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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 main tools are available to assist with the 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.

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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_THICKNESS	tread (without cap base height) thickness vs. lateral belt co-ordinate		x/y data pairs (distance less than 10 mm) or drawing to be digitized, as well as the cap 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.Rrelease 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	.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
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

Data / Measurement Term example(s) of respective file name or data item	**Description**	**Measurement Procedure**	**Result Data / additional .tdx channels**
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	zero load, zero camber angle, zero toe angle, both with (a) original and (b) reduced tread thickness 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 thickness 2 mm; 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 thickness 2 mm; 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; 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 thickness 2 mm; 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; 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 thickness 2 mm; 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; 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 longitudinal 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% 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 thickness 2 mm; 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 longitudinal 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% 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 thickness 2 mm; 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 longitudinal 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 File Format

FE result files (fer files) serve for result exchange between FE analyses and FTire/fit. The format 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.

The first line holds one of the keywords `$geometry`, `$mode`, or `$load_case`. Subsequent 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 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 `forces_moments`, `nodes`, `nodes_displacements`, and `contact_forces` may follow, each in a separate line. After every such keyword, some lines follow, each containing the same number of numerical values (6 in case of `forces_moments`, 3 in case of `nodes`, 6 in case of `nodes_displacements`, and 6 in case of `contact_forces`). The meaning of these values (nodal coordinates or contact forces) is described above.

The variable values in the first data-block specify operating and boundary conditions of the respective analysis. Mandatory values for the different analysis types are mentioned in the sections above and in the table below:

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 × [mm]	*	*	*
`rim_orientation`	rim orientation angles (camber angle, rotation angle about spin axis, toe angle)	3 × [deg]	*	*	*
`radial_deflection`	difference between wheel center height at first road contact and actual wheel center height	[mm]		*	*
`inflation_pressure`	inflation pressure	[bar]	*	*	*
`tread_thickness`	tread thickness at tire zenith (tread base height + tread depth)	[mm]	*	*	*
`tread_depth` (instead of `tread_thickness`)	tread depth at tire zenith (tread thickness - tread base height)	[mm]	*	*	*
`cleat_height`	cleat height	[mm]			*
`cleat_width`	cleat width	[mm]			*
`cleat_orientation`	cleat orientation angle (0 deg for transversal cleat, 90 deg for longitudinal cleat)	[deg]			*

This is an example of a fer file:

```
$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_thickness         2.000000                                     ! [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
- tread thickness (not to be confused with tread depth) is understood to be radial distance between outer contour and belt layer
- 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_thickness:
  first row - axial distance (tire mid plane=0.0), second row - tread thickness

```
95.0    8.0
87.0    9.5
84.2   10.1
75.0   11.0
  ..     ..
20.0   11.1
10.0   11.2
 0.0   11.2
```

4.4 Measurement 10

- image files must contain a horizontal or vertical red line on the outside of the footprint of known length (preferably 100 mm)
- preferable, the tire mid plane should be perpendicular to the red 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 dots

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