ABSTRACT

Ride Comfort of the passenger travelling in a car is an important factor to be analysed. The ride comfort of a human being is measured in terms of the Head Acceleration (HA). This is based on the vibration produced in the vehicle due to unevenness in the roads. Therefore, the vibration control of the vehicle leads to ride comfort. The active suspension system in a car is mainly used to reduce the vibration and hence the Body Acceleration (BA) of the vehicle as well as the passengers HA. This is achieved by designing the controller with feedback from road conditions.

The vertical vibration plays a major role in ride comfort. The Quarter Car Model (QCM) is a commonly considered by the researchers. In Half Car Model (HCM), the interaction between the front and rear wheel is analysed by measuring the pitch angle at the centre of the sprung mass. Therefore, the control force applied to the front actuator is based on the road input of the front wheel as well as the rear wheel and vice-versa. Most of the present studies on active suspensions are concerned with vibration reduction of the sprung mass containing vertical acceleration in the QCM and HCM. The passenger seats are fixed in the front half and rear half of the sprung mass. The yaw, roll and pitch motion of the vehicle affect the acceleration of the passenger seats. Due to this reason, the passengers whole body is vibrating. Undesirable effects of the human body vibration (particularly the HA) are experienced when the exposure time is longer than the recommended standard set by ISO 2631. Hence, considering the drivers biodynamics in the controller design can improve its performance. While considering the driver dynamics in the QCM then the system is called as the Quarter Car with Driver Model (QCDM). Since, two seats can be placed in the HCM, the dynamics of the driver and the passenger are
considered and the system is named as the Half Car with Driver and Passenger Model (HCDPM).

To control the vibration in the vehicle, SMC is one of the good choice because of the uncertainties in the road disturbance. Initially, the sliding mode controllers (SMC) are designed and its performances are analysed for the QCM. While choosing the sliding surface, the derivative power of the state variable is changed into the fraction order, then the Fractional order SMC (FOSMC) is designed. Terminal SMC (TSMC) is derived by choosing the power of the state variable in terms of the non-integer value.

The combination of the FOSMC and TSMC are used to design the Fractional Order Terminal SMC (FOTSMC). The switching function in the SMC and FOSMC are implemented using Fuzzy Logic controller then the Fuzzy based SMC (FSMC) and Fuzzy based FOSMC (FOFSMC) are designed. The performances of the FSMC and FOFSMC are similar to the SMC and FOSMC respectively, but the variable gain in the FLC produces smaller switching function is the advantage of the FSMC and FOFSMC. Therefore, the FOTSMC, FOSMC and TSMCs are designed tested for the QCDM, HCM, HCDPM and Experimental active suspension system. While considering the QCDM and HCDPM the seat suspensions are included in the system. The performance of the single suspension (which has the primary suspension alone) are compared with the dual suspension system (both primary suspension with a saturation limit and seat suspension).

The controller parameter such as the sliding surface gain, fractional order for the FOSMC and terminal parameter in TSMC are designed by trial and error method. While testing the performance of the system three types of the road inputs are considered. They are single bump, random road as per ISO 8606 and sinusoidal road. The results are compared graphically as
well as numerically. The Root Mean Square (RMS) and Frequency weighted RMS value of the HA and BA of the system with and without controllers are computed. Its corresponding control forces plotted and its RMS values are calculated.

These systems with controllers and the road profiles are simulated in the MATLAB 2012b. The simulation is repeated for the different speeds of the vehicle (10 kmph to 100 kmph) and the reduction in the acceleration is computed. Similarly, the reduction in head acceleration is computed while varying the driver’s mass (40 kg to 100 kg) in QCDM and HCDPM.

The designed controllers improved the ride comfort from the extremely uncomfortable level into little uncomfortable level or uncomfortable level (as per ISO 2631). The power spectrum density of the acceleration are plotted which graphically shows the effectiveness of the designed controllers in the human sensitive frequency range (4 Hz to 8 Hz).

The FOTSMC outperforms the other designed controllers in all the cases and FOSMC performs better than TSMC. The dual suspension system performs better than the single suspension system.