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cosin/tools for tires

Tire Data File Editor and Analyzer

Documentation and User's Guide

Contents

Document Revision: 2021-4-r25795

Preface

This documentation describes the tire data file editing and analysis tool **cosin/tools for tires**. For more material about **FTire**, and other tire simulation tools, please visit cosin.eu.

cosin/tools for tires is a convenient, GUI-based editor for **FTire** data files, especially helpful together with manual identification within **FTire/fit**. It allows easy access to all relevant **FTire** data, without detailed knowledge of the tire data file format.

This editor:

- groups together all important data into few small and manageable menus;
- renders unnecessary the use of an ASCII editor for data file changes;
- dramatically simplifies the finding and changing of parameter values;
- provides direct and rapid access to individual parameter descriptions in **FTire**'s documentation chapter;
- allows easy changes in the selection choice of nominal modal/stiffness/steady-state data;
- indicates what parameters would actually be used with the current setting;
- provides simple access to several graphical data visualization tools;
- allows to select between SI and USC unit systems;
- allows to forcing renewal of pre-processing, or to disregard old pre-processed data;
- allows to easily 'undoing' latest or all changes during a session;
- provides short-cuts to several other **FTire** tools.

1 cosin/tools for tires's Main Menu

Figure 1 shows **cosin/tools for tires**'s main menu. This menu will be loaded when a **FTire data-file** is opened from within all **FTire** applications.

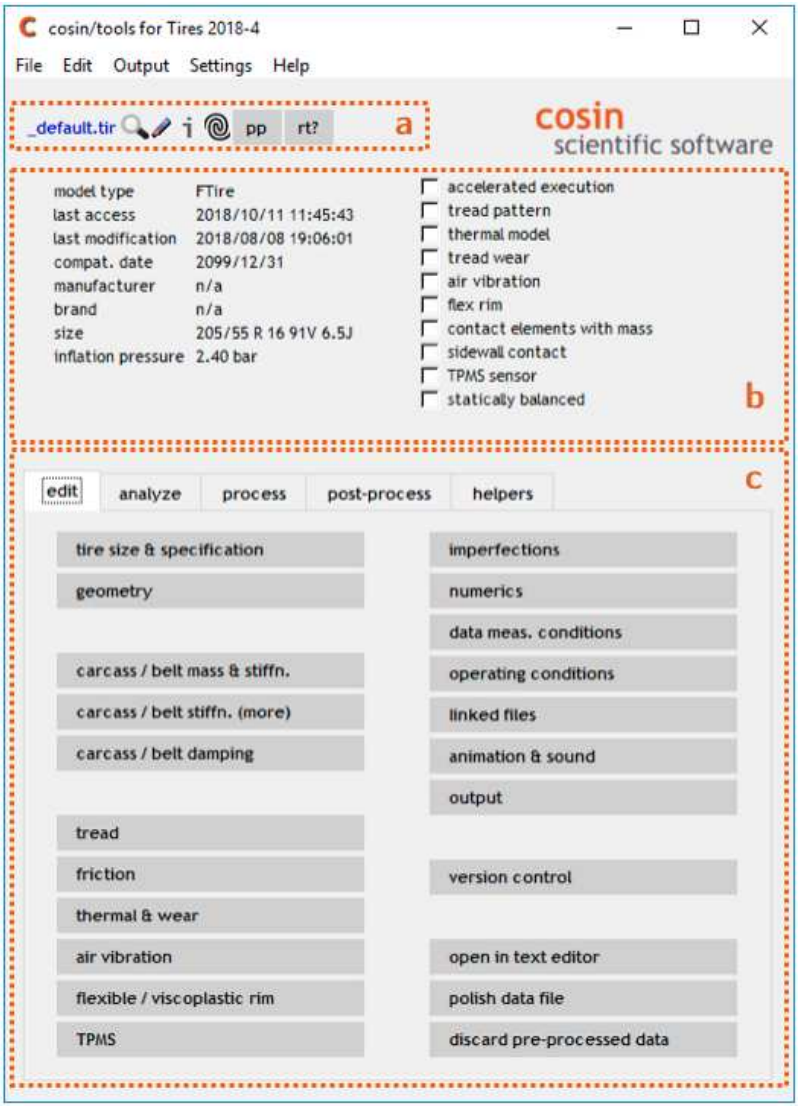

Figure 1: **cosin/tools for tires** main menu

The **cosin/tools for tires**'s main menu is divided into three regions. In the top region (section **a** in figure 1) the file name of the currently open tire data file is displayed. This section also includes four tools that can be used to analyze and view some of the tire properties:

- (**loupe** button), to show the effective tire cross section(see figure 4);
- (**edit** button), to open the tire data file in an ASCII file editor;
- (**info** button), to analyze and show the tire properties;
- (**fingerprint** button), left click the button to compute and show the finger print report. If the right mouse button is used the report will be competed, shown and saved to a user specified location.

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- pp (**pre-process** button), pre-process tire data for non-RT speed modes. Selecting the button with the left mouse button will initiate the pre-processing calculation. Selecting the button with the right mouse button will force a repeat of the preprocessing. The color of the button indicates the quality of the pre-processing - Grey= no pre-processed data is available, Green= OK, Red=Fail;
- rt? (**info** button), pre-process tire data for RT (Real Time) speed modes (requires RT license). A real-time performance test will also be conducted, on a rgr road, to determine if the current machine is real-time capable. Selecting the button with the right mouse button will output the animation of the calculation. The color of the button indicates the quality of the pre-processing - Grey= no pre-processed data is available, Green= OK, Red=Fail;

In section **b** a summary of the tire model properties are shown. The first entry defines the type of the tyre model, either FTire or HTire / MF 2002. The displayed information, and available tools, are dependent on the type of the opened tyre data file. If the opened tire data file is a **FTire** data file, the manufacturer, brand and tire size is shown (if available) on the left. The nominal tire inflation pressure, and 2nd inflation pressure (if defined), is also shown. On the right hand side the current speed-mode (SPM), as well as all activated model extensions are listed.

Section **c** allows the user to have direct access to several tools. The tools are grouped in the following tabs:

- **'edit'**, access to tire data entry menus (section 2);
- **'analyze'**, access to tire data analyzes tools (section 3);
- **'process'**, access to tire data processing tools (section 4);
- **'post-processing'**, access to tire results post-processing tools (section 5);
- **'helpers'**, access to the helpers menu (section 6).

2 cosin/tools for tires*'s Data Entry Menu (edit)*

In the data entry menu (**edit**) all relevant parameters and model data is grouped into a few manageable menus. The data entry menu consists of the following sub-menus:

- **Tire Size and Specification;**
- **Geometry;**
- **Carcass / Belt Mass & Stiffness;**
- **Carcass / Belt Stiffn. (more);**
- **Carcass / Belt Damping;**
- **Tread;**
- **Friction;**
- **Thermal & Wear;**
- **Air Vibration;**

- **Flexible / Viscoplastic Rim;**
- **TPMS;**
- **Imperfections;**
- **Numerics;**
- **Data Meas. Conditions;**
- **Operating Conditions;**
- **Animation & Sound;**
- **Output;**
- **Version Control;**
- **Open in Text Editor;**
- **Polish Data File;**
- **Discard Pre-Processed Data;**

The menus allow easy access to all relevant model parameters by means of an entry field. By selecting the ? (**parameter information** button) next to an entry field (see figure 2), **cosin/tools for tires** will display the **FTire modelization and parameter specification** documentation, together with links to the respective parameter description.

The buttons, in the bottom of all data entry menus (see figure 2), initiate the following:

- **'ok'**, will save all changes to the data file and close the data entry menu;
- **'cancel'**, will leave the menu, without saving the parameters to the data file;
- **'undo'**, will undo the most recent change, both in the menu and in the data file (if available);
- **'apply'**, will store all changed values in any of the entry fields in the data file without closing the data entry menu;

2.1 Tire Size and Specification

The tire size & specification menu groups all data entries that define the tire, and rim, size and key operating specifications. This information can often be found on the tyre side wall, by an alphanumeric tire code, and by product information that is published by the tire manufacturer. Entry fields of optional parameters, such as the `tire polar moment of inertia`, may be left empty or may be specified with the abbreviation **n/a**. For more information about the parameters, please visit the **FTire modelization and parameter specification** documentation.

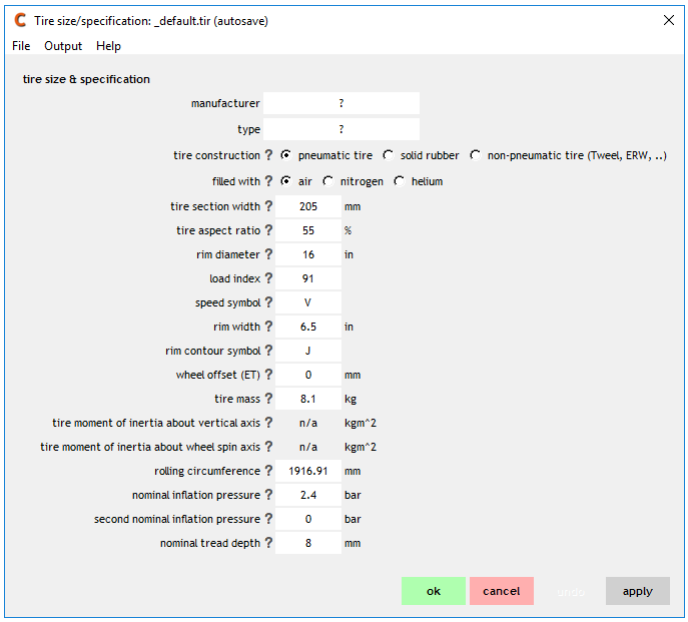

Figure 2: **cosin/tools for tires** tire size and tire specification menu

2.2 Geometry

The geometry menu groups all parameters that can be used to specify the tire and rim geometrical shape. These parameters define the belt dimensions and effective belt shape, as well as the geometrical shape of the tread surface. Additional, and optional, parameters may also be defined the influence the calculation of the interior tire volume.

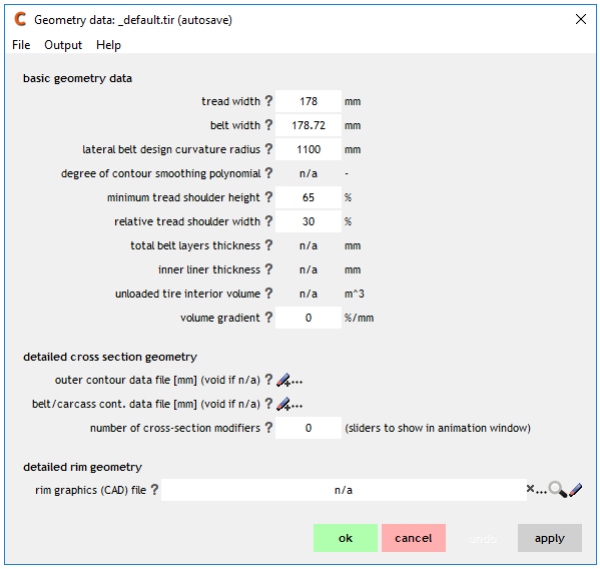

Figure 3: **cosin/tools for tires** geometry data menu

The optional detailed cross section geometry allows for the precise description of the tire's cross section geometry. If defined, they replace $r_{tread,lat}$, $w_{shoulder,rel}$ and $h_{shoulder,rel,min}$. Additional buttons are available to:

- **?** (**help** button), to open the relevant help documentation;

- ••• (**browse** button), to select the spline data file;
- (**create** button), to enter new contour table data in an ASCII file editor;
- (**edit** button), to edit the contour table in an ASCII file editor;
- (**loupe** button), to show the effective tire cross section(see figure 4);
- (**delete** button), to remove the spline data;

Selecting the **(loupe** button), will display a graphical representation of the model's cross section (figure 4), with the numerical carcass line shown in blue color, the tread surface shown in red color, and the contact element's position, direction, and length, also shown with red lines. The theoretical rim and tire main dimensions, as derived from the tire/rim size string, are indicated the light grey area. The maximum tire radius, and width, is also shown in the figure.

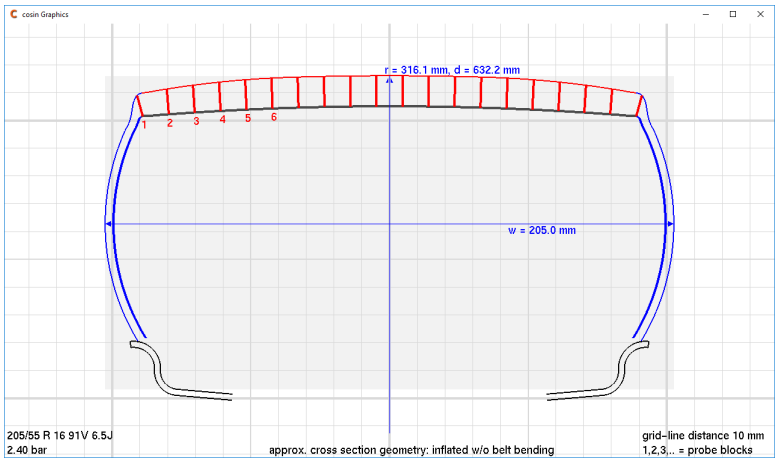

Figure 4: **cosin/tools for tires** cross-section geometry visualization

A name of an optional CAD data file in shl, obj, or stl format, containing the detailed rim geometry, may also be defined. Data will be automatically shifted, rotated, and scaled to exactly match the given rim size. This specification of the rim geometry is an alternative to the specification of the rim geometry in the animation settings, and is only needed when interfacing to cosin/prm. Additional buttons are available to:

- ? (**help** button), to open the relevant help documentation;
- ✕ (**clear** button), to clear all the entry field;
- ••• (**browse** button), to select the rim CAD file;
- (**loupe** button), to show the rim geometry;
- (**edit** button), to edit the rim CAD file in an ASCII file editor;

2.3 Carcass / Belt Mass & Stiffness

Selecting the carcass / belt mass & stiffn. button, in the **cosin/tools for tires** main menu, will open a new window and allows entering parameters defining the primary carcass / belt mass and stiffness. The

mass and stiffness data for the nominal inflation pressure is shown in the first column. If a secondary pressure is defined, the pressure dependent stiffness data will be shown in a second column.

In the top section of the carcass / belt mass & stiffn. menu the tire radial stiffness is defined. Additional mass and stiffness parameters, and their respective specification alternatives, are listed in the bottom section of the menu. The parameters are grouped according to the parameter type, and can be accessed by selecting the tabs in the sub menu(see figure 5, 7 and 8). The data in this section is also arranged in columns, corresponding to the nominal and second(if available) inflation pressure. In some special cases a yellow radio-button, with a corresponding nominal parameter value, will be available in a parameter row. This nominal value has been determined on basis of a special measurement and is not used otherwise. Selecting the yellow radio-button will select the parameter for usage. Note that nominal values are only displayed, but cannot be changed in the menu. This is because nominal values are determined from measurements, and by this are not subject to user changes. Clearly, only those nominal value selection buttons will be displayed for which values are available in the data file.

Figure 5 shows the direct mass and stiffness data on the left, and the modal data on the right-hand side. The tire's structural stiffness can be defined by specifying static tire stiffness data together with the free vibrating mass (direct), or by specifying the tire modal, handling and or static parameters. See **FTire modelization and parameter specification** documentation for more details.

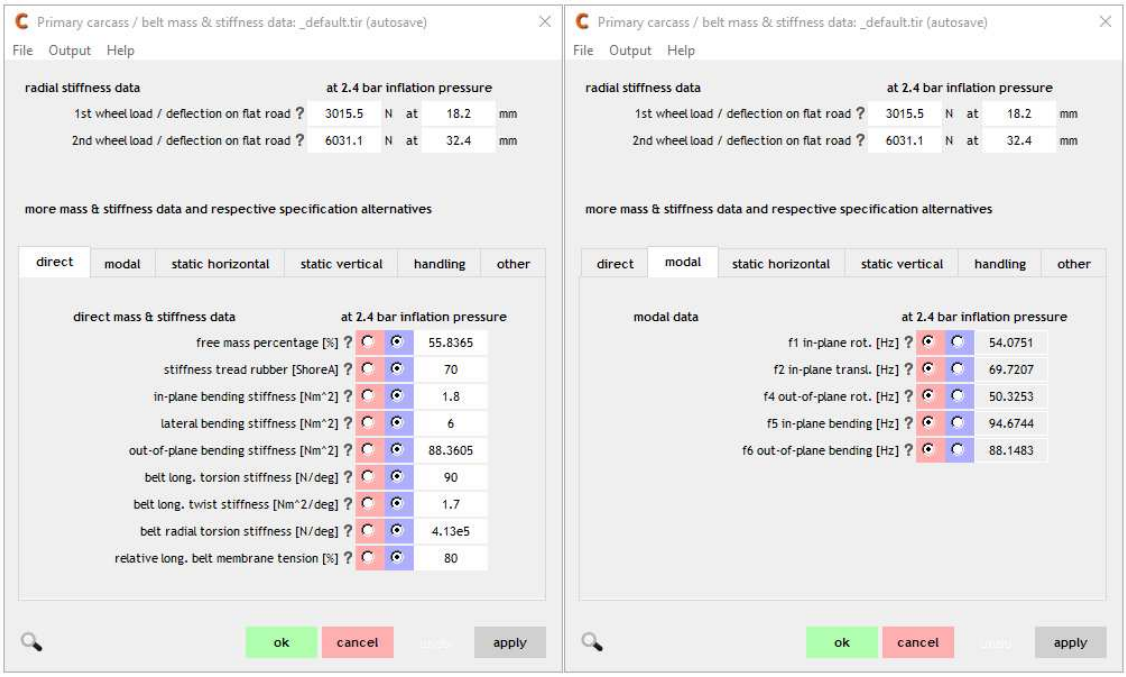

Figure 5: **cosin/tools for tires** carcass/belt mass & stiffn. data menu; Left: direct; Right: modal

The carcass / belt mass & stiffn. menu does not only allow entering parameter values for belt and carcass mass and stiffness, but also the selection which of these parameters are actually to be used during pre-processing. This is done by selecting on of the two radio-buttons associated with the respective parameter (figure 5). Selecting the red radio-button will exclude the parameter from pre-processing, while selecting the blue radio-button will include the parameter.

Note that the selection/deselection of parameters might have a wanted side-effect. For several combi-

nations of parameters, **cosin/tools for tires** knows dependencies which require deselection of one, or more, parameter/s, if another one is selected. To confirm that the system is not over defined, and to see which parameter set is used during preprocessing, the 🔍 (**loupe** button), in the bottom left comer of the carcass / belt mass & stiffn. menu, may be used. In a separate information window (figure 6), **cosin/tools for tires** will show exactly what parameters are specified and used, and what parameters are disregarded.

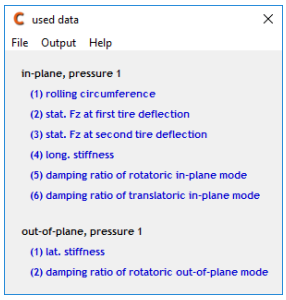

Figure 6: **cosin/tools for tires** used data window

Figure 7 shows the carcass/belt mass & stiffn 'static horizontal' sub menu, left; and the 'static vertical' sub menu on the right-hand side. In addition to the parameter entry fields, additional entry fields are available to define the tire radial deflection that was applied during the measurements of the subsequent stiffness and FZ decrease values.

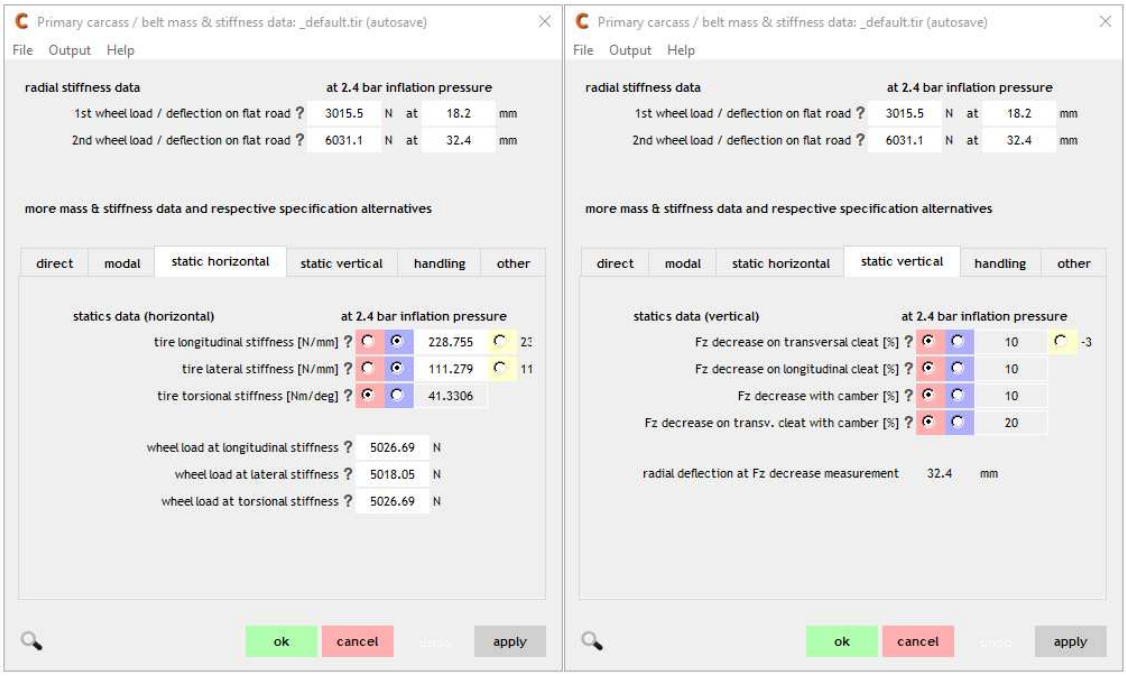

Figure 7: **cosin/tools for tires** carcass/belt mass & stiffn.; Left: static horizontal; Right: static vertical

Figure 8 shows the carcass/belt mass & stiffn static 'handling' sub menu, left; and the 'other' sub menu on the right-hand side. In addition to the parameter entry fields, additional entry fields are available to define the tire radial deflection that was applied during the measurements of the subsequent stiffness values.

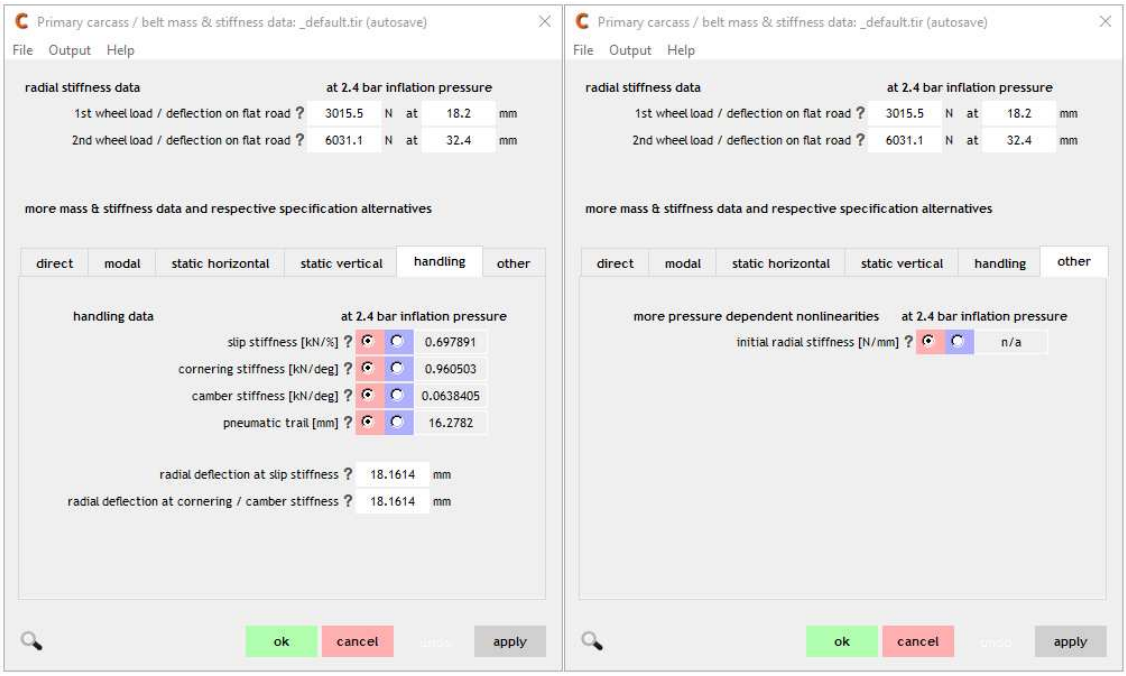

Figure 8: **cosin/tools for tires** carcass/belt mass & stiffn. data menu; Left: handling; Right: other

2.4 Carcass / Belt Stiffn. (more)

The additional belt stiffness data menu is shown in figure 9. The menu consist of four sections:

- **belt kinematics & special structural stiffness data**
  - items in this group, among others, define the progressivity, of various stiffness parameters, and the assumed coupling of various parameters.
- **side wall contact model**
  - radio-buttons to activate/deactivate the sidewall contact model. If the sidewall contact model is activated, tire contact elements will be activated on the tyre sidewall, allowing the sidewall to make contact with the road. If this model is activated, it is recommended to **increase the number of contact elements**, to ensure the model fidelity.
- **stiffness data for misuse conditions**
  - items in this group, among others, define the progressive radial stiffness property of the tire when the tire inner liner near a belt edge touches the inner side of the bead, and thus comes into indirect contact with the rim flange.
- **tire/rim bead friction data**
  - optional items to define the sticking and sliding friction torque between the tire and the rim

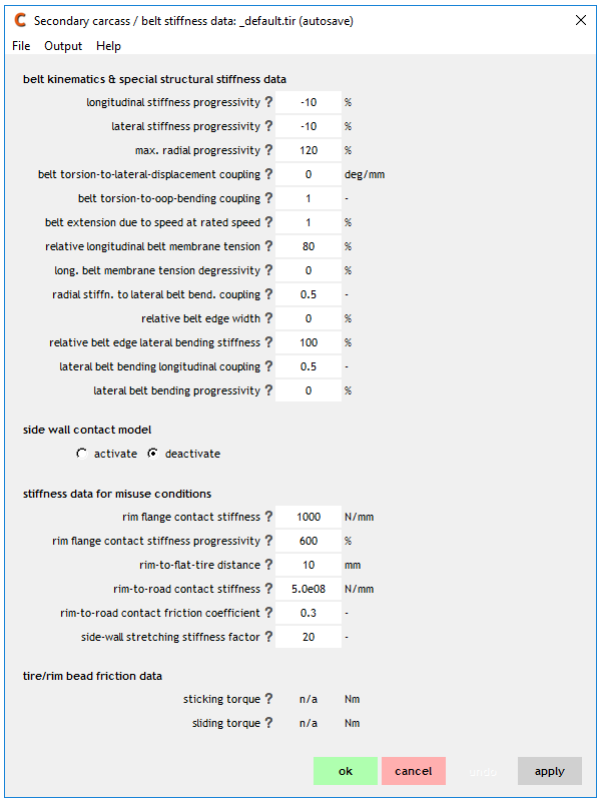

Figure 9: **cosin/tools for tires** additional belt stiffness data menu

2.5 Carcass / Belt Damping

The damping data menu (shown in figure 10) groups the damping parameters into three sections:

- **damping data**
  - items in this group, among others, define the respective modal damping values, belt torsional damping and lateral belt damping parameters;
- **dynamic stiffening data**
  - defining the dynamic tire stiffening, at higher rolling speeds, in radial, tangential (longitudinal), and lateral direction;
- **hysteresis data**
  - describes the structural friction properties which cause the hysteresis loops in radial, tangential (longitudinal), and lateral stiffness characteristics;

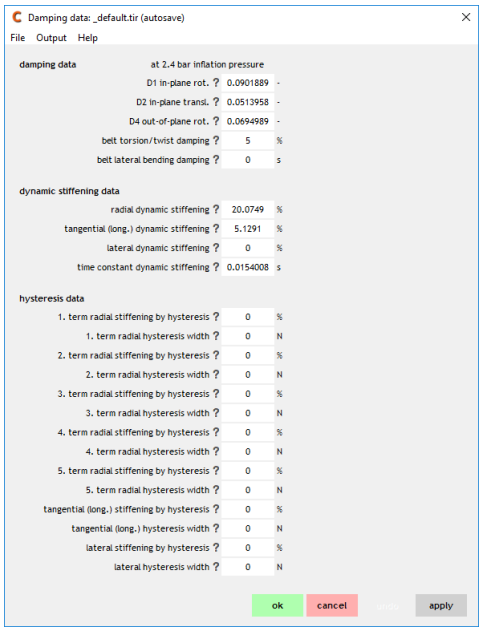

Figure 10: **cosin/tools for tires** damping data menu

2.6 Tread

The tread data menu (shown in figure 11) groups all parameters to describe the tire tread, into two sections:

- **tread stiffness data**
  - items in this group, among others, define the tread depth, stiffness and shape factors;
- **tread pattern data**
  - radio-buttons to activate/deactivate the tread pattern. If activated **FTire** will set the contact element height according to the specified tread pattern.
  - tread pattern image file (supported image file formats are png, gif, tiff, bmp) or geometry defining string, with the following buttons:
    - ? (**help** button), to open the relevant help documentation;
    - ✖ (**clear** button), to clear all the entry field;
    - ••• (**browse** button), to select the tread pattern image file;
    - 🔍 (**loupe** button), to display the tread pattern image file;
    - i (**info** button), compute, and show, the net-to-gross tire contact distribution; Left click: show longitudinal distribution; Right click: show lateral distribution;

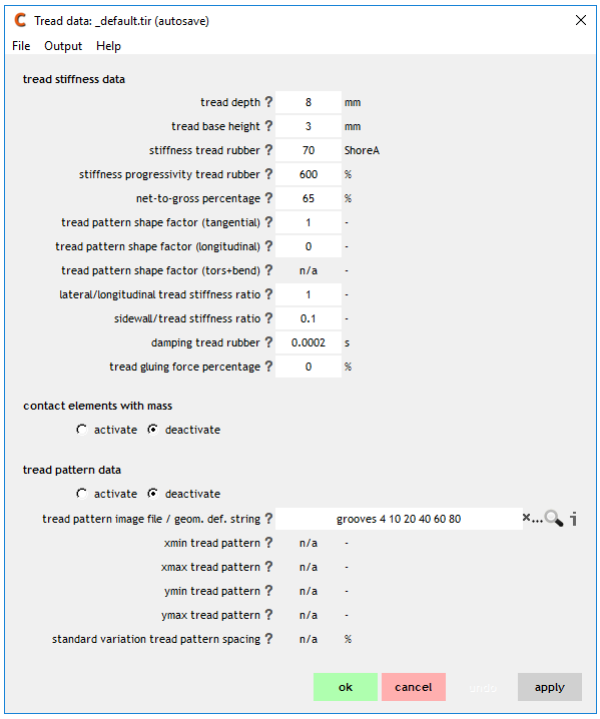

Figure 11: **cosin/tools for tires** tread data menu

2.7 Friction

In the friction data menu (figure 12), the group of variables that describe the dry friction characteristics of the friction couple tread rubber / road surface under normal road conditions is shown. The friction coefficient is a function of the three independent variables **sliding velocity**, **ground pressure**, and **tread rubber temperature**.

In the top section of the friction menu, the sliding velocity and ground pressure influence on friction is shown in a 2-Dimensional table. The friction coefficients can be changed individually, by entering a respective numerical value, or alternatively, complete columns, or rows, or even all values at the same time, can be increased or decreased simultaneously. This is done by clicking a respective '<' or '>' button for a single **column**, or **row**, or the '<<<' or '>>>' buttons for **all** values .

Alternatively, a group of coefficients can be increased or decreased by turning the **mouse wheel** up or down, as long as the mouse points to one of the respective '<' or '>' buttons. In this mode, it doesn't make a difference whether the mouse points to the '<' or to the '>' button. Only the mouse wheel turning direction defines the increase or decrease of values by a constant factor. With the button '**reset all to 1.0**', all friction coefficients can be **reset** to the default value '1'.

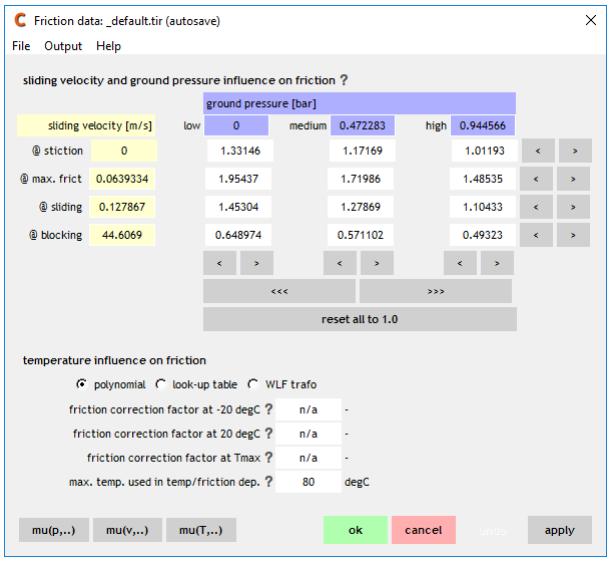

Figure 12: **cosin/tools for tires** friction data menu

In the bottom section of the friction menu, the temperature influence on friction can be specified. For this a set of friction correction factors need to be defined. For a more detailed way to specify the temperature influence, on the friction behavior, a optional look-up table or WLF transform can be defined (Thermal & Wear).

The buttons in the bottom right corner of the friction window, can be used to plot the friction dependencies on the three independent variables:

- **'mu(p,..)'**, to plot the friction coefficients vs. ground pressure friction behavior (shown on the left-hand side of figure 13);
- **'mu(v,..)'**, to plot the friction coefficients vs. sliding velocity friction behavior (shown on the right-hand side of figure 13);
- **'mu(T,..)'**, to plot the friction coefficients vs. surface temperature friction behavior.

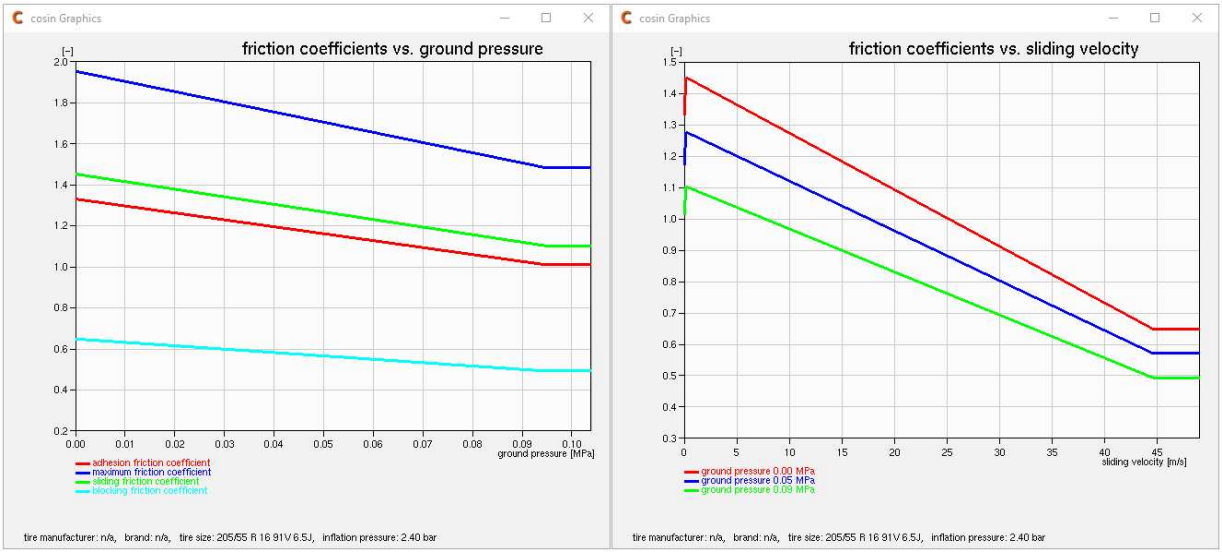

Figure 13: **cosin/tools for tires** friction data visualization

2.8 Thermal & Wear

The thermal and wear menu (shown in figure 14) displays all parameters that are used in the tire thermal and wear models. The menu is divided into three sections:

- **thermal model**
  - radio-buttons to activate/deactivate the thermal model;
  - items in this group define the parameters that used in the heat generation and heat transfer model;
- **temperature influence on friction**
  - items in this group define the temperature influence on friction. Radio-buttons to specify the optional data using a:
    * polynomial, polynomial that defines the temperature influence on friction.
      · entry fields to define polynomial friction corrections factors;
    * look-up table, table that defines the fiction factor change vs. temperature. The following buttons are available:
      · ? (**help** button), to open the relevant help documentation;
      · (**create** button), to create the table in an ASCII file editor;
      · (**edit** button), to edit the table in an ASCII file editor;
      · ••• (**browse** button), to select the spline data file;
      · **'smooth'** (**check-box**), if selected a smooth spline interpolation will be used, deselect to use the piecewise linear interpolation method for the table data;
      · (**loupe** button), to plot the specified table data;
      · (**delete** button), to remove the table data;
    * WLF trafo, Williams-Landel-Ferry equation that defines the temperature influence on friction.
      · entry field to define the tread rubber glass temperature;
- **temperature influence on stiffness**
  - items in this group define the temperature influence on friction, structural stiffness and the tread stiffness. This optional spline or table data can be specified and analysed with the following buttons:
    * ? (**help** button), to open the relevant help documentation;
    * (**create** button), to create the table in an ASCII file editor;
    * (**edit** button), to edit the table in an ASCII file editor;
    * ••• (**browse** button), to select the spline data file;

    * **'smooth'** (**check-box**), if selected a smooth spline interpolation will be used for the table data, deselect to use the piecewise linear interpolation method;
    * (**loupe** button), to plot the specified table data;
    * (**delete** button), to remove the table data;

- **tread wear model**
  - radio-buttons to activate/activate averaged/only compute/deactivate the tread wear model;
  - lists all parameters that define the tread wear model.

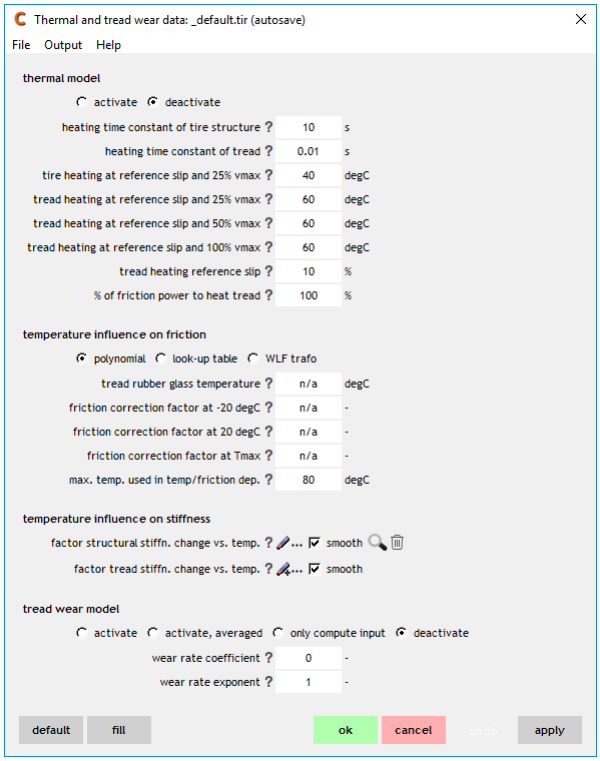

Figure 14: **cosin/tools for tires** thermal and tread wear data menu

Two additional buttons are available in the bottom right corner of the window:

- **'default'**, to reset all data in the current menu to the default values (if available)
- **'fill'**, to complete all missing/empty data entry fields, in the current menu, with the default values (if available)

2.9 Air Vibration

The air vibration menu (shown in figure 15) displays all parameters that are used in the air vibration model. The menu is divided into two sections:

- **air vibration activation**
  - radio-buttons to activate the standard model/activate the detailed model/deactivate the air vibration model;

- **filling gas**
  - radio-buttons to select the tire filling gas. A selection between air, nitrogen or helium is possible.

A additional button is available in the bottom right corner of the window:

- **'default'**, to reset all data in the current menu to the default values (if available)

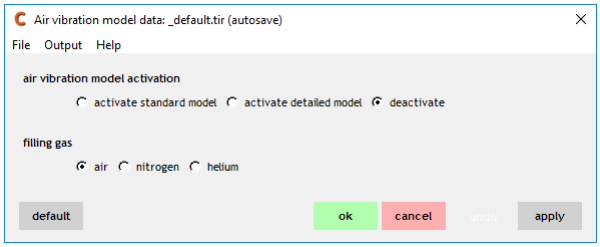

Figure 15: **cosin/tools for tires** air vibration data menu

2.10 Flexible / Viscoplastic Rim

The flexible or viscoplastic rim menu (shown in figure 16) displays all parameters that are used in the flexible rim models. The menu is divided into three sections:

- **flexible - viscoplastic rim model activation**
  - radio-buttons to activate the internal model/activate the user-defined model/deactivate the rim model;
- **model data file**
  - entry field to specify the optional rim data file. The following buttons are available:
    - ? (**help** button), to open the relevant help documentation;
    - ✖ (**clear** button), to clear all the entry field;
    - ••• (**browse** button), to select the rim data file;
    - 🔍 (**loupe** button), to display the rim data file;
    - ✎ (**edit** button), to edit the rim data file;
- **model data**

Two additional buttons are available in the bottom right corner of the window:

- **'default'**, to reset all data in the current menu to the default values (if available)
- **'fill'**, to complete all missing/empty data entry fields, in the current menu, with the default values (if available)

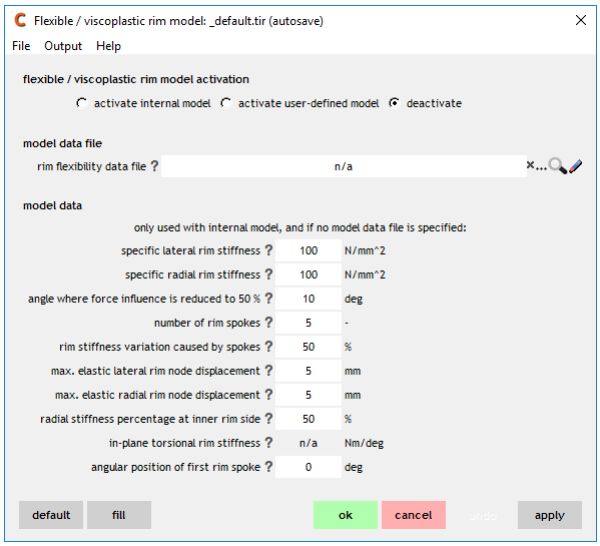

Figure 16: **cosin/tools for tires** thermal and tread wear data menu

2.11 TPMS

The tire pressure monitoring system (TPMS) menu (shown in figure 17) displays all parameters that are used to define a TPMS sensor. The menu is divided into two sections:

- **TPMS sensor model activation**
  - radio-buttons to activate/deactivate the sensor;
- **TPMS sensor position and mass**
  - parameters defining the position and mass of the sensor;

Figure 17: **cosin/tools for tires** tire pressure monitoring system data menu

2.12 Imperfections

The imperfections menu (shown in figure 18) displays all parameters that are used to simulate imbalances in the tire by inhomogeneous mass and stiffness distribution and geometric imperfections. The menu is divided into three sections:

- **imbalance data**
  - defines the optional static and dynamic mass imbalance data

  - defines a optional one dimensional mass variation table or spline.
    * ? (**help** button), to open the relevant help documentation;
    * (**create** button), to create the table in an ASCII file editor;
    * (**edit** button), to edit the table in an ASCII file editor;
    * ... (**browse** button), to select the spline data file;
    * **'smooth'** (**check-box**), if selected a smooth spline interpolation will be used for the table data, deselect to use the piecewise linear interpolation method;
    * (**loupe** button), to plot the specified table data;
    * (**delete** button), to remove the table data;
- **non-uniformity data**
  - defines the optional radial and tangential stiffness non-uniformity
  - defines a optional one dimensional radial and tangential stiffness non-uniformity table or spline.
    * ? (**help** button), to open the relevant help documentation;
    * (**create** button), to create the table in an ASCII file editor;
    * (**edit** button), to edit the table in an ASCII file editor;
    * ... (**browse** button), to select the spline data file;
    * **'smooth'** (**check-box**), if selected a smooth spline interpolation will be used for the table data, deselect to use the piecewise linear interpolation method;
    * (**loupe** button), to plot the specified table data;
    * (**delete** button), to remove the table data;
- **geometry imperfections**
  - items in this group, among others, define optional geometry imperfections such as conicity and ply-steer
  - optional one and two dimensional radius and tread gauge variations,
    * ? (**help** button), to open the relevant help documentation;
    * (**create** button), to create the table in an ASCII file editor;
    * (**edit** button), to edit the table in an ASCII file editor;
    * ... (**browse** button), to select the spline data file;
    * **'smooth'** (**check-box**), if selected a smooth spline interpolation will be used for the table data, deselect to use the piecewise linear interpolation method;
    * (**loupe** button), to plot the specified table data;
    * (**delete** button), to remove the table data;

A additional button is available in the bottom right corner of the window:

- **'default'**, to reset all data in the current menu to the default values (if available)

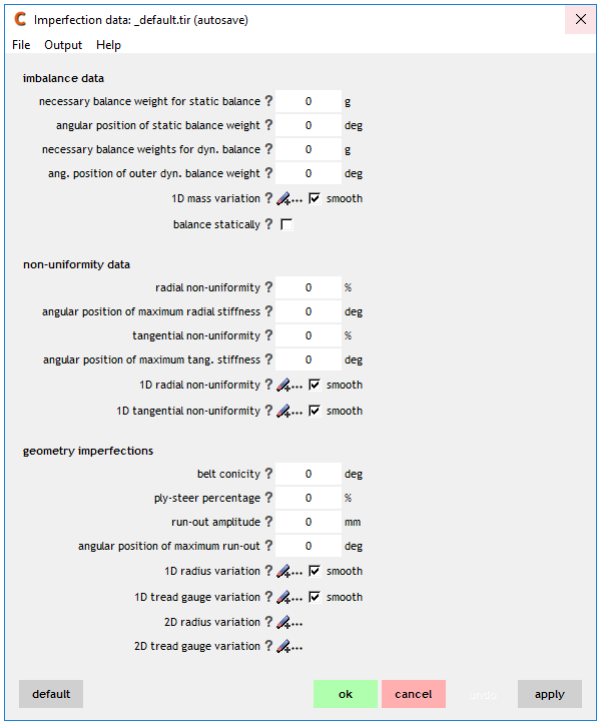

Figure 18: **cosin/tools for tires** imperfection data menu

2.13 Numerics

This dataset controls the numerical properties of FTire (shown in figure 19 and 20). In the top section the **FTire** run-time speed mode can be set by selecting the corresponding radio-button. An additional license key is required for the accelerated run-time mode level 3 and 4 , as well as for all real-time run-time mode levels.

The pre-processing sub menu (shown on the left-hand side of figure 19) menu displays the numerical properties the control the pre-processing.

The run-time sub menu (shown on the right-hand side of figure 19) menu displays all run-time numerical settings. The settings in this sub-menu are dependent on the selected run-time mode. The run-time mode should thus be defined first before changing any of the run-time sub menu entries. The sub menu is divided into three sections:

- **mesh size**
  - items in this section define the **FTire** mesh resolution
- **integrator**
  - items in this section control the numerical integrator, such as the integration step size and parameters that control the implicit integration scheme;
- **contact processor**

– items in this group control the tire-road contact processor.

Two additional buttons are available in the bottom right corner of the numerics window:

- **'default'**, to reset all data in the current menu to the default values (if available)
- **'RTF?'**, to determine the real-time factor (RTF) with the current parameter values and numerical settings

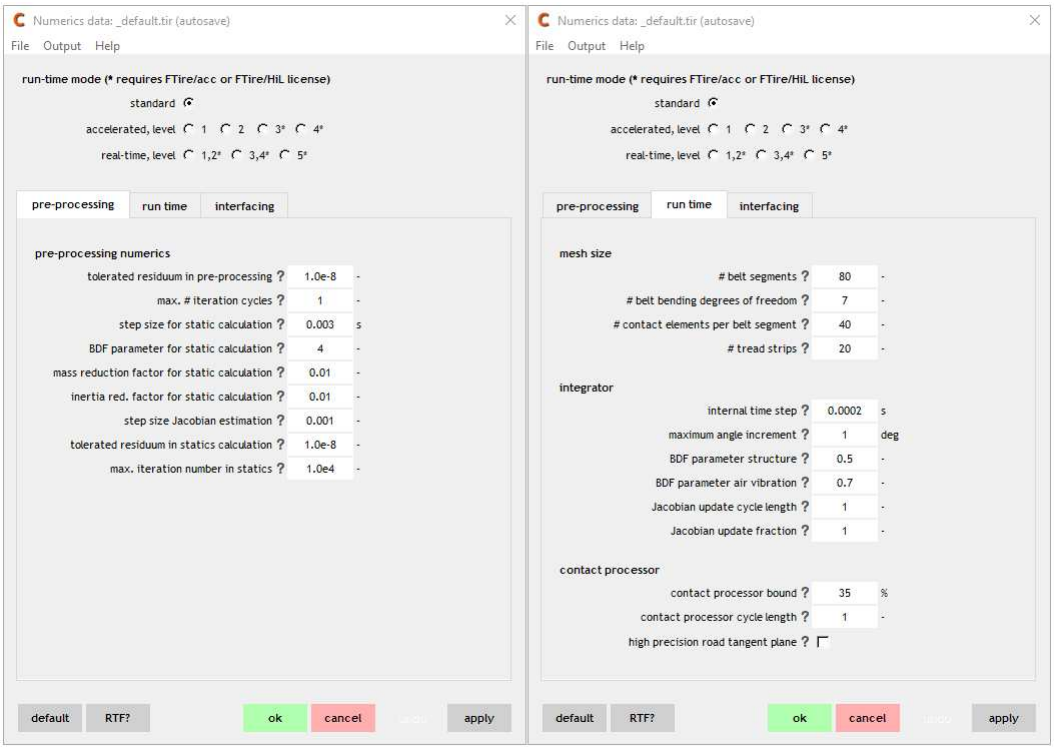

Figure 19: **cosin/tools for tires** numerical settings menu; Left: pre-processing, Right: run time

The interfacing sub menu is shown in figure 20. The settings control the interfacing numerics, that are used in the interface with 3rd-party environments, and can be used to generate extra output files for cosin/prm or CFD co-simulations.

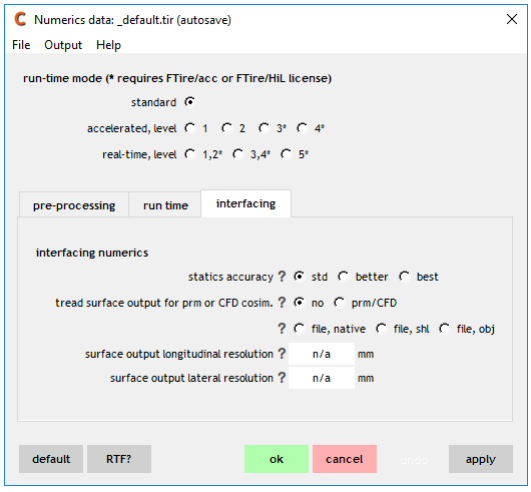

Figure 20: **cosin/tools for tires** numerical settings sub menu: interfacing

2.14 Data Meas. Conditions

The data meas. conditions menu (shown in figure 21) lists all parameters that define the measurement conditions of the parameterization tests.

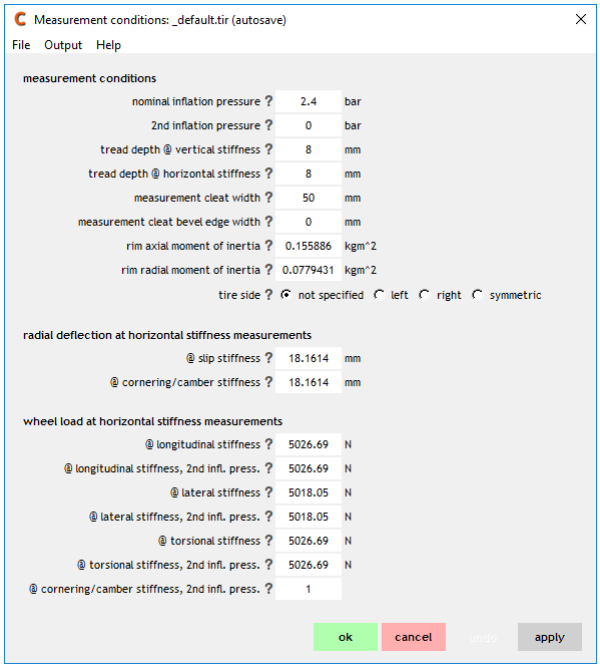

Figure 21: **cosin/tools for tires** measurement conditions menu

The menu is divided into three sections:

- **measurement conditions**
  - items in this section define, among others, the used inflation pressures, tread depth, cleat dimensions and rim moment of inertia;
- **radial deflection at horizontal stiffness measurements**
  - items in this section define, among others, the radial tire deflection during the longitudinal, slip and cornering/camber stiffness measurements;
- **wheel load at horizontal stiffness measurements**
  - defines the wheel load during horizontal stiffness measurements.

2.15 Operating Conditions

The operating conditions menu (shown in figure 22) lists all parameters that define the actual operating conditions, or initial conditions, of the FTire model. Certain tire data can be controlled during a simulation, without re-running the pre-processing step. These parameters are called operating condition parameters.The available operating conditions are:

- actual inflation pressure;
- actual tread depth;

- tread and filling gas temperature;
- road and ambient temperature;
- gravity.

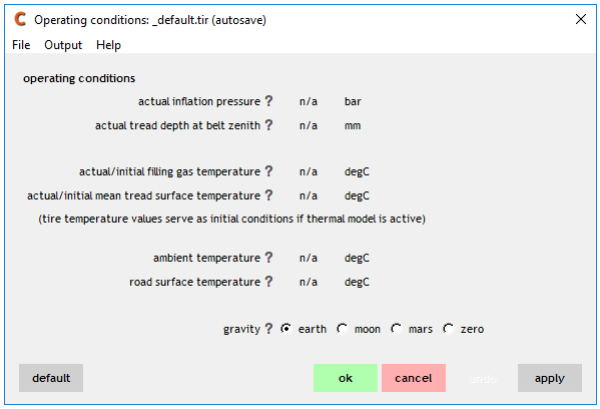

Figure 22: **cosin/tools for tires** operating conditions menu

2.16 Linked Files

The linked files menu (shown in figure 23) lists all files, and optional library path, that are linked to this tire data file.The following files are listed in this section:

- tread patter image / geometry definition string;
- rim data file;
- sidewall texture image;
- rim graphics (CAD) file;
- car-body graphics (CAD) file;
- sound file;
- user library path.

The following buttons are available:

- ? (**help** button), to open the relevant help documentation;
- ✖ (**clear** button), to clear all the entry field;
- ••• (**browse** button), to select a file;
- 🔍 (**loupe** button), to display the contents of the file;
- ✎ (**edit** button), to edit the file.

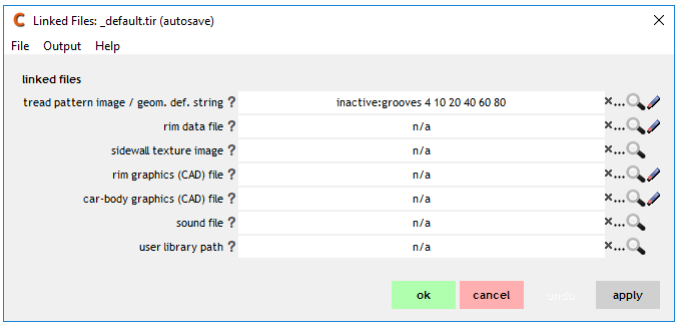

Figure 23: **cosin/tools for tires** linked files menu

2.17 Animation & Sound

The animation and sound settings menu (shown in figure 24) lists all **FTire** animation settings. In the top section, the animation output type can be defined. Current options include:

- **none**, to disable the animation output and all other animation related output;
- **on-line**, to enable the animation output. For efficiency reasons, not all animation features are available in the accelerated speed modes. The on-line animations are by default disabled for all real-time speed modes. For real-time debugging purposes, the animation output can be enabled by activating the option '**if ordered, write output files and show animation even in real-time mode**' (**edit>output>diagnostics**). Additional settings for this option can be activated with the following check-boxes:
  - **full screen**, to enable the full-screen animation output;
  - **enable in 3rd-party env.**, to output the animation, even if suppressed by certain calling solvers in 3rd-party environments;
- **on-line + movie**, to activate the animation output and simultaneously create a movie file. The following codecs are available (if supported by the user environment):
  - **mp4**, create movie in mp4 (MPEG-4) codec, compatible with VLC, QuickTime, Windows Media Player;
  - **lossless**, create movie in ffv1 lossless archiving codec, compatible with VLC and Windows Media Player;
- **on-line + ogl file**, to activate the animation output and simultaneously record a off-line animation file (ogl-file). The ogl-file can be used to play back the simulation off-line in the **cosin/player** or 3rd-party post-processors;
- **on-line + frame list (bmp)**, to activate the animation output and simultaneously create a sequence of bitmap(bmp) files;
- **only ogl-file**, to only output the off-line animation file (ogl-file);

The bottom part of the animations menu lists sub-menus that control the animation output. The sub-menus are:

- **scene** (pg. 23)

- **tire surface** (pg. 27)
- **sidewall** (pg. 28)
- **footprint** (pg. 29)
- **scopes** (pg. 30)
- **rim** (pg. 31)
- **road** (pg. 32)
- **car-body** (pg. 33)
- **decoration** (pg. 34)
- **sound** (pg. 35)

Selecting the 🔍 (**loupe** button), in the bottom right corner of the animation menu window, will open a animation window and visualize the current animation settings (if the tire data does not contain valid pre-processed data, it may take a while before the animation window is shown) .

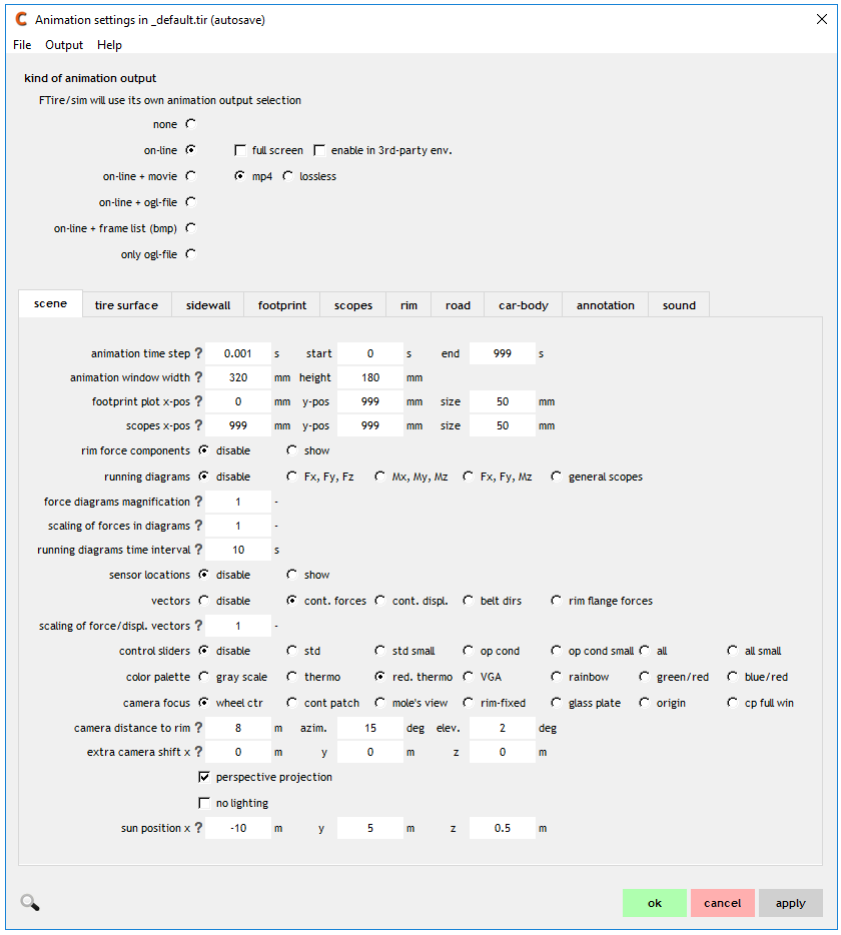

Figure 24: **cosin/tools for tires** animation settings menu: scene

The **scene** sub-menu (shown in figure 24) lists all settings that control the animation scene. The following settings are available:

- **animation time**, defining the animation output duration and step size. The following entry fields are available:
  - **time step**, animation output step size. If the defined animation step size is smaller than the internal solver step size, the internal solver step size will be used instead;
  - **start time**, animation output start time;
  - **end time**, animation output end time;
- **animation window size**, defining the on-line animation window size with the following entries:
  - **window width**, on-line animation widow width;
  - **window height**, on-line animation window height;
- **footprint plot position**, defining the footprint plot position in the animation window with the following entries:
  - **x-position**, x-position of the bottom left corner of the footprint plot. If the position is on the outside of the defined animation window, the closest position that is located on the animation window will be chosen;
  - **y-position**, y-position of the bottom left corner of the footprint plot. If the position is on the outside of the defined animation window, the closest position that is located on the animation window will be chosen;
  - **size**, the size of the footprint plot;
- **scopes position**, defining the position of the scopes in the animation window with the following entries:
  - **x-position**, x-position of the bottom left corner of the scope. If the position is on the outside of the defined animation window, the closest position that is located on the animation window will be chosen;
  - **y-position**, x-position of the bottom left corner of the first scope. If the position is on the outside of the defined animation window, the closest position that is located on the animation window will be chosen;
  - **size**, the size of the scope;
- **rim force components**, radio-buttons to show/hide the rim force components;
- **running diagrams**, radio-buttons defining which running diagrams or scopes should be shown during the animation. The running diagrams may require information that is saved to the additional plot output file. To generate the additional plot output file go to **edit>output>output files>plot file** and select the **extended, ascii** option. The following running diagrams are available:
  - **disable**, to hide all diagrams during the animation;
  - **Fx, Fy, Fz**, to display the three tire force components in a running diagram;
  - **Mx, My, Mz**, to display the three tire moments in a running diagram;
  - **Fx, Fy, Mz**, to display the handling relevant tire forces and moment in a running diagram;

  - **general scopes**, to display the defined scopes in a running diagram/s (see figure 28);
- **force diagram magnification**, force diagrams magnification factor. The scope size will be multiplied with this magnification factor;
- **force diagram scaling**, the force diagrams scaling factor is used to scale the rim force components;
- **running diagrams time interval**, plot time interval to be used in the running diagrams;
- **sensor locations**, radio-buttons to show/hide the sensor locations;
- **vectors**, radio-buttons defining the vector output during animations. The following options are available:
  - **disable**, to hide all display vectors during animations;
  - **cont. forces**, to display contact force vectors. Contact forces will be shown for each contact element, either in red, orange or in yellow. A red color indicates that the element is sticking to ground, an orange color indicates that the element is starting to slide but has not reached the maximum friction level, whereas a yellow color indicates that the element is sliding;
  - **cont. displ**, to display contact element displacement vectors. Contact element displacements will be shown for each contact element, either in red, orange or in yellow. A red color indicates that the element is sticking to ground, an orange color indicates that the element is starting to slide but has not reached the maximum friction level, whereas a yellow color indicates that the element is sliding;
  - **belt dirs**, to display the belt direction. Belt directions will be shown for all belt elements;
  - **rim flange forces**, to display the rim contact force vectors. Rim contact force vectors will be shown for each contact element. The contact force vectors will be displayed in red if the internal force is at least 50% larger than the centrifugal force of the free tire mass. If this condition is not met then the contact forces will be shown in blue;
- **scaling of force/displ. vectors**, the factor is use to scale the contact force /rim flange force/contact displacement vectors;
- **control sliders**, radio-buttons defining the set of sliders that are shown during the animation. The sliders control, among others, scaling factors and the tire graphics resolution. The following options are available:
  - **disable**, to hide all control sliders during animations;
  - **std**, to display the standard set of control sliders during the animation;
  - **std small**, to display a smaller version of the standard set of control sliders during the animation;
  - **op cond**, to display only the set of control sliders that control the output conditions during the animation;
  - **op cond small**, to display a smaller version of the set of control sliders that control the output conditions;
  - **all**, to display all available control sliders during the animation;

  - **all small**, to display a smaller version of all available control sliders during the animation;

- **color palette**, radio-buttons defining the color palette that is used in the footprint plot. The following color palettes are available:
  -  - **grey scale;**
  -  - **thermo;**
  -  - **reduced thermo;**
  -  - **VGA;**
  -  - **rainbow;**
  -  - **green/red;**
  -  - **blue/red**;

- **camera focus**, radio-buttons defining the camera focus point. The following options are available:
  - **wheel ctr**, to focus the camera on the wheel center;
  - **cont patch**, to focus the camera on the contact patch;
  - **mole's view**, to view the scene from above;
  - **rim-fixed**, to move the camera with the rim;
  - **glass plate**, to view the scene from below;
  - **origin**, to focus the camera on the origin;
  - **cp full win**, to display only the footprint plot in the animation window;

- **camera position**, defining the camera position relative to the rim. The following entry fields are available:
  - **distance to rim**, to set the camera distance to the rim;
  - **azim.**, to set the azimuth camera view angle;
  - **elev.**, to set the elevation(altitude) camera view angle;

- **extra camera shift**, defining an additional camera shift. The following entry fields are available:
  - **shift x**, to shift the camera in the x-direction;
  - **shift y**, to shift the camera in the y-direction;
  - **shift z**, to shift the camera in the z-direction;

- **scene projection**, defining the projection mode during the animation. The default projection mode (no selection is made) is the orthographic (or parallel) mode; if the check box is however marked, then the perspective projection mode will be used instead;

- **lighting**, defining the lighting mode during the animation. The default lighting mode (no selection is made) is the ON mode; if the the check box is however marked, then the lighting will be switched OFF;

- **sun position**, defining the light source (sun) position. The following entry fields are available:
  - **position x**, to set the x-position of the light source;
  - **position y**, to set the y-position of the light source;
  - **position z**, to set the z-position of the light source;

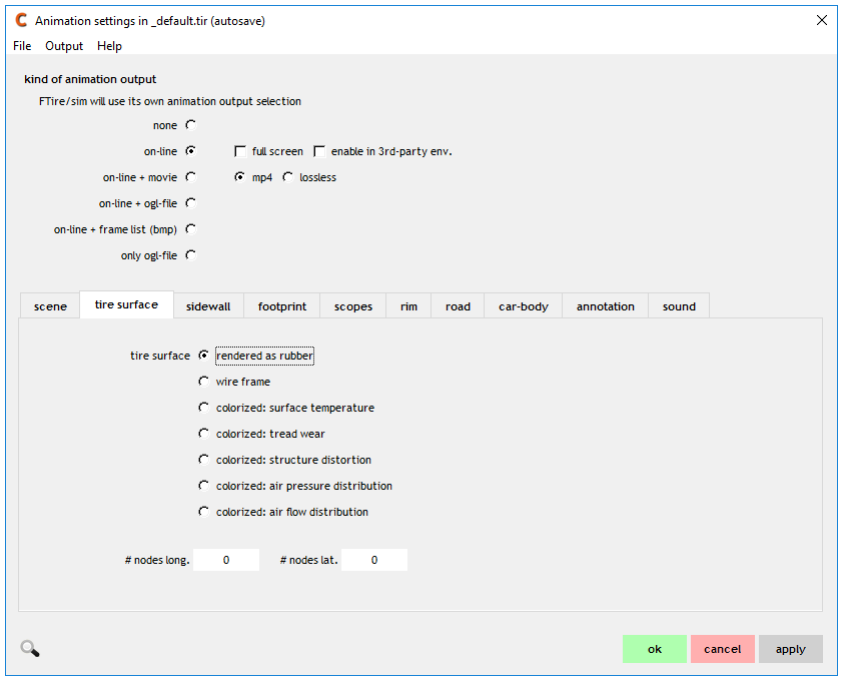

Figure 25: **cosin/tools for tires** animation settings menu: tire surface

The **tire surface** sub-menu (shown in figure 25) lists all settings that control the rendering of the tire in the animation. The following settings can be set:

- **tire surface**, radio-buttons defining the rendering of the tire structure. The following options are available:
  - **render as rubber;**
  - **wire frame;**
  - **colorized: surface temperature;**
  - **colorized: tread wear;**
  - **colorized: structure distortion;**
  - **colorized: air pressure distribution;**
  - **colorized: air flow distribution;**
- **# nodes**, defining the rendering resolution of the tire structure. The following entry fields are available:
  - **long.**, defining the number of nodes in the longitudinal direction. Set to 0 for default values;
  - **lat.**, defining the number of nodes in the lateral direction. Set to 0 for default values;

- **temperature scale final value**, defining the value of the maximum temperature to be used in the color scale;

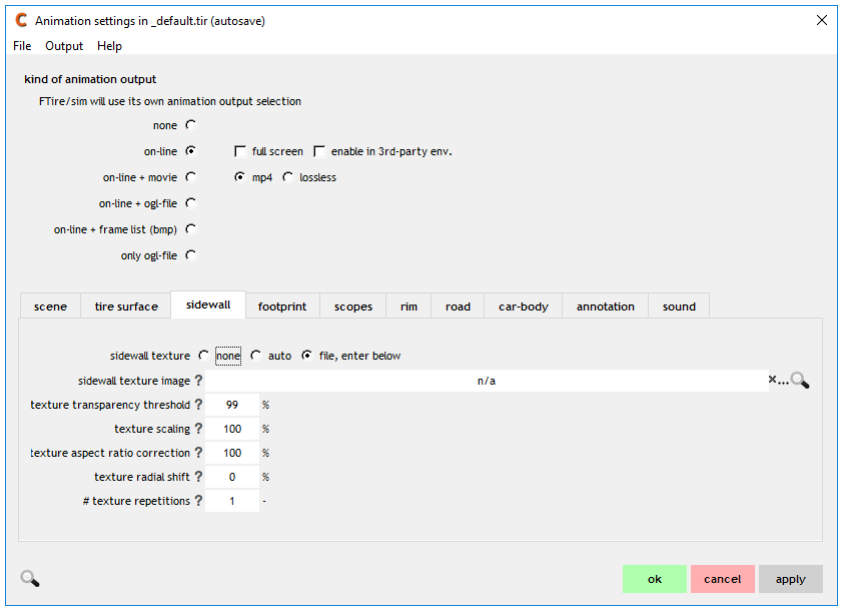

Figure 26: **cosin/tools for tires** animation settings menu: sidewall

The **sidewall** sub-menu (shown in figure 26) lists all settings that control the rendering of the tire sidewall in the animation. The following settings can be set:

- **tire surface**, radio-buttons defining the sidewall marking. The following options are available:
  - **none**, to hide all tire markings;
  - **auto**, to display the alphanumeric tire identification code;
  - **file**, to us the defined image file as sidewall marking;
- **sidewall texture image file**, to define the sidewall texture image file that should be used;
- **texture transparency threshold**, to define the pixel transparency threshold:
  - positive threshold - pixels lighter than threshold are set to transparent;
  - negative threshold - pixels darker than threshold are set to transparent;
- **texture scaling**, to define a percentual resize scaling factor of the texture image;
- **texture aspect ratio correction**, to define a texture aspect ratio correction factor. If the correction factor is:
  - smaller than 100% - the width of the image will increase;
  - larger than 100% - the width of the image will decrease;
- **texture radial shift**, to define a radial shift, relative to the sidewall hight, of the sidewall texture. If the shift is:
  - positive - the shift is outward, away from the rim center;
  - negative - the shift is inward, towards the rim center;

- # **texture repetitions**, to define the number of texture repetitions in circumferential direction;

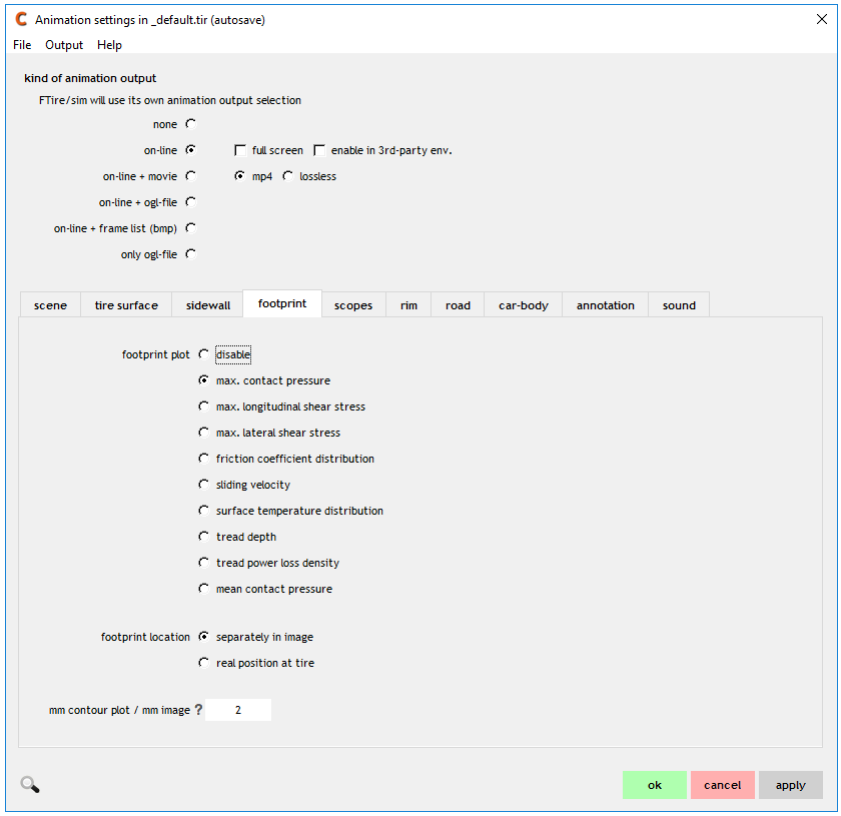

Figure 27: **cosin/tools for tires** animation settings menu: footprint

The **footprint** sub-menu (shown in figure 27) lists all settings that control the footprint plot in the animation. The following settings can be set:

- **footprint plot**, radio-buttons to show/hide the various footprint plots during the animation. The following options are available:
  - **disable**, to hide the footprint plot;
  - **contact pressure**, to show the current tire contact pressure distribution;
  - **longitudinal shear force**, to show the current longitudinal shear stress in the contact patch;
  - **lateral shear force**, to show the current lateral shear stress in the contact patch;
  - **friction coefficient**, to show the current friction coefficients of the contact elements;
  - **sliding velocity**, to show the current sliding velocity of the contact elements;
  - **temperature**, to show the current temperature of the contact elements;
  - **tread depth**, to show the current tread depth of the contact elements;
  - **power loss**, to show the current power loss in the contact patch;
- **footprint location**, radio-buttons to define the location where the plot is shown. The following options are available:

  - **separately in image**, to display the footprint plot in the animation window. The location is defined in the **scene** options tab;
  - **real position at tire**, to render the footprint plot to the the tire surface;
- **mm contour plot / mm image**, to define the factor that scales the size of the contact patch, if shown in the full window mode. It specifies the true size of contact patch relative to the shown size, in terms of an integer number.

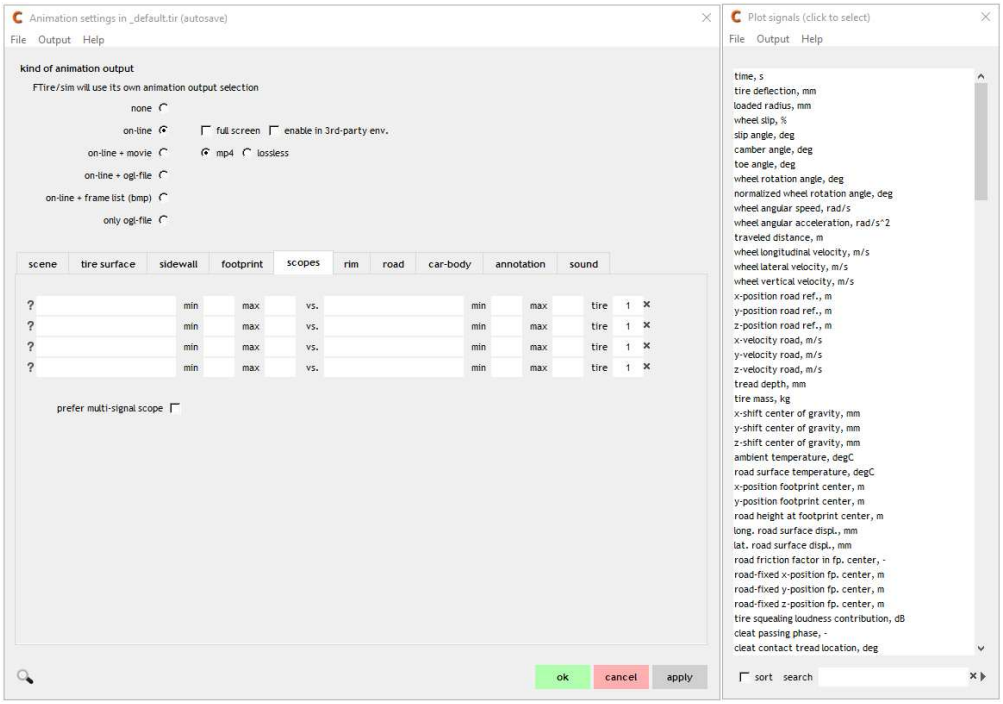

Figure 28: **cosin/tools for tires** animation settings menu: scopes

The **scopes** sub-menu (shown in figure 28) lists settings that define the general scopes in the animation. A maximum of three scopes can be defined. The following settings can be set:

- entry fields defining the scopes, the following entry fields need to be defined:
  - **?** (**help** button), to display the instructions on how to define the scopes;
  - **y-axis plot signal**, entry field to define the y-axis plot signal. Select the entry field with the left mouse button and then select the required plot signal from the '**Plot signals**' window. The entry field will automatically be filled with the relevant information;
  - **min**, to specify the minimum y-axis value. A blank field sets the scaling to '**auto-scaling**';
  - **max**, to specify the maximum y-axis value. A blank field sets the scaling to '**auto-scaling**';
  - **x-axis plot signal**, entry field to define the x-axis plot signal, the default is '**time, s**'. Select the entry field with the left mouse button and then select the required plot signal from the '**Plot signals**' window. The entry field will automatically be filled with the relevant information;
  - **min**, to specify the minimum x-axis value. A blank field sets the scaling to '**auto-scaling**';

- **max**, to specify the maximum x-axis value. A blank field sets the scaling to '**auto-scaling**';
- ✖ (**clear** button), to clear all the entry fields of the scope;

- **prefer multi-signal scope**, combines all defined scoped into a single plot.

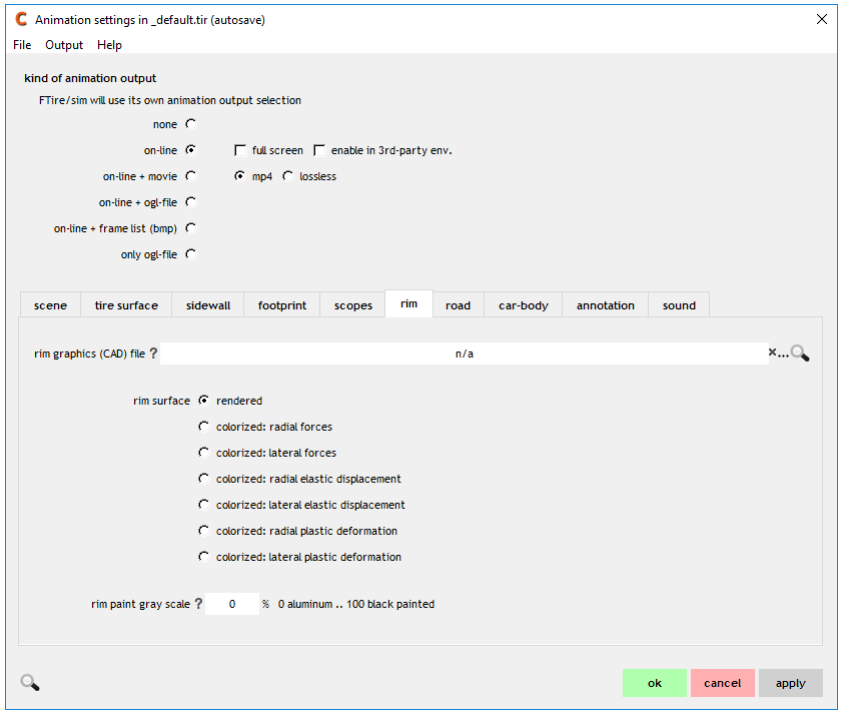

Figure 29: **cosin/tools for tires** animation settings menu: rim

The **rim** sub-menu (shown in figure 29) lists all settings that control the rendering of the rim in the animation. The following settings can be set:

- **rim graphics file**, entry field defining the rim CAD file. The following buttons are available:
  - ? (**help** button), to open the relevant help documentation;
  - ✖ (**clear** button), to clear the entry field;
  - ••• (**browse** button), to select the rim graphics file from a file browser;
  - 🔍 (**loupe** button), to view the rim graphics file in the **cosin/CADbrowser**;
- **rim surface**, radio-buttons controlling the rim surface render settings. The following options are available:
  - **rendered**;
  - **colorized: radial forces**;
  - **colorized: lateral forces**;
  - **colorized: radial elastic displacement**;
  - **colorized: lateral elastic displacement**;
  - **colorized: radial plastic deformation**;

  - **colorized: lateral plastic deformation**;

- **rim paint gray scale**, scaling factor controlling the rendered color of the rim. Setting the value to 0% will result in an aluminum finish while setting the value to 100% will result in a black paint finish.

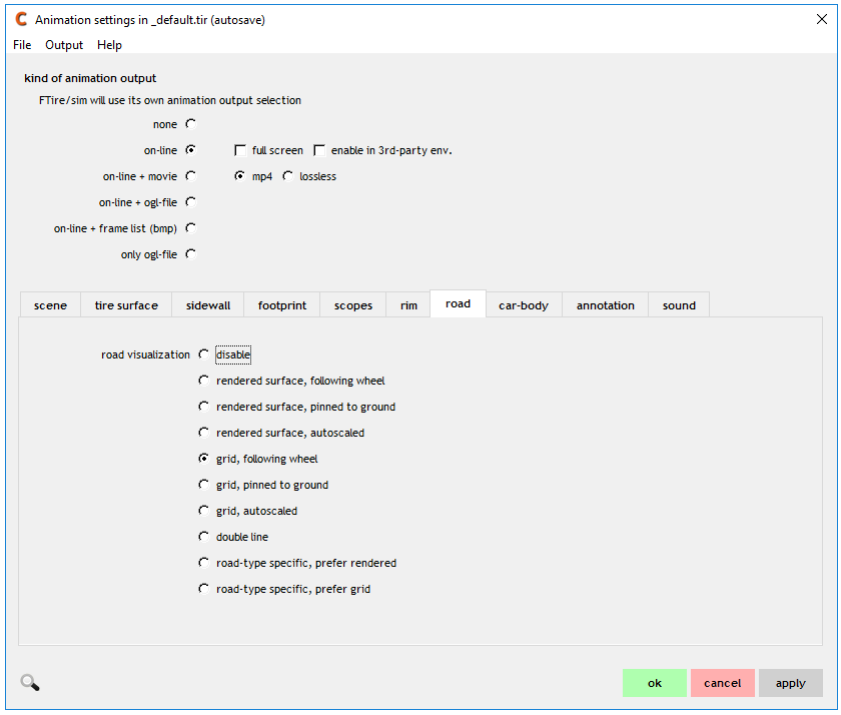

Figure 30: **cosin/tools for tires** animation settings menu: road

The **road** sub-menu (shown in figure 30) lists all settings that control the rendering of the road in the animation. The following settings can be set:

- **road visualization**, radio-buttons controlling the road surface render settings. The following options are available:
  - **disable**;
  - **rendered surface, following wheel**, grey scale color palette is used;
  - **rendered surface, pinned to ground**, grey scale color palette is used;
  - **rendered surface, autoscaled**, reduced thermo color palette is used;
  - **grid surface, following wheel**, grey scale color palette is used;
  - **grid surface, pinned to ground**, grey scale color palette is used;
  - **grid surface, autoscaled**, grey scale color palette is used;
  - **double line,** single black line per tire instance;
  - **road type specific, prefer rendered**;
  - **road type specific, prefer grid**;
- **grid size**, to define the visualized road grid size:

  - **x**, defining the length of the visualized road;
  - **y**, defining the width of the visualized road;
- **grid line distance**, to define the grid resolution:
  - **x**, defining the x line spacing;
  - **y**, defining the y line spacing;

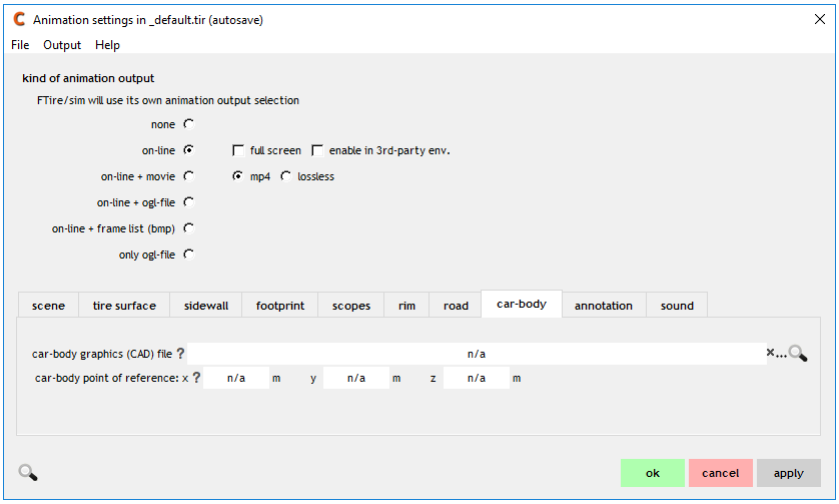

Figure 31: **cosin/tools for tires** animation settings menu: car-body

The **car-body** sub-menu (shown in figure 31) lists all settings that control the rendering of the car-body in the animation. The following settings can be set:

- **car-body graphics file**, entry field defining the rim CAD file. The following buttons are available:
  - **?** (**help** button), to open the relevant help documentation;
  - **✖** (**clear** button), to clear the entry field;
  - **...** (**browse** button), to select the car-body graphics file from a file browser;
- **car-body point of reference**, to define the car-body reference point with:
  - **x**, defining the reference location along the x-axis;
  - **y**, defining the reference location along the y-axis;
  - **z**, defining the reference location along the z-axis;

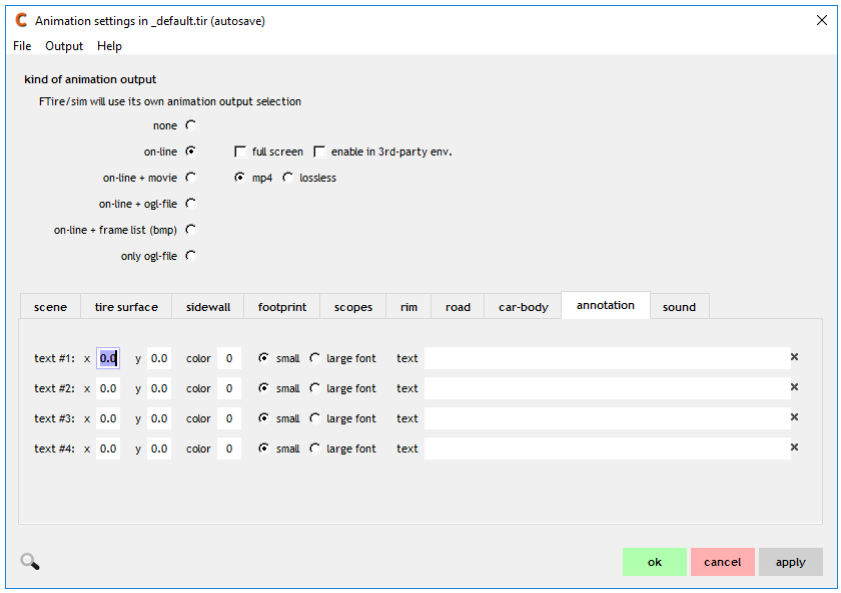

Figure 32: **cosin/tools for tires** animation settings menu: decoration

The **decoration** sub-menu (shown in figure 32) lists all settings that define optional text that should be displayed during the animation. The following settings can be set:

- **text**, to specify up-to three user-defined strings as decoration. The following fields need to be defined:
  - **x**, defining the x starting position of the decoration;
  - **y**, defining the y starting position of the decoration;
  - **color**, defining the color of the decoration;
  - **font size**, defining the font-size of the decoration;
  - **text**, defining the string that should be displayed as decoration;
  - ✖ (**clear** button), to clear the text entry fields;

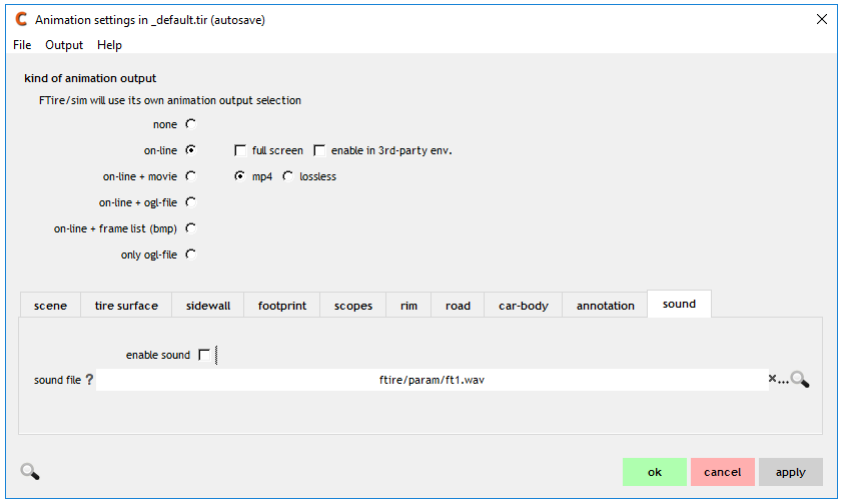

Figure 33: **cosin/tools for tires** animation settings menu: sound

The **sound** sub-menu (shown in figure 33) lists all settings that define the tire sound of the animation. The following settings can be set:

- **enable sound**, check-box to enable the sound;
- **sound file**, entry field defining the rim sound file. The following buttons are available:
  - ? (**help** button), to open the relevant help documentation;
  - ✖ (**clear** button), to clear the entry field;
  - ••• (**browse** button), to select the sound file from a file browser;
  - 🔍 (**loupe** button), to view the sound file with a media player;

2.18 Output

The output settings menu (shown in figure 34) lists all settings that control the **FTire** result file and other outputs. The menu is divided into four sub-menus. The sub-menus are:

- **output files** (pg. 35)
- **diagnostics** (pg. 39)
- **sensor signals** (pg. 40)
- **pre-processing control** (pg. 41)

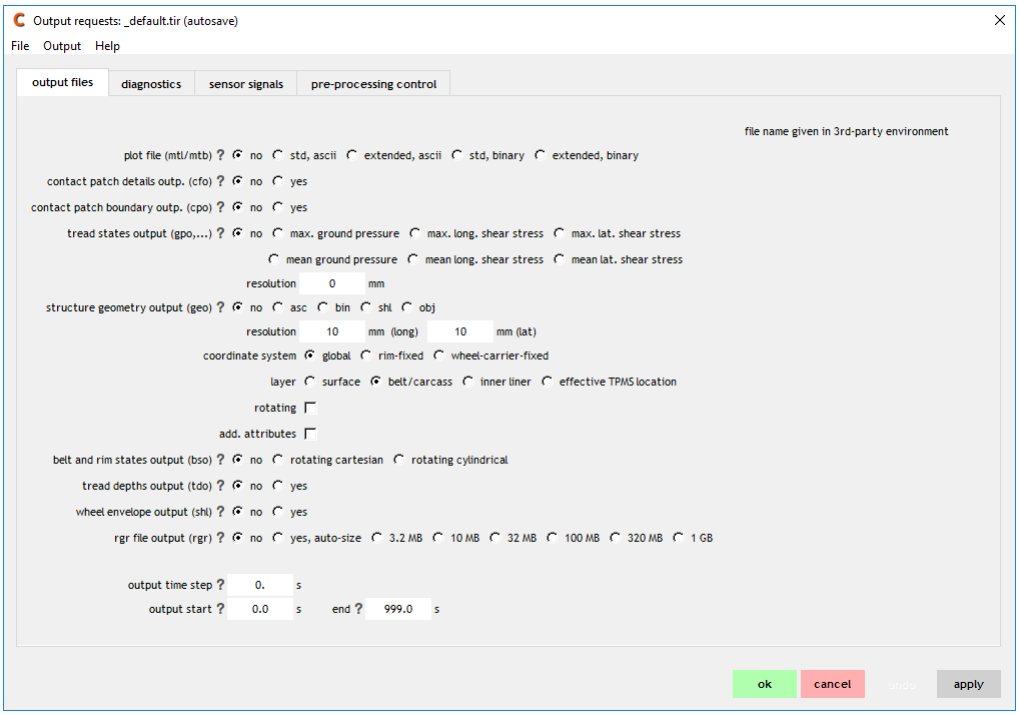

Figure 34: **cosin/tools for tires** output specification menu

The **output files** sub-menu (shown in figure 34) lists all settings that define the result file output during a **FTire** simulation. If an output option is selected, then the output file name, given in a 3rd-party environment, is show in blue on the left-hand side of the output files menu. The sample file name and

file extension are shown. The 'x', in the file name, is a placeholder for the tire instance (one output file will be generated per tire instance). The following settings can be set in the menu:

- **plot file (mtl/mtb)**, radio-buttons to generate additional plot output files (one per tire instance) with FTire states and other output signals. The following options are available:
  - **no**, to disable the plot file output;
  - **std, ascii**, to output the most important plot signals, saved in a Matlab-compatible ascii-file (.mtl);
  - **extended, ascii**, to output all available plot signals, saved in a Matlab-compatible ascii-file (.mtl);
  - **std, binary**, to output the most important plot signals, saved in a Matlab-compatible binary-file (.mtb);
  - **extended, binary**, to output all available plot signals, saved in a Matlab-compatible binary-file (.mtb);
- **contact patch details output (cfo)**, radio-buttons to generate extra output files containing the distributed ground contact forces and several state variables of the tread, for further user-specific post-processing purposes. The following options are available:
  - **no**, to disable the contact patch details output;
  - **yes**, to output the distributed ground contact forces and several state variables of the tread, saved in Matlab-compatible ascii-file;
- **contact patch boundary output (cpo)**, radio-buttons to generate extra output files containing the containing the contact patch boundary data points, for further user-specific post-processing purposes.The output files consist of a sequence of (n_boundary_data_points $\times$ 2)-matrices, each containing the contact patch boundary data points at the simulation time written in the respective matrix head-line (for example: % time=0.1 112 boundary data points). The following options are available:
  - **no**, to disable the contact patch details output;
  - **yes**, to output the contact patch boundary data points, saved in Matlab-compatible ascii-file;
- **tread states output (gpo,...)**, radio-buttons to generate extra output files containing tread state values, interpolated onto a regular and uniform grid. The output files consist of a sequence of (nx $\times$ ny)-matrices, each containing tread state values at the simulation time written in the respective matrix head-line (for example: % time=0.1 dx=0.0032 dy=0.0032 nx=101 ny=101). The tread state values are given in [MPa] over a regular (equally spaced) grid with nx $\times$ ny grid points (101 x 101 in this example), centered to wheel coordinates, with grid line distances as specified in the header-line (3.2 mm both for x and y in this example). The following tread state outputs are available:
  - **no**, to disable the contact patch details output;
  - **max. ground pressure**, to output the interpolated maximum ground pressure, saved in a Matlab-compatible ascii-file (.gpo);

- **mean ground pressure**, to output the interpolated mean ground pressure, saved in a Matlab-compatible ascii-file (.gpo);
- **max. long. shear stress**, to output the interpolated maximum longitudinal shear stress, saved in a Matlab-compatible ascii-file (.sxo);
- **mean long shear stress**, to output the interpolated mean longitudinal shear stress, saved in a Matlab-compatible ascii-file (.sxo);
- **max. lat. shear stress**, to output the interpolated maximum lateral shear stress, saved in a Matlab-compatible ascii-file (.syo);
- **mean lat. shear stress**, to output the interpolated mean lateral shear stress, saved in a Matlab-compatible ascii-file (.syo);
- **resolution**, entry field to define the grid spacing of the regular output grid;

- **structure geometry output (geo)**, radio-buttons to generate extra output files containing the actual, distorted carcass and belt geometry for further user-specific post-processing purposes. The following options are available:
  - **no**, to disable the contact patch details output;
  - **asc**, to output the permanent tire geometry, saved in a Matlab-compatible ascii-file (.geo);
  - **bin**, to output the permanent tire geometry, saved in a Matlab-compatible binary format (.geo);
  - **shl**, to output the most recent tire geometry, saved as a shel (.shl);
  - **obj**, to output the most recent tire geometry, saved as a object (.obj);
  - **resolution**, to define the approximate lateral and longitudinal output resolution;
  - **coord. system**, radio-buttons defining the output coordinate system. The following options are available:
    - **global**;
    - **rim-fixed**;
    - **wheel-carrier-fixed**;
  - **layer**, to define the geometry output layer. The following options are available:
    - **belt/carcass**;
    - **surface**;
    - **inner liner**;
    - **eff. TPMS loc.** (effective TPMS sensor location);
  - **rotating**, if selected the axis system is rotating with the tyre;
  - **add. attributes**, check-box to enable/disable the output of additional nodal states. These attributes can for example be used for tire structure coloring proposes. If enabled the following attributes will be saved to the structure geometry file (ascii and bin output only):

        * **local tread depth**;
        * **local surface temperature**;
        * **local structure distortion**;
        * **local air pressure distribution**;
        * **local air flow distribution**;

- **belt states and forces output (bso)**, radio-buttons to generate extra output files containing additional, belt-state related output signals, together with the circumferentially distributed interfacial forces between the sidewalls and the rim flanges, for further user-specific post-processing purposes. The following options are available:
  - **no**, to disable the belt states and forces output;
  - **yes**, to output the belt-state related output signals, saved in a Matlab-compatible ascii-file (.bso);
- **tread depths output (tdo)**, radio-buttons to generate extra output files containing the tread depths of all contact elements, for further user-specific post-processing purposes. The tread depth output values include the tread base height. The following options are available:
  - **no**, to disable the tread depths output;
  - **yes**, to output the tread depths, saved in a Matlab-compatible ascii-file (.tdo);
- **wheel envelope output (shl)**, radio-buttons to generate extra output files containing the current wheel envelope, for further user-specific post-processing purposes. The following options are available:
  - **no**, to disable the wheel envelope output;
  - **yes**, to output the wheel envelope, saved as a shell (.shl);
- **rgr file output output (rgr)**, radio-buttons to generate rgr road data. The bounds of the rgr domain rectangle in x/y-plane are determined by the area covered by the respective wheel during simulation. As an example, these rgr files can be used when replaying the simulation outside the 3rd-party environment, where the original road evaluation library might not be available. The following options are available:
  - **no**, to disable the wheel envelope output;
  - **yes**, to output the road output, saved as a regular grid road data file (.rgr). rgr-file size can be limited to:
    * auto-size
    * 3.2MB
    * 10MB
    * 32MB
    * 100MB

    * 320MB
    * 1GB

- **output time step**, approximate time step for the additional output of the plot signals, contact forces, and belt states. Note that FTire does not interpolate any output signals, nor, for efficiency reasons, does it try to exactly match the desired time step. For these reasons, the actual output steps might slightly differ from this value. Output time step is to be specified in the data file's time unit. If zero or not specified, each successful integration step will be saved;
- **output start**, approximate simulation time to begin the additional output. If not specified, the output (if requested) will begin with the simulation;
- **output end**, approximate simulation time to end the additional output. If not specified, the output will end with the simulation;

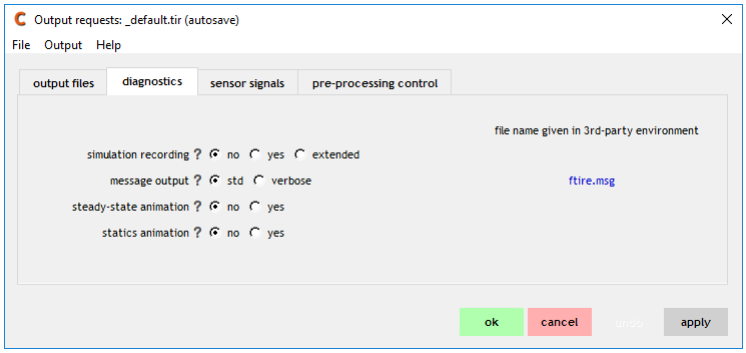

Figure 35: **cosin/tools for tires** output specification menu

The **diagnostics** sub-menu (shown in figure 35) lists all settings that can be used for troubleshooting a **FTire** simulation failure. If an output option is selected, then the output file name, given in a 3rd-party environment, is show in blue on the left-hand side of the output files menu. The following options are available:

- **simulation recording**, radio-buttons to generate a file which enables the analysis and exact 'replay' of the current **FTire** simulation. The following options are available:
  - **no**, to disable the simulation recording output;
  - **yes**, to save all information that is required to replay the **FTire** simulation, saved in a Matlab-compatible binary-file (ftire.rec);
  - **extended**, to save a comprehensive set of information to replay the **FTire** simulation, saved in a Matlab-compatible binary-file (ftire.rec). When this option is selected, the rec-file might become very large in size. This option is only required for debugging in certain special cases;
- **message output**, radio-buttons to set the log-file message detail level. The following options are available:
  - **std**, to define the standard message output, saved in the log file (.log);
  - **verbose**, write extra messages to the message and log file;

- **steady-state animation**, radio-buttons to disable/enable the animation output during steady-state simulations. The following options are available:
  - **no**, to disable the steady-state animation output;
  - **yes**, to enable the steady-state animation output;
- **statics animation**, radio-buttons to disable/enable the animation output during statics. The following options are available:
  - **no**, to disable the statics animation output;
  - **yes**, to enable the statics animation output;
- **if ordered, write output files and show animation even in real-time mode**, check-box that defines the animation output if called in real-time mode. If selected the FTire animation will be shown. For efficiency reasons the on-line animations are by default disabled for all real-time speed modes and should only be activated for debugging purposes.

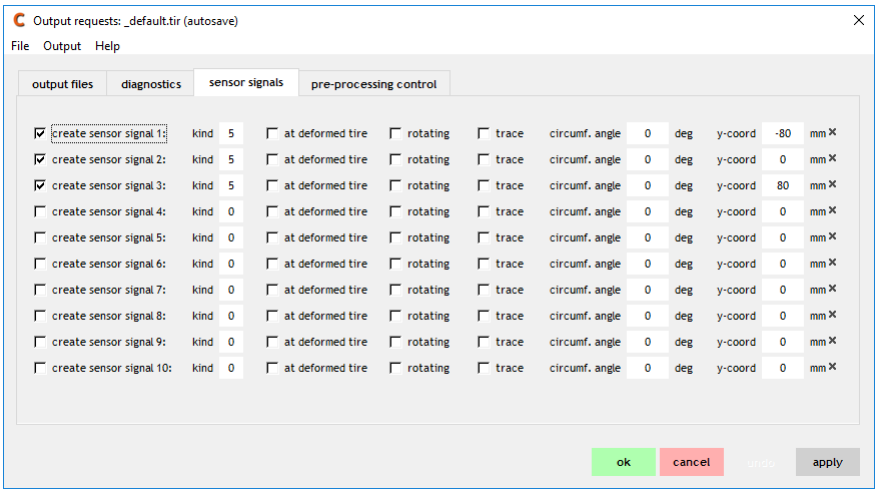

Figure 36: **cosin/tools for tires** output specification menu

The **sensor signals** sub-menu (shown in figure 36) lists up-to 10 sensors, that can be defined by the user, to output additional information during a **FTire** simulation. The following options are available:

- **activation tick-box**, to activate the sensor. The sensor signal number is also shown;
- **kind**, entry field to specify the type of sensor. The sensors type is defined by a number, zero (0) indicated that the sensor is not used. The following types are available:
  1. **normal deflection**;
  2. **longitudinal shear displacement**;
  3. **lateral shear displacement**;
  4. **tread height**;
  5. **surface temperature**;
  6. **stick/slip state**;

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- **at deformed tyre**, check box to specify the sensor location relative to the tire. If selected the sensor is fixed to the deformed tyre surface. If not selected the sensor position is fixed relative to the rim is used;
- **rotating**, check-box to define wether or not the sensor is rotating with the tyre/rim, or if the sensor is fixed relative to the wheel carrier;
- **trace**, check-box to hide/show a trace, of the sensor location, in the animation;
- **circumf. angle**, to specify the circumferential angle where the sensor should be located. If the sensor is not rotating, or during the initial conditions, then the orientation is defined as follows
  - 0deg, bottom / center of tire contact patch;
  - 90deg, foremost position;
  - 180deg, topmost position;
  - 270deg, rearmost position;
- **y-coord**, to define the lateral position of the sensor. Zero indicates the center of the belt. Negative coordinate values are to the left of the belt center while positive values are located to the right.
- ✖ (**clear** button), to clear the sensor signal entry;

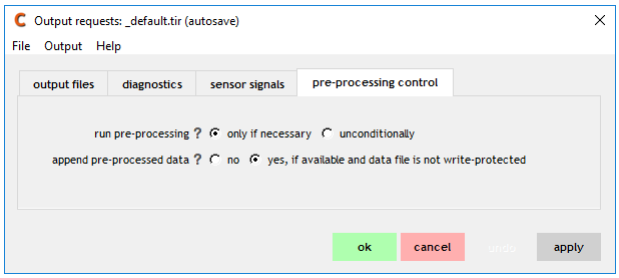

Figure 37: **cosin/tools for tires** output specification menu

The **pre-processing control** sub-menu (shown in figure 37) defines the pre-processing behavior of the model during a **FTire** simulation call. The following options are available:

- **run pre-processing**, radio-buttons to define when the pre-processing calculations should be conducted. The following options are available:
  - **only if necessary**, to run the preprocessing only when the parameter file has changed or if the pre-processed data is not available (recommended);
  - **unconditionally**, to run the pre-processing for every solver call;
- **append pre-processed data**, radio-buttons to define whether or not the pre-processed data is allowed to be appended to the original data file. The following options are available:
  - **no**, to not write data to the original file;
  - **yes, if available and data file is not write-protected**, to appended the pre-processed data to the original file;

2.19 Version Control

The **version control** menu (shown in figure 38) lists settings that control the compatibility mode, library locations and road evaluation preferences. The menu is divided into four sub-menus. The sub-menus are:

- **compatibility mode**, radio-buttons to set the optional parameter (called compatibility date or previously feature date) that allows the user to specify a date such that all FTire model changes, being implemented after this date, will be deactivated. Full compatibility with older versions is comprehensively tested only from compatibility mode date 2015/07/01 on, due to major numerical optimizations in the core solver routines with version 2015-1. It is generally recommended not to use the compatibility mode unless there is a good reason to do so. The compatibility mode date is no „version string“ related to the library version used, and it is not required to tag older input data if used with a more recent library version. Nor is the compatibility mode intended to fix model stability problems. On the contrary, in general, the most recent version is the best. If you will find a certain solver issue that seems to be cured in compatibility mode, please contact the product support hotline for an investigation of the problem. For all available compatibility dates, and corresponding model changes, please visit the **FTire modelization and parameter specification** documentation. The following options are available:
  - **use all standard features (recommended)**;
  - **use all standard + experimental features**;
  - **only use features introduced until the file generation date**;
  - **only use features introduced until today**;
  - **only use features introduced until..**;
- **cti library selection (only Adams)**, radio-buttons to specify the **cosin tire interface** library that should be used. The following options are available:
  - from cosin installation;
  - from Adams installation;
- **user library location**, to define the path to the directory holding optional user-defined libraries for rim and road models. The following options are available:
  - default, lib folder in the private directory;
  - specify, to specify a path to the library. The following button is available:
    - ✖ (**clear** button), to clear the entry field;
    - ••• (**browse** button), to select the sound file from a file browser;
- **road evaluation preference**, to define the preferred road evaluation method. The following options are available:
  - **default**;
  - **cosin**;

– **cosin (no 3rd-party calibration)**;

– **3rd-party road evaluation methods**;

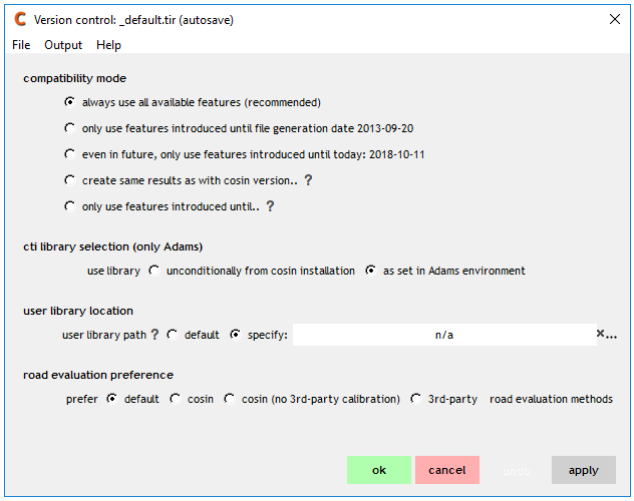

Figure 38: **cosin/tools for tires** version control menu

2.20 Open in Text Editor

Selecting the '**open in text editor**' button will open the current tire data file in a text editor.

2.21 Polish Data File

Selecting the '**polish data file**' button will clean the data file, and remove all unused parameters.

2.22 Discard Pre-Processed Data

Selecting the '**discard pre-processed data**' will remove the pre-processed data from the tire data file.

3 cosin/tools for tires*'s Data Analyzes Menu (analyze)*

In the data analyzes menu - **analyze** (shown in figure 39) all relevant tire data file analyzes tools are grouped into a few manageable menus. The menu consists of the following sub-menus:

- Fingerprint;
- General Properties;
- Cross Section;
- Mass correction data;
- Local Belt Stiffness;
- Pressure Dependencies;

- Visualize Structural DOF's;
- Vary Design Parameters;
- Compare With;
- Configurable Fingerprint;
- Static Analysis;
- Steady-State Analysis;
- Interactive Analysis;
- Linearization;
- Modal Analysis;

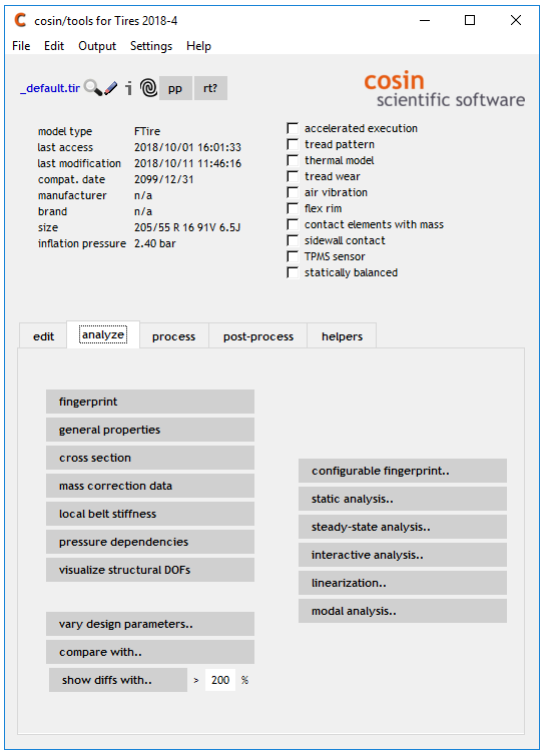

Figure 39: **cosin/tools for tires** analyze main menu

3.1 Fingerprint

The **FTire** fingerprint report comprises of a set of standard simulation results that can be used to analyze and compare the tire behavior without sharing the tire parameters. This report can further be used to identify a tire data file. The results presented in the report comprise of footprints, static and steady sate tests, as well as dynamic cleat test simulation results. The computation time, to generate the report, is a few minutes(approximately 5-15 minutes depending on the computer hardware used). The report can be requested by selecting the '**fingerprint**' button, in the '**analyze**' tab, or by selecting the (**fingerprint** button) in the cosin/tools for tires's Main Menu. The following options are available:

- **left clicking the buttons**, to compute and show the fingerprint report;

- **right clicking the buttons**, to compute, shown and save the fingerprint report to a user specified location;

3.2 General Properties

The '**general properties**' button can be used to determine a set of key **FTire** model properties. The computation time, to compute the key model properties, is a few seconds(approximately 20-60 seconds depending on the computer hardware used). The results will be shown in a **cosin Message** window. Buttons are available to edit, save or print the model properties.

3.3 Cross Section

Selecting the '**cross section**' button, or the **(loupe** button) in the cosin/tools for tires's Main Menu menu, will display a graphical representation of the model's cross section (see figure 4). The sidewall contour line is shown in blue color, the tread surface shown in red color, and the contact element's position, direction, and length, also shown with red lines. The theoretical rim and tire main dimensions, as derived from the tire/rim size string, are indicated the yellow area. The maximum tire radius, and width, is also shown in the figure.

If the '**cross section**' button is selected with the right mouse button, then the cross-section node numbers will be shown on the cross section.

3.4 Mass correction data

The '**mass correction data**' button can be used to determine the **FTire** mass and inertia correction data that needs to be accounted for in a multi-body-system (MBS) model. **FTire** discretizes the mass and inertia properties of tire into two bodies, tire_free and tire_fixed. The tire_free mass is spread over the belt nodes, and is accounted for by **FTire**, while the fire_fixed mass is fixed to the rim and needs to be accounted for in the MBS model. The difference between total tire mass and free tire mass, together with the respective axial and radial moments of inertia, are to be added to the rim part in the calling MBS model. The **FTire** mass correction data output is shown in figure 40. Buttons are available to edit, save or print the mass correction data.

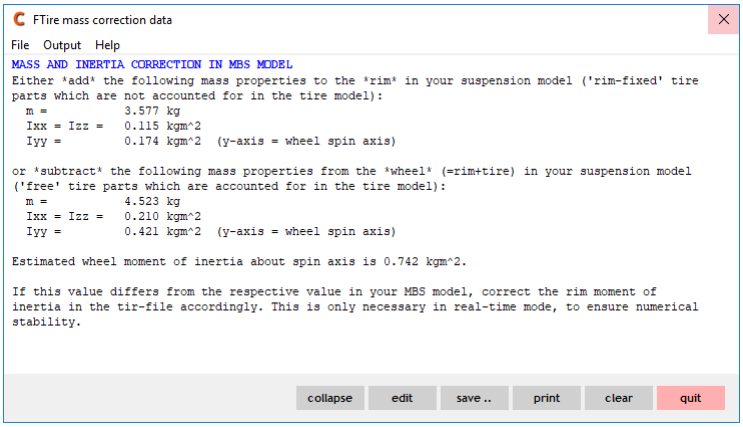

Figure 40: **cosin/tools for tires** FTire mass correction data

A visual representation of the two modeling approaches is shown in figure 41.

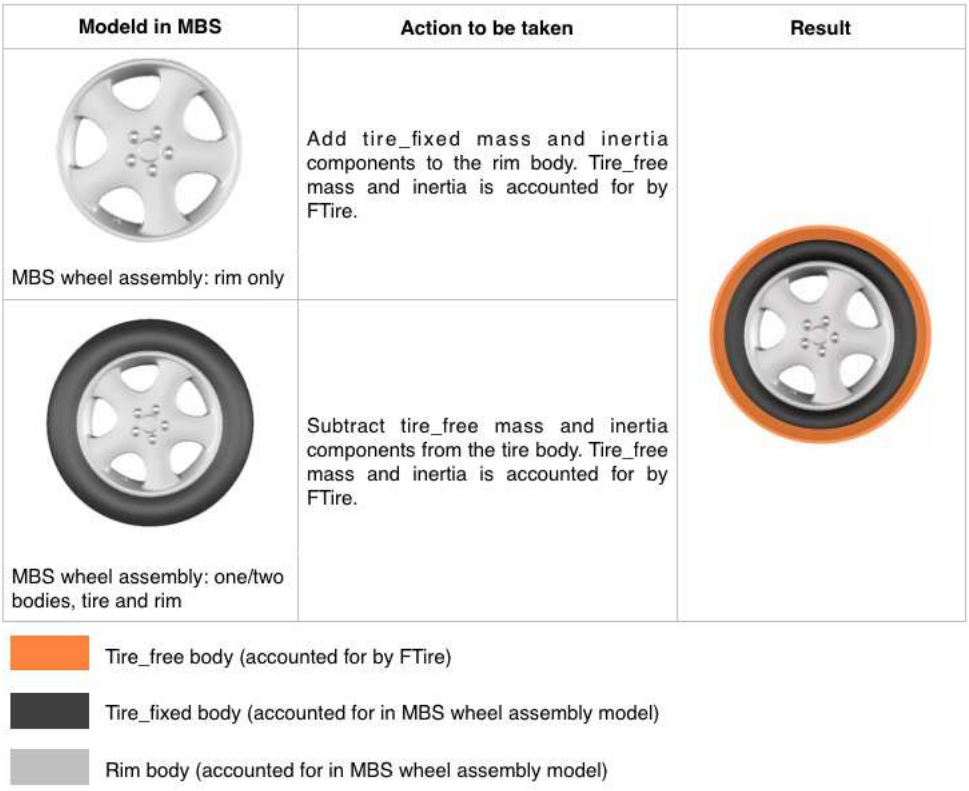

Figure 41: **FTire** mass correction visualization

3.5 Local Belt Stiffness

The button '**local belt stiffness**' will display the **normalized static load-deflection characteristic of a belt element** (figure 42, not to be confused with the tire's global load-deflection curve). This characteristic is shown merely for plausibility checks. The slopes, of the local radial, lateral and longitudinal belt stiffness, should neither become too progressive, nor too degressive. Most of all, the slope should remain positive.

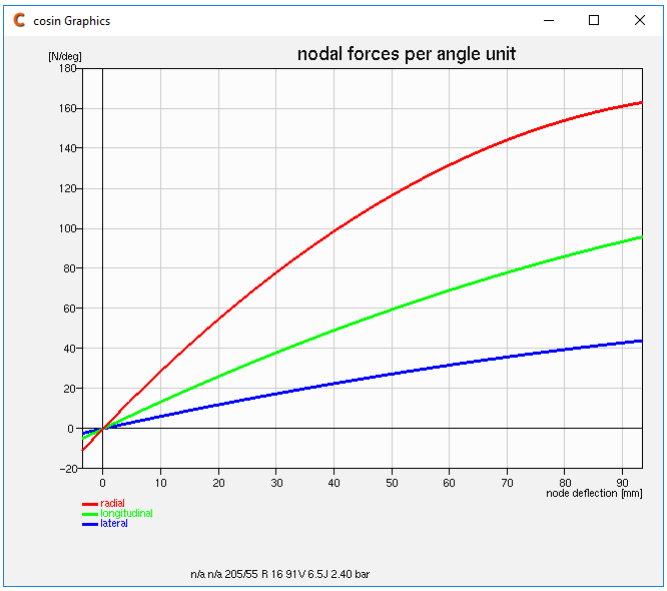

Figure 42: **cosin/tools for tires** local belt stiffness plausibility visualization

3.6 Pressure Dependencies

The '**pressure dependencies**' button can be used to determine the tire model dependencies on the tire inflation pressure. Among others the pressure dependency on the rolling circumference, tire stiffness and damping behavior as well as frequency response is determined. The computation time is a few minutes(approximately 1-5 minutes depending on the computer hardware used). For further analyses the results are opened in **cosin/ip**.

