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FTire Parameterization

Proposed Measurement and Data Processing Procedures for Use with *FTire/fit*

1 Preface

Parameterization of **FTire**, as for all comparable physically based tire models, is not easy and clearly needs some experience.

On the other hand, **FTire** is able to pre-process different kinds of data in a very flexible and user-friendly way. By this, the parameterization process can be adapted, to the kind of measurements that are available, or that can be acquired at an affordable costs.

Three cosin tools are available to assist with parameterization:

- *FTire/fit* identifies most of **FTire's** parameters on basis of static and steady-state measurements, as well as dynamic cleat tests and tire footprints. The measurements that are proposed in the next chapter are meant to be processed by **FTire/fit**;
- *FTire/calc* calculates most of the tire structural parameters used by **FTire**, on basis of tire design data that is typically used for an FE model. **FTire/calc** is understood to be an **FTire/fit** extension, and available from within **FTire/fit**;
- *FTire/estim* estimates **FTire** parameters by comparing its dimension with a similar, well known reference tire, and applying customizable arithmetic estimation formulae. **FTire/estim** is contained in both **FTire/fit** and **cosin/tools**.

For more information on how to get and apply these tools, please contact info@cosin.eu, or visit cosin.eu.

2 Standardized Measurement Procedure

This proposal is primarily meant for passenger car tires. For other types of tires, the measuring conditions have to be adapted accordingly.

The standardized TYDEX file format is strongly recommended for measurement ids 8 and 11..24. All measurement files should contain a time channel, camber angle, slip angle, wheel slip, rolling speed (drum or flat-track surface velocity if applicable), and all force and moment components in one of the TYDEX coordinate systems. We recommend the TYDEX C system. The files should strictly adhere to the standardized TYDEX format. If applicable, the signals can be specified by constants rather than measurement channels.

Data resulting from the procedure should be processed with the aid of **FTire/fit**. Measurement ids 8 and 10..24 are to be repeated for two different inflation pressure values, if a variation of inflation pressure is intended during the model application.

All proposed measurements are designed to be potentially replaced by simulation results from an advanced FE model, compare next chapter.

The term 'LI load' refers to the maximum admissible vertical load of the tire as specified in the respective ETRTO table, at medium inflation pressure (which is 2.5 bar = 36 psi for passenger car tires).

Data / Measurement Term example(s) of respective file name or data item	**Description**	**Measurement Procedure**	**Result Data / additional .tdx channels**
1 DIMENSION 205/55R16 91V 6.5J	tire and rim dimension (ECE-R 30 and ETRTO), including load index, speed symbol, and rim width		string
2 MANUFACTURER Continental SportContact 6	manufacturer and brand		string
3 PRESSURE 2.4 bar	inflation pressure(s) (nominal (first) and if intended max. possible) applied during measurements		single value(s)
4 MASS 9.6 kg	tire mass without rim		single value [kg]
5 OUTER_CONTOUR	tire's cross section outer contour in inflated but unloaded condition, for first inflation pressure		x/y data pairs (distance less than 10 mm) or drawing to be digitized
6 TREAD_DEPTH	local tread depth vs. lateral belt co-ordinate		x/y data pairs (distance less than 10 mm) or drawing to be digitized, as well as the tread base height
7 RMAX rmax.tdx	maximum radius	measure circumference (and divide by 2*pi for radius or by pi for diameter) of the tire at the following percentages of the nominal (first) inflation pressure: 0, 25, 50, 75, 100, 125, 150 %	.tdx-file with channels INFLPRES (inflation pressure) and OVALLDIA (overall diameter)
8 RDYN rdyn_2p4_3fz0.tdx	dynamic rolling radius/circumference, rolling resistance, ply-steer/conicity	wheel free rolling on/in drum or flat-track at half LI load with v = 3 km/h (or less) .. 100 km/h (slowly accelerated), zero camber, wheel neither driven nor braked	.tdx-file. Extra channels: drum or flat-trac surface speed, wheel angular speed
9 SHORE_A	Shore A stiffness (or Young's modulus); only required if measurement id 21 (traction) is not available	standard Shore test	single value; [Shore A] or [MPa]
10 FOOTPRINT fp_2p4_50li_0cam.bmp	footprint	gray-scale footprint at: half LI load, zero camber LI load, zero camber, half LI load, 6 deg camber, LI load, 6 deg camber	4 bitmap files.
11 CVERT cvert_2p4.tdx cvert_bottoming_2p4.tdx	vertical stiffness on flat surface	release brake. Slowly move tire downward against a flat surface. Find first contact = zero deflection	.tdx-file

