Spatiotemporal parametric modulation of a soft beam

Eléonore Duval[1,2,3], Johann Asnacios[2], Stephan Fauve[2], Vincent Tournat[1], François Pétrélis[2], Maxime Lanoy[1]

[1] Laboratoire d'Acoustique de l'Université du Mans (LAUM), UMR 6613, Institut d'Acoustique – Graduate School (IA-GS), CNRS, Le Mans Université
[2] Laboratoire de Physique de l'École normale supérieure, ENS, Université PSL, CNRS, Sorbonne Université, Université Paris Cité, F-75005 Paris, France
[3] Université Paris Cité, CNRS, MSC, UMR 7057, F-75013 Paris, France
eleonore.duval.etu@univ-lemans.fr

A parametric oscillator is a system whose natural frequency is periodically modulated, via the time variation of one of its physical parameters. When this parameter is modulated to about twice the natural frequency, the amplitude of the oscillation increases exponentially : this is known as parametric resonance [1].

Here, we study the behaviour of a pre-stressed beam undergoing longitudinal excitation, which induces a parametric modulation of its tension. At first sight, this system appears similar to a classical parametric oscillator, as described by Melde's experiment [1]. But, when the beam is soft enough, we find that its natural frequency varies both in time and space. This double modulation yields the dynamics of the instability growth to be very different from what is usually observed. We first investigate the beam's linear dynamics by characterising both the compression and bending modes. We then drive the system in the vicinity of the bending natural frequencies, and report the growth of atypical elastic instabilities. To explain our observations, we propose a model taking into account the spatio-temporal modulation and the frequency-dependent dissipation.

Understanding the origin of such unstable behaviours has implications for the domains of soft robotics [2] and energy recovery.

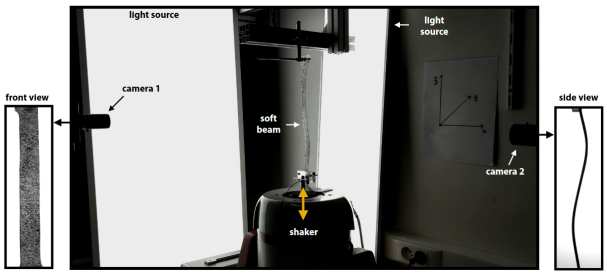

Figure 1. Experiment set-up. A soft beam is fixed at its upper end and parametrically excited at its lower end. Displacements are extracted from the front and side views.

Références

1. Franz Melde, Ueber die Erregung stehender Wellen eines fadenförmigen Körpers, *Annalen der Physik*, **185**, 193–215. (1860)
2. Amit Nagarkar & Won-Kyu Lee & Daniel Preston & et al., Elastic-instability–enabled locomotion, *Proceedings of the National Academy of Sciences*. **118**, (2021)

[1] Other modulation frequencies can also lead to resonance but are usually less efficient.