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Bistable Elements for Application in Controllable High Performance Valves

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Mitigation of consequences of heavy dynamic loads acting on engineering structures is very important from the point of view of general safety. Typically applied passive systems of energy dissipation provide constant mechanical characteristics, which cannot be adapted to a specific loading scenario. Therefore it's very unlikely, that the response of the structure is close to the optimal one.

The concept of Adaptive Impact Absorption (AIA), which proposes structural adaptation to a particular impact scenario significantly improves the overall performance of an energy absorbing system. During the process of adaptation the choice of optimal control strategy is followed by adjustment of the dynamic characteristics of adaptive elements of the absorber. Depending on type of applied control, the changes of structural parameters occur only once (usually before impact) or they are controlled in real time during the impact process.

One of the most promising class of AIA systems are Adaptive Inflatable Structures (AIS), which contain sealed chambers filled with compressed gas and are equipped with controllable inflators and fast, efficient discharge valves. Currently, our research focuses on two types of innovative solutions: high performance valve which utilizes bistable snap-through effect and high performance membrane valve with ultra-fast actuation provided by exploding wires.

The controllable valve which utilizes bistable snap-through effect is equipped with two independent elastic shell elements with two stable configurations, which are aligned in the initial configuration such that the flow of the gas is totally blocked. Opening of the valve is performed by a controllable snap-through of the first shell element which causes creation of the flow channel. Closing of the valve is performed by controllable snap-through of the second shell element which causes alignment of the both shells and blocking the gas flow. Recovering the initial configuration may be conducted by controllable snap-back of shell elements. The proposed solution provides the possibility of fast opening and closing of the valves, which is required for realization of the optimal control strategy for the pneumatic absorbers. The proposed valves are characterized by large mass flow rate of the gas, small total mass and small inertia of the device.

The presented research discusses theoretical and numerical analysis of snap through effects of shell elements of the valve. The experimental results for the basic configuration of bistable elements will be presented, including different snap-through modes and force-displacement characteristics. Additionally, the simplified models of fluid flow through the flow channel will be proposed.

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