cosin
scientific software

Gipser + Hofmann, Ingenieure, Partnerschaft

Agnes-Pockels-Bogen 1
80992 München
GERMANY

info@cosin.eu
www.cosin.eu

FTire/link

FTire Blockset for MATLAB/Simulink
Documentation and User's Guide

Contents

Preface

This documentation describes the Flexible Ring Tire Model (*FTire*) interface to MATLAB/Simulink. The interface is implemented in terms of an easy-to-use blockset. The blockset contains three alternative blocks with different variants of connection to the wheel and suspension model.

For a documentation of the *FTire* modelization, please refer to the respective chapters of the FTire Tire Model documentation.

FTire/link will run under MATLAB Release 12 or higher. At present, only the version for Windows (NT, 2000, XP, Vista) is available.

A user might wonder why not any **road attributes** or **road conditions** appear as input signals to the blocks. Reason is quite simple: the road is completely defined by the road data file (see *cosin/road* documentation), and computation of road height, friction coefficients, banking, motion etc. is completely managed inside *FTire*. You can use the same road data files as in MD ADAMS, Simpack, *cosin/mbs*, and all other software packages for which an interface to *FTire* is available.

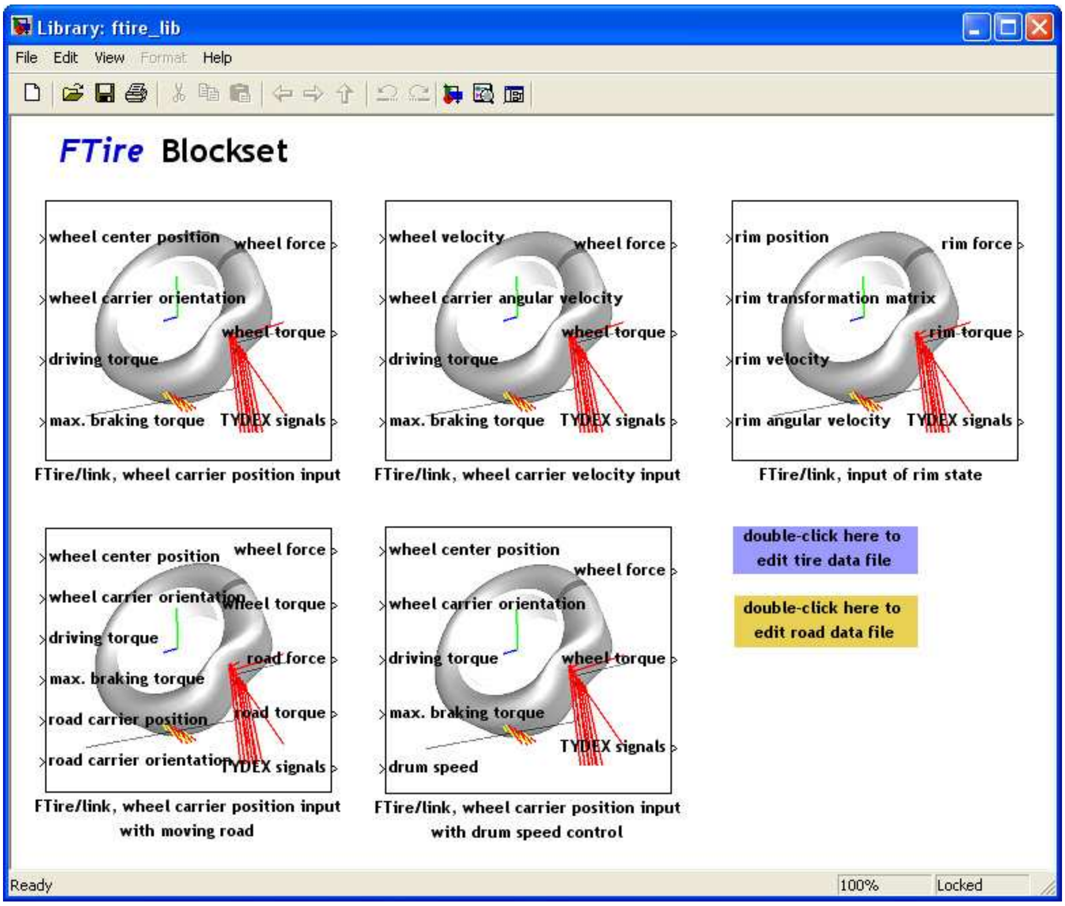

Figure 1: *FTire* Blockset

1 *FTire* Blockset

