Design against fatigue

Fatigue damage is one of the most frequent form of failure of metallic structures. With the increasing demand for high performance structures, the fatigue damage has become more and more important, in particular for metallic structures subjected to complex multiaxial loads due to random vibrations.

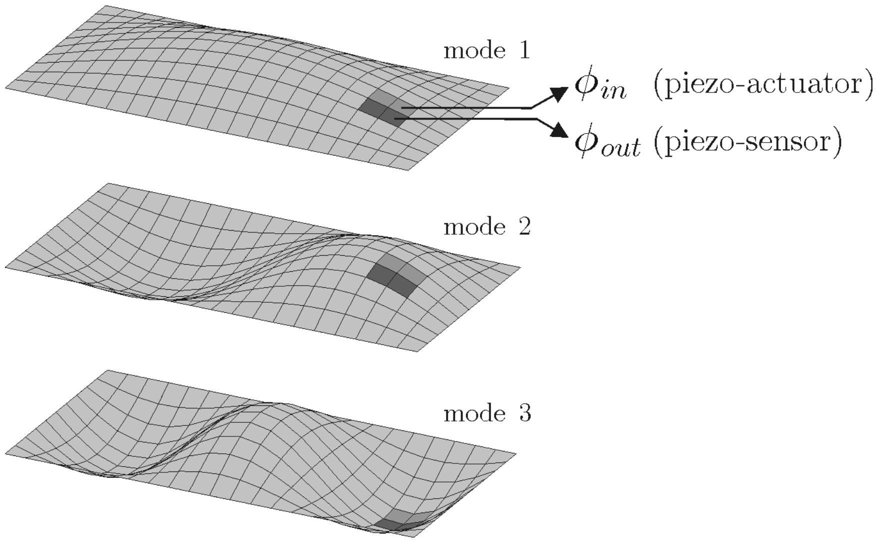

Figure 1: Piezoelectric elements location and first vibration modes

The active damping can be considered as a solution to reduce the vibrations level and at the same time, reduce the weight and increase the fatigue lifetime of such structures. Simulation tools allowing the designer to include directly piezoelectric actuators and sensors in a finite-element model have been developed as well as a *multiaxial random fatigue matlab toolbox* (Pitoiset et al., 1998; Pitoiset & Preumont, 2000; Pitoiset, 2001) allowing the direct assessment of the fatigue lifetime of a structure from a spectral analysis.

The quantification of the damage reduction that can be achieved thanks to an active damping can then be performed very easily, directly from a modal and a spectral analysis with finite-elements. This has been done on a simple example: A simply supported rectangular steel plate (15.24 cm×30.48 cm×0.813 mm) is considered. It is subjected to a band limited white noise random pressure field with perfect spatial coherence; Its *PSD* (Power Spectral Density) is $\Psi_{pp}(\omega) = 400$ Pa^2/rad/s between 0 Hz and 1000 Hz. The first three vibration modes are within the bandwidth of excitation. A piezoelectric actuator and a piezoelectric sensor (*PZT* 15.24 cm×30.48 mm×0.2 mm) are bonded to the surface as shown on Fig.1.

The *multiaxial random fatigue matlab toolbox* was used after a *FE* spectral analysis to evaluate the fatigue damage ratio (per second) over the plate. The state space form of the system is built under *Matlab* directly from the results of a *FE* modal analysis. A controller is designed using *Matlab* functionalities, in this case: a *PPF* tuned on the first mode (Positive Position Feedback).

The new modal damping ratios and eigen frequencies can be used in the *multiaxial random fatigue matlab toolbox* to evaluate the fatigue damage ratio over the controlled plate. The comparison between damage maps for the plate without and with active damping is shown on Fig.2. The same comparison for the *PSD* of the stress components in an element in the center of the plate are shown on Fig.3.

