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MECHANICAL ANALYSIS OF FIRST WALL TUBES FOR THE LIBRA CONCEPTUAL REACTOR*

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The mechanical design of a first wall tube bank system for ICF reactor cavities is strongly influenced by parametric results of dynamic response analyses. Under sequential lateral pressure pulses, transient startup motion of tubes is followed by steady state oscillations of a frequency corresponding to the reactor repetition rate. It is shown that the steady-state amplitude and the corresponding alternating amplitude are sensitive to the repetition rate, tensile preload and internal liquid metal flow velocity.

Introduction

LIBRA represents a conceptual ICF reactor design based upon a light ion driver system. Key parameters are identified in Table I and a schematic cross sectional diagram of the reaction chamber is shown in Fig. 1. An annular bank of vertical tubes (INPORTs [1]) encircle the cavity. INPORTs are fabricated from continuous silicon carbide fiber, braided to produce a tube with a porous, pliable wall. Liquid $\text{Li}_{17}\text{Pb}_{83}$, used as a coolant and breeding material, flows axially within the INPORT and through the tube wall to develop a protective outer film. This concept is shown in Fig. 2. The first two rows of INPORTs are subjected to repetitive mechanical shock loading during operation. The dynamic response has been analyzed and will be described in the work which follows.

Mechanical Modeling

INPORTs are modeled as being completely flexible and elastically supported at the top and bottom ends. Such spring loading allows for control of axial tension in each unit. Viscous damping is included in the model and expressed as a percentage of critical damping. The effects of fluid velocity are also included in the

Table I. Preliminary LIBRA Parameters

Cavity shape	cylindrical
Cavity radius (m)	5
Cavity gas (torr)	Ar(10) + Li(0.002)
First wall	SiC INPORTs
Breeder/coolant	$\text{Li}_{17}\text{Pb}_{83}$
Rep. rate (Hz)	1.5
Ion type (MeV)	Li(21)
Driver efficiency (%)	20
Total driver energy (MJ)	4
Target gain	80
Fusion yield (MJ)	320
Fusion power (MWt)	480

equations of motion. However, the secondary effects of flow through the tube wall are not considered at this time.

The dynamic pressures are obtained from the simulation code, FIRE [2]. The pulse shown in Fig. 3 is used for all calculations and is analytically modeled as a combination of a linear ramp and exponential decay, uniformly distributed on one side of an INPORT. A computer code has been developed to determine the dynamic mechanical response, using the pressure pulse sequentially applied at the repetition rate of the reactor.

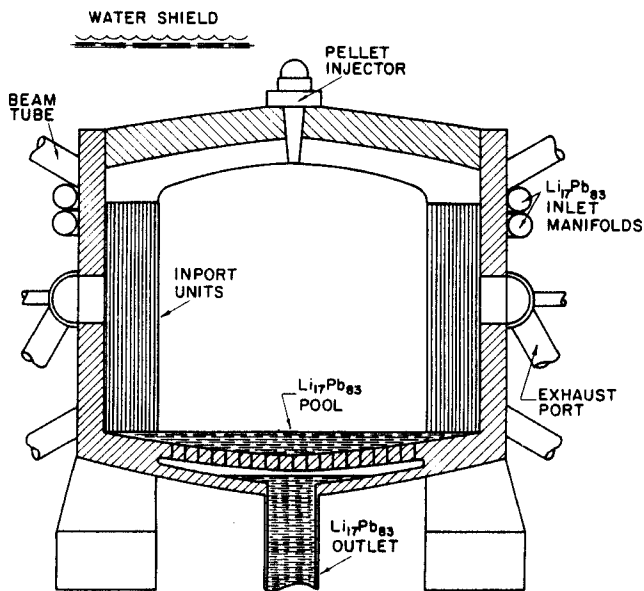


Fig. 1. Schematic of LIBRA Reactor Chamber.

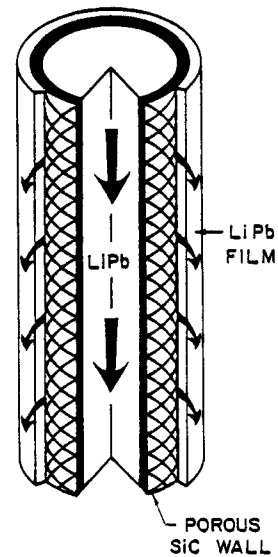


Fig. 2. Sectioned INPORT Unit.