FTire/link blockset is opened with the MATLAB command `ftire_lib`, provided all files of the appropriate Matlab subfolder (the one which fits to your Matlab version) of your cosin software installation folder had been copied into a folder that belongs to the MATLAB search path. Please refer to the MATLAB documentation to learn more about its search path.

After opening, the blockset will be displayed in a separate window, as shown in figure 1. It consists of three different blocks, each of which shows the typical structure of *FTire* as a force element for MBS (multi-body dynamics) models. Input signals are certain position and/or velocity states of the wheel carrier or rim. Output signals are those forces and moments that will be generated in the tire model, and that are to be applied to the body which carries the tire.

The blocks differ in the choice of the body which is considered to carry the tire, and in the choice of either using position or velocity variables, or both, as input. Below, the three most important ones are described in detail.

1.1 Block with Wheel Carrier Position Input

The first block (used in the example model in figure 4) uses only position variables of the wheel carrier.

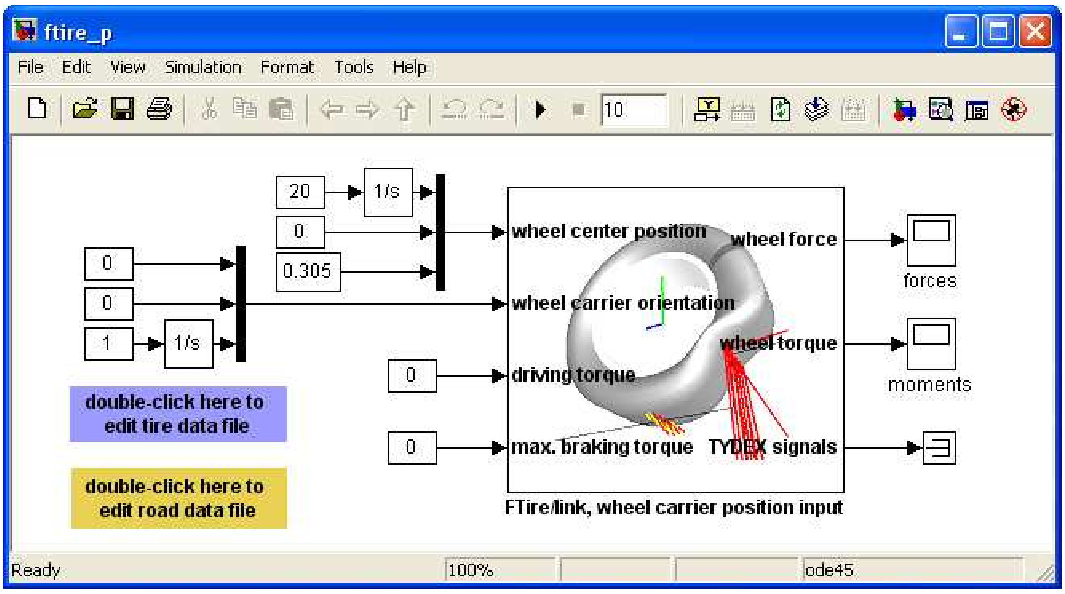

Figure 2: Simple model, using FTire block with wheel carrier position and orientation as input

The translational and angular velocity variables are determined inside the block, using numerical differentiation. Moreover, *FTire* updates rim rotation angle and angular velocity internally. To do so, it needs to know additionally driving and braking torque, coming from drive-train and brake model, respectively.

