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Summary

These release-notes document the changes in CONTACT version 26.1 with respect to version 25.1. The main changes are as follows.

- A new 'effective contact location' is introduced in the conformal contact approach, improving the results of equivalent conicity computations.
- Track curvature is added for better integration in vehicle system dynamics simulation.
- Smaller extensions and changes were made to the User subroutine for SIMPACK Rail, profile smoothing, plotting functions, and CONTACT library version.

1 Equivalent conicity – effective contact location

The calculation of equivalent conicities relies on the rolling radius difference $\Delta r = r_r - r_w$ between left and right wheels as a function of y_{ws}, the lateral wheelset position. Using CONTACT, this

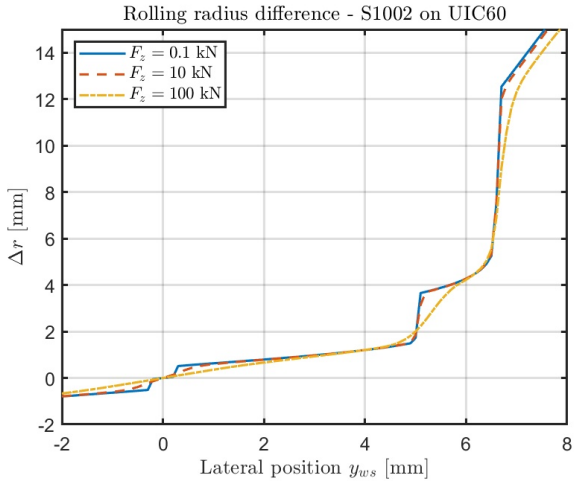

Figure 1: *Rolling radius difference function for S1002 on UIC60 using rigid ($F_z = 0.1$ kN) and elastic contact models ($F_z = 10, 100$ kN).*

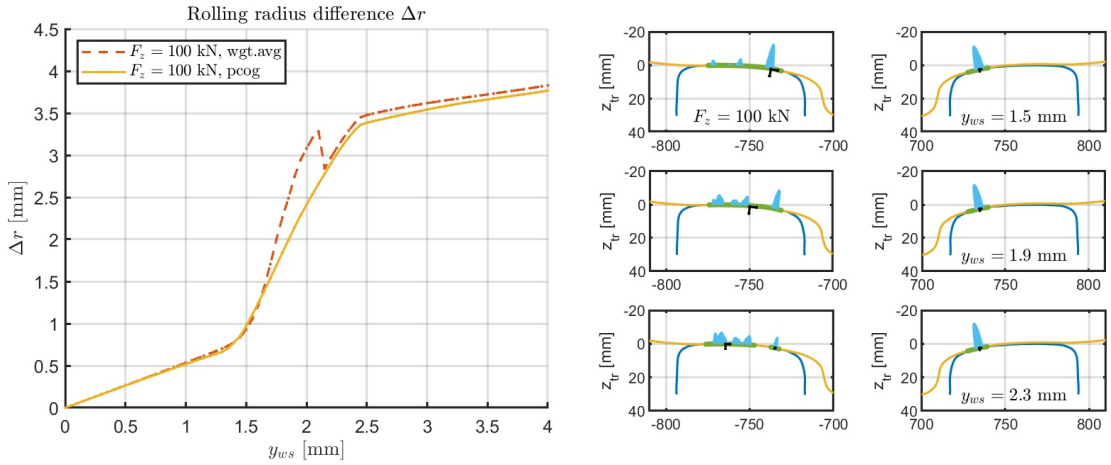

Figure 2: *Rolling radius difference function for measured, worn rail and wheel profiles using the original 'weighted gap' and new 'pressure center of gravity' computations, with hick-up in the original results due to separation of contact patches around* $y_{ws} = 2.2$ mm.

rolling radius difference may be computed using an elastic contact approach, avoiding the sudden jumps of contact location obtained from a rigid contact model, providing more gradual changes of the resulting rolling radius difference Δr (Figure 1).

The rolling radii r_l and r_r are based on the estimated contact location, presented in CONTACT using the contact reference marker. Inaccuracies were found in the reference position that was based on the undeformed distance function. These inaccuracies show up for two-point contacts, especially in situations with measured, worn profiles, where two or more contact patches are separated sometimes and combined into one patch in other configurations (Figure 2).

The conformal contact approach has been improved by (re-)definition of the contact reference position. The reference position is changed from an *a priori* estimate to an *a posteriori* calculation based on the contact solution. The new computation determines the center of gravity of the pressure distribution ('pcog', [1]). This provides a robust and elegant meaning to the *effective contact location*. The improvement is shown in Figure 2, left, with a hick-up in the original results and smoothness for the new calculation.

Previously, the contact reference position $\mathbf{m}_{cp} = \mathbf{m}_{ref}$ was used in two different roles, representing the center of an interpenetration area, and setting the origin for the local coordinates for the contact solution. These roles are separated. A marker $\mathbf{m}_{pot}$ is introduced for the contact grid origin. This requires changes in the conversion from grid locations $[x, s, n]^T_{(pot)}$ to for instance the track coordinate frame, $[x, y, z]^T_{(tr)}$.

- The roll angle of $\mathbf{m}_{pot(tr)}$ is obtained using the roll angle $\phi_{cp(tr)}$ minus the roll angle $\phi_{cp(pot)}$.
- The offset $\mathbf{x}_{cp(tr)} - \mathbf{x}_{pot(tr)}$ is obtained by rotating $\mathbf{x}_{cp(pot)}$ using $\phi_{pot(tr)}$.

This uses the variables `[xyz]cp_pot` and `deltcp_pot` from the mat-file or from library function

`cntc_getcontactlocation`.

2 Improvement of the conformal contact approach

Further changes are made to improve the usability of the conformal contact approach. All-in-all, the conformal method `D` = 4 has become robust and easy to use, while avoiding stability issues of planar contact methods (§1, [2]).

- The outputs regarding contact forces are changed, distinguishing between 'curved' and 'planar' creep forces F_{crv} and F_{pln}. The former consists of the direct integral of contact stresses, ignoring the change of normal direction, used to show how close tangential stresses are to the traction bound. The latter describes the resultant force at the contact reference marker as used in a multibody simulation. Further information is provided in the User guide, [3, §4.5.4].
- An option `D` = 7 is added to use conformal contact with the grid-based contact search algorithm instead of the contact locus.
- The blending of contact patches that lie close together ([3, §3.5]) is improved for conformal computations. The turning of contact reference angles ($d \leq d_{turn}$) appeared ineffective in conformal contact and has been deactivated.
- Additional fields are added to the function `cntc_getfield`, such that the curved reference surface and reference angle can be retrieved in Matlab or other programs using the CONTACT library version.

3 Integration in vehicle system dynamics simulation

A couple of changes were made to facilitate the integration of CONTACT in vehicle dynamics simulation.

- Options are added to retrieve the case number as used in a result element in the previous calculation or setting the case number for the next case to be computed. This may be used to change the numbering of mat-files obtained from a simulation.
- The CONTACT stand-alone program is extended to support multiple result elements and contact patches, adding inputs `reid` and `cpid` in the stand-alone program as used in the CONTACT library. This supports a work-flow where the library is used to generate an inp-file that is then used to study isolated cases in an off-line computation.
- An optional input parameter `CURV` is added to describe track curvature.

`CURV`	$[\mathrm{mm}^{-1}]$	Signed track curvature $k_{trk} = 1/r_{curv}$ with $r_{curv} < 0$ for a left hand curve, > 0 for a right hand curve. Default: tangent track, $k_{trk} = 0$.

In the computation of curving scenarios, the track coordinate system changes its forward direction by $1/r_{curv}$ rad/mm for a curve radius r_{curv} in mm. The wheelset yaw velocity is measured relative to this changing orientation, producing $\dot{\psi}_{ws} = 0$ (constant ψ_{ws}) in steady curving.

- The computation of the gauge point on the rail is changed to sampling the rail profile at the gauge height $z_r = g_{height}$, instead of considering the left-most point for $z_r \in [0, g_{height}]$, cf. Figure 3.4 in the documentation [3].

  A new, optional control digit $\mathtt{Z}_2$ is added to override this change, recovering the original approach using $\mathtt{Z}_2 = 1$.

4 General improvements

4.1 License management

- An extension is made to catch signals, especially Ctrl-C, releasing a floating license gracefully in case of an aborted simulation.

4.2 User subroutine for SIMPACK Rail

- Support is added for Flexible wheelsets with eigenmodes obtained from a finite element model (FBI-file).
- Track curvature is communicated to the CONTACT library directly instead of using the wheelset's yaw velocity.
- Inconsistencies have been resolved regarding rail placement as obtained from Simpack's Result Element and CONTACT's inp-file.
- Robustness is improved by a more elaborate scheme for detecting when a new time step is started.
- An option is added to run CONTACT in measurements mode using the same vertical force F_z as obtained from Simpack's w/r contact calculation. A force element needs to be provided (parameter 6) from which the vertical forces are used. The vertical force used is reported in output parameter #5.
- Output parameters 29, 59, and 89 are renamed to (true) 'geometric penetration', to distinguish from the scaled 'equivalent penetration' values as used in Simpack. Outputs regarding the actual rolling radius r_w are improved using the true penetration value.
- The example '`s1002_uic60`' is changed to use the conformal contact computation (`D = 4` instead of 2). Matlab scripts `get_mat_times` and `select_case` are added to facilitate the inspection of specific time instances in Matlab. The documentation is extended, showing additional results for each of the test models.

4.3 Wheel and rail profile inputs

- The spline smoothing algorithm is improved for situations with relatively large fluctuations in the data compared to the sample spacing (large differences δn compared to steps δs). When such situations are detected, the summed chord lengths s along the profile curve are corrected using the component in the average heading direction. The same is implemented in the Matlab-function `make_arclength`.
- Profile smoothing in Matlab is simplified using an options structure with preferred settings filled in by `smooth_profile`:

```
opt = smooth_profile;
opt.l_filt = 4;
smth = smooth_profile(prr, opt);
```

- A new option `'delete_zigzag'` is added to the Matlab function `modify_profile`.

4.4 Contact geometry stage

- Contact patches that seemed to have interpenetration but for which no actual contact is found are discarded before output is generated.
- The interpolation of roller surfaces is improved for cases where large steps are used in the profile data compared to the discretization step size δs.

4.5 Contact solution

- Support is added for slightly negative vertical forces $F_z < 0$ that may occur during the vertical-force iteration at steep contact angles in combination with a large coefficient of friction.
- The behavior is changed for the case where a negative vertical force $F_{z,inp} \leq 0$ is specified in the input. The solution is set $z_{ws} = 0, F_{trk} = 0$.

4.6 Plot programs in Matlab

- The function `plot3d` is extended for easy initialization of options for different configurations:

```
opt = plot3d(1); opt = plot3d('1d'); opt = plot3d('rear');  % rear view (w/r)
opt = plot3d(2); opt = plot3d('2d'); opt = plot3d('tract'); % top view
opt = plot3d(3); opt = plot3d('3d');                        % 3D view (w/r)
```

4.7 CONTACT library version

- Subroutines `cntc_initializefirst_new` and `cntc_getprofilevalues_new` have been removed.
- The obsolete functions `cntc_setmaterialproperties` and `cntc_setinterfaciallayer` have been deleted. These functions were superseded by `cntc_setmaterialparameters` in version v21.1.
- Function `cntc_setmaterialparameters` is changed with respect to the M_2 digit, concerning the parameters for force-based proportional damping. These parameters are configured using `imeth` = 20–22 instead of 10–12.
- Function `cntc_settrackdimensions` is changed regarding the inputs to the massless rail model. These inputs are now specified in a separate call using `Z` = 32 or 33. Track curvature is added as an optional 6th parameter for options `Z` = 1 or 3.
- Function `cntc_getparameters` is extended, providing access to the track dimensions via `itask` = 4 and using `itask` = 5 for wheelset dimensions.
- A memory leak is fixed in subroutine `cntc_finalize` that played up in long simulations using repeated deleting and re-initialization of result elements.

4.8 General fixes

- The size of the out-file is reduced by avoiding the printing of redundant inputs, e.g. skipping the friction parameters when `L` = 1, skipping discretization parameters when `D` $\leq$ 1, and so on.
- Additional inputs are printed to the out-file when new values are set, such as parameters for wheelset dimensions.

5 Compatibility w.r.t. previous versions

No changes are needed to user input files *per sé* to upgrade from the previous release to the current one.

- The default behavior of CONTACT is changed regarding the rail gauge point computation, affecting cases with a lip on the gauge side. Original results may be retrieved by setting $Z_2 = 1$.

New features in the input are as follows.

- Added support for multiple result elements and contact patches using `REID` and `CPID` numbers.

- Added conformal contact using the grid-based contact search algorithm, activated using `D` = 7.
- Added the possibility to specify track curvature, activated using an optional `CURV` input.

Minor changes are made to the output-file.

- In conformal computations, the output `FS` shows the resultant force $F_{pln,s}$ in the tangent plane direction, while `FSREL` is computed using $F_{crv,s}$ and $F_{crv,n}$ accumulated in local orientation.
- Redundant printing of inputs is suppressed for parameters that are retained between successive cases.
- Additional parameters are printed to the out-file regarding the wheelset and track dimensions, to capture the inputs used in a computation.

The format of the mat-file is changed with respect to version 24.1.

- The contact grid origin is placed at a marker $\mathbf{m}_{pot}$ instead of being centered at the contact reference location $\mathbf{m}_{cp}$.
- Parameters `[xyz]cp_pot` and `deltcp_pot` are added on the second line, representing the offset $\mathbf{m}_{cp(pot)}$.
- Parameters `spin[xy]o` are deleted from the third line of meta data.

Minor changes may be needed to user programs calling the CONTACT library version.

- Subroutines `cntc_initializefirst_new` and `cntc_getprofilevalues_new` have been removed.
- The use of `cntc_materialparameters` changed regarding force-based proportional damping (M_2-digit), using `imeth` = 20–22 instead of 10–12.
- The use of `cntc_settrackdimensions` needs to be changed when using the massless rail model (`F` = 3, `N` = 1): using a separate call with `zdigit` = 32 or 33 for the configuration of the relevant inputs.
- The use of `cntc_getparameters` changed in particular regarding the position of `tauc0` in `itask` = 1.

6 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, 7).

References

[1] E.A.H. Vollebregt. Conformal contact: Corrections and new results. *Vehicle System Dynamics*, 56(10):1622–1632, 2018. DOI: 10.1080/00423114.2018.1424917.

[2] E.A.H. Vollebregt. Detailed wheel/rail geometry processing using the conformal contact approach. *Multibody System Dynamics*, 52:135–167, 2021. Open access.

[3] E.A.H. Vollebregt. User guide for CONTACT, Rolling and sliding contact with friction. Technical Report TR20-01, version 26.1, Vtech CMCC, 2026. See `www.cmcc.nl/documentation`.