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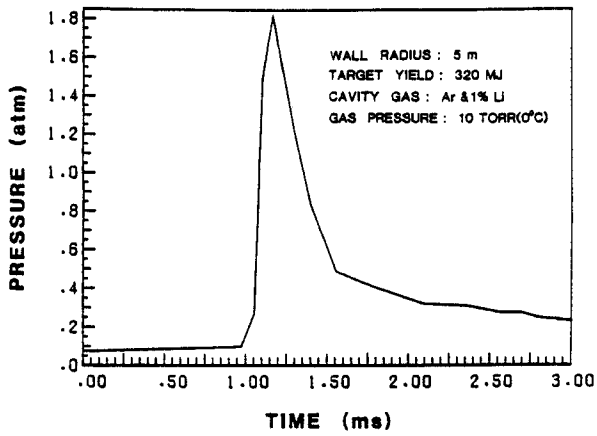


Fig. 3. Dynamic Overpressure at the First Wall.

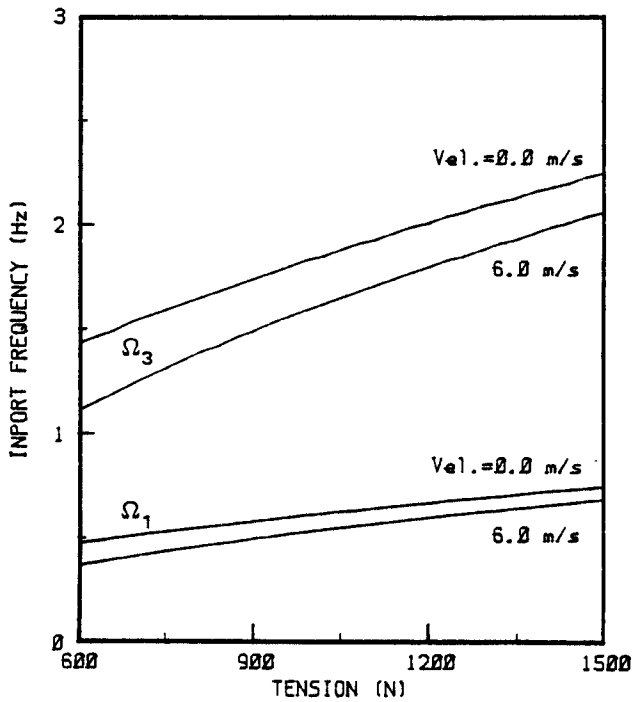


Fig. 4. INPORT Natural Frequencies Versus Preload Tension.

Mechanical Response

All numerical results are based upon an INPORT with a length, diameter and wall thickness of 10 m, 3 cm and 1 mm, respectively. For such components, the response depends upon the natural modes and corresponding frequencies. As shown in Fig. 4, natural frequencies are moderately increased by axial preload and reduced as fluid velocity increases, with the value producing a frequency of zero referred to as the critical velocity. The response will be most strongly influenced by the lower modes and frequencies, such as those shown corresponding to one and three half waves, respectively (Ω_1 and Ω_3).

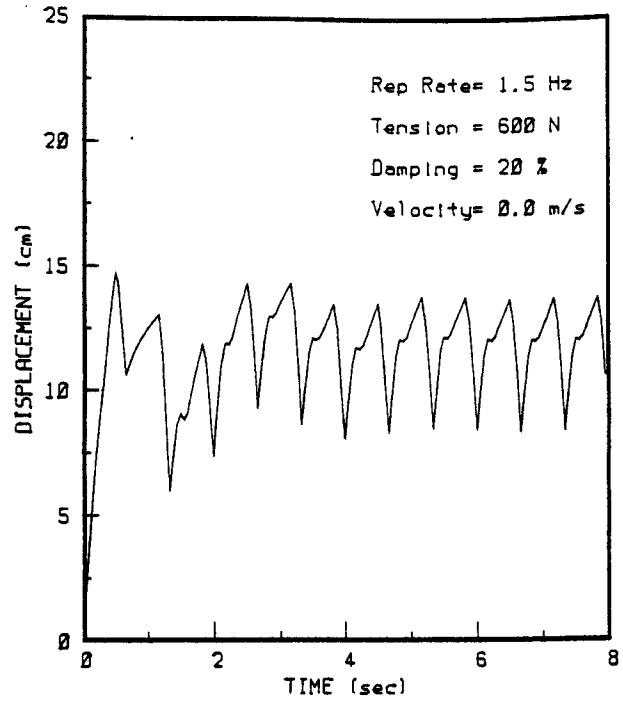


Fig. 5. INPORT Midpoint Displacement Versus Time.

