Power harvesting in a helicopter lag damper

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Introduction

In light of the European *Clean Sky* project power harvesting in a helicopter rotor using piezo material is investigated. A prestressed stack of hard PZT (1.5 cm^2, 25 cm length) is considered within the piston assembly of a lag damper, attached to an 8.15m blade (fig. 1). The harvesting potential is investigated of which the energy may be used for autonomous health monitoring thereby limiting electric connections to the helicopter chassis.
The damper is a non-linear viscous type with a highly regressive profile. It dampens in-plane motion of the hinged blade. For forward flight the force-time profile resembles a step function with $\pm$9kN at 4.18Hz.

Figure 1 : External view of a lag damper

Modeling

The mechanical degree of freedom of interest is displacement *u*, together with the damper it has a damped natural frequency ω_{mech} (fig. 2a).

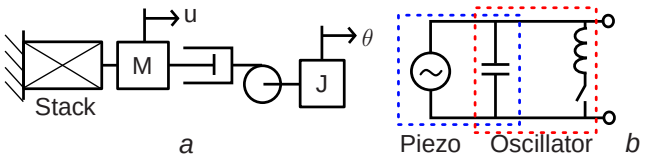

Figure 2 : Mechanical IPM(a) and partial electric schematic showing the switched electrical oscillator (b)

To maximize power an active electric circuit [1] is modeled in *Simulink*. A switched inductor is coupled with the stack's capacitance forming an electrical oscillator with natural frequency ω_{elec} (fig. 2b). The switch is closed for half the period on load peaks inverting the piezo voltage. Harvested energy is conducted to a storage circuit.

Results

Most interesting is the influence of the ratio $\omega_{mech}/\omega_{elec}$. Due to strong electromechanical coupling not only the inductor quality but also the frequency ratio influences optimum inversion duration and efficiency.

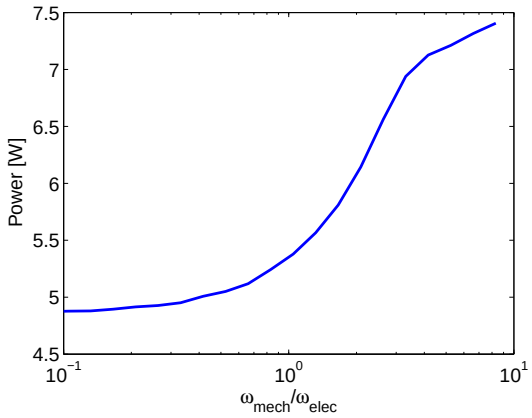

Figure 3 : Power output versus frequency ratio

Figure 3 shows power output against the frequency ratio. During forward flight 7.4W of electricity can be generated from a single lag damper. It is clear that for maximum voltage inversion and output both a high inductor quality and frequency ratio are required. The mechanical degree of freedom associated with the stack must 'catch up' to the equilibrium set by the piezo voltage before inversion is complete and do it as slow as possible to minimize viscous losses.

Conclusions and future work

A useful amount of power can be harvested from the damper. The voltage inversion control circuitry must be developed and the inversion duration optimized and finally a prototype may be constructed.

References

1. D. Guyomar, IEEE T ULTRASON FERR. 52(4):584-595 (2005)

Project and main partners:

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