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Estimation of Absolute Speed of Vehicle with the Simplified Inverse Model

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Abstract: Presently the calculations of complete speed of railway vehicles are very useful for the people in Pakistan. This is obtained by observing the stimulated time shift for the arbitrary track between two wheel sets of a bogie. The model developed in this research work is aimed to collect specific characteristics of the movements at the wheel sets via two inertial sensors seated onto a bogie. An input in the system is provided by means of the rough surface of track that produces bounce in both wheels that is identical except in the delay of time. This delay of time is detected by the space between the two wheels. The cross-correlation calculation technique has been used to determine the delay in time between the movements from one to another. The calculating method is achieved by extraction, which is based on a discursive model of vehicle.

Keywords: Cross Correlation, Simplified Inverse Model, Time delay

I. INTRODUCTION

The rail vehicle speed's measurement is often conquered by noticing the speed of revolution of the wheels, as the width of the wheel is static. This standard practice has been providing acceptable accuracy for a long time because there is no extreme possibility for the wheel slide; this is a process that allows a wheel to lag and to overrun for the station of trains. This technique will be employed for the modeling and simulation of speed of the railway vehicles. This research is based to study the up to date data available for the estimation of railway vehicle ground speed and to acquire a detailed model of vehicle by using one of the most extensive methods of multimode packages of simulation, mostly used by the manufacturers of vehicle and to contrast with the International Union of Railways (UIC). Finally, the model ought to be able to calculate the speed. The chief principle of this research work is to study and estimate the simulation of the measurement of the absolute vehicle speed and finally analyze the simulated results.

II. STATE OF THE ART

[1] presents dependable and appropriate measurements of absolute vehicle speed by estimating the time shift of two adjacent wheels' motion via cross correlation which is vital for control purposes of vehicle tracking. [2] shows an approach for the fault control tolerant for the vehicles connected to an electrical independent four-wheel driven system also for that a controller is prepared for ensuring the stability of vehicles. [3] used an accelerometer and wheel based speed sensor to accurately estimate the speed of the vehicle. Filter is used to sense the speed of the vehicle and fuzzy logic is implemented for this. Basically, three types of sensing filters are used to reduce high frequency noise of the acceleration calculations and the error is also measured that is coming between the vehicle speed [4][5] discussed that for the development of modern vehicle, its safety and traction control are the facts of under consideration. The presented work in this paper is based on Composite Nonlinear Feedback (CNF) controller application for the controlling strategies of vehicle lateral dynamic behaviour based on direct yaw moment compensation. Basically, for the model of vehicle, two models are constructed one for the non-linear and the other one for tire. All the controlling performances have been conducted by means of numerical simulations using MATLAB/Simulink platform. The main factors for roadway usage, specially by large vehicles is discussed to evaluate the infrastructure of highway lifespan, for this purpose, non-conventional techniques are specifically designed for the purpose of calculating the speed of vehicle by means of single loop detectors [6][7] present the calculations of the speed of vehicles based on grey constraint optical flow algorithm. A vital role is played by the vehicle speed measurement for Intelligent transportation systems (ITS). The speed of vehicle basically can be measured in two ways i.e. via hardware- based methods or software-based methods. In this paper, a software based method is implemented to estimate the speed of any vehicle by video images. A loop detector named" Induction-coil loop speed measurement" is embedded into the ground as whenever a vehicle goes across this loop to detect the speed. Also, a laser detector is used to be placed

above the roadway to detect the distance of moving objects and their speed.

[8] Presented a fault tolerance approach that is done without any use of redundant actuators to offer stability for various failure modes.

[9] suggests a new technique for the calculation of speed of train by using inertial sensors mounted onto a bogie. The suggested method estimates the speed of time shift for the continuous movement for wheels that is obtained from the behaviour of a railway bogie to observe the excitations that always occur in railway tracks.

[10] Presented to accomplish the control approach for the various speed tracking control systems. The used method for estimating the control functions of brake and drive is done by means of an algorithm named" Switching algorithm" without calibration, which is also connected with the model of inverse longitudinal vehicle and adaptive regulation of MPC which is used as engine brake torque for the variety of driving conditions and to pass up high frequency oscillations repeatedly.

III. PROPOSED WORK

A simple railway bogie is given in Figure 1, consisting of two wheel sets that are joined frame with the help of primary suspensions. Then the secondary suspensions link this frame to the vehicle body. This Fig. is the key to the development of the model for the proposed work.

