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Modal behaviour of PFBR model thermal baffles

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ABSTRACT: Modal properties namely, natural frequency and damping factor of the thermal baffles of the 500 MW(e) Prototype Fast Breeder Reactor were measured on a 1/16 scale model. Impulse excitation method was used and experiments were carried out with different levels of water in the annulus between the two baffles. Value of each modal frequency was found to be nearly independent of water level whereas the damping ratio showed a decreasing trend with lower level in the annulus.

1 INTRODUCTION

In the proposed 500 MW(e) Prototype Fast Breeder Reactor (PFBR), there are two thermal baffles concentric with the main vessel. A small fraction of core flow from the cold pool is diverted along the annulus between main vessel and the outer baffle for cooling the main vessel. Sodium flows over the outer baffle and falls into the annulus between the two baffles before returning to the cold pool. These thermal baffles are prone to flow induced vibrations due to instability caused by sloshing and fluid structure interaction type excitations. Details of main vessel cooling arrangement and theoretical background on the instability mechanisms have been described in Jalaldeen, Ravi, Chellapandi and Bhoje (1993).

For analysis of this vibration phenomenon, a knowledge of the modal properties namely, natural frequency and damping factor is necessary. These parameters also depend on the level of the fluid in the annuli and can not be computed accurately. Hence experiments were carried out on a 1/16 scale model with aluminium thermal baffles and water as the test fluid to study the effect of water level on modal frequency and damping.

This paper discusses the model, experimental procedure, the results and the conclusions.

2 MODEL DESCRIPTION

The model schematically illustrated in Fig.1 consists of an outer steel vessel corresponding to the main vessel of PFBR. The two thermal baffles are made of 0.5 mm thick aluminium sheet and are bolted together and the outer baffle is in turn bolted to the main vessel part. Baffles were fabricated by rolling the aluminium sheet and crimping the vertical edge.

This model was earlier used to study the flow induced vibration problems of the baffles. Modelling laws and the results have been discussed in Premnath, Thirumalai, Prabhakar and Kale (1993).

3 INSTRUMENTATION AND EXPERIMENTAL PROCEDURE

Impulse excitation method was used for determining natural frequency, mode shape and damping and measurements were carried out with different water levels in the annulus between the two baffles. The outer annulus however always contained water upto the top edge of the outer baffle and this situation simulates the liquid levels in the two annuli in PFBR.

Strain gages fixed along circumferential orientation at many locations and a piezoelectric accelerometer which could be attached at various locations at the top of the baffle were used for measuring the vibration response of the outer baffle. The signals from these transducers were coupled to a FFT based signal analyser for obtaining the response frequency spectrum and phase information for determining the mode shape. For obtaining the mode shape, measurements were taken at 17 circumferentially equispaced points in one half sector using the accelerometer.

Damping factor (ζ) was determined by logarithmic decrement method. An exponential curve was fit to envelop the decaying signal to find out δ (log decrement) and damping factor was calculated as $\zeta = \delta / 2\pi$.

4 RESULTS AND DISCUSSION

Frequency spectrum plots for different water levels (referred to as fall height and defined in Fig.1) are shown in Fig.2 Mode (1,8) with a frequency of approximately 6.8 Hz was excited at low fall heights alongwith a few other components, while mode (1,9) with a frequency of approximately 6.0 Hz was alone excited at higher fall heights. There was an intermediate range offall heights where both the modes were present. From the spectra, variationin natural frequency with fall height for the above two prominent modes was determined and is shown in Fig.3.

The modal frequency essentially remains independent of water level in the annulus between the two baffles. Reducing the water level, i.e. increasing the fall height, decreases the added mass but increases the external hydrostatic pressure on the outer baffle. Former effect tends to increase the natural frequency whereas the latter effect tends to decrease the natural frequency and hence these two effects tend to cancel each other. To confirm this, measurements were also carried out by varying the water level simultaneously in both the annuli. Natural frequency monotonically increased with fall height, as shown in Fig.4. Only the added mass effect is present in this case.

The variation of damping ratio with fall height for (1,9) mode is shown in Fig.5. The damping ratio decreases from about 8% to 4% with increase in fall height from 0.04 to 0.11 m. Damping ratio was approximately 5.7% at zero fall height and showed an increasing trend upto 0.04 m fall height. At low fall heights, damping ratio could not be precisely determined by the logarithmic decrement method because of the irregular decaying pattern.

5 CONCLUSIONS

Measurements on 1/16 scale model show that the value of baffle natural frequency of a given mode does not depend on the water level in the annulus due to the opposing effects of added mass and external pressure. However, the damping ratio tends to decrease with increasing fall height and this measurement has provided necessary input to analytical predictions of instability.

