Study of semi-active steering system for Urban Maglev

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ABSTRACT: Urban maglev has such characteristics as not only environmentally friendliness and excellent driving capability but also curve negotiation performance because its tracks have narrow curves. In general Maglev vehicle has at least 3 bogies and this configuration affects the curving negotiation of Maglev. To achieve appropriate performance of running on narrow curve steering mechanism is to be considered on the vehicle. In this paper, three kinds of steering system for urban maglev are to be introduced as passive system, full-active system and semi-active system. Then comparison of running performance simulation of three systems will be discussed. In the end the proto-type of semi-active steering system on developing will be introduced.

1 INTRODUCTION

Urban maglev should have such characteristics as not only environmentally friendliness and excellent driving capability but also curve negotiation performance because its routes have many sharp curves.

In general Maglev consists of 3 ~ 6 bogies per vehicle and one module has two secondary springs at the both ends of frame of bogie which supports the mass of car-body and transfers levitation force of electromagnet. Due to this kind of system configuration of urban maglev its relative displacements of secondary spring are bigger than conventional railway vehicle. Additionally the centering force of levitation electromagnet is comparatively smaller than the centering force from friction of wheel-on-rail system. These features of maglev affect the curving negotiation.

Therefore an additional mechanism is to be required to solve this situation of nominal urban maglev, called as ‘Steering system’ in this paper.

Some developed urban maglev already has the passive steering device which consists of mechanical linkage or hydraulic cylinder with closed-route piping. But passive system has room of improvement of running performance and some drawback in the view of vehicle system engineering.

In this paper, active steering and semi-active steering system are suggested and curve negotiations of passive and active system are to be compared through dynamic analysis. And in the end the proto-type system of semi-active steering device will be introduced.

Figure 1. Target vehicle for passive steering system

2 STEERING SYSTEM

2.1 Target vehicle

The target vehicle is proto-type car of urban Maglev, which was developed through Maglev Realization Program. The developed urban Maglev train-set consists of 2 vehicles and each vehicle has 4 bogies as Figure 1. One bogie has two module and Each module is composed of one electromagnet, LIM and two air-springs. The reason of two springs instead of conventional arrangement as one spring on center of module is to improve the vibrational characteristics of one module, especially yaw and pitch motion. Its maximum design speed is 110 km/h and Min. radius as R50m. The passive steering system was already applied on the proto-type vehicle for curving negotiation.

Figure 2 shows schematics of passive steering system. Steering system is composed of connection mechanism between carbody and modules and coupling mechanism of motion of modules motion. Concerning the connection mechanism two kinds of joint are applied as ‘Fixed joint’ and ‘Moving joint’ to make yaw movements of module related to car-body with very low resistance. And passive coupling mechanism was applied between moving joints located at car ends and car center to avoid unexpected or abnormal vibration.

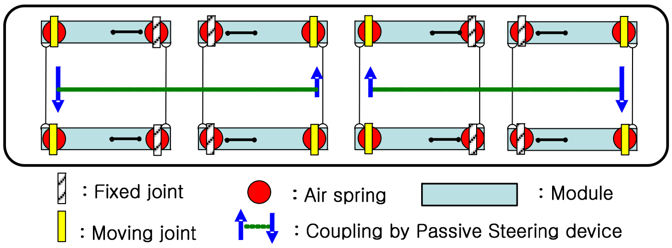

Figure 2. Schematics of passive steering system of target vehicle

This configuration of several components is to induce ideal arrangement of 8 modules of one vehicle on narrow curve and to improve the performance of curving negotiation, which was verified through the field test of proto-type vehicle on test track located in KIMM.

2.2 Active steering system

To improve performance of running on curve the active steering system is introduced as shown in figure 3. The purpose of this suggestion is to substitute active system for existing passive system, so active steering system is required additional components as controller, driver, actuators and two types of sensors as acceleration sensors for car-body and displacement sensor for each actuators. It is assumed that Position of train-set on track is informed to controller through signal system.

