Performance Measurements System of the Scaled Active Steering Railway Vehicle using the Telemetry Systems

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Abstract: This paper describes the performance measurement system of the active steering railway vehicle with the scaled test bed using the acquisition system about the wheel lateral force. Active steering system of railway vehicles has proven its ability to bridge the gap between stability and curve friendliness. This scaled testbed system consists of two steering actuators, a steering controller, and various sensor systems to detect lateral displacement, vibration, track curvature, and sensor systems. To compare with the various control strategies, we installed the telemetry systems on the steering wheelsets to detect the wheel/rail lateral force. Running test results of 1/5 scaled active steering vehicle on the curved track show that the proposed measuring system has good performance.

Key-Words: Telemetry System, Lateral Force, Active Steering Controller, Railway Vehicle, Scaled Model

1 Introduction
In urban transit systems, rail passenger vehicles are often required to construct tight curves. During curve negotiation, the wheelsets of conventional vehicles generally misalign radically with the track increasing wheel/rail contact forces and resulting in increased wheel and rail wear, outbreak of squeal noise, fuel consumption, and risk of derailment. To alleviate these problems, modified suspension system designs, application for alternate wheel profiles, active and semi-active steering techniques have been proposed. Over the past few decades, a considerable number of studies have been conducted on the effects of the active steering system of railway vehicles. And the active steering system has proven its ability to bridge the gap between stability and curve friendliness [1]–[8].

Generally scaled railway vehicles were developed to reproduce the fundamental dynamic behavior of the full size railway vehicle in laboratory conditions. In this paper, a 1/5 scaled railway vehicle is carried out for the development and testing of prototype bogie design, and the investigation of fundamental railway vehicle running behavior

In this paper, we design an experimental testbed with a telemetry system for measuring the wheel lateral force and tested the performance of the various active steering strategies on the a curved track.

This paper is organized as the followings. Section 2 describes an active steering control system for 1/5 scale model. Section 3 contains the experiment results. The main conclusions are then summarized in section 4.

Fig.1 Block diagram of active steering control system

2 Active Steering Control Systems
An active steering control system is constituted a steering controller module in charge of steering control algorithm as the core part including A/D and D/A input/output terminals, a control station module having function of
remote command and data acquisition, actuator module for driving the steering bogie corresponding to the controller output signals, and various sensors system module.

The basic concept of steering control strategy is to apply a controlled torque to the wheelsets in the yaw direction. This can be achieved through longitudinal actuators as shown in Fig.2. This strategy is founded on the coupling of the lateral and yawing motions of the wheelsets by using the laser sensor signals represented in the wheel/rail displacement.

Fig.2 Active steering control strategy: longitudinal actuator method

As the feedback signals, the relative movement between the wheels and the rail are considered in the development of controllers using the measured distance of the laser sensor from axle box to rail head.

Fig.3 Realization of the active steering control module with MATLAB/SIMULINK

Fig.3 shows a realization of the active steering control module with MATLAB/ SIMULINK for scale model.

3 Construction of Testbed

Testbed is carried out for the development and testing of active steering bogie. A block diagram of testbed for the active steering control system is given in Fig.4.

Fig.4 Research testbed: the 1/5 scale active steering vehicle and the curved track

3.1 Curved Track

For running test, 27.11 [m] and R=20 curved track is used. This track has not a cant, and consists of the straight track (6.41m), curve track (14.30m) and straight line track (6.41m).

Fig.5 Drawings of the curved track of testbed for running test for active steering control system

3.2 The Scaled Research Vehicle

The scaled research vehicle is consisted of the diving bogie module, the steering bogie module, the controller module, the sensor system module, and carbody module.

First, driving bogie module consists of a BLDC motor of DC48V 39.1A, a 5:1 reduction gear, a driving motor driver, and a braking system. Two encoders which are mounted two wheel side of the driving motor axle are used for calculating the vehicle speed.

Fig.6 Driving bogie module

Second, the dSPACE system (DS1103 PPC Controller Board) is mounted in a dSPACE expansion box to control
the active steering bogie in a scaled railway vehicle[9]. The research vehicle has an active steering controller that works in coordination with control signals of the steering controller to alleviate wheel/rail contact forces and to decrease wheel/rail wear. The role of the active steering control module is followings:

- Generation of steering command to actuator based on the control algorithm
- A/D and D/A input/output terminals
- MATLAB/SIMULINK and dSPACE as a rapid control prototyper

Third, the steering bogie of F-link type which consists of two steering actuators and several links is depicted in Fig.7.

![Fig.7 Active steering bogie module](image)

The actuator force is proportional to the input voltage values. That is, the actuator force increases from 0 [N] to 200 [N] approximately proportionally to the actuator command voltage (0 [V] to 4 [V]).

Finally, the sensor system of the testbed mainly consists of four components:

- Wheel/rail relative displacement measurement using laser sensor
- Carbody vibration characteristic measurement using accelerometer sensor
- Yaw angle measurement of the steering bogie using gyro sensor
- Detection of the start/end point of the curve track using magnetic sensor
- Wheel/rail dynamics monitoring using wireless camera systems

### 3.3 Measurement System of the Wheel Lateral Force

For active steering control of the testbed, it is vital to confirm the performance of the various steering strategy and control algorithms.

Fig.8 The scaled vehicle with various sensor systems

![Fig.8 The scaled vehicle with various sensor systems](image)

Fig. 9 shows the signals flow and bridge circuits for the measuring the later force and Fig.10 illustrates the lateral force measuring systems.

![Fig.9 The signals flow and bridge circuits for the measuring the later force](image)

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### 4 Experiments of Test-bed

In the running test of the research vehicle, the testbed for the active steering control system can be tried and validated under real-time condition.

The experimental results of the vehicle speed and the moving distance are shown in Fig. 11.
The experimental results of the lateral force of the left trailing wheel for comparison with the various steering strategies (i.e. no control, displacement control strategy, radial steering control strategy) to produce the pure rolling are shown in Fig. 13.

5 Conclusion

In this paper, we present the performance measurement system of the active steering railway vehicle on the scaled test bed to collect the wheel lateral force. Control strategy to the active steering system based on two axle vehicle attached to actuator of the yaw torque considering the riding quality has been applied. Experiment results show that the proposed measuring systems yields good performance through comparing with the passive system, the displacement control strategy, and the radial steering control strategy.

References: