

Preface

Helicopters are susceptible to high vibration levels. The development of smart-material based piezoelectric actuators has made it possible to address this high vibration problem directly by developing a smart helicopter rotor. The basic idea of the smart rotor concept is to generate new unsteady aerodynamic forces and moments on the rotor blade which cancel the existing forces and moments which are the key sources of helicopter vibration. By appropriately actuating the piezoelectric materials using an electric field, the motion of the rotor blade can be actively controlled. The smart rotor development is multidisciplinary and requires knowledge of structural dynamics, aeroelasticity, helicopter dynamics, control theory, and piezoelectric materials. In this book, the concepts of active trailing edge flap and active twist rotor blade are investigated for the helicopter vibration reduction problem. These are the two most promising concepts for the development of smart rotor. The active trailing edge flaps are placed near the tip of the rotor blades and actuated at higher harmonics of the main rotor speed. In the active twist concept, the full blade is twisted at higher harmonics of the main rotor speed.

Fundamental issues in the trailing edge flap problem include (a) the optimal number of flaps, (b) placement of the flaps along the rotor blade, and (c) optimal controller design for helicopter vibration and flap deflection objective. Typically, the active flap rotor is actuated by a piezostack actuator. Such an actuator can lead to hysteresis which can cause poor performance of the controller. In this book, we present a novel hysteresis compensation algorithm to alleviate this problem. Another problem in the trailing edge flap concept is the ability to use multiple trailing edge flaps effectively. This book presents a controller algorithm to maximize the potential of multiple trailing edge flaps and a response surface-based optimization method to place such trailing edge flaps for best vibration reduction performance at least flap power. An optimization study, which shows that dual trailing edge flaps are best for vibration reduction, is also discussed. Multi-objective optimization is used and the pareto front for the flap design problem is studied.

The book also showcases the concept of using piezoceramic-induced shear actuation for the active twist rotor concept. Active twist is investigated for a rotating

beam, a box-beam blade and an airfoil cross-section blade. Single-crystal piezoceramics are considered. It is also shown that nonlinearity of piezoceramic shear coefficient with respect to the applied electric field can be used to extract more actuation out of the material. A velocity feedback controller is implemented and found to be suitable for vibration control using active twist. Finally, it is shown that dynamic stall-induced vibration can be actively controlled using active twist rotor. As smart material concepts develop, the active twist concept becomes useful for reducing helicopter vibration and suppressing dynamic stall.

This book will help researchers who are engaged in the development of active vibration control methods for helicopter rotors. It is also useful for researchers and engineers in the fields of smart structures, aerospace and mechanical engineering, control theory, applied mathematics, material science, and optimization. Most of the concepts are useful in all applications of rotating systems such as wind turbines, turbomachinery, and propellers. The authors are grateful to the Rotary Wing Research and Development Centre, Hindustan Aeronautics Limited, for supporting much of this work through a sponsored research project.

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Smart Helicopter Rotors

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