Nonlinear Phenomena in Shells with Random Excitation

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Summary. The nonlinear dynamics of a thin circular cylindrical shell subjected to thermal gradients and random excitation is experimentally investigated. The combination of broadband random loading and thermal conditions both at different homogenous temperature and with thermal gradients across the shell thickness. The phenomenon of synchronization is observed at particular thermal and loading conditions: a severe transfer of energy from a broadband excitation to an almost subharmonic out of band response is experimentally observed.

Introduction

In several applications like aerospace automotive and civil engineering the role of thin-walled structures have a key function, for example, bodywork panels, fuselage or aircraft and satellite panels together with storage tower.
A crucial factor in thin walled structures is the performance under random forcing whose dynamics, characterized by strong nonlinearity can give rise to unexpected complex phenomena that cannot be predicted by the traditional engineering tools and theories.
It is well known that chain of non-linear oscillators under intense periodic forcing could exhibit a "mode-locking" phenomenon that synchronizes the exciting load with the response. A similar phenomenon, which is much less investigated, can happen when a nonlinear system is excited with a broadband random forcing [1], for example when internal resonances are present; in such cases it has been proven the possibility of entrainment of regular harmonic responses by the system. This phenomenon is said “synchronization” of non-linear oscillators subjected to random forcing [2,7], it has been partly investigated proving the unusual phenomenon of conveying the random spectral energy to specific frequencies, determining remarkable vibration amplitudes.
In recent research published on Ref. [4, 5] it is proved that the effect of temperature greatly influences the instability regions and the vibration levels, moreover, it was pointed out that high environmental temperature leads to a more complex dynamics.
In the present work an experimental investigation of the synchronization phenomenon is carried out. A circular cylindrical shell made of polymeric material is considered; the shell is mounted on a shaking table, the shell axis is vertical, the bottom is clamped to the table, the top is closed with a rigid disk. The shaking table provides a base motion in the direction of the shell axis. The temperature is controlled inside and outside the shell. Several random excitation level and types are considered (different frequency bands) as well as several internal and internal temperatures.

Experimental setup and results

The experimental test consists of a specimen mounted on an electrodynamic shaker coupled with a climate chamber and monitored by accelerometers, laser vibrometer and a telemeter. The specimen is a thin cylindrical shell made of Polyethylene terephthalate (P.E.T.), a thermoplastic polymer, a top mass, made of aluminum alloy, is glued with special epoxy glue, resistant to high temperature, on the top of the specimen. The bottom of the shell is clamped to the fixture through a shaft collar that guarantees a uniform connection to the vibration table adapter (VTA), i.e. a clamped-clamped boundary condition is guaranteed on the bottom and the top.
Figure 1 shows the experimental setup including the control system, the shaker and the climate chamber. Inside the shell, a cartridge heater is mounted and is used to adjust the temperature inside the shell and to obtain the desired thermal gradient across the shell wall, see Figure 2; a mirror periscope has been used to allow the laser beam measuring the lateral vibration of the shell. An accelerometer located on the base of fixture, for control purposes, three triaxial accelerometers are located equally spaced on the top disk.
A random controlled broadband base excitation is applied at the base through the electrodynamic shaker. Each test is carried out at different bandwidth and different overall RMS.
The forcing is a band limited random (900-1500 Hz), see figure 3, with a 28°C thermal gradient from 48°C in the inner surface and 20°C in the outer surface, the Power Spectral Density is shown. In figure 3a the pink box identifies the electrical flat spectrum of the random signal provided to the shaker and controlled by the electronic controller, no out of band electric power is provided out of band. On the base the spectral energy is uniform in the band (900-1500 Hz) which is controlled; there is an energy transfer to superharmonics, where evident spikes are present; such spikes are due to the shaker-shell nonlinear interaction; therefore, the base motion contains a strong deterministic component (harmonic). On the top disk a clear deterministic (subharmonic) response takes place in correspondence of the first axisymmetric mode of the shell (467Hz) and, similarly to the base spectrum, high frequency out of band spikes are present.
The novelty of the present paper consists in the experimental evidence of the synchronization phenomenon: when the nonlinear system is excited with random forcing a strong transfer of energy to specific harmonics can take place. It is worthwhile to point out that the phenomenon appears only for certain environmental and forcing conditions.

