7th ECCOMAS Thematic Conference on Smart Structures and Materials
SMART 2015
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ADAPTIVE IMPACT ABSORPTION - POTENTIAL APPLICATIONS FOR SAFETY ENGINEERING

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Keywords: Smart And Adaptive Structures, Adaptive Impact Absorption, Safety Engineering

Summary: Increasing demand for safety becomes a clearly visible trend in contemporary engineering. The widespread research is oriented towards development of systems serving for protection against heavy dynamic excitation (impact or blast) or harsh environmental loading (hurricane or earthquake). Examples of such structures are vehicles with high crashworthiness, thin-walled tanks with increased impact endurance or large scale protective barriers. Typically suggested solutions focus on design of passive dissipative systems (e.g. aluminium or steel honeycomb packages), which are characterized by a high ratio of specific energy absorption. These passive structures work efficiently in case of accurately pre-defined impact scenario and correctly predicted value of impact energy. However, in many practical cases the characteristics of the impact loading acting on the structure may vary significantly or it may be difficult for precise evaluation. Therefore, classical passive energy absorbing structures cannot provide optimal protection against all possible impacts of various locations, energies and scenarios.

Above shortcomings of passive structures can be overcome by application of the concept of Adaptive Impact Absorption (AIA), which has been extensively developed during the last decade in our research group [1, 2, 3, 4]. The essence of AIA is real-time adaptation of energy absorbing structures to actual dynamic loading by changing local mechanical properties of particular elements during the period of impact. In order to achieve that goal the impact absorbing structure is equipped with system of sensors, hardware controller and controllable dissipaters based on functional materials ("structural fuses"). The subsequent stages of adaptation involve impact detection and identification by using system of sensors, assumption of the proper control strategy and its realization with the use of structural fuses. The adaptation strategy is executed entirely in semi-active way and the task of actuators is reduced to modification of local mechanical properties of the dissipaters. Application the above described strategy allows to precisely control the process of energy dissipation and to effectively mitigate corresponding structural response.

The first challenge related to AIA systems is development of the adaptation strategy for optimal mitigation of the impact effect. Various strategies of adaptation to identified impact scenario can be proposed depending on the particular problem under consideration, e.g. repetitive exploitive loads vs. critical emergency impact. Minimization of accelerations values in selected locations for smoothing down the impact reception corresponds to the first case, when reduction of fatigue accumulation is an important issue. On the other hand, maximization of the impact energy dissipation in selected time interval for the most effective adaptation to the emergency situation corresponds to the second case. Other desirable control strategies for particular applications include local structural degradation (e.g. due to provoked perforation in impacted location) in order to minimize the damaged zone and to preserve global structural integrity. In addition, the AIA system should be designed for random impact multi-loads, which creates new research challenges related to optimal forming of structural geometry and optimal location of structural fuses.

Another challenge in Adaptive Impact Absorption is selection of appropriate technology and design of the controllable dissipative devices, which will allow for adaptation to impact loading in particular practical application. As it will be discussed in the paper, adaptive hydraulic and pneumatic shock absorbers based on piezoelectric valves can be successfully applied as adaptive landing gears. On the other hand, controllable dissipaters utilizing friction forces controlled by shape memory alloys (SMA) actuators can be used in adaptive zones protecting offshore towers. Moreover, adaptive joints based on piezoelectric actuators may be applied to control response of the skeletal structure and to effectively damp its post-impact vibrations. Finally, high performance valves based on controllable snap-through effect allow for control of internal pressure inside adaptive inflatable structures such as adaptive airbags and fenders.

The objective of this talk is to introduce the concept of Adaptive Impact Absorption by using several examples from various branches of engineering and to present recent achievements of our group in this fascinating and fast developing research topic.

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