

SIMPACK at the Railway Technology Research Centre CITEF

The Railway Technology Research Centre (CITEF) in Madrid is an university institute of the Politecnico University of Madrid (UPM), founded in 1999. An enormous amount of knowledge in the field of railway engineering has been accumulated over the past six years. In order to satisfy the needs of our customers we combine the expertise of highly qualified specialists in various, railway-related fields, such as Drive Simulators, Field Measuring/Testing, and Railway Dynamics Analysis. When dealing with exigent projects in the railway dynamics sector, CITEF is opting for the simulation tool SIMPACK which we consider to be extremely suitable for MBS simulation in the railway engineering field. SIMPACK has been used at CITEF in a wide variety of applications, some of which will be presented in the following paragraphs.

ROLLING STOCK MODELLING AND SIMULATION

CITEF has acquired a great amount of knowledge in the modelling of all types of rolling stock vehicles. Successfully completed projects include highly detailed models of underground, intercity and freight trains, as well as locomotives.

For example, the entire rolling stock of Metro de Madrid underground, comprising five different train series, has been modelled (Figures 1 and 2). The models present a high degree of detail in order to maximize the exactness of the simulations results. With the completed SIMPACK models, several types of simulations were carried out in order to compare the various rolling stock series. The simulations included derailment risk and ride comfort analyses, as well as assessment of guidance ability and running stability. By means of a non-linear stability analysis, the Hopf bifurcation diagram of the vehicle was obtained, showing a strong dependence of the wheel and rail profiles used. For quasi-static curving analysis, several characteristic parameters were gathered, such as vertical and lateral

wheel-rail forces, longitudinal creep forces, Nadal's derailment coefficients, wear indexes, lateral wheelset forces, roll coefficients, and uncompensated lateral accelerations. With regard to comfort study, the Sperling index, and other indexes, suggested in the ISO 2631 standard, were used.

In another appealing project, commissioned by the Spanish freight train manufacturer Tafesa, simulation techniques were used in order to analyse a freight train from the point of view of dynamic behaviour, safety, ride quality, and track fatigue, as proposed in the UIC 518 leaflet. The freight train is equipped with modified Y-21 bogies that had been adapted for meter-gauge (Figure 3). Difficulties in finding an appropriate narrow track section for field testing, as recommended in the UIC 518 leaflet, necessitated simulating in SIMPACK and turned out to be a suitable alternative. For this purpose, a complete wagon was modelled, several track layouts and quality classes of track were defined, and a set of simulations at the maximum allowed speed were performed. In the post process stage, several parameters were gathered, similar to those mentioned in the previous paragraph. Finally, an elaborate statistical analysis of these results was performed, in order to compare them with the admissible values stated in the aforementioned leaflet.

TRACK MODELLING AND STUDY OF THE EFFECTS OF A BROKEN RAIL

Another project involved the investigation of the influence of a broken rail on overall vehicle stability (Figure 4). For that task, the track was modelled entirely in the finite element program ANSYS. One of the track models incorporated a discontinuity, simulating a broken rail. The track models were then imported to SIMPACK as elastic bodies. The combined model included not only the standard wheel-rail contact module but also contact surfaces allowing the simulation of the impact between wheel and broken rail. The

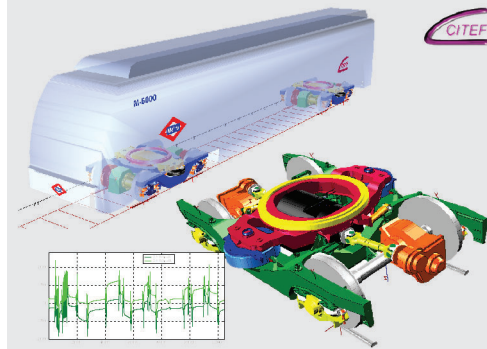


Fig. 1 Curve Riding Analysis with Metro de Madrid Rolling Stock

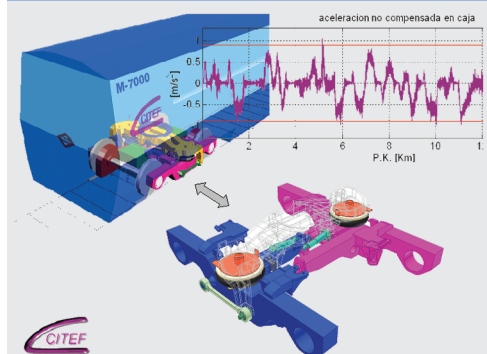


Fig. 2 Simulation of a Two-Piece-Bogie

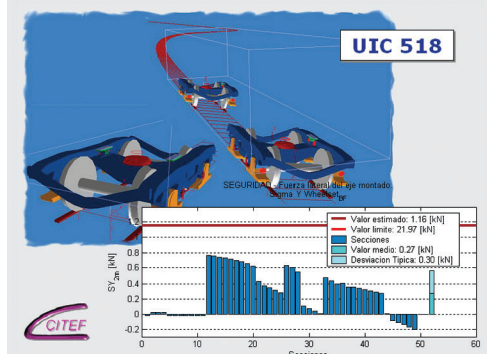


Fig. 3 Meter Gauge Freight Wagon - Application of UIC 518

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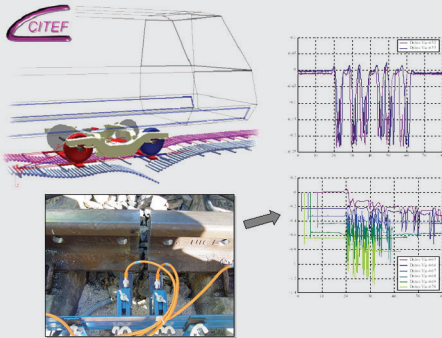


Fig. 4 Broken Rail Analysis

stiffness and damping constants needed in the latter contact model were determined by comparing measured data with simulation results. With the validated model, pending simulations will be carried out, analysing the influence of several variables, such as track layout (straight/curved), wheel load, track elasticity, sleeper distance, etc. This research project has been financed by Metro de Madrid.