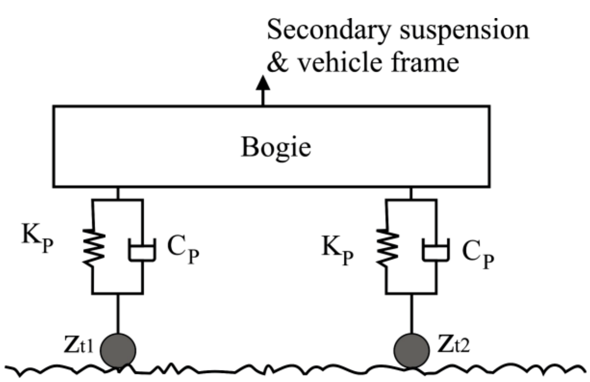

Figure 1 Schematic of a bogie.

All the parameters influencing on the performance of the wheel set of train caused by the roughness of the track are exactly same; the only parameter that varies is the time delay between the two wheels as shown in Figure 2. The determination of this delay is calculated with help of the distance between the wheels and its own speed. Thus, the time delay will be the only parameter that will help in gathering the exact speed measurement of the specific vehicle.

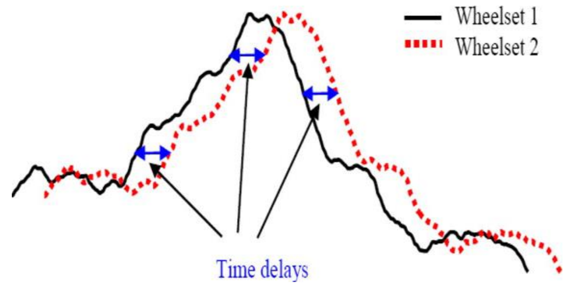

Figure 2 Movement of wheels due to track roughness.

Figure 3 below provides a method for the calculation of the speed of the vehicle. Two inertial sensors are mounted on the bogie frame to perform pitch and bounce dimensions. An inverse model filters are produced that work as observers, after that output signals are merged together to present the assessed upright movements of the two sets of the wheel, (A1 and A2). After that, cross-correlation measurements are done of these merged signals that are forwarded to the moving windows, that helps to estimate the delay in time of the two wheel sets, the result is further utilized to measure the absolute speed of the vehicle by the help of given equation:

$$Vm = 2Lb/T\text{delay} \qquad (1)$$

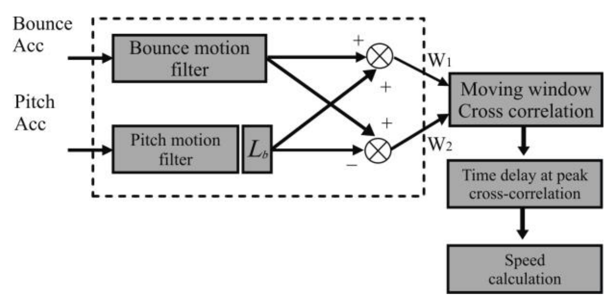

Figure 3 Speed measurement scheme.

The vertical dynamics of a vehicle included lateral, yaw and longitudinal motions are the concerned parameters for the accurate speed of the vehicle, however this paper neglected the above-mentioned parameters and only two parameters are considered, that are the acceleration and pitch motions for the speed of the vehicle

IV. PERFORMANCE EVALUATION

The key purpose of the design of the filter is to extract the delay in time between the two sets of the wheels. This is elaborated in Figures 4 and 5, setting the initial velocity of the train to be 183.67 km/h in the simulation.

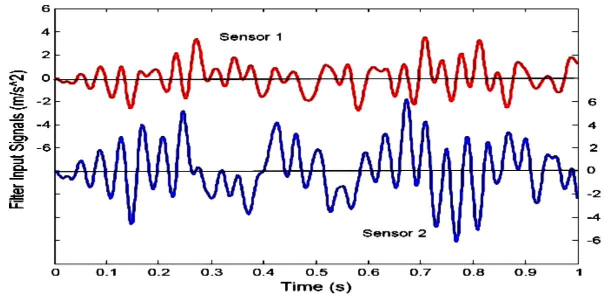

Figure 4 Signals from sensor at the velocity of 183.67 km/h.

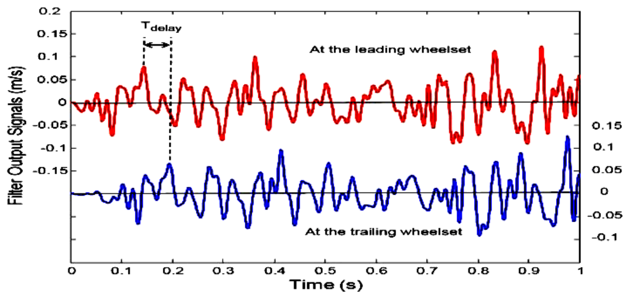

Figure 5 Signals out from the filters.

The cross-correlation calculations of the signals from Figures 4 and 5 are shown in Figure 6.

The maximum amplitude signifies delay (Td) as:

Td=52ms or 51.5ms if *T*s=0.51 ms, where Ts is the sampling interval.

