

MEMO EV/M20.002
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Subject Release-notes for CONTACT version 20.2

Summary

These release-notes document the changes in CONTACT version 20.2 with respect to version 19.1.

- New methods are implemented for the automated and detailed analysis of wheel/rail contacts using planar and conformal contact approaches [1, 2].
- New calculations are added for surface temperatures and corresponding changes to the coefficient of friction [3].
- A new sub-model is provided for the effects of local plasticity in a third body or near surface layer [3, 4].
- Module 1 for wheel/rail contacts is extended for profile smoothing and variation of friction parameters across the rail profile.
- A new licensing scheme is implemented, with 2-month free use of the full CONTACT program (including module 1) and the CONTACT library version.

The temperature and plasticity models were developed with the financial support of the US FRA under contract DFTR 5317 C00012.

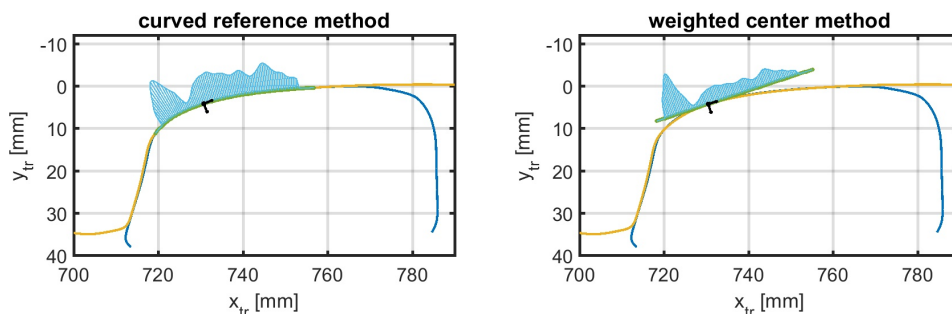


Figure 1: Contact pressures computed for conforming wheel and rail profiles using the conformal and planar contact approaches [2, Fig. 18].

1 New methods for planar and conformal contacts

The contact problem is generally divided into three consecutive stages: (1) the contact geometry stage, identifying the contact location and tangent plane; (2) the kinematic stage, determining the creepages; and (3) the dynamic stage, computing the normal and tangential forces. These stages are implemented in CONTACT's **module 1** for the automated analysis of contact geometry for wheel/rail contacts, introduced in version 17.1. This module is extended regarding the methods used for planar and conformal contacts.

Planar contact method A new method is developed for the definition of the tangent plane used in planar contacts. This concerns the contact reference point and reference angle, used as the origin and orientation for the local coordinate system. These are defined using averaging of parameters on interpenetration areas, weighted with the squared gap values [1]:

$$[x_{tr}, y_{tr}, \alpha_{tr}]_{cwg12} = \int_{g<0} [x, y, \alpha] g^2(x, y) dx dy \Bigg/ \int_{g<0} g^2(x, y) dx dy. \quad (1)$$

This method appeared to give closer correspondence to the conformal approach than several other planar contact approaches, in a test with four-thousand worn wheels in steady curving [2]. This method is activated when $D = 2$, replacing the previous method that was based on linear weights and used the local contact angle.

Conformal contact method A further extension is developed that replaces the tangent plane by the so-called curved reference surface. This curved reference is computed robustly and automatically, providing fully automated calculation of contact problems on curved contact patches. This is illustrated in Figure 1. A more refined pressure distribution is obtained using the local normal direction at each point instead of one overall normal direction. The creepages are refined accordingly, obeying the actual rolling radii at each point instead of using a planar/conical approximation. This method is selected using $D = 4$.

Contact locus approach The contact search was implemented previously using a brute-force, grid-based approach. This is replaced by a faster method based on the contact locus. This uses analytical derivations to reduce the contact search to a one-dimensional problem [1]. This is implemented for wheel-on-rail contacts ($C_1 = 0, 1$) as well as for wheel-on-rollers ($C_1 = 4, 5$) and accounting for flexibilities of rails, wheels, and wheelsets. The contact locus is used automatically when $D = 2$ or 4 . The brute-force approach is provided via $D = 5$ for the purpose of cross-validation.