3.7 Visualize Structural DOF's

The '**visualize structural DOF's**' button can be used to visualize the degrees of freedom of a single **FTire** belt segment. The animations are opened in a **cosin Graphics** window. Figure 3.7 shows two screen grabs of the first belt segments third and sixth structural degree of freedom animation.

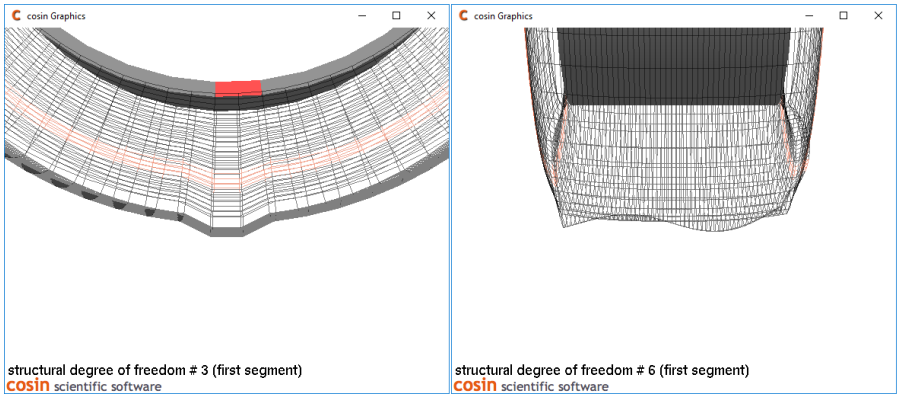

Figure 43: **cosin/tools for tires** structural DOFs visualization

3.8 Vary Design Parameters

The '**vary design parameters..**' menu button can be used to set up-to four design parameters. These parameters can be used for tire parameter sensitivity studies. The design parameters can be used as a place holders of a parameters (eg `tread_depth=p1`) or as scaling factors (eg `tread_depth=8*p1`) in the tire data file.

3.9 Compare With

The '**compare with..**' button can be used to run a **FTire** data file comparison. The currently open tyre data file will be compared to a user defined tire data file to determine a list of parameters that differ between the two files. The list , containing all differing parameters, their values and percentual deviation, will be shown in a **FTire Data Comparison** window (figure 44). Buttons are available to edit, save or print the parameter list.

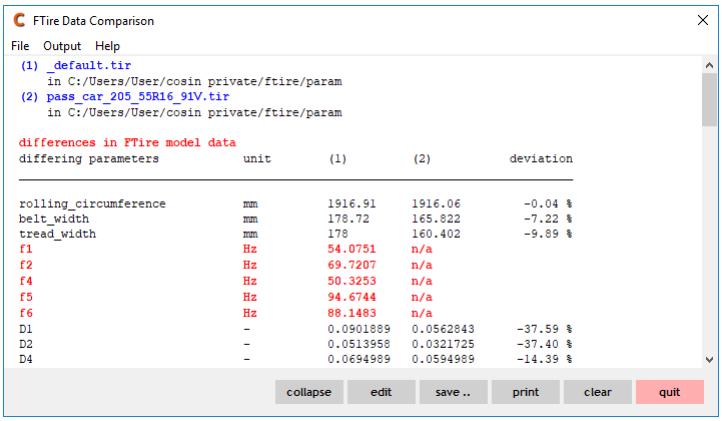

Figure 44: **cosin/tools for tires** FTire Data Comparison window

3.10 Configurable Fingerprint

The '**configurable fingerprint..**' menu button can be used to define a set of operating conditions that should be used during the fingerprint simulations. The following options are available:

- **operating conditions**, to change the following operating conditions:
  - **inflation pressure**;
  - **filling gas temperature**;
  - **mean tread surface temperature**;
  - **tread depth**;
  - **FTire speed mode**;
- **parameter variation ranges**, to define the variation ranges of the following parameters:
  - **max camber angle** and # **variations**;
  - **max load percentage relative to LI load** and # **variations**;

  - **max speed** and # **variations**;

- **component selection**, to define the report sections that should be included in the fingerprint report. The following components can be selected:
  - **all**, to create an complete fingerprint report;
  - **properties**, to only compute and report the model properties;
  - **footprints**, to only compute and report the footprint results;
  - **static**, to only compute and report the static results;
  - **steady-state**, to only compute and report the steady-state results;
  - **cleats**, to only compute and report the dynamic cleat simulation results;

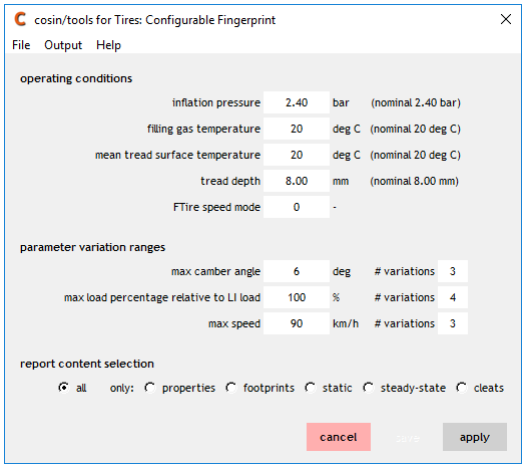

Figure 45: **cosin/tools for tires** configurable fingerprint window

3.11 Static Analysis

The '**static analysis..**' menu (shown in figure 46) can be used to define and run a static tire analysis. The following options are available:

- **operating conditions**, to define the following tyre operating conditions:
  - **inflation pressure**;
  - **filling gas temperature**;
  - **mean tread surface temperature**;
  - **tread depth**;
  - **use tread pattern if available**;
  - **sticky surface**;
  - tire rolling condition radio buttons:
    - **stand-still**;
    - **slowly rolling**;

- **load/deflection**, to define the loading condition with the following radio buttons:
  - **deflection**, to apply a vertical wheel displacement;
    - additional entry fields are available to define the lateral and longitudinal wheel displacements as well as the camber, wheel rotation, and toe angle of the tire;
  - **wheel load**, to apply a vertical wheel load;
    - additional entry fields are available to define the lateral and longitudinal wheel displacements as well as the camber, wheel rotation, and toe angle of the tire;
  - **LI load prec.**, to define the vertical loading condition by the load index percentage;
    - additional entry fields are available to define the lateral and longitudinal wheel displacements as well as the camber, wheel rotation, and toe angle of the tire;
  - **forces & moments**, to define the loading condition by specifying the:
    - **longitudinal force**;
    - **lateral force**;
    - **wheel load**;
    - **aligning torque**;
- **surface geometry**, to define the road surface conditions for the analyses with the following inputs:
  - surface type:
    - **flat**;
    - **transv. cleat**;
    - **long. cleat**;
    - **45deg cleat**;
    - **block**;
  - cleat/block width;
  - cleat bevel edge width;
  - longitudinal obstacle shift;
  - lateral obstacle shift;
  - longitudinal obstacle move;
  - lateral obstacle move;
- **alternative road data file**, to define a road road data file. The following buttons are available:
  - ✖ (**clear** button), to clear the entry field;
  - ••• (**browse** button), to select the road data file from a file browser;
  -  (**loupe** button), to view the road data file with **cosin/tools for roads**;
  -  (**edit** button), to edit the road data file in an ascii editor;

- **external forces/moments**, to define externally applied forces and moments. The following forces/moments can be defined:
  - **external radial force**;
  - **external lateral force**;
  - **external twist torque**;
- **output**, check-box to activate the visualization output . If the check-box is selected then the static simulation results will be shown in a **cosin Animation** window.

Three buttons are available on the bottom right corner of the Static Analysis window:

- **cancel**, to close the **cosin/tools for tires: Static Analysis** window;
- **loop..**, to run the static analysis for multiple conditions. This option is discussed below;
- **apply**, to run the static analysis;

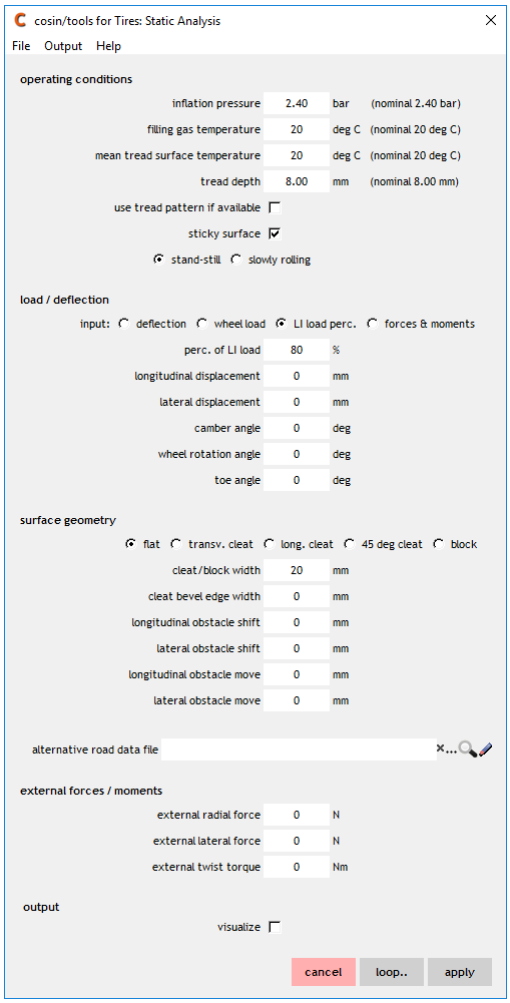

Figure 46: **cosin/tools for tires** static analysis menu

The Multiple Parallel Simulation Loop window, is shown in figure 47. The menu can be used to define up to two nested parameter and/or operating condition variations for which simulations should be conducted. The following options are available:

- **vary operating conditions, equally spaced,** check-boxes to activate the variation of various operating conditions. Entry fields are available to define the starting, step end values;
- **vary predefined design parameters, equally spaced**, check-boxes to activate the variation of various predefined design parameters. Entry fields are available to define the starting, step end values;
- **vary user-defined parameters, equally spaced**, check-boxes to activate the variation of various user-defined parameters. Entry fields are available to define the parameter names, starting, step end values;
- **vary user-defined parameters, generally spaced**, check-boxes to activate the variation of various user-defined parameters. Entry fields are available to define the parameter names and comma-separated parameter values;

To use this function, replace any numeric simulation input value, that is listed in the analysis menu (eg. figure 46), or **FTire** model parameter with a predefined parameter name (eg. **p1/p2/p3/p4**). The user-defined parameters may only be used to replace the simulation input values. Three buttons are available in the the **Multiple Parallel Simulation Loop** window:

- (**loupe** button), to show the selected parameter variations and corresponding case numbers;
- **ok**, to create and run the variation cases. After the simulation the window will be closed;
- **cancel**, to close the **Multiple Parallel Simulation Loop** window;
- **apply**, to create and run the variation cases;

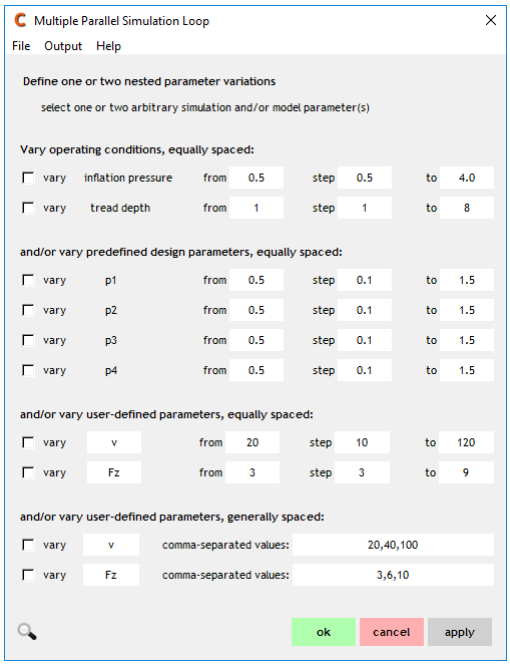

Figure 47: **cosin/tools for tires** analysis loop menu

3.12 Steady-State Analysis

The '**steady-state analysis..**' menu (shown in figure 48) can be used to define and run a steady-state tire analysis. The following options are available:

- **operating conditions**, to define the following tyre operating conditions:
  - **inflation pressure**;
  - **filling gas temperature**;
  - **mean tread surface temperature**;
  - **tread depth**;
  - **rolling speed**;
  - **turning speed**;
  - **drum diameter**;
  - **friction modification factor**;
- **load/deflection**, radio-buttons to define the vertical loading condition with the following radio buttons:
  - **deflection**, to apply a vertical wheel displacement;
  - **wheel load**, to apply a vertical wheel load;
  - **LI load prec.**, to define the vertical loading condition by the load index percentage;
- **horizontal control**, radio buttons to define the horizontal loading condition with the following options:
  - **wheel slip**, to define a wheel slip percentage;
    - additional entry fields are available to define the **slip** and **camber** angle of the tire;
  - **drive torque**, to apply a drive/braking torque;
    - additional entry fields are available to define the **slip** and **camber** angle of the tire;
- simulation details, to define additional simulation and animation settings. The following options are available:
  - **simulation time**, to define the simulation duration;
  - **surface distortion amplification**, to define the tire surface distortion amplification factor that should be used for the animation;
  - **switch off model extensions**, check-box to disable all active model extensions (eg side wall contact model, thermal model, etc.);
- **additional output**, to define additional output parameters. The following options are available:
  - **visualize**, to output the simulation animation;
  - **don't compute additional dynamic properties**, radio-button to disable the computation of additional dynamic tire properties;

- **compute damping (blocked wheel)**, radio-buttons to enable the computation of additional damping tire properties with a blocked wheel. The following options are available:
  - **long.**, to compute the longitudinal damping value;
    - additional entry fields are available to define the **deflection amplitude** and **frequency** to be used for the damping calculation;
  - **lat.**, to compute the lateral damping value;
    - additional entry fields are available to define the **deflection amplitude** and **frequency** to be used for the damping calculation;
  - **radial**, to compute the radial damping value;
    - additional entry fields are available to define the **deflection amplitude** and **frequency** to be used for the damping calculation;
- **compute relaxation length**, radio-buttons to enable the computation of tyre relaxation length. The following options are available:
  - **Fx**, to compute the fore-aft force relaxation length;
    - an additional entry field is available to define the **wheel slip step** size, to be used for the relaxation length calculation;
  - **Fy**, to compute the side force relaxation length;
    - an additional entry field is available to define the **slip angle step** size, to be used for the relaxation length calculation;
  - **Mz**, to compute the aligning torque relaxation length;
    - an additional entry field is available to define the **slip angle step** size, to be used for the relaxation length calculation;
- **compute dynamic rolling radius**, check-box to compute the dynamic rolling radius;
- **validate footprint**, check-box to compute the simulation footprint result to a footprint measurement. If selected the following information is required:
  - **measured footprint img file (in)**, to define the measurement input file. The following buttons are available:
    - ••• (**browse** button), to select the footprint image file from a file browser;
    -  (**loupe** button), to view the footprint image file;
  - **footprint comparison img file (out)**, to define the comparison output file. The following buttons are available:
    - ••• (**browse** button), to select the footprint image output file from a file browser;
    -  (**loupe** button), to view the footprint image file;
  - **footprint bitmap scaling factor**, to define the image scaling factor;

* **footprint bitmap rotation**, to define a image rotation angle to align the measured footprint with the simulation output.

Three buttons are available on the bottom right corner of the **cosin/tools for tires: Steady-State Analysis** window:

- **cancel**, to close the **cosin/tools for tires: Steady-State Analysis** window;
- **loop..**, to run the steady-state analysis for multiple conditions. This option is discussed in section 3.11;
- **apply**, to run the steady-state analysis;

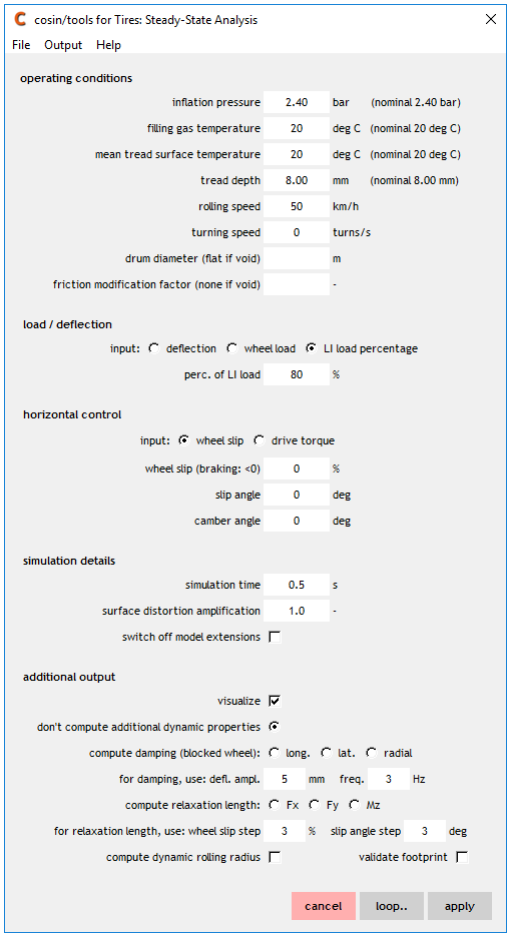

Figure 48: **cosin/tools for tires** steady-state analysis menu

3.13 Interactive Analysis

The '**interactive analysis..**' menu (shown in figure 49) can be used to define and run a user interactive tire analysis. The following options are available:

- **interactive simulation details**, to define the following simulation operating conditions:
  - rolling condition, radio-buttons to define the tire rolling condition. The following options are available:
    * **control wheel slip**, to control the wheel slip during the interactive simulation;

        * **free rolling**, to run a free rolling interactive tire analysis;
    - **drum diameter (flat if void)**, to define the road curvature during the analysis;
    - **friction modification factor (none if void)**, to define a road -tire friction modification factor;
    - # **cross-section modifiers**, to define the number of control sliders that can be used to vary the local belt radius during the interactive analysis. The cross-section modifiers will be equally spaced across the belt width;
- **animation settings**, to define the simulation animation settings. The following options are available:
    - **tire structure**, radio-buttons to define the rendering of the tire structure. The following render settings are available:
        * **rendered**;
        * wire frame;
    - **colorized**, to define the tire structure surface color dependencies (if the **rendered** option is selected). The following options are available:
        * **temperature**;
        * **wear**;
        * **distortion**;
        * **air pressure distribution**;
        * **air flow distribution**;

Two buttons are available on the bottom right corner of the **cosin/tools for tires: Interactive Analysis** window:

- **cancel**, to close the **cosin/tools for tires: Interactive Analysis** window;
- **apply**, to run the interactive analysis;

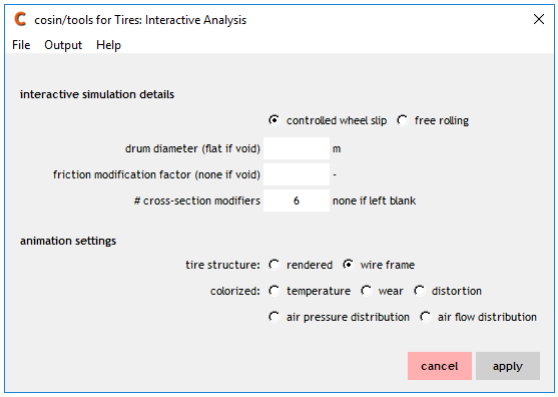

Figure 49: **cosin/tools for tires** interactive analysis menu

3.14 Linearization

The '**linearization..**' menu (shown in figure 50) can be used to define and run a non-linear system linearization. The following options are available:

- **operating conditions**, to define the following operating conditions:
  - **inflation pressure**;
  - **filling gas temperature**;
  - **mean tread surface temperature**;
  - **tread depth**;
  - **rolling speed**, for numerical reasons any rolling speed below 10km/h will be treated as a non-rolling case;
  - **glue footprint to ground, if not rolling** (check-box);
- **load/deflection**, to define the vertical loading condition with:
  - **vertical deflection**;
- **horizontal motion**, radio buttons to define the horizontal motion loading condition with the following options:
  - **wheel slip**, to define a wheel slip percentage;
    - additional entry fields are available to define the **slip** and **camber** angle of the tire;
  - **drive torque**, to apply a drive/braking torque;
    - additional entry fields are available to define the **slip** and **camber** angle of the tire;
- **horizontal displacement**, radio buttons to define the horizontal displacement loading condition with the following entry fields:
  - **longitudinal displacement**;
  - **lateral displacement**;
  - **rotation about vertical axis**;
  - **rim rotation angle**
- **surface geometry**, to define the road surface conditions for the analyses with the following options:
  - **flat**;
  - **transv. cleat**;
  - **long. cleat**;
  - **45deg cleat**;
  - **block**;
- **linearization details**, to define the linearization details with the following entries:
  - **frequency**, to define the the upper frequency limit;

  - **modal damping**, to define the upper damping limit;
  - **mode selection gain tolerance**;
  - **linearized system order**;
- M-file output, to define the Matlab compatible output file names. The following options are available:
  - **save time-discrete A,B,C,D**, to define the output file name and location. The following button is available:
    - ... (**browse** button), to select the output file save location from a file browser;
  - **save time-discrete A,B,C,D**, to define the output file name and location. The following button is available:
    - ... (**browse** button), to select the output file save location from a file browser;
  - **matrix name suffix**, to define the matrix suffix that should be used in the output files;

Two buttons are available on the bottom right corner of the **cosin/tools for tires: Linearization** window:

- **cancel**, to close the **cosin/tools for tires: Linearization** window;
- **apply**, to run the linearization;

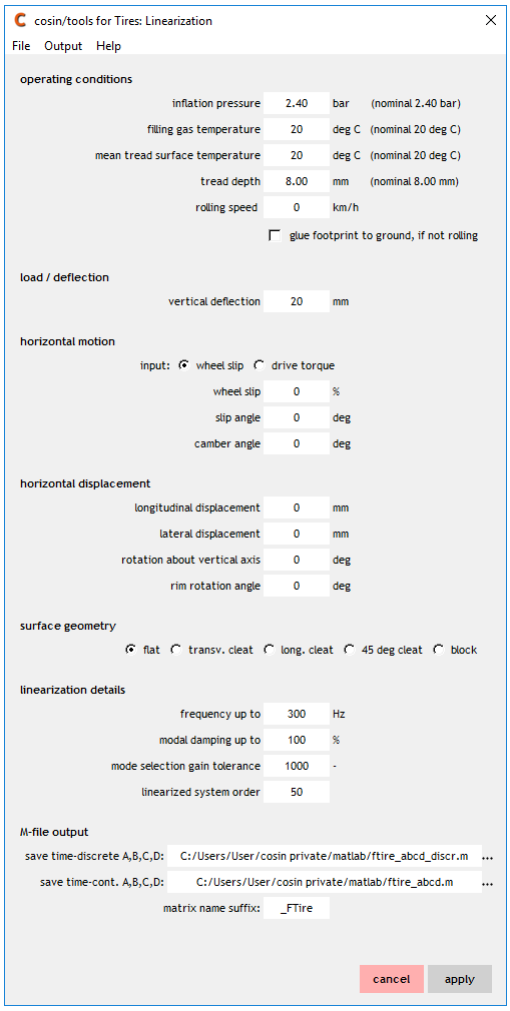

Figure 50: **cosin/tools for tires** linearization menu

3.15 Modal Analysis

The '**modal analysis..**' menu (shown in figure 51) can be used to define and run a modal analysis. The following options are available:

- **modal analysis in**, to define the modal analysis loading conditions:
  - **unloaded**, to conduct a modal analysis on an unloaded tire. The following information is required:
    - **order up to**, to define the upper order limit;
    - **frequency up to**, to define the upper frequency limit;
  - **loaded**, to conduct a modal analysis on a laden tire. The following information is required:
    - **order up to**, to define the upper order limit;
    - **frequency up to**, to define the upper frequency limit;
    - **modal damping up to**, to define the upper damping limit;
- **operating conditions**, to define the following operating conditions:

  - **inflation pressure**;
  - **filling gas temperature**;
  - **mean tread surface temperature**;
  - **tread depth**, (only available for loaded condition);
  - **rolling speed**, (only available for loaded condition) for numerical reasons any rolling speed below 10km/h will be treated as a non-rolling case;
  - **glue footprint to ground, if not rolling** (check-box, only available for loaded condition);
- **load/deflection**,(only available for loaded condition) to define the vertical loading condition with:
  - **vertical deflection**;
- **horizontal motion**, (only available for loaded condition) radio buttons to define the horizontal motion loading condition with the following options:
  - **wheel slip**, to define a wheel slip percentage;
    - additional entry fields are available to define the **slip** and **camber** angle of the tire;
  - **drive torque**, to apply a drive/braking torque;
    - additional entry fields are available to define the **slip** and **camber** angle of the tire;
- **horizontal displacement**, (only available for loaded condition) radio buttons to define the horizontal displacement loading condition with the following entry fields:
  - **longitudinal displacement**;
  - **lateral displacement**;
  - **rotation about vertical axis**;
  - **rim rotation angle**
- **surface geometry**, (only available for loaded condition) to define the road surface conditions for the analyses with the following options:
  - **flat**;
  - **transv. cleat**;
  - **long. cleat**;
  - **45deg cleat**;
  - **block**;

Two buttons are available on the bottom right corner of the **cosin/tools for tires: Modal Analysis** window:

- **cancel**, to close the **cosin/tools for tires:Modal Analysis** window;
- **apply**, to run the modal analysis;

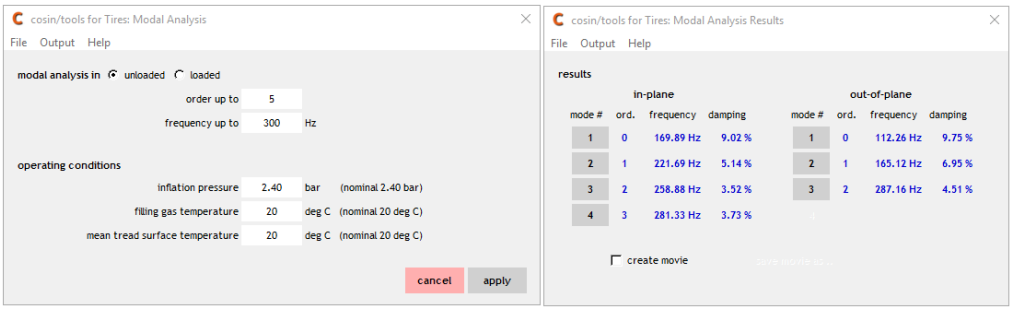

Figure 51: **cosin/tools for tires** modal analysis window, Left: menu; Right: results

The '**Modal Analysis Results**' window (shown on the right-hand side of figure 51) can be used to view the modal analysis results. The results are sorted into in-plane and out-of-plane mode shapes. The following information is shown for all mode shapes:

- **mode #**, displaying the mode number of the in/out-of-plane mode. Selecting the mode number will open the mode shape animation in a cosin Graphics window. The following options and sliders are available:
  - **mode shape amplification**, slider to set the animation amplification factor;
  - **animation speed**, slider to control the animation speed;
  - render mode, left menu option to show the tyre surface as:
    - **rendered**, keyboard shortcut 'r';
    - **meshed**, keyboard shortcut 'm';
- **ord**, displaying the mode shape order;
- **frequency**, displaying the mode shape frequency;
- **damping**, displaying the damping value of the mode;
- **create movie**, check-box to create movie file of a mode shape animation.
  - **save movie as..**, button to save the movie file;

4 cosin/tools for tires's *Data Processing Menu (process)*

4.1 Repeat Pre-Processing

Button to force a repeat of the pre-processing.

4.2 Optimize Numerical Settings

Button to run a optimization of the numerical settings to improve and reduce the duration of the model pre-processing.

4.3 Reformat

The '**reformat**' menu (shown on the right-hand side of figure 52) can be used to export the FTire data file in a different format or with a preferred kind of tire properties. The following options are available:

- **create this format**, to define the export file format and unit system.
  - The following file formats are available:
    - **TeimOrbit .tir file** (default);
    - **cosin/io .ft file**;
  - The following unit systems are available:
    - **user-friendly** (SI user-friendly);
    - **SI: mmks** (millimeter/kilogram/second);
    - **SI: mks** (meter/kilogram/second);
    - **USC** (inch/pound/second);
- **prefer this kind of tire properties when specifying data**, to prefer the following kind of parameters (see **Carcass / Belt Mass & Stiffness**):
  - **don't change**;
  - **direct (preferred)**;
  - **static**;
  - **handling (standard)**;
  - **handling (motorcycle)**;
  - **static + handling (standard)**;
  - **static + handling (motorcycle)**;
  - **modal data**;

Three buttons are available on the bottom right corner of the **cosin/tools for tires: Export** window:

- **ok**, to export the tire data file and to close the **cosin/tools for tires: Export** window;
- **cancel**, to close the **cosin/tools for tires: Export** window;
- **apply**, export the tire data file;

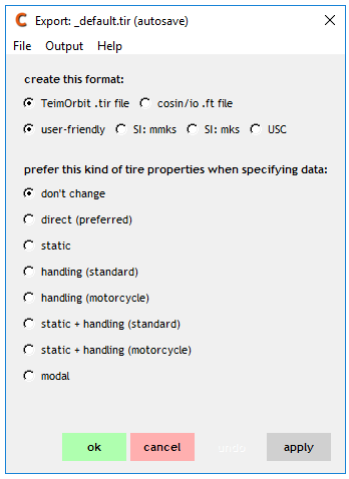

Figure 52: **cosin/tools for tires** reformat tire data file

4.4 Export To Pac2002 Model

The '**export to Pac2002 model**' menu (shown in figure 53) can be used to create a Pac2002 model data file from the current FTire data file. The following options are available:

- **job**, to define the job that should be run. The following options are available:
  - **automatically run through all steps**;
    - **fast**;
    - **accurate**;
    - **full HTire model id.**
    - **HTire w/o combined slip id.**
  - **only create virtual measurements**;
  - **only identify parameters**;
  - **only validate and create report**;
- **virtual measurement settings**, to define the virtual test conditions that are used to create the virtual measurements. The following options are available:
  - **min...max Fz**, minimum and maximum load index percentage that should be used;
  - **max. camber angle**;
  - **max. combined wheel slip**;
  - **max. combined slip angle**;
  - **single sweep duration**;
  - **sweep ranges:**
    - **wheel slip**;
    - **slip angle**;

- **Pac2002 parameter identification settings**, the following options are available:
  - **identify**, radio-buttons to define what virtual measurements should be used to identify the Pac2002 model parameters. The following options are available:
    - **all**;
    - **only Fx**;
    - **only Fy**;
    - **only Mz**;
    - **only Fy + Mz**;
    - **only combined slip**;
    - **only combined slip for Fx**;
    - **only combined slip for Fy**;
    - **only combined slip for Mz**;
  - **number of data points to be used**;
  - **max. number of objective evaluations**;
  - **max parameter variation**;
  - **start with this Pac2002 data file**, to define the initial Pac2002 data file. The following buttons are available:
    - ··· (**browse** button), to select the Pac2002 data file from a file browser;
    - 🔍 (**loupe** button), to open the Pac2002 data file with **cosin/tools for tires**;
    - ✎ (**edit** button), to edit the Pac2002 data file in an ascii editor;
  - **create this Pac2002 data file**, to define the name of the output Pac2002 data file. The following buttons are available:
    - ··· (**browse** button), to select the Pac2002 data file location from a file browser;
    - 🔍 (**loupe** button), to open the Pac2002 data file with **cosin/tools for tires**;
    - ✎ (**edit** button), to edit the Pac2002 data file in an ascii editor;
- report, buttons to display and pack the report of the Pac2002 export. The following buttons are available:
  - **show report**, to open the created pdf export report(if available);
  - **pack report**, to pack the created pdf export report(if available) and tire data files into a folder;
  - **show single Fx comp.**, to show a single longitudinal test comparison (if available);
  - **show single Fy comp.**, to show a single lateral test comparison (if available);
  - **show single Mz comp.**, to show a single aligning torque comparison (if available);

Two buttons are available on the bottom right corner of the **cosin/tools for tires: create Pac2002 data file** window:

- **cancel**, to close the **cosin/tools for tires: create Pac2002 data file** window;
- **apply**, export the Pac2002 tire data file;

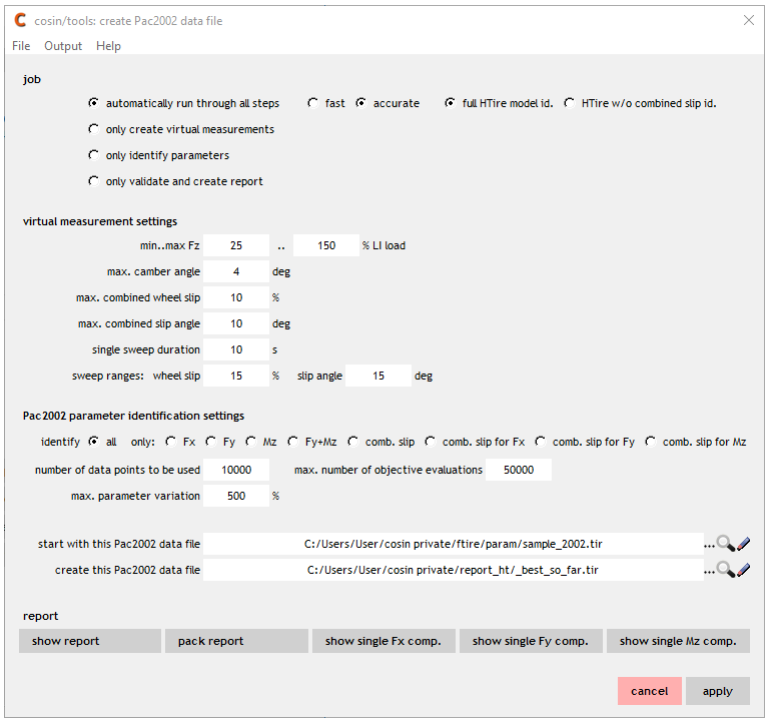

Figure 53: **cosin/tools for tires** export **Ftire** data file to Pac2002 model

5 cosin/tools for tires's *Results Post-Processing Menu (post-process)*

5.1 Plot Results

The button '**plot results (mtl- or tdx -file)**' can be used to load, brows and plot measurement and/or simulation results in the interactive plot program - **cosin/ip**. The following file formats are supported:

- tdx, TDX;
- mtl, MTL;
- mtb, MTB;
- req, REQ;
- fft, FFT;
- csv, CSV;
- dwt, DWT;

5.2 Replay Record File

The button '**replay record file**' can be used to replay a recorded **FTire** simulation. The record file enables the analysis and exact 'replay' of the recorded **FTire** simulation without the calling vehicle model. The following file formats are supported:

- rec, REC;

5.3 Replay Animation

The button '**replay animation**' can be used to replay a recorded off-line **FTire** animation. The following file formats are supported:

- ogl;

5.4 Show Wheel Envelope

The button '**show wheel envelope (shl-file)**' can be used to visualize the wheel envelope as saved during a previous **FTire** simulation. This button can also be used to visualize various CAD files (eg detailed rim CAD files, car body etc.). The following file formats are supported:

- str, STR;
- shl, SHL;
- stl, STL;
- obj, OBJ;

6 cosin/tools for tires*'s Data Helpers Menu (helpers)*

The '**helpers'** menu (shown in figure 54) includes a units conversion tool as well as a calculator to evaluate any arbitrary arithmetic and/or function expression. The following unit conversions are available:

- **millimeter < > inch (mm < > in);**
- **bar < > pound-force per square inch (bar < > psi);**
- **newton < > pound-force (N < > lbf);**
- **kilogram < > pound (kg < > lbs);**
- **kilometer per hour < > miles per hour (km/h < > mph);**
- **megapascal < > ShoreA hardness (MPa < > ShoreA);**

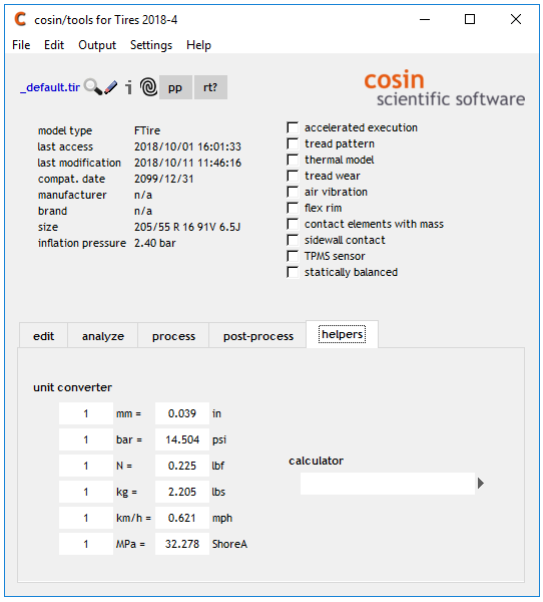

Figure 54: **cosin/tools for tires** helpers menu

7 cosin/tools for tires's *Menu-bar Functions*

The buttons in the menu bar of the **cosin/tools for tires** perform the following functions:

- **File:**
  - **New tire** – creates a new tire data file with the use of some basic tire data;
  - **Open tire ..** – opens a file explorer to open a tire data file;
  - **Search tire in** – defines the location to search for a tire data file;
  - **Open last** – open the last opened tire data file;
  - **Open Recent** – open a tire data file from a selection of previously opened data files;
  - **Save tire** – save current tire data file;
  - **Save tire as ..** – save current tire data file with a new name;
  - **Save tire in new format as ..** – save current tire data file in a new format (different file format, units and/or kind of tire properties);
  - **Quit** – close **cosin/tools for tires**;
- **Edit**:
  - **Diff with** – compares current data file to a previous data file;
  - **Compare with** – lists all parameter changes between the current and previous data files;
  - **Undo** – Undo recent parameter changes;
  - **Undo all** – Undo all parameter changes;
- **Output**

  - **Hide/Show message window** – hide/show **cosin** message window;
  - **Show verbose msg window** – show the comprehensive log output in the **cosin** message window;
  - **Animation off/on** – Switch the animations on/off;
  - **Browse log file** – open the **cosin** Messages of the most recent application call;
  - **Browse auxiliary log file** – open the **cosin** Messages of the most recent auxiliary routine call;
  - **Save log file as..** – save the **cosin** Messages of the most recent application call;
  - **Print log file** – print the **cosin** Messages of the most recent application call;
  - **Clear log file** – clear the **cosin** Messages of the most recent application call;
  - **List files of last run** – list all files that were created during the most recent application call;
- **Settings**
  - **Preferences ..**
    - **unit system** – specifies the unit system that is used in **cosin/tools for tires**. The following unit systems are available:
      - **user-friendly** (SI user-friendly);
      - **SI: mmks** (millimeter/kilogram/second);
      - **SI: mks** (meter/kilogram/second);
      - **USC** (inch/pound/second);
    - **save any data changes automatically** – set if data changes are automatically saved when modified in **cosin/tools for tires**;
- **Help**
  - **cosin docu** – opens the **cosin** documentation, with links to all cosin documentation, user guides and copyright information;
  - **FTire docu** – opens the **FTire Modelization and Parameter specification** documentation;
  - **Support checklist** – opens the trouble-shooting guide, **Support checklist**, that should be checked before requesting technical support;
  - **Load index table** – opens the load index (LI) table;
  - **Speed index table** – opens the speed index table;
  - **TYDEX axis system docu** – opens the **TYDEX axis systems** documentation;
  - **TYDEX file format docu** – opens the **TYDEX Description and Reference Manual;**
  - **About cosin/tools** – displays information about the installed **cosin** software version, revision and installation directory;
  - **www.cosin.eu** – link to the **cosin** website