

Design of lightweight, temperature stable and highly dynamic amplified piezoelectric actuators

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Abstract

Piezoelectric actuators are recognised for their fast response and large force generation. However they are often limited in terms of displacement, therefore justifying the need for a mechanical amplification. For demanding applications such as in aerospace, the additional mass and inefficiency implied by the amplification mechanism is often an inhibitor for the development of the technology. In order to address this issue, actuators have to be designed specifically to maximise their energy density, i.e. the amount of mechanical energy available for a given mass.

In addition, amplified actuators are very often unstable in temperature due to the differential thermal expansion between the piezoelectric element and the amplification frame. Any relative motion is amplified, therefore generating unwanted movement of the output. This effect is another important drawback for aerospace applications which require operation over a wide temperature range.

The present study has been focusing on the field of active rotor control through the use of trailing edge flaps, a field that has been widely covered in the literature. Although the benefits (reduction of the vibration levels by up to 80%) are well recognised, up to now no application has reached commercial success. It is thought that the reasons for this are both a too large mass penalty at a critical location and performance issues in temperature. In the UK Technology Strategy Board (TSB) funded REACT project, Noliac A/S and Anglo-Italian helicopter company AgustaWestland, part of the Finmeccanica Group, team-up to provide a more effective solution.

The presented work started with a study of the literature and of commercially available solutions. Their advantages and drawbacks are discussed and compared to the requirements of the considered application. Commercial solutions have obviously not been optimised for mass. Both flex tensional and hinged-frame actuators can be found commercially that would fulfil the requirements in terms of force and displacement. However the frame and eventual pre-loading mechanisms represent an important mass penalty and are not temperature stable. Specifically developed actuators, such as the X-frame and EADS's RACT, provide better performance but are still limited in terms of energy density.

A new actuator design was developed, providing improved performance for a minimum mass. In addition, thanks to a built-in differential configuration, the actuator is temperature stable. The design led to a joint patent application. The design is based on two pairs of piezoelectric stacks, arranged in a flat octagonal or so-called "diamond" configuration, operated with opposite signals.

Prototypes have been manufactured and tested. Their performance in terms of energy density was found to be above previously published results. Based on this first success, a new series of prototypes was designed and manufactured, aiming at lower energy levels while maintaining high energy density. Results are presented and analysed. In addition to a high energy density and temperature stable design, the technology allows a high bandwidth thanks to the minimal moving mass.