Study on Failure Modes of Piping Structures under Realistic Seismic Waves

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Abstract: This study focuses on frequency dependent characteristics and proposes a failure mode map of piping structures under realistic seismic loads.

Keywords: Failure modes, Piping structures, Seismic waves, Frequency effects on failure

1. Introduction

After the Fukushima Daiichi nuclear accident, some recommendations have been made on Design Extension Conditions (DECs), which may occur due to excessive seismic loading. DECs need best estimation of structural strength against seismic loading. The final purpose of the research is clarification of failure modes of piping structures against realistic seismic loads, which include various frequency components. This paper studied characteristics of the composite inputs comprising two sinusoidal waves of different frequencies (CITS).

2. Methodology

The analytical modelling was made by FEMAP software and the finite element analyses were done by FINAS/STAR. There were two types of loadings applied to the beam model. Gravity acts as primary loading and was applied by two ways – one was by the additional mass put at the free end of the beam and the other was the self-weight of the beam. A cyclic acceleration at the base of the beam was put as the secondary loading. This base acceleration acted as the source of alternating dynamic loading which can be assumed as seismic loading. Equivalent loading conditions were put in the case of experiment as in analytical analysis to validate the finite element analyses.

3. Results

It was found that with low-frequency input, the seismic load acts like a load-controlled one. On contrary, at higher frequency, the seismic load is acting more like displacement-controlled one rather than load-controlled loading. Besides, ratcheting is more likely to happen with natural frequency. Regrading to the loading of two sinusoidal waves with different frequencies, the component with lower frequency has dominant effect regarding ratcheting failure. The comparison of the occurrence of ratcheting between single sinusoidal and CITS is shown in Fig.1, in which the dominant frequency is the one among the two components which needs less acceleration for the occurrence of ratchetting and is normalized by natural frequency. Y is the non-dimensional secondary stress parameter which is the ratio of bending stress due to maximum acceleration to yield stress. In general, the single sinusoidal input is more dangerous than the composite input. If one component is of higher frequency, the combined loading has less probability of the occurrence of ratcheting.

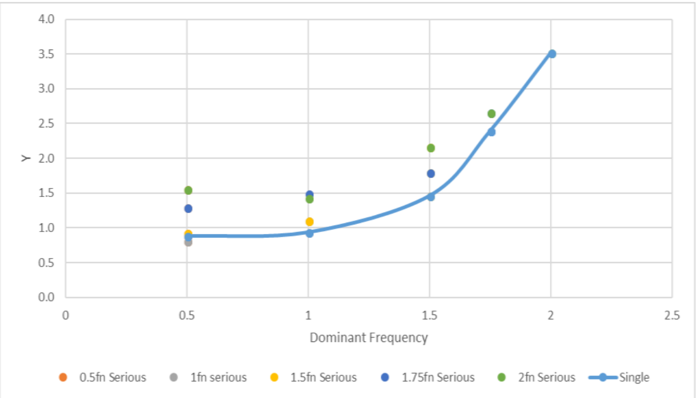

Fig.1 Comparison between single sinusoidal input and CITS

References

[1] Al Bari, Md Abdullah, Ryota Sakemi, and Naoto Kasahara. "Failure Mode Map of Pipes Under Dynamic Loadings." ASME 2017 Pressure Vessels and Piping Conference. American Society of Mechanical Engineers, 2017.