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Detection of Fault in Actively Controlled Railway Vehicle

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Abstract: It was the recent study when the traditional passive suspension used to stabilize the sets of wheel for the railway but it created the obstacle of the effect of rolling for the wheels. The design dispute between the stability and the rolling performance can crack by active components instead of the straight passive suspension which has been shown theoretically that the use of active control can mitigate wear of the wheels and its tracking forces. The study of active control in the place of traditional components that substituted by the actuators, sensors and data processor may increase the problems of stability which is a serious case, results in the derailment. Additionally, the cost of the actuators is expensive and it takes more space than sensors and needs an electronic control unit in the active control system for railway vehicles. The Kalman Bucy filter is used to generate the values for detection and isolation of faults in the railway wheelsets.

Keywords: Kalman: Bucy filter; actively controlled modeling; systematic railway behavior; inspecting conditions; detection of fault and isolation.

I. INTRODUCTION

In the modern study, the safety of the passenger is the first preference of the designer. The conventional two wheels which rotate at constant speed. When it comes on the curved path it would cause the instability and in the most severe case, the derailment [1]. The use of passive components in the primary suspension results in the poor curved performance which further mitigates the stability and reliability of the system [2]. Taking into account a conformist set of wheels for a vehicle of railway it brought under study that this conventional railway wheelset is made of two described vehicles. These bi-profiled wheels are tightly positioned with the common axle. This particular type of procedure provides with the advantage of usual curving. In addition, the wheelset, which when unconstrained shows a constant fluctuation. Traditionally, the passive suspension is mounted on a conventional rail vehicle, which stabilizes the wheelset [3]. However, this surplus stiffness poses an impact on the uncontaminated curving act of the wheels amid the curve concession [4]. Eventually, this research work suggests a possible compromise between steering and stability only when passive components are used. This active control is applied in primary suspension with a purpose to bring stability in a wheelset. This is done so without undermining the performance of the vehicle during curve negotiation. Resultantly, this leads to the momentous decrease in wheelsets wear, path and minimized the path switching forces [4]. These actuators, sensors are used in place of conventional passive suspensions. This replacement increases the issue for system stability in the case of the collapse of the actively controlled [5]. Such collapse of active control is the consequence of loss of stability. This high level of integrity is realized via the approach of fault tolerance. Consequently, this approach allows the component fault and brings about the basic functionality of the overall system. Furthermore, to realize the significant functionality of the system, the hardware redundancies are the possible options [6]. Hence, to keep the price down, a method named as "Analytical redundancy" can be employed to reduce the use of the hardware redundancies [7] This makes the development of an analytical based fault detection methodology more essential [9]. As it does not bring up the increased number of actuators. Hence, building an (FDI) methodology for wheelsets, which are dynamically organized in the case of fail of actuator and sensor. This gives a momentous assignment by facilitating info, which confirms actuator faults within the system. The main purpose of this research paper is to make the model-based system which will consider the changed fiasco conditions: Fail-Hard and Fail-Soft in the actuators and sensors.

II. LITERATURE REVIEW

In this research paper, the Actuation of solid axle wheels is discussed. It is used for stability and for good curving performance. The yaw force is superior to the lateral force [10]. The second technique the actuation of independent rotating vehicles is discussed in the two wheels of the same axle is allowed to rotate independently with using wheel sets. This reduces the cause of hunting of decoupling of the yaw motion as well as lateral displacement [11]. The driving of two independent wheels can control the torsional coupling. This technique provides the drive and guidance through the motor control [12]. In this research paper, the secondary yaw technique is elaborated. For improving stability and rotating performance, this concept is used because it is based on applying a yaw torque on the bogie [13]. The traditional method for designing the rail wheels used dampers and springs in the secondary suspension of the bogie. This old system is replaced by the active components like sensors and actuators which are the reliable as well as affordable. It comforts the journey by improving the stability criteria. Hydraulic actuators and sky-hook method are used as a controller [14]. The Kalman filter and Artificial Neural Network are the two methods which are proposed to identify the faults in the complex system [15].