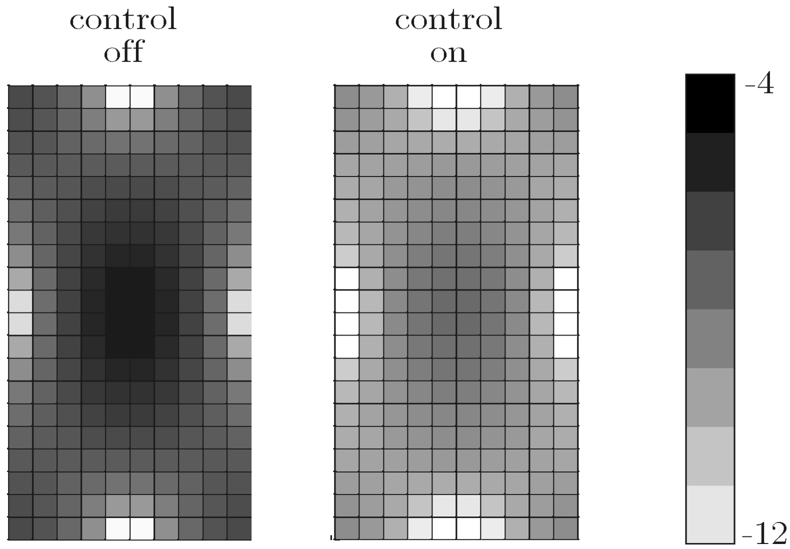

Figure 2: Damage map (Von Mises) with and without control (Log Scale)

References

Pitoiset, X., 2001, *Méthodes Spectrales pour une Analyse en Fatigue des Structures Métalliques sous Chargements Aléatoires Multiaxiaux*, Ph.D. thesis, Université Libre de Bruxelles, Brussels, Belgium.

Pitoiset, X. & Preumont, A., 2000, 'Spectral methods for multiaxial random fatigue analysis of metallic structures', *International Journal of Fatigue*, 22(7):541–550.

Pitoiset, X., Preumont, A. & Kernilis, A., 1998, 'Tools for a multiaxial fatigue analysis of structures submitted to random vibration', European Conference on Spacecraft Structures, Materials and Mechanical Testing, Braunschweig.

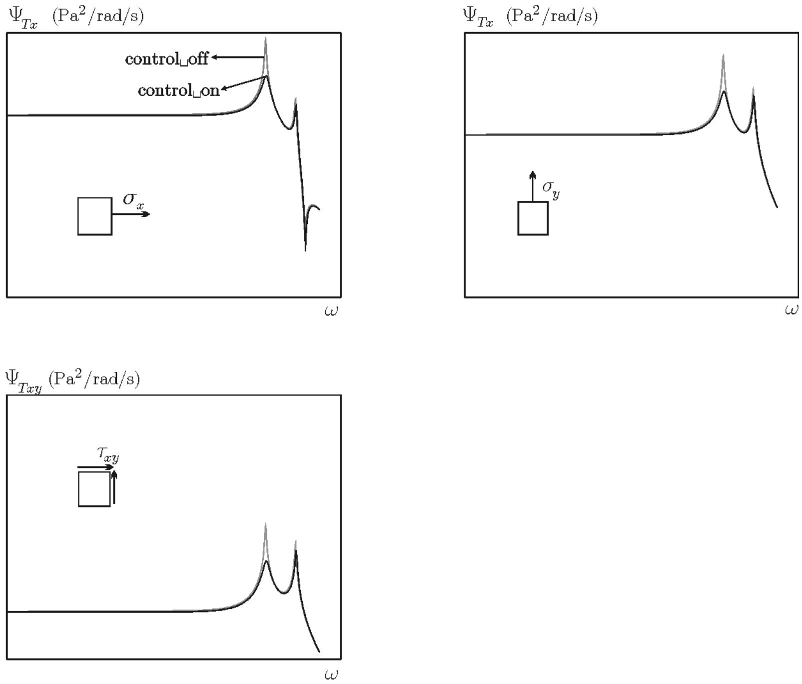

Figure 3: *PSD* of the stress components in the center of the plate with and without control