



Coastdown Adaption

Documentation v.1.20

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1 Introduction

The Coastdown Adaption tool was designed for powertrain applications to achieve the same resistance force like determined in a coastdown test with a real vehicle. It has a graphical user interface for the parametrization and uses predefined TestRuns to compare the resistance force of measurement and simulation. Certain parameters are adjusted automatically to achieve the given resistance. As result, the user can select a new vehicle with adjusted resistance according to the coastdown measurement.

1.1 Basic Information

The Coastdown Adaption tool uses a vehicle that is selected by the user like in any other TestRun in CarMaker. A copy of the vehicle and the tires will be generated and edited according to the calculation results of the coastdown procedure.

During the Coastdown Adaption, the tool adjusts some parameters of the tires and of the aerodynamics of the vehicle to achieve the correct resistance. In the case of "RealTime Tire", it automatically switches the rolling resistance model of the tire to a load and velocity dependent model (according to SAE J2452).

Additionally, a cornering coastdown can be performed to adjust the resistance in corners. As the resistance in the corner depends on the kinematics and suspension setup, the accuracy of the cornering coastdown is limited to a cornering stiffness factor that is adjusted.

1.2 Resistance Force

The driving resistance force, also known as road load, can be expressed as a function of vehicle velocity. ISO 10521-1 shows different ways how to identify the road load. In case of using one of the methods that are conducted on real roads, the driving resistance is calculated by the following equation:

$$F_{resistance} = -\frac{1}{3,6} * (m + m_{rot}) * \frac{dv}{dt}$$

where

- m is the test vehicle mass including driver and measuring equipment in kg
- m_{rot} is the equivalent effective mass of all the wheels and vehicle components rotating with the wheels during coastdown on road in kg; m_{rot} may be estimated as 3% of the unladen vehicle mass when calculation is not possible
- v is the vehicle velocity in km/h

By deploying the equation shown above on the entire vehicle velocity range and performing polynomial fitting as well as corrections due to varying boundary conditions, the driving resistance force will be defined with the coefficients $f0$, $f1$ and