Braking torque only needs to be entered as absolute value. *FTire* will determine the correct sign automatically, to ensure the braking torque is decelerating the wheel, independent on the sense of rotation. Note that any 'reaction' torque of brake torque is not to be taken into account separately. Rather, it is contained in the vector-valued output signal 'torque', which is to be applied to the wheel carrier body.

In contrast to brake torque, driving torque will not be altered in sign. Depending on drive-train state, it may be both positive and negative, both for forward and reverse wheel rotation sense. Other than with brake torque, driving torque will react on a part which is not included in *FTire* modeling. Depending on the 'granularity' of the suspension and vehicle model, this part might be drive shaft, or differential, or gear-box, or engine, or full vehicle. It is under the responsibility of the calling model to not only apply the driving torque into *FTire*, but also to the reaction body. Note that the vector-valued sum of driving torque and driving reaction torque is to be zero.

Here are the details of the **input** signals:

- **wheel center position** (signal dimension 3, units [m]) is the position of the geometrical center of the rim, being defined by the intersection of spin axis with rim mid-plane. The position is defined in global co-ordinates
- **wheel carrier orientation** (signal dimension 3, unit [deg]) is the vector of roll, pitch, and yaw angles of wheel carrier relative to ground (not to vehicle!). These angles are defined in ISO 8855
- **driving torque** (signal dimension 1, unit [Nm]) is the scalar driving torque applied to the rim, in direction of wheel spin axis
- **max. braking torque** (signal dimension 1, unit [Nm]) is the scalar braking torque applied to the rim, in direction of wheel spin axis. The sign of this signal is not used, but rather determined internally. Moreover, when wheel is blocked it might happen that only a certain fraction of this torque is effective. This is done to prevent the wheel from being accelerated in reverse direction. Please note that this is more than just a numerical trick. Rather, it is the physically correct description of dry friction between brake pads and disc.

These are the **output** signals:

- **wheel force** (signal dimension 3, units [N]) is the vector-valued tire force acting on the wheel carrier, expressed in global co-ordinates. This force contains tire weight
- **wheel torque** (signal dimension 3, units [Nm]) is the vector-valued tire torque acting on the wheel carrier, expressed in global co-ordinates. Assumed point of attack of tire forces is the geometrical rim mid-point, which might differ from the wheel center of gravity. The wheel torque contains brake reaction torque
- **TYDEX signals** (signal dimension 100, different units) is a collection of additional output signals for diagnosis purposes. The first 25 components (called 'VARINF' in TYDEX/STI) are defined by the TYDEX working group for tire and vehicle model interfaces (STI). In detail, the output vector contains the following components:

1-6	tire forces and torques, expressed in TYDEX W-axis	[N], [Nm]
7	slip angle	[rad]
8	longitudinal slip	[-]
9	camber angle	[rad]
10-25	not used	
26-28	geometrical center of contact patch in global co-ordinates	[m]
29-37	3x3 transformation matrix from contact tangential plane to global coordinates (storage column-wise)	[-]
38-43	tire forces and torques, expressed in ISO axis system	[N], [Nm]
44	tire deflection	[-]
45	vertical rim center velocity	[m/s]
46	longitudinal slip velocity at contact point	[m/s]
47	lateral slip velocity at contact point	[m/s]
48	longitudinal rim center velocity	[m/s]
49	maximum belt radius after inflation	[m]
50	rim angular velocity relative to wheel carrier (ABS signal)	[rad/s]
51-77	do not use, only for interfacing to 3^{rd}-party software	
78	mean road friction factor in contact patch	[-]
79	tire deflection	[-]
80	slip angle	[deg]
81	longitudinal slip	[%]
82-87	tire forces and torques, expressed in TYDEX C-axis	[N], [Nm]
88	rolling loss	[N]
89	maximum belt-to-rim contact intrusion	[m]
90	dynamic rolling radius	[m]
91-96	tire forces and torques, expressed in ISO axis	[N], [Nm]
97-100	not used	

Please note there are many more signals available in the 'additional output file', which can be requested by the respective switch in the tire data file.