REFERENCES

Jalaldeen, S., Ravi, R., Chellapandi, P. and Bhoje, S.B. 1993. Fluid elastic instability analysis of 1/16th experimental model of PFBR main vessel cooling circuit. Trans. 12th Int. Conf. on SMiRT: Vol E,309-314.

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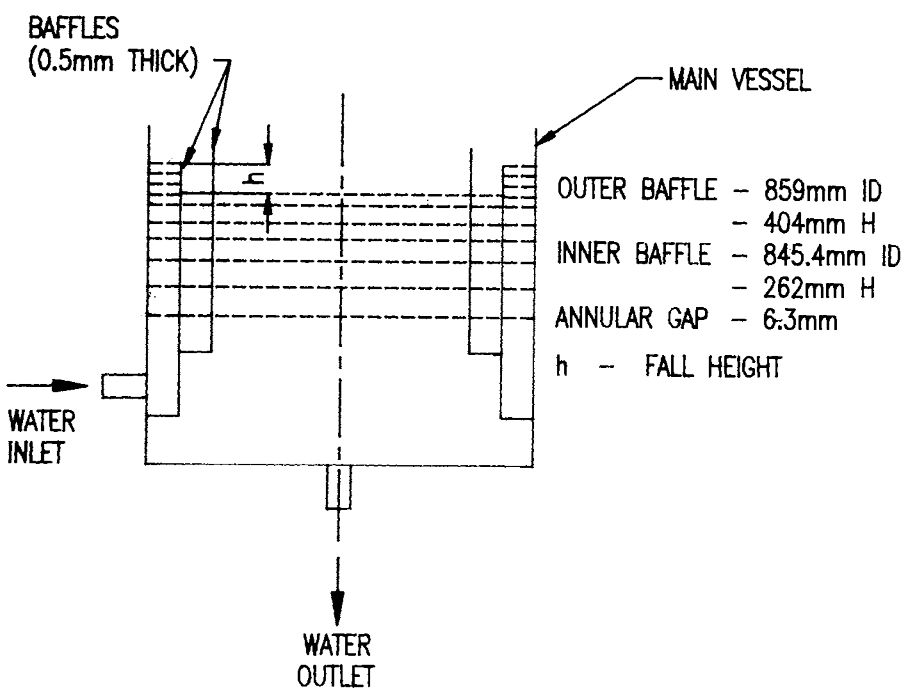

