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Summary

These release-notes document the changes in CONTACT version 23.2 with respect to version 23.1. The main changes are as follows.

- Added variable wheel profiles for the simulation of wheel out-of-roundness.

1 Simulation of wheel out-of-roundness

Out-of-roundness of railway wheels can cause increased levels of noise and vibration (in case of polygonisation) or severe impact loading (in case of discrete irregularities) [1]. Computer simulation techniques are needed to study the dynamic wheel/rail interaction for out-of-round wheels. On the

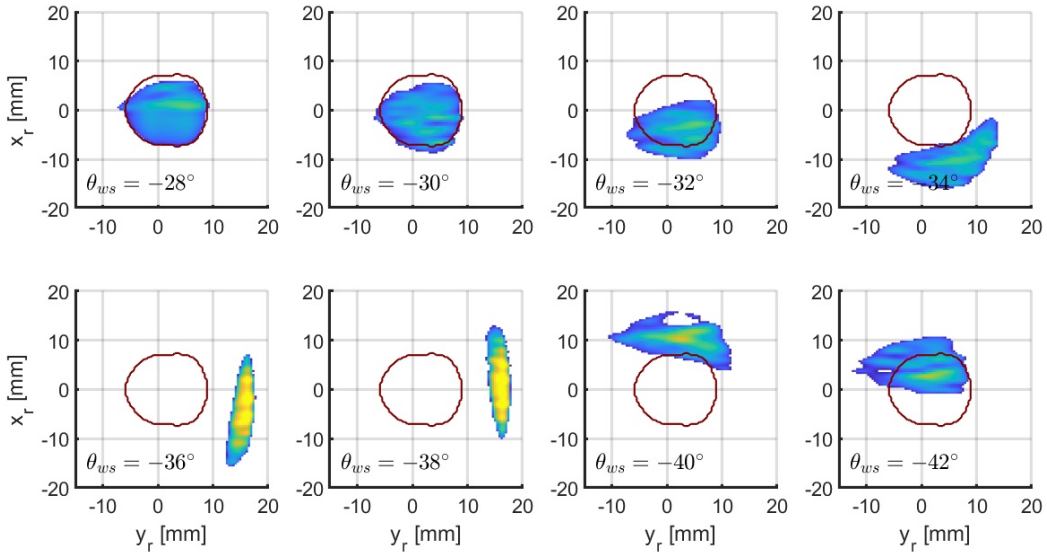

Figure 1: *Computed contact patch shapes and pressures p_n for Chalmers' measured wheel flat approaching, passing through and leaving contact at constant vertical force. Contour: corresponding contact patch on nominal wheel profile without out-of-roundness.*

one hand this aims at the investigation of formation mechanisms and growth of out-of-roundness, and on the other hand its consequences like noise, vibration or deterioration of the track system [1].

Support is added to CONTACT for the detailed modeling of wheel out-of-roundness. Generic algorithms are used to analyze the wheel/rail contact geometry based on a full 3-dimensional wheel representation, capable of predicting contact at any location along the wheel's surface. This development is part of a project supported by the US Federal Railroad Administration (FRA).

The surface for an out-of-round wheel is input to CONTACT using a wheel slices-file with `slcw` filename extension. Wheel slices-files are structured similarly as rail slices-files that were introduced previously for modelling of switches and crossings [2], except that longitudinal s_{fc} positions along the track curve are replaced by angles $\theta_{wc} \in [-\pi, \pi)$ around the circumference of the wheel, and vertical heights z are replaced by radial heights dr with respect to the nominal radius.

Wheels with out-of-roundness cannot be computed using the contact search method based on the contact locus. CONTACT automatically switches to use the grid-based method instead. This grid-based contact search is rather slow. New contact search methods are needed to speed up this calculation.

