IPGKinematics ‘Forces Off’ Simulation

Formula CarMaker 9.1

SOLUTIONS FOR VIRTUAL TEST DRIVING

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Introduction

IPGKinematics is a program designed to simulate a vehicle axle on an axle test bench and is used to calculate the kinematics, steering kinematics and elastokinematics of a variety of suspension types.

For the simulation of high-performance competitive vehicles, such as Formula Student cars, the effects of compliance and elastokinematics become less prevalent due to generally stiffer suspension components and bushings being implemented - as opposed to that of a consumer vehicle as comfort is of a lower priority.

For this reason, it may be more relevant for a team to negate the effects of spring forces and torsion to produce a pure kinematics simulation, allowing suspension linkages to move freely throughout their range of motion.

This document instructs the user on how to parameterize IPGKinematics to complete a '*Forces Off*' simulation for a Double Wishbone, Pull-/Pushrod actuated suspension system. By ignoring such forces, certain inputs do not need accurate parametrization and therefore saving time during the modelling process. For ease of use, the following diagrams have been annotated using the following key:

 = *Requires Parameterization*

All other inputs can be left as their default value. At the end of each section, suggested settings are provided.

Although not required, it may be useful to use accurate values for all inputs when possible if you wish to complete a 'Forces On' simulation in the future.

Before reading this document, it is highly advised that the user has a substantial level of familiarity with the software which can be gained by completing the exercises within the Formula CarMaker Tutorial. This document is intended to be supplementary to the list of help manuals provided with CarMaker and therefore explanations offered within are not extensive. Example input values can be within the Formula CarMaker Tutorial document.

Chapter 1

Simulation Control

The *Simulation Control* GUI allows the user to parameterize the way in which the kinematics results will be generated and stored via the *General*, *Kinematics*, *Compliance* and *MixedForce* tabs. It is within this GUI that the simulation can be configured to run with 'Forces Off'. More information regarding Simulation Control and the various settings can be found within the IPGKinematics User Guide.

Creating a New File

Before parameterizing simulation settings, the suspension configuration to be modelled must be specified first. This can be achieved by navigating to *File* > *New* upon the IPGKinematics GUI.

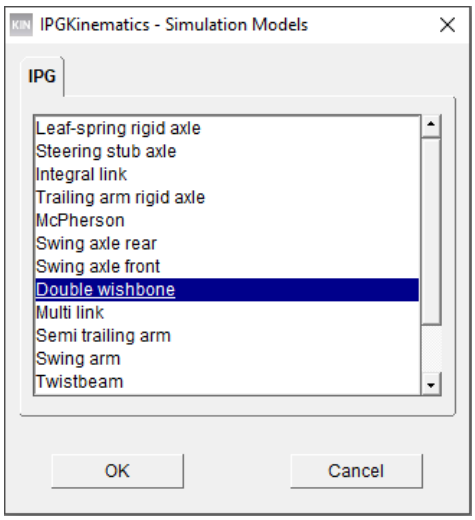

Figure 1.1 Defining the suspension configuration

Upon the resulting window the user can select from range of pre-defined suspension configurations. As it the case for most open-wheeled race cars, i.e., Formula Student vehicles, a Double Wishbone arrangement is often implemented.

It is then recommended to then save the file, ensuring that a name is chosen which differentiates from previous simulations - i.e., "DWB_Forces_OFF.kin".

Simulation Control GUI

This dialog controls the simulation parameters.

