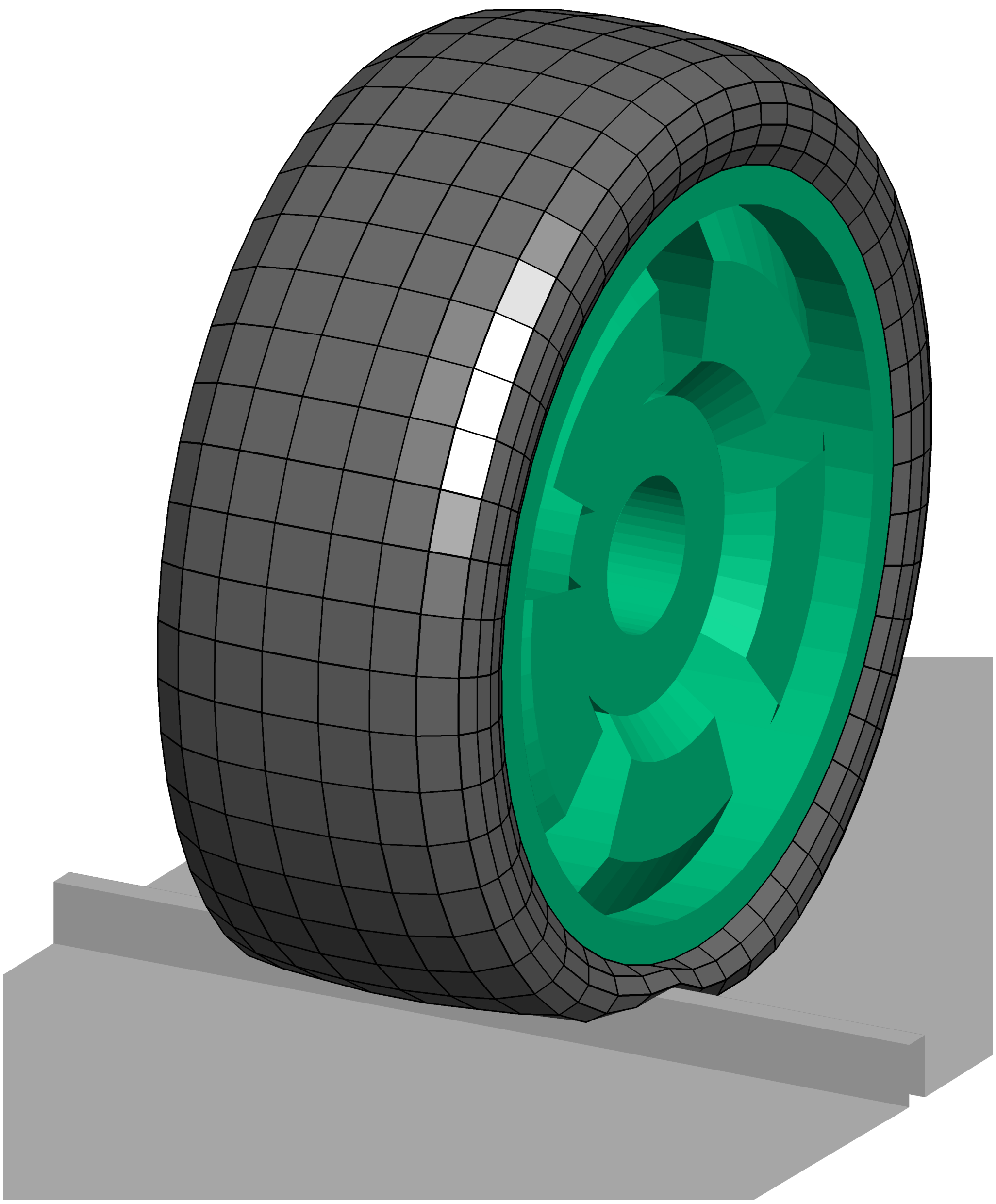
# CDTire

## User Manual
## Version 4.2.7



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## Authoring notes

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# Introduction

The *Comfort and Durability Tire* is a tire model family to be used with the MBS software systems. It focuses on comfort and durability applications but also allows for handling analysis.

**Remark**: In the further text *Comfort and Durability Tire* will be referenced as *CDTire*.

# Tire Model Background

CDTire is a tire model for passenger car and light truck tires that allows engineers to do full vehicle ride comfort and durability analysis in respective MBS software systems, taking into account tire belt dynamics and interaction with 3D road surfaces.

During the multi-body simulation CDTire computes the spindle forces and moments acting on each wheel in the model as well as the local contact forces while driving on a 3D road surface. CDTire accurately captures the vibrations in the frequency range for durability and comfort studies up to 150 Hz.

## CDTire Model Family

*CDTire* offers 3 basic tire models

- **CDTire/3D**
- **CDTire/Realtime**
- **CDTire/MF++**

The following models are considered CDTire/Legacy and are not actively developed anymore:

- **CDTire 20, CDTire 30, CDTire 40, 2030, 2040**

However, existing model 30 parameter files can be used as they are automatically converted to CDTire/Realtime and model 40 files can be used as they are automatically converted to CDTire/3D.

The following paragraphs give some general background information to the sub-models. See the *Appendix* for a detailed description of the corresponding parameter files and their function.

# CDTire/3D

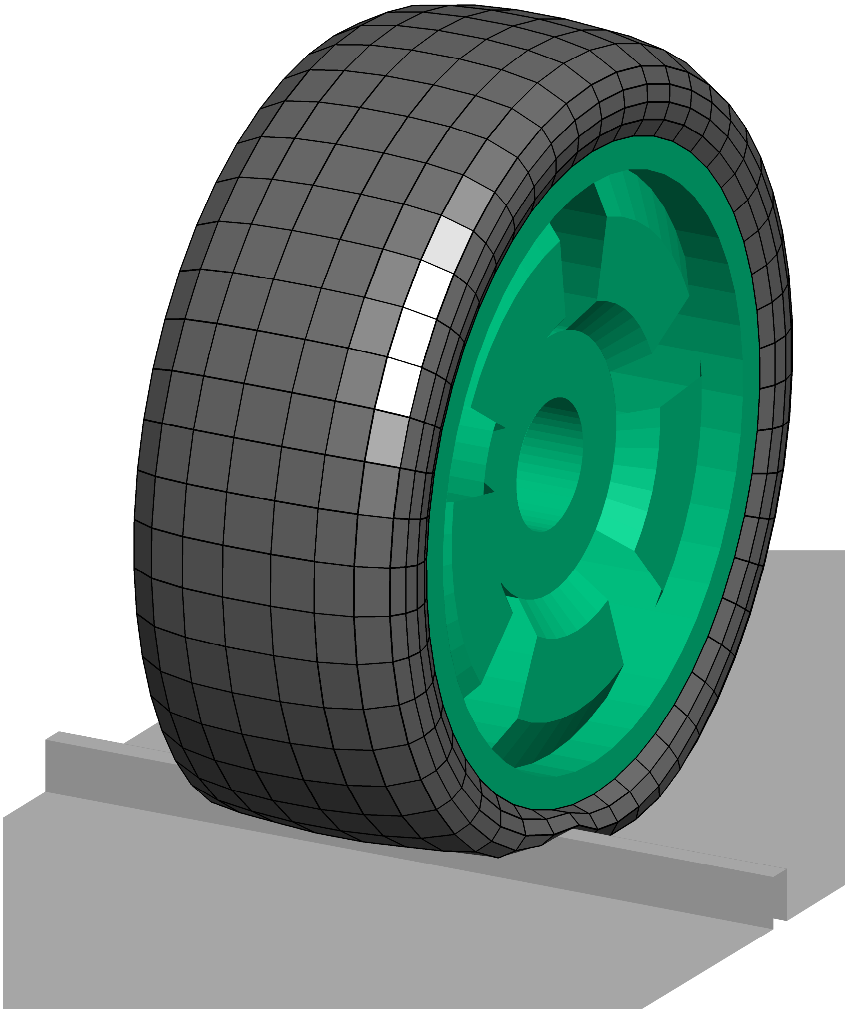


Fig. 1: CDTire/3D

Tire Model Structure:

- belt is flexible shell ( default: 6x3x50 dof´s )
- both sidewalls are flexible shells ( default: 8x3x50 dof´s )

Contact Formulation:

- brush type contact
- local static stick-slip ability

Performance:

- substantial effort
- $lambda_{road}$ can be arbitrary
- full obstacle enveloping

# CDTire/Realtime

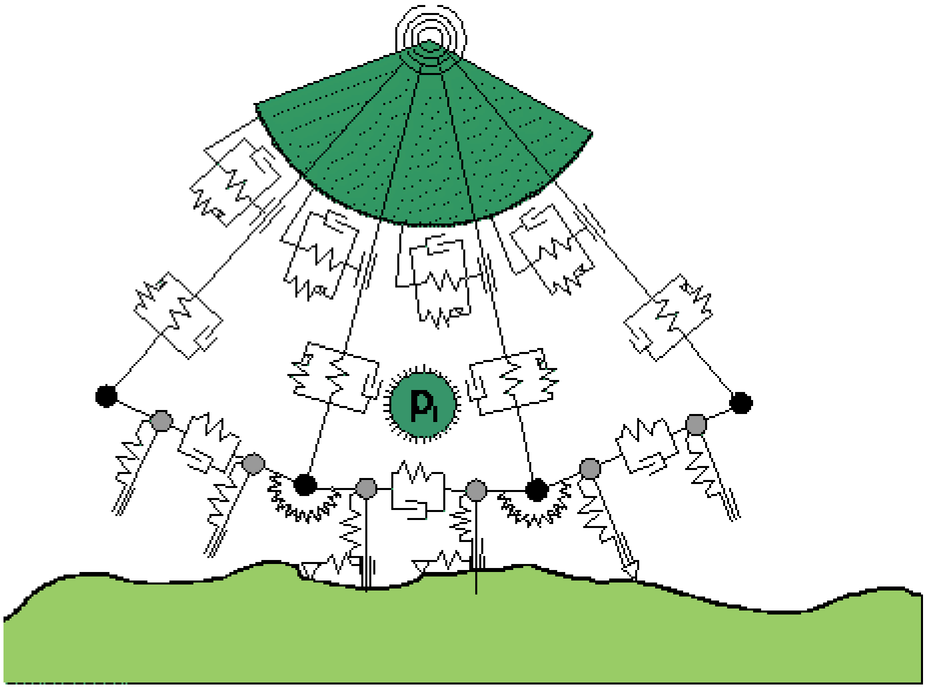


Fig. 2: CDTire/Realtime

Tire Model Structure:

- belt is flexible ring ( default: 3x50 dof´s )
- sidewall is local viscoelastic foundation

Contact Formulation:

- brush type contact
- local static stick-slip ability

Performance:

- hard real time capable
- road surface wavelength $lambda_{road}$ can be arbitrary in tire in-plane direction
- restriction: only in-plane obstacle enveloping, as lateral extension of in-plane tire-road intersection is considered constant for each tire

