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Determination of yaw motion estimation for noise and error value based upon creep coefficient

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Abstract

Yaw/spin motion is one of the crucial parameters for three degrees of motion (forward and lateral movements) for railway vehicle wheelset for analyzing its dynamics and modeling system. Perturbation is the cardinal problem during running of railway wheelset over railway track. This comprises many factors particularly improper adhesion and creep analysis which cause disturbance on its smooth performance. Thus impropriate ratio of adhesion based upon contamination owing to creep creates slippage of rail wheels from track. This slip is procured by unbalanced lateral motion associated with yaw motion based upon variation of creep coefficient. In this paper, the produced noise by running high speed of railway wheelset is estimated by using kalman filter (KF). The basic objective of this paper is development of an estimator like Kalman filter that measures the actual parameter by estimated signal to minimize the noise and error. Thus error percentage is established by assuming higher and lower creep coefficient to avoid slip. The control of yaw motion noise due to longitudinal and lateral motion analysis reflects the sign of smooth running of train over rails.

Keywords: spin moment, lateral motion, adhesion, creep, estimator, railway vehicle wheelset.

Introduction

The lateral longitudinal suspension forces and yaw moment act on the leading turn of the wheelset of the railway truck through their suspension elements. These affect upon its frame or the bolster due to its primary suspension forward and lateral elements. According to coulombs, the torsional is affected due to damping between the truck frame and its bolster. The railway dampers allow yaw motion between the bogie frame and its bolster on railway wheelset [1].

As the railway wheels are fixed firmly together through common axle always spin with same rate of motion. The longitudinal speed of one left wheel becomes greater than the speed of the other right wheel to cause rotation of the axle towards the center line of the railway track on curved path. On curving path, the radius of right wheel is assumed higher to get lower speed than left wheel (possess higher velocity than that of right wheel). The yaw angle continues to enhance when centre of the axle turns back to the middle of the rail track. The spin motion occurs with oscillation of the axle from one side to other in combined lateral and yaw motion with reference to the hunting of the wheelset axle [2].

The process of providing feedback to lateral speed of railway wheelset creates yaw moment of wheelset and to retard the controlling force. This is feasible way as it cannot necessitate more measurements besides its running velocity. The speed and the steering are testified by arithmetic simulation with track occurring irregularities and disturbances [3].

Two degrees of freedom (DOF) comprise of lateral motion 'Y_w ' and Yaw motions 'Ψ_w ' for railway wheelset as shown in fig-1(A). The railway truck blocks are bolsterless type consisting upon dual yaw dampers supporting railway trucks. The yaw damper fitted between the truck frame and car body is installed through the stiffness of bushings made by rubber (which intervenes continuously with the damping characteristic) [4].

When comparing with the conservative railway trucks (NOT track rails), the spin angle for the actively steering system (NOT fixed, it depends upon its size or property) becomes lower at the entrance of transitional path then lateral forces are decreased. An average value of the spin angle is set lower in the middle of path, when the leading side of axle is steered by the actively control of the wheelset. The yaw angel is same in the tangential tracking for the lateral force monitoring trucks when comparing with the conservative trucks [5].

Since yaw measurement is complicated hence it is suggested [6] for measuring the relevant yawing distance among truck frames and wheelset instead of the yaw creep moment between rail wheels. This is due to the self-acting moment backing to the concerned spin movement of rail wheels as shown in fig-1.B. Here F_{lat} and F_n are lateral and normal forces. M_{spin} and λ are spin moment and creep respectively.

Previously invented mechanism for estimating unknown parameters are usually estimated by using one of three feasible methods through kalman filter. The first technique is designed, known as the 'dual Kalman filter' (DKF) in acting two Kalman filter chains in parallel to estimate the states and parameters sequentially [7]. The other approach is joint Kalman filter (JKF) that serves to expand the vector of latent states, fitted on comprising unknown parameters to be estimated collectively with the unknown states implementation. The final estimator is the combination of dual and joint Kalman filter approaches are usually used when parameter estimations have to be resulting successively as noval experimental data. These are being stored for several applications for tracking the moving objects [8].

