Railway car body lateral hunting attenuation using body-based modified skyhook control for secondary suspension

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ABSTRACT – The unwanted lateral hunting on railway vehicle body will reduce the performance of railway vehicle ride comfort. Due to this, a simplified model of railway vehicle suspension with five degrees of freedom (5 DOF) is utilized to study the response of the railway vehicle body due to lateral track irregularities. A new body-based modified skyhook control algorithm is proposed in order to overcome the limitation of the passive system in absorbing the unwanted lateral disturbances from the track. The results of the presented scheme show an improvement in the performance of the proposed scheme when the railway vehicle running on an uneven track compared to a passive system.

1. INTRODUCTION

In railway vehicle dynamics, increasing the level of ride comfort and safety is one of a difficult task for railway engineers to solve. An existing passive suspension system in a railway vehicle usually has constant characteristics (spring stiffness and damping coefficient) for all the movements and running conditions [1]. For example, a passive suspension system for passenger rail is designed differently with suspension systems that are used to carry heavy items such as logs, cements, palm oils, etc. Typically, it is specially designed to control the vibration of the railway vehicle by setting a small damping and soft spring that produce only a small force in accordance with the low vehicle speed [2]. However, this specification is not suitable for high speed railway vehicle because this condition requires a large spring and damper force. Therefore, to ensure passenger comfort is at satisfactory level, the suspension on passenger railway should be able to control vibration in different conditions [2, 3]. In order to prevent unwanted vehicle body motions, in this paper, a body-based modified skyhook control is applied on the secondary railway vehicle suspension system.

2. RAILWAY VEHICLE DYNAMIC MODEL

A 5-DOF full model of railway vehicle consists of a vehicle body and two bogies are derived based on the Newton's Second Law equation which consists of yaw, roll and lateral motion of vehicle body and each two bogies [4]. Figure 1 indicates the diagram of railway vehicle that presents the secondary suspension system consisting of springs and dampers in the vertical and lateral positions. Figure 2 and 3 show the effects of yaw and roll of the railway body when subjected to the disturbances on the front and rear bogies respectively. The lateral input disturbances applied are sine-wave and random.

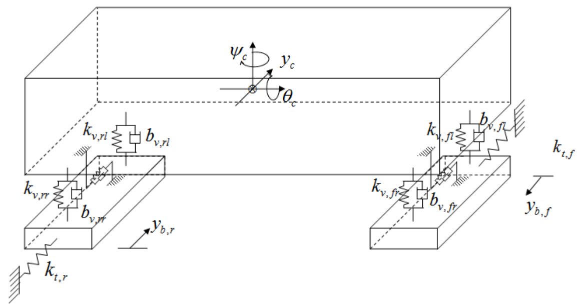


Figure 1 Full car railway vehicle suspension model.

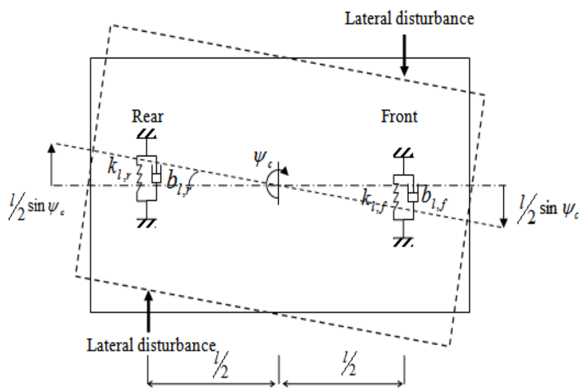


Figure 2 Top side view.

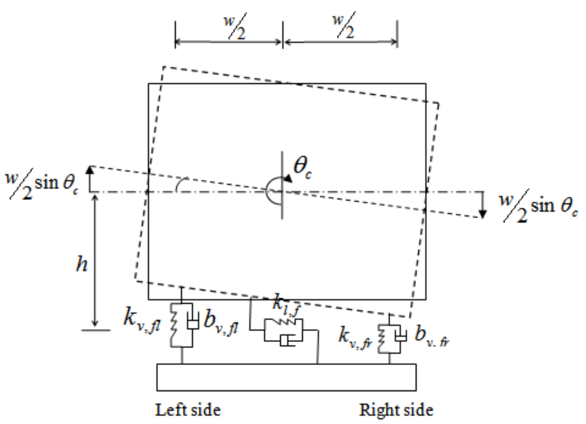


Figure 3 Top side view.

