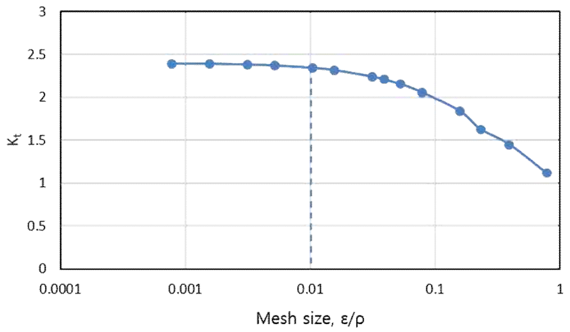

Fig. 3. Mesh size sensitivity for an externally notched guide tube.

2.4 Effect of notch Depth

Fig. 4 shows the effect of the notch depth on the stress concentration factor. The factor increases with increasing normalized notch depth d/t and reach its maximum at d/t ≈ 0.6. By further increasing d/t, stress concentration factor decreases with d/t. It rapidly decreases especially in the range d/t > 0.7

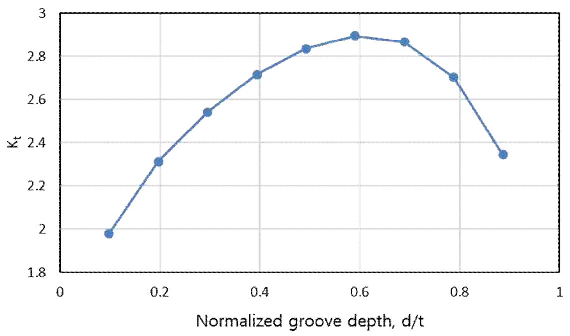

Fig. 4. Stress concentration factors as a function of notch depth.

2.5 Effect of Notch width

Fig. 5 shows the effect of the notch width on the stress concentration factor. When the notch width is above 10 mm, stress concentration factor is not significantly affected on notch width. For a width below 6 mm, stress concentration factor decreased as the width decreased, and then sharply increased at 0.2 mm of width, namely circumferential U-notch shape.

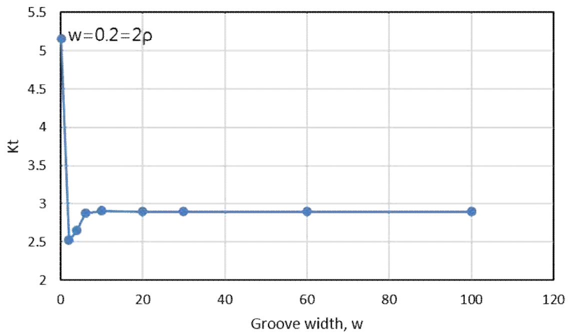

Fig. 5. Stress concentration factors as a function of notch width.

3. Conclusion

The research was conducted to estimate the integrity of a guide tube with damage. Stress concentration factor was considered as one of the many influencing factors.

First of all, The FEM model on a guide tube was made and analyzed using ANSYS. The results of the FEM are acceptable when compared to that of experiment.

Finally, it is found that the variation of the notch depth and width affect the stress concentration factors.

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