Nonlinear dynamics of a synthetic spider web

M. Garrad*, L. Renson** and H. Hauser*
*Department of Engineering Mathematics, University of Bristol, UK
** Department of Mechanical Engineering, Imperial College London, UK

Abstract. Spiders dedicate a significant amount of energy and a variety of different types of silk to build their webs. Therefore, it has been speculated that spider webs are more than just simple traps. Spider web are highly complex mechanical structures that might act also as mechanical filters that significantly enhance and extend the sensory capabilities of spiders, enabling them to identify and localise preys and predators. This paper experimentally investigates the dynamic behaviour of a synthetic, 3D-printed spider web to identity general morphological features that can contribute to this filtering capability. First results show, even a simple, artificial web exhibits a wide range of complex dynamic behaviours such as sub- and super-harmonic interactions.

Introduction

Vibration is a major component of spiders' sensory landscape [2]. Using information perceived by the mechanoreceptors on their legs, spiders are able to localise and categorise predators and preys, identify potential mates and detect damage to their webs [1]. These *computational* tasks must be performed accurately and robustly as the cost of failure can be significant. In the case of orb-weaver spiders, observations suggest they are aided in by the properties of their web [3]. Spiders' webs are complex, dynamic structures that are more elaborate than it would be necessary for a simple trap. In fact spider webs act as (mechanical) nonlinear dynamic filters that simplify the interpretation of vibration signals. Therefore, structures inspired by spider webs could lead to a new class of vibration(-based) sensors. To develop this idea and understand which morphological features are contributing to filtering capabilities we investigate the dynamics of a number of 3D printed artificial webs.

Results and Discussion

Artificial webs are 3D printed on a Stratasys Fortus out of ABS. Different types of webs are printed to investigate the contribution of different morphological features of spider webs. Figure 1A shows an image of one of the printed webs, including excited and measured locations 1–4. The response of the web to a constant-amplitude sine sweep excitation is analysed using the wavelet transform (Figure 1B) and clearly shows the presence of higher-harmonics and a 4:1 modal interaction.
A wide range of similar interactions are observed and studied in detail to assess how vibrational energy and information flow throughout the web. Further analysis of the vibration data will allow us to identify to what extent nonlinear effects contribute to the response of the web and to its biological functions. Theoretical investigations (modelling and simulation) are performed in parallel with experiments. By repeating our analysis on a variety of web structures and varying morphological features, we hope to identify how the geometrical features of the web impact upon its behaviour and functions. Together, these results will inspire a new class of vibration sensors.

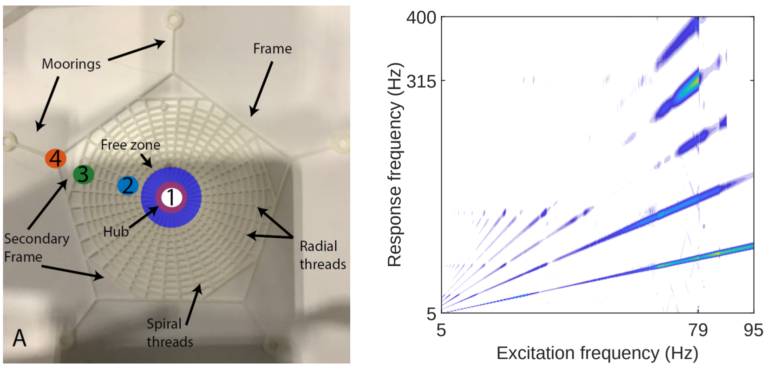

Figure 1: **A** shows a 3D printed web with characteristic orb web features labelled. Excitation and measurement points are labelled 1–4. **B** shows the time-frequency analysis of a constant-amplitude sine-sweep excitation.

References

[1] Mortimer, B. (2019) A spider's vibration landscape: adaptations to promote vibrational information transfer in orb webs. *Integrative and Comparative Biology* **59(6)**:1636-1645.
[2] Masters, W.M. and Markl, H. (1981) Vibration signal transmission in spider orb webs. *Science* **213(4505)**:363-365.
[3] Japyassú, H.F. and Laland, K.N. (2017) Extended spider cognition. *Animal Cognition* **20(3)**:375-395.