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Passive flutter suppression using a nonlinear tuned vibration absorber.

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Abstract A recent study showed that the addition of a linear tuned vibration absorber could increase the flutter speed of a rigid wing with pitch and flap degrees of freedom by about 35%. However, the absorber was turning the initial super-critical bifurcation into a sub-critical one. This work shows numerically that adding a nonlinear restoring force to the absorber can restore the supercritical behaviour of the bifurcation and further reduce the post-instability limit cycle amplitude.

Aeronautic structures such as turbine and helicopter blades or wings become more flexible as engineers optimise their weight. As a result, geometric nonlinearity may be increasingly important. Therefore, nonlinearity-induced aeroelastic instabilities could become a design issue. Furthermore, there are several mild aeroelastic issues, such as transonic buzz, that affect mainly military operational aircraft. A solution to these problems is the linear tuned vibration absorber (LTVA) and its nonlinear counterpart, the nonlinear tuned vibration absorber (NLTVA). Habib and Kerschen [1] demonstrated that the NLTVA can improve the critical speed of the Van der Pol - Duffing oscillator, an archetypical system with self-sustained oscillations. Alternatively, Gu et al. [2] showed the effectiveness of the LTVA in increasing the flutter speed of a long span bridge. In [3], the aeroelastic setup sketched in figure 1 was investigated numerically and in the wind tunnel. The system consisted of a wing with structurally hardening pitch and linear flap degrees of freedom coupled to a LTVA. The study showed that the addition of an absorber improves the flutter speed but according to the model, the LTVA can turn the super-critical bifurcation into a sub-critical one. In this study, a nonlinear force is added to the LTVA in order to control the Generalized Hopf bifurcation and prove that the conclusion drawn from the Van der Pol oscillator can also be applied to more realistic structures.

Figure 2 plots the pitch bifurcation diagram of the system without absorber (black), with an optimal LTVA (blue) and with a NLTVA whose linear part is identical to the optimal LTVA (orange). The reference system undergoes a super-critical Hopf bifurcation at the non-dimensional airspeed of 1. After flutter, a smooth increase in LCO amplitude characteristic of a hardening system is observed. The addition of the LTVA increases the flutter speed to 1.35 but causes the bifurcation to become subcritical because the hardening nonlinearity detunes the absorber at high enough amplitudes of oscillation. As a result, the airspeed at which oscillations start to appear is lower than the flutter airspeed of the system with LTVA and a large amplitude jump is observed at flutter. The addition of the nonlinear force successfully changes the Hopf bifurcation back into subcritical and delays the fold. These observations are similar to these made in [1] on the Van der Pol - Duffing oscillator.

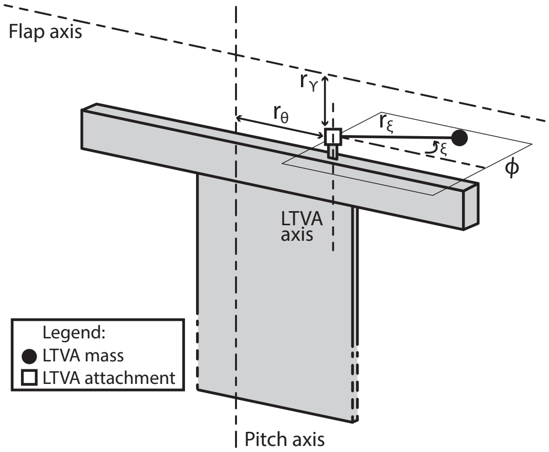

Figure 1: Sketch of the pitch-flap wing with a NLTVA

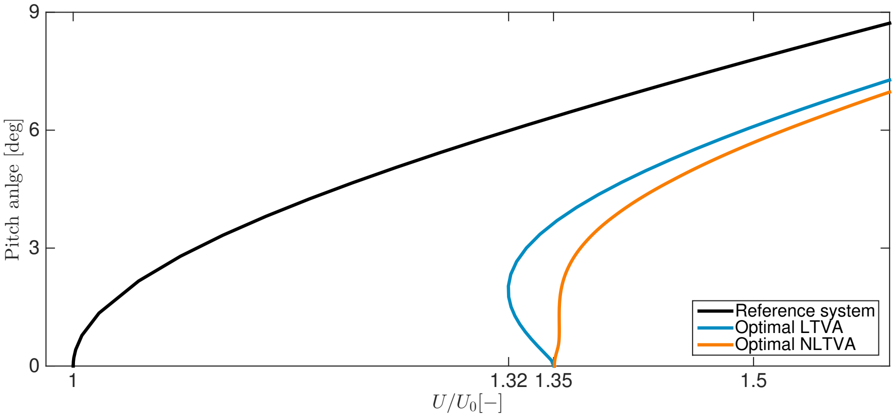

Figure 2: Bifurcation diagram of the system with different absorbers

In conclusion, this work demonstrates the better performance of the NLTVA compared to the LTVA in a flutter case that is more realistic than the previous Van der Pol study.

References

[1] G. Habib and G. Kerschen, Suppression of limit cycle oscillations using the nonlinear tuned vibration absorber. In Proceedings of the Royal Society of London A: Mathematical, Physical and Engineering Sciences, vol. 471. The Royal Society, p. 20140976, 2015.

[2] Gu, M., Chang, C., Wu, W., et al. Increase of critical flutter wind speed of long-span bridges using tuned mass dampers. Journal of Wind Engineering and Industrial Aerodynamics, 73(2), 111-123, 1998

[3] E. Verstraelen, G. Habib, G. Kerschen and G. Dimitriadis, Experimental Passive Flutter Mitigation Using a Linear Tuned Vibrations Absorber. In Proceedings of the IMAC conference, Orlando FL, 2015.