Failure mechanism under extreme loading and prevention of catastrophic failure (15) Numerical study on ratcheting and collapse failure due to seismic loading

*Bari Md Abdullah Al[1], Katsura Yamato[1], Sakemi Ryota[1], Sato Takuya[1], Kasahara Naoto[1]

[1]The University of Tokyo

Such failure modes are possible for seismic loading as ratcheting deformation, collapse and low cycle fatigue. Here, occurrence conditions of these failure modes are not clear. This article investigates numerically the dominant parameters of ratcheting and collapse as the combination of gravity and seismic acceleration.

Keywords: Seismic load, ratcheting, collapse

1. Introduction

Excessive seismic loadings can induce such failure modes as low cycle fatigue, collapse and ratcheting deformation. In this article numerical investigation has carried out in order to understand the occurrence conditions of ratcheting and collapse. Also to see the behavior of seismic response at different frequencies.

2. Numerical model

Dynamic elastic plastic analysis has been done by FEA with the FINAS code. The following model made of plane stress elements is used for ratcheting and collapse analysis. The gravity and sinusoidal acceleration are put in the base and additional mass is placed at the top of the model. Frequencies are 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 times of the 1st mode natural frequency.

3. Analysis results

Paying attention to analogy to the thermal ratcheting controlled by a primary load and secondary cyclic load, the stress produced by the gravity is considered as primary stress whereas the hypothetical stress which is statically equilibrium to the base acceleration is considered as pseudo secondary stress. The theoretical boundary is provided by the Yamashita et. al. bending–bending ratcheting model [1]. The graphs below show the ratcheting and collapse boundary for different acceleration and frequencies. The non-dimensional parameters X and Y in this diagram are defined as -

$$X = \frac{\sigma^g}{S_y} \qquad \text{Where, } \sigma^g = \textit{Bending stress due to gravity},\ S_y = \textit{Yield stress}$$

$$\sigma^{in} = \textit{Hypothetical stress which is statically equilibrium to the base acceleration}$$

$$Y = \frac{\sigma^{in}}{S_y}$$

Figure1: Numerical Analysis Model

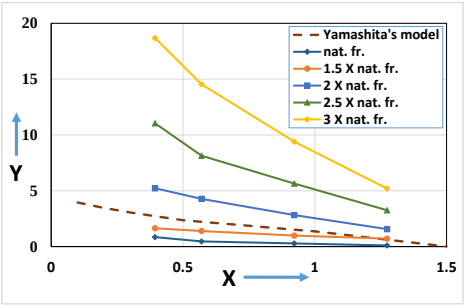

Figure2: Occurrence condition of ratcheting at different frequencies

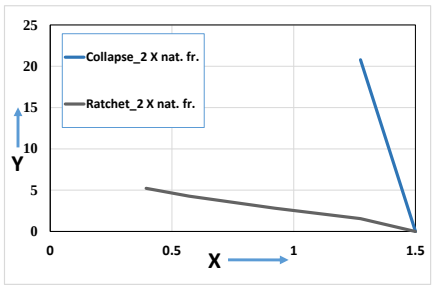

Figure3: Failure mode map for ratcheting and collapse

It has seen that for higher frequency (like twice the natural frequency of each model), ratchet boundary follows the Yamashita et. al. ratcheting model [1], which proves that seismic load behaves as secondary load at higher frequency.

References

[1] T. Yamashita et al., "A simplified method of evaluating ratcheting in bellows and a test of its validation", Int. J. of pressure vessel & piping, 42 (263-285), 1990