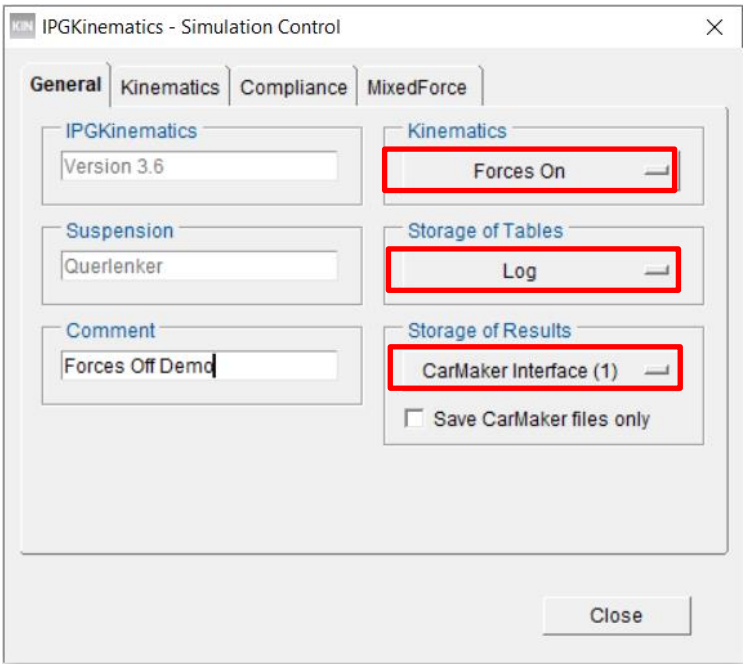

Figure 1.2 The *General* tab of the Simulation Control GUI

General

Upon the *General* tab, the following settings should be implemented to run a 'Forces Off' simulation:

Kinematics

Forces Off should be selected from the *Kinematics* drop down menu. This ensures that neither inertial nor spring forces are considered, and only pure kinematics are calculated.

Storage of Tables

The options for the output of the calculated tables. *Log* should be selected which will display all results tables within the GUI and will also produce an output file.

Storage of Results

To export the results to CarMaker you must choose one of the CarMaker Interface options:

• *CarMaker Interface (1)* provides linear compliance model.

• *CarMaker Interface (2)* provides a non-linear compliance model.

As a non-linear compliance model will lead to unnecessarily increased computation times, it is recommended to select *CarMaker Interface (1)*. If the *Save CarMaker files only* option is enabled, only the .kin and .skc files will be stored which will reduce memory usage.

Simulation Control - General

Within the *General* tab, set:

- *Kinematics* = Forces Off
- *Storage of Tables* = Log
- *Storage of Results* = CarMaker Interface (1)

Kinematics

This tab defines the procedure according to which the movement of the wheels is calculated.

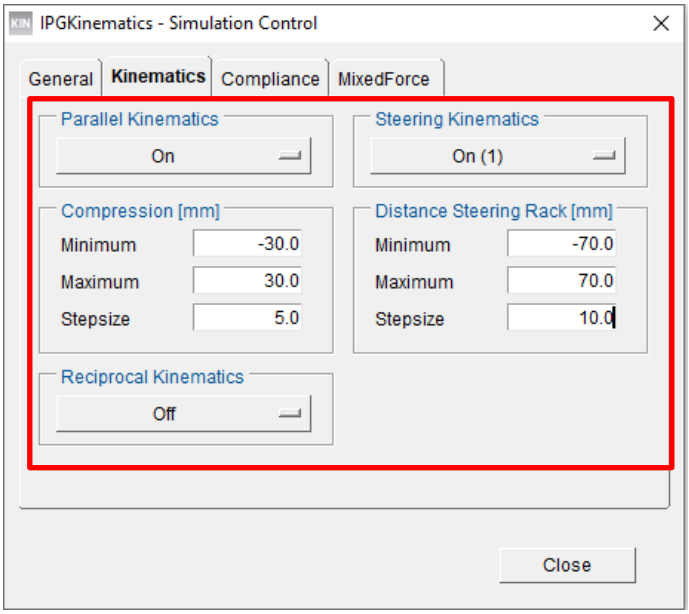

Figure 1.2 The *Kinematics* tab of the Simulation Control GUI

Parallel Kinematics

Both wheels of an axle will move in the same direction upon compression when activated. This should be set to *On*.

Reciprocal Kinematics

This option will move the axle's wheels in opposite directions. This parameter will not affect the output of the .skc file but will produce additional files describing the vehicle's reciprocal kinematics, however this may unnecessarily increase simulation time.

Steering Kinematics

This is used only for the front axle to calculate steering parameters. *On (1)* should be selected as it does not consider the interaction between steering and reciprocal wheel travel.

Compression and Distance Steering Rack

The maximum/minimum values for Compression and Distance Steering Rack should be kept close to the designed range to not unnecessarily increase computation time.

