Chapter 20
Algorithms and Principles for Intelligent Design of Flapping Wing Micro Aerial Vehicles

Ajay Bangalore Harish
Indian Institute of Science, India

Dineshkumar Harursampath
Indian Institute of Science, India

ABSTRACT

Almost all Micro Aerial Vehicles (MAVs) designed so far facilitate the flapping motion of their wings by means of a mounted actuating mechanism, driven, for example, by a piezoelectric crystal. The developments over the past decade or so in smart material technologies like the invention of Piezoelectric Fiber Reinforced Composite (PFRC) materials and innovative manufacturing techniques to reduce cost have resulted in favorable materials for dynamic actuating applications. Thus, the concept of actively deformable wings to produce combined flapping and feathering actions is evolving as an attractive enabler for design of future MAVs. A smart material like PFRC can both sense and actuate in a collocated fashion, thus building an additional level of computational intelligence into the MAV itself. Such a promising opportunity indicates an urgent need for reliable design tools to accelerate development of MAVs. In this work, the authors propose a modular design tool specifically for design of self-actuating flapping wing MAVs.

DOI: 10.4018/978-1-4666-2518-1.ch020

INTRODUCTION

There has been a rapid surge in research and development of MAVs owing to the identification of a large range of potential civilian and military applications in the twenty first century. This surge, in turn, has led to an immediate need for design tools to enable more efficient research, optimization and rapid prototyping of MAVs. MAVs fall under the class of Unmanned Aerial Vehicles (UAVs). Owing to their small size, they cannot be seen by an operator on ground from beyond a couple of hundred meters. Carrying on-board receivers and transmitters for control, guidance and navigation adds avoidable weight to the MAVs. Realizing that weight is at a premium and that mission-effectiveness demands autonomy, employment of manual control for MAVs is almost impractical. The direction adopted by most researchers has been to develop fully autonomous MAVs. Realization of such an autonomous MAV would also require development of sophisticated computational intelligence systems for control and navigation.

Most of the known generations of MAVs designed so far either have fixed wings to generate lift and engine/motor-driven propellers for thrust or have rotary wings to generate both lift and thrust. The exceptions are ornithopters which facilitate the flapping motion by means of a mounted actuating mechanism driven, for example, by a piezoelectric crystal (Delaurier & Harris, 1993, DeLaurier, 1994; DeLaurier, 1999, Yan, Wood, Avadhamula, Sitti & Fearing, 2001). The main shortcomings of such systems include increased weight mechanisms, larger number of moving parts, additional maintenance etc. Recently published articles in the literature also show significant improvement in MAV performance and flying capability by deforming (or morphing for fixed) the wings themselves (Ansari, 2006; Whitney & Wood, 2010) in the desired manner. The difficulty in realizing such a system till recently has been due to lack of material technology to be used in such dynamic applications like flapping wings. Most of the known piezoelectric materials are ceramics and hence brittle and unsuitable for dynamic applications like self-actuating flapping wings. Recent developments in smart material technology like embedding piezoelectric fibers in highly-flexible epoxy polymer materials have resulted in many favorable properties making them suitable for dynamic applications. The PFRC further enhances most of the favorable properties of the piezoelectric materials (like high energy density and directional actuation) and also offer multiple secondary non-structural functions (apart from the primary structural function) like sensing, health monitoring, energy harvesting etc. Thus, the concept of flapping-wing MAVs with actively deformable wings to produce the combined global and local bending, twisting and feathering actions is evolving as an attractive way for design of MAV (Ming, Huang, Fukushima & Shimojo, 2008). Using a smart material like PFRC, which can both sense and actuate in a collocated fashion, builds in an additional level of computational intelligence into the structure and thus the MAV itself.

However, at typical operating conditions in MAV applications, PFRC materials exhibit complex and nonlinear material behavior apart from electro-mechanical interactions. Hence accurate design tools with simplicity of usage are an absolute necessity to accelerate the process of MAV design, research, optimization and rapid prototyping. The work described here has been motivated by such need for a computationally intelligent design tool. The developed tool specifically targets design and development of self-actuating flapping wing MAVs. As known to the authors, the mathematical tool, Desktop and Web-based Micro Air Vehicle Design and Testing Software (MAVDTS) is the first of its kind for design and development of MAVs. MAVDTS models the self-actuating flapping wings as strip-like pretwisted anisotropic beams or thin-walled open-section anisotropic beams in cantilevered configurations. The analytical solutions used are obtained using

Related Content