Data / Measurement Term example(s) of respective file name or data item	**Description**	**Measurement Procedure**	**Result Data / additional .tdx channels**
12 CVERT_CLEAT cvert_cleat_2p4.tdx	vertical stiffness on a transversal cleat.	release brake. Slowly move tire downward against the cleat. Find first contact = zero deflection	.tdx-file
13 CVERT_OBLI_CLEAT cvert_cleat_b_2p4.tdx	vertical stiffness on an oblique cleat (45°)	release brake. Slowly move tire downward against the cleat. Find first contact = zero deflection	.tdx-file
14 CVERT_LONG_CLEAT cvert_cleat_2p4.tdx	vertical stiffness on a longitudinal cleat	release brake. Slowly move tire downward against the cleat. Find first contact = zero deflection	.tdx-file
15 CVERT_CAMBER cvert_2p4_p6cam.tdx	vertical stiffness on flat surface 6 deg camber angle	release brake. Slowly move cambered tire downward (z-axis in TYDEX W) against a flat surface. Find first contact = zero deflection	.tdx-file
16 CVERT_CLEAT_CAMBER cvert_cleat_2p4_p6cam.tdx	vertical stiffness on a transversal cleat. 6 deg camber angle	release brake. Slowly move cambered tire downward against the cleat. Find first contact = zero deflection	.tdx-file
17 CLAT clat_2p4_2fz5.tdx	lateral stiffness on flat surface	release brake. Release brake. Slowly move tire downward against a flat surface until it reaches half LI load. Slowly move tire in lateral direction (at least twice the vertical displacement)	.tdx-file, including time channel and additional channel: lateral tire displacement
18 CLONG clong_2p4_2fz5.tdx	longitudinal stiffness on flat surface	release brake. Slowly move tire downward against a flat surface until it reaches half LI load deflection. Lock brake. Slowly move tire forward (at least twice the vertical displacement)	.tdx-file, additional channel: longitudinal displacement
19 CTORS ctors_2p4_5fz0.tdx	torsional stiffness on flat surface	release brake. Slowly move tire downward against a flat surface until it reaches half LI load. Slowly turn tire at least 6 deg about vertical axis in contact patch center, at a constant rate of about 1 deg/s. Wait for about 1 s at maximum turning angle. Turn back at about -1 deg/s to respective negative amplitude. Wait about 1 s. Turn back to 0 angle	.tdx-file
20 CVERT_DYN cvert_dyn_idr_2p4.tdx cvert_dyn_idr_2p4_50v.tdx	vertical stiffness on/in drum, at 0, 50, 100 km/h drum speed	for standing (brakes released) or free rolling tire on/in drum, apply sinusoidal tire deflection (1Hz, 0..30 mm, 5 cycles)	3 .tdx-files

Data / Measurement Term example(s) of respective file name or data item	Description	Measurement Procedure	Result Data / additional .tdx channels
21 TRACTION muslip_2p4_5fz0_60v.tdx	longitudinal force characteristic	for free rolling tire on/in drum (v = 50 km/h), increase brake torque until wheel is completely locked (1-2sec). Camber angle 0 deg, 50% and 100% LI load	2 .tdx-files
22 HANDLING side_2p4_5fz0_60v.tdx	side force characteristics	for free rolling tire on/in drum (v = 50 km/h), slowly sweep slip angle between +/-12 deg. Camber angle 0 and 6 deg, 50% and 100% LI load	4 .tdx-files
23 CLEAT cleat_a_3fz0_30v_2p4.tdx cleat_a_6cam_3fz0_30v_2p4.tdx	rolling on/in drum over a transversal cleat, at 30, 60, 90 (if possible) km/h drum speed	for free rolling tire on/in drum, run over cleat, at half and full LI wheel load. Make sure at least 10 ms are recorded from start of measurement to fist cleat contact	6 .tdx-files
24 CLEAT_OBLIQUE cleat_b_3fz0_30v_2p4.tdx	rolling on/in drum over a 45 deg obliquely oriented cleat, at 30, 60, 90 (if possible) km/h drum speed.	for free rolling tire on/in drum, run over cleat, at half and full LI wheel load. Make sure at least 10 ms are recorded from start of measurement to fist cleat contact	6 .tdx-files

These measurements have to reflect the physical behavior of the tire and are used to identify parameters of the physical tire model **FTire**. For all tests where friction takes place: Identical ground surfaces (friction behavior) should be provided. If not, differences have to be reported and taken into account.