III. ACTUATOR TENDENCY

The employment for the actively controlling actions needs the usage of an actuator for an individual set of wheel to transport the controlling act in the direction of yaw. Various different technologies of the actuator are to be found [16]. Though, in the learning process, electro-mechanical actuation is selected to encounter the chief necessities for actively controlled processes so that to steady the set of the wheel in the modes of kinematic, which are comparatively in the high range of frequency [17]. Though the models of actuator are not involved in the process to design control to escape the additional complication for the structures of control, all the dynamics of the actuator will be involved in the process of simulation to assess the performance of vehicle [18]. The basic model of actuator dynamics contains the two fragments: the electrical portion like dc motor and a portion for mechanical comprises the gearbox and rotor.
The parameters are given in the following equations.

$$I_\mu \ddot{\theta}_m = K_\tau . i_\alpha + \tau_\gamma \qquad (1)$$

$$di_a/dt = {}^{Ra}/_{La} . i_a + {}^{Va}/_{La} + K . {}^{\dot{\theta}m}/_{La} \qquad (2)$$

The basic model is further summed up with the dynamics of the vehicle and its model for the simulation purpose to gage the presentation of the actively controlled system. Figures 1 and 2 relate the Displacements of lateral and yaw motions of the foremost and trailing sets of the wheel by and deprived of the dynamics of the actuator, correspondingly.

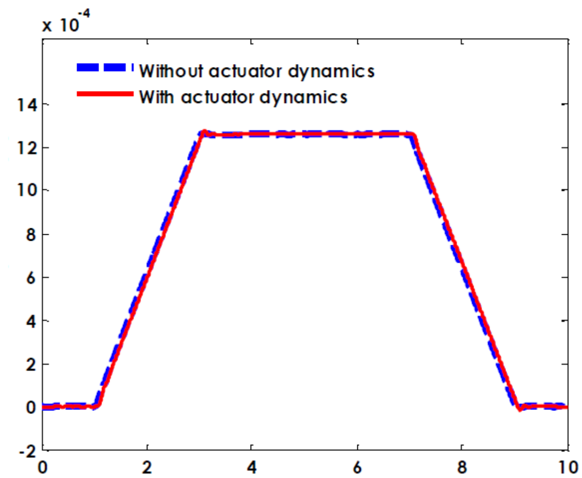

Figure 1: lateral displacement with and without actuator dynamics

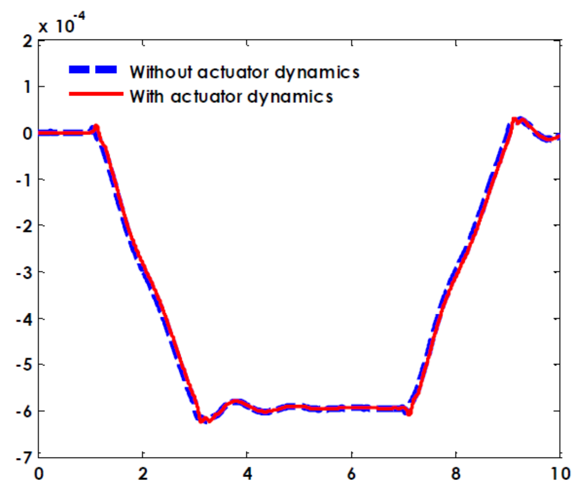

Figure 2: Angle of attack with and without actuator dynamics

IV. FDI MODELING AND SCHEME

This research work is based on the Kalman Filter technique which is employed to handle the actuator state, the KF filter is implemented which does so in the place of approximating the states of the actuators.

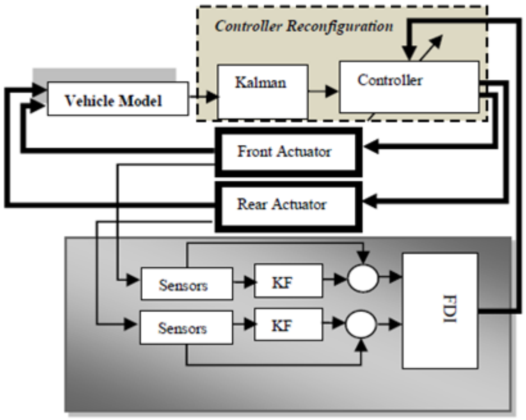

Figure 3: Schematic diagram of the FDI system

The equation (3) serves the purpose to define an illustrative picture of the actuator for the KF design.

$$\dot{x}_c = A_\chi \,.\, \xi_\chi + B_\chi \,.\, Y_\chi + \Gamma_\chi \,.\, \Omega_\chi \;; \qquad (3)$$

Where,

$$\dot{x}_c = [\; \ddot{\theta}_m \;\; di_a/dt \;\; \dot{\tau}_g \;]^T$$

The equation explicitly shows the derivative of the torque which is represented in the appendix. The derivative of torque is amid the set of wheels and gear that is measured as a noise source in strategy. The presence of ($\dot{\tau}_g$) is integral primarily because it demonstrates that the ensuing KF gives suitable info for FDI. Moreover, in the scheme pattern, a little value of 0.0001 is put for the torque variable. This is done to have a full rank of the matrix. The further discussion considers two sensing options: The first one is two sensors are equipped onto each actuator. One sensor measures the actuator speed and the second sensor measure the motor current [15].

