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Study on Control Techniques for Adaptive Impact Mitigation

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Abstract : Progress in the field of sensors, electronics and computing results in more and more often applications of adaptive techniques for dynamic response mitigation. When it comes to systems excited with mechanical impacts, the control system has to take into account the significant limitations of actuators responsible for system adaptation. The paper provides a comprehensive discussion of the problem of appropriate design and implementation of adaptation techniques and mechanisms. Two case studies are presented in order to compare completely different adaptation schemes. The first example concerns a double-chamber pneumatic shock absorber with a fast piezo-electric valve and parameters corresponding to the suspension of a small unmanned aerial vehicle, whereas the second considered system is a safety air cushion applied for evacuation of people from heights during a fire. For both systems, it is possible to ensure adaptive performance, but a realization of the system's adaptation is completely different. The reason for this is technical limitations corresponding to specific types of shock-absorbing devices and their parameters. Impact mitigation using a pneumatic shock absorber corresponds to much higher pressures and small mass flow rates, which can be achieved with minimal change of valve opening. In turn, mass flow rates in safety air cushions relate to gas release areas counted in thousands of sq. cm. Because of these facts, both shock-absorbing systems are controlled based on completely different approaches. Pneumatic shock-absorber takes advantage of real-time control with valve opening recalculated at least every millisecond. In contrast, safety air cushion is controlled using the semi-passive technique, where adaptation is provided using prediction of the entire impact mitigation process. Similarities of both approaches, including applied models, algorithms and equipment, are discussed. The entire study is supported by numerical simulations and experimental tests, which prove the effectiveness of both adaptive impact mitigation techniques.

Keywords : adaptive control, adaptive system, impact mitigation, pneumatic system, shock-absorber
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