Tests on a drum can be done on a flat-trac as well. The drum curvature (0 in case of flat-trac) has to be included in the .tdx file.

Please note: even if only single measurements differ too much from the physical tire behavior (because of mis-calibration or unknown test rig compliance, say), it might be impossible to get a consistent set of physical parameters. Obviously, in case of large differences between measurement and true physical properties (such as tire mass, say), the identification process might not come to a satisfying end.

3 Modified Measurement Procedure Combined with FE Analyses

If a validated FE model of the tire is available, some or all measurements can be replaced or completed by certain FE load case results. Depending on the capabilities of the FE model, a wide range of procedures can be thought of, beginning by merely replacing some of the statics measurements, and ending with a fully FE-based parameterization, completely omitting all test-rig measurements.

In this documentation, as an example, a procedure is described which combines FE geometry, FE modal analysis, and static FE load cases (providing more detailed results than respective measurements on a test-rig typically do) with rolling dynamics measurements on test-rigs.

3.1 FE Analyses

Compute and provide results of several analyses according to the following specification:

3.1.1 Surface Geometry of Inflated but Unloaded Tire

Data Term example(s) of respective file name	**Description**	**Load Case Details**	**Result Data**
31 GEOM_FE geom_fe_2p4_2td0.fer	location of sufficiently many and well-distributed nodes on the tire surface, covering both tread and sidewalls, as used in load cases described below. This analysis type replaces type 5 (OUTER_CONTOUR)	zero load, zero camber angle, zero toe angle, both with (a) original and (b) reduced tread depth as set in load cases below, at inflation pressure(s) as specified in 3	.fer-files as specified below

Geometry result file: ASCII file (detailed file format is specified below), containing

- rim center global coordinates x,y,z [m]
- inflation pressure [bar]
- tread depth [mm]
- one line for every node, containing global coordinates of nodes in inflated but unloaded tire state: x,y,z [m].

3.1.2 Eigenfrequencies and Mode Shapes of Unloaded and Loaded Tire

Perform modal analysis of unloaded and loaded tire with **zero damping**, in case of loaded tire on flat surface:

Data Term example(s) of respective file name	**Description**	**Load Case Details**	**Result Data**
32 MODE_FE mode_fe_84Hz6_2p4_2td.fer	mode shape amplitudes (spatial displacements) of nodes as specified in 31	vertical displacement 20% sidewall height; zero camber angle; tread depth 2 mm or less; inflation pressure(s) as specified in 3	.fer-files as specified below

Modal result file: one ASCII file per eigenfrequency (covering at least the first 6 ones, both in unloaded and loaded condition; detailed file format is specified below), containing

- rim center global coordinates x,y,z [m]
- Fz [N]
- tread depth [mm]
- eigenfrequency [Hz]
- one line for every node, containing global coordinates of nodes in undeformed tire state and displacement of the nodes in the mode's deformed tire state: x0,y0,z0,dx,dy,dz [m].

3.1.3 Surface Distortion under Static Load on Different Surface Geometries

Solve statics load cases:

Data Term example(s) of respective file name	**Description**	**Load Case Details**	**Result Data**

