VORtech Computing

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Subject	Release-notes for CONTACT version 16.1

Summary

These release-notes document the changes in CONTACT version 16.1 with respect to the previous version 15.1.

- The main change in the program itself concerns extension and speed-up of the subsurface stress calculation.

- Further the CONTACT library has been improved and is now provided integrated in Universal Mechanism.

1 Calculation of subsurface stresses

The stresses in the wheel and rail interiors are needed in order to evaluate various damage criteria. For instance yielding (plastic flow) occurs at locations where the shear stress exceeds the shear yield strength. This may be assessed using the Tresca yield criterion

$$\sigma_{tresca} = \max(|\sigma_1 - \sigma_2|, |\sigma_2 - \sigma_3|, |\sigma_3 - \sigma_1|) \le 2k = 2\tau_{yield}. \tag{1}$$
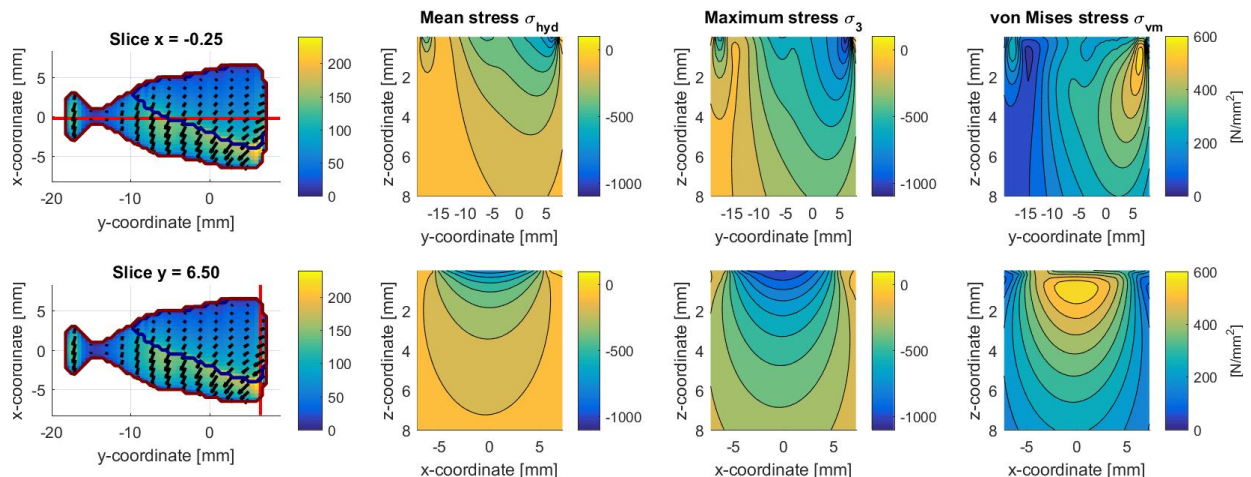

Figure 1: *Subsurface stresses for a locomotive wheel during steady curving.*

Here σ_1, σ_2 and σ_3 are the principal stresses of the stress tensor $\boldsymbol{\sigma}$, σ_{tresca} is the maximum shear stress at the given location, and $k = \tau_{yield}$ is the shear yield strength of the material. The von Mises theory starts from somewhat different assumptions and arrives at a different criterion

$$\sigma_{vm}^2 = \sigma_1^2 + \sigma_2^2 + \sigma_3^2 - 2\nu\left(\sigma_1\sigma_2 + \sigma_2\sigma_3 + \sigma_3\sigma_1\right) \leq \sigma_{yield}^2. \tag{2}$$

Here σ_{vm} is the von Mises stress or "equivalent tensile stress" and σ_{yield} is the uniaxial tensile yield strength of the material. Rolling contact fatigue is another phenomenon where the interior stresses need to be evaluated. In this case the amplitude of the stress cycle is important, which may be assessed using the minimum and maximum values of σ_1, σ_2 and σ_3.

These interior stresses are provided by CONTACT's subsurface stress calculation. See for example Figure 1, taken from an actual investigation of rail damage mechanisms (locomotive in steady curving, curve radius $5000\,m$, first axle, outer wheel, driven). The figure shows the mean stress σ_{hyd}, the largest principal stress σ_3 and the von Mises stress σ_{vm}, on vertical cross-sections of the rail material. The cross-sections are selected so as to contain the maximum values.

This subsurface stress calculation is now greatly improved:

- Fast calculation for multiple layers under the potential contact area;

- Deriving the principal stresses σ_1, σ_2 and σ_3;

- Automatic calculation and printing of the maximum values in the sub-surface.