Using (1) we get the speed of vehicle as 50 m/s (at *Ts*= 1.0 ms) or 50.38 m/s (at *Ts*= 0.51 ms).

The errors of 1 m/s (1.960%) and 0.521 m/s (1.021%), respectively in the calculations, are mainly due to limited samples. Two more speeds of the vehicles have been extracted from the calculation of cross-correlation by setting two different sampling intervals as Ts=1ms and Ts=0.5ms as shown in Figure 7. That gives the speed of the vehicle to be 46 km/h (12.5 m/s) with a delay of 209ms and 95.32km/h (26.2m/s) with a delay of 100ms respectively.

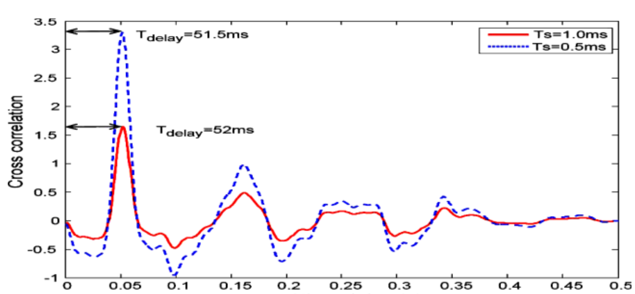

Figure 6 Resulting Cross correlation of the productive motion at 183.67 km/h

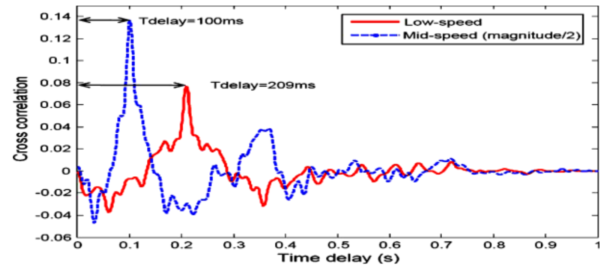

Figure 7 Resulting Cross correlation of the productive motions at 46, and 95.32 km/h

V. OUTCOME OF THE PROPOSED PROTOTYPE

Figure 8 illustrates the increase in speed and then decrease in speed of the train. Whereas, the error is measured in Figure 9. From these measurements, it can be stated that the model is capable to estimate the real velocity of the vehicle, while the estimated error is less than 6 km/h, which is mainly due to a frequent deceleration.

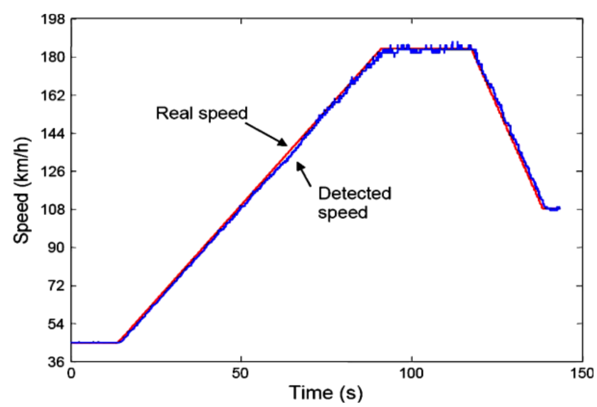

Figure 8 Increase and decrease in speed

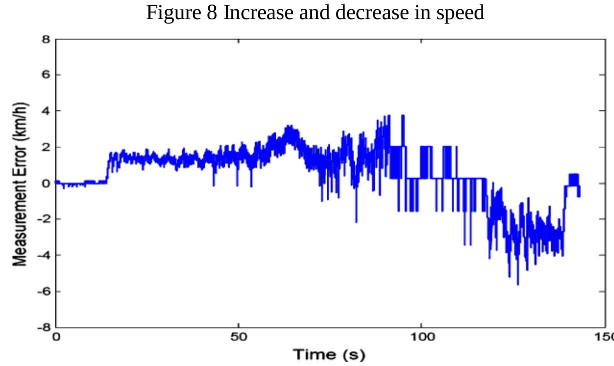

Figure 9 Error in acceleration and deceleration

VI. CONCLUSION

In this paper, an easy implementation technique has been used to serve a productive calculation of the railway vehicle speed for ground. An itemized model has demonstrated for a variety of vehicles speed and operation condition using two sensing techniques for bounce and pitch acceleration using simplified inverse model for the shift in time between two set for the wheels that was further used for the speed of vehicles and its calculation and the benefit of this developed system is that it has a higher efficiency rate.

VII. FUTURE ENDORSEMENT

As in the designed model, after successful implementation on simulation; it is suggested for the future that this project will be applied for different actions per result, also for the calculations for the speed of trains at various speed ranges with minimal errors. Moreover, the design could also be implemented on hardware for efficient speed calculations for various ranges of speed although it would require a huge cost.

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