Experimental investigation of Circular Cylindrical Shell with non newtonian fluid

Antonio Zippo*, Giovanni Iarriccio* and Francesco Pellicano*
* *Università degli Studi di Modena e Reggio Emilia, Dipartimento di Ingegneria Enzo Ferrari, Centre InterMech - MO.RE.*

Summary. In the presented study the nonlinear vibrations of a fluid-filled circular cylindrical shell under base excitation is investigated. A PET thin shell with an aluminium top mass is harmonically excited through an electrodynamic shaker in the neighbourhood 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.

Introduction

The behaviour of thin-walled structure dynamics is always of high attention from the scientific community due to the extensive number of applications that can be found in engineering from macro to nanoscales (propellant tanks, micro-electro-mechanical systems, nanotubes, etc.).
In literature, it is possible to find several references where the response of thin-walled structures subjected to external forcing has been analyzed in presence of fluid-structure interaction [1-3], extreme temperature conditions [4-5] or interaction with electrodynamic shakers [6]. With the purpose of analyzing the response of the shell in presence of multiple interactions, an experimental study on the nonlinear vibrations of a fluid-filled cylindrical shell carrying a top mass has been carried out: the test setup is described, and preliminary results of the bifurcation analysis are presented.

Experimental setup and tests procedure

The specimen is a polymeric circular cylindrical shell, see Figure 1: 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.

Figure 1: fluid-filled polymeric circular cylindrical shell with a top mass

Preliminary results

In this section, a short overview of the preliminary results, obtained from the postprocessing of the experimental data, is shown. In figure 2 the amplitude frequency diagrams shown a transfer of energy to the lateral motion at increasing of the excitation. The bifurcation diagram of the radial velocity (figure 3a) and top acceleration (figure 3 b) of the downwards test at 0.48 Volt and the bifurcation diagram of the radial velocity (figure 3c) of the upwards test at 0.34 Volt shows clearly that the dynamic scenario of the shell is strongly nonlinear.

(a) (b) (c)

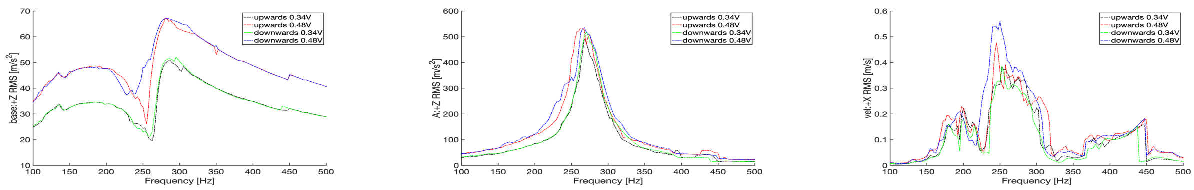

Figure 2: amplitude frequency diagram of (a) base acceleration (b) top acceleration (c)lateral velocity

This remark is confirmed by the Poincaré maps of the vertical acceleration of the top mass and the radial velocity of the shell: a 4-period subharmonic (Figure 3d) to chaotic states at 250Hz(Figure 3e) confirmed by the time history of the velocity (figure 3f) , and in the case of upwards at 0.34 Volt a period-doubling with amplitude modulation at 292.5 Hz: Poincarè maps (figure 3g) and spectrum of lateral velocity normalized respect to the forcing frequency at 292.5Hz (figure 3h) has been observed in the experimental analysis.