3. CONTROL STRATEGIES

The skyhook and modified skyhook controllers are given by

$$F_{sky,f} = C_{sky,f}\left(\dot{y}_{cf} - \tfrac{1}{2}\dot{\psi}_c\right) \quad (1)$$

$$F_{sky,r} = C_{sky,r}\left(\dot{y}_{cr} - \tfrac{1}{2}\dot{\psi}_c\right) \quad (2)$$

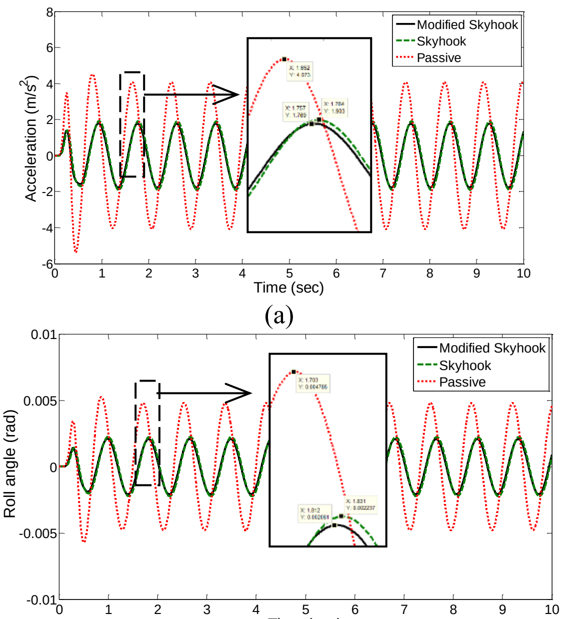
$$F_{msky,f} = \left(C_{sky,f}.\dot{y}_{cf}\right) + b_f\left(\dot{y}_{cf} - \dot{y}_{bf}\right) \quad (3)$$

$$F_{msky,r} = \left(C_{sky,r}.\dot{y}_{cr}\right) + b_r\left(\dot{y}_{cr} - \dot{y}_{br}\right) \quad (4)$$

where $F_{sky,f}$, $F_{sky,r}$, $F_{msky,f}$, $F_{msky,r}$ are the skyhook and modified skyhook forces of front and rear dampers respectively.

4. RESULTS AND DISCUSSION

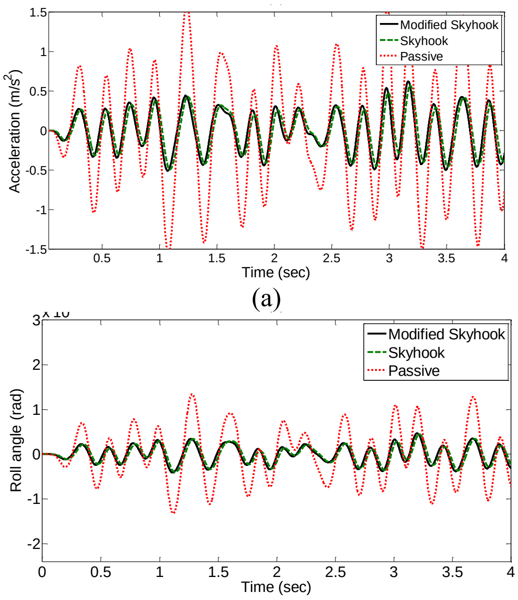
Figure 4 depict the responses of railway vehicle body. The maximum acceleration of modified skyhook is 1.769 m/s^2 and skyhook controller is 1.903 m/s^2 which are closed to each other, while for the passive system, the acceleration of the railway vehicle body has exceeded to 4.073 m/s^2. The amplitude of roll angle is improved when it is compared with the passive system, where the system with modified skyhook control scheme is 2.08×10^{-3} rad, and skyhook control is 2.24×10^{-3} rad. The system with the conventional suspension system exceeds 4.79×10^{-3} rad of railway vehicle body roll angle. Figure 5 shows the responses of railway vehicle body when disturbed by random irregularities of the track. The railway vehicle suspension using modified skyhook and skyhook controllers have improved the performance of the acceleration and roll of vehicle body by reducing the amplitude as compared to the passive system. The result of lateral responses under random input disturbance indicates that modified skyhook controller has a faster response compared to the skyhook controller. This is due to the capability of the non-linear controller of modified skyhook to react on the non-linear system.



(a)

(b)

Figure 4 Railway vehicle body responses for sine-wave input disturbance (a) acceleration (b) roll angle.



(a)

(b)

Figure 5 Railway vehicle body responses for random input disturbance (a) acceleration (b) roll angle.

5. CONCLUSION

A comparison of the railway vehicle body response in terms of body acceleration, and body roll angle were discussed. From the simulation results, it shows that the suspension system of railway vehicle with both modified skyhook and skyhook controllers improve ride quality of railway vehicle by reducing the unwanted railway lateral hunting due to lateral disturbances.

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