Data Term example(s) of respective file name	Description	Load Case Details	Result Data
33 CVERT_FE cvert_fe_20defl_2p4_2td0.fer	tire surface distortion and wheel load at medium and high vertical load on flat surface at zero camber angle	tread depth 2 mm or less; camber angle 0 deg; wheel center above flat surface such that tire deflection is 20% and 40% of sidewall height; road contact by unilateral contact elements between tread nodes and road surface; road surface friction coefficient set to 0; inflation pressure(s) as specified in 3	.fer-file as specified below
34 CVERT_CLEAT_FE cvert_fe_20defl_2p4_2td0.fer	tire surface distortion and wheel load at medium and high vertical load on transversal cleat at zero camber angle	tread depth 2 mm or less; camber angle 0 deg; wheel center above transversal cleat (height 20mm) such that tire deflection is 20% and 40% of sidewall height; road contact by unilateral contact elements between tread nodes and cleat/road surface; cleat/road surface friction coefficient set to 0; inflation pressure(s) as specified in 3	.fer-file as specified below
35 CVERT_LONG_CLEAT_FE cvert_fe_20defl_2p4_2td0.fer	tire surface distortion and wheel load at medium and high vertical load on longitudinal cleat at zero camber angle	tread depth 2 mm or less; camber angle 0 deg; wheel center above longitudinal cleat (height 20mm) such that tire deflection is 20% and 40% of sidewall height; road contact by unilateral contact elements between tread nodes and cleat/road surface; cleat/road surface friction coefficient set to 0; inflation pressure(s) as specified in 3	.fer-file as specified below
36 CVERT_CAMBER_FE cvert_fe_20defl_6cam0_2p4_2td0.fer	tire surface distortion and wheel load at medium and high vertical load on flat surface at 6 deg camber angle	tread depth 2 mm or less; camber angle 6 deg; wheel center above flat surface such that tire deflection is 20% and 40% of sidewall height; road contact by unilateral contact elements between tread nodes and road surface; road surface friction coefficient set to 0; inflation pressure(s) as specified in 3	.fer-file as specified below

Data Term example(s) of respective file name	Description	Load Case Details	Result Data
37 CVERT_CLEAT_CAMBER_FE cvert_fe_20defl_6cam0_2p4_2td0.fer	tire surface distortion and wheel load at medium and high vertical load on transversal cleat at 6 deg camber angle	tread depth 2 mm or less; camber angle 6 deg; wheel center above transversal cleat (height 20mm) such that tire deflection is 20% and 40% of sidewall height; road contact by unilateral contact elements between tread nodes and cleat/road surface; cleat/road surface friction coefficient set to 0; inflation pressure(s) as specified in 3	.fer-file as specified below
38 CLAT_FE clat_fe_40defl_2p4_2td0.fer	tire surface distortion at lateral displacement, high vertical load, and zero camber angle	tread depth 2 mm or less; camber angle 0 deg; wheel center above flat surface such that tire deflection is 20% and 40% of sidewall height. First, compute statics w/o any horizontal displacement, using unilateral contact elements between tread nodes and road surface. Then, fix nodes that have road contact by respective boundary conditions, and move tire by 20%/40% of sidewall height in lateral direction; inflation pressure(s) as specified in 3	.fer-file as specified below
39 CLONG_FE clong_fe_40defl_2p4_2td0.fer	tire surface distortion at longitudinal displacement, high vertical load, and zero camber angle	tread depth 2 mm or less; camber angle 0 deg; wheel center above flat surface such that tire deflection is 20% and 40% of sidewall height. First, compute statics w/o any horizontal displacement, using unilateral contact elements between tread nodes and road surface. Then, fix nodes that have road contact by respective boundary conditions, and move tire by 20%/40% of sidewall height in longitudinal direction; inflation pressure(s) as specified in 3	.fer-file as specified below

Data Term example(s) of respective file name	Description	Load Case Details	Result Data
40 CTORS_FE ctors_fe_40defl_2p4_2td0.fer	tire surface distortion at torsional displacement, high vertical load, and zero camber angle	tread depth 2 mm or less; camber angle 0 deg; wheel center above flat surface such that tire deflection is 20% and 40% of sidewall height. First, compute statics w/o any horizontal displacement, using unilateral contact elements between tread nodes and road surface. Then, fix nodes that have road contact by respective boundary conditions, and rotate tire 6 deg counter-clockwise about vertical axis; inflation pressure(s) as specified in 3	.fer-file as specified below

Statics result file: one ASCII file per load case (detailed file format is specified below), containing

- rim center coordinates x,y,z [m]
- spindle forces/moments Fx, Fy, Fz [N], Mx, My, Mz [Nm]
- camber angle [deg]
- toe angle [deg]
- tread depth [mm]
- cleat height [mm]
- cleat width [mm]
- cleat orientation [deg]; 0 deg = transversal
- one line for every node, containing global coordinates of nodes in undeformed tire state and displacement of the nodes in deformed tire state: x0,y0,z0,dx,dy,dz [m]
- one line for every node in contact with road, containing global coordinates of nodes in deformed tire state together with contact forces, expressed in global coordinates: x,y,z,Fx,Fy,Fz [m], [N].

