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Summary

These release-notes document the changes in CONTACT version 21.1 with respect to version 20.2.

- A new experimental solver GDsteady is added for steady rolling with fine grid discretization.
- Many smaller extensions are added to module 1 for wheel/rail contact, e.g. for profiles with kinks, mirroring in z-direction, or for a reversed rolling direction.

1 New solver GDsteady for steady rolling

Over the years, we conducted research into the solution algorithms for frictional contact problems. This resulted previously in the Gauss-Seidel based solvers ConvexGS and SteadyGS for steady rolling [1, 2] and the Conjugate Gradients based solvers NormCG for the normal contact problem [3] and TangCG for the transient rolling problem [4]. Our CG-based solvers are much faster than the GS-based solvers when many elements are used in the contact area. This is achieved using the fast Fourier transform, reducing the work per iteration from $O(n^2)$ to $O(n\log(n))$.

Until now, we didn't succeed in the extension of the idea towards steady rolling. This is changed in version 21.1. A new experimental solver GDsteady is added to CONTACT that takes a Gradient Descent approach, and that does need $O(n\log(n))$ work per iteration. This improves the speed of CONTACT 4 to 29 times as shown in Table 1.

GDsteady is activated by setting `G` = 5. This is currently restricted to standard friction (`L` = 0) and the standard material model (`M` = 0) excluding the third body layer. Further work concentrates on these extensions, the performance, and the robustness for general situations. Students and supervisors are invited for discussions and collaboration.

	ConvexGS	→	SteadyGS	→	GDsteady
tang_problm_1c, 71 × 81 elements	13.6 s	5×	2.9 s	4×	0.8 s
tang_problm_2c, 143 × 163 elements	343 s	5×	73.7 s	11×	6.7 s
tang_problm_4c, 287 × 323 elements	9039 s	5×	1743 s	29×	59.7 s

Table 1: *Computing times of solvers ConvexGS, SteadyGS and GDsteady for steady rolling with creepage prescribed.*

2 Improvements for wheel/rail contact

Many smaller extensions are added to module 1 for wheel/rail contact, e.g. for profiles with kinks, mirroring in z-direction, or for a reversed rolling direction.

2.1 Mirroring profiles in z-direction

A new option `MIRRORZ` is added that gives control over the mirroring of profiles in z-direction.

`MIRROR_Z`	[−]	Auto-detect whether mirroring of z-values is needed (0, default), use the profile as is (−1), or mirror its z-values (1).

This value may be given on the same line in the input as the profile and corresponding values

```
if Z=3,4:   [ 'RFNAME'  MIRRORY   SCLFAC   SMOOTH   {MIRRORZ}  ]
```

Curly brackets `{}` signal that this is an optional value. The default 0 is applied when the parameter is omitted. The same option is added to `cntc_setprofileinputfname` and `cntc_setprofile-inputvalues`, using the 4th position of the `iparam` array.

2.2 Detection of kinks in wheel/rail profiles

A large variety of profiles arise from measurements and theoretical considerations. Now and then, these contain intended sharp corners that are troublesome to spline smoothing, or that could otherwise affect the computation results. Extensions are made to detect kinks, dents, and zig-zag patterns.

- Kinks are defined at profile positions where the angle between consecutive segments exceeds 30°. Our smoothing splines are split there into multiple sections, such that kinks are kept in the profile.
- Zig-zag patterns are defined at locations where one sharp angle (±90°) is followed by one in opposite direction (∓90°). This should not happen; the profile is adjusted towards a more smooth approximation.
- Dents are local indentations into a profile. These are problematic for the contact search, when found on a near-vertical profile section. The contact search is extended to keep on working in such configurations, excluding contact in the dent itself.

2.3 Support for rolling in the reversed direction

Extensions are made for roller-rigs to support $\omega_{rol} < 0, \omega_{ws} > 0$, leading to rolling in the negative x-direction ($\chi = 180°$). This is particularly relevant for robotics, where joints may operate in four quadrants of rolling and creepage direction. Similar extensions are made for wheel/rail contacts using $v_s < 0, \omega_{ws} > 0$.

2.4 Support for a wheel in a raceway

Extensions are made for roller-rigs to support a negative radius $r_{nom,r} < 0$. This is used to model a hollow roller with the wheel on the inner side. The center of the roller is defined at $\mathbf{m}_{rol} = [0, 0, r_{nom,r}]^T$, which then lies in the negative half-space. The material of the roller is found still at $z_{tr} > 0$.

2.5 Extension of Modified Fastsim for non-Hertzian configurations

The Modified Fastsim implementation is extended for non-Hertian contacts, using flexibilities on the basis of an equivalent ellipse [5]. These extensions are used to enable Fastsim in wheel/rail calculations with module 1.

2.6 Further improvements for wheel/rail contact

Our schemes for wheel/rail contact geometry analysis are updated further for specific profiles, supporting certain edge cases.

The iteration procedure for a prescribed vertical force is extended with respect to negative forces at large flange angles.

3 Resolved problems and general improvements

A small extension is made to input-file reading, such that numerical data can be given with high precision (more than 20 characters long).

The functioning of the solver SteadyGS is improved in different circumstances:

- An issue is solved with respect to elements moving between the slip and plasticity areas. This improves convergence in cases where a third body layer is used.
- A general update is made that yields a small improvement of the convergence.

In the CONTACT library version:

- An issue was solved regarding the `inp`-file written for module 1. The `E`-digit wasn't printed correctly in certain combinations of setting the wheelset position, velocity and dimensions.
- A new subroutine `cntc_setmaterialparameters` is added for the configuration of material parameters, including viscoelasticity (`M` = 1), Modified Fastsim (`M` = 2, 3), and the elasto-plastic third body layer (`M` = 4).

Several smaller updates were made to the licensing scheme introduced in version 20.2.

- License management actions are documented in a file `licensing.pdf`.
- Robustness of the floating mechanism is improved with respect to Internet connectivity.
- The option "`deactivate`" is added for moving a license to another computer.
- An issue was also resolved with respect to starting a new run in the CONTACT library after finalizing a previous run.

In the plotting routine `plot3d`, an extension is made for user-defined data. Slight corrections are made for mirroring between left and right sides. The performance of `parse_out1` is improved for large `out`-files, as well as the performance of `read_simpack` and `read_miniprof` for reading many profiles.

4 Compatibility w.r.t. previous versions

No changes need to be made to `inp`-files when going from version 20.2 to 21.1. This will use the default `MIRROR_Z` = 0 for autodetecting whether z-mirroring of profiles is needed.

For the CONTACT library,

- The input `imeth` = 1 to `cntc_setwheelsetvelocity` should be changed to `ewheel` = 2.
- Subroutines `cntc_setmaterialproperties` and `cntc_setinterfaciallayer` are obsolete and should be replaced by `cntc_setmaterialparameters`.

An additional input argument `mirror_z` is added to the Matlab-routine `read_profile.m`.

5 Known problems and restrictions

- plotting on rail/wheel surfaces doesn't account properly for $\Delta\phi_{rr}$.
- Subsurface stresses are computed using elastic influence functions, also when the problem uses the viscoelastic material model.

References

[1] E.A.H. Vollebregt. A Gauss-Seidel type solver for special convex programs, with application to frictional contact mechanics. *J. of Optimization Theory and Applications*, 87(1):47–67, 1995.

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[3] E.A.H. Vollebregt. A new solver for the elastic normal contact problem using conjugate gradients, deflation, and an FFT-based preconditioner. *J. of Computational Physics*, 257, Part A:333–351, 2014.

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