Development of a New Railway Simulator

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We are developing a computer-based railway simulator to reproduce various events taking place during train operation for use in the future as a tool to evaluate the safety, reliability, comfort and economics of railway operations. It is designed to support management of the whole railway with the aid of computers. As the first step, in fiscal 2010 we started the development of a core software system of railway dynamics simulations to begin the eventual construction of "a virtual railway test line" and "an earthquake disaster simulator." The latter is discussed elsewhere in this newsletter. The virtual railway test line software will be built to reproduce and predict the vibration, noise and track failure experienced in normal train operation (Fig. 1), using a high performance computing (HPC) technology lying in the background. The test line not only reproduces field tests of trains but also enables investigation of hitherto difficult-to-observe phenomena through the application of HPC technology. We are now developing the following four subsystems that will function under the core system, each through the modeling techniques specified below within the affixed brackets.

(1) Vehicle and track dynamics simulator (Multi-Body Dynamics (MBD))
(2) Wheel/rail/track dynamic interaction simulator (Finite Element Method (FEM), Distinct Element Method (DEM)), Fig. 2
(3) Pantograph/catenary dynamic interaction simulator (FEM), Fig. 3
(4) Aerodynamic force and noise simulator (Finite Difference Method (FDM)), Fig. 4

We will use the subsystem shown in Fig 2 to analyze the rolling contact between wheel and rail, determine the wheel/rail creepages and forces at very high frequencies, reproduce the dynamic behavior of track components when the changing load propagates to the ballast and sleepers, and clarify the mechanisms of rail wear/damage and track deterioration. We will use the simulator shown in Fig.4 to reproduce the air flow around trucks, roof-top current collecting devices and other objects with complicated profiles with the train running at high speed, and predict aerodynamic force and noise generated on cars. As these models for analysis feature a tremendous number of elements, 100 million or more, a parallel computation technology is used to reduce the calculation time.

The virtual railway test line will exhibit its true power in the prediction of long-term deterioration, wear/damage of wheel/rail and track irregularities that will progress as train passes increase. To reproduce and evaluate countermeasures against these phenomena, it would take several years on revenue service lines, whereas simulators will complete the task only in several days. Therefore, we are now doing our utmost to develop the subsystem in Fig.2. We have already established an elasto-plastic FEM model that can be accelerated up to 300 km/h with wheels subjected to vertical loads and driving torque. We have also developed a model to enable analysis of the wave transmission phenomenon with loads fluctuating at high frequencies applied on an assembly that has reproduced a three-dimensional ballast configuration (Fig. 2).

After completing the subsystems, we will integrate them into a virtual railway test line in the future.

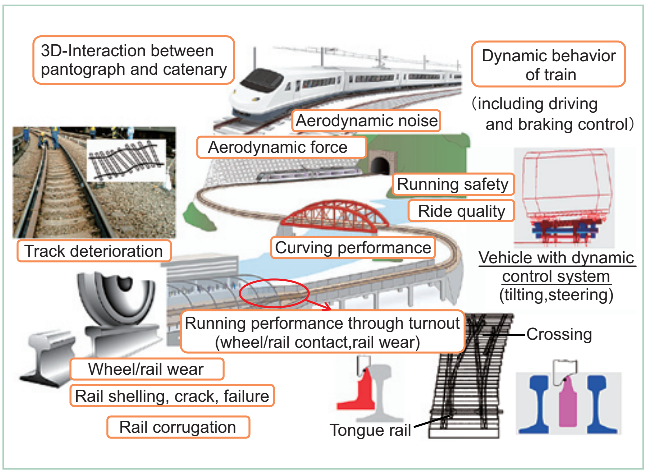

Fig. 1 Virtual Railway Test Line

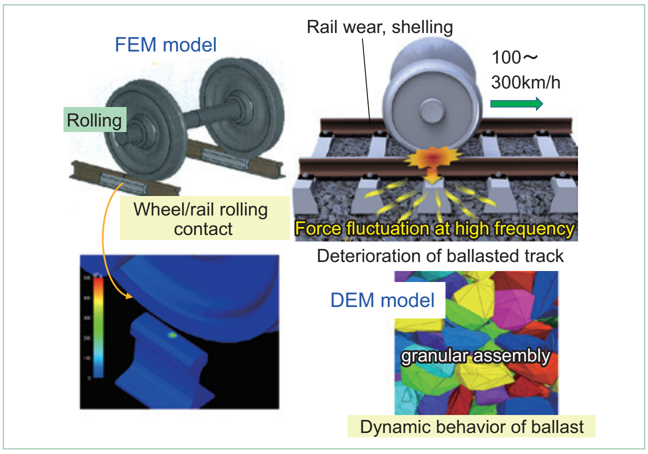

Fig. 2 Wheel/rail/track dynamic interaction simulator

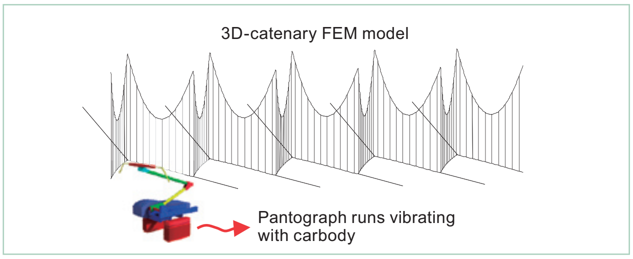

Fig. 3 Pantograph/catenary dynamic interaction simulator

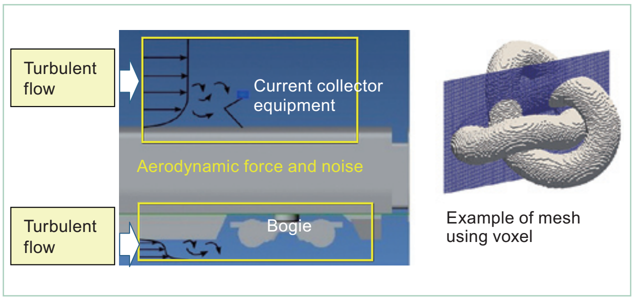

Fig. 4 Aerodynamic force and noise simulator