

MEMO EV/M23.005
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Subject Release-notes for CONTACT version 23.1

Summary

These release-notes document the changes in CONTACT version 23.1 with respect to version 22.1. The main changes are as follows.

- Added variable rail profiles for the simulation of contact in switches and crossings.
- Changed coordinate systems for left-side wheel/rail contacts, **changing signs** with respect to previous versions.

1 Simulation of switches and crossings

Background In recent years, there has been considerable interest in the simulation of vehicle track interaction in switches and crossings. A number of benchmark problems have been defined and run using different software codes [1, 2]. Details on the methods used are presented in the method statements [3] and subsequent scientific papers, e.g. [4].

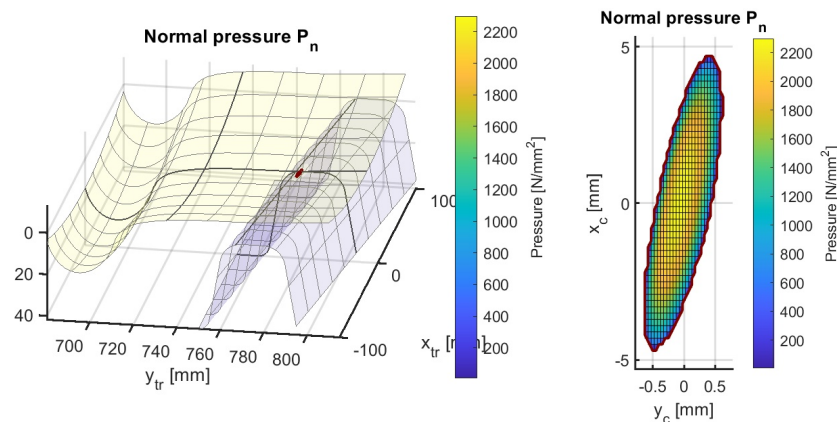


Figure 1: *Contact of a wheel with an artificial wing rail diverging at rate 1 : 10, creating an effective angle of attack of -5.7° .*

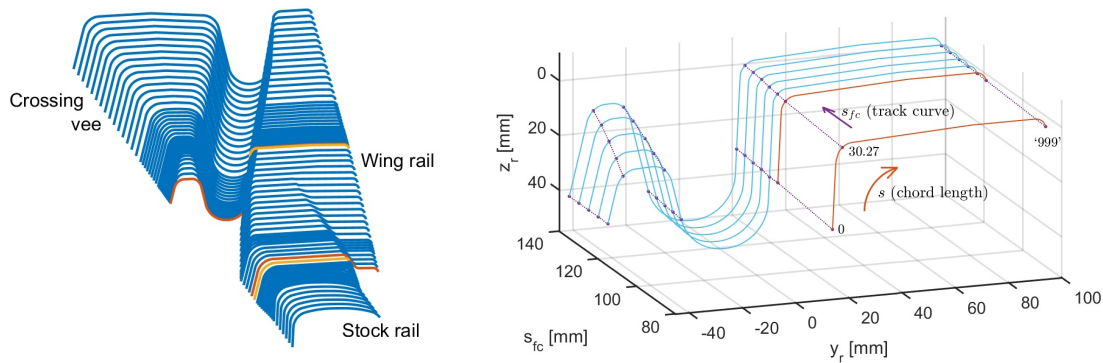


Figure 2: Successive profile slices defining the geometry for a crossing, with geometrical features connected into 'interpolation paths'.

Whereas the benchmark results show reliability and efficiency regarding vehicle dynamics, there is room for improvement regarding the detailed contact results, concerning the contact position, angle, contact patch size and pressure distribution. CONTACT is extended to fill this gap and deliver detailed results for the validation of fast computation approaches as shown in Figure 1.

Variable rail profiles The geometry of switches and crossings is characterized using a series of lateral cross-sections as illustrated in Figure 2. This entered in CONTACT through a so-called 'slices file' (.slcs) with 'feature information' as discussed in the User guide [5], Section 3.2.

Feature information is used to guide CONTACT in 2D spline construction and evaluation.

- Features are helpful to reduce spline overshoot and fluctuations at sudden changes in profile slope and curvature.
- Features are needed to indicate 'missing parts' on shorter slices and corresponding parts on longer slices.

Two different methods are provided for connecting and interpolating between successive slices: an 'interpolating spline' that passes through the points on the slices, and an 'approximating spline' that uses the points as corners of a 'control polygon', creating a smooth approximation.

3D contact search CONTACT uses a fully 3D contact search as discussed in [6], including the effects of yaw and the corresponding longitudinal shift of the contact position. This has been extended for rail profiles with longitudinal variation and the consequent effects on the contact position. Fully 3D surfaces are constructed and used in the contact search and undeformed distance computation.