Simulation Control - Kinematics

Within the *Kinematics* tab, set:

- *Parallel Kinematics* = "On".
- *Steering Kinematics* = "On".
- *Reciprocal Kinematics* = "Off".
- *Compression* = "+/- 30mm", Stepsize = "5.0".
- *Distance Steering Rack* = "+/- 70mm", Stepsize = "5.0".

Compliance and MixedForce

The last two tabs are used to apply external forces to the wheels in the longitudinal and lateral directions. These are used to determine the stresses upon individual suspension components for FEM analysis. For pure kinematics, external forces are deactivated and compliance is irrelevant which is why these options should be configured to *Off*.

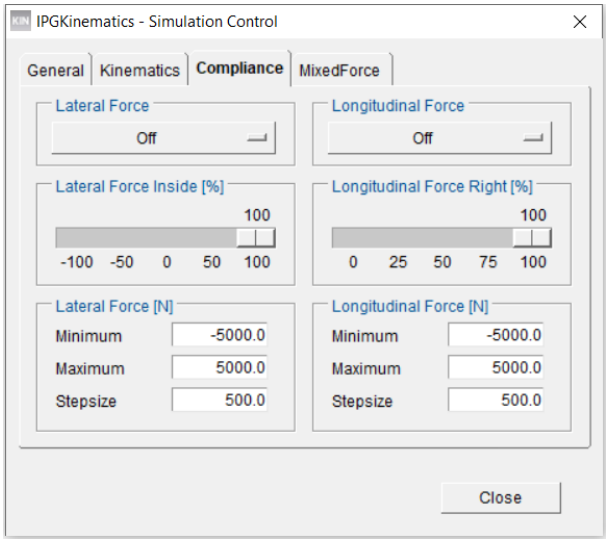

Figure 1.3 The *Compliance* tab of the Simulation Control GUI

Simulation Control - Compliance and MixedForce

- Within the *Compliance* and *MixedForce* tabs, configure all settings to *Off*.
- Leave numerical inputs as their default values.

Chapter 2

Vehicle Data

This chapter describes the parametrization of the *Vehicle Data* section of IPGKinematics, accessed via *Edit* > *Vehicle Data.* This process mainly involves the specification of various hardpoints to allow the software to calculate the various movements of the suspension mechanism, however, with 'forces off' the definition of some of these components becomes redundant as they will no longer have an effect upon the simulation's results.

This section will therefore identify which settings can be disregarded, and in some instances provide suggested values as to prevent the program from producing an error. If you do not have values specific to your vehicle, the FCM Tutorial provides representative values.

It may be of interest to enter representative vehicle data where possible for all values in case the need for a 'Forces On' simulation arises which may save time later, however this may not be necessary. In this case, the FCM Tutorial should be referenced when parameterizing.

Vehicle Data GUI

General

The *General* Tab contains miscellaneous vehicle settings.

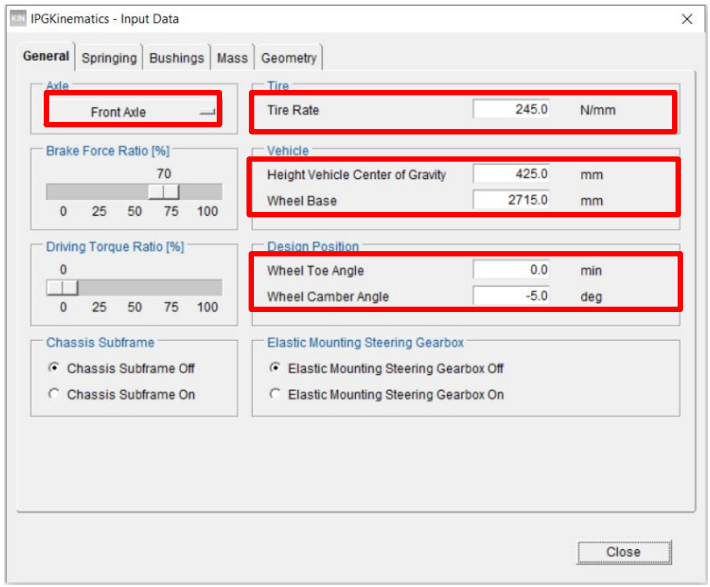

Figure 2.1 The *General* tab of the Input Data GUI

Axle This option defines which axle will be defined. The *Front Axle* option will include the calculation of various steering quantities.