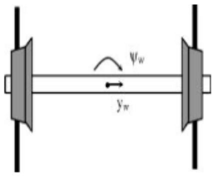

Fig-1(A) yaw motion of rail wheelset

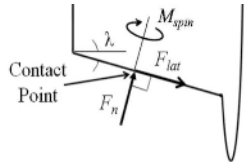

Fig-1(B) Spin moment on rail wheel contact

In this paper, in first section dynamics of rail wheelset is discussed, and in second section Kalman filter strategy is applied then the prescribed results are simulated. In third section of this paper, error percentage based upon higher and lower creep coefficients is displayed. Finally some suitable postulate is developed and concluded.

Railway Wheelset Yaw Dynamics

The tangential contact problem resolves the tangential creep forces acting on the contact patch. A deviation from pure rolling motion of the wheelset is caused by acceleration, traction, braking and the presence of lateral forces acting on the wheel-rail interface. Creepages are thus formed as a result and can be represented as under and displayed by above fig-1 except Ω = Mspin in A &B.

$$\lambda_z = \frac{\Omega_1 - \Omega_2}{v} \qquad (1)$$

Where v is velocity and Ω_2 are the real velocity while Ω_1 is the pure rolling velocity of the wheels in the absence of creep. The longitudinal creepages at left and right rail- wheel contacts. The spin creepages at railway wheelset contact is related and formulated as under [9].

$$\lambda_{zR} = \left(\frac{v}{\dot{\psi}} - {}^{\lambda}\!/_{R_o} \right) \quad (2) \qquad \lambda_{zL} = \left(\frac{v}{\dot{\psi}} + {}^{\lambda}\!/_{R_o} \right) \quad (3)$$

Kalker is established a linear relationship between the developed creepages at the contact patch and the creep forces [3]. The maximum creep forces as determined by Kalker are as follows

$$M_{zR} = f_{23} v_{yR} - f_{33}.\lambda_{zR} \quad (4) \qquad M_{zL} = f_{23} v_{yL} - f_{33}.\lambda_{zL} \quad (5)$$

Neglecting the effect of the gyroscopic wheel moment (inertial and rotational effects), the two degree of freedom equations of motion comprise of the lateral displacement and the yaw angle are already described in above theory. In above expressions M_{zR}, M_{zL} are spin moments, V_{yR}, λ_{zL} lateral velocities for right and left wheels, , f_{23}, f_{33}, are lateral and yaw creep coefficients ψ, $\dot{\psi}$ are the yaw motion and velocity.

Kalman Filter Application

In the context for the linear Kalman filter, its predicting error putrefaction function derives relation based upon one step ahead from the linear Kalman filter (KF) for prediction errors. These analyzed errors are recognized as new information or discrepancies carried on by present observations are known as new innovations form of the likelihood function as referred as the prediction error decomposition [10].

$$\underbrace{\hat{X}_K}_{\text{Current Estimation}} = \underbrace{K_K}_{\text{Kalman gain}}.\overbrace{Z_K}^{\text{Measured value}} + (1 - K_K).\underbrace{\hat{X}_{K-1}}_{\text{Previous estimation}}$$

The proposed dynamic model presented here as the special event for normal state space model-have linearity and Gaussian factors. The forecasting and estimating is acquired as recursive by famous technique like Kalman estimator for the dynamic linear models [11]. The problems for estimating and forecasting can be resolved by recursively computation by given the available information through the provisional delivery of the good quantitative application [12].

Simulation Results

The results depending dynamic modelling of the rail wheelset are simulated for filtration of noise by applying klaman filter (KF). In second part, error percentage ratio is also analysed by various creep coefficient is enumerated as under.

4.1 Yaw Motion of Wheelset at Different Creep Co-Efficient

The yaw motion of the railway wheelset on the railway track has been shown in the fig. 2-4. Here yaw motion of the railway wheelset is testified by three different co-efficient of creep versions to watch the performance of the railway wheelset.