$$\Psi_\chi = X_\chi \;.\; \xi_\chi \;+\; H_\chi \,.\, \varsigma_\chi \qquad (4)$$

Where,

$$\Psi_\chi = [\;\; \dot{\theta}_\mu \;\;\; \iota_\alpha \;]^T;$$

The second option differs from option 1 in the manner that in the former an additional sensor is included. This is a strain gauge with the sole objective to measure the torque, which has been applied to the wheelset from the actuator gearbox. This research work has all measurement noises to 3% with respect to their absolute value that too at the vehicle speed of 60 m/s.

A. *Fail Hard*

Under the ambit of fail-hard actuators, the motor gets fixed at a particular position with respect to the motion between the wheelset. In the addition, the bogie gets constrained by the material stiffness in the actuator connections.

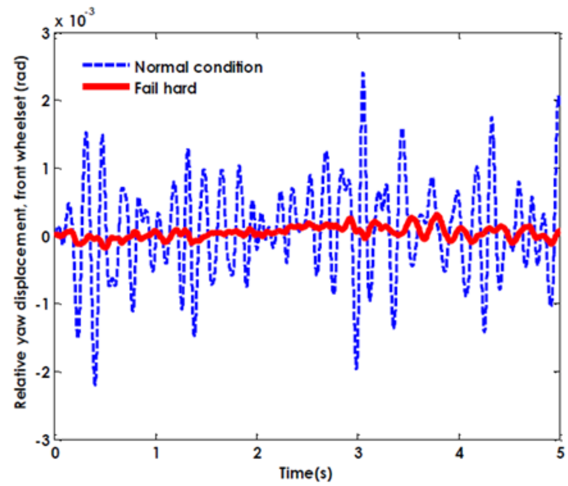

Figure 4: Displacement due to yaw for the forward-facing wheel (FH)

A thorough research proves that in such cases the vehicle stability is not the main concern even though the level of the damping might be reduced.

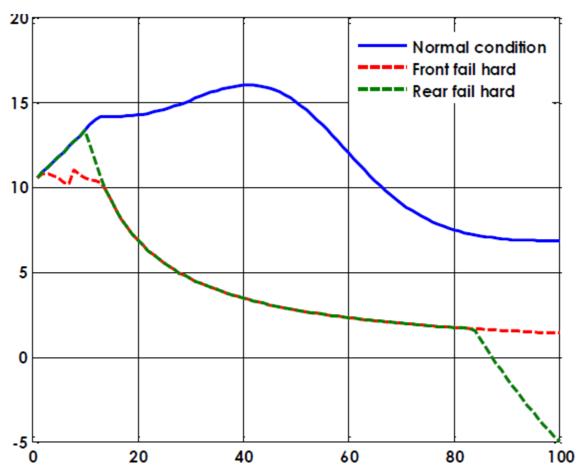

Figure 5: Comparison between FH and normal situation minutest damping.

The Figure 4 explicitly demonstrate that the two cases of the actuator, namely the leading actuator or trailing actuator in the fail hard condition increase the contact creep forces at both leading and trailing sets of the wheel during the curve negotiation. Primarily because of the limited freedom of movement of the damaged actuator. This results in poor steering performance. Hence to achieve a good curving performance, it is highly recommended that the forces generated in the lateral direction for the leading and the trailing wheelsets must be ideally equal. This equality is capable of maintaining the wheelsets in a peculiar position, where they can follow track that too without any deviation from each other.