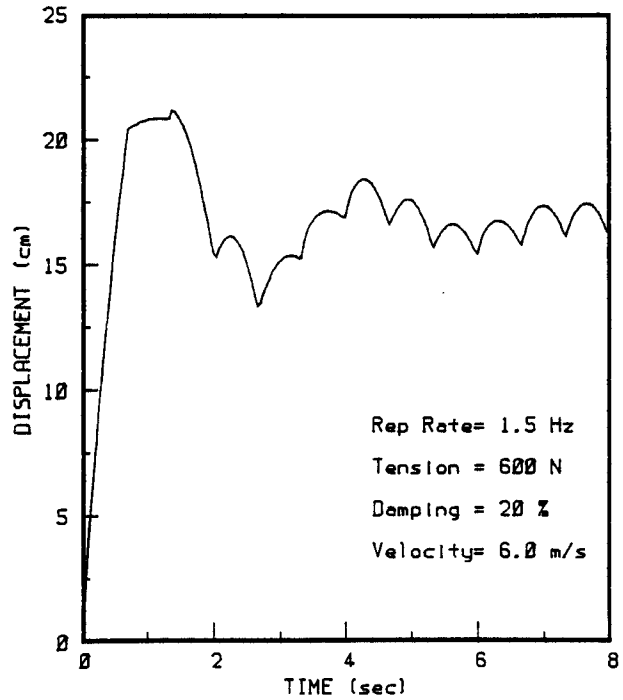


Fig. 6. INPORT Midpoint Displacement Versus Time.

The reaction chamber is expected to operate at a repetition rate of 1.5 Hz but slight variations from this are possible. Typical midpoint displacement histories are shown in Figs. 5 and 6 for 1.5 Hz. A change in fluid velocity from zero to 6 m/s (63% of the critical) results in a steady state mean displacement

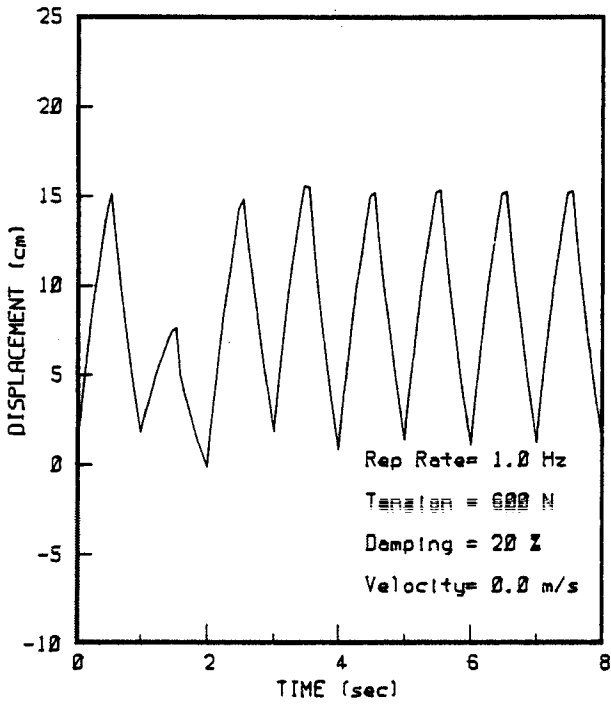


Fig. 7. INPORT Midpoint Displacement Versus Time.

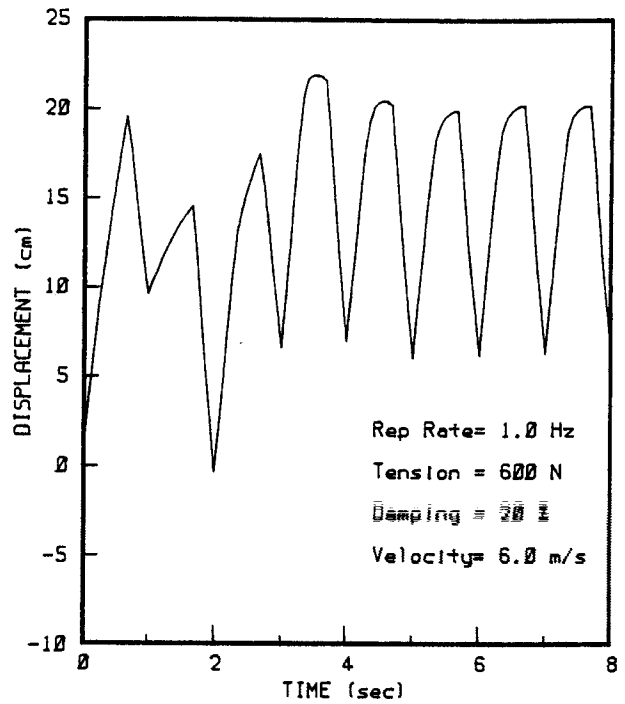


Fig. 8. INPORT Midpoint Displacement Versus Time.