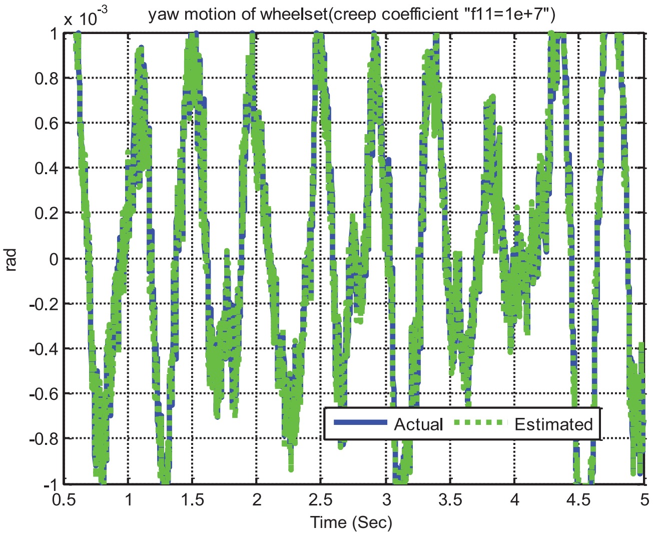

Fig. 2: yaw motion of rail wheelset at higher co-efficient of creep

In fig. 2, when co-efficient of the creep is taken as 1e+7, we observe that yaw motion of the railway wheelset moves with motion of 1e-3 rad initially to end at -0.4 rad in 5 seconds by chaos zigzag manner with time intervals from 0.5 sec up to 5 sec. It reaches to finishing point with increment of 0.5 seconds consisting upon both actual and estimated parameters. Here actual values denoted by 'blue colour' moves along with the estimated values denoted by 'green colour' overlapping each other in peaks.

In figure-3, when the co-efficient of the creep is taken as 1e+6 (various values of creep co- efficient are assumed to check the behaviour noise estimation through kalman filter). The yaw movement of the railway wheelset varies from 6.2 rad to 10e-3 rad for the estimated parameter upward with higher perturbations within 5 seconds. While actual signal starts from 1e-3 rad slightly upward to 1.5 rad with the smaller disturbances. This curve moves within zone of nearly between 1e-3 to -0.1e-3 radians in 5 seconds by disordered zigzag. Here both actual and estimated values are moving separately from each other.

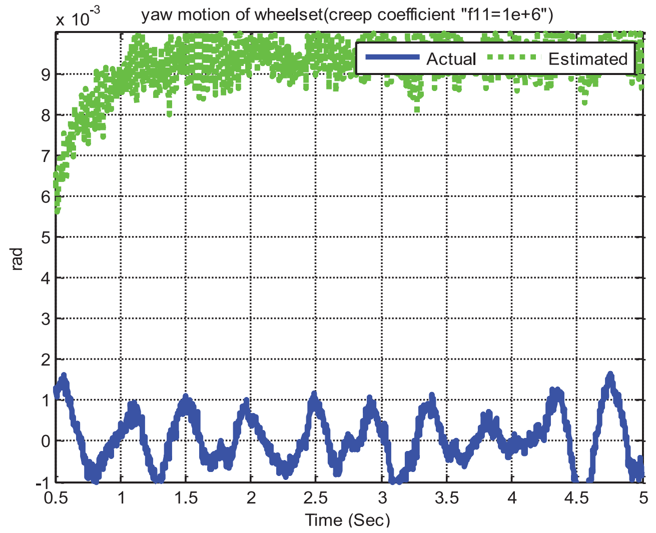

Fig. 3: Yaw motion of rail wheelset at average co-efficient of creep.

In fig. 4, when the co-efficient of the creep is taken as 1e+5 (Lower level), then the yaw movement of the railway wheelset varies from -2e-3 rad to 3.5e-3 rad for the estimated parameter upward with smaller perturbations in 5 seconds. Whereas the actual signal with the smaller disturbances starts from slightly nearer 1e-3 radian upwardly to zero radian in 0.5 seconds by un-regular zigzag manner to end at -1e-3 rad in 5 seconds. Here both actual and estimated values vary and overlap each other.

