Abstract Submitted to the Seventh Triennial International Fire and Cabin Safety Research Conference, Philadelphia, PA, December 2-5, 2013

Control Schemes for Shock Mitigation Using Adaptive Shock Absorbers

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This research addresses implementation of two different control schemes with the goal of minimizing the transmitted shock loads to the occupant during an impact of a helicopter with the ground. A linear stroke adaptive magnetorheological shock absorber was considered with a large control authority to accommodate a wide spectrum for shock mitigation. For the experiments, a rigid payload with a total weight of 380 lbs was dropped vertically on the shock absorber from two different heights of 35 inches and 60 inches imparting different crash velocities for the control schemes under consideration.

The first control scheme, termed as constant stroking load control (CSLC), provided a constant load-stroke profile from the energy absorber to the dropped payload during the impact event based on the maximum permissible dynamic load limit. Large drop height provided increased kinetic energy to the payload and correspondingly larger stroke was utilized since the payload stroked at constant shock absorber load. A closed loop feedback control was developed such that the adaptive magnetorheological force was tuned appropriately with the intent of not exceeding the constant stroking threshold. The time delay of control electronics proved to be a critical parameter in determining the performance of the shock absorber.

Another control scheme was optimal terminal trajectory control (TTC) implemented with the intent of maximizing the shock attenuation by adopting two terminal goals. The first terminal goal was to utilize the available shock absorber stroke completely such that the kinetic energy of the payload was mitigated over the entire stroke. In other words, the energy dissipation per unit shock absorber stroke was minimized by exploiting the full stroke. The condition of utilizing the full stroke was maintained for both drop heights. The second and the most important goal was to eliminate the potentially injurious end-stop impact. The end-stop impact is characterized by large shock load transmissions arising when the kinetic energy is not fully dissipated and the shock absorber runs out of stroke. A soft landing was assured to the payload by attaining these terminal goals for varying shock conditions. In order to achieve terminal goals, the adaptive magnetorheological force was controlled using an open loop control methodology, which was quite simpler compared to the control methodology implemented for a CSLC.