Analysis of the Vibration Isolation Performance of an Active Suspension System Designed for a Child Car Seat

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The aim of the study is to analyse the vibration damping properties of an active suspension system designed for a child car seat that is designed to reduce the impact of vertical accelerations on the child's body during vehicle travel. The motivation for undertaking this research is the absence of vibration isolation solutions dedicated to this group of users, despite the well-documented sensitivity of children to vibrations in the frequency range of 4–10 Hz [1-3]. The proposed system extends a previously developed passive suspension by introducing an active actuator in order to improve vibration reduction under varying operating conditions. The actuator is implemented using a permanent magnet synchronous motor (PMSM) controlled with a field-oriented control (FOC) strategy [4]. A physical and mathematical model of the suspension system was developed in the MATLAB/Simulink environment. The model includes passive suspension components as well as an active control force generated by the electric drive. The control algorithm determines the desired actuator force based on the displacement of the isolated mass and the relative displacement of the suspension system. To evaluate the vibration isolation performance, the SEAT coefficient and the relative displacement RS were used as optimisation criteria. A multi-objective optimisation procedure was applied to determine the optimal control parameters and to identify Pareto-optimal solutions representing a compromise between vibration reduction and allowable suspension stroke. The dynamic response of the system was analysed using broadband excitation representing road-induced vibrations in the frequency range typical for vehicle operation. The obtained results indicate that the application of active control significantly improves the vibration isolation performance of the suspension system. The proposed approach enables effective reduction of vibration transmissibility while maintaining acceptable values of relative displacement. The developed model also allows investigation of the influence of control parameters on the dynamic behaviour of the system. The presented results provide a basis for further experimental validation and future development of actively controlled suspension systems for child car seats.

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