VORtech CMCC

Contact Mechanics Computing & Consulting

P.O. Box 260
2600 AG Delft
The Netherlands

tel. +31(0)15-285 0125
fax. +31(0)15-285 0126
info@vortech-cmcc.nl

MEMO	EV/M17.049
Date	September 15, 2017
Author(s)	Edwin Vollebregt
Subject	Release-notes for CONTACT version 17.1, update 1

Summary

These release-notes document the changes in CONTACT version 17.1, update 1, with respect to version 16.1.

- The new version provides a number of smaller extensions, like providing the Modified FASTSIM and SDEC approaches in CONTACT.
- A bigger change is in preparation, concerning the automated processing of wheel and rail profiles, as shown in Figure 1.

The new wheel/rail contact module is now provided as a beta-version, that will be completed in the subsequent release.

1 Implementation of the Modified FASTSIM algorithm

CONTACT now provides the Modified FASTSIM algorithm by Spiryagin et al. [1], extending upon Kalker's original FASTSIM approach [2]. This allows to incorporate, provisionally, the

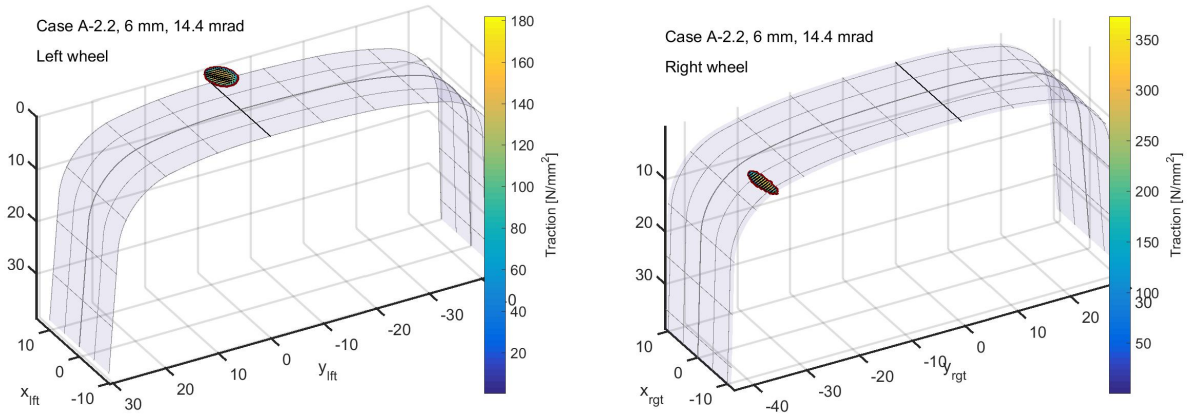

Figure 1: *Results of the new w/r contact module (beta) for the Manchester benchmark example: 6 mm lateral displacement, yawed at $\psi_{ws} = 14.4\,mrad$.*

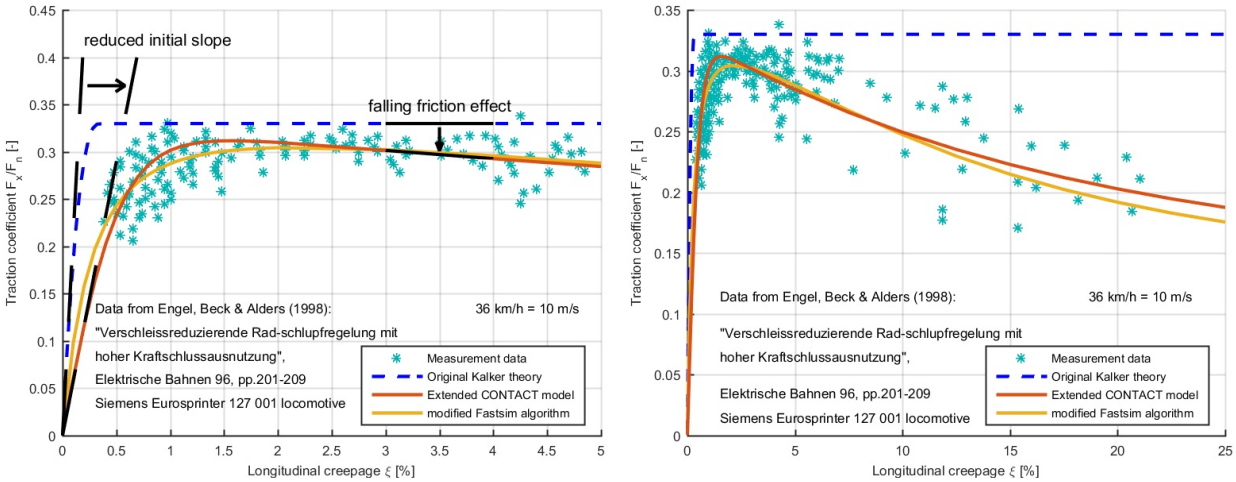

Figure 2: *Measured and computed creep forces for the Siemens locomotive Eurosprinter 127001 for pure longitudinal creepage, including results for the Modified FASTSIM approach.*