3.2 Dynamics Measurements

Provide data/measurements **1 to 10 and 20 to 24** as specified in above table. Obviously and if feasible, test-rig measurements can always be replaced by respective FE simulations.

3.3 FER Files

FE result files (fer files) serve for result exchange between FE analyses and FTire/fit. The format used is designed both for easy creation and easy interpretation, and is open to future expansions. Intentionally, no 'rich' file format like xml was chosen, to keep the files as simple as possible, and avoid the necessity of special software to browse its content.

Any blank line or line beginning with an asterisk (*) is treated as comment line and neglected.

The first non-comment line holds one of the keywords `$geometry`, `$mode`, or `$load_case`. Subsequent non-comment lines contain, in arbitrary sequence, **variable specifications**. Every variable specification consists of a keyword (see list below), followed by one ore more numerical values, and an optional in-line comment, separated by an exclamation mark (!) from the numerical value(s). Keyword, values, and optional exclamation mark are separated from each other by at least one blank space or tab.

After specification of all variables, the next line consists of the keyword `$results`. After this keyword, one or more of the keywords as listed below may follow, each in a separate line:

- in case of type $geometry
  - nodes (or nodes_surface)
  - nodes_belt
  - nodes_carcass
  - nodes_innerliner
- in case of type $mode
  - nodes_displacements (or nodes_displacements_surface)
  - nodes_displacements_belt
  - nodes_displacements_carcass
  - nodes_displacements_innerliner
- in case of type $load_case
  - forces_moments
  - nodes_displacements (or nodes_displacements_surface)
  - nodes_displacements_belt
  - nodes_displacements_carcass
  - nodes_displacements_innerliner
  - contact_forces

After every such keyword, some lines follow, each containing a certain number of numerical values. The number and meaning of these values (nodal coordinates, hub forces, contact forces etc.) is described below.

The variable values in the **first** data-block specify operating and boundary conditions of the respective analysis. All mandatory values for the different analysis types, together with important non-mandatory values, are listed here:

Variable	Description	Unit	Mandatory for Surface Geometry	Mandatory for Modal Analysis	Mandatory for Static Load case
rim_center_position	x/y/z position of rim center in global coordinates	3 x [mm]	*	*	*
rim_orientation	rim orientation angles (camber angle, rotation angle about spin axis, toe angle)	3 x [deg]	*	*	*
radial_deflection	difference between wheel center height at first road contact and actual wheel center height	[mm]		*	*
inflation_pressure	inflation pressure	[bar]	*	*	*
tread_depth	tread depth at tire zenith	[mm]	*	*	*
cleat_height	cleat height	[mm]			*
cleat_width	cleat width	[mm]			*
cleat_angle	cleat orientation angle (0 deg for transversal cleat, 90 deg for longitudinal cleat)	[deg]			*
layer	layer nodes of which have to be used: 0 neutral belt/carcass line 1 outer surface (default) 2 inner surface	-			
sticky_surface	0 low-friction surface (do not allow horizontal shear stress in tread, default) 1 high-friction surface (allow horizontal shear stress in tread)	-			

For the **second** and **following** data blocks, meaning of the data is as described below.

Every line under one of the keywords

- nodes

- nodes_surface
- nodes_belt
- nodes_carcass
- nodes_innerliner

holds 3 numerical values, describing the location of a node on the respective layer of the unloaded tire in rim-fixed coordinates, in [mm]. Keywords `nodes` and `nodes_surface` are equivalent; both indicate nodes of the undistorted tire surface.

Every line under the keyword

- nodes_displacements
- nodes_displacements_belt
- nodes_displacements_carcass
- nodes_displacements_innerliner

holds **6** numerical values. The first 3 values describe the location of a node on the respective layer on the undistorted tire surface in rim-fixed coordinates, in [mm]. The next 3 values hold the spatial displacement of this node under loading conditions as described with values above, described in rim-fixed coordinates. Keywords `nodes_displacements` and `nodes_displacements_surface` are equivalent; both indicate nodes of the undistorted tire surface.

The (single) line under the keyword

- forces_moments

holds 6 numerical values. The first 3 values describe the tire-induced forces on the wheel hub in global coordinates, in [N], whereas the remaining 3 values are the moments on the wheel hub in global coordinates, in [Nm].