Double-clicking the block will open its dialog box (figure 5). In this box, you can specify tire and road data files. Moreover, you may control certain operating and simulation conditions, and branch to on-line documentation.

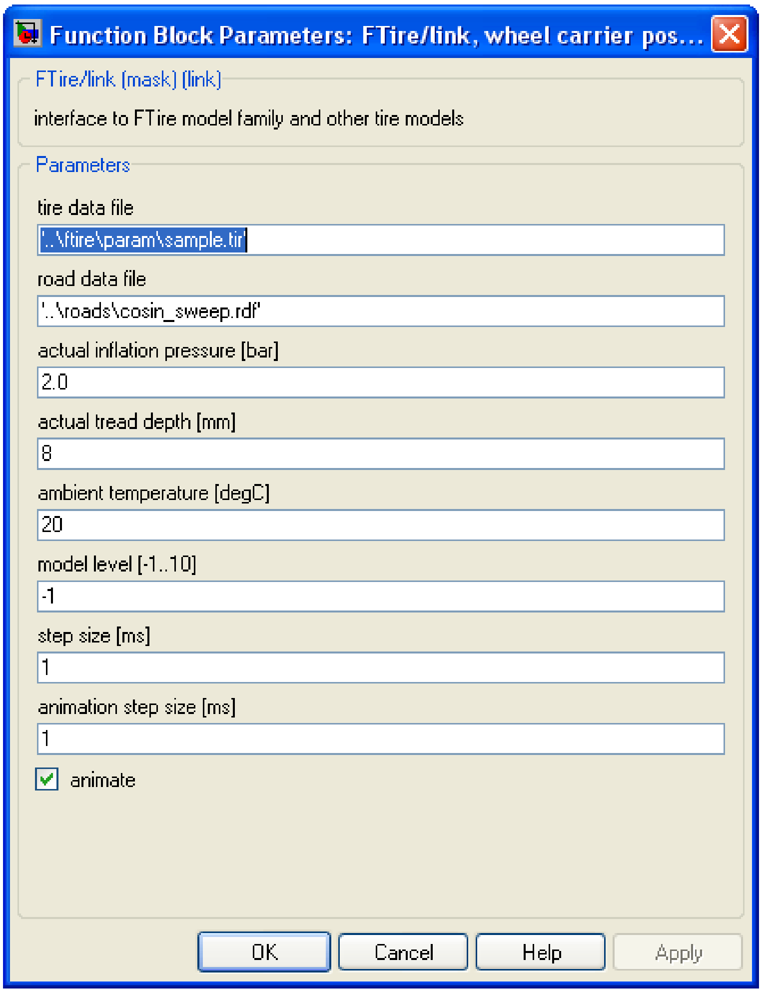

Figure 3: Simulink dialog box for the first block

Here is a description of the entry fields:

- **tire data file** is a string defining the name of the tire data file to be used. This string must be a valid file name, absolute or relative to the working directory. The string is to be enclosed in simple quotes. *FTire* will automatically detect any supported tire data file format
- **road data file** is a string defining the name of the road data file to be used. This string must be either blank or a valid file name, absolute or relative to the working directory. The string is to be enclosed in simple quotes, even if blank. *FTire* will automatically detect any supported road data file format. If the string is blank, a flat road surface located at $z = 0$ is assumed
- **actual inflation pressure** [bar], may override the default inflation pressure, specified in the tire data file. The value is only used if positive
- **actual tread depth** [mm], may override the default tread depth, specified in the tire data file. The value is only used if positive
- **ambient temperature** [degC], may override the default ambient temperature of 20 degC. The value is only used if greater -273 degC
- **model level** [-] will be used later to select a member and/or variant of *FTire*'s model family. For example, 6 = reduced *FTire*, 7 = standard *FTire*, 8 = *FETire*, and so on. At present, by default only *FTire* and reduced *FTire* is available

1.2 Block with Wheel Carrier Velocity Input

The second block (used in the example model in figure 4) uses only velocity variables of the wheel carrier. Position and orientation of the wheel carrier are determined inside the block, by transforming and integrating the respective velocity signals. As with the first block, FTire updates rim rotation angle and angular velocity internally. This has the same consequences as explained above for the first block.