DESIGN OF A NEW OVERHEAD CURRENT CONDUCTOR RAIL

The advantages of overhead rail current collection system for railway traction, such as low installation height, ease of installation and reduced maintenance, have been the key factor for Metro de Madrid when choosing the rigid catenary to be their future electrification system.

CITEF was asked to evaluate the original current collection system and to develop a new, superior overhead conductor rail for application in future underground lines and upgrading of existent ones. A complex simulation model of pantograph and catenary was set-up entirely in SIMPACK. The advantages that SIMPACK offers when modelling in three dimensions were utilised in both pantograph and catenary models. The modelled pantograph incorporated all features and components of its real counterpart, including the elevation gear and all degrees-of-freedom of the pantograph mechanism. The conductor rail was first modelled in a finite element program, and then imported to SIMPACK as an elastic body. Three-dimensional features, such as stagger and section overlaps were also included. The complete pantograph-catenary interaction model included contact surfaces that simulated the contact areas between contact wire (catenary) and contact strips (pantograph). Parameter variation facilitated the development and design of a completely new overhead rail current collecting system. The efforts lead to a new design which was protected by two European patents

for both conductor rail and an innovative, light-weight section insulator (Figure 5).

TRAIN ACCIDENT ANALYSES AND DERAILMENT STUDIES

A special field of rolling stock application are derailment reconstructions. Simulation can provide important insight into the mechanisms and causes of a real derailment. The reproduction of two important derailment accidents in European intercity rail traffic was commissioned by the Spanish Railway Administration, RENFE, and the Spanish Infrastructure Administration, ADIF. Possible derailment processes were reconstructed and used as evidence in juridical court (Figure 6). In train accident analyses, parametric variations are commonly used in order to locate the possible derailment causes, such as obstacles on the track, excessive running speed, rail defects, failure of suspension components, etc.

An uncritical derailment occurrence, involving an underground train passing through a turnout, also has been reconstructed satisfactorily using the SIMPACK contact module. Intense testing with contact surfaces, simulating the collision between wheel flange and frog, was performed.

SIMULATION OF LIQUID-VEHICLE INTERACTION IN A FREIGHT TRAIN WITH TANK CONTAINERS

Another example for interdisciplinary modelling is the simulation of fluid motion in partially filled tank containers of freight wagons which has been realized for the Spanish Rail Operator, RENFE Operadora.

Two-axle freight wagons are connected to each other through UIC standard European couplers, located at mid-distance between buffers. As each platform is equipped with a coupling screw hook at each end, only one of them is used, while the other rests on a hanger. Due to sloshing effects in tank containers used to transport liquid cargo, this un-used hook jumps out of

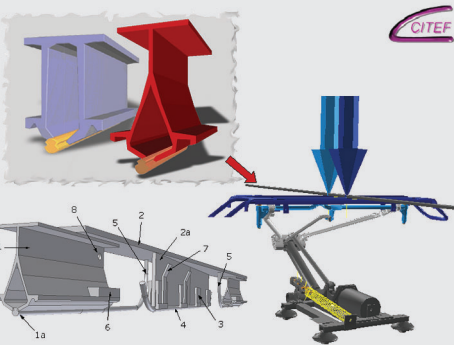


Fig. 5 Design of an Improved Conductor Rail

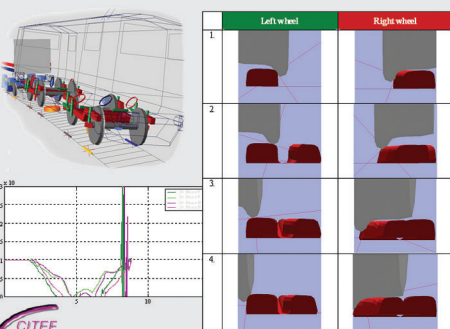


Fig. 6 Derailment Studies

its hanger, oscillating like a pendulum. In order to find the main cause for the sloshing effects, a model of fluid-vehicle interaction was set up (Figure 7). The freight train has been modelled as a multibody system. The fluid sloshing motion has been incorporated by means of equivalent mechanical models. These equivalent mechanical models have been validated by two- and three-dimensional simulations of liquid motion inside tanks. Fluid dynamic modelling in the finite element program ANSYS was used in order to study the liquid motion. Simulations of the combined model in SIMPACK showed that the freight train's overall stability was not in danger at any time. Several factors had been taken into account for assessing system stability, such as track layout, track defects, wheel wear, and traction/brake pattern. However, the original problem of the undesired release of the traction hook was attributed to an uncritical resonance phenomenon that had been observed in simulation.

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Fig. 7 Fluid-Vehicle Interaction