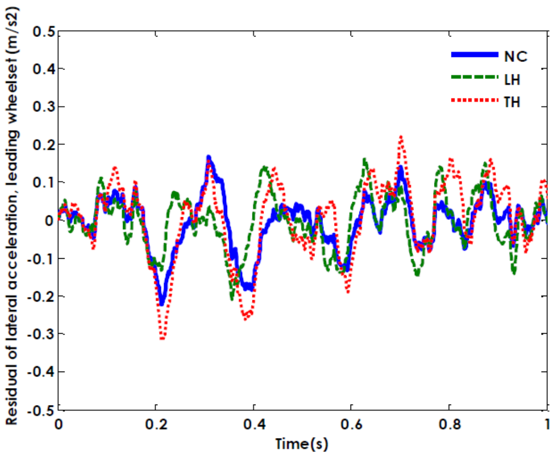

Figure 6: lateral acceleration residual values of the front wheel

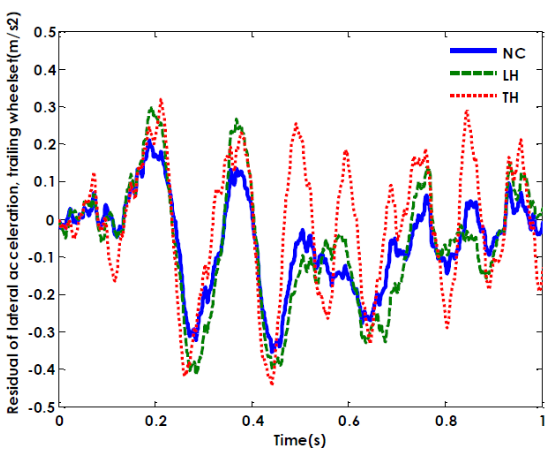

Figure 7: lateral acceleration residual values of rare wheel

If we consider the Figure 5 it shows the fluctuations in the signal as compared to the normal condition. When we generate the new residual values in the time domain as shown in Figure 6 and 7, we get the most similar response to the normal condition for front and rare wheels. This is particularly relevant on tight curves ion terms of lateral displacement at the angle of attack.

B. Fail Soft

In the FH case, be it the SC or the OC case, the actuator will not be in a too well position to give the required control torque that stabilizes the kinematic mode of the wheelset.

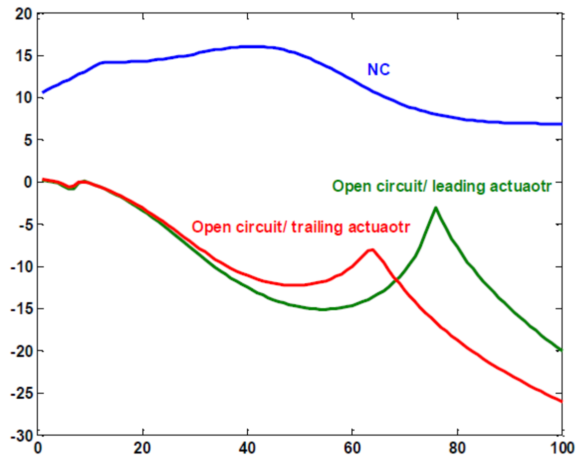

Figure 8: OC vs normalize condition damping ratio

Undoubtedly, In the SC and OC conditions for the active control system, the fault handling strategy is majority concerned with the preservation of the stability control. On the other hand, the curving performance is a secondary design issue.

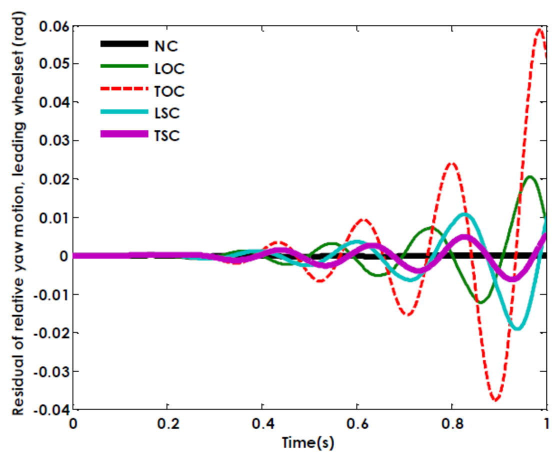

Figure 9: Yaw displacement residual values (FS)

Figure 9 shows that by generating the different residual value for different parameters mitigate the chances of open and short circuit loses.

V. Result

The detection of faults is successfully achieved. There are two faults which normally occur in the actuators and sensors. The Kalman bucy filter is designed to estimate the residual values for the fail hard and fail-soft failures through the above-given equations. The graphs show that by changing the residual values of lateral acceleration of rare and front wheels. The fault has been mitigated as shown in Figure 6 and 7. The fail soft that occurred in sensors is due to an open and short circuit which is minimized by changing residual values of yaw displacement as shown in graph 9.

VI. CONCLUSION AND FUTURE WORK

The research deliberates the formation of a fault tolerant strategy to accomplish an active control of wheelsets. This strategy constitutes FDI and RC. Two types of actuator failures are considered in this research, namely FH and FS. The identification and fault detection is achieved through the use of the Kalman Bucy filter by estimating the residual values in the time domain. The FD system depends on the stability of the sensors that is the negative aspect of the system which must be robust. By considering the reliability and stability of the system, the robustness is a basic factor which must be considered for the future work.

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