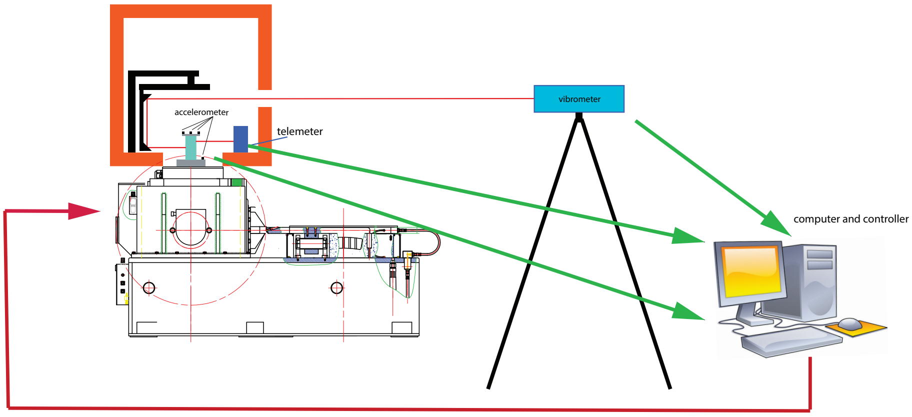

Figure 1: schematic view of experimental setup

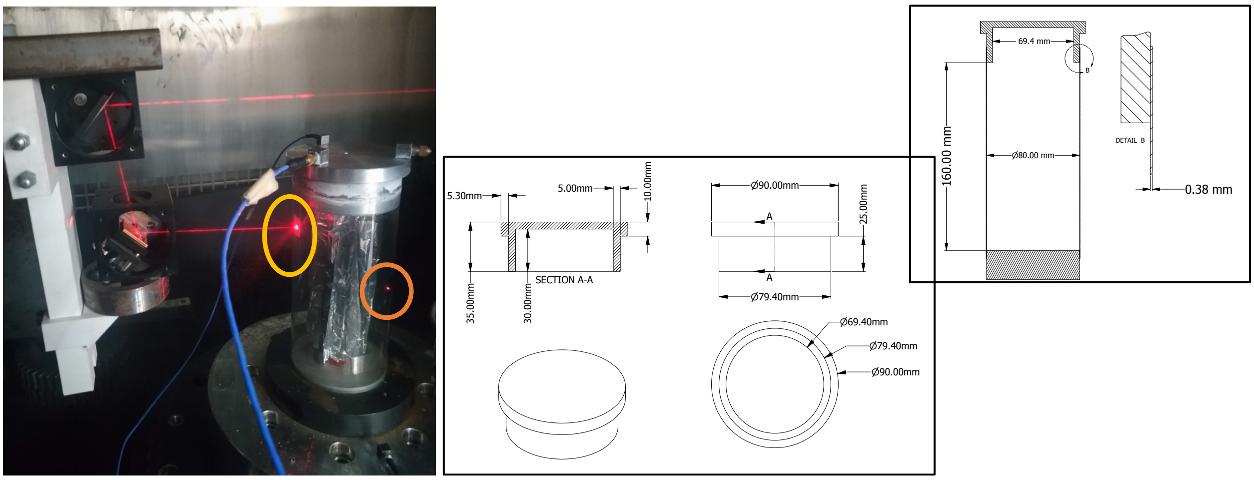

Figure 2: specimen, internal heater cartridge, vibrometer spot light (yellow circle) and telemeter spot light (orange circle)

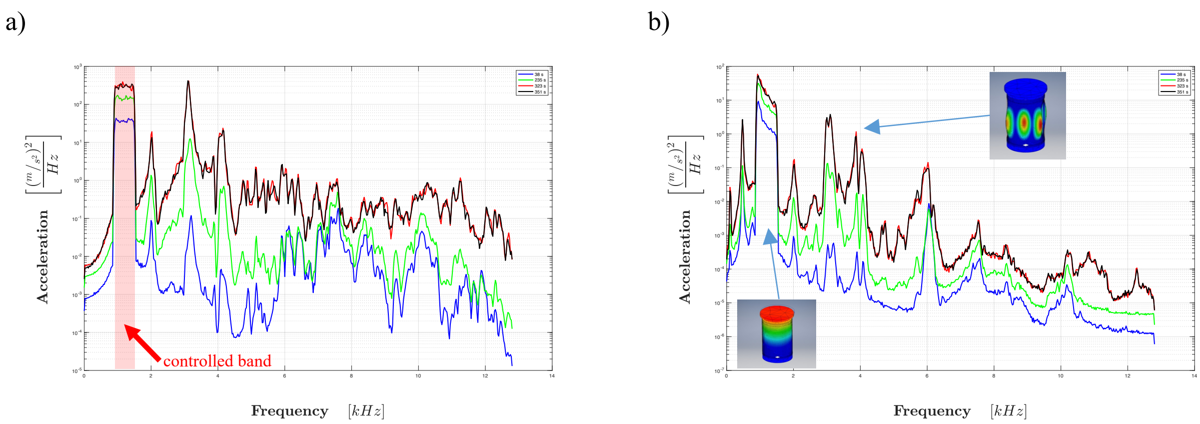

Figure 3: PSD of VTA a) base excitation and b) top shell vertical response

References

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