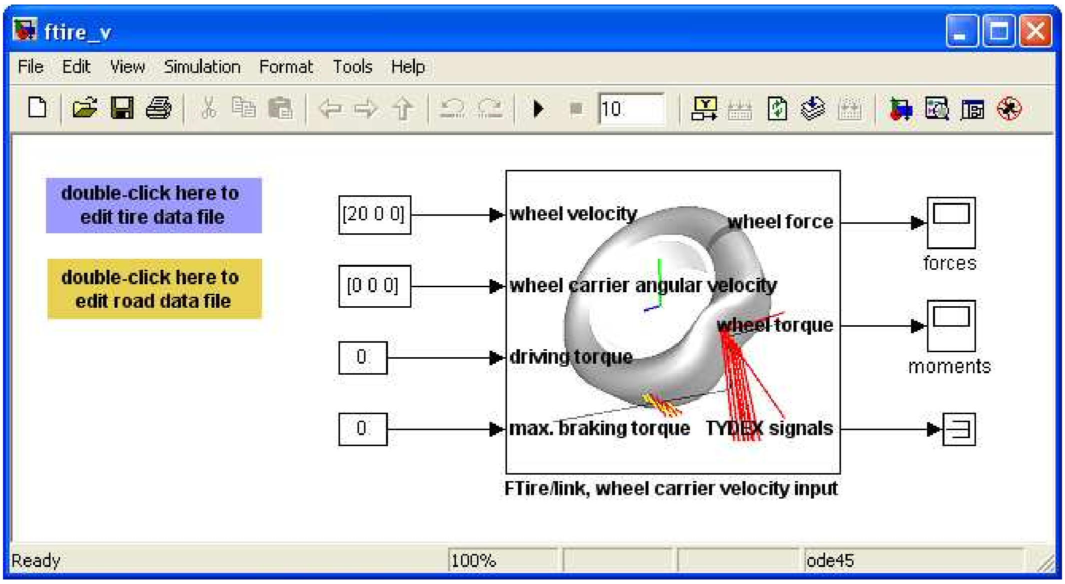

Figure 4: Simple model, using *FTire* block with wheel carrier velocity and angular velocity as input

The following are the details of the **input** signals:

- **wheel velocity** (signal dimension 3, units [m/s]) is the translational velocity of the geometrical center of the rim, being defined by the intersection of spin axis with rim mid-plane. The velocity is expressed in global co-ordinates
- **wheel carrier angular velocity** (signal dimension 3, unit [rad/s]) is the wheel carrier's angular velocity vector ω, expressed in global co-ordinates. Note that, for large displacement angles, this vector differs from the time derivative of the orientation angles
- **driving torque** (signal dimension 1, unit [Nm]) is the scalar driving torque applied to the rim, in direction of wheel spin axis
- **max. braking torque** (signal dimension 1, units [Nm]) is the scalar braking torque applied to the rim, in direction of wheel spin axis. Sign of this signal is not used, but determined internally. Moreover, when wheel is blocked it might happen that only a certain fraction of this torque is effective. This is done to prevent the wheel from being accelerated in reverse direction. Please note that this is more than just a numerical trick. Rather, it is the physically correct description of dry friction between brake pads and disc.

