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**Summary**

These release-notes document the changes in CONTACT version 25.1 with respect to version 24.1. The main changes are as follows.

- Introducing balance equations for a massless rail model.
- Introducing the Modified FaStrip algorithm improving on Fastsim.
- Providing multiple smaller corrections and extensions.

## 1 Massless rail model

Contact problems arise in different forms, dependent on whether positions or forces are known or sought for. For CONTACT, the main mode of operation is to take states as input, i.e. the positions and velocities for the wheel and rail, and to compute the corresponding contact forces. One alternative is using the $\mathtt{N}_1$-digit, specifying the vertical force ($F_z$) instead of the vertical wheel position ($z_{ws}$). A second alternative is added that is based on a massless rail supported by linear spring and damping.

Two parameters are added, $\delta y_{defl}, \delta z_{defl}$, that are the displacements of the rail in lateral and vertical direction. Balance equations are added to describe their value

$$F_{y(tr)} - k_y^* \, \delta y_{defl} + F_y^* = 0, \quad F_{z(tr)} - k_z^* \, \delta z_{defl} + F_z^* = 0 \tag{1}$$

Here $F_{y(tr)}, F_{z(tr)}$ are the contact forces, $k_y^*, k_z^*$ stiffnesses in lateral and vertical direction, and $F_y^*, F_z^*$ are prescribed external forces on the rail. Damping is included in the stiffnesses and external forces as discussed in the user guide [1, §3.1].

The model is activated using control digit $\mathtt{F}_1 = 3$, and takes the following inputs:

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|---|---|---|
| `KYRAIL` | [N/mm] | Effective lateral rail stiffness $k_y^*$. |
| `FYRAIL` | [N] | Prescribed lateral force $F_y^*$ on the rail. |
| `KZRAIL` | [N/mm] | Effective vertical rail stiffness $k_z^*$. |
| `FZRAIL` | [N] | Prescribed vertical force $F_z^*$ on the rail. |

A new iteration method is introduced to solve problems with prescribed vertical and/or lateral forces. This is called the powerlaw method. For each contact patch $i$, contact forces are expressed as

$$F_{n,i} = C_{hz,i}\delta_i^{1.5}, \quad F_{s,i} = f_{rel,i}F_{n,i}. \tag{2}$$

Assuming slow variation of the contact angle, $\alpha_i$, and Hertzian and friction parameters $C_{hz,i}$, $f_{rel,i}$, permits solution of positions to satisfy the balance equations. This is worked out for situations with 0, 1, or more contact patches and for the transitions between such configurations. 'Near miss' contact patches are introduced to look ahead, include patches that come into being at changed positions. Overall, this yields a robust solver for lateral deflections, $\mathtt{F}_1 = 3$, and a slight performance improvement for a prescribed vertical force, $\mathtt{N}_1 = 1$.

## 2 The Modified FaStrip approach

CONTACT provides several approximate methods for a quick assessment of the contact situation. These are KPEC and Analyn for the normal contact problem ($\mathtt{B} = 5, 6$), and Modified Fastsim for the tangential solution ($\mathtt{M} = 2, 3$). 'Modified FaStrip' is added to this collection that is activated using option $\mathtt{M} = 5$. This method generally improves results compared to Modified Fastsim [2]. An example is given in the input-file `fastsim.inp`.

The FaStrip method was proposed to overcome the limitations of Fastsim with a parabolical traction bound and to improve the accuracy of the tangential forces [3]. An adhesion area is placed at the leading edge of the contact area, with length and tractions according to the strip theory [4], while the slip area is computed using Fastsim with an ellipsoidal traction bound. Heuristics were added to switch between different cases.

The FaStrip method was implemented in CONTACT and tested with help from the original Matlab implementation by Matin Sichani. Results were computed for 3220 test-cases as defined in the statistical assessment approach [5]. This revealed an issue in FaStrip for large spin on contact ellipses that are elongated in the rolling direction ($a/b > 1$) [2].

Modified FaStrip is made by reviewing and revising the components used in the original FaStrip version. Results are improved using the blending approach introduced previously in Fastsim [6]. Extensions are provided to account for the effects of interfacial layers, reducing the initial slope of the creep-force characteristic and providing falling friction. Additionally, the method is extended to non-elliptic contact patches using an equivalent ellipse, with ellipsoidal traction bound replaced by the actual pressures obtained from CONTACT.

An improvement is made to the blending approach that is used in Modified FaStrip and Modified Fastsim. The original equation (10a) from [6] was found to combine both non-dimensional and dimensioned values, such that its results depend on the scaling of the contact problem. Exploring different ways to amend Equation (10a) we found that spin may be omitted without degradation of the results

$$\text{blending, new implementation}: \quad f = \sqrt{\frac{\xi^2 + \eta^2}{\xi_{char}^2 + \eta_{char}^2}}. \tag{3}$$

An example program '`test_table`' is provided with CONTACT that loops through the 3220 test-cases used for the statistical evaluation. This example program is changed to use more meaningful curvatures, material $G$, and contact forces $F_n$, producing more common contact patch sizes $a, b$.

## 3 Resolved problems and general improvements

Multiple smaller extensions and improvements are made as discussed in the following sections.

### 3.1 License management

- Extensions are made to the CONTACT GUI to support license management for the CONTACT library version.

### 3.2 User subroutine for integration in SIMPACK Rail

- A new option $\texttt{V} = 2$ is added in module 1 for variation of the coefficient of friction in track direction. An example is given in `mbench_a22_varfric.inp`.
- New output channels are added for the coefficient of friction $\mu$, the extent of the contact patch, and the frictional power.
- The example using S1002 on UIC60 is extended regarding the detailed outputs and plotting of snapshots in Matlab.
- The preload computation is extended to avoid situations with loss of contact.