Two different methods are provided using 'grid based' and 'contact locus' approaches. The contact locus method proves to be more delicate, sensitive to spline fluctuations. To make this work, this needs quite good information on profile features. More robustness is provided by the grid based method, at the expense of lower performance.

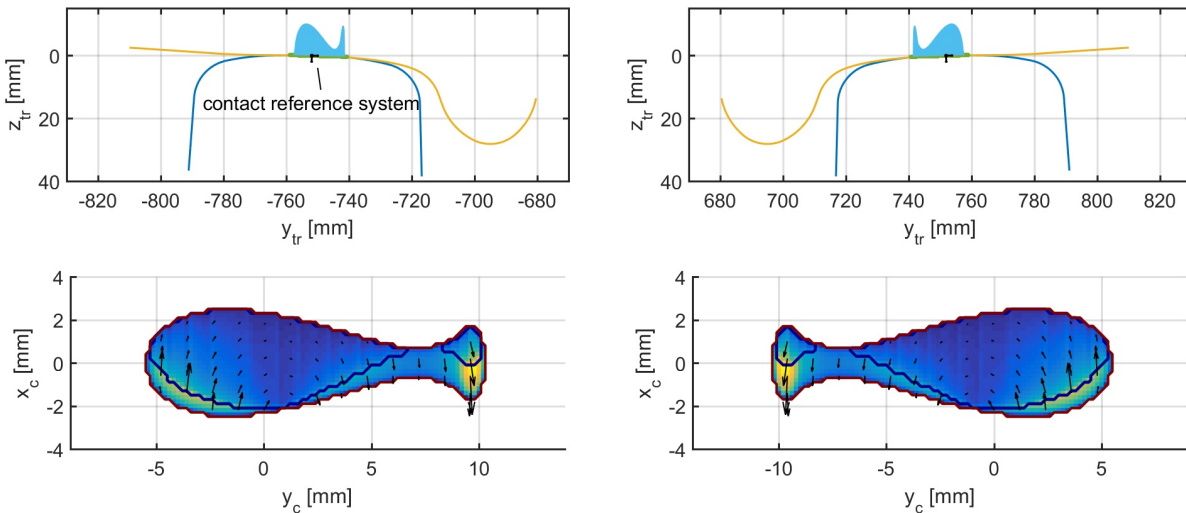


Figure 3: Matlab plots for Manchester benchmark example for left and right wheels. Top: plot of pressures p_n in ‘rear view’ using the track coordinate system. Bottom: surface tractions (p_x, p_y) in ‘top view’ (ptabs+vec) in contact coordinate system.

The contact locus method is selected using $D = 2$ and 4 , for planar and conformal contact approaches. Setting $D = 5$ activates the grid based method, which is provided for planar contact only.

2 Coordinate system for left-side wheel/rail contacts

Inside the CONTACT program, contacts for the left-side wheel of an axle are mirrored to an equivalent problem for a right-side wheel. Previously, this mirroring worked through in the interface, affecting the signs of certain inputs and outputs. At some places there were differences between the stand-alone program and CONTACT library version. This has been corrected.

From now on, CONTACT uses right-handed coordinate systems and corresponding numbering also for left-side wheel/rail contact problems.

Programs working with left-side wheel/rail contacts (CONFIG = $C_1 = 0$ or 4) need to be updated for the changes in sign conventions. This is discussed in detail in Section 4.

The new coordinate conventions are illustrated in Figure 3. y -coordinates are increasing towards the right in all cases. The data in the mat-file are stored using these conventions. The same goes for data in subs-files, and data used in the CONTACT library version.

3 Resolved problems and general improvements

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

- A new function `cntc_getcprresults` is added in the Matlab interface to the CONTACT li-

brary version. This retrieves all relevant results and configuration from a contact patch, in the same structure as used by `loadcase.m`. This facilitates plotting using `plot3d.m` without using a mat-file.

```
sol = cntc_getcpresults(iwhe);  
opt = plot3d;  
plot3d(sol, opt);
```

This is illustrated further in the example `matlab_mbench.m`.

- A maximum ‘`npot_max`’ is introduced for the number of grid elements used in wheel/rail contact problems (module 1). This avoids trouble for cases with incorrect placement of the wheel on the rail, with excessively large interpenetration values. CONTACT uses a fairly large default `npot_max = 20000`. In the CONTACT library this may be changed using `cntc_setflags`; in the input-file, via the input for the G-digit.
- A new feature is introduced to improve the continuity of total forces for contact patches that lie close together. This is called the ‘turning of the reference angle’. An optional input parameter `D_TURN` is introduced for this. For more information consult the User guide [5], Section 3.5.
- The automatic detection for mirroring of z -values is changed, improving the decision for a number of profiles found in switches and crossings.
- An option `scale_yz` is introduced in the Matlab script `read_profile.m`, e.g. to convert data from `m` to `mm`.

4 Compatibility w.r.t. previous versions

New options concerning rail placement were added in version 22.1. At that time, two new routines were added. The old interface was kept in `cntc_settrackdimensions_old` and the new one provided via `cntc_settrackdimensions_new`. Subroutine `cntc_settrackdimensions` was kept as an alias for the old version.

- In this version, the behavior of `cntc_settrackdimensions` is changed, linking to the new version. The necessary steps for updating are shown in the User Guide, Section 7.3.4.

The signs and numbering have been changed for different input- and output variables, regarding cases using `MODULE 1` (wheel/rail contact) for a left-side wheel/rail combination, `CONFIG = 0` or `4`.

- Input: the sign is changed for y -values used in the subsurface stress calculation. Previously y would be increasing to the left on a left-side rail. From now on, y increases towards the right in all cases.

- Output: in the out-file, the sign is changed for variables $y_{cp(r)}$ and $y_{cp(w)}$, the lateral position of the contact reference in terms of rail and wheel coordinates. The profiles are input for the right side and mirrored for use at the left side of a wheelset and track. The outputs are for this final configuration, with y increasing to the right.
- Output: the sensitivities of forces with respect to creepages are adjusted regarding the sign convention.
- Mat-file: the meta-data at the top of the mat-file are adjusted for left-side wheel/rail combinations. This affects the wheel (marker) position y_w , $roll_w$, yaw_w , the rail (marker) position y_r , $roll_r$, and the contact position y_{cp_r} , $deltcp_r$, y_{cp_w} .
- Mat-file: the signs are changed for y -components of vectorial outputs: tractions p_y , rigid slip w_y , and elastic/plastic displacements u_y , $u_{pl,y}$.
- Mat-file: the numbering of grid elements is changed for field data. In lateral direction, numbering starts at the left-most point and increases to the right.
- Subs-file: the signs of output quantities are defined corresponding to a right-handed coordinate system. Numbering of points start at the left-most point and increases to the right.

Corresponding changes to the CONTACT library version are as follows:

- In `cntc_getcontactlocation`, the signs are changed for outputs on the contact reference position, viz. y_{cp_r} , $deltcp_r$ (items 6, 9), y_{cp_w} , $deltcp_w$ (items 11, 14), and pn_y (16), for left-side wheel/rail pairs.
- In `cntc_getcontactforces` the signs are changed for f_y and m_z for left-side wheel/rail pairs.
- In `cntc_getcreepages`, the signs are changed for v_y and ϕ for left-side wheel/rail pairs.
- In `cntc_getsensitivities`, the signs are changed for all sensitivities involving creepages v_y , ϕ , force f_y , and moment m_z .
- The signs are changed on the lateral component of vectorial outputs: quantities p_y , u_y , $u_{pl,y}$, s_y , and w_y , in functions `cntc_getfielddata`, `cntc_gettractions`, `cntc_getmicroslip`, `cntc_getdisplacements`.
- The numbering changed for gridded outputs from `cntc_getelementdivision`, `cntc_getfielddata`, `cntc_gettractions`, `cntc_getmicroslip`, `cntc_getdisplacements`, and `subs_getresults`, reversed in y -direction for left-side wheel/rail pairs.

The format of the mat-file is changed with respect to the previous release, adding the nominal radius for the wheel and (optionally) roller. In the script `read_profile.m`, an optional argument `scale_yz` is added.

5 Known problems and restrictions

- Computations using variable rail 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

- [1] Y. Bezin and B.A. Pålsson. Multibody simulation benchmark for dynamic vehicle-track interaction in switches and crossings: modelling description and simulation tasks. *Vehicle System Dynamics*, 2021.
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- [3] Repository for participants' method statements. University of Huddersfield, 2021. <https://doi.org/10.34696/s60x-ay18>.
- [4] H. Magalhães, F. Marques, P. Antunes, P. Flores, J. Pombo, J. Ambrósio, A. Qazi, M. Sebes, H. Yin, and Y. Bezin. Wheel-rail contact models in the presence of switches and crossings. *Vehicle System Dynamics*, 2022. DOI: 10.1080/00423114.2022.2045026.
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- [6] E.A.H. Vollebregt. Detailed wheel/rail geometry processing using the planar contact approach. *Vehicle System Dynamics*, 60(4):1253–1291, 2022. [Open access](#).