# CDTire/MF++

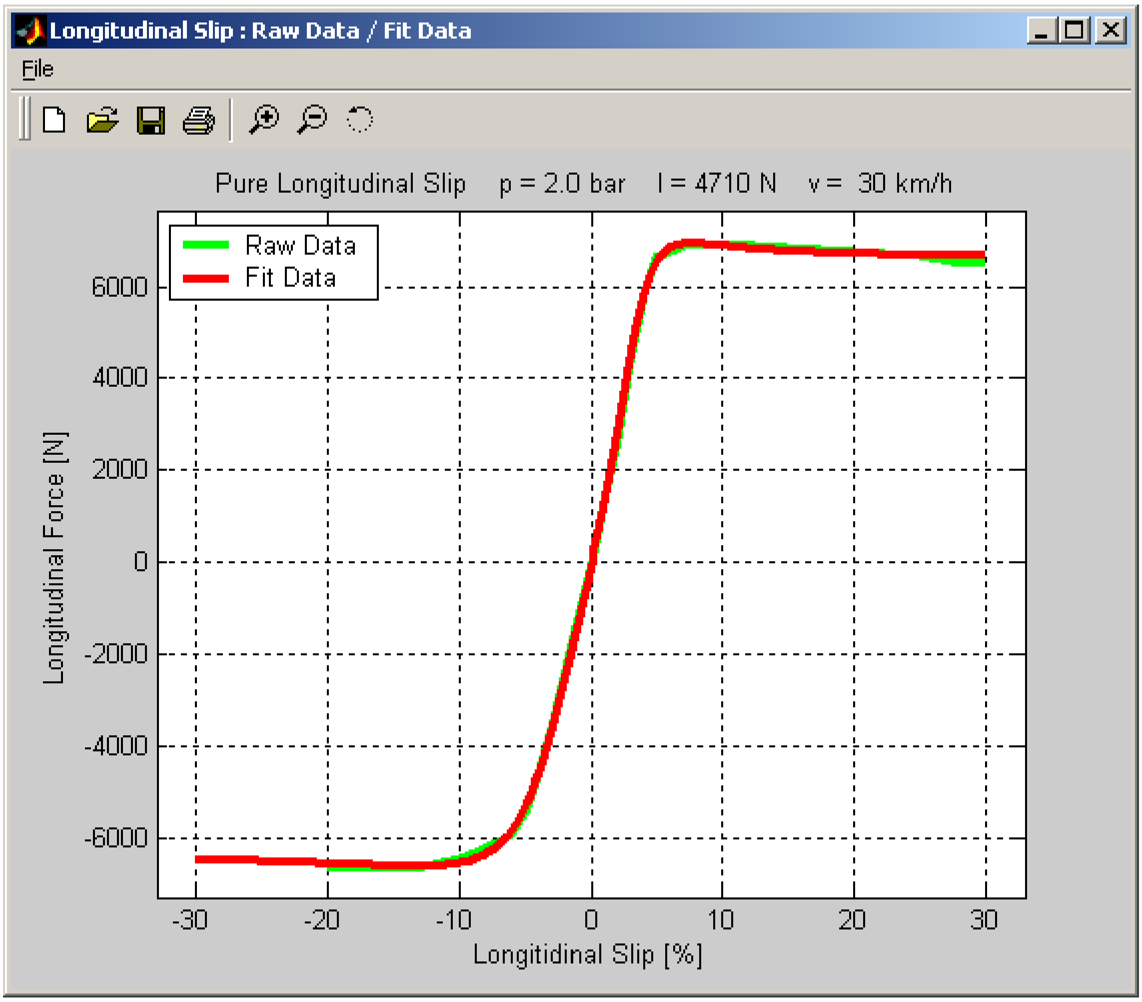



Fig. 3: CDTire/MF++

Tire Model Structure:

- MF 5.2 / PAC2002
- Coupled with CDTire/Thermal

Contact Formulation:

- Estimation of contact patch shape, location and stick/slip zones
- Temperature dependent friction and grip levels

Performance:

- hard real time capable

# Road Surface Models

Technically, the  Road Surface Model is a software library through which *CDTire* can interrogate road surfaces in order to sense contact. Three mechanisms for road surface definitions are supported with the  Road Surface Model:

- CDTire internal road surface models (RSM 1000, 1002, 1008, 2000, 3000)
- User defined road surface model (RSM 1100)
- MBS dependent road surface models may be available, see the corresponding *CDTireMBSManual* for more information.

## CDTire road surfaces models (RSMs)

See the chapter ***Model Usage*** for detailed information on the single models.

CDTire now also supports the OpenCRG® road format as Road Surface Model 3000. This part of the software and the respective data is licensed under the Apache License, Version 2.0 (the "License"); you may not use this file except in compliance with the License. You may obtain a copy of the License at  http://www.apache.org/licenses/LICENSE-2.0. Unless required by applicable law or agreed to in writing, software distributed under the License is distributed on an "AS IS" BASIS, WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied. See the License for the specific language governing permissions and limitations under the License. More Information on OpenCRG® open file formats and tools can be found at http://www.opencrg.org

## MBS road surfaces models (RSMs)

Some MBS systems allow CDTire to utilize their own road surface models. See the respective ***CDTire MBS Guide*** for detailed information on the these models and how to use them.

# Model Implementation

The implementation is done by using a dedicated element to include *CDTire* in your vehicle or testrig model.

## Modeling with CDTire

The *CDTire* element is a dedicated element in the modeling process and supports various commercially available MBS software packages :

- Altair MotionSolve
- LMS Samtech Samcef Mecano
- LMS Virtual.Lab Motion
- MATLAB / Simulink
- MSC ADAMS
- SIMPACK
- VI-grade VI-CarRealTime

Please see the *CDTire MBS Guide* documentation of the specific guides on how to model with CDTire.

# Model Usage

To include the CDTire in a MBS model also road data is required. This data can, in the simplest form, describe a plain surface without any obstacles or tracks. More complex data give an analytical description of a road surface with obstacles or tracks, digitized measured data, a combination of those or of a drum surface.

*CDTire* supports several road surface models:

| Road Surface Model | Surface Type |
|---|---|
| 1000 | parametric road surface description |
| 1002 | rolling drum with or without a cleat |
| 1008 | 3D surface |
| 1100 | User road model (ADAMS only) |
| 2000 | parametric and digitized road data |
| 3000 | OpenCRG® (1.1.1) road data |

## Road Surface Model 1000

The  Road Surface Model 1000 is adapted for an analytical description of the road surface. A number of different obstacle types and tracks are available to model the road. It will generate a surface Z(X,Y) with respect to the coordinate system representing the surface origin as defined in the MBS model (P5).

A road definition file for the  Road Surface Model 1000 is structured as follows:

- **Header**: This part specifies the additional translation and the used data type (obstacles, equidistant tracks or non-equidistant tracks).
- **Data Part**: For each obstacle or track the corresponding data is defined

# Header (Road Surface Model 1000)

```
# HEADER ROAD MODEL 1000
# X0_ROAD    Y0_ROAD    Z0_ROAD    MU_ROAD
  200.0      200.0      100.0      0.9
# DATA TYPE: (2, 3 OR 4)
  2
```

The first line is a comment line starting with a hash (#). You may use it for specifying a short description or general comment to the road definition file. This line is required but all contents will be ignored by *CDTire*.

The second and the fourth lines are comment lines starting with a hash (#), too. Here you should enter "placeholders" for the data in the following lines. *CDTire* ignores these lines but the file will be easier to read for all users.

The third line contains the data defining the additional translation. The data type is defined by the entry in the fifth line.

## Additional Translation

You may define a translation of the road coordinate system (X0) from the road origin marker (P5) of the MBS model.


Fig. 4: additional translation

The additional translation is defined in the third line:

```
Line 1: # HEADER ROAD MODEL 1000
Line 2: # X0_ROAD    Y0_ROAD    Z0_ROAD    MU_ROAD
Line 3:   200.0      200.0      100.0      0.9
```

with

| | |
|---|---|
| **X0_ROAD** | Translation in x-direction |
| **Y0_ROAD** | Translation in y-direction |
| **Z0_ROAD** | Translation in z-direction |
| **MU_ROAD** | friction coefficient road |

The parameters **X0_ROAD**, **Y0_ROAD** and **Z0_ROAD** determine the position of the subsequent definitions with respect to the coordinate system representing the surface origin as defined in the MBS model.

The friction coefficient of the road defines the friction of the defined plane except for all explicitly defined parts like tracks or obstacles, as these must specify their own friction coefficient.

## Data Type

The data type defines the surface structure in general. It is given in the 5th line of the road definition file:

```
Line 1: # HEADER ROAD MODEL 1000
Line 2: # X0_ROAD    Y0_ROAD    Z0_ROAD    MU_ROAD
Line 3:   200.0      200.0      100.0      0.9
Line 4: # DATA TYPE: (2, 3 OR 4)
Line 5:   2
```

with

| | |
|---|---|
| **DATA TYPE** | 2 = equidistant track data |
| | 3 = non-equidistant track data |
| | 4 = matrix track data |

---

The previously available **Data Type 1** road surface description is not supported anymore and will generate an error message.

---

# Data Part (Road Surface Model 1000)

Depending on the data type defined in the header the data part contains one or more definitions of either obstacles or equidistant tracks or non-equidistant tracks. Mixing the data types is not possible.

## Equidistant Track Data (DATA TYPE 2)

This is the preferred data type to construct track surfaces Z(X) on equidistant data (**DATA TYPE** = 2 ).

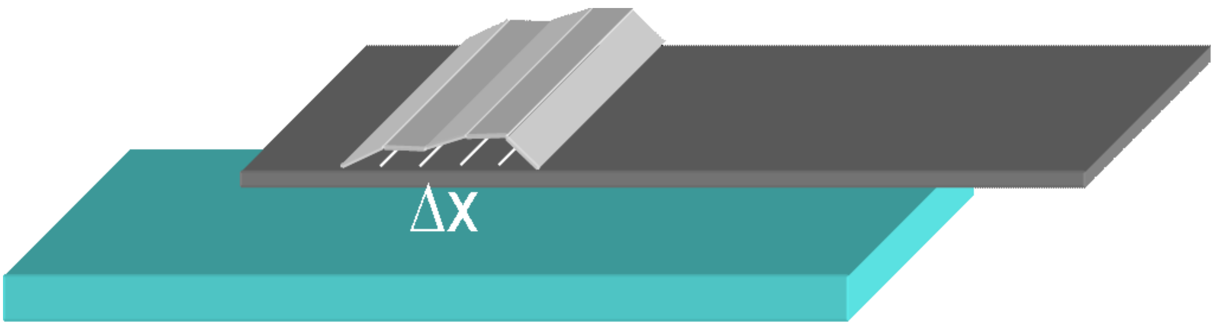



Fig. 5: Road Surface Model 1000: equidistant track data

The direction of the track will be the x-direction of the coordinate system representing the surface origin as defined in the MBS model. Interpolation of the track data will be linear.

There can be several tracks defined in one file. Therefore the header of a road definition file for equidistant track data contains two additional lines:

```
Line 6: # NTRACKS
Line 7:   3
```

with

| | |
|---|---|
| **NTRACKS** | total number of tracks |

For each of the **NTRACKS** tracks a body definition follows. If these tracks overlap, *CDTire* will generate a runtime error once it tries to evaluate a multiply defined surface point. The body of a track consists of 2 + **NDATA** lines:

```
# NDATA  X0_TRACK  Y0_TRACK  HALF_WIDTH  DX    MU_TRACK
  4      0.0       0.0       300.0       10.0  1.0
  0.0
  10.0
  10.0
  0.0
```

with

| | |
|---|---|
| **NDATA** | number of data points of the track |
| **X0_TRACK** | track origin x-coordinate with respect to the road data origin |
| **Y0_TRACK** | track origin y-coordinate with respect to the road data origin |
| **HALF_WIDTH** | half width of the track |
| **DX** | equidistant spacing $\Delta x$ of the track data |
| **MU_TRACK** | friction coefficient of the track surface |
| Line 10 ... Line 9 + **NDATA** | these lines contain the z data of the single tracks (local hight) |

The total width of the track is 2***HALF_WIDTH**, i.e. **HALF_WIDTH** is applied in the positive and the negative Y-direction, starting at **Y0_TRACK**.