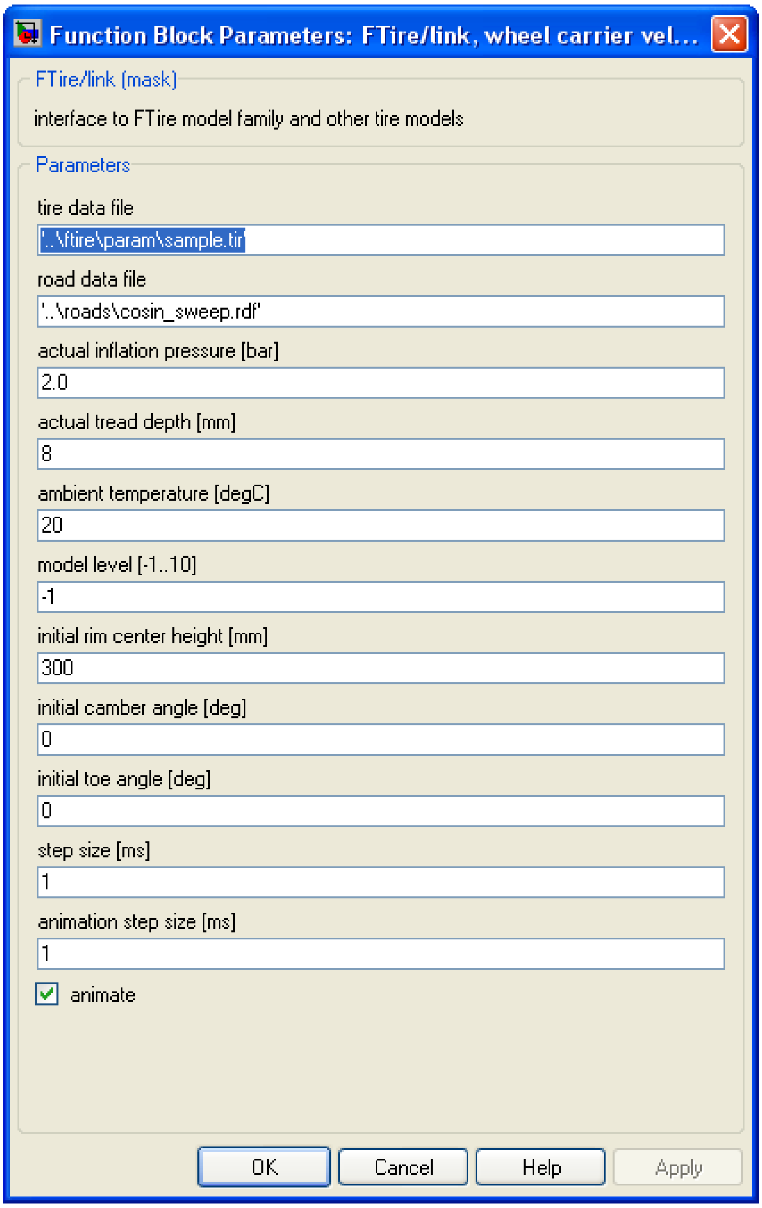

Figure 5: Simulink dialog box for the second and third block

Here are the **output** signals:

- **wheel force** (signal dimension 3, units [N]) is the vector-valued tire force acting on the wheel carrier, expressed in global co-ordinates. This force contains tire weight
- **wheel torque** (signal dimension 3, units [Nm]) is the vector-valued tire torque acting on the wheel carrier, expressed in global co-ordinates. Assumed point of attack of tire forces is the geometrical rim mid-point, which might differ from the wheel center of gravity. The wheel torque contains brake reaction torque
- **TYDEX signals** (signal dimension 60, different units) is a collection of additional output signals for diagnosis purposes. For the definition of these signals, see chapter 1.2.

The block's dialog box is shown in figure 5. It possesses the same entry fields as the first block, and in addition

- **initial rim center height** [mm], used as initial condition in the respective integrator of vertical velocity

- **initial camber angle** [deg], used as initial condition in the respective integrator of camber velocity. Here, camber angle is defined to be positive if wheel-carrier-fixed y-axis points towards the sky
- **initial toe angle** [deg], used as initial condition in the respective integrator of toe velocity. Here, toe angle is defined to be negative if wheel-carrier-fixed y-axis points towards the forward direction.

1.3 Block with Rim Position and Velocity Input

The third block (shown in the example model in figure 6) uses both position and velocity variables of the rim. It is meant to be used in conjunction with detailed MBS models, where all these signals are usually available.