Brake Force Ratio *This parameter does not affect 'Forces Off' kinematics.*

Driving Torque Ratio *This parameter does not affect 'Forces Off' kinematics.*

Chassis Subframe For a Formula Student car *Chassis Subframe off* should be selected as only the chassis supports the engine and lower suspension components (i.e. there is no subframe).

Tire This field is used to define the vertical stiffness of the tire (in N/mm). As the tire is modeled as a linear spring, a tire spring coefficient must also be entered. To negate the effects of tire deflection, it is recommended to enter a high value such as 5000 N/mm.

Design Position Here, the static wheel toe and camber angles are defined. The design position is the position of the car with only the axle load upon it. This corresponds to a wheel travel of 0 mm. Therefore, it must be established if the weight of the driver was included in the design position calculation or not. If not, attention must be paid to various settings such as the location of the center of gravity, camber and toe angles etc. All of these should be measured or calculated without the driver's weight.

Elastic Mounting Steering Gearbox This offers the option to model the rack-and-pinion steering rack elastically. However, as compliance will not be considered with 'Forces Off' this feature should not be enabled.

Vehicle Data - General

Within the *General* tab, set:

- *Axle* to either Front or Rear - depending upon what you are modelling.
- *Brake Force Ratio* and *Driving Torque Ratio* can be set to any values.
- *Chassis Subframe* = Chassis Subframe Off
- *Tire Rate* = '5000 N/mm'
- *Vehicle* and *Design Position* should be set to representative values.
- *Elastic Mounting Steering Gearbox* = Elastic Mounting Steering Gearbox Off.

Springing

The *Springing* tab features settings for the pull/push-rod, springing and the stabilizer bar.

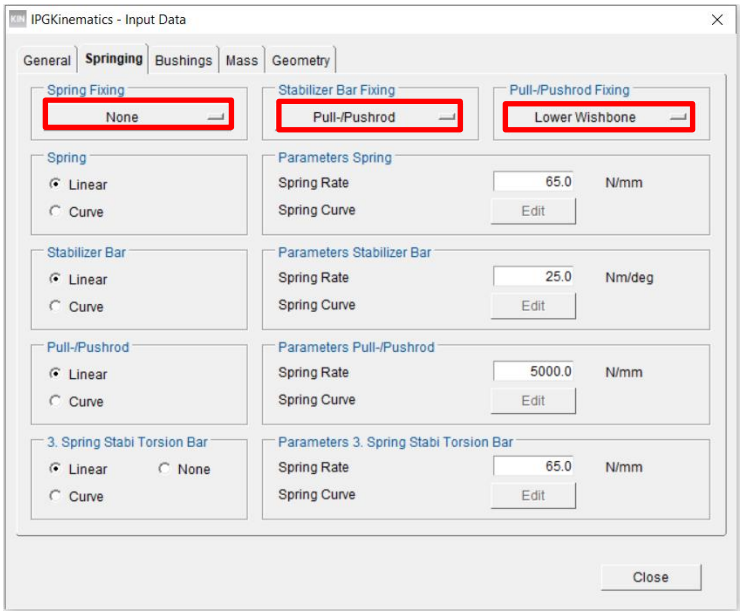

Figure 2.2 The *Springing* tab of the Input Data GUI

As 'Forces Off' does not consider inertial nor spring forces, many of the settings upon this tab merely require a non-zero value to prevent a computational error.

Spring Fixing

Defines which component the spring is fastened to. It is assumed that the "Spring Fixing" is on the suspension side. The option *None* is chosen in the case of a pull-/pushrod.

Stabilizer Bar Fixing

This parameter does not affect 'Forces Off' kinematics, however you should select pull-/pushrod.

Pull-/Pushrod Fixing

Defines how the push-/pull rod is connected to the wheel.

Parameter Spring/ Stabilizer/ /Pull-/Pushrod /Torsion Bar

These parameters do not affect 'Forces Off' kinematics, however non-zero values should be input to prevent a computational error. These stiffness values are used to consider compliance effects of various suspension compnents, which does not concern a pure kinematics simulation.

