DYNAMIC SIMULATION AND ANALYSIS FOR SUSTAINABLE TRANSPORT SYSTEMS

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ABSTRACT
For the achievement of sustainable society, the energy efficiency of transportation system has become more important. “Low Emission & Energy Saving”, “Safety & Security” and “Comfort & Healthy” are important target for the sustainable transportation. In this presentation, the author will show examples of dynamic simulation and analysis using various modeling and simulation.

1. INTRODUCTION
For the achievement of sustainable transportation, The Advanced Mobility Research Center was established in the Institute of Industrial Science, The University of Tokyo for the integrated research of human-vehicle-infrastructure in April 2009 concentrated to the following three topics: Research and development of ITS (Intelligent Transport System) for road traffic and automobiles, Advanced Public Transit System, and Personal Mobility. For these topics, the research and development of various types of vehicles are made using dynamic simulation and analysis have been conducted. The use of motion simulator and analyses using hardware-in-the-simulation technologies are useful methods in these research areas, and it requires real-time simulation and detailed modeling in the vehicle motion. The application of control technology to improve vehicle behavior and ride comfort becomes very important. The modeling for vehicles for controlling is required by the simple and reduced degrees of freedom, however, the precious multibody dynamic simulation are also necessary to confirm the availability and check the control performance. Especially, the modeling of interface of road and tire in automobiles, rail and wheel in railway vehicles are key points for modeling. The validation of dynamic simulation is also important process for development of advanced mobility. Scaled model experiments and full scale experiments should be made under the fixed conditions of parameters affected to the vehicle motion. In this article, the author will show some results of dynamic simulation and analysis using various modeling and simulation.
2. AUTOMOBILE APPLICATIONS

For the automobile application, control of light weight body of heavy duty trucks and trailer, and control of tire camber angle. Electromagnetic active suspension system was developed to suppress torsional vibration of a heavy vehicle frame with focus on the anti-rolling performance. As rigorous analysis, the heavy vehicles are treated as the torsional body is modeled as a cylindrical model of torsional vibration to describe the torsion of the frame of the heavy vehicles (Figure 1). The electromagnetic suspensions which are suspensions including actuators composed of electric motors and ball-screw-and-nuts were used to the heavy vehicle. Heavy vehicles are known to have high positions of centers of gravity. This fact causes heavy vehicles to have pronounced roll motions, which consequently affect the motions and stability of the heavy vehicles. Therefore with electric circuits coupling electromagnetic devices and supplied electric energy, electromagnetic suspensions can increase the stiffness of the truck frame like a stabilizer therefore the maneuverability and the stability of the large vehicle can be improved. In this application, real vehicle experiments were made.

![Figure 1: Modeling of heavy vehicle and experiments with trucks.](image)

Another application of heavy duty trucks is rollover prevention of articulated vehicles by usyng flywheel energy storage system (Figure 2). The use of long articulated vehicles is economically attractive due to lower costs per mass of cargo. However, it has been shown that articulated vehicles can suffer from dangerous rollover instabilities from its distinct structure. The use of flywheel energy storage systems as a stabilizer for articulated vehicles by using gyroscopic effect is proposed. The flywheel has the gyroscopic effect. In this application, modeling for controlling and multibody dynamics simulation are made for confirm the controlled performance and validation of modeling with scaled model experiments of the articulated vehicle.

![Figure 2: Rollover prevention using gyro stabilizer.](image)

For the tire dynamics and control, the camber control by tire with tow layer compound for tread part is made to improve fuel efficiency of automobile (Figure 3). A tire with two tread
regions was developed: one region was designed for low loss and the other for high grip. The tire characteristics were determined using a tire testing machine and analysis. For comparison, the characteristics of a low loss tire and a high grip tire were also measured. In subsequent vehicle experiments, the tire with the two-compound tread was evaluated for both rolling resistance and full braking characteristics. The proper implementation of camber control with the two-compound tire was shown to result in both reduced coasting coefficient and improved braking performance.

![Figure 3: Camber control with two compound tire.](image)

3. RAIL VEHICLE APPLICATIONS

For the railway and public transport application, the new concept of LRT (Light Rail Transit) vehicles with negative conicity for very tight curving and safety improvement of railway vehicles is made.

The self-steering ability is very low with independently rotating wheels (IRW) with axle. So, the new concept of independently rotating wheelset using inverse tread conicity is proposed by author (Figure 4). The new concept of the use of independently rotating wheelset to achieve self-steering ability using inverse or negative tread conicity. In the design of conventional railway bogie with two rigid wheel sets, the optimization design method for suspension stiffness and the theory of asymmetric suspension design have been developed.

The LRT system attracts attention as urban traffic system as the next generation mobility, because of eco-ability and accessibility. LRV often has independently rotating wheels to get low floor design. The effectiveness of the vehicle with two single-axle bogies that use two IRW units with inverse tread conicity is confirmed by theoretical analysis, numerical simulations and 1/10 scaled model experiments.

![Figure 4: Self-steering IRW wheel set with negative conicity.](image)

Another application is the study on the development of the detection system of signs before the wheelclimb derailment at low speed (Figure 5). The proposed system detects abnormal vehicle signs before derailment using MEMS (micro-electro-mechanical system) acceleration sensors for automobiles. A derailment detection algorithm is investigated using derailment simulations and experiments. Numerical analysis with a scaled vehicle model simulating
wheelclimb derailment at low speed is examined. A scale model of a railway vehicle including one carbody with two bogies as well as an original device that can simulate various wheelclimb derailments for the selected wheel were designed and made. Based on numerical analysis and scaled derailment experiments, an algorithm for detecting signs of derailment beforehand is proposed and verified. It is found that, using the peak threshold of the pitch angular rate and the integral threshold of the roll angular rate of the truck frame, it is possible to detect signs of potential derailment.

4. CONCLUDING REMARKS
The modelling of dynamic systems and simulations are important tools for analyses of sustainable transportation systems. The new concept and the new mechanism of the system should be examined for availability in the real world. Finally experiments with actual vehicles or the scaled model experiments are made for validation of analyses.