1. INTRODUCTION

The acoustic annoyance is one of the critical issues concerning the flight of helicopters. The main rotor plays a crucial role in noise generation, through several aerodynamic phenomena that affect its performance. Among these, blade-vortex interactions (BVI) are relevant sources of noise. Indeed, BVI noise has an impulsive nature, which is particularly annoying for the human ear and typically occurs when the helicopter is in descent or in slow advancing flight.1–2 (i.e., when it operates near the ground and the community). As a consequence, prediction and control of BVI noise (in terms of magnitude and directivity pattern) are important issues for rotorcraft designers both for civil applications and for improving stealthiness in military missions.

Identification of optimal rotor blade shapes and active controls, as well as a definition of optimal minimum noise descent trajectories are strategies extensively investigated by researchers to reduce the acoustic impact of helicopters on communities. Active control systems are particularly suitable for BVI alleviation, in that severe BVI occur during low speed flight when more power is available to actuators, as compared to high speed forward flight. Approaches based on higher harmonic blade control have been investigated in detail, both numerically and experimentally in the past literature.2–5 Specifically, the attention has focused mainly on two types of control systems: the individual blade control (IBC), for which each blade is controlled in the rotating frame through pitch links or flaps, and the so-called higher harmonic control (HHC), which acts on all the blades simultaneously by driving the non-rotating component of the swashplate. The benefits of HHC and IBC in reducing both vibrations and acoustic annoyance have been widely discussed, although some drawbacks emerged. Besides problems related to the increase of weight and complexity of the actuation devices, the way these controllers act for BVI noise reduction often corresponds to an increase in low-frequency noise content and in rotor vibration levels.2–6 Furthermore, the actuators that are typically used for the conventional active control are characterized by limited frequency bandwidth and high vulnerability of the hydraulic systems. Active materials help to overcome most of these limitations, since they operate through the direct conversion from the electrical signal to the mechanical deformation of the material. This allows low-mass and high-bandwidth actuators thus increasing the ability to control the aeroelastic behavior of the individual blades for cancelling the unsteady high-frequency aerodynamic loads, which are the main cause of rotor noise and vibrations. Indeed, in recent years increasing attention to the application of the smart materials to rotorcraft systems has been paid by the research community.7–12

This paper presents an IBC controller relying on active twist (ATR) actuation that is aimed at reducing high-frequency rotor noise aerodynamically generated by BVI. It is an extended version of the work recently presented by the authors,13 where the conceptual idea of this active twist BVI-controller has been introduced.

The proposed control strategy relies on high-frequency actuation to generate loads aimed at direct suppression/alleviation of those due to BVI. This approach is different from the more...