ACTIVE NONLINEAR CONTROL OF A STROKE LIMITED INERTIAL ACTUATOR

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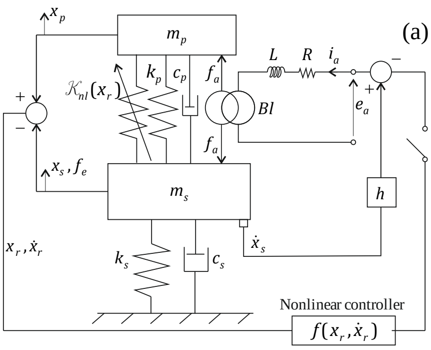
Keywords: velocity feedback, inertial actuator, stroke saturation, nonlinear feedback control

ABSTRACT

This paper presents a theoretical and experimental study of a stroke limited inertial actuator used in active vibration control. Electromechanical inertial, or proof mass, actuators are devices commonly used to generate the control force on a vibrating structure. The main concern over inertial actuators within a feedback control loop is that they are only conditionally stable. Moreover, design constraints limit the stroke of the proof mass, such that collisions of the proof mass with the actuator casing can cause both damage and destabilising effects. Most studies in this area have not looked at nonlinear models of inertial actuators, therefore limiting them to restricted operating conditions. This research examines the experimental implementation of a nonlinear feedback controller to avoid collisions of the proof mass with the actuator's end stops.

Firstly, a lumped parameter model of a nonlinear inertial actuator attached to a single degree of freedom structure is derived, as shown in Figure 1(a). The nonlinear behaviour of the inertial actuator is described by a symmetric piecewise linear stiffness, which has been taken from a previous experimental characterisation study [1]. The active control consists of two parts. A velocity feedback controller, where the absolute velocity of the structure is fed back to the actuator input current and multiplied by the feedback gain h. The second part, the nonlinear feedback controller, is a nonlinear function of the relative displacement and velocity, which can be activated or deactivated using a switching device. Then, an experiment on a cantilever beam is considered, which is excited by a shaker and controlled by an inertial actuator placed on its free end, as shown in Figure 1(b). The aim is to control the first flexural mode of the cantilever beam using linear and nonlinear control.



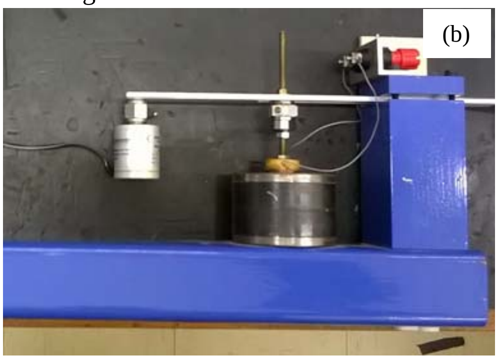


Fig. 1 (a) A lumped parameter model of the actuator, structure and control; (b) Experimental test rig.

Then, we introduce the nonlinear feedback control law to the system in Figure 1(a) as,

$$f\left(x_r(t), \dot{x}_r(t)\right) = \frac{h_r \dot{x}_r(t)}{\left(x_0 - |x_r(t)|\right)^2} \tag{1}$$

Here h_r is the feedback gain of the nonlinear controller and x_0 is the stroke length. Equation (1) increases the damping of the inertial actuator as the proof mass approaches its end stops. Simulation studies under different scenarios are then performed. It has been found that the nonlinear controller prevents stroke saturation. This increases the safe operating region of the actuator, without losing the performance in vibration reduction. Finally, the nonlinear controller has been implemented experimentally on the cantilever beam-inertial actuator system. The results are then compared with the simulated data.

References:

[1] Dal Borgo M., Ghandchi Tehrani M., Elliott S. J. (2016) Dynamic analysis of nonlinear behaviour in inertial actuators. *RASD2016*, Southampton, UK, *J. Phys. Conf. Ser.* **744**:012027.