

## Piping System Damping Evaluation Study

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### Abstract

EPRI and Toshiba have jointly carried out a piping system damping evaluation study. The study was conducted by applying the single variable Auto Regressive Method (ARM) and the Curve-Fit Method (CFM), currently used in Japan, and the Logarithmic Decrement Method (LDM), used in the EPRI study, to the part of EPRI High-Amplitude Dynamic Test Data for Prototypical Nuclear Piping Systems. The first mode damping was calculated to be in the range of 5-10%. Generally, differences in dampings due to different evaluation methods are small when compared with the spread of the evaluated dampings due to test data variations.

### 1. Damping Evaluation Methods

In the present study, ARM and CFM, currently used in Japan, and LDM, used in the EPRI study, were applied to the data obtained in high level vibration tests sponsored by EPRI [1]. The natures of these methods are described in [2,3].

#### 1.1 Curve Fit Method

There are several versions of CFM. The one used in the present study is based on Sato[4]. The curve fit procedure in CFM attempts to identify the parameters of an existing system by using imaginary part of the transfer function (frequency response function) of the experimental data. The method takes into account the effect of the marginal part of other peaks around a particular peak in a transfer function to evaluate the characteristics of the vibrational mode corresponding to that particular peak.

#### 1.2 Auto Regressive Method

At present, two kinds of ARM are proposed for equipment seismic damping calculations. These are single variable ARM and double variable ARM. The single variable ARM has been applied widely and has demonstrated its applicability to test data obtained from mockup equipment tests and to earthquake observation data obtained from actual plant pipe [2]. The double variable ARM was recently developed to overcome some shortcomings found in the single variable ARM [2]. For example, the single variable ARM cannot exclude the frequency components contained in an input vibrational motion to SMiRT 11 Transactions Vol. K (August 1991) Tokyo, Japan, © 1991

the mockup equipment from the estimated transfer function. The method can calculate dampings with considerably high accuracy level when it is applied to simulated equipment earthquake response time histories. However, at present, the method is not necessary effective for the actual test data. Thus, in the present study, only the single variable AR method was used.

### 1.3 Logarithmic Decrement Method

LDM is used to derive damping values from a time domain representation of free vibration response. The damping value is calculated based on the relative amplitudes of successive cycles in the free vibration time history. If the peak response amplitude of some arbitrary starting cycle is  $X_0$  and the peak response amplitude  $m$  cycles later is  $X_m$ , then damping,  $h$ , can be found using the following equation :

$$h = \ln(X_0/X_m)/2 \pi m$$

LDM can be applied only where the response is strongly dominated by a single mode which is normally the lowest frequency mode.

## 2 Test Data

Test data used for the present study were the results of testing a three-dimensional six-inch (150 mm) and eight-inch (200 mm) diameter piping system as shown in Figure 1. The pipe was water filled and pressurized to 1,150 psig at room temperature. The pipe was clamped on S1 and S4 base sleds and supported inbetween the sleds at S2 and S3. The pipe supports consisted of struts, mechanical shock arresters and hydraulic shock arresters. Struts were used as vertical supports for S2 and S3. Horizontal supports were changed for each test case. Four kinds of pipe support configuration test data were used in the present study. These include C1 (struts were used for both S2 and S3), C2 (mechanical snubber was used for S2 and strut was used for S3), C3 (mechanical snubbers were used for both S2 and S3) and C5 (hydraulic snubbers were used for both S2 and S3). The method of testing consisted of impulse, sine dwell, and a representative earthquake. The excitation levels ranged from those inducing stresses below OBE (Operation Basis Earthquake) level to above SSE (Safe Shutdown Earthquake) level.