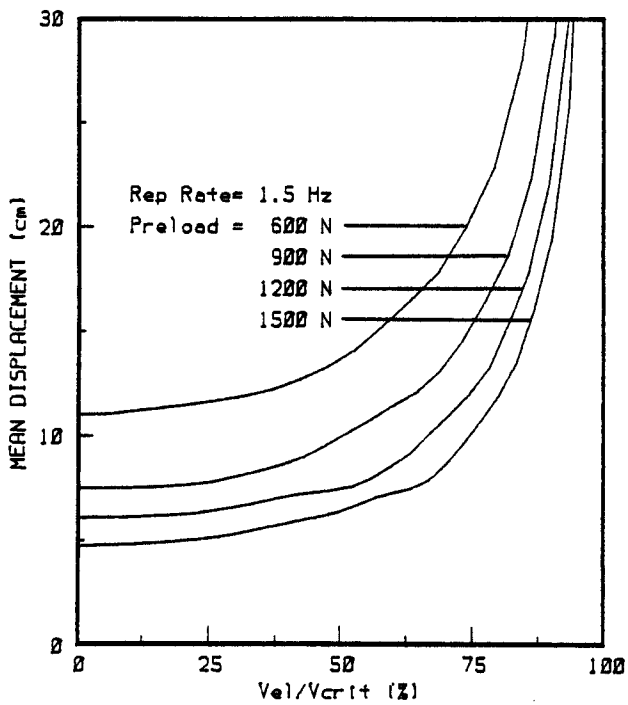


Fig. 9. Steady State Mean Displacement Versus Fluid Velocity Ratio.

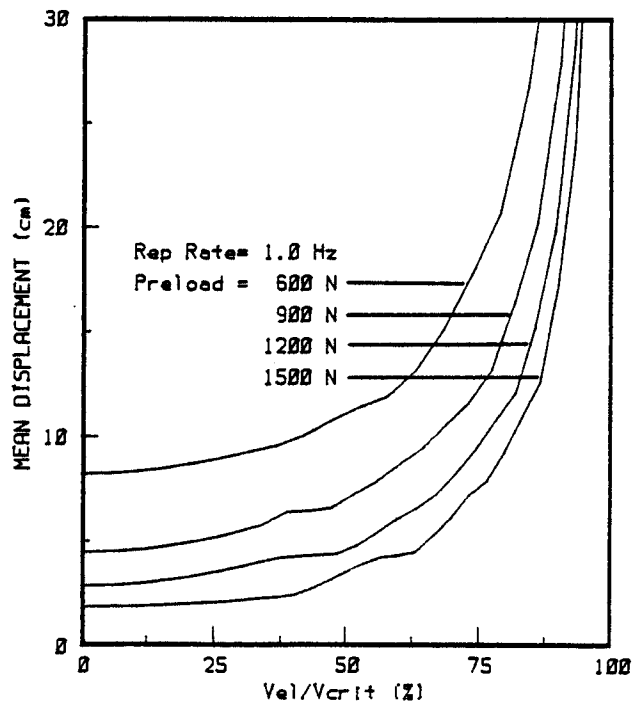


Fig. 10. Steady State Mean Displacement Versus Fluid Velocity Ratio.

which is larger but with a reduced alternating amplitude after motion has stabilized. Similar results are shown in Figs. 7 and 8 for a reduced repetition rate of 1.0 Hz. However, the alternating amplitudes for fully developed motion in these two cases is large and would

degrade the fatigue life of the components. In Figs. 9 and 10, the steady state mean amplitude at 1.5 and 1.0 Hz is shown as a function of the critical velocity ratio for various preloads. Clearly the mean value increases with increasing velocity but can be controlled