Combination of contact patches A challenge for the planar contact approach comes from the combination of contact patches that lie close together. The decision to combine them or not may cause jumps in the numerical results when varying the inputs, such as a prescribed vertical force. These jumps are mitigated by a number of countermeasures: using the averaged contact angle instead of a sampled value, combining patches earlier, and introducing a blending approach in which the interaction is gradually turned on when contact patches get closer to one another [1].

The separation or combination is governed by two threshold values for the distance d between interpenetration areas, $d_{sep} \geq d_{comb}$, and one threshold α_{sep} for the difference in contact reference angle. Two patches are processed separately when $|\alpha_{cp1} - \alpha_{cp2}| \geq \alpha_{sep}$ or when $d \geq d_{sep}$. Else, the patches are combined fully when $d \leq d_{comb}$ or using blending when $d_{comb} \leq d \leq d_{sep}$.

A_SEP	[rad]	Threshold α_{sep} for the angle difference above which patches are processed separately.
D_SEP	[mm]	Threshold distance d_{sep} above which patches are processed separately.
D_COMB	[mm]	Threshold distance d_{comb} below which patches are combined fully, if not prohibited by the angle threshold.

Plotting on r/w profiles The Matlab script `plot3d` is extended to give the nice overview of contact situations cf. Figure 1. This is called the “rw_rear” view, with the wheel rolling away from the user. The picture shows the potential contact areas used by the extent of the tangent plane, and the local coordinate origin by the black marker. Conformal cases ($D = 4$) use the rail profile instead of the curved reference used in the actual calculation.

2 Surface temperatures and temperature-dependent friction

New calculations are added to compute near-surface temperatures due to frictional heating [3]. This is based mainly on the analyses of Ertz and Knothe [5]. The model focuses on locally averaged values, excluding flash temperatures in asperity contacts. The calculations are activated using a new control digit H. Additional inputs are the heat related material parameters and the initial bulk temperatures of the two bodies (User guide [6, §5.1.2.]).

Increasing surface temperatures may be used to explain friction reducing at increased creepage. This is implemented in friction law L = 6, postulating a coefficient of friction dependent on surface temperature. A simple piecewise linear formula is used for the dependence, that allows for exploring the significance of the input parameters ([6, §5.2.3]). In the current model, temperature dependence has little influence on the initial slope of creep force curves. The falling part appears to be captured nicely, at reasonable values for the input parameters [3].

Additional columns are added to the mat-file for the computed surface temperatures, letting additional fields `temp1` and `temp2` be plotted with `plot3d` (Figure 2). New functions added to the CONTACT library are `cntc_settemperaturesdata`, `cntc_getmaximumtemperature`, and `cntc_getfielddata`.

These extensions were developed with the financial support of the US FRA under contract DFTR 5317 C00012.

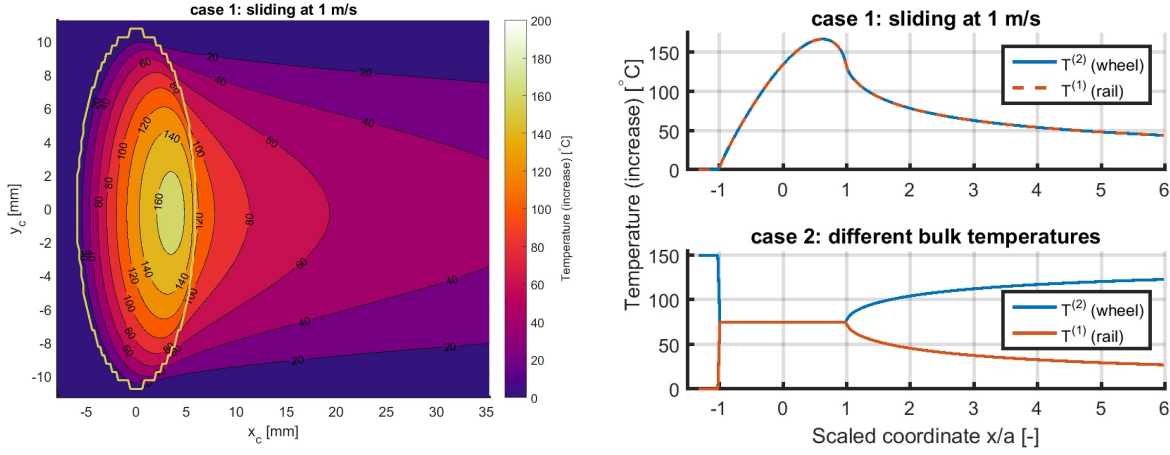


Figure 2: Surface temperatures for example ertz_temperature.inp. Left & top-right: results for a case with full sliding (1 m/s) and equal bulk temperatures. Bottom-right: results for no sliding and different bulk temperatures (centerline $y = 0$).