Vehicle Data - Springing

Within the *Springing* tab, set:

- *Spring Fixing* = None
- *Stabilizer Bar Fixing* = Push-/Pullrod
- *Pull-/Pushrod Fixing* = Lower Wishbone
- *All LHS settings* = Linear
- *Spring Rates* = Default values

Bushings

The drop-down menu upon the *Bushings* tab allows you to allocate properties to each of the bushings of the selected suspension system.

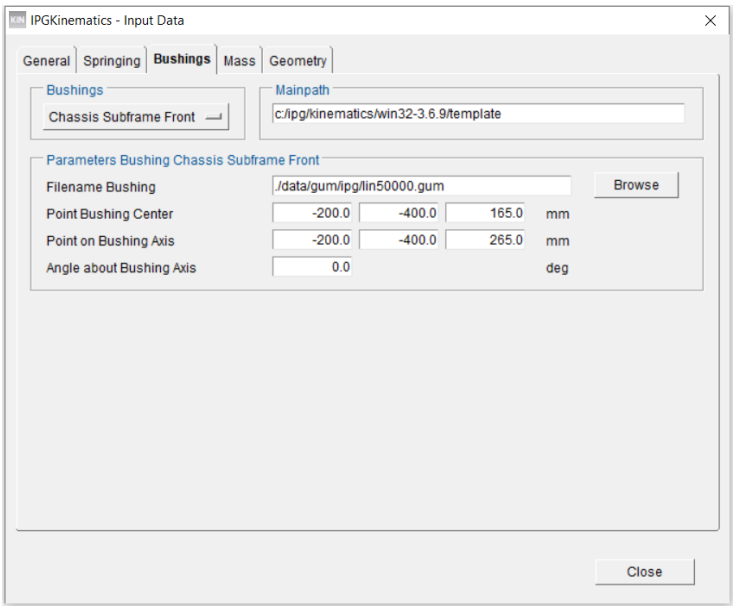

Figure 2.3 The *Bushings* tab of the Input Data GUI

Again, as compliance is not considering during a 'Forces Off' simulation, the specification of bushings has no effect upon the results and will therefore be modelled as rigid.

Vehicle Data - Bushings

Within the *Bushings* tab, leave all parameters as their default values - bushings only need to not be parallel to connected members for a 'Forces Off' simulation. I.e., the cross product of the connected member and bushing axis should not be zero. For a 'Forces On' simulation the Bushing axis should be aligned with the general axis of rotation of the connected member. I.e., the cross product of the connected member and bushing axis should be as large as possible.

Mass

The *Mass* tab is used to specify the weights of certain suspension system components.

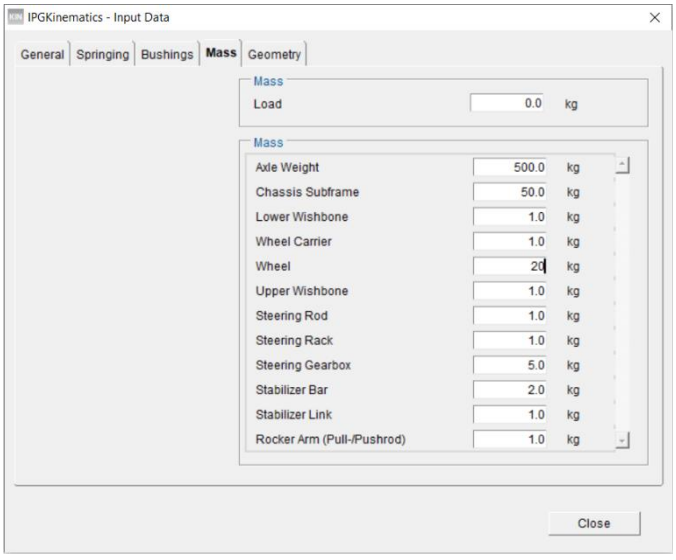

Figure 2.4 The *Mass* tab of the Input Data GUI

As no mass forces will be considered during the kinematics calculations, these values can be left as their defaults. (Note: ‘zero’ values will result in a computational error)

Vehicle Data - Bushings

Within the *Mass* tab, leave all parameters as their default values - masses do not need to be defined for a ‘Forces Off’ simulation.

Geometry

The *Geometry* tab is used to define the hardpoints of various suspension components and its correct parametrization is critical to the accuracy of kinematics calculations.

