Amplified Piezoelectric Actuators: From Aerospace to Underwater applications

Philippe Bouchilloux[*a], F. Claeyssen[b], R. Le Letty[b]
[a]Adaptronics, Inc., 1223 Peoples Avenue, Troy, NY 12180
[b]Cedrat Technologies S.A., 10 Chemin de Pré Carré, 38240 Meylan, France

ABSTRACT

Aerospace and underwater applications typically require actuators capable of large displacements, precise positioning, and fast response times. To meet these requirements, several classes of actuators based on low-voltage piezoelectric materials have been developed, and, in the case of the Amplified Piezoelectric Actuators (APA series), space qualified. The APA actuators offer large displacements (up to 1mm), large deformations (up to 3%), and large forces (up to 1kN) at low electrical power. These actuators can withstand large external forces and have successfully passed severe qualification tests such as centrifugal accelerations and vibration forces encountered during space launch. Aerospace applications of APAs include scientific instrumentation, such as telescopes and microscopes, microsatellite propulsion valves, and structural vibration control. Aeronautical applications include active flap control in aircraft wings and helicopter blades. Underwater applications focus on the silencing of ships, the piezodiagnostic (NDE) of structural defects in pipelines and hulls, and guidance systems of unmanned vehicles. This paper reviews the use of piezoelectric actuators, in particular APAs, in such applications. Qualification results, when available, are presented and discussed.

Keywords: Piezoelectric actuator, Prestressed actuator, Aerospace, Aeronautics, Underwater

1. INTRODUCTION

Smart actuators and intelligent structures receive a considerable interest in the aerospace, aeronautics and underwater fields, for developing new functions or increase the efficiency of functions based on passive structures. In these fields, actuation requirements focus on high mechanical energy density, low power consumption, ruggedness as well as other, situation-specific, needs such as high resolution (embedded active optics for cameras and telescopes), fast response (active shape control of structures, active damping of vibration), etc.

Because piezoelectric MultiLayer Actuators (MLAs)[1] offer many advantages, such as high energy density, compared to other active materials[2], they are increasingly used in various smart actuator applications and contribute to the development of new areas for the application of intelligent structures[3,4]. These MLAs are derived from the capacitor technology and have been on the market since 1988. They exhibit deformations approximately proportional to the applied voltage, up to about 0.1% (1µm/mm) at typically 150V. A 100mm-long stack (which is the maximum realistic length for common applications) with section of 1cm^2 provides a free stroke of 100µm and a blocked force of about 3kN. Although usable in some cases, such actuators are not suited to most applications due to their limited stroke. In addition, as underlined by ceramic manufacturers[5,6] the tensile strength of these ceramics is low. This is a source of failure in bending conditions, in vibration environment and in dynamic applications where high transient stresses are present. In addition, such stacks do not offer practical mechanical interfaces for mounting. As a consequence MLAs are not readily usable, in their bare form, into most industrial applications.

To overcome these limits, Cedrat Technologies has proposed different innovative concepts of piezoelectric actuators[7] and mechanisms. These actuators have received support from several European organizations (such as CNES, ESA, and ONERA) have been available as commercial products since 1998. For instance, the Amplified Piezoelectric Actuators (APAs) cover a large range of displacements (up to 1mm) and forces (up to 1kN). They have been designed to withstand large external forces, and can therefore pass all severe qualification tests such as launching vibration forces and centrifugal forces. Initially developed for positioning control of space optics, these actuators are widely used in other engineering fields such as active damping and active shape control in aircrafts.

2. PIEZOELECTRIC ACTUATOR TECHNOLOGY

To overcome the tensile stress limitation of MLAs, a well-known solution consists in applying a compressive prestress on the ceramic, which, additionally, enhances the piezoelectric deformation[8]. To offer a practical mechanical interfaces and protection, Cedrat Technologies encapsulates the actuators in a (generally metallic) frame.

[*] pb@adaptronics.com; phone 518-266-1146; fax 518-266-1142; www.adaptronics.com

Smart Structures and Materials 2004: Industrial and Commercial Applications of Smart Structures Technologies, edited by Eric H. Anderson, Proceedings of SPIE Vol. 5388 (SPIE, Bellingham, WA, 2004) · 0277-786X/04/$15 · doi: 10.1117/12.540781