1 General

These are the SIMPACK results of the US DOT LD Benchmark. The following pages show the result data in graphical form (plots). Each exercise occupies 12 pages. Additionally to the required results, the energies in the degrees of freedom, the contact forces and the wheelset load and gravity are also plotted separately.

Due to the chosen integration method SIMPACK has nearly no numerical damping. Due to the fact that no contact damping was allowed for the benchmark calculations, some of the results show strong oscillations, especially for Exercise 2.

These results have been generated with one of SIMPACK's new rail-wheel contact methods: for all exercises a Hertzian elastic contact formulation has been used since it was supposed to fulfil the requirement of an accurate prediction of the normal forces in the best way.

1.1 Result Annotations

The sampling rate is 5 kHz for case 1 and 2 kHz for case 2. Please note that the actual integration stepsize is chosen automatically and may vary during the simulation, in order to cover all dynamic effects.

The signs of all positions and forces are as shown on page 3 of the *LD Benchmark Call for Simulations* paper: x in direction of travel, y to the left, z upwards. Please note that this system is different from SIMPACK's original system (y to the right, z downwards), so the results have been mirrored for the plot and the ASCII export. Since profile origins in SIMPACK are usually related to the taper line and the rail head middle, the profiles were shifted by the following amounts:

- wheel profiles (actual and synthetic): by –70 mm,
- rail profile, actual: by –35.56 mm,
- rail profile, synthetic: by –57.9855 mm.

The contact angles and contact point positions are given in SIMPACK's wheel co-ordinate system with the y origin in the taper line. The contact point positions and the rolling radii take the elastic deformation (of the wheel) into account.

The vertical and lateral wheel forces are given in the track system.

In Exercise 2, Case 5 the energy of the external lateral force has not been considered for the total energy, so the total energy sum is not constant.

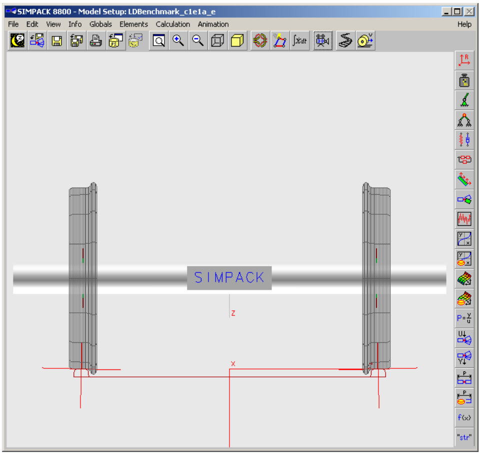
A constant offset of 10^{-12} rad in the tread contact angle plots had to be added in order to avoid some plotting problems. It does not come from the profile data and does not appear in the ASCII results.

The nomenclature of the file names is: "c*n*" = Case *n*, "e*n*" = Exercise *n*, "a/s" = Actual/Synthetic Profiles, "_e" = elastic (Hertzian) contact.

2 Software Description

SIMPACK is a general multi body simulation software. The add-on module SIMPACK Wheel/Rail provides the modelling elements necessary for wheel-rail simulations: track, irregularities, wheel-rail contact, force elements like airsprings etc.

SIMPACK Wheel/Rail is the common MBS tool at Siemens Transportation Systems, Bombardier Transportation, Stadler Rail Systems, Vossloh Locomotives, Voith Turbo Lokomotivtechnik, Ansaldobreda and other companies. It is used at Alstom LHB, Deutsche Bahn, JR East and consultant and engineering companies as well as at many universities worldwide.



Model Setup of the LD Benchmark Wheelset in SIMPACK

2.1 General

The core of SIMPACK is based on a non-linear multi body system formalism (MBS), using absolute and relative co-ordinates. No small angle assumptions are made for a model's kinematic relations. (If linear system analysis is requested, SIMPACK starts a numerical linearisation in the sense of a Taylor series development.) Due to a relative-kinematics formulation of the equations of motion, the calculation effort increases only linearly with the number of the degrees of freedom.

Although SIMPACK offers several types of solvers (fixed stepsize and tolerance-based variable stepsize, ODE and DAE solvers), the SODASRT integrator is used in most cases and has therefore been used for this benchmark as well. It is a numerically very stable variable-stepsize DAE solver based on DASSL.

The following steps are required for producing the simulation results:

- Model set up (definition of the structure and the parameters of the simulation model, definition of the animation model).
- Configuration of the track cases using SIMPACK standard elements and tables (the benchmark analyses included only straight track without irregularities).

- Computing the nominal pre-stress forces for the given reference position (for the benchmark analyses not necessary).
- Numerical integration of the equations of motion (for the benchmark the standard settings were used, but with refined solver tolerances to achieve a higher accuracy).
- Configuration of the sensors and output channels for getting the measurement signals.
- Configuration of the plot pages for the plot output by selecting the output channels of state variables, internal values of the force elements and sensors signals.
- Script-based automatic output of graphics and ASCII files.

2.2 Description of the Contact Modelling

2.2.1 General

One of SIMPACK's new rail-wheel contact models, a Hertzian contact model, has been used, allowing an arbitrary number of contact patches on a rail-wheel pair simultaneously, each of which is evaluated separately. In order to achieve maximum accuracy, the contact equations are calculated online, no tables are used.

2.2.2 Normal Force

The normal force is calculated using the Hertzian formulas. The contact condition is the equality of the profile tangents of rail and wheel in combination with a minimum profile normal distance.

The material constants were E = 2.1e11 N/m² and ν = 0.28.

The contact damping has been set to zero.

2.2.3 Creep Forces

The creep forces are usually calculated by means of the FASTSIM algorithm (SIMPACK offers several other creep force laws as well as user force laws). For this benchmark however the creep force calculation has been switched off.