Results are shown in Figure 1 for a measured wheel flat at eight wheelset pitch angles θ_{ws}. Dynamic effects are excluded using a constant prescribed vertical force $F_z = 125\,\text{kN}$. The dark-red contour shows the outline of the contact patch for the nominal profile. From this we see how the contact patch shifts back at first, moves sideways and then advances ahead of the nominal patch, after which it finally comes back to the reference shape and position. Measurement data for this wheel-flat were provided thanks to prof. Nielsen of Chalmers University of Technology [3, 4], see the example `wheelflat.inp` in the User guide, Section 5.8.

2 Resolved problems and general improvements

Several smaller extensions and improvements are made, the main ones being

- A programming error is corrected in the grid-based contact search concerning the estimate of sensitivity $\partial F_z/\partial z_{ws}$. This correction yields a 1.5 time performance improvement for cases with prescribed vertical force ($\texttt{D} = 5, \texttt{N}_1 = 1$).
- Improvements are made for wheel-on-roller contact situations ($\texttt{C}_1 = 4, 5$) at larger yaw angles ψ_{ws} introducing longitudinal shift of the contact position.
- An issue is fixed in the `npot_max` feature combined with conformal contact computation ($\texttt{D} = 4$). (`npot_max` is a safeguard against excessively large interpenetration values introduced in version 23.1.)
- An additional control integer X (XFLOW) is introduced to provide access to developer print-output. Using $\texttt{X} = 1$, the program reads a fourth control word PSFLRIN configuring output on Profiles, Smoothing, total Force iteration, contact Location, input Reading, Influence coefficients, and the Norm and tang algorithms.

- An issue is solved in the KPEC algorithm regarding small contact patches.
- The CONTACT library will reset the output-file when initialized anew after `cntc_finalize_last` has been called, i.e. restarting without unloading/loading the dll.
- A new function `getprofilevalues_new` is added for retrieving profiles with resampling.
- The arcfit smoothing method has been deleted.
- The Matlab function `cntc_getcpresults.m` is extended to deliver the rail and wheel profile data, facilitating making pictures using `plot3d`.

3 Compatibility w.r.t. previous versions

No changes are needed to user input files to upgrade from the previous release to the current one, and no changes are made to the output-file.

The format of the mat-file is changed with respect to the previous release, adding the wheelset pitch angle θ_{ws}.

No changes are needed to user programs calling the CONTACT library version.

- A new subroutine `cntc_getprofilevalues_new` is added with additional options and additional inputs compared to `cntc_getprofilevalues`. This can be used safely instead of the original version.

The Matlab-scripts for plotting have been extended in several places.

- `make_2dspline`: added optional inputs `xij`, `use_insert`, `use_cylindr`;
- `eval_2dspline`: added optional input `x_in` and optional output `x_out`;
- `plot_2dspline`: removed the first argument `sol` and reorganized the options: `x/urange` are renamed to `u/vrange`, `coordsys` is removed, `typplot` and `reflec_a` are added.
- `plot_update`: added an optional argument `show_angl`.

4 Known problems and restrictions

- Computations using variable rail or wheel profiles are rather slow, compared to computations with constant profiles.
- The contact locus method (`D` = 2) is not fully robust for variable rail profiles with rapid fluctuations, especially related to poor feature information. This may be circumvented using the grid based approach (`D` = 5).
- Subsurface stresses are computed using elastic influence functions, also when the problem uses the viscoelastic material model.

References

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[2] E.A.H. Vollebregt, P. Klauser, A. Keylin, P. Schreiber, D. Sammon, and N. Wilson. Extension of CONTACT for switches and crossings and demonstration for S&C benchmark cases. In W. Huang and M. Ahmadian, editors, *The 28th IAVSD Symposium on Dynamics of Vehicles on Roads and Tracks (IAVSD2023)*, Lecture Notes in Mechanical Engineering, page paper 236, Cham, 2023. Springer.

[3] M. Maglio, T. Vernersson, J.C.O. Nielsen, A. Ekberg, and E. Kabo. Influence of railway wheel tread damage on wheel-rail impact loads and the durability of wheelsets. *Railway Engineering Science*, 2023.

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