Fuel Assembly Damping Summary

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1. Introduction

Damping is an energy dissipation mechanism in a vibrating mechanical structure and prevents a resonant structure from having infinite vibration amplitudes. The sources of fuel assembly damping are various from support friction to flow contribution, and it can be increased by the viscosity or drag of surrounding fluid medium or the average velocity of water flowing [1].

Fuel licensing requires fuel design evaluation in transient or accidental condition. Dynamic response analysis of fuel assembly is to show fuel integrity and requires information on assembly-wise damping in dry condition and under wet or water flowing condition. However, damping measurement test for the full-scale fuel assembly prototype is not easy to carry out because of the scale (fuel prototype, test facility), unsteadiness of test data (scattering, random sampling and processing), instrumentation under water flowing (water-proof response measurement), and noise.

LWR fuel technology division in KAERI is preparing the infra structure for damping measurement test of full-scale fuel assembly, to support fuel industries and related research activities. Here is a preliminary summary of fuel assembly damping, published in the literature. Some technical issues in fuel assembly damping measurement testing under flow are also briefly discussed.

2. Fuel assembly damping summary

Table 1 summarizes fuel assembly damping, released from the major foreign fuel vendors [2~5], published in the literature. Some references did not give complete details about their tests and analysis estimation. Author thinks that testing method, facilities, and damping estimation method are somewhat different, but the overall results show similar trend in values of damping coefficient according to the surrounding medium; Damping under flow, up to 5 m/s, can increase up to nearly 50~60 %. The mean flow velocity significantly increases fuel assembly damping up to 2 ~ 2.5 times higher than those in dry or wet condition. In dry condition, grids spring support friction to fuel rod is major source of fuel assembly damping, but wet damping coefficient increase up to 20~25 % by the flow drag and viscosity effect. Wet and dry damping increases almost linearly as initial release (or pluck) displacement goes up. KAERI have a plan to carry out full-scale fuel assembly damping measurement testing under still fluid and water flowing condition. Reason why significant increase in fuel assembly damping under water flow, quantitative characterization of damping, and experimental methodology establishment of fuel assembly system dynamic characterization are the major motivations of this experimental research work. The results of the test will be used for new fuel design, fuel performance evaluation, and analysis work for licensing support.

Table I: Fuel assembly damping coefficient (%) summary

Test Condition	A[2]	B[3]	C[4] (3~15mm)	D[5] (~5.08 mm)	KAERI FAMeCT [6, 7]
Dry	~10	~18	12~20	~12	~6
Wet	~20	~25	15~28	~18	To be tested
Under flow	~60	~45	42~48 at 5 m/s	50~60 > 3.4 m/s	To be tested

Note, KAERI's FAMeCT (Fuel Assembly Mechanical Characterization Tester) facility will be moved and renovated soon to carry out the under-flow damping measurement test.

3. On fuel assembly damping measurement

There are two conventional methods of damping measurement; pluck testing (free-decay response measurement) and resonant excitation techniques (half power bandwidth method). Conventional modal testing for system dynamic characterization, of course, can cover the system damping information, associated with natural modes of fuel assembly vibration. The pluck testing is to pull (or push) a test object back first and suddenly release (or withdraw) it. One can estimate (logarithmic decreased) damping ratio from the peak trace of free-decaying response. Value of the damping can be changed according to the number of peak counts to be considered. The second method is to excite a test object by a frequency-sweeping dynamic shaker and leads to resonant state. Damping ratio (or Q-factor) can be obtained by the bandwidth of resonant response spectrum (half power bandwidth method). Fine frequency resolution around resonant frequency is needed for this type of damping estimation method and multiple averaging is required.

Test facility for measuring fuel assembly damping under flow should be a full-scale hydraulic loop that can circulate coolant water within a test channel by frequency-controlled pump and drive. Realization of water-proof measurement under flow and excitation system delivering controlled force to a test object through water-flow boundary would be technically challenging. Both ends of test assembly would be mounted on the test platform, simulating a reactor core support system. Purified, temperature-controlled water would be used as an active fluid medium. Various sensors including laser vibrometer, water-proof under-water accelerometer, and LVDT would be adapted for fuel assembly response tracking under water and flow. Test conditions to be planed are in air, in still water, and under varying flow velocity up to ~6 m/s. Maximum pluck displacement is 15~20 mm, and increment step of initial pluck displacement is 1 or 2~5 mm. Temperature effect of surrounding fluid medium on fuel assembly damping is known as being negligible [2, 5]. Random sampling and processing of estimated damping coefficient would be needed for scattering data due to the lack of repeatability.

4. Conclusions

Fuel assembly damping is an essential parameter to determine fuel assembly dynamic behavior in operating or accidental core. Dry damping coefficient from the out-pile pluck testing was used for the accident analysis model in conservative and simplified manner. But, this is way lower than wet or under-flow damping. This paper summary the fuel assembly damping data in air/in still water/under flow, released from foreign fuel vendors, compared our data with the published data. Some technical issues in fuel assembly damping measurement testing are also briefly discussed.

Understanding of each fuel assembly damping mechanisms according to the surrounding medium and flow velocity can support the fuel design improvement in fuel assembly dynamics and structural integrity aspect. Because the upgraded requirements of the newly-developed advanced reactor system will demands to minimize fuel design margin in integrity evaluation, reduction in conservatism of fuel assembly damping can contribute to alleviate the fuel design margin for sure.

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