Fig.1 1/16 MODEL FOR MODAL MEASUREMENTS

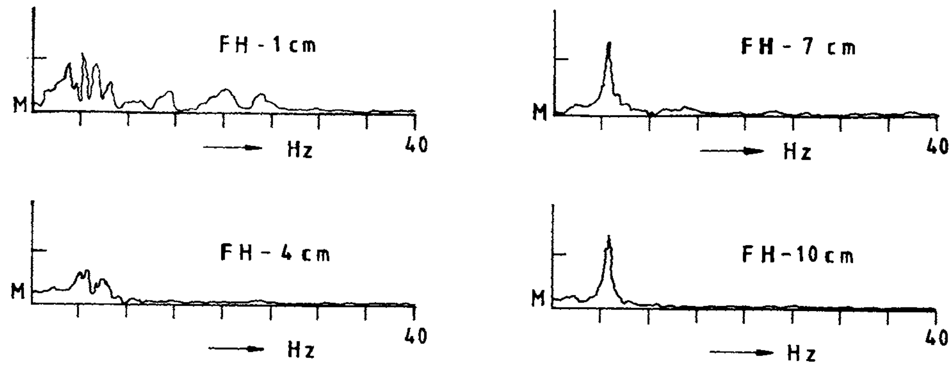

Fig. 2 FFT PLOTS FOR SELECTED FALL HEIGHTS

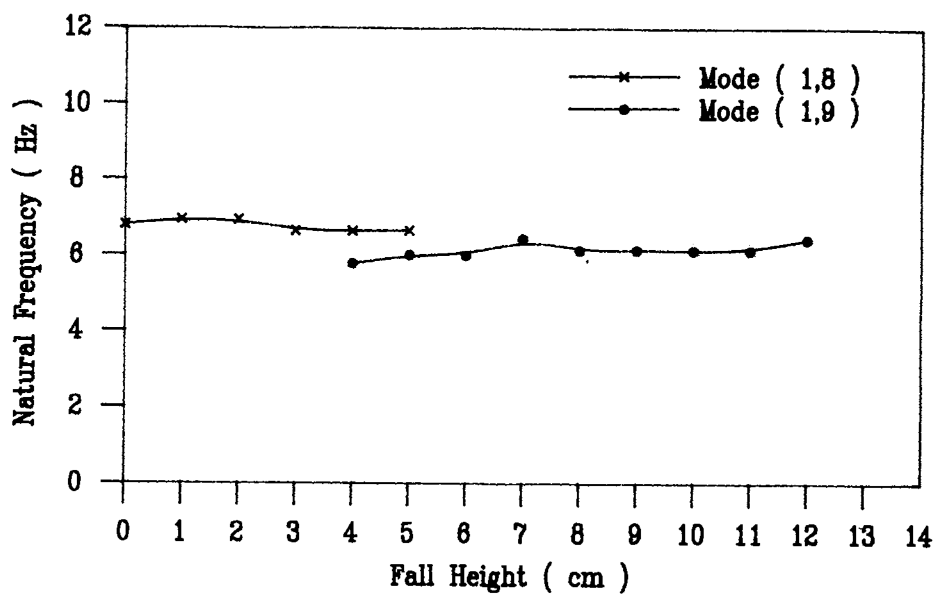

Fig. 3 VARIATION OF MODAL FREQUENCY WITH FALL HEIGHT

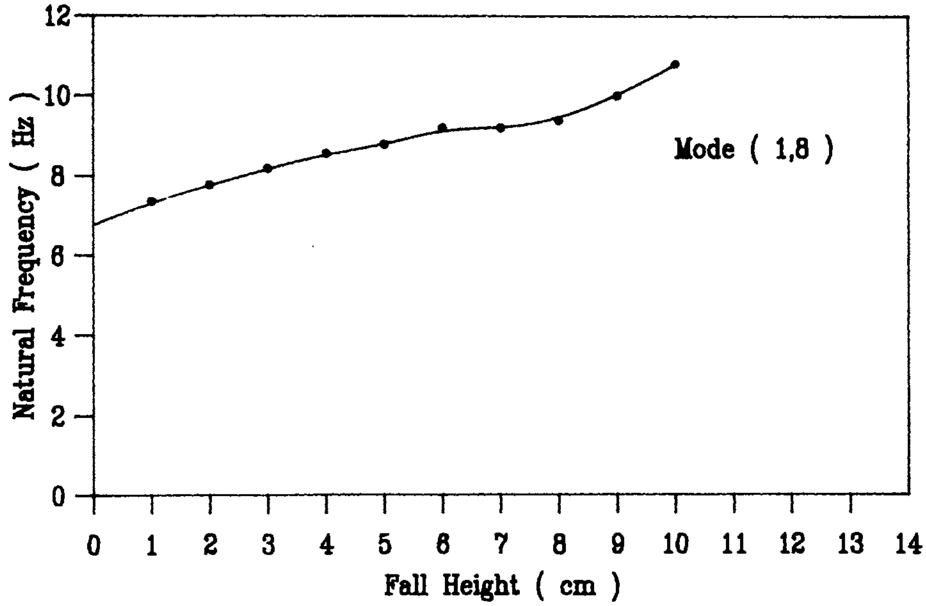

Fig.4 MODAL FREQUENCY V/S FALL HEIGHT-LEVEL VARIED IN BOTH ANNULI

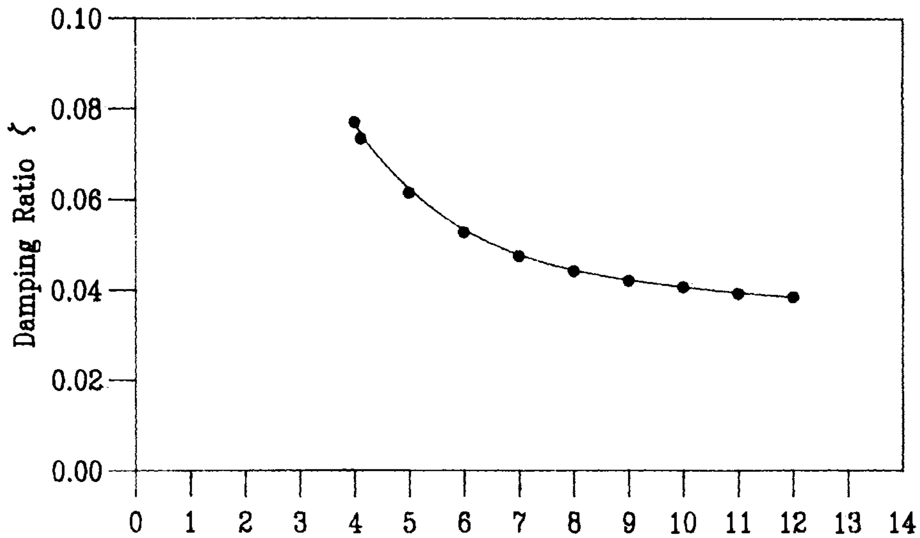

Fig. 5 VARIATION OF DAMPING RATIO WITH FALL HEIGHT