In this study both full-active system and semi-active system are to be considered. It is assumed that full-active system should have actuator and its driver, meanwhile semi-active system have adjustable damper.

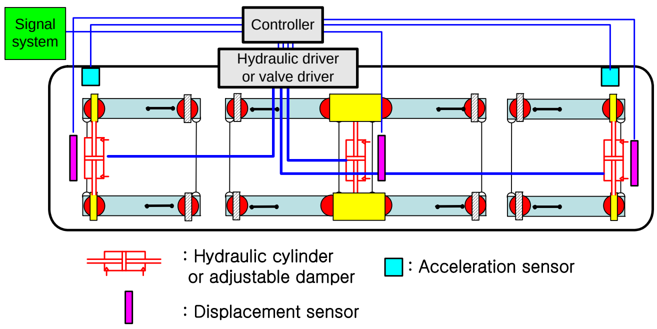

Figure 3. Schematics of active steering system

The Control algorithm is designed with two modes, one is sky hook algorithm for straight track and the other is input shaping algorithm for transient curve track. Control algorithm switches one mode to the other according to location of vehicle.

3 SIMULATION

3.1 Modeling of vehicle and steering system

The vehicle model for dynamic simulation was developed by dynamic analysis program as shown in figure 4. To simplify simulation model of total vehicle model including levitation system, the model of levitation system was made by elements of wheel/rail and primary suspension of railway dynamic software as ‘VI-rail’, which imitate vertical resonance and centering force of levitation of characteristics of proto-type maglev.

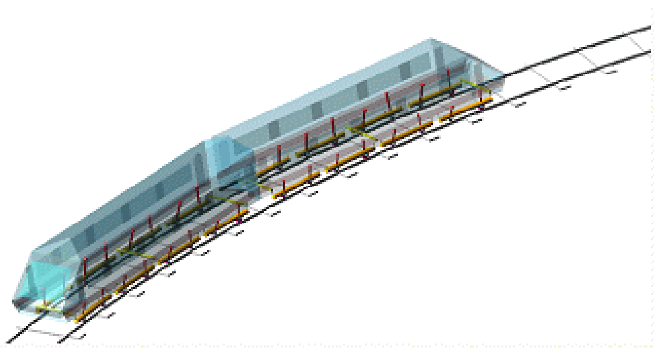

Figure 4. Simulation model of Maglev

The simulation model for full-active steering and semi-active steering system was made in Simulink as shown in figure 5. The vehicle model was included in this model as orange sub-system block. Then co-simulation was done to analyze and to compare performance of passive steering system with one of active system. The mode of full-active and semi-active system is selected by manual switch in simulate model.

The applied track was design according to existing test track with curve radius, cant angle and transient curve length as 180mR, 14 m/s and 3 degree of cant.

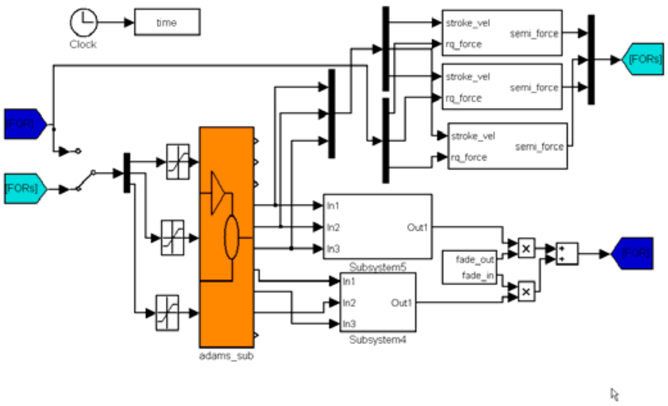

Figure 5. Simulation model of steering system with vehicle

3.2 *Simulation results*

Dynamic analysis of proto-type maglev with passive, semi-active and full-active steering system was done through co-simulation of vehicle running 190m during 12 sec and the pattern of vehicle motion is very similar with one of conventional railway vehicle.

