Adaptable ball-screw inerter for optimal impact absorption

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ABSTRACT

For over two decades, inerter-based devices are a subject of research papers, patents and engineering reports. Since 2002, when Malcom Smith introduced the inerter as the missing element of mechanical networks [1], various applications of the inerter has been proposed and they include solutions for earthquake engineering, suspensions of vehicles, aircraft landing gears and even systems improving walking performance of humanoid robots.

In contrast to majority of the inerter implementations, which are mainly focused on the vibration mitigation, this paper concerns the impact absorption problem. In particular, adaptive performance of the ball-screw inerter with variable thread lead, introduced in [2], is investigated. In order to ensure efficient adaptation of the inerter to various excitation conditions, the single reconfiguration technique, which were successfully applied for pneumatic absorber [3], is now adjusted and implemented in proposed inertial system. For comparison, other adjustable inerter-based devices can be found in the literature, e.g. [4].

The contribution consists of the concept introduction, discussion of the mathematical model of the system, theoretical as well as numerical analyses. Results of the presented study show that optimal impact absorption can be obtained in semi-passive manner. The properly manufactured geometry of the thread provides optimal deceleration of the amortized object independently from the impact velocity. In turn, adjustment of the flywheel moment of inertia, which is performed ones just after identification of the excitation, allows to adapt the system to different masses of the amortized object. It should be highlighted that any additional control actions are not required. As a result, the optimal impact absorption for one particular loading conditions is obtained in pure passive way and mechanical reconfiguration of the system is used only for adaptation to different excitation conditions. Such characteristics are very promising in terms of practical applications because the quantity of control elements and the number of control actions are minimized.

Moreover, the paper includes analyses of various adaptation schemes and presents comparative evaluation of their effectiveness. Efficiency of simplified adaptation mechanisms is examined and challenging issues in terms of prototype design are mentioned and discussed. Possible applications and directions of further research are indicated.

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