STUDIES ON PASSIVE AND ACTIVE SUSPENSION SYSTEM OF A LIGHT PASSENGER VEHICLE

ABSTRACT

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ABSTRACT

Suspension systems have been widely applied to vehicles, right from the horse-drawn carriage with flexible leaf springs fixed at the four corners, to the modern automobile with complex control algorithms. Every vehicle moving on the randomly profiled road is exposed to vibration which is harmful both for the passengers in terms of comfort and for the durability of the vehicle itself. Different disturbances occur when a vehicle leans over during cornering (rolling) and dives to the front during braking (pitching). Also, unpleasant vertical vibrations (bouncing) of the vehicle body can occur while driving over road irregularities. These dynamic motions do not only have an adverse effect on comfort but can also be unsafe, because the tyres might loose their grip on the road. Therefore the main task of a vehicle suspension is to ensure ride comfort and road holding for a variety of road conditions and vehicle maneuvers. This in turn would directly contribute to the safety of the user.

From a system design point of view, there are two main categories of disturbances on a vehicle, namely road and load disturbances. A suspension system with proper cushioning needs to be “soft” against road disturbances and “hard” against load disturbances. A heavily damped suspension will yield good vehicle handling, but also transfers much of the road input to the vehicle body. But, a lightly damped suspension will yield a more comfortable ride, but would significantly reduce the stability of the vehicle at turns, lane change

maneuvers, or during negotiating an exit ramp. Therefore, a suspension design is an art of compromise between these two conflicting criteria. A good design of a passive suspension can work up to some extent with respect to optimized riding comfort and road holding ability, but cannot eliminate this compromise.

In this context, it is very much essential to carry out a detailed study on passive suspension system, and the feasibility of various control systems for the development of active suspension system to improve the performance criteria such as ride comfort and road holding ability for the various road and load disturbances. The performance characteristics of passive suspension system of the quarter car model are evaluated. A detailed procedure of evaluation of performance characteristics of passive suspension system is presented. Also, the effect of the ratio of the equivalent tyre stiffness to the suspension spring stiffness on the ride comfort, suspension travel and road holding ability of the system is analyzed in both frequency and time domain.

It is found that a softer suspension leads to increased suspension deflection at low frequencies, thus increasing rattle space requirements. In the analysis carried out, the optimum stiffness ratio is found to be 8 because it has marginally less peak values over the whole frequency range.

A detailed study on Proportional-Integral-Derivative (PID) control system for developing active suspension systems is made. It is found that increasing the gain of the system may not result in better performance. Active suspension system with PID controller has been designed and simulated for bumpy road, pot hole and random road inputs. It is observed that the developed system improves the ride comfort significantly. Rattle space utilization is also reduced in active suspension system when compared with passive suspension system in which suspension travel limit of 8 cm is almost used. However there is no significant improvement in road holding ability is observed especially for random road surface. Hence it is proved that PID controller can be used to improve the ride performance of the suspension system.

In frequency-domain analysis with low-pass filter, the active suspension design reduces both vehicle body displacement and acceleration in comparison to the passive one, but increases the rattle space. On the other hand, if high-pass filter is used, the rattle space utilization can be significantly reduced while the vehicle body displacement and acceleration are increased. The reduced wheel oscillations with active suspension system with low pass filter have been observed. The road-holding ability is improved with both filters around resonant frequency.

In order to obtain a better design trade-off, optimal control theory (Linear Quadratic Regulator, LQR) is studied. It is observed that passenger displacement and passenger acceleration have significantly reduced for the active system compared to the passive one. Also, the passenger displacement and acceleration for active system with acceleration dependent method (ADM) system is slightly lower than that of conventional method (CM) system.

Moreover, the sprung mass displacement and the tyre displacement are also less for the active system than the passive one. However, in active ADM system there is a slight increase in suspension travel after the peak when compared to active CM system, but it is still lesser than the corresponding value of the passive system. The comparison clearly shows that active suspension gives better passenger comfort and that the active suspension with acceleration dependent method (ADM) gives still better passenger comfort.

The optimal values of damping coefficient and spring stiffness are found to be 1 kNs/m and 6.8 kN/m respectively. Thus it is possible to reduce expenditure of control force by a proper choice of the passive element of the active suspension.

Experiments were conducted on both passive and developed active suspension systems to study the performance on the quarter car suspension system test rig. Different road profiles were used to a make detailed analysis and for comparison purpose. It is found that the theoretical performance of active suspension system is better than the experimental passive suspension system. But, the experimental results show that active suspension system works better than both experimental passive and theoretical active suspension system. Also, it is found that, at higher frequencies (1 Hz and more) the performance of active suspension system deteriorates, as the force tracking at higher frequencies is difficult because of the limitation of a hydraulic system. However, this can be overcome by using sophisticated servo-hydraulic system. Therefore it is found experimentally that the active suspension system is superior to passive suspension system.