THE CONCEPT OF MULTIFOLDIG AND ITS EXPERIMENTAL VALIDATION

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Summary The problem of energy absorption under impact loading is very important in a wide range of engineering applications. Although typically designed, passive energy absorbing systems provide a sufficient level of energy dissipation, they are unable to optimally decrease the level of acceleration. In contrast to the passive solutions, the proposed approach offers ability of structural adaptation to the conditions of the impact. Due to the presence of controllable micro-fuses, elements of the Multifolding Microstructure can optimally adjust their internal forces and therefore provide better performance in comparison to the passive absorbers. The undertaken experiment aims at the validation of the concept of multifolding and the verification of numerical models and control strategies applied in previous research.

INTRODUCTION

The problem of energy absorption under impact loading is very important in a wide range of engineering applications. (e.g. in the structures exposed to the risk of extreme blast, light, thin wall tanks with high impact protection, vehicles with high crashworthiness, protective barriers, etc).

The three substantial requirements for energy absorbing systems are following:

- to provide full dissipation of the kinetic energy
- to constrain excessive deformation
- to minimise the level of acceleration

The typically designed, passive energy absorbing devices fulfil the first two requirements, but because of the unchangeable characteristics, they are unable to optimally decrease the level of acceleration. Therefore a new generation of systems, which are able to adapt themselves to the conditions of the impact, should be taken into consideration.

MULTIFOLDING MICROSTRUCTURE (MFM)

The concept of the intelligent, energy-absorbing microstructure was first presented in [1] and [2]. The structure is composed of truss-like elements arranged into a special pattern, depicted in Fig.1. The elements are equipped with micro-devices (so-called "micro-fuses") which control the axial force in each element. The stress thresholds, triggering the micro-fuses, are uniformly distributed along horizontal layers but may change in the vertical direction. Therefore, during deformation, layers with the lowest stress values collapse first. The repetitive use of elements (multifolding effect, e.g. element 2 in Fig. 3a.) provides the synergistic effect in the process of energy dissipation.

The initial distribution of the control thresholds plays a crucial role in the adjustment of the stiffness characteristics of the MFM to the impact loading. Different initial distributions of those parameters will result in different folding sequences and therefore will change the capability of energy absorption and the level of acceleration during the impact.

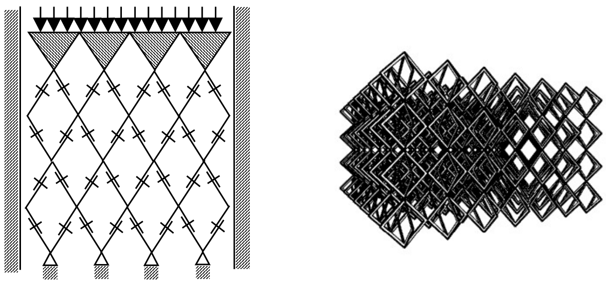

Fig.1. The Multifolding Microstructure layout.

The most basic substructure of the MFM is presented in Fig.2. It consists of six elements with two control parameters (marked 1 and 2). Therefore, only two effective deformation sequences are possible: the folding mode "m1" with the stress threshold 1 lower than 2 and the mode "m2" with an opposite relation of the thresholds. The sequence "m1" provides a low level of acceleration while the folding mode "m2" provides maximal energy absorption.

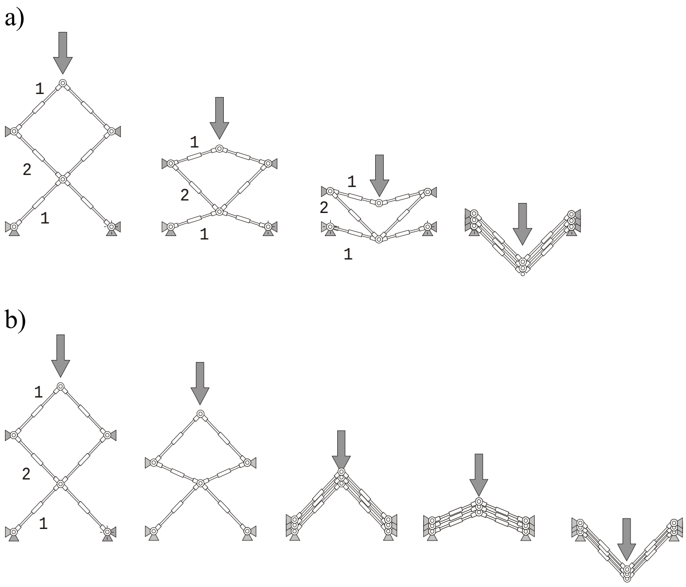

Fig.2. The basic folding modes of the absorber: a) “m1” b) “m2”

EXPERIMENTAL VALIDATION

In order to validate the concept of multifolding and its efficiency, an experimental set-up has been created (Fig. 3). Planned tests aim at verifying the numerical models and control strategies applied in previous research.
The presented device represents the basic MFM substructure, depicted in Fig.2. Six active elements provide control over the behaviour of the structure. Each active element is the RD-1005-3 magnetorheological fluid damper, supplied by LORD-Rheonetic Corporation, with maximum stroke equal to 53mm and maximum tensile force of 4448N. Because the input current (up to 2A) can be applied separately to each damper, apart from the two basic folding sequences, additional, non-symmetric deformation modes are also possible.

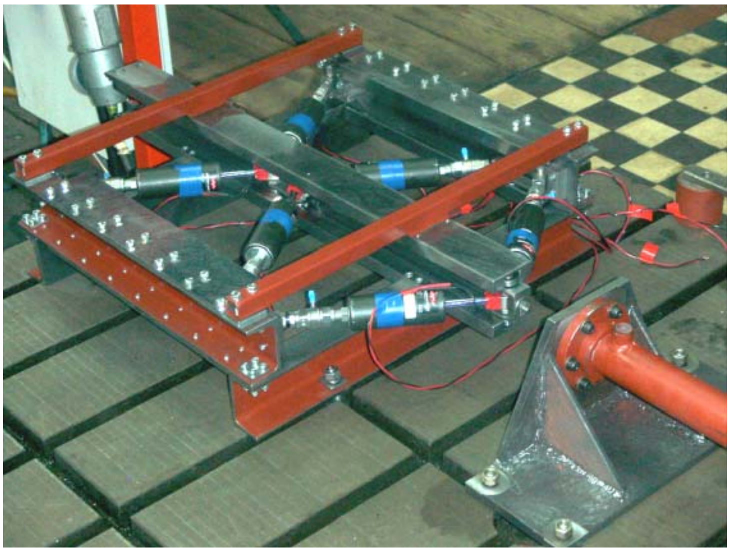

Fig.3. Experimental setup

Force sensors are placed in all six elements and additionally at the loaded node. Nodes of the structure are guided by slide bearings, providing only one direction of movement. Displacements, forced by a hydraulic actuator, are measured at all moving nodes.

References

[1] Holnicki-Szulc J., Pawlowski P., WikloM.: High-performance impact absorbing materials - the concept, design tools and applications, *Smart Materials and Structures*, vol.12, number 3, 2003.

[2] Holnicki-Szulc J., Pawlowski P., Wiklo M.: Optimal Strategies of Adaptive Impact Absorption, Proc. 5th World Congress on Structural and Multidisciplinary Optimisation, Lido di Jesolo, Italy,. May 19-23, 2003.