The calculation speed is improved using the Fast Fourier Transform, yielding a 100-fold speed-up for detailed calculations. For instance the results of Figure 1 employ a grid of $30 \times 55 \times 41$ subsurface points. In a parallel run on 8 threads, the calculation time shrinks from 29.3 to $0.2\,s$. This brings the time needed to the same order as needed for solving the surface tractions.

In order to get the best results from the calculation, it is advised to sample the subsurface stresses at the centers of the elements of the contact grid. This is facilitated by new input options "ISUBS = 1–7" that rely on element numbers (i_x, i_y) instead of (x, y)-coordinates.

Two different variants are introduced for the control digits A (MATFIL) and O (OUTPUT), separating the amount of output for the subsurface from that of the surface problem. The new digits A and O for the subsurface are entered with the subsurface points when S = 2 or 3. For information on these options, refer to Section 4.9 of the User guide.

2   Refinement of the CONTACT library

The CONTACT library that was introduced in v15.1 is further completed and refined. For instance allowing to specify the inputs and get outputs in SI units, providing an option to specify tangential forces (F = 1, 2), refined control over the undeformed distance function (cf.

IBASE = 1–3), allowing to set the solver configuration (`MAXOUT`, `EPS`), etc. These features are discussed in the documentation, see Chapter 7 of the User guide.

A different way of parallel computing is also introduced. The computational core of CONTACT uses parallel computing with moderate success, yielding speed-up only when rather fine grids are used. There we let multiple threads cooperate on a single contact problem, which requires a lot of coordination of the threads. The new way that is introduced in the CONTACT library is to solve multiple contact problems concurrently. Each thread works on a different one, eliminating all coordination. To this end the functions of the CONTACT library are made thread-safe. The main use-cases are to build tables, and to compute multiple wheels of a rail vehicle in parallel.

3   General improvements

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

- The option `G` = 1 is introduced to maintain settings for the iterative solvers from the previous case, shortening the input-file. This works analogously as `L` = 1.

- New options are added to the Matlab plot-programs: show/hide the element division `addeldiv` (color `eldivcol`). Additional fields are provided for the shift distance ('`shft`') or slip velocity ('`srel`', '`sabs+vec`', etc.).

4   Resolved problems

No serious bugs were found in the past period in CONTACT itself, but one complication arose due to changes in Matlab.

- The Matlab plot-programs are updated in order to function correctly with newer Matlab versions ($\geq$ R2014b) with new graphics subsystem.

A few smaller issues that are resolved are as follows:

- When Fastsim is used for steady state rolling, the rolling step `DQ` must be equal to the grid size `DX`. This is now ensured by the program.

- The names `SIGMA` and `SI` for the Poisson ratio ν are changed into `POISS` or `NU`. Stresses in the subsurface calculation are now named `SIGMA` instead of `TAU`.

- The names `FUN`, `FUX`, `FUY` are changed into either `PEN` or `FN`, `CKSI` or `FX` and `CETA` or `FY`.

5   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.

- The picture of the contact area is now suppressed when $O = 2$. In order to keep the picture, change into $O = 3$.

- In cases that use $G = 1$–3 (detailed control over the iterative solvers), increment the G-digit by one ($G = 2$–4).

- For the subsurface stress calculation the following changes are needed:

    - change $S = 2$ into $S = 3$;
    - add the control digits A and O, MATFIL and OUTPUT, in the subsurface input;
    - start each block with ISUBS, using the value 9 for explicitly specified X, Y and Z;
    - remove the flags ZNEXT;
    - terminate the input with a line O ISUBS.

    For details refer to Section 4.9 or Appendix A.3 of the User guide.

The main changes to the output are as follows:

- The subsurface stress calculation now prints the "equivalent tensile stress" σ_{vm} instead of the "ideal shear stress" σ_I.

- Further, the subsurface points are now presented per layer instead of per vertical slice.

Other than that, several textual changes are made in the output-files.

In Matlab, the field 'ptabs+vec' is made the default picture, using $\texttt{exterval} = \texttt{NaN}$.

- The data are transposed such that the rows printed by `disp(sol.pn)` now correspond to rows of the potential contact area. This means that element (i_x, i_y) is now found at `sol.pn(iy,ix)`.

6   Known problems and restrictions

The Windows uninstaller does not support multiple versions (v15.1, v16.1) 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 $\texttt{CHI} = 0$ 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 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.