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Experiments of Shells With Non-Newtonian Fluid Interaction

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Abstract: In this study the nonlinear vibrations of a fluid-filled circular cylindrical shell under seismic excitation is investigated. A PET thin shell with an aluminum top mass is harmonically excited from the base through an electrodynamic shaker in the neighborhood of the natural frequency of the first axisymmetric mode. The dilatant fluid is composed of a cornstarch-water mixture with 60% cornstarch and 40% water of total weight. The preliminary results show a strong non-linear response due to the coupling between the fluid and structure and the shaker-structure interaction that leads to a very interesting dynamic response of the system. The specimen is a polymeric circular cylindrical shell: an aluminum cylindrical mass is glued on the shell top edge; conversely, the bottom edge of the shell is clamped to a shaking table. The following sensors have been adopted: three triaxial accelerometers placed on the top mass at 120°, a monoaxial accelerometer at the base of the shell, a laser vibrometer to measure the lateral velocity on the mid-height of the shell. The test article has been excited in the axial direction through a harmonic load, with a step-sweep controlled output, the voltage signal sent to the shaker amplifier is closed-loop controlled; to avoid interaction between the control system and the specimen under study, no controls have been used for controlling the shaker base motion. The harmonic forcing load consists of a stepped-sine sweep of frequency band 100-500 Hz with a step of 2.5 Hz. All the tests have been performed with the shell full filled with quiescent fluid. The dynamic scenario is analyzed by means of time histories, spectra, phase portraits and Poincaré maps. The experiments show the onset of complex dynamics: subharmonic and quasiperiodic responses, Chaos.

Keywords: FSI Fluid Structure Interaction, Nonlinear Dynamics, Shells, Chaos, Experimental

1. Introduction

The present paper is the first outcome of the Project *InterFlu* focused on Non-Newtonian fluids and interactions with vibrating structures. Here the goal is to analyze the dynamic scenario of a circular cylindrical shell in presence of interactions with fluids, the study is fully experimental. Our attention was focused on large amplitude of oscillations generated by an highly energetic seismic excitation, having a single tone spectral content, such excitations induces nonlinear vibrations on a fluid-filled cylindrical shell carrying a top mass (upper rigid closer cap), preliminary results of the bifurcation analysis are presented.

2. Results and Discussion

In this section, a short overview of the preliminary results, obtained from the postprocessing of the experimental data, is shown. In addition to the main instability region around the first axisymmetric mode between 235Hz and 300Hz, the bifurcation diagram of the lateral velocity, figure 3a and 3c, shows a second interesting region between 366Hz and 442Hz, where a subharmonic response is predominant, see the spectrum of the lateral velocity in the upward 0.34V case at 400Hz in figure 3i, the branches of the diagram separate and rejoin several times, showing a strong dynamic instability with a period doubling behaviour. This remark is confirmed by the Poincaré maps of the vertical acceleration of the top mass and the radial velocity of the shell: a 4T subharmonic (Figure 3a) move to chaotic states at 250Hz(Figure 3b) confirmed by the time history of the velocity (figure 3c) , and in the case of upwards at 0.34 Volt a period-doubling with amplitude modulation at 292.5 Hz: Poincaré maps (figure 3d) and spectrum of lateral velocity normalized respect to the forcing frequency at 292.5Hz (figure 3e) and 400Hz (figure 3f)has been observed in the experimental analysis.

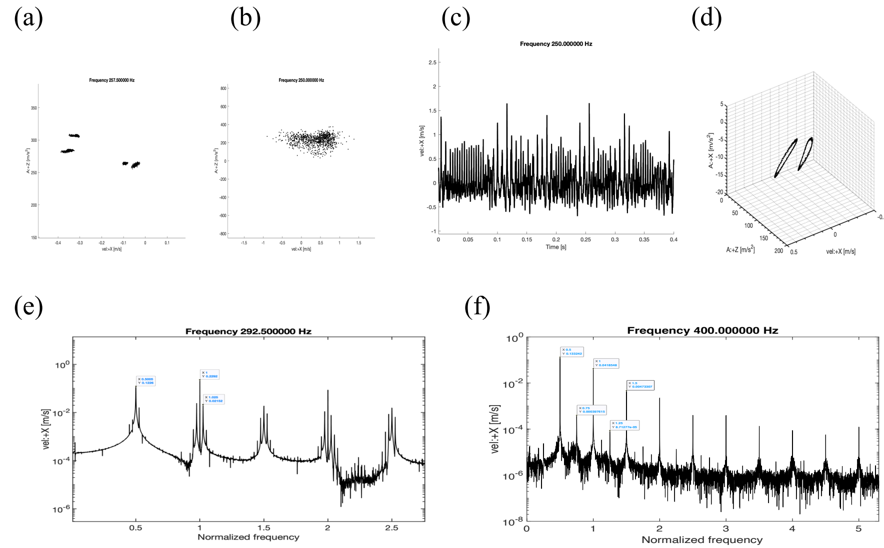

Fig. 1. 4T subharmonic response (a) and chaotic motion: Poincaré maps(b) and time history (c), period-doubling with amplitude modulation: Poincaré maps (d) and spectrum of lateral velocity at 292.5Hz (e),400Hz (f)

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