Analysis results of lateral accelerations of both ends of vehicle with three steering systems were presented for comparison of their performance in figure 6 and 7. As expected, full-active steering system makes the least peak acceleration and semi-active does less.

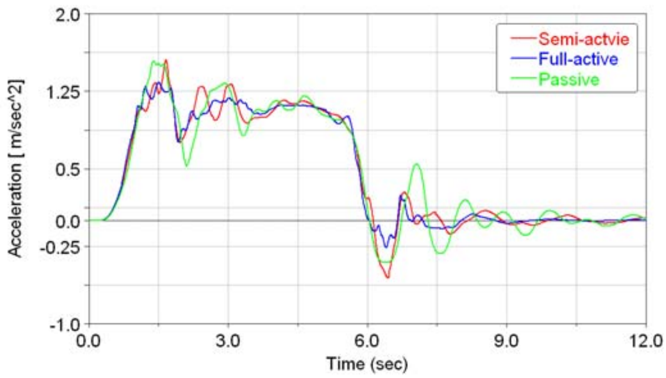

Figure 6. Lateral accelerations of front end of car-body

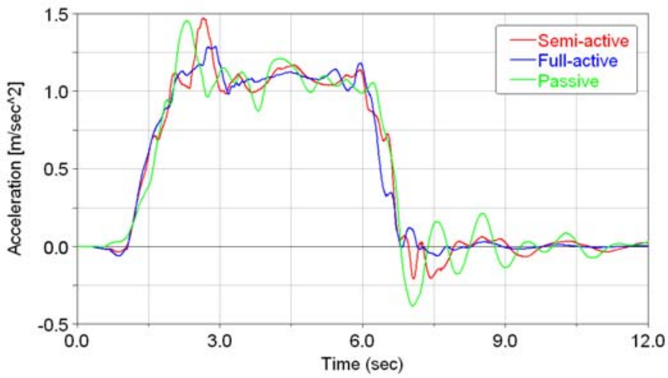

Figure 7. Lateral accelerations of rear end of car-body

The obvious improvement of vibration of carbody is located in returning straight line from curve track and the peak acceleration was reduced as at least 10%. The advantage of full-active system is not shown through this analysis but it is to be increased through additional study for control algorism.

3.3 *Design of semi-active steering system*

Though full-active steering system makes best running performance, but it is not easy to realize because a full-active steering system should have actuators and additional inverter or hydraulic power source and it influences the total mass of vehicle and increase the complexity of arrangement of vehicle.

In the view of realization semi-active steering system can be solution on existing proto-type vehcile and had been determined to develop that for existing maglev and the proto-type components were developed as figure 8.

We got a plan to take a field test for semi-active steering system on proto-type maglev on KIMM test track within near future.

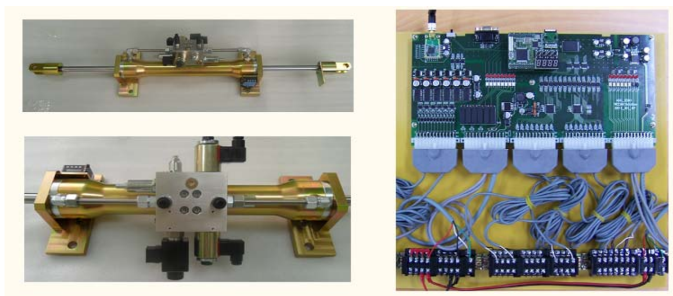

Figure 8. Proto-type of semi-active actuator and controller

4 CONCLUSION

Passive steering system was equipped with on proto-type vehicle and it works as designed. And full-active and semi-active steering system were introduced to improve the running performance, especially curving negotiation. For dynamic analysis, simulation model of steering system and developed urban maglev was developed with two different simulation softwares. Then co-simulation was done and analysis results of different systems were compared. Through this study possibility and necessity of active steering system for maglev was found out.

ACKNOWLEDGEMENTS

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