In contrast to the first two blocks, this one does not administer rim rotation. Rather, the rim is considered to be a standard rigid body, connected to the wheel carrier by some kind of revolute joint or special force element. However, this part of the model is defined completely outside *FTire*, and the respective modelization is up to the user. This is why driving or braking torque do no longer appear as input signals.

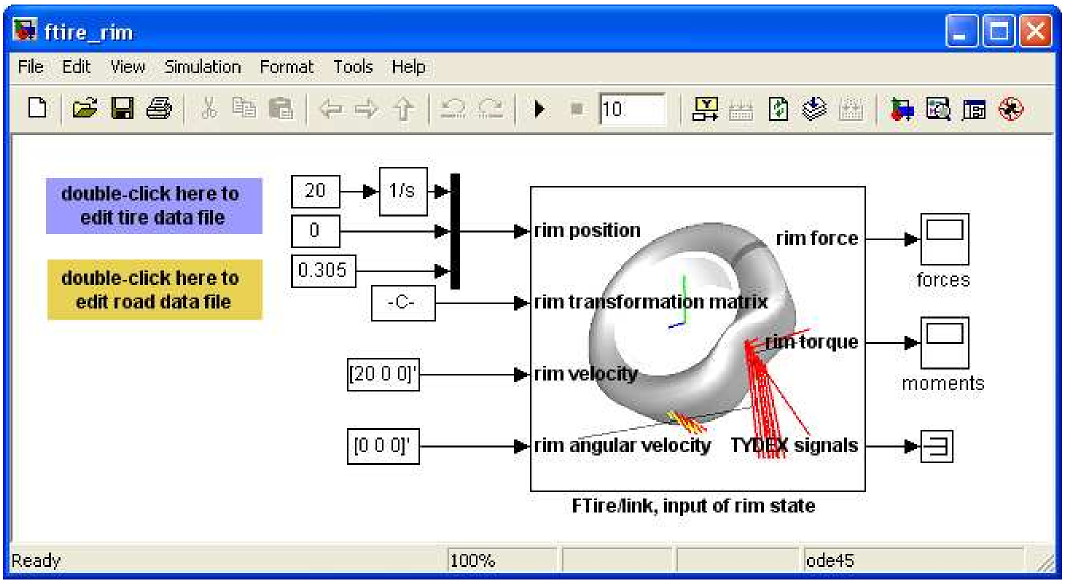

Figure 6: Simple model, using FTire block with rim position and velocity state as input

Here are the **input** signals:

- **rim center position** (signal dimension 3, units [m]) is the position of the geometrical center of the rim, being defined by the intersection of spin axis with rim mid-plane. The position is defined in global co-ordinates
- **rim transformation matrix** (signal dimension 9, no unit) is the 3x3 transformation matrix from rim-fixed co-ordinates to global co-ordinates. This matrix is stored column-wise, that means in the sequence T11,T21.T31,T12 ,T22 ,T32 ,T13 ,T23 ,T33 , like in Fortran, but unlike in C or C++
- **rim velocity** (signal dimension 3, units [m/s]) is the translational velocity of the geometrical center of the rim, being defined by the intersection of spin axis with rim mid-plane. The velocity is expressed in global co-ordinates
- **rim angular velocity** (signal dimension 3, unit [rad/s]) is the rim's angular velocity vector ω, expressed in global co-ordinates. Note that, for large displacement angles, this vector differs from the time derivative of the orientation angles.

Finally, these are the **output** signals:

- **rim force** (signal dimension 3, units [N]) is the vector-valued tire force acting on the rim, expressed in global co-ordinates. This force contains tire weight
- **rim torque** (signal dimension 3, units [Nm]) is the vector-valued tire torque acting on the rim, expressed in global co-ordinates. Assumed point of attack of tire forces is the geometrical rim mid-point, which might slightly differ from the rim center of gravity. Clearly, the rim torque does not contain any brake reaction torque
- **TYDEX signals** (signal dimension 60, different units) is a collection of additional output signals for diagnosis purposes. For the definition of these signals, see chapter 1.2.

The block's dialog box is the same as that one of the second block, see chapter 1.2.