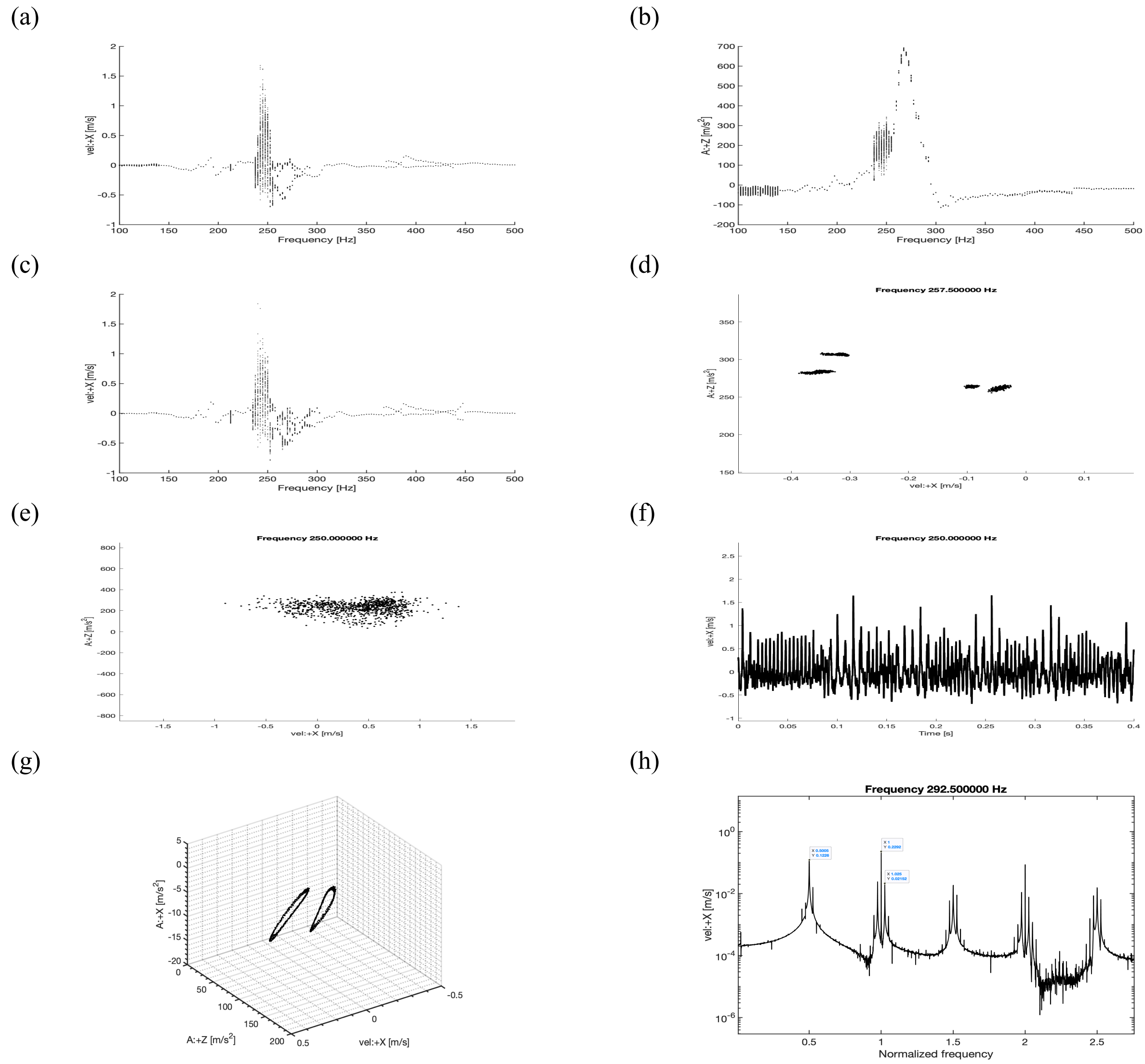

Figure 3: Bifurcation diagram and Poincaré maps of the fluid-filled shell response: experimental bifurcation diagram of the lateral velocity (a), top mass acceleration in axial direction (b) downwards 0.48V and lateral velocity upwards case at 0.34 V(c) , 4-period subharmonic response (d), chaotic motion: Poincaré maps(e) and time history (f), period-doubling with amplitude modulation: Poincarè maps (g) and spectrum of lateral velocity (h)

References

[1] Chiba, N., Tani, J., Yamaki, N., (1987) Dynamic stability of liquid-filled cylindrical shells under vertical excitation, part I: experimental results. *Earthquake Engineering and Structural Dynamics* **15**:23-26.

[2] Sivak, V. F., Telalov, A. I., (1991) Experimental investigation of vibrations of a cylindrical shell in contact with a liquid. *Soviet Applied Mechanics* **27**:484-488.

[3] Amabili, M., Pellicano, F., Païdoussis, M. P., (1998) Nonlinear vibrations of simply supported, circular cylindrical shells, coupled to quiescent fluid. *Journal of Fluid and Structure* **12**:883-918.

[4] Zippo, A., Barbieri, M., Iarriccio, G., Pellicano, F., Nonlinear vibrations of circular cylindrical shells with thermal effects: an experimental study(2020) Nonlinear Dynamics, 99 (1), pp. 373-391. DOI: 10.1007/s11071-018-04753-1

[5] Zippo, A., Barbieri, M., Pellicano, F., Temperature gradient effect on dynamic properties of a polymeric circular cylindrical shell (2019) Composite Structures, 216, pp. 301-314, DOI: 10.1016/j.compstruct.2019.02.098

[6] Pellicano, F., (2011) Dynamic instability of circular cylindrical shell carrying a top mass under base excitation: experiments and theory. *International Journal of Solids and Structures* **48**:408-427.