Construction of Active Steering Control System for the Curving Performance Analysis of the Scaled Railway Vehicle

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Abstract: - This paper describes the construction of active steering control system for the curving performance analysis of scaled railway vehicle. Active steering system of railway vehicles is designed to alleviate wheel/rail contact forces and to decrease wheel/rail wear. The active steering control system consists of the remote control station module, the steering controller module, the battery module, the driving bogie module, the steering bogie module, and various sensors module. The proposed active steering control system is tested in the 1/5 scale research vehicle and R=20 curved track, and we could verify the effectiveness and performance of the proposed system.

Key-Words: - Active Steering, Control System, Railway Vehicle, Scaled Model

1 Introduction
Rail vehicles originally have self-steering ability on curved tracks, and this function is originated from the wheel conicity and rigid connection of two wheelsets by an axle. But this mechanism has two problems. One is a hunting phenomenon by a self-excited vibration of the wheelsets and the other is a curving ability by self-steering mechanism. To solve this problem and compromise between stability and curving performance, there are number of studies and developments such as passive, semi-active control, active control, independently-rotating wheelsets (IRW), and so on.

To alleviate these problems, modified suspension system designs, application for alternate wheel profiles, active and semi-active steering techniques have been proposed. Active steering system has proven its ability to bridge the gap between stability and curve friendliness. In this paper, we design an experimental testbed with a vehicle and a track of 1/5 scale model and perform the curving performance verification of the proposed active steering control system[1]~[7].

Generally scaled railway vehicles were developed to reproduce the fundamental dynamic behavior of the full size railway vehicle in laboratory conditions. In this paper, 1/5 scaled railway vehicle is carried out for the development and testing of prototype bogie, and the investigation of fundamental railway vehicle running behavior[8].

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

2 Active Steering Control System
Fig.1 shows a block diagram of the active steering control system using MATLAB/SIMULINK for the research vehicle.

![Block diagram of active steering control system](image-url)
The basic concept of steering control strategy is to apply a controlled torque to the wheelset 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.

An F-link type steering bogies which consists of two steering actuators and several links is depicted in Fig.2.

![Fig.2 Schematic views of an active steering bogie](image)

The relative movement between the wheels and the rail measured by laser sensors is considered as the system output. These laser sensors are installed at the both ends of the wheelset for sensing the distance of the laser sensor from axle box to rail head. And this measured value is compared with the reference input.

3 Construction of Testbed

Testbed is carried out for the development and testing of active steering bogie. The testbed mainly consists of seven components:
- The curved track module
- The steering bogie module
- The steering controller module
- The battery module
- The sensors system module

A block diagram of testbed for the active steering control system is given in Fig.3.

3.1 Curved Track Module
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.4 Drawings of the curved track of testbed for running test for active steering control system](image)

3.2 Control Station Module
The control station module takes functions as remote control of the research vehicle, remotely signal monitoring of the steering controller, and the image data acquisition of wheel/rail contact using wireless camera systems.

![Fig.5 Research testbed: the 1/5 scale active steering vehicle and the curved track](image)
3.3 Driving Bogie Module

Driving bogie module consists of a BLDC motor of DC48V 39.1A, a 5:1 reduction gear, a driving motor driver, a braking system and connection panels. The rated output power of BLDC motor is 1.5KW and it rotates with 2000 [rpm] maximally. The motor driver is including the motor ON/OFF terminal, the velocity control terminal with 0V~5V and the direction selective terminal (0V and 5V). A photoelectric sensor which is mounted the wheel side of the driving motor axle is used for calculating the vehicle speed.

3.4 Active Steering Controller Module

The dSPACE system (DS1103 PPC Controller Board) is a powerful controller board for rapid control prototyping[9]. This board is mounted in a dSPACE expansion box to test the active steering control functions in a scaled railway vehicle.

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

3.5 Steering Bogie Module

The steering bogie of F-link type which consists of two steering actuators and several links is depicted in Fig.9.

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]).

3.6 Battery Module

Fig.10 Main battery part for providing a driving motor, two actuators and a controller with power
Battery module is composed of the main battery part for providing a driving motor, two actuators and a controller with power, and the auxiliary battery part for supplying power to several sensors.

The main battery part consists of one 48V 40Ah lithium-ion-polymer battery pack and two 24V 20Ah lithium-ion-polymer battery packs, while three 13.2V 2300mAh LiFePO4 battery packs make up the auxiliary battery part.

### 3.7 Sensor System Module

For active steering control of the testbed, it is vital to know the exact relative displacement of wheel/rail, vehicle speed, radius of the curve track, and so on. 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

![Fig.11 Sensor system module of the testbed](image)

### 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.

Fig. 12 shows the testbed for the active steering control system. The measuring signals of the relative displacement of wheel/rail are transmitted to the dSPACE controller via A/D converter, these signals are process based on the control algorithm, and finally the signals are retransmitted to the steering actuator through D/A converter.

![Fig.12 The 1/5 scaled testbed for the active steering control system](image)

The steering bogie of the vehicle model was driven by the driving bogie at 2 [m/s] speed. Fig. 13 shows the experimental results of the pulse train of the number of rotations, the vehicle speed, the moving distance, and the gyro sensor signals, respectively.

![Fig.13 The experimental results: the pulse train, the vehicle speed, the moving distance, and the gyro sensor signals](image)

The experimental results of the relative displacement, the actuator command voltage, and a characteristic vibration of carbody are shown in Fig. 14, respectively.

![Fig.14 The experimental results: the relative displacement, the actuator command voltage, and a characteristic vibration of carbody](image)
5 Conclusion

In this paper, we present the construction of active steering control system for the curving performance analysis. 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. The dSPACE system is used for implementing the active steering controller. The proposed testbed for active steering control system is tested in the 1/5 scale research vehicle and R=20 curved track, and we could verify the effectiveness and performance of the proposed system.

References: