Elastic instabilities in soft structures

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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 system in which the natural frequency varies both temporally and spatially. We use a flexible pre-stressed strip undergoing longitudinal excitation. This induces parametric changes in the tension of the strip. We first study the linear domain by characterising the different compression and bending modes. Then, by exciting this system in the vicinity of the natural frequencies of the bending modes, we observe and study the growth of elastic instabilities.

If at first sight the system seems to be close to a classical case of parametric oscillator (similar to Melde's experiment [1]), it turns out that the dynamics of instability growth is very different from what is usually observed. We propose a model to explain this atypical phenomenon by taking into account a spatio-temporal modulation of the strip tension and a mode-dependent dissipation.

The study and understanding of these unstable behaviours in soft materials is particularly motivated by applications in energy recovery or soft robotics [2].

Références

1. David Rowland (2004). Parametric resonance and nonlinear string vibrations. *American Journal of Physics - AMER J PHYS*. **72**. 10.1119/1.1645281.
2. Amit Nagarkar, Won-Kyu Lee, Daniel Preston, Markus Nemitz, Nan-Nan Deng, George Whitesides, L. Mahadevan (2021). Elastic-instability–enabled locomotion. *Proceedings of the National Academy of Sciences*. **118**. e2013801118. 10.1073/pnas.2013801118.

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