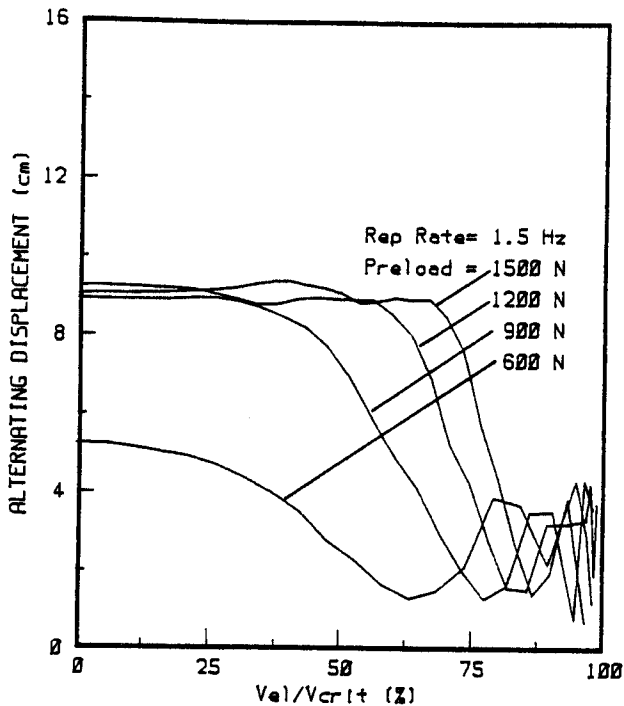


Fig. 11. Steady State Alternating Displacement Versus Fluid Velocity Ratio.

at lower velocities with a larger preload force. More pronounced response is shown for the alternating displacement as shown in Figs. 11 and 12. In general this component is rather insensitive to initial increases in liquid velocity but drops quickly for larger velocities and subsequently oscillates moderately as the upper limit is approached. It can be seen that the alternating displacement is generally lower for the 1.5 Hz case compared with 1.0 Hz.

Conclusions

It has been shown that the dynamic mechanical response of INPORTs comprising the first wall of the LIBRA ICF conceptual reactor is influenced significantly by pretension loads, the repetition rate of the driver system and the flow velocity of lithium/lead within the tubes. In particular, as the repetition rate is raised, it was found that the steady-state mean displacement amplitude increased but the associated alternating displacement decreased. In addition, if the liquid metal velocity is increased, the steady-state mean displacement grows but the alternating amplitude drops. Such results will have a direct

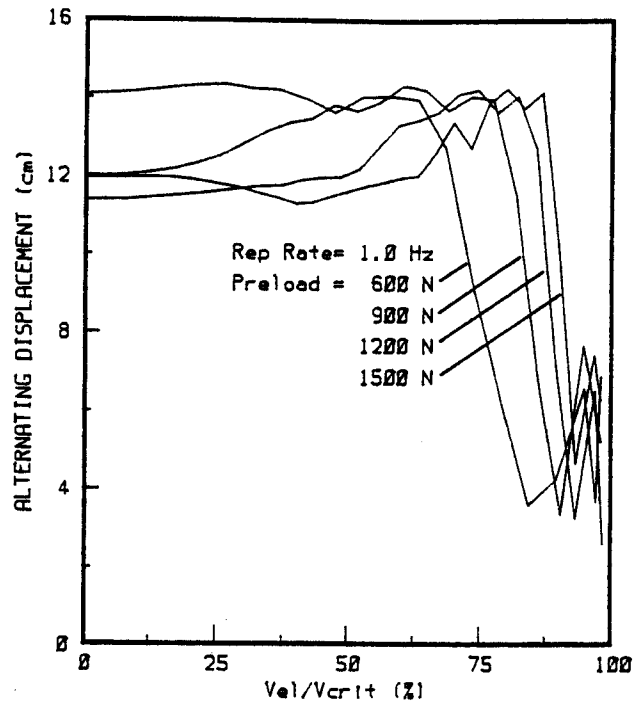


Fig. 12. Steady State Alternating Displacement Versus Fluid Velocity Ratio.

bearing on the determination of the fatigue life of INPORTs [3]. In general, the parametric mechanical response data will be correlated with results from nonmechanical analyses to further develop a more refined design of the LIBRA reaction chamber.

References

- [1] G.L. Kulcinski et al., "The INPORT Concept - An Improved Method to Protect ICF Reactor First Walls," *J. Nucl. Matls.*, vol. 103-104, pp. 103-108, 1981.
- [2] G.A. Moses and R.R. Peterson, "FIRE - A Computer Code to Simulate Cavity Gas Response to Inertial Confinement Target Explosions," University of Wisconsin Fusion Engineering Program Report UWFD-336, January 1980.
- [3] R.L. Engelstad, E.G. Lovell and S.J. Covey, "Strength and Fatigue Analysis of Fibrous Silicon Carbide for ICF Reactor Applications," to appear in *J. Nucl. Matls.*, 1983.