3 Shearing of interfacial layers

A new sub-model is added for the effects of local plasticity in a third body or a near surface layer [3, 4]. This extends the functionality of interfacial layers provided at $M = 4$.

The model postulates tangential plastic deformation at locations where the tangential stress reaches the local yield limit τ_c . This yield limit is characterized using linear work-hardening or work-softening behavior, $\tau_c = \tau_{c0} + k_\tau u_{pl}^*$. Here τ_{c0} is the initial yield limit of fresh material, entering the contact area, while u_{pl}^* measures the amount of plastic deformation accumulated while passing through the contact. This modeling approach reproduces the interfacial layer characteristics presented by Hou [7] as shown in Figure 3.

The new model is implemented by changing the input parameters used for $M = 4$.

GG3	[N/mm ²]	Shear elastic modulus of the interface layer, $G^{(3)} > 0$.
LAYTHK	[mm]	Thickness of the interface layer, $h^{(3)} \geq 0$.
TAU_CO	[N/mm ²]	Initial yield limit $\tau_{c0}^{(3)}$ at which plasticity starts to occur. No plasticity is computed when $\tau_{c0} \leq 0$.
K_TAU	[N/mm ³]	Rate of increase k_τ of the yield limit τ_c with accumulated plastic deformation.

It is possible to use the tangential plasticity feature of CONTACT without using a third body layer. This is accomplished by setting $h^{(3)} = 0$. In that case, plasticity is thought to occur near the surface of the softer one of the primary bodies.

An additional code $P = 3$ is introduced in element divisions. Additional outputs are added to the

3 rd body layer	u_{c0} <i>mm</i>	τ_{c0} <i>N/mm²</i>	k_u <i>N/mm³</i>
“magnetite”	0.070	560	0.
“clay”	0.040	200	400.
“sand”	0.050	400	-200.
“MoS2”	0.020	20	20.

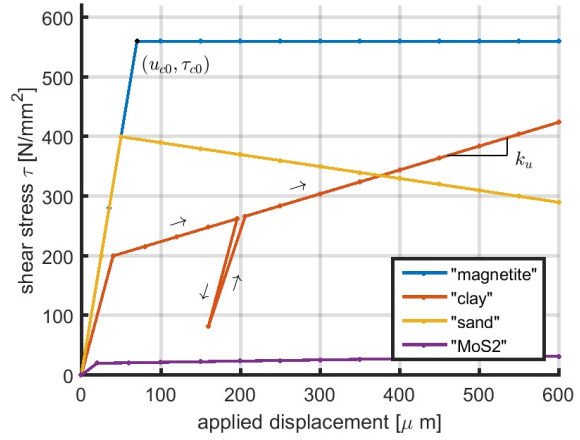


Figure 3: Shear stress curves computed for several interfacial layers using CONTACT’s local plasticity model, mimicking the results of Hou et al. [7, Fig. 4].

mat-file for the computed yield limit τ_c and plastic displacements $u_{pl,x}, u_{pl,y}$. These are provided in the CONTACT library via `cntc_getfielddata`. The values are plotted in `plot3d` using the fields `taucr`, `uplsx`, `uplsy`, `upls+vec`.

This extension was developed with the financial support of the US FRA under contract DFTR 5317 C00012.

4 Further improvements for wheel/rail contact

Profile smoothing and scaling Facilities are added for profile scaling (e.g. unit conversion) and smoothing. This is achieved with `sc1fac` and `smooth` parameters. In the input-file, these must be provided for all rail and wheel profiles.

- SCALE [–] Scale factor for unit conversion, e.g. `scale = 1000` to convert profile values given in [m] to [mm].
- SMOOTH [–] Enable profile smoothing with smoothness parameter `smooth = λ > 0` cf. user guide Eq. (4.1), or disable smoothing if $\lambda \leq 0$.