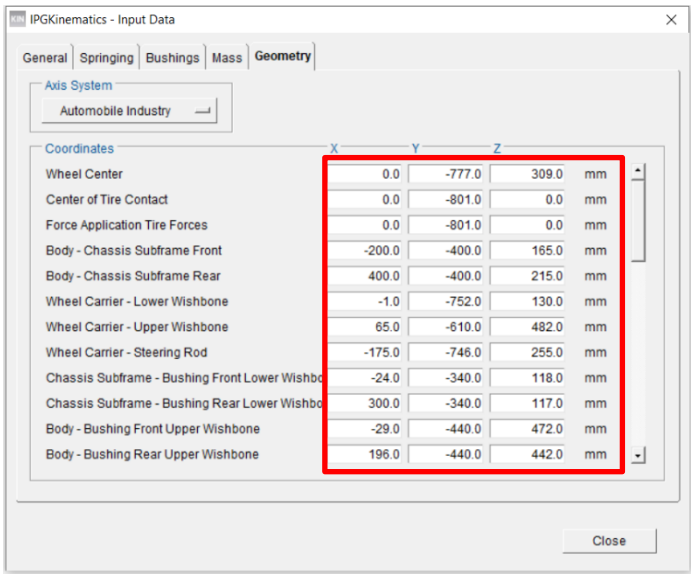

Figure 2.5 The *Geometry* tab of the Input Data GUI

As the forces associated with the springs and anti-rollbar are not considered, some of the inputs merely require a non-zero value to calculate the vehicle’s kinematic properties. These are summarized in the following table.

Vehicle Data - Geometry

- Populate the Geometry tab according to the below table. All other inputs can be any non-zero value during the parametrization process.

Table 2.1: All *Geometry* inputs which require parameterizing

Parameter	Comment
Wheel Centre	-
Centre of Tire Contact	-
Body - Chassis Subframe Front	Can be set same as Chassis Subframe - Bushing Front Lower Wishbone.
Body - Chassis Subframe Rear	Can be set same as Chassis Subframe - Bushing Rear Lower Wishbone.
Wheel Carrier - Lower Wishbone	-
Wheel Carrier - Upper Wishbone	-
Wheel Carrier - Steering Rod	Not used by rear axle - will still require a non-zero value e.g., coordinates of Wheel Centre.
Chassis Subframe - Bushing Front Lower Wishbone	As the subframe is deactivated this corresponds to the mounting points of the lower wishbones to the body.

Parameter	Comment
Chassis Subframe - Bushing Rear Lower Wishbone	As the subframe is deactivated this corresponds to the mounting points of the lower wishbones to the body.
Body - Bushing Front Upper Wishbone	-
Body - Rear Upper Wishbone	-
Body - Rocker Arm	-
Rotation Axis - Rocker Arm	Can be any point upon the rotation axis of the rocker arm.
Pull-/Pushrod - Wheel Suspension	-
Pull-/Pushrod - Rocker Arm	-
Spring Element - Body	The point at which the spring assembly is connected to the vehicle body / chassis.
Spring Element - Rocker Arm	The point at which the spring assembly is connected to the rocker.

All other inputs can be a non-zero value.

Saving Results

Once the Simulation Control and Vehicle Data have been configured, the simulation can be initiated by clicking the *Start* button upon the IPGKinematics GUI.

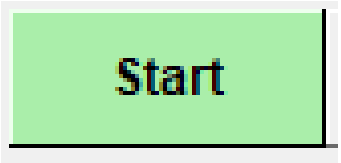

Figure 2.6: *Start* button upon IPGKinemtics GUI

This button will momentarily turn grey whilst the simulation is running and will return to green once it has completed**.** The resulting files should then be saved via *File* > *Save*.

Amongst the numerous data files generated by the simulation, one will be called:

• `NameOfResults_front.skc` (for a front axle)

or

• `NameOfResults_rear.skc` (for a rear axle).

To use IPGKinematics results in CarMaker you must copy the skc-files and paste them into the "<yourProjectDirectory>/Data/Chassis" folder of your CarMaker project directory, for example:

“FormulaCarMaker_Release2021.1 /Data/Chassis”

This process is demonstrated in the Formula CarMaker Tutorial chapter 5, ‘*Preparing a Vehicle Dataset in CarMaker*’ pg. 75.