effects of 3^{rd} body layers and falling friction into FASTSIM, as illustrated in Figure 2. The implementation is made for Hertzian and non-Hertzian geometries.

Modified FASTSIM relies on changing the flexibility L with the ratio of the slip area to the area of adhesion:

$$L_{eff} = \frac{L}{k}, \quad \text{with} \quad k = k_0 \left(\alpha_{inf} + \frac{1 - \alpha_{inf}}{1 + \beta\varepsilon} \right). \tag{1}$$

This increases the flexibility when $k < 1$. The ratio of the slip to adhesion areas is described by the parameter ε that's computed in the program on the basis of prescribed creepages. The parameters k_0, α_{inf} and β must be provided in all cases where FASTSIM is used (`M` $= 2$ or 3). The original FASTSIM algorithm is recovered by using $k_0 = 1$ and $\alpha_{inf} = 1$.

Note that (Modified) FASTSIM is provided in CONTACT mainly for comparison purposes, allowing to inspect the detailed results. One should be aware that FASTSIM is approximate by nature, schematizing full linear elasticity using a bed of springs.

2 Implementation of the SDEC approach

CONTACT is extended to provide Piotrowski's SDEC approach [3], that generates a-symmetrical contact patches in an elegant way. This allows to extend the table-based approach for the wheel-rail creep force calculation towards non-Hertzian contact geometry. This is an important line of research, because FASTSIM is intricate for non-Hertzian contacts whereas CONTACT requires long calculation times.

The SDEC approach provides the contact shape and pressures p_n of the desired form, without consideration of the geometry, see Figure 3. It is activated by the bound option `B` $= 4$ together with `IPOTCN` $= -4$.

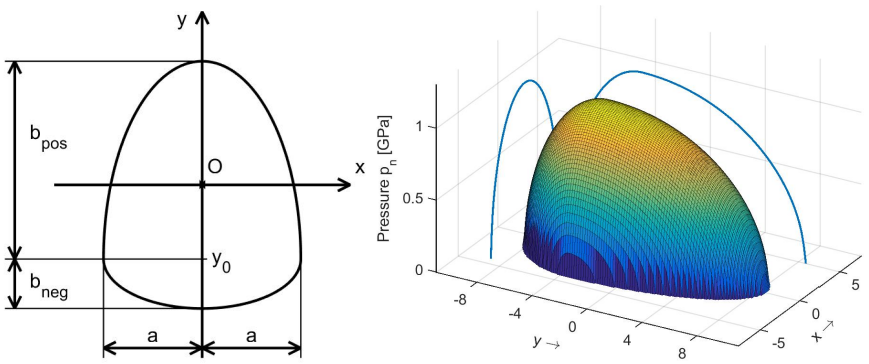

Figure 3: *A-symmetric contact patch and pressure distribution of the "simple double-elliptical contact" (SDEC) approach [3].*

3 Refinement of the model for viscoelastic materials

Several smaller improvements are made for the calculation of steady rolling with viscoelastic materials:

- The description of the inputs is improved in the user guide (§4.1.2), in particular showing the relationship $E_r = E_g/(1 + f_g)$ between the elastic moduli for the initial, glassy behavior and the final rubbery state;
- It is recognized that the numerical integration that's used implicitly assumes rolling in positive x-direction, which is now enforced by a constraint.
- The relaxation time `TC` was given in units of ms instead of s. Also, using a value of $\tau_C = 0$ appeared to cause problems in some cases. These issues are corrected.

4 General improvements

Several smaller extensions are made to improve the functioning of CONTACT in different circumstances:

- Subtle changes are made to the formulas used in grid discretization, particularly in the leading edge correction that was introduced in [4], which appeared to produce small artefacts in transient rolling.
- The description of curvatures for Hertzian problems is extended, in particular for the effect of the contact angle on rolling radius R_x, see §4.3.1 of the user guide.
- The stopping criterion is changed for the Panagiotopoulos process, that's used in case of dissimilar materials.