Every line under the keyword

- contact_forces

holds 6 numerical values. The first 3 values describe the point of attack, located in the footprint, of a single contact force. These points of attack are given in global coordinates, in [mm]. The next 3 values hold the respective spatial contact force, described in global coordinates, in [N]. Note that respective 'point-wise' contact moments currently are neither provided nor used. This is in contrast to the **global** contact moment, created by all contact forces together with their lever arms relative to the contact patch center.

This is an example of a fer file:

```
* Demo Tire 225/45 R 17 91V 7J

$load_case
 rim_center_position     0.000000     0.000000   289.424955           ! 3x[mm]
 rim_orientation         0.000000     0.000000     0.000000           ! 3x[deg]
 radial_deflection      26.622646                                     ! [mm]
 inflation_pressure      2.400000                                     ! [bar]
 tread_depth             0.000000                                     ! [mm]

$results
 forces_moments
    -0.000000    -0.000000  4824.871413     0.000254     0.024426    -0.004835

 nodes_displacements
   -164.623910   -82.550000  228.691988     0.000000     0.000000     0.000000
   -215.170518   -90.004420  210.750361     0.459279     0.640362     0.875439
   -252.667752  -101.437930  200.106690     2.456547     1.181784     4.802058
   -295.433385   -80.670195  187.407784    -3.668724     0.000148     5.620496
   -301.375309   -26.889964  185.355971    -5.226958     0.000150     5.185911
   -301.375363    26.890265  185.355965    -5.227012     0.000150     5.185905
   -295.433548    80.670490  187.407767    -3.668887     0.000148     5.620479
```

4 Additional Remarks

4.1 Result Data

In case of measuring forces/torques (11 ... 24), always include at least the following channels in the TYDEX file:

- time
- Fx, Fy, Fz (TYDEX C, H, or W axis system)
- Mx, My, Mz (TYDEX C, H, or W axis system)
- deflection (zero=first contact to ground or cleat)
- distance ground - wheel centre
- long slip
- slip angle
- camber angle
- velocity
- wheel rotation speed
- temperature
- tread depth

A measurement duration of 2..15sec (depending on test) should be sufficient for all steady state tests.

4.2 Filter

Use low-pass filtering adequate to kind of test (200-300Hz for cleat tests). Do not use filter orders higher than 2. High order filters might generate harmonic distortions.

4.3 Measurements 5 and 6

(refer also to ftire_model.pdf)

- outer contour: grooves and ribs need not to be resolved. Measure in inflated (nominal pressure) and unloaded condition
- local tread depth is understood to be local radial distance between (1) outermost belt layer surface + tread base height and (2) tire outer surface
- alternatively, a detailed cross-section drawing in inflated but unloaded condition can be used, which includes belt and carcass layers
- x/y data pairs should have distance not larger than about 10mm
- measuring the left side is sufficient in case of a symmetric tire
- example ASCII file for outer contour:

```
89.0   310.0 !  start at left tread border (tread_width/2), or more outside
80.0   316.0
  ..      ..
20.0   319.40
10.0   319.60
 0.0   319.65 !  tyre center
```

- example ASCII file for tread_depth:
  first row - axial distance (tire mid plane=0.0), second row - local tread depth

```
95.0   5.0
87.0   5.5
84.2   7.1
75.0   8.0
  ..    ..
20.0   8.1
10.0   8.2
 0.0   8.2
```

4.4 Measurement 10

Set of images of the the tire contact patch at various loads. All images must use a file format that supports uncompressed (eg. BMP) or a lossless image compression (eg. PNG, TIFF). Images stored using a lossy compression method (eg JPEG) will result in inaccurate results, and is thus not recommended. Measurements can be supplied as contact patch images (binary black/white images), and/or colored footprint pressure distribution images.

Contact patch (default):

- binary black/white images (or grey scale images)
- black pixels must represent actual contact with the road surface
- image files must contain a horizontal, or vertical, **red** calibration line on the outside of the footprint of known length (preferably 100 mm)
- preferable, the tire mid plane should be perpendicular to the red calibration line
- please include sufficiently large margins around footprint (at least 2 cm). The area outside the main footprint should be white; avoid single dark or black pixels

Alternatively colored footprint pressure distribution images can be used:

- colored images (or grey scale images) of the the tire contact patch pressure distribution at various loads
- colored pixels must represent local tire contact pressure with the road surface
- image files must contain a horizontal, or vertical, **black** calibration line on the outside of the footprint of known length (preferably 100 mm)
- preferable, the tire mid plane should be perpendicular to the **black** calibration line
- images must contain a color(or grey scale) color palette that corresponds to the tire contact pressure
- the four corners of the color pallet must be marked with a single black pixel(one on each corner), to enable automatic processing of the image
- the minimum and maximum values of the color pallet needs to be supplied during check-in, please see Proposed Specification of Filenames section for more information. These values will be used to interpolate the color palette
- no black pixels other than the black calibration line and the four pixels marking the color palette, are allowed in the image
- please include sufficiently large margins around footprint (at least 2 cm). The area outside the main footprint should be white; avoid single colored pixels

4.5 Measurements 11 ... 16

- let graphs start at origin (Fz=0/deflection=0). A vertical force of about 150% LI should be reached. For identifying tire-rim contact (bottoming), load can be extended beyond this point. Please take care about the maximum rim load. The vertical movement of the tire is defined along the z-axis of the W-axis system (refer to TYDEX axis systems)
- the cleat height is comparable in size to tire deflection at half LI load. If used, the type of cleat should be defined in the TYDEX file. Make sure the wheel center is placed right above the cleat center-line

4.6 Measurements 17 ... 19

- begin measurement with loaded tire, zero longitudinal deflection / lateral deflection / slip angle, and zero Fx/Fy/Mz. Just pull the tire once after vertical loading, and use this sample; the following samples would start with a pre-stress in the contact patch and falsify the result. Full sliding of the contact patch should be reached. This can be recognized if Fx/Fy/Mz does not increase anymore

4.7 Measurements 21 ... 24

- obviously, you might measure more combinations of wheel load, drum speed, camber angle etc. than specified above; but these combinations should cover the tire model's operating conditions of interest
- to keep the tire temperature and wear as low as possible, the measurement duration should be kept short. 1..2sec for traction and 10..15sec for handling is sufficient

4.8 Measurements 23 and 24

- cleat width: 20-30mm for passenger tires

- cleat height should be at least in the range of tire deflection at half rated load (whereas there is no need to use exactly this height). 10..15mm are adequate for most passenger tires
- a cleat definition file should be provided. An example (demo_cleat.clt) can be found in the private data folder which is create during installation of the cosin software
- use a sampling rate 1kHz or higher, to resolve frequencies up to at least 250Hz
- the type of cleat (A, B, ...) should be logged in the TYDEX file, using the undocumented parameter label OBSTTYPE
- since it might make a considerable difference which part of the tire has the first cleat contact (groove or block), averaging 5-10 cleat tests (with equal measurement conditions) will improve the comparability

4.9 Proposed Specification of Filenames

In order to facilitate recognition and check-in of measurements, and to reduce risk of mis-interpretation of file content, it is advised to choose the measurement file names according to the following scheme (see the FTire/fit demo project for examples):

- specification of file name prefix and extension

file name begins with	**file content**	**file type**
`clat_`	lateral stiffness test	tdx
`cleat_x_`	dynamic cleat test on cleat X (X = A,B,C,..)	tdx
`clong_`	longitudinal stiffness test	tdx
`ctors_`	torsional stiffness test	tdx
`cvert_`	static vertical stiffness test	tdx
`cvert_dyn_`	dynamic vertical stiffness test	tdx
`fp_`	footprint	png or bmp
`muslip_`	traction test	tdx
`rdyn_`	dynamic rolling radius test	tdx
`rmax_`	maximum radius test	tdx
`side_`	handling test	tdx
`geom_fe`	FE-based surface geometry	fer
`mode_fe`	FE-based modal analysis	fer
`cvert_fe`	FE-based vertical statics	fer
`clat_fe`	FE-based lateral statics	fer
`clong_fe`	FE-based longitudinal statics	fer
`ctors_fe`	FE-based torsional statics	fer

- specification of optional file name components after prefix (separated by an underscore):

file name contains(numerical values serve as example)	**measurement detail**
`_2p4_`	inflation pressure = 2.4bar
`_2fz5_`	vertical-force = 2.5kN
`_30v_`	velocity = 30kmh
`_6cam_`	camber = +6deg
`_m6cam_`	camber = -6deg
`_cleat_`	transversal, longitudinal, or oblique cleat
`_1pmax0_`	max. ground pressure = 1MPa
`_0pmin1_`	min. ground pressure = 0.1MPa