## 3 Damping Evaluations

Seventeen cases were analyzed. The natural frequencies of the pipe were estimated to be in the vicinity of 4Hz, 7Hz, 9Hz, 11Hz, 12Hz, 13Hz and 16Hz. The 4 Hz mode is along the Y-directional excitation. The vibrational characteristics of the prototypical nuclear piping system were evaluated using both CFM and ARM for the first (4Hz) and the second (7Hz) modes. Examples of the evaluation results are shown in Figure 2. Figure 2(a) is an example of earthquake excitation test data evaluation obtained using CFM and Figure 2(b) shows the evaluation using ARM. All the evaluated dampings of the first and the second vibrational modes are drawn in Figure 3 for various pipe support configurations. Figure 3(a) shows that relatively high dampings, about 5-10%, were calculated for the first vibrational mode for pipe support configurations C1, C2 and C3. For the C5 configuration where hydraulic snubbers were used for both S2 and S3 supports, smaller dampings in the range of 3-5% were calculated. For the second vibrational mode, the dampings were found to be about 3% for configurations C1 and C2, 3-4% for configuration C5 and 5% for configuration C3. From Figure3, one observes that differences in damping calculation results due to different evaluation methods, CFM and ARM, are small, particularly when compared with the spread

of the evaluated dampings due to test data variations.

#### 4 Comparison with LDM Evaluation Results

A comparison of dampings evaluated using CFM and ARM with those evaluated using LDM [1] was conducted. LDM was applied to the Y-directional excitation displacement time histories. Figure 4 shows an example of displacement time history used and its power spectrum. The 4 Hz dominant mode can be seen. Evaluated dampings are shown in Figure 5 for A through E of the impulse response displacement time histories obtained at different observation points. Dampings are evaluated for six peaks appeared in each time history. These dampings are shown in Figure 3(a) together with those based on CFM and ARM. One notes that dampings evaluated using LDM show smaller values than those evaluated using CFM. The differences, however, are small.

#### 5 Comments and Conclusions

Piping damping evaluation on a three-dimensional laboratory piping system was carried out using three different methods, ARM, CFM and LDM. The database was obtained by applying many levels of impulse (snapback) forces and random motions including simulated earthquake motions through sled actuators. Dampings in the range of 5-10% were calculated for the first vibrational mode for the case where struts and mechanical snubbers were used as the horizontal pipe supports and 3-5% for the case where hydraulic snubbers were used. Differences in evaluated dampings, due to different methods, CFM and ARM are small when compared with the spread of the evaluated dampings due to test data scattering. The ARM and CFM results were compared with those based on LDM. The latter generally show smaller values. The results of the present study confirm the appropriateness of the piping damping values currently accepted for design both in Japan and the United States.