Line 3 starts with the first data value. This value does not need to be zero, allowing for discontinuous surfaces. All further data must be on consecutive lines, one value each, as specified by NDATA.

See the chapter ***Example for Equidistant Track Data (Data Type 2)*** in the Appendix for a detailed example.

# Non-equidistant Track Data (DATA TYPE 3)

This data type (**DATA TYPE** = 3 ) is used to construct track surfaces with non-equidistant data (based on pairs of (X,Z) data). For certain types of street profiles the use of this data type would be much more efficient than equidistant data (e.g. a ramp). The direction of the track is the same as for the equidistant data. Again, several tracks can be defined in one file.

As for equidistant track data, the header is extended by the lines

```
Line 6: # NTRACKS
Line 7:   3
```

with

| | |
|---|---|
| **NTRACKS** | total number of tracks |

For each of the **NTRACKS** tracks a body definition follows. If these tracks overlap, *CDTire* will generate a runtime error once it tries to evaluate a multiply defined surface point. The body of a track consists of 2 + **NDATA** lines:

```
# NDATA  X0_TRACK  Y0_TRACK  HALF_WIDTH  MU_TRACK
  3      0.0       0.0       300.0       1.0
  0      0
  30000  1000
  50000  0
```

with

| | |
|---|---|
| **NDATA** | number of data points of the track |
| **X0_TRACK** | track origin x-coordinate with respect to the road data origin |
| **Y0_TRACK** | track origin y-coordinate with respect to the road data origin |
| **HALF_WIDTH** | half width of the track |
| **MU_TRACK** | friction coefficient of the track surface |
| Line 10 ...<br>Line 9 + **NDATA** | these lines contain the x and z data of the single tracks |

See the chapter ***Example for Non-Equidistant Track Data (Data Type 3)*** in the Appendix for a detailed example.

# Matrix Track Data (DATA TYPE 4)

This data type (**DATA TYPE** = 4 ) is used to construct track surfaces with matrix data. The direction of the track is the same as for the equidistant data. Again, several tracks can be defined in one file.

```
Line 6: # NTRACKS
Line 7:   3
```

with

| | |
|---|---|
| **NTRACKS** | total number of tracks |

For each of the **NTRACKS** tracks a body definition follows. If these tracks overlap, *CDTire* will generate a runtime error once it tries to evaluate a multiply defined surface point. The body of a track consists of 2 + **NDATA** lines:

```
# NX     NY     X0     Y0     DX     DY     MU     ZSCALE     Z0
  3      5     -10.0 -10.0  10.0   5.0    0.9    1.0        0.0
  6.0  6.0  6.0  6.0  6.0
  6.0  3.0  0.0  3.0  6.0
  6.0  6.0  6.0  6.0  6.0
```

with

| | |
|---|---|
| **NX** | number of matrix rows of the track matrix |
| **NY** | number of matrix columns of the track matrix |
| **X0** | track origin x-coordinate with respect to the road data origin (upper left point) |
| **Y0** | track origin y-coordinate with respect to the road data origin (upper left point) |
| **DX** | (signed) spacing x direction (between rows) |
| **DY** | (signed) spacing y direction (between columns) |
| **MU** | friction coefficient of the track matrix |
| **ZSCALE** | Scaling of matrix values (z values) |
| **Z0** | Additive offset of matrix values (z values) |

# Road Surface Model 1002

The Road Surface Model 1002 adapts an analytical description of a drum surface. A number of different obstacle types and tracks are available to model the drum. It will generate a surface dR(phi,Y) with respect to the coordinate system representing the surface origin as defined in the MBS model (P5).

A road definition file for the Road Surface Model 1002 is structured as follows:

- **Header**: This part specifies the additional translation and the used data type (obstacles, equidistant tracks or non-equidistant tracks).
- **Data Part**: For each obstacle or track the corresponding data is defined

# Header (Road Surface Model 1002)

```
# DESCRIPTION LINE
# RADIUS_DRUM      MU_DRUM     PERIODIC
  1000.0           1.0         1
# SURFACE TYPE
  1
```

The first line is a comment line starting with a hash (#). You may use it for specifying a short description or general comment to the drum definition file. This line is required but all contents will be ignored by *CDTire*.

The second and fourth lines are comment lines starting with a hash (#), too. Here you should enter "placeholders" for the data in the following lines. *CDTire* ignores these lines but the file will be easier to read for all users.

The third line contains the data defining the drum surface without any obstacles or data. It consists of the radius of the drum (in [mm]) and the friction coefficient (in [1]). A third parameter is the periodic flag, and if set obstacles appear with every revolution of the drum surface. If not set, the obstacle will appear only once (depending on S_0 settings). The fifth line contains the type of obstacle data.

```
Line 1: # DESCRIPTION LINE
Line 2: # RADIUS_DRUM      MU_DRUM     PERIODIC
Line 3:   1000.0           1.0         1
Line 4: # SURFACE TYPE
Line 5:   1
```

with

| | |
|---|---|
| **RADIUS_DRUM** | drum radius in [mm] |
| **MU_DRUM** | friction coefficient drum surface outside obstacle data |
| **PERIODIC** | repeat cleat (1) or only once (0) |
| **SURFACE TYPE** | 1 = no data |
| | 2 = with rectangular cleat |
| | 3 = with chamfered cleat |
| | 4 = matrix data |

Fig. 6: Road Surface Model 1002: rolling drum

# Header (Road Surface Model 1002)

With R4.2.7, there are 4 surface types to construct drum surfaceswith.

## No data (SURFACE TYPE 1)

The road definition file for a drum surface without any additional data (SURFACE TYPE 1) has the following structure:

```
# DESCRIPTION LINE
# RADIUS_DRUM      MU_DRUM     PERIODIC
  1000.0           1.0         1
# SURFACE TYPE
  1
```

## Rectangular cleat (SURFACE TYPE 2)

The road definition file for a drum surface with any rectangular cleat (SURFACE TYPE 2) has the following structure:

```
# DESCRIPTION LINE
# RADIUS_DRUM      MU_DRUM     PERIODIC
  1000.0           1.0         1
# SURFACE TYPE
  2
# H      W      S_0       PHI       MU_CLEAT
  10.0   20.0   -2522.2   90.0        0.8
```

with

| | |
|---|---|
| **H** | height [mm] of cleat |
| **W** | width [mm] of cleat (length of cleat is infinite) |
| **S_0** | arc length[mm] from top of drum to cleat origin - for PERIODIC_FLAG = 1, this must be -RADIUS_DRUM*PI < S_0 < RADIUS_DRUM*PI |
| **PHI** | direction angle of cleat, measured from wheel plane, transversal cleat is 90° |
| **MU_CLEAT** | friction coefficient on cleat |

## Ramped / trapezoid cleat (SURFACE TYPE 3)

The road definition file for a drum surface with any ramped or trapezoid cleat (SURFACE TYPE 3) has the following structure:

```
# DESCRIPTION LINE
# RADIUS_DRUM      MU_DRUM     PERIODIC
  1000.0           1.0         1
# SURFACE TYPE
  3
# H      W1     W2     W3      S_0       PHI        MU_CLEAT
  10.0   20.0   40.0   20.0   -2522.2    90.0          0.8
```

with

| | |
|---|---|
| **H** | height [mm] of cleat |
| **W1** | width (arclength) [mm] of leading ramp |
| **W2** | width (arclength) [mm] of leading ramp |
| **W3** | width (arclength) [mm] of trailing ramp |
| **S_0** | arclength [mm] from top of drum to cleat origin - for PERIODIC_FLAG = 1, this must be -RADIUS_DRUM*PI < S_0 < RADIUS_DRUM*PI |
| **PHI** | direction angle of cleat, measured from wheel plane |
| **MU_CLEAT** | friction coefficient on cleat |

## Matrix data (SURFACE TYPE 4)

The road definition file for a drum surface with any equidistant grid or matrix data dR(phi,y) (SURFACE TYPE 4) has the following structure:

```
# DESCRIPTION LINE
# RADIUS_DRUM      MU_DRUM     PERIODIC
  1000.0           1.0         1
# SURFACE TYPE
  4
```

```
# NPHI   NY   PHI0   DPHISEG   Y0       DY   MU    SCALE   RADIUSOFFSET
  4       2   0.0    3.438    -200.0   400  0.8   1.0     0.0
10.0  10.0
20.0  20.0
20.0  20.0
10.0  10.0
```

with

| | |
|---|---|
| **NPHI** | number of circumferential data points |
| **NY** | number of lateral (axial) data points |
| **PHI0** | angular segment range [deg] of data, 360 for full drum |
| **DPHISEG** | angular spacing [deg] of data, 360/NPHI for full drum |
| **Y0** | starting lateral coordinale [mm] of data |
| **DY** | Lateral segment range [mm] of data, range is [Y0,Y0+DY] |
| **MU** | friction coefficient on data |
| **SCALE** | scaling coefficiant for radial data |
| **RADIUSOFFSET** | Offset value [mm] |
| **DATA** | NPHI rows, NY columns |

Above example makes up a trapeze,

All lines starting with a hash (#) are comment files used to define placeholders for the data in the following lines. Even if *CDTire* will skip over them, these lines are required. Do not delete them!

If the direction angle of the cleat is not specified, a perpendicular cleat (90°) is assumed.

# Road Surface Model 1008

This road surface model is the CDTire implementation of the 3D method of MSC Adams .rdf data files. Some MBS systems can also visualize this road format in their respective Pre-/Postprocessor. This documentation lists only the required data format to work with CDTire - for visualization support of MBS systems, please refer to the respective MBS documentation.

## Data structure and format

The data file is based on section / keyword format. A valid section line contains the name of the section is square brackets. A valid keyword line contains the name of the keyword, followed by the '=' character, followed by the value. A valid CDTire RSM1008 file is shown here:

```
[MODEL]
METHOD = '3D'

[UNITS]
LENGTH = 'MM'

[OFFSET]
X = 100.0
Y = 200.0
Z = -10.0

[NODES]
NUMBER_OF_NODES = 4
{ node  x_value  y_value  z_value }
  1     -10.0    -200.0   10.0
  2      10.0    -200.0   10.0
  3      10.0     200.0   10.0
  4     -10.0     200.0   10.0

[ELEMENTS]
NUMBER_OF_ELEMENTS = 2
{ node_1  node_2  node_3  u }
  1       2       3       0.8
  1       3       4       0.8
```

The following format details may only be valid for the CDTire implementation of .rdf files:

- Section names, keyword names and strings are case insensitive. All of "METHOD", "method", "Method" are the same valid keyword.
- Supported units are "MM" (millimeter), "CM" (centimeter), and "M" (meter)
- In node and element section, a comment line containing a left brace (curly) bracket indicates that the next line starts with the respective data matrix (nodes or elements). The following NUMBER_OF_xxx lines must contain valid line data for each line.

# Road Surface Model 2000

## CDTire Setup for Road Surface Model 2000

CDTire needs to be set up for road surface type “2000” in order to make use of the Road Surface Model.

In order to run *CDTire* on road data, following set of files is required in the

In order to run *CDTire* on road data, following set of files is required in the directory referred to in the CDTire setup:

- a global definition file that defines the boundaries of the track **`MasterRectangle.h`**
- a surface type classification file **`SurfacType.h`** that defines the friction coefficient for the different surface types as referred in the road data files
- a set of "macropatch" header files named **`MP_0_0.h`**, **`MP_0_1.h`** etc.
- (when applicable) a set of “macropatch” binary data files named **`MP_0_0.d`**, **`MP_0_1.d`** etc.
- (when applicable) a set of parametric road description files

---

Note : the mention "when applicable" relates to the fact that a track definition for CDTire may be defined either through digitized data only, parametric description files only, or a mix of both.

---

**IMPORTANT** : all the files mentioned above are ***strictly required***, and need to adhere to the specified naming and format conventions. The format of the needed header files is explained in the following sections.

The fundamental idea behind the *Road Format* concept is that any track will be described in a rectangular grid ; which has three levels of discretization :

- a "master rectangle" that envelopes the complete track
- a series of "macropatches" (typically size 10 x 10 m) defined inside this master rectangle
- a series of "micropatches" per macropatch (typical size 0.5 x 0.5 m)
- a rectangular mesh in each micropatch (grid size typically 5 x 5 mm), where per grid point in the mesh the track Z-coordinate has been measured and stored

## MasterRectangle.h

The structure of the file **`MasterRectangle.h`** is:

| | |
|---|---|
| `version indicator` | actual value : v002 (string) |
| `comment` | string(s) of arbitrary length beginning with # |
| `platform-flag` | specifies platform where binary data have been written (integer)<br>1→Unix, 2→Windows NT, 3→SGI IRIX |
| `. . .` | |
| `Xoff Yoff Zoff` | real altitude and offset of left lower corner of the Master Rectangle (double) |
| `indicator` | to read the Macro-patches column-wise (1 char: c) |
| `rows <space> columns` | number of rows and columns of Macro-patches (long) |
| `width <space> height` | width and height of a Macro patch (double) |
| `units` | string max 17 characters – reserved for future use |

### Example for MasterRectangle.h

```
v002
# Master rectangle definition for Track A
2
-100.000 -100.000 15.000
c
7 1
10000.000 10000.000
mm
```

## MacroPatch header files

The structure of the macropatch files **`MP_0_0.h`**, **`MP_0_1.h`**, …is:

| **File entry** | **Meaning** |
|---|---|
| `Macropatch column_nr row_n` | |
| `{` | |
| `version indicator` | actual value : v002 (string) |
| `comment` | string(s) of arbitrary length beginning with # |
| `platform-flag` | specifies platform where binary data have been written (integer) |

| File entry | Meaning |
|---|---|
| | 1→Unix, 2→Windows NT, 3→SGI IRIX |
| `Zoff` | z-Position of left lower corner relative to origin of Master-rectangle (double) |
| `columns <space> rows` | number of columns and rows of micro-patches (long) |
| `width <space> height` | width and height in mm of a micro-patch (double) |
| `indicator` | to read the micro-patches column-wise (1 char: c) |
| **`}`** | |
| `Micropatch 0 0` | header of micro patch section 0 0 |
| `    <header info>` | header info of micro patch section 0 0 |
| `Micropatch 0 1` | header of micro patch section 0 1 |
| `    <header info>` | header info of micro patch section 0 1 |
| `Micropatch 0 2` | header of micro patch section 0 2 |
| `    <header info>` | header info of micro patch section 0 2 |
| `. . .` | |

The format of the micro patch sections in the macro patch header files depends on the type of road description:

- off-road

| File entry | Meaning |
|---|---|
| `Micropatch micro_column_nr micro_row_n` | micro patch header |
| `    datatype` | 0 -> off road (integer) |

- digitized

| File entry | Meaning |
|---|---|

| File entry | Meaning |
|---|---|
| `Micropatch micro_column_nr micro_row_n` | micro patch header |
| `datatype` | 1 -> digitized (integer) |
| `trackclassification` | refers to a classification number in surface classification file (integer) |
| `width <space> height` | width and height in mm of an element (double) |
| `lines_h <space> lines_v` | number of grid lines horizontally and vertically (integer) |
| `. . .` | |
| `byte number` | byte number of the first micro-patch identifier index in the data file (unsigned integer) |
| `indicator` | to read the micro-patches column-wise (1 char: c) |
| `. . .` | |
| `tiretype_proposed` | 20 \| 30 \| 40 (integer) |
| `flag` | reserved for future use (integer) |

- parameterized

| File entry | Meaning |
|---|---|
| `Micropatch micro_column_nr micro_row_n` | micro patch header |
| `datatype` | 2 -> parameterized (integer) |
| `trackclassification` | refers to a classification number in surface classification file (integer) |
| `filename` | Filename withozt pathname for data specification (string) |
| `tiretype_proposed` | 20 \| 30 \| 40 (integer) |
| `flag` | reserved for future use (integer) |

## Example for a MacroPatch header file

The following example contains the 3 types of micropatches. This file shows only the first and second column.

```
Macropatch 0 0
{
 v002
# Example
 2
 -10.0000
 20 20
 500.000 500.000
 c
}
Micropatch 0 0
1
1
5.000 5.000
101 101
0
c
20
2030
Micropatch 0 1
1
1
5.000 5.000
101 101
40812
c
20
2030
Micropatch 0 2
1
1
5.000 5.000
101 101
81624
c
20
2030
Micropatch 0 3
1
1
5.000 5.000
101 101
122436
c
```

```
20
2030
Micropatch 0 4
1
1
5.000 5.000
101 101
163248
c
20
2030
Micropatch 0 5
1
1
5.000 5.000
101 101
204060
c
20
2030
. . .
Micropatch 0 9
2
1
ParametricFile.h
20
2030
Micropatch 0 10
2
1
ParametricFile.h
20
2030
Micropatch 0 11
2
1
ParametricFile.h
20
2030
Micropatch 0 12
2
1
ParametricFile.h
20
2030
. . .
Micropatch 1 7
1
```

```
1
5.000 5.000
101 101
652992
c
20
2030
Micropatch 1 8
1
1
5.000 5.000
101 101
693804
c
20
2030
Micropatch 1 9
0
Micropatch 1 10
0
Micropatch 1 11
0
Micropatch 1 12
0
Micropatch 1 13
0
Micropatch 1 14
0
Micropatch 1 15
0
Micropatch 1 16
0
Micropatch 1 17
0
Micropatch 1 18
0
Micropatch 1 19
0
```

## Surface type classification file

This file contains an ascii table defining the friction coefficient that corresponds to the surface types as specified in each micro patch header file.

### Example for a surface type classification file

```
17          →   Maximum class number defined in the file
0<tab>1.00  →   Surface class  <tab>  friction coefficient
5<tab>1.01  →   Surface class  <tab>  friction coefficient
12<tab>1.05 →   …
13<tab>1.1  →   …
17<tab>1.15 →   …
```

# Customizing CDTire

Even though *CDTire* tries to present a setup in a plug-and-play fashion, there are several considerations for a successful simulation that can not be tuned automatically. These include structural discretization, integrator tuning and inflation pressure.

For more information on

- Structural discretization and inflation pressure refer to the chapters in the Appendix:
  - ***Tire Parameter Files for CDTire/MF++***
  - ***Tire Parameter Files for CDTire/Realtime*** and
  - ***Tire Parameter Files for CDTire/3D***

# Appendix

# Tire Parameters

The following paragraphs explain the parameter files for the tire models *CDTire/MF++*, *CDTire/Realtime* and *CDTire/3D* in detail. For each tire model a listing of the corresponding parameter file and explanations to the single parameters are given.

## Tire Parameter File - CDTire/MF++

The following listing shows the input file for a tire as used in the tire model *CDTire/MF++*:

```
 [UNITS]
LENGTH = 'meter'
FORCE = 'newton'
ANGLE = 'radians'
MASS = 'kg'
TIME = 'second'

[MODEL]
LONGVL = 16.6                $Measurement speed
THERMAL_MODEL_FLAG = 0
VELOCITY_TRESHOLD = 0.5      $Lower cut off velocity

[DIMENSION]
UNLOADED_RADIUS = 0.312      $Free tyre radius
WIDTH = 0.195                $Nominal section width of tyre
ASPECT_RATIO = 0.65          $Nominal aspect ratio
RIM_RADIUS = 0.19            $Nominal rim radius
RIM_WIDTH = 0.1524           $Rim width

[VERTICAL]
VERTICAL_STIFFNESS = 2e+005  $Tyre vertical stiffness
VERTICAL_DAMPING = 0         $Tyre vertical damping
BREFF = 6.1                  $Low load stiffness e.r.r.
DREFF = 0.45                 $Peak value of e.r.r.
FREFF = 0.01                 $High load stiffness e.r.r.
FNOMIN = 4000                $Nominal wheel load

[PARAMETER]
```

```
VERTICAL_STIFFNESS = 2e+005     $Tyre vertical stiffness

[LONG_SLIP_RANGE]
KPUMIN = -1.5                   $Minimum valid wheel slip
KPUMAX = 1.5                    $Maximum valid wheel slip

[SLIP_ANGLE_RANGE]
ALPMIN = -1.5708                $Minimum valid slip angle
ALPMAX = 1.5708                 $Maximum valid slip angle

[INCLINATION_ANGLE_RANGE]
CAMMIN = -0.26181               $Minimum valid camber angle
CAMMAX = 0.26181                $Maximum valid camber angle

[VERTICAL_FORCE_RANGE]
FZMIN = 200                     $Minimum allowed wheel load
FZMAX = 9000                    $Maximum allowed wheel load

[SCALING_COEFFICIENTS]
LFZO = 1       $Scale factor of nominal (rated) load
LCX = 1        $Scale factor of Fx shape factor
LMUX = 1       $Scale factor of Fx peak friction coefficient
LEX = 1        $Scale factor of Fx curvature factor
LKX = 1        $Scale factor of Fx slip stiffness
LHX = 1        $Scale factor of Fx horizontal shift
LVX = 1        $Scale factor of Fx vertical shift
LGAX = 1       $Scale factor of camber for Fx
LCY = 1        $Scale factor of Fy shape factor
LMUY = 1       $Scale factor of Fy peak friction coefficient
LEY = 1        $Scale factor of Fy curvature factor
LKY = 1        $Scale factor of Fy cornering stiffness
LHY = 1        $Scale factor of Fy horizontal shift
LVY = 1        $Scale factor of Fy vertical shift
LGAY = 1       $Scale factor of camber for Fy
LTR = 1        $Scale factor of Peak of pneumatic trail
LRES = 1       $Scale factor for offset of residual torque
LGAZ = 1       $Scale factor of camber for Mz
LXAL = 1       $Scale factor of alpha influence on Fx
LYKA = 1       $Scale factor of alpha influence on Fx
LVYKA = 1      $Scale factor of kappa induced Fy
LS = 1         $Scale factor of Moment arm of Fx
LSGKP = 1      $Scale factor of Relaxation length of Fx
LSGAL = 1      $Scale factor of Relaxation length of Fy
LGYR = 1       $Scale factor of gyroscopic torque
LMX = 1        $Scale factor of overturning couple
LVMX = 1       $Scale factor of Mx vertical shift
LMY = 1        $Scale factor of rolling resistance torque
```

```
[LONGITUDINAL_COEFFICIENTS]
PCX1 = 1.839     $Shape factor Cfx for longitudinal force
PDX1 = 1.1387    $Longitudinal friction Mux at Fznom
PDX2 = -0.11999  $Variation of friction Mux with load
PDX3 = -2.2142e-005 $Variation of friction Mux with camber
PEX1 = 0.62727   $Longitudinal curvature Efx at Fznom
PEX2 = -0.12336  $Variation of curvature Efx with load
PEX3 = -0.03448  $Variation of curvature Efx with load squared
PEX4 = -1.5066e-005 $Factor in curvature Efx while driving
PKX1 = 18.886    $Longitudinal slip stiffness Kfx/Fz at Fznom
PKX2 = -3.988    $Variation of slip stiffness Kfx/Fz with load
PKX3 = 0.21542   $Exponent in slip stiffness Kfx/Fz with load
PHX1 = -0.00033912 $Horizontal shift Shx at Fznom
PHX2 = -8.5877e-006 $Variation of shift Shx with load
PVX1 = -4.638e-006 $Vertical shift Svx/Fz at Fznom
PVX2 = 1.9874e-005  $Variation of shift Svx/Fz with load
RBX1 = 5.9945    $Slope factor for combined slip Fx reduction
RBX2 = -8.2609   $Variation of slope Fx reduction with kappa
RCX1 = 1.07816   $Shape factor for combined slip Fx reduction
REX1 = 1.644     $Curvature factor of combined Fx
REX2 = -0.0064359 $Curvature factor of combined Fx with load
RHX1 = 0.008847  $Shift factor for combined slip Fx reduction
PTX1 = 1.85      $Relaxation length SigKap0/Fz at Fznom
PTX2 = 0.000109  $Variation of SigKap0/Fz with load
PTX3 = 0.101    $Variation of SigKap0/Fz with exponent of load

[OVERTURNING_COEFFICIENTS]
QSX1 = 0         $Lateral force induced overturning moment
QSX2 = 0         $Camber induced overturning couple
QSX3 = 0         $Fy induced overturning couple

[LATERAL_COEFFICIENTS]
PCY1 = 1.3223    $Shape factor Cfy for lateral forces
PDY1 = 1.0141    $Lateral friction Muy
PDY2 = -0.12274  $Variation of friction Muy with load
PDY3 = -1.0426  $Variation of friction Muy with squared camber
PEY1 = -0.63772  $Lateral curvature Efy at Fznom
PEY2 = -0.050782 $Variation of curvature Efy with load
PEY3 = -0.27333 $Zero order camber dependency of curvature Efy
PEY4 = -8.3143   $Variation of curvature Efy with camber
PKY1 = -19.797   $Maximum value of stiffness Kfy/Fznom
PKY2 = 1.7999    $Load at which Kfy reaches maximum value
PKY3 = 0.0095418 $Variation of Kfy/Fznom with camber
PHY1 = 0.0011453 $Horizontal shift Shy at Fznom
PHY2 = -6.6688e-005 $Variation of shift Shy with load
PHY3 = 0.044112  $Variation of shift Shy with camber
PVY1 = 0.031305  $Vertical shift in Svy/Fz at Fznom
PVY2 = -0.0085749  $Variation of shift Svy/Fz with load
```

```
PVY3 = -0.092912 $Variation of shift Svy/Fz with camber
PVY4 = -0.27907  $Variation of shift Svy/Fz with camber + load
RBY1 = 6.2238    $Slope factor for combined Fy reduction
RBY2 = 3.0734    $Variation of slope Fy reduction with alpha
RBY3 = 0.016076  $Shift term for alpha in slope Fy reduction
RCY1 = 1.0051    $Shape factor for combined Fy reduction
REY1 = 0.019749  $Curvature factor of combined Fy
REY2 = -0.0020691 $Curvature factor of combined Fy with load
RHY1 = -0.0010319 $Shift factor for combined Fy reduction
RHY2 = 7.4123e-006 $Shift factor for combined Fy red. w. load
RVY1 = 0.02962 $Kappa induced side force Svyk/Muy*Fz at Fznom
RVY2 = -0.011053 $Variation of Svyk/Muy*Fz with load
RVY3 = -0.0009317 $Variation of Svyk/Muy*Fz with camber
RVY4 = 11.842    $Variation of Svyk/Muy*Fz with alpha
RVY5 = 1.9       $Variation of Svyk/Muy*Fz with kappa
RVY6 = 0         $Variation of Svyk/Muy*Fz with atan(kappa)
PTY1 = 1.9       $Peak value of relaxation length SigAlp0/R0
PTY2 = 2.25      $Value of Fz/Fznom where SigAlp0 is extreme

[ROLLING_COEFFICIENTS]
QSY1 = 0.01      $Rolling resistance torque coefficient
QSY2 = 0         $Rolling resistance torque depending on Fx
QSY3 = 0         $Rolling resistance torque depending on speed
QSY4 = 0         $Rolling resistance torque depending on speed

[ALIGNING_COEFFICIENTS]
QBZ1 = 7.5088    $Trail slope factor for trail Bpt at Fznom
QBZ2 = -1.9428   $Variation of slope Bpt with load
QBZ3 = 0.61681   $Variation of slope Bpt with load squared
QBZ4 = 0.12231   $Variation of slope Bpt with camber
QBZ5 = 0.50016   $Variation of slope Bpt with absolute camber
QBZ9 = 5.5144    $Slope factor Br of residual torque Mzr
QBZ10 = 0        $Slope factor Br of residual torque Mzr
QCZ1 = 1.2237    $Shape factor Cpt for pneumatic trail
QDZ1 = 0.062582  $Peak trail
QDZ2 = 0.00052585 $Variation of peak Dpt" with load
QDZ3 = -0.60661  $Variation of peak Dpt" with camber
QDZ4 = 8.634     $Variation of peak Dpt" with camber squared
QDZ6 = -0.0048467 $Peak residual torque
QDZ7 = 0.0034983 $Variation of peak factor Dmr" with load
QDZ8 = -0.11032  $Variation of peak factor Dmr" with camber
QDZ9 = 0.021277  $Variation of peak factor Dmr" w. camber+load
QEZ1 = -5.3971   $Trail curvature Ept at Fznom
QEZ2 = 1.1207    $Variation of curvature Ept with load
QEZ3 = 0         $Variation of curvature Ept with load squared
QEZ4 = 0.14942  $Variation of curvature Ept w. sign of Alpha-t
QEZ5 = -1.1429  $Variation of Ept with camber and sign Alpha-t
QHZ1 = -0.00069905 $Trail horizontal shift Sht at Fznom
```

```
QHZ2 = 0.0055192 $Variation of shift Sht with load
QHZ3 = 0.065953  $Variation of shift Sht with camber
QHZ4 = 0.11393   $Variation of shift Sht with camber and load
SSZ1 = 0.022576  $Nominal value of s/R0: effect of Fx on Mz
SSZ2 = 0.024754  $Variation of distance s/R0 with Fy/Fznom
SSZ3 = 0.0014697 $Variation of distance s/R0 with camber
SSZ4 = 0.0014801 $Variation of distance s/R0 with load+camber
QTZ1 = 0.2       $Gyration torque constant
MBELT = 4.9      $Belt mass of the wheel
```

# Tire Parameter File - CDTire/Realtime

The following listing shows the input file for a tire with the dimension 195/65 R 15 as used in the tire model *CDTire/Realtime*:

```
[CDT30-HPS MODEL PARAMETERS]

###Pressure Discretization parameters
PIN=0.21
PREF=0.21
PIN_FLAG=0
NMP=100

###Tire size and rim size
R_BELT=307
R_RIM=203
W_BELT=190
###BGRT=190
```

```
###Mass parameters
MASS_BELT=0.005

###Sidewall parameters
FTX=75
FTY=38
FRY=60
DTX=0.08
DTY=0.08
DRY=0.08
RAD_NL_MOD=0.3
###KARED=0.3

###Optional parameters for CRY reduction for big deflections
CRY_RED_FLAG=1
CRY_RED_DEF=40
CRY_RED_RES=0.1

###Belt parameters
CIRC_STIFF=1e+006
###EF=1e+006
Y_BENDING_STIFF=3e+006
###EIY=3e+006
CIRC_DAMP=1e-006
###D_TAN=1e-006
Y_BENDING_DAMP=1e-005
###D_ALPHA=1e-005

###Tread parameters
TREAD_NSEN_X=5
###NSEN=5
TREAD_HEIGHT=10
###HL=10
TREAD_EG=120
###EG=120
TREAD_GG=40
###BL=40
TREAD_RAD_D=5e-004
###D_RAD_TREAD=5e-004
TREAD_KM=0.9
###KM=0.9
TREAD_SCAN_HEIGHT=150
###SCAN_HEIGHT=150
TREAD_MAX_COMPRESS=0.95
KSRED=-70
PNEUMATIC_TRAIL_SCALE=2.1
```

```
###Friction parameters (velocity dependend)
MU=[1.0,1.0,1.0]
###MGLT=[1.0,1.0,1.0]
V_MU=[0,1000,10000]
###VGLT=[0,1000,10000]

###Large Deformation Extension parameters
LDE_FLAG=1
LDE_CNL=50
LDE_CLIN=100
LDE_RNL=28
LDE_RLIN=18

###Global linear radial tire stiffness used for static (if not
available set to 250.0)
R_STAT=317
CR1_STAT=235
```

```
[CDT30-HPS SOLVER PARAMETERS]

###Solver parameters
TOL = 1.001E-3
DTM = 2.001E-4
DT_START_EXPL = 2e-005
NMAX_IMPL_ITER = 4
PRE_STEP_TIME = 0.05
TYPE = 2
ALPHA_EXPLICIT = 0
BETA_EXPLICIT =  0.1666666666667
GAMMA_EXPLICIT = 0.5
ALPHA_IMPLICIT = 0
BETA_IMPLICIT =  0.25
GAMMA_IMPLICIT = 0.5
UPDATE_FOR_MASTERCORRECTOR = 0
IMPL_STEP_CTRL_ENABLE = 1
IMPL_STEP_CTRL_EPS = 200
IMPL_STEP_CTRL_NSUBSTEPS = 3
IMPL_JAC_EVAL_AT_ITER = 0
```

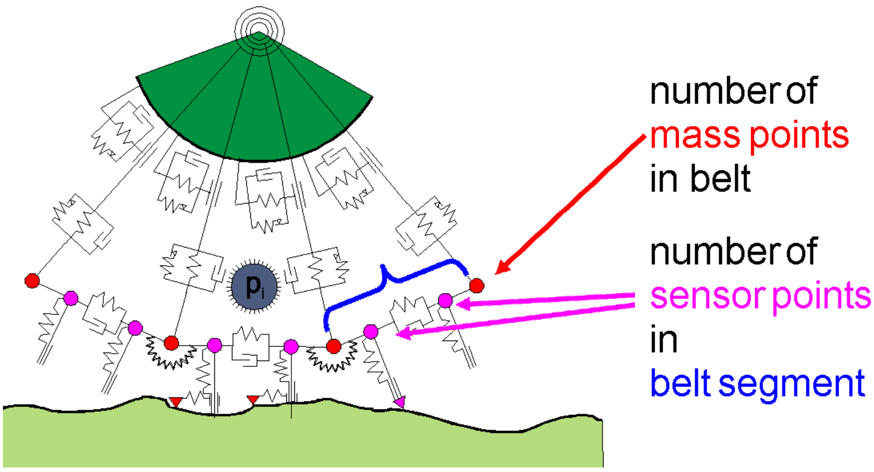
**Remark**: You may edit some parameters to suit your requirements. These parameters are colored blue in the listing above and an according remark is given in the following table. The parameters colored in orange are optional and (if used) change model behavior or introduce new functionality.

The parameters are keyword based and reside in respective sections. These 2 mandatory sections are:

- [CDT30-HPS MODEL PARAMETERS]
  contains all geometric, discretization, material and other physical modelling parameters

- [CDT30-HPS SOLVER PARAMETERS]
  contains all numerical parameters of the internal integrator

All parameters of both sections are explained in the following table.

| Name | Explanation | Default | Unit |
|---|---|---|---|
| | CDT30-HPS MODEL PARAMETERS | | |
| NMP | Number of mass points in belt<br>you may need to edit this value: the distance between two mass points (2 pi RGRT/NMP) must be around half of the fundamental wavelength of the surface, e.g. for a 20x20mm obstacle, this is 20 mm. | 100 | - |
| TREAD_NSEN_X | Number of sensor points in belt segment (Optional: NSEN)<br><br>number of mass points in belt<br>number of sensor points in belt segment<br>you may edit this value to account for the higher wavelengths of the surface | 5 | - |

| Name | Explanation | Default | Unit |
|---|---|---|---|
| R_RIM | Radius of the rim<br>(Alternative name: RFEL) | 203 | mm |
| R_BELT | Radius of the belt (inflated)<br>(Alternative name: RGRT) | 307 | mm |
| W_BELT | Effective width of the belt<br>(Alternative name: BGRT) | 190 | mm |
| MASS_BELT | Mass of belt and tread<br>(Alternative name: MGRT) | 5.0E-3 | t |
| CIRC_STIFF | Tensile stiffness of belt in circumferential direction<br>(Alternative name: EF) | 1.0E6 | N |
| CIRC_DAMP | Damping factor of EF<br>(CDT30: hard-coded 1.0E-6)<br>(Alternative name: D_TAN) | 1.0E-6 | - |
| Y_BENDING_STIFF | Bending stiffness of the belt (around y-axis)<br>(Alternative name: EIY) | 3.0E6 | $Nmm^2$ |
| Y_BENDING_DAMP | Damping factor of EIY<br>(CDT30: hard-coded 1.0E-5)<br>(Alternative name: D_ALPHA) | 1.0E-5 | - |
| FTX | Natural frequency: Translation in x/z direction (mode $R_1$) | 75 | Hz |
| FTY | Natural frequency: Translation in y direction (mode $L_0$) | 38 | Hz |
| FRY | Natural frequency: rotation around y axis (mode $C_0$) | 60 | Hz |
| DTX | Damping coefficient of mode $R_1$ | 0.08 | - |
| DTY | Damping coefficient of mode $L_0$ | 0.08 | - |
| DRY | Damping coefficient of mode $C_0$ | 0.08 | - |
| RAD_NL_MOD | Stiffness influence factor radial<br>(Alternative name: KARED) | 0.3 | - |
| KSRED | Stiffness influence factor lateral | -70 | - |
| PNEUMATIC_ TRAIL_SCALE | Scaling of the pneumatic trail | 1.0 | - |
| CRY_RED_ | Activates reduction of circumferential | 0 | - |

| Name | Explanation | Default | Unit |
|---|---|---|---|
| FLAG | stiffness CRY for big deflections | | |
| CRY_RED_ DEF | Deflection value at which reduction of stiffness CRY starts | 100 | mm |
| CRY_RED_ RES | Residual stiffness factor of stiffness CRY at full deflection | 1 | - |
| PIN | Actual inflation pressure (may be overruled by interface mechanism) | 2.1E-1 | MPa |
| PREF | Reference inflation pressure (optional, only active if PIN_FLAG=1) | 2.1E-1 | MPa |
| PIN_FLAG | Activates modification of natural frequencies difference of PIN to PREF (optional, needs PREF also) | 0 | - |
| TREAD_EG | Young's modulus of the tread rubber times tread width per circumferential unit length (Alternative name: EG) | 120 | N/mm^2 |
| TREAD_KM | Shear stiffness reduction coefficient (Alternative name: KM) | 0.9 | 1 |
| TREAD_HEIGHT | Height of tread (Alternative name: HL) | 10.0 | mm |
| TREAD_GG | Shear modulus of the tread rubber times tread width per circumferential unit length (Alternative name: BL) | 40.0 | N/mm^2 |
| TREAD_SCAN _HEIGHT | Height in mm above surface where contact sensors are active | 150.0 | mm |
| TREAD_MAX _COMPRESS | Maximum compression of tread before warning is issued | 0.95 | - |
| TREAD_RAD_D | Damping factor of EG<br>(CDT30: hard-coded 5.0E-4)<br>(Alternative name: D_RAD_TREAD) | 5.0E-4 | - |
| MU | Relative friction coefficient<br>e.g. [1.0, 1.0, 1.0]<br>(Alternative name: MGLT) | table | - |
| V_MU | Sliding velocity<br>e.g. [0.0, 1000, 10000]<br>(Alternative name: VGLT) | table | mm/s |
| LDE_FLAG | Activates LDE (Large Deformation Element) calculation for tire ground out (bottoming) | 0 | - |
| LDE_CNL | Radial stiffness of non-linear part per | 30 | N/mm^2 |

| Name | Explanation | Default | Unit |
|---|---|---|---|
| | circumferential unit length | | |
| LDE_CLIN | Radial stiffness of linear part per circumferential unit length | 150 | N/mm^2 |
| LDE_RNL | Radius from rim at which non-linear part becomes active (must be > LDE_RLIN) | 20 | mm |
| LDE_RLIN | Radius from rim at which linear part becomes active | 10 | mm |
| R_STAT | Unloaded static radius | 317 | mm |
| CR1_STAT | Linear vertical stiffness | 200 | N/mm |

CDT30-HPS SOLVER PARAMETERS

| | | | |
|---|---|---|---|
| TOL | Error tolerance of internal integrator | 1.0E-3 | - |
| DTM | Maximum step size of internal integrator | 2.0E-4 | s |
| DT_START _EXPL | Initial step size of internal explicit integrator | 2.0E-5 | s |
| NMAX_IMPL _ITER | Maximum number of iteration for the implicit integrator | 4 | - |
| PRE_STEP _TIME | Duration of pre-step in beginning of simulation (inflation, deflection) | 0.05 | s |
| TYPE | Explicit 1, Implicit 2 | 2 | - |
| ALPHA _EXPLICIT | Explicit Newmark alpha integrator value | 0 | - |
| BETA _EXPLICIT | Explicit Newmark beta integrator value | 0.166667 | - |
| GAMMA _EXPLICIT | Explicit Newmark gamma integrator value | 0.5 | - |
| ALPHA _IMPLICIT | Implicit Newmark alpha integrator value | 0 | - |

| Name | Explanation | Default | Unit |
|---|---|---|---|
| BETA _IMPLICIT | Implicit Newmark beta integrator value | 0.25 | - |
| GAMMA _IMPLICIT | Implicit Newmark gamma integrator value | 0.5 | - |
| UPDATE_FOR _MASTERCORRE CTOR | Toggle corrector iterations to be taken into account (0 off, 1 on) | 0 | - |
| IMPL_STEP _CTRL _ENABLE | Toggle internal step size control of implicit integrator (0 off, 1 on) | 1 | - |
| IMPL_STEP _CTRL_EPS | Percentage of error tolerance TOL used to activate step size control | 200 | - |
| IMPL_STEP_CTRL_N SUBSTEPS | Subdivion of steps if step size reduction is activated for implicit integrator | 3 | - |
| IMPL_JAC _EVAL_AT _ITER | Toggle update of jacobian calculation during iteration (0 off, 1 on) for implicit integrator | 0 | - |

# Tire Parameter File for CDTire/3D

The following listing shows the input file for a tire with the dimension 245/40 R 18 as used in the tire model *CDTire/3D*:

```
[CDT50-N MODEL PARAMETERS]

###Discretization parameters
PIN=0.27
NCS=50
NR=16
NRSW=4
NRSENSTART=4


###Sidewall modeling: = 40 --> CDT40-Sidewall
SW_MODE=50

###Cross Section discretization
CONTOUR_SHELL_Y = [-111.2,-112.35,-115,-120.6,-109.2,-78.9,
      -46.3,-13.2,13.2,46.3,78.9,109.2,120.6,115,112.35,111.2]
CONTOUR_SHELL_Z =
[248.1,262.45,278.25,292.2,304.4,306.1,306.2,
      306.8,306.8,306.2,306.1,304.4,292.2,278.25,262.45,248.1]


###Mass parameters
MASS_SIDEWALL=0.003
MASS_BELT=0.006
MASS_BEAD=0.001
MASS_W=[1.5,1,0.5,0.5,0.8,1,1,1,1,1,1,0.8,0.5,0.5,1,1.5]


###Rubber base material parameters
RUBBER_CIRC_EH=40
RUBBER_LAT_EH=40
RUBBER_SHEAR_GH=0
RUBBER_DIAG_EH=25
RUBBER_CIRC_DAMP = 0.0003
RUBBER_LAT_DAMP = 0.0003
RUBBER_DIAG_DAMP = 0.0007
RUBBER_SHEAR_DAMP = 1e-005
RUBBER_CIRC_EH_W = [3,2,0.8,0.8,1,1,1,1,1,1,1,1,0.8,0.8,2,3]
RUBBER_LAT_EH_W = [2.5,2,0.5,0.8,1,1,1,1,1,1,1,0.8,0.5,2,2.5]
RUBBER_SHEAR_EH_W = [3,2,1,0.5,1,1,1,1,1,1,1,1,0.5,1,2,3]
RUBBER_DIAG_EH_W = [3,2,0.8,0.8,1,1,1,1,1.1,1,1,0.8,0.8,2,3]
```

```
###Carcess (radial) parameters
CARCASS_CORDLAYER_STIFF = 900
CARCASS_CORDLAYER_DAMP = 1e-005
CARCASS_CORDLAYER_STIFF_W = [1,1,1,1,1,1,1,1,1,1,1,1,1,1,1]
CARCASS_CORDLAYER_L0_REDFACTOR = 0.98

###Bandage (circumferential) parameters
BANDAGE_CORDLAYER_STIFF = 400
BANDAGE_CORDLAYER_DAMP = 1e-005
BANDAGE_CORDLAYER_STIFF_W = [0,0,0,0,1,1,1,1,1,1,1,1,0,0,0,0]
BANDAGE_CORDLAYER_L0_REDFACTOR =
[1,1,1,1,1,1,0.94,0.94,0.94,0.94,1,1,1,1,1,1]


###Steel belt parameters
NUMB_STEEL_CORDLAYERS = 2
STEEL_CORDLAYER_ANGLE = [24,-24]
STEEL_CORDLAYER_STIFF = [2000,2000]
STEEL_CORDLAYER_DAMP = [1e-005,1e-005]
STEEL_CORDLAYER_L0_REDFACTOR = [1,1]
STEEL_CORDLAYER_STIFF_COMPRESSION_FACTOR = 0.0
NUMB_DISCRETE_STRIPES_IN_STEEL_CORDLAYER=2

###Bending parameters
X_BENDING_STIFF=500
X_BENDING_DAMP=0.0001
X_BENDING_STIFF_W=[2,0.5,0.4,0.8,1,1,1,1,1,1,1,1,0.8,0.4,0.5,2
]
X_BENDING_ALPHANL=0
X_BENDING_EXPNL=1

Y_BENDING_STIFF = 5000
Y_BENDING_DAMP = 0.0001
Y_BENDING_STIFF_W =
      [0.5,0.3,0.125,0.2,0.5,1,1,1,1,1,0.5,0.2,0.125,0.3,0.5]
Y_BENDING_ALPHANL=0
Y_BENDING_EXPNL=1

XY_DIAG_BENDING_STIFF = 1000
XY_DIAG_BENDING_DAMP = 0.0001
XY_DIAG_BENDING_STIFF_W = [1,1,1,1,1,1,1,1,1,1,1,1,1,1,1]
XY_DIAG_BENDING_ALPHANL=0
XY_DIAG_BENDING_EXPNL=1


###Tread parameters
TREAD_NSEN_X=5
```

```
TREAD_NSEN_Y=3
TREAD_HEIGHT=[5,8,10,10,10,10,10,10,8,5]
TREAD_SCAN_HEIGHT=150
TREAD_MAX_COMPRESS=0.95
TREAD_RAD_D=0.0005
TREAD_RAD_D_DEGRESSION_FACTOR=1
TREAD_RAD_D_DEGRESSION_VEL=0
TREAD_CSG=0
TREAD_CSMUE=0
TREAD_E/H=0.26
TREAD_Gx/H=0.1
TREAD_Gy/H=0.1


###Friction parameters (velocity dependent)
MU=[1.05,1.05,0.9]
##MGLT=[1.05,1.05,0.9]
V_MU=[0,1000,10000]
##VGLT=[0,1000,10000]

###Optional parameters LOSSENERGY_FLAG and THERMAL_MODEL_FLAG
LOSSENERGY_FLAG=0
THERMAL_MODEL_FLAG=0

###Large Deformation Extension parameters
LDE_FLAG=0
LDE_Y_COORD=[-140,-120,-100,-80,80,100,120,140]
LDE_W=[0,1,1,0,0,1,1,0]
LDE_CNL=0.3
LDE_CLIN=3
LDE_RNL=12
LDE_RLIN=5
LDE_SCAN_RADIUS=20
LDE_ACTIVE_RADIUS=5

###Effective rolling radius used for postprocessing
R_EFF=320
R_STAT=320

###Global linear radial tire stiffness used for static (if not
available set to 250.0)
CR1_STAT=250


[CDT40-N MODEL PARAMETERS]

PREF = 0.27
PIN_FLAG = 0
```

```
FTX = 76.0
FTY = 41.0
FRY = 80.0
DTX = 0.08
DTY = 0.08
DRY = 0.08
SWBEND = 40.0
CRY_RED_DEF=20
CRY_RED_RES=0

[CDT50-N SOLVER PARAMETERS]

TOL = 1.001E-3
DTM = 5.001E-5
DT_START_EXPL = 2e-005
PRE_STEP_TIME = 0.05
TYPE = 1
ALPHA_EXPLICIT = 0
BETA_EXPLICIT =  0.16666666666667
GAMMA_EXPLICIT = 0.5
UPDATE_FOR_MASTERCORRECTOR = 0
```

---

**Remark**: You may edit some parameters to suit your requirements. These parameters are colored blue in the listing above and an according remark is given in the following table. The parameters colored in orange are optional and (if used) change model behavior or introduce new functionality.

---

The parameters are keyword based and reside in respective sections. These 2 mandatory sections are:

- [CDT50-N MODEL PARAMETERS]
  contains all geometric, discretization, material and other physical modelling parameters (except SW_MODE=40 parameters)
- [CDT50-N SOLVER PARAMETERS]
  contains all numerical parameters of the internal integrator

and 3 optional section:

- [CDT40-N MODEL PARAMETERS]
  contains all SW_MODE = 40 parameters for analytical sidewall model
- [TIRE_AND_RIM_RESIZING]
  contains reference and target tire and rim specification for automatic resizing
- [CDT50-N ADVANCED OUTPUT PARAMETERS]
  contains advanced output options for post processing via CDTireViewer

The parameters may contain one dimensional arrays. One has to be careful about the lengths of these arrays. There are 3 types of entities utilizing arrays:

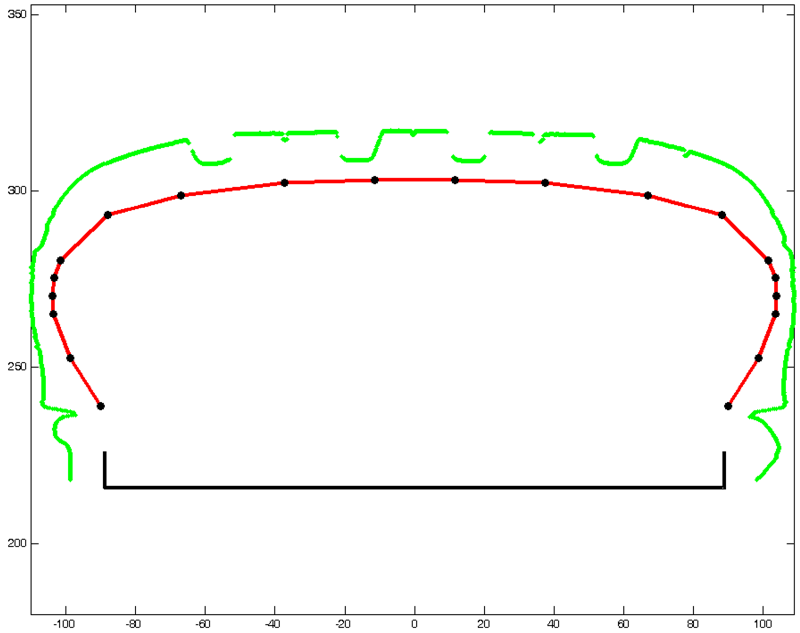
- ring entities (table length is NR)
- segment entities (table length is NR-1)
- contact entities (table length NR-2*(NRSENSTART-1)).

If NRSENSTART is not set, it defaults to NRSW+1.

Ring entities are all entities that are associated with mass, geometry or circumferential properties, e.g. MASS_W, CONTOUR_SHELL_Y or RUBBER_CIRC_EH_W. Segment entities are all entities associated with lateral or diagonal properties, e.g. RUBBER_LAT_EH_W or RUBBER_DIAG_EH_W.

Additionally, many entities consist of a material property and an associated weight, e.g. X_BENDING_STIFF and X_BENDING_STIFF_W. The local property then is a multiplication of the material property with its associated weight. In that way, it is possible to easily modify one local property or all properties simultaneously.

| **Name** | **Explanation** | **Default** | **Unit** |
|---|---|---|---|
| | CDT50-N MODEL PARAMETERS | | |
| PIN | Actual inflation pressure (maybe overruled by interface mechanism) | 0.27 | MPa |
| NCS | Number of cross sections | 50 | - |
| NR | Number of rings | 16 | - |
| NRSW | Number of rings in either sidewall (including bead node) | 4 | - |
| NRSENSTART | Index of ring from where contact calculation starts | NRSW+1 | - |
| SW_MODE | Materialized sidewall (50) or analytical sidewall (40) | 50 | - |
| CONTOUR_SHELL_Y | Lateral cross section coordinate of non-inflated configuration | Table | mm |
| CONTOUR_SHELL_Z | Radial cross section coordinate of non-inflated configuration | Table | mm |

| Name | Explanation | Default | Unit |
|---|---|---|---|
| |  | | |
| MASS_ SIDEWALL | Mass of one sidewall | 0.003 | t |
| MASS_BELT | Mass of belt | 0.006 | t |
| MASS_BEAD | Mass of one bead | 0.001 | t |
| MASS_W | Weighting factors of mass distribution (table of length NR) | table | - |
| RUBBER _CIRC_EH | Rubber stiffness in circumferential direction (think Young E * thickness H) | 40 | N/mm |
| RUBBER _LAT_EH | Rubber stiffness in lateral direction (think Young E * thickness H) | 40 | N/mm |
| RUBBER _DIAG_EH | Rubber stiffness in diagonal direction (think Young E * thickness H) | 25 | N/mm |
| RUBBER _SHEAR_GH | Remaining rubber shear stiffness (think Shearmodulus G * thickness H) | 0 | N/mm |
| RUBBER _XXX_DAMP | Corresponding (CIRC, LAT,DIAG, SHEAR) damping factors | 0.0003 0.0007 | - |
| RUBBER _XXX_W | Corresponding (CIRC, LAT,DIAG, SHEAR) weighting factors | table | - |
| NUMB_STEEL _CORDLAYERS | Number of steel cord layers | 2 | - |
| STEEL_CORD LAYER_ANGLE | Angle of steel cord layers against circumferential direction | table | deg |
| STEEL_CORD LAYER_STIFF | Cordlayer stiffness in cord angle direction (think Young E * thickness H) | table | N/mm |

| Name | Explanation | Default | Unit |
|---|---|---|---|
| STEEL_CORD LAYER_DAMP | Cordlayer damping factor in cord angle direction | table | - |
| STEEL_CORDLAYER_STIFF_COMPRESSION_FACTOR | Cordlayer stiffness factor under compression condition | 0 | - |
| STEEL_CORDLAYER_L0_REDFACTOR | Cordlayer zero length factor relative to reference configuration | table | - |
| NUMB_DISCRETE_STRIPES_IN_STEEL_CORDLAYER | Number of discrete stripes in steel cord layer | 2 | - |
| CARCASS_CORD LAYER_STIFF | Carcass stiffness in cord angle direction (think Young E * thickness H) | 900 | N/mm |
| CARCASS_CORD LAYER_DAMP | Carcass damping factor in cord angle direction | 1.0E-5 | - |
| CARCASS_CORD LAYER_STIFF_W | Carcass stiffness weighting factors | table | - |
| CARCASS_CORD LAYER_L0 _REDFACTOR | Carcass zero length factor relative to reference configuration | table | - |
| BANDAGE_CORD LAYER_STIFF | Bandage stiffness in cord angle direction (think Young E * thickness H) | 400 | N/mm |
| BANDAGE_CORD LAYER_DAMP | Bandage damping factor in cord angle direction | 1.0E-5 | - |
| BANDAGE_CORD LAYER_STIFF_W | Bandage stiffness weighting factors | table | - |
| BANDAGE_CORD LAYER_L0 _REDFACTOR | Bandage zero length factor relative to reference configuration | table | - |
| Y_BENDING _STIFF | Bending stiffness in circumferential direction (think Young E * thickness H^3) | 5000 | Nmm |
| Y_BENDING _DAMP | Bending damping factor in circumferential direction | 1.0E-4 | - |
| Y_BENDING _STIFF_W | Bending stiffness weighting factors in circumferential direction | table | - |
| Y_BENDING_ ALPHANL | Angle where non-linear progression starts (it ends at angle 0) | 0 | rad |
| Y_BENDING_ EXPNL | Exponent of non-linear progression ( c * (x-x0)^Y_BENDING_EXPNL) ) | 1 | - |
| X_BENDING _STIFF | Bending stiffness in lateral direction (think Young E * thickness H^3) | 500 | Nmm |