The CONTACT library provides access to this via the functions `cntc_setprofileinputfname` and `cntc_setprofileinputvalues`. These are used to specify one rail profile or one wheel profile at a time. The older routines for rail and wheel profiles are maintained for backward compatibility reasons.

Reporting on the actual profiles used The actual profiles used after smoothing can be written to the out-file using `0 ≥ 4`. The curved reference used for conformal contacts is written when `0 ≥ 3`. These outputs are obtained in the CONTACT library with function `cntc_getprofilevalues`. A new script `parse_profiles.m` is provided to read values into Matlab.

Variation of friction parameters A new option is added that allows variation of friction parameters across the rail profile. This uses the surface inclination α measured in rail profile coordinates. Parameters are then specified at one or more control points, using piecewise linear interpolation. A basic example is to use $\mu = 0.20$ at the gauge side of the rail, $\alpha \leq -30^\circ$, $\mu = 0.35$ at the top of the rail, $\alpha \geq -20^\circ$, with μ varying linearly between these control points. The planar contact approach uses the contact reference angle for interpolation, resulting in constant friction parameters throughout each contact patch. The conformal approach uses the inclination of the curved reference, resulting in friction varying within patches too. This feature is activated using a new control digit $v = 1$.

5 New licensing scheme

A new licensing scheme is implemented, with free use of the full CONTACT program and CONTACT library version during two months. After this period, the use can be extended using a paid license.

CONTACT licenses are distributed by e-mail, providing the license ID and activation password. These are used to activate the software on the user PC. This generates a request that's transmitted via the Internet to a web-based licensing server, checked, and used to generate a license file for the user PC.

A new option `imode = 1` is added to the CONTACT program for license management actions **activate**, **print**, and **refresh**. A new function `cntc_managelicense` is added to the CONTACT library that performs the same actions.

6 General improvements

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

- Additional outputs are provided on the total moments on wheel and rail in module 1, in the output-file and in `cntc_gettotalforces`.
- A preliminary set of wrapper-routines is made to access the CONTACT library from Python.
- New flags are provided in the CONTACT library to control the output of subsurface stresses.

7 Resolved problems

Wheel and rail profile handling is improved by detecting a number of additional edge cases and dealing with them appropriately, like strongly hollow worn wheels, profiles without any points, and Miniprof files that don't fully adhere to the original file specification.

The subsurface stress calculation was flawed in cases with $M = 4$, using a third body layer. This is fixed and extensively tested.

A subtle issue was found in the computation of shift problems ($T = 1$) using the CONTACT library. The scaling of the shift $cksi = \delta_x$ is corrected.

8 Compatibility w.r.t. previous versions

The default installation location is changed from C:\Program Files (x86)\KalkerSoftware\ to C:\Program Files\Vtech CMCC\.

This version of CONTACT produces slightly different results than the previous one when using module 1. This is due to the new methods for the contact reference point and reference angle and for separation or combination of contact patches.

A few changes may be needed to user input files to change from the previous to the current release:

- The SAFETY parameter should be replaced by A_SEP, D_SEP, D_COMP, for instance using 3.14, 8.0, 4.0.
- Additional values for SCLFAC and SMOOTH must be added in the input for rail and wheel profiles. You may use values 1.0, 0.0 for no scaling/no smoothing.
- The old codes $C_1 = 2, 3$ for roller rigs are changed to $C_1 = 4, 5$, preparing for future options for wheelset equilibrium equations.
- The third and fourth values prescribed for interfacial layers ($M = 4$) are no longer ignored. You may set the third one to a high value, e.g. $TAU_{C0} = 10^9$, to disable the local plasticity model.

Apart from the output for new features, the changes to the output-file are mainly cosmetic.

The format of the mat-file is extended to facilitate optional additional columns for plasticity and temperature data.

The main changes to the CONTACT library are as follows:

- Function `cntc_managelicense` is added for license management actions.
- New functions are added for wheel and rail profiles, `cntc_setprofileinputfname`, `cntc_setprofileinputvalues`, and `cntc_getprofilevalues`.
- A new option is added in `cntc_setpotcontact` for contact patch separation and combination.
- New outputs are provided by `cntc_getglobalforces` for total forces and moments at different markers.

9 Known problems and restrictions

- Subsurface stresses are computed using elastic influence functions, also when the problem uses the viscoelastic material model.

References

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