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Study of Active Suspension System Application in Hybrid Electric Vehicles

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Abstract:

Vehicle active suspension (AS) system has been developed to improve the vehicle ride comfort and safety. However, application of this system in conventional vehicles encounters some obstacles. In these vehicles, if AS load varies faster than what the combustion engine can adjust, engine hesitation will occur. Moreover, sudden engine unloading will results in vehicle surge which is unpleasant to the passengers. On the other hand, in hybrid electric vehicles (HEVs), vehicle sub-systems may be supplied by the electrical power source and benefit from its faster power supply response. Moreover, in these vehicles, due to electrical energy storage system (ESS), it is possible to regenerate and restore vehicle sub-systems energy.

In this research, application of AS system in HEV is studied. The main goal of this research is exploring the various aspects of the idea of AS application in HEVs as an alternative for the conventional vehicles in order to tackle the problems exist in the conventional application. For this purpose, a new simulation approach is proposed for simultaneous simulation of suspension and power train systems which can model the systems energy and data interactions. One of these interactions is the power train input (velocity) influence on the suspension system time-domain road disturbance. Considering this interaction and employing the simultaneous simulation approach a new approach for vehicle ride evaluation based on a variable-speed driving pattern is proposed. Employing this approach, it has been shown that vehicle ride comfort is influenced by the driving pattern.

For AS system control, a new genetic-fuzzy controller is proposed. In the genetic-fuzzy controller, the parameters of the initial fuzzy controller are optimized based on a multi-objective performance index which incorporates not only the suspension travel and energy consumption of AS system, but also the sensitivity of the human to the transmitted vibrations. It is seen that, optimization of fuzzy AS system based on the human sensitivity performance index, in comparison with conventional rms criterion, results in better ride comfort. Moreover, multi-objective optimization of fuzzy AS system, results in a compromise between vehicle ride comfort, suspension travel and energy consumption.

The HEV simulation is based on a conventional vehicle one whose emissions and fuel consumption simulations are verified against laboratory tests. Moreover, utilizing genetic algorithm, the size of the HEV components is determined in a constrained optimization process. For HEV control a genetic-fuzzy scheme is employed. Moreover, a combined ESS is proposed for the AS power supply in HEV. Finally, the idea of AS system energy regeneration in HEV is studied using the combined ESS and simultaneous simulation approach. According to the simulation results, it can be stated that in the conventional vehicle AS load dynamics affects the combustion engine torque demand directly. However, in HEV, AS load dynamic effects are transferred to the ultra-capacitors of the combined ESS. Moreover, although, AS load causes a considerable increase in exhaust emissions and fuel consumption of the HEV, optimization of fuzzy controller compensates this increase to some extent. Besides, regeneration of AS energy in HEV causes a further decrease in the fuel consumption and exhaust emissions of the HEV.

Key Words: Active Suspension, Hybrid Electric Vehicle, Simultaneous Simulation, Combined Energy Storage System, Ride Comfort, Driving Pattern, Optimization, Genetic-Fuzzy Controlle