1. INTRODUCTION

The aim of active vibration control is to enhance the performance of a system (e.g., comfort, fatigue life, etc.) by limiting vibrations. One of the most effective techniques to reach this goal is to increase the equivalent damping of the system and then the dissipation of the kinetic energy (the so-called sky-hook damping technique).1

This practice can be advantageously realized by using inertial actuators to exert the desired control forces. An inertial actuator is a mass supported on a spring and driven by an external force. The force is normally generated electromagnetically2,3 or exploiting piezoelectric4,5 and magnetostrictive effects.6,7 Unlike reactive actuators, inertial actuators do not need to react off the base structure, so they can be used as modules that can be directly installed on a vibrating structure. Among the numerous applications in this field some recent studies are reported.8–11

Although the feedback loop for the ideal sky-hook damper is unconditionally stable, it becomes conditionally stable once inertial actuators are used. Stability limits due to the use of proof-mass devices have been deeply studied12–14 and different control strategies have been implemented to increase the performance of these devices.15–19 Despite the use of these actuators is characterized by limitations on stability, their use is still intensive.

In practice, however, applications of active vibration suppression require a complex experimental setup. As a matter of fact, on large structures a large number of sensors and actuators have to be installed (often even in places difficult to be reached) and all the devices must be wired to a real-time control system to manage measurements and control signals. This paper presents a solution developed to achieve an active damper based on inertial actuator embedding both the sensors needed to obtain feedback signals, both the control logic that determines the control force to be exerted to perform the sky-hook damping technique. This solution therefore allows to have, in a single stand-alone device, all that is required to effectively perform the task of suppressing vibration. It is worth to note that, as to control a large structure a huge number of actuators and sensors is required, the new device allows wiring minimization as the feedback control loops only act locally, providing a decentralized control strategy.

The paper is structured as follows. Section 2 introduces the layout of the smart damper, while Sections 3 and 4 describe the model and the design of the device. In Section 5 the damper is realized and tested to assess its performance in suppressing vibration autonomously. Finally conclusions are drawn in Section 6.

2. LAYOUT OF THE SMART DAMPER

The layout of the smart damper is shown in Fig. 1. The vibrating structure is modeled with an equivalent mass \( m_s \), stiffness \( k_s \), and damping \( c_s \). The smart damper is made of an inertial actuator, whose main mechanical features are \( m, k \) and \( c \), and an electronic board embedding the sensors and the controller. The acceleration of the structure (\( \ddot{y} \)) is measured by an accelerometer placed on the fixed frame of the actuator. This signal must be integrated and suitably conditioned to estimate the velocity of the structure (\( \dot{y} \)). According to this feedback, the controller gives as output a control signal that has to be amplified and then sent to the actuator to exert the corresponding force \( F_a \).

As all of these features are embedded on a PCB board, the damper does not require any other device and can work autonomously, thus reaching the goal of this work. Obviously the smart device does require an integrated design of all the constituent elements and their synergistic operation. In particular, the design of the electronics embedded on the device can not be separated from the knowledge of the dynamics of the actuator and its interaction with the structure.