| Name | Explanation | Default | Unit |
|---|---|---|---|
| X_BENDING _DAMP | Bending damping factor in lateral direction | 1.0E-4 | - |
| X_BENDING _STIFF_W | Bending stiffness weighting factors in lateral direction | table | - |
| X_BENDING_ ALPHANL | Angle where non-linear progression starts (it ends at angle 0) | 0 | rad |
| X_BENDING_ EXPNL | Exponent of non-linear progression ( c * (x-x0)^Y_BENDING_EXPNL) ) | 1 | - |
| XY_DIAG _BENDING_STIFF | Bending stiffness in diagonal direction (think Young E * thickness H^3) | 1000 | Nmm |
| XY_DIAG _BENDING_DAMP | Bending damping factor in diagonal direction | 1.0E-4 | - |
| XY_DIAG_BENDING_STIF F_W | Bending stiffness weighting factors in diagonal direction | table | - |
| XY_BENDING_ ALPHANL | Angle where non-linear progression starts (it ends at angle 0) | 0 | rad |
| XY_BENDING_ EXPNL | Exponent of non-linear progression ( c * (x-x0)^Y_BENDING_EXPNL) ) | 1 | - |
| TREAD _NSEN_X | Number of sensors per element in circumferential direction | 5 | - |
| TREAD _NSEN_Y | Number of sensors per element in lateral direction | 3 | - |
| TREAD_HEIGHT | Height of tread | table | mm |
| TREAD_CSG | Tread shear stiffness reduction coefficient due to compression | 0 | 1 |
| TREAD_CSMUE | Friction reduction coefficient due to compression | 0 | - |
| TREAD_KM | Simultanious setting of TREAD_CSG and TREAD_CSMUE (ignored if either is also present in parameter set) | 0 | - |
| TREAD_E/H | Radial tread stiffness (think Young E / thickness H) | 0.3 | N/mm^3 |
| TREAD_Gx/H | Tread shear stiffness in circumferential direction (think Shear G / thickness H) | 0.1 | N/mm^3 |
| TREAD_Gy/H | Tread shear stiffness in lateral direction (think Shear G / thickness H) | 0.1 | N/mm^3 |
| TREAD_RAD_D | Radial tread damping factor | 5.0E-4 | - |
| TREAD_MAX _COMPRESS | Maximum compression of tread before warning is issued | 0.95 | - |

| Name | Explanation | Default | Unit |
|---|---|---|---|
| TREAD_SCAN _HEIGHT | Height in mm above surface where contact sensors are active | 150 | mm |
| MU | Relative friction coefficient e.g. [1.0, 1.0, 1.0] | table | - |
| V_MU | Sliding velocity e.g. [0.0, 1000, 10000] | table | mm/s |
| LDE_FLAG | Toggle Large Deformation Element | 0 | - |
| LDE_CNL | Radial LDE progression stiffness | 1.0E-9 | N/mm^2 |
| LDE_CLIN | Radial LDE final stiffness | 0 | N/mm^2 |
| LDE_RNL | Radial LDE progression radius | 1.0E-9 | mm |
| LDE_RLIN | Radial LDE final radius | 0 | mm |
| LDE_Y_COORD | Lateral coordinate of LDE weighting | table | mm |
| LDE_W | LDE weighting | table | - |
| LDE_SCAN_RADIUS | Enable LDE search (from rim point) | 20 | mm |
| R_EFF | Unloaded static radius | 320 | mm |
| R_STAT | Unloaded static radius | 320 | mm |
| | CDT40-N SOLVER PARAMETERS | | |
| FTX | Natural frequency: Translation in x/z direction (mode $R_1$) | 89.5 | Hz |
| FTY | Natural frequency: Translation in y direction (mode $L_0$) | 45.7 | Hz |
| FRY | Natural frequency: rotation around y axis (mode $C_0$) | 65.4 | Hz |
| SWBEND | Percent of radial stiffness due to bending | 0 | % |
| DTX | Damping coefficient mode $R_1$ | 0.05 | - |
| DTY | Damping coefficient mode $L_0$ | 0.05 | - |
| DRY | Damping coefficient mode $C_0$ | 0.05 | - |
| CRY_RED_ DEF | Deflection value at which reduction of stiffness CRY starts | 100 | mm |
| CRY_RED_ RES | Residual stiffness factor of stiffness CRY at full deflection | 1 | - |

| Name | Explanation | Default | Unit |
|---|---|---|---|
| | CDT50-N SOLVER PARAMETERS | | |
| TOL | Error tolerance of internal integrator | 1.0E-3 | - |
| DTM | Maximum step size of internal integrator | 2.0E-4 | s |
| DT_START _EXPL | Initial step size of internal explicit integrator | 2.0E-5 | s |
| PRE_STEP _TIME | Duration of pre-step in beginning of simulation | 0.05 | s |
| TYPE | Explicit 1 | 1 | - |
| ALPHA _EXPLICIT | Explicit Newmark alpha integrator value | 0 | - |
| BETA _EXPLICIT | Explicit Newmark beta integrator value | 0.166667 | - |
| GAMMA _EXPLICIT | Explicit Newmark gamma integrator value | 0.5 | - |
| UPDATE_FOR _MASTERCORRECTOR | Toggle corrector iterations to be taken into account<br>(0 off, 1 on) | 0 | - |
| | TIRE_AND_RIM_RESIZING | | |
| TIRE_REF | Reference tire specification | 205/50R16 | - |
| RIM_REF | Reference rim specification | 16x6 | - |
| TIRE_NEW | Target tire specification | 225/45R17 | - |
| RIM_NEW | Target rim specification | 17x7 | - |
| | CDT50-N ADVANCED OUTPUT PARAMETERS | | |
| T_START | Start of output simulation time | 0 | s |
| T_END | End of output simulation time | 100 | s |
| DT_OUT | Output step size | 0.01 | s |
| OUTPUT_TIRESTATES | Flag to output the tire states (0 = off, 1 = on) | 0 | - |
| OUTPUT_ ROADCONTACTFORCES | Flag to output the road contact forces (0 = off, 1 = on) | 0 | - |
| TAKE_LOGFILENAME_AS _PREFIX | Naming convention of resulting output file | - | - |

# Road Parameters

The following paragraphs show detailed examples for

- equidistant track data and
- non-equidistant track data.

Each example contains a road definition file and a figure displaying the defined road surface.

## Example for Equidistant Track Data (Data Type 2)

```
# EXAMPLE EQUIDISTANT TRACK DATA
# X0_ROAD    Y0_ROAD    Z0_ROAD    MU_ROAD
  200.0      200.0      50.0       1.0
# DATA TYPE : EQUIDISTANT TRACK DATA
  2
# NTRACKS
  2
# NDATA   X0_TRACK   Y0_TRACK   HALF_WIDTH   DX     MU_TRACK
  21      -300       -150       150          25     1.0
    0.0000
   -9.5492
  -34.5492
  -65.4508
  -90.4508
 -100.0000
  -90.4508
  -65.4508
  -34.5492
   -9.5492
    0.0000
   -9.5492
  -34.5492
  -65.4508
  -90.4508
 -100.0000
  -90.4508
  -65.4508
  -34.5492
   -9.5492
    0.0000
# NDATA   X0_TRACK   Y0_TRACK   HALF_WIDTH   DX     MU_TRACK
  4       -100       350        150          200    1.0
    50.0000
   100.0000
```

```
  100.0000
   50.0000
END
```

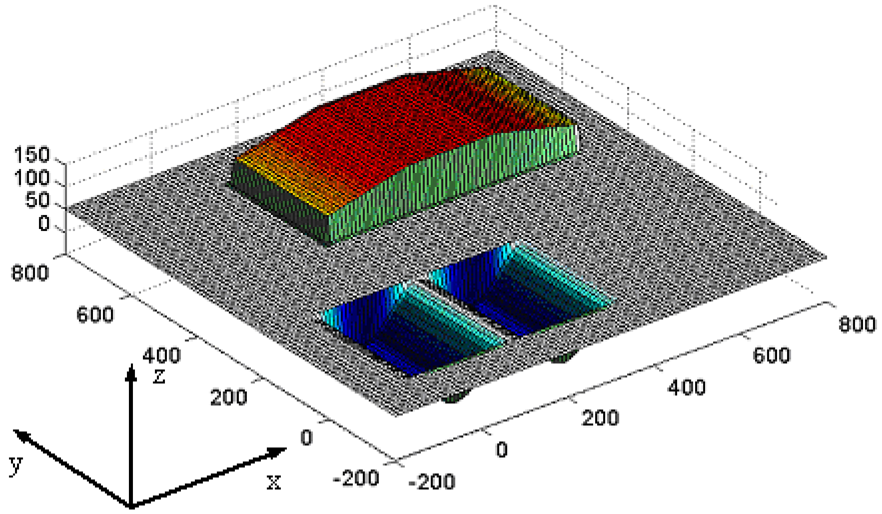



Fig. 7: Road Surface Model 1000: equidistant track

# Example for Non-Equidistant Track Data (Data Type 3)

```
# EXAMPLE NON-EQUIDISTANT TRACK DATA
# X0_ROAD    Y0_ROAD    Z0_ROAD    MU_ROAD
  200.0      200.0      50.0       1.0
# DATA TYPE : NON-EQUIDISTANT TRACK DATA
  3
# NTRACKS
  1
# NDATA   X0_TRACK   Y0_TRACK   HALF_WIDTH   MU_TRACK
  24      -300        100       400       1.0
     0.0000    0.0000
    25.0000   -9.5492
    50.0000  -34.5492
    75.0000  -65.4508
   100.0000  -90.4508
   125.0000 -100.0000
   225.0000 -100.0000
   250.0000  -90.4508
   275.0000  -65.4508
   300.0000  -34.5492
   325.0000   -9.5492
   350.0000    0.0000
   450.0000    0.0000
```

```
   475.0000    9.5492
   500.0000   34.5492
   525.0000   65.4508
   550.0000   90.4508
   575.0000  100.0000
   675.0000  100.0000
   700.0000   90.4508
   725.0000   65.4508
   750.0000   34.5492
   775.0000    9.5492
   800.0000    0.0000
END
```

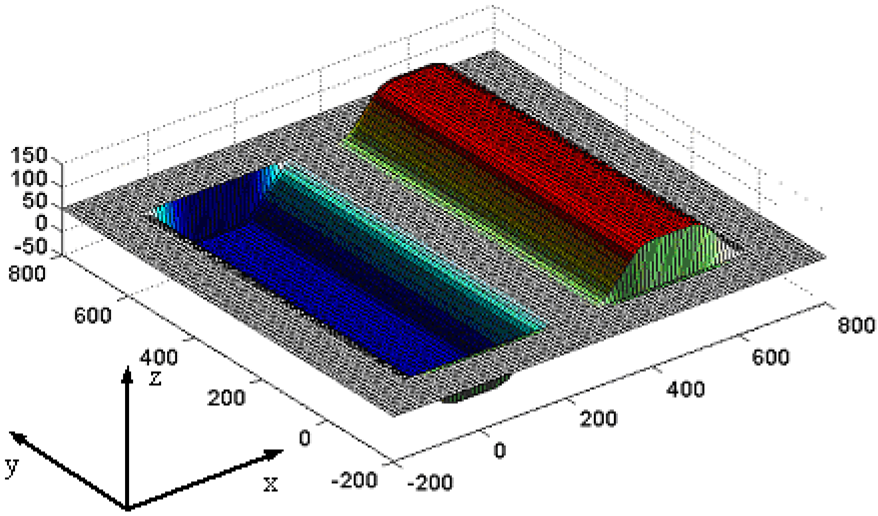



Fig. 8: Road Surface Model 1000: non-equidistant track

# Warnings and Errors

For errors and warnings, please see the CDTire log files and/or the log files of the respective MBS solver run.