

HIGH PERFORMANCE VALVE FOR ADAPTIVE PNEUMATIC IMPACT ABSORBERS

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Dissipation of the energy in mechanical systems is a vitally important engineering and scientific problem. Current stringent safety requirements enforce substantial change of methods of structural design and application of new solutions and technologies which ensure structural integrity.

Currently applied passive safety systems are typically not equipped with control devices. Their dynamic characteristics remains unaltered and thus it is well adjusted to a narrow range of actual loadings. In case of impact loading, it is highly advantageous to apply systems of Adaptive Impact Absorption (AIA) [1], which are capable of fast change of the dynamic characteristics. Recent fast development of the material technologies and, in particular, development in the field of functional (smart) materials and electronic measurement and control systems had created new possibilities of practical applications of the AIA systems.

During the adaptation process the choice of optimal control strategy is followed by adjustment of the dynamic characteristics of adaptive elements of the absorber. These elements can entirely made of functional materials (as e.g. shape memory alloys) or, alternatively, they can be equipped with controllable devices, so-called structural fuses, which provide controlled response of the element. 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.

The systems of Adaptive Impact Absorption can be effectively used to increase the level of safety during the action of the impact loading. In particular, very promising results are obtained with the use of adaptive inflatable structures [2]. However, the possibilities of their practical applications are limited due to the lack methods allowing for the efficient and fast control of the gas flow during impact.

The presented work focuses on the pneumatic adaptive impact absorbing system equipped with a novel, high performance valve, which utilizes bistable snap-through effect.

Snap-through effects are mainly the subject of theoretical analysis and they do not find many practical engineering applications. The classical example of snap-through behaviour is the two-bar von Mises truss. The extension of the above effect to multilayered structure (multifolding system, c.f. Fig. 1) providing multiple folding sequences and equilibrium paths, which could be potentially applied in smart pneumatic structures, was a subject of earlier investigations presented e.g. in [3].

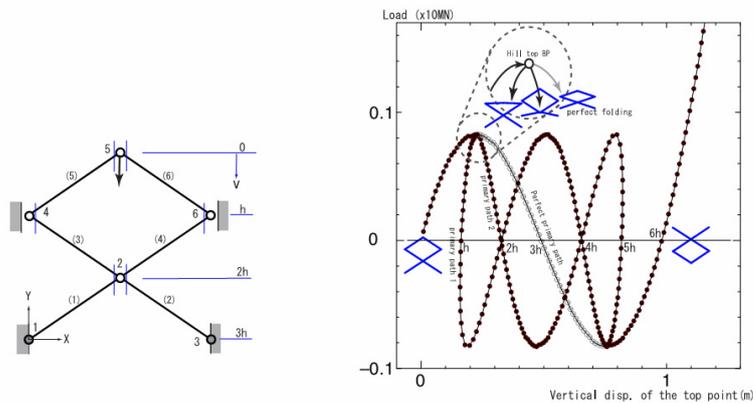


Fig.1. The multi-folding system and its equilibrium paths.

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 closed. Opening of the valve is performed by controllable snap-through (e.g. evoked by a the use of piezoelectric fibers) of the first shell element which creates 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 blocks the gas flow. The examples of the preliminary analyses of the snap-through effect of shell elements are depicted in Fig.2.

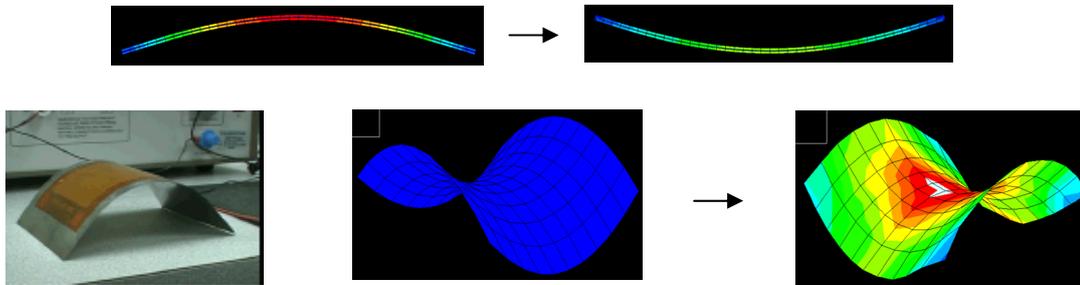


Fig. 2. Stable configurations obtained as a result of the snap-through of shall element shaped as part of the cylinder or hyperbolic paraboloid.

The above concept can be also used to design a multi-stage valve in the form of matrix of elastic shell elements, which are aligned in the initial configuration such that they totally block the gas flow (Fig.3). Control of the valve opening is performed by the sequentially controlled snap-through of chosen shell elements which allows for opening or closing of the appropriate number of flow channels. Recovering the initial configuration is conducted by controllable snap-back of shell elements or rotation of the valve assembly.

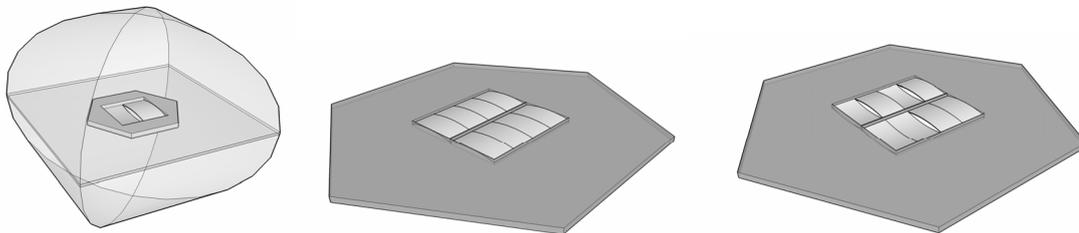


Fig. 3. General view: absorber equipped with bistable valve, the valve composed of a matrix of shell elements.

The proposed solution is characterized by large mass flow rate of the gas, small total mass and inertia of the device providing the possibility of fast opening and closing, which is required for realization of the optimal control strategy for the pneumatic absorbers.

References

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