5 Resolved problems

- A mistake has been found in the Hertzian reference test-case for the conformal example [5]. The example is changed to display the corrected results.
- The extended subsurface stress calculations introduced in v16.1 did not work well in parallel calculations. This has been corrected.
- A few issues were found in the calculations for viscoelastic materials, as discussed in paragraph 3.

6 Compatibility w.r.t. previous versions

A few changes are needed to the user's input files in order to change from the previous to the current release.

CONTACT's unit convention is changed to use $[mm/s]$ for velocities and $[rad]$ for angles. This resolves the inconsistencies in formulas combining lengths, times and velocities.

- The unit of velocities affects the input parameters `VELOC`, `SABSH1`, `SABSH2` and `MEM_S0` of velocity dependent friction, and the parameter B of Polach's approach, see §4.2 in the user guide.
- The progress output of the iteration process for velocity dependent friction shows 1000 times bigger residuals and a 1000 times bigger tolerance.
- The relaxation time for viscoelastic materials must be divided by a factor 1000 in order to keep the same results as before.

With respect to the unit of angles, it was decided to use radians inside the program, but to keep degrees at some places in the user interface:

- In the input, the value of `CHI` may be given in radians or in degrees, using notations `3.1416r` and `180d`. Radians are assumed if no `r` or `d` is provided.
- In the output, the direction of tangential tractions are shown in degrees.

The main changes to the output are as follows:

- The unit of elastic energy `ELEN` is changed from $[mJ]$ to $[J]$, dividing the values by a factor 1000.
- In shifts (`T` = 1), the frictional work ($[W]$) is reported instead of the frictional power ($[mJ]$). This reduces the values reported by a factor 1000.

Several textual changes have been made to the output-file as well.

The `mat`-file is changed slightly with respect to the velocities, which are now in $[mm/s]$.

A number of changes are made to the interfacing of the CONTACT library for Matlab and Fortran/C:

- New subroutines are added for accessing the functionality of the new w/r module, as described in Chapter 8 of the User guide;
- Subroutine `cntc_getforces` is renamed to `cntc_getcontactforces`;
- The Hertzian subroutines `cntc_setsemiaxes`, `cntc_setcurvatures`, `cntc_setellipticity` and `cntc_sethertzscale` have been replaced by `cntc_sethertzcontact`;
- Subroutines `cntc_setnumelements` and `cntc_setgriddiscretization` have been replaced by (incorporated in) `cntc_setpotcontact`;
- Subroutine `cntc_setfrictioncoefficient` has been deleted in favour of the more general subroutine `cntc_setfrictionmethod`.

7 Known problems and restrictions

The Windows uninstaller does not support multiple versions (v16.1, v17.1) side by side. If you want to uninstall a previous version then do it first, before installing a newer version. If an installation is broken, consult the "Installation" section in the file `README.txt` for manual installation tips.

One feature that is not treated well is the rolling direction parameter `CHI`. It is generally advised to use `CHI` $= 0$ or $180°$ or restrict `CHI` to at most a few degrees.

The results may contain a significant discretisation error when a small number of elements (7×7, 15×15) is used. Particularly the frictional work appears to be susceptible to this.

Premium version & CONTACT library

The basic version of CONTACT is freely available in binary form, and can be downloaded from `www.kalkersoftware.org`. Extended features are provided commercially through a premium version and through the CONTACT library. These features concern the new w/r module, fast calculation, conformal contact, third body layer, extended support, etc.. They are marked blue in the release notes and in the User Guide. For information on licenses you may contact us at `support@kalkersoftware.org`.

References

[1] M. Spiryagin, O. Polach, and C. Cole. Creep force modelling for rail traction vehicles based on the Fastsim algorithm. *Vehicle System Dynamics*, 51:1765–1783, 2013.

[2] J.J. Kalker. A fast algorithm for the simplified theory of rolling contact. *Vehicle System Dynamics*, 11:1–13, 1982.

[3] J. Piotrowski, B.B. Liu, and S. Bruni. The Kalker book of tables for non-Hertzian contact of wheel and rail. *Vehicle System Dynamics*, 55:875–901, 2017. DOI: 10.1080/00423114.2017.1291980.

[4] E.A.H. Vollebregt. Refinement of Kalker's rolling contact model. In A. Bracciali, editor, *Proceedings of the 8th International Conference on Contact Mechanics and Wear of Rail/Wheel Systems*, pages 149–156, Firenze, Italy, 2009.

[5] E.A.H. Vollebregt. Conformal contact: Corrections and new results. *Vehicle System Dynamics*, 2017. submitted.