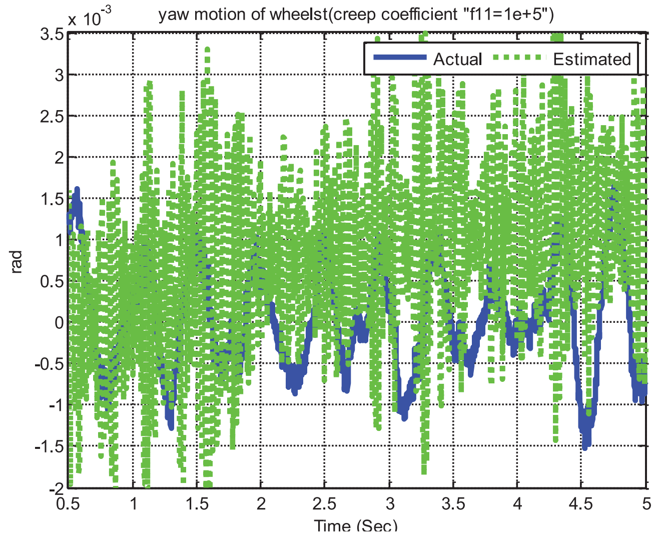

Fig. 4: Yaw motion of wheelset at lower creep co-efficient

The results obtained from these graphs are different from each other, except the image of the fig. 2, in which both actual and estimated parameters travel together parallel in zigzag manner. In fig. 3 estimated parameter starts slightly and curvedly upward with some noise while the actual parameter runs through specified zone by zigzag manner. In fig. 4, the estimated curve has extreme disturbance with actual parameter moving in zigzag path. This shows that when the creep co-efficient is enhanced then both actual and estimated parameters overlap each other in zigzag manner. But whenever co-efficient of the creep is decreased then both the actual and estimated values curves are separated from each other significantly at smaller distance from each other. The perturbations rise smaller in estimated parameter.

4.2 Error Estimation for Yaw Motion of Wheelset

The rail train track dynamic parameters are estimated to analyse the error ratio through high creep coefficient by blue line and low creep coefficient by green line. The higher co-efficient of creep is selected as 1e+7 and lower coefficient is taken as 1e+6 for estimation of error (two different values of creep co efficient are assumed to check the existing error percentage). The values of the high and low creep coefficient mentioned are applied to estimate the error ratio for yaw motion of wheelset of the train in fig. 5 as under. Here blue line representing high creep co-efficient travels in straight direction with small noise from zero error measured scale. This means that there is no error in adhesion to occur slip under higher creep coefficient (adhesion is remained constant). While low creep coefficient denoted by green line passes through -0.05 to 0.05 in vertical scale of error value through major zigzag way with disturbances. It travels below zero at 0.23 sec to travel with minor up downs to end at slightly above -0.01 in 1 second shows improper deficiency of adhesion.

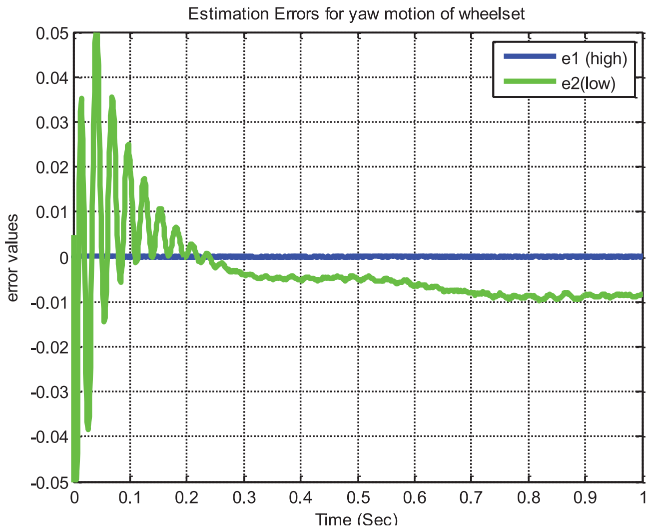

Fig. 5: Error estimation for Yaw motion of wheelset

In fig. 5 above, the higher value for error estimation is denoted by 'e1' by creep coefficient and 'e2' is displayed by lower error estimation depending upon the coefficient of the creep with time in seconds horizontally.

5. Conclusion

In this paper, the dynamics about yaw motion for railway wheelset is discussed with reference to creep analysis comprising creep co-efficient and creepage along with spin moment with respect to right and left rail wheelset. The kalman filter scheme process is briefed and applied for the estimation of noise along with actual parameters by simulation procedure. Here it is observed that on applying higher coefficient of creep both estimated and actual quantity parameters overlap parallel with each other in zigzag manner (adhesion increases on increase of creep shows stability of system). But when creep coefficient is decreased both parameters are separated from each other with some disturbance in estimated parameter and zigzag manner for actual parameter with smaller noise. On further lowering the value for creep coefficient, the ratio of perturbation is observed higher for estimated parameter while rise in zigzag motion for actual parameter. Finally error percentage technique is applied to check behaviour of adhesion and creepage for possible detection of slip by wheelset (simulated results cannot be expressed in above literature).

Hence it is concluded that on higher creep coefficient that there is negligible difference between actual and estimated parameters for noise, but on decreasing coefficient of creep, some noise is increased with estimated parameter, and error becomes zero on increasing creepage percent.

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