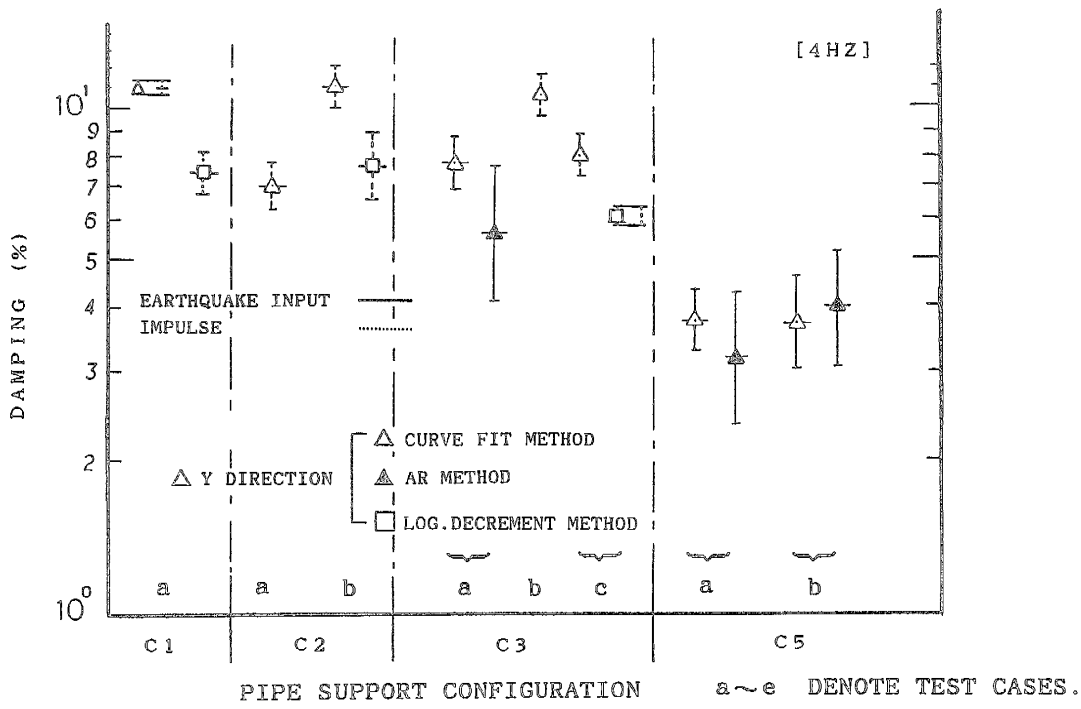
#### Acknowledgements

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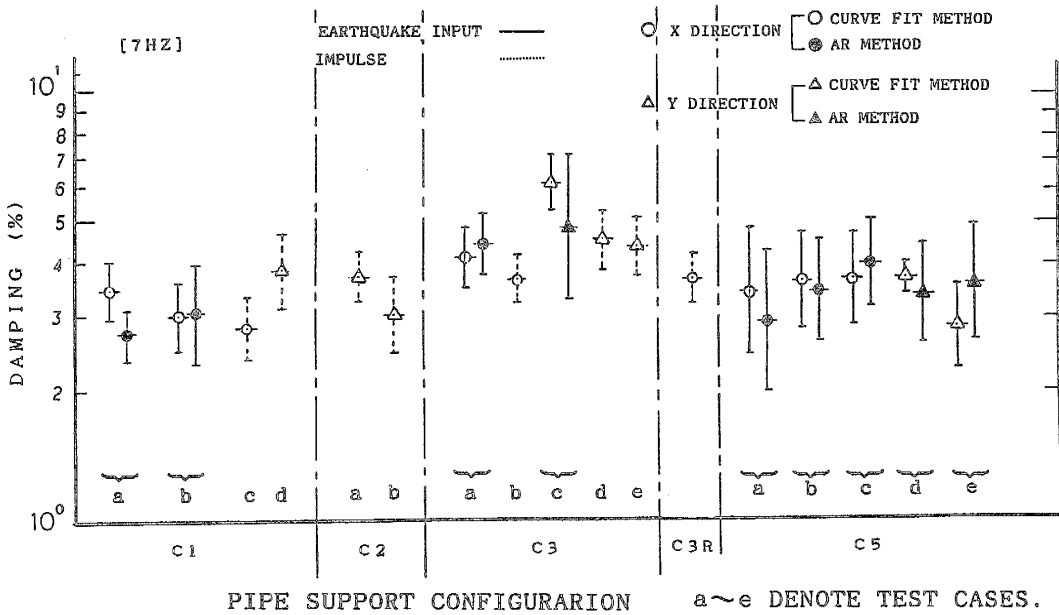
#### References

- [1]. "High Amplitude Dynamic Tests of Prototypical Nuclear Piping Systems", EPRI NP-3916, February, 1985.
- [2]. Y.Kitada, M.Nakajima, T.Taira and K.Suzuki : "A Study on Structural Seismic Damping Ratio Evaluation Methods - Their Application to Vibration Test Data", Trans. ASME PVP Conf., Vol.182,pp.25-30, July, 1989, Honolulu Hawaii.
- [3]. Y.Kitada, K.Hattori, M.Nakajima, T.Taira, K.Suzuki and A.Sone : "Structural Seismic Damping Ratio Evaluation Methods", Trans. ASME PVP Conf., Vol.197,pp.55-60, June,1990, Nashville Tennessee.
- [4]. S.Wang, H.Sato and M.Ohori : "New Approaches to the Modal Analysis for Machine Tool Structure", Trans. ASME, Journal of Eng., Indust., Vol.106, February, 1984.





a) FOR THE FIRST VIBRATIONAL MODE (4 Hz)



b) FOR THE SECOND VIBRTIONAL MODE (7 Hz)

FIG.3 EVALUATED DAMPINGS FOR PROTOTYPICAL NUCLEAR PIPING SYSTEM

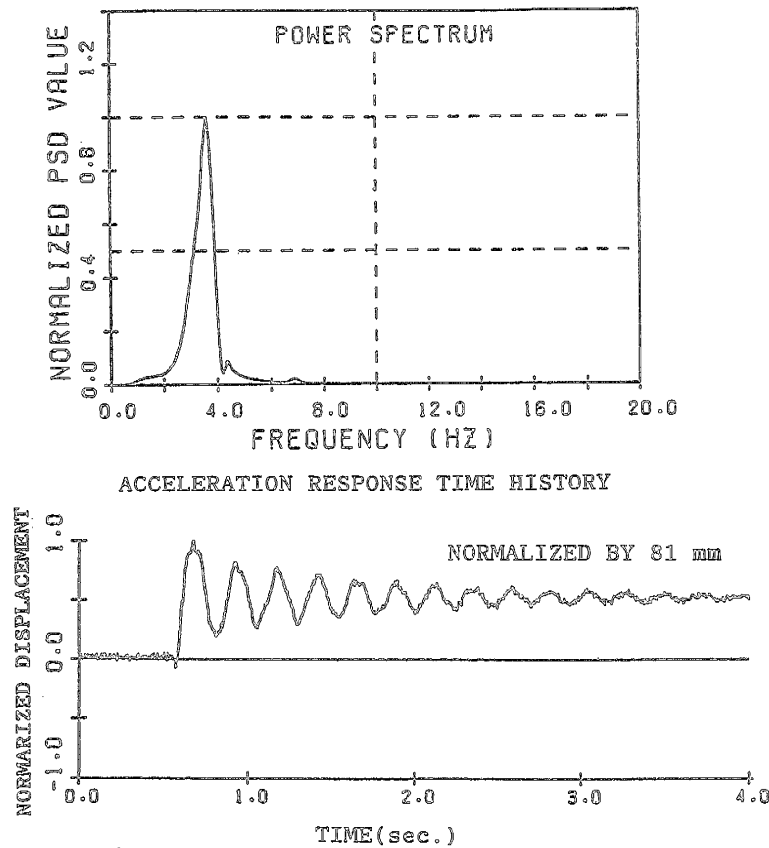


FIG. 4  
 AN IMPULSE RESPONSE DISPLACEMENT TIME HISTORY  
 EXAMPLE USED FOR THE DAMPING EVALUATION WITH  
 THE LOG DECREMENT METHOD.

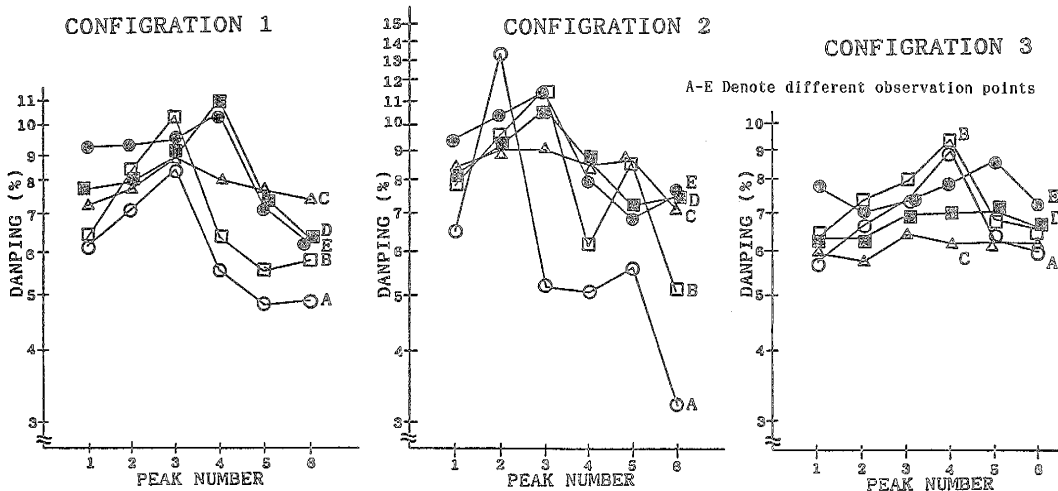


FIG. 5 EVALUATED DAMPINGS WITH LOGARITHMIC DECREMENT METHOD  
 AFTER EPRI PIPING SYSTEM DAMPING EVALUATION STUDY.