### 3.3 Transient contact

- Performance is improved by reuse of influence coefficients between successive cases ($\texttt{C}_3 = 1$).

### 3.4 Contact geometry stage

- An optional input parameter '`y_tape`' is added, shifting the wheel profile vertically to get radius $r = r_{nom}$ at the tape circle line.
- A requirement is introduced on the total length of w/r profile curves: $s_{tot} \in [5, 500]$ mm, to detect incorrect units in profile inputs.
- Contact at the ends of w/r profiles is prohibited in the first case of a simulation, to detect incorrect placement of the wheel with respect to the rail.
- Corrections are made for rollers with a negative radius for situations with planar and conformal contact.

### 3.5 Conformal contact approach

- A warning is added for large variation of the contact angle within a contact patch while using the planar contact approach (D = 2).
- 'Average creepages' are defined in conformal contacts (D = 4), using a least squares approach.
- A correction is made in the determination of the curved reference, excluding regions where the wheel and rail are turning away from each other.

### 3.6 Contact solution

- A small correction is made to the input parameters `bneg`, `bpos` used in the SDEC approach (`ipotcn` = −6).

### 3.7 Temperature and plasticity calculation

- Use of the temperature calculation is permitted in runs with T = 0, using the background temperature.
- Function `cntc_settemperaturedata` is extended for simulations with plasticity calculation, requiring an additional input parameter `betapl`.
- The computation of frictional power is extended to include contributions from plastic deformation in the third body layer.
- The inputs for interfacial layers are changed such that `tau_c0` = 0 may be used for a purely elastic third body layer, instead of `tau_c0` = $10^9$.
- Performance is improved for interfacial layers with elastic-perfectly plastic behavior, $k_\tau = 0$, using the solvers TangCG and GDsteady.

### 3.8 Plot programs in Matlab

- An extension is made in module 1 to support A = 2, exporting data on the full, rectangular potential contact area.
- Extensions are made to `plot3d` for the inspection of differences in element division.
- Function `diffcase` is extended to support arrays for multiple contact patches.

### 3.9 CONTACT library version

- Function `cntc_readinpfile` is extended to support the input-format used in module 1.
- The interface of function `cntc_initializefirst` is changed cf. `cntc_initializefirst_new`, adding the effective working folder.
- The interface of function `cntc_getprofilevalues` is changed cf. `cntc_getprofilevalues_new`, adding real parameters.
- New tasks 6–8 are added to function `cntc_getprofilevalues` to get slices of a variable profile at constant $u$, constant $v$, or constant $y$ coordinate value.
- New outputs $dy_{defl}, dz_{defl}$ are added to function `cntc_getcontactlocation` at positions 18–19 (rail deflections). New outputs $\mathbf{m}_{cp(ws)}, \mathbf{m}_{w(ws)}$ are added at positions 30–38.
- A new input argument `itask` is added to function `cntc_getparameters`. New outputs are added regarding the material and friction data.

## 4 Compatibility w.r.t. previous versions

No changes are needed to user input files to upgrade from the previous release to the current one. New features in the input are as follows.

- Added the massless rail model, activated using $\texttt{F}_1 = 3$.
- Added the Modified FaStrip algorithm, selected using `M` = 5.
- Added friction variation along the track direction, activated using `V` = 2.
- Added an optional parameter `Y_TAPE` for vertical alignment of wheel profiles.

Minor changes are made to the output-file.

- Results are slightly different due to the new solution method for vertical forces (powerlaw iteration).
- Results for Fastsim are changed slightly due to improvements in the blending approach.
- ‘Average creepages’ are printed when the conformal contact method is used.

No changes were made in the format of the mat-file with respect to version 24.1.

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

- The interface changed for function `read_profile`, inserting a new argument `y_tape` in the 6th position.

- The interface changed for function `modify_profile`, moving argument `scale_yz` to the 5th position and inserting `y_tape` in the 6th position.

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

- The interface of subroutine `cntc_initializefirst` is changed conform the interface of `cntc_initializefirst_new`, see [1, §7.3.1].
- The interface of subroutine `cntc_getprofilevalues` is changed conform the interface of `cntc_getprofilevalues_new`, see [1, §7.3.4].
- The interface changed for subroutine `cntc_settemperaturedata`, adding `betapl` in the 9th position of array `params`.
- The interface changed for subroutine `cntc_getparameters`, adding the `itask` parameter.

## 5 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

[1] E.A.H. Vollebregt. User guide for CONTACT, Rolling and sliding contact with friction. Technical Report TR20-01, version 25.1, Vtech CMCC, 2025. See `www.cmcc.nl/documentation`.

[2] E.A.H. Vollebregt. Assessing the results of simplified non-Hertzian contact algorithms. In J. Wang and T.J. Gordon, editors, *The 29th IAVSD Symposium on Dynamics of Vehicles on Roads and Tracks (IAVSD2025)*, 2025.

[3] M. Sichani, R. Enblom, and M. Berg. An alternative to FASTSIM for tangential solution of the wheel–rail contact. *Vehicle System Dynamics*, 54(6):748–764, 2016.

[4] J.J. Kalker. A strip theory for rolling with slip and spin. *Proceedings of the Konklijke Nederlandse Akademie van Wetenschappen*, B70:10–62, 1966.

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[6] E.A.H. Vollebregt and P. Voltr. Improved accuracy for FASTSIM using one or three flexibility values. *Vehicle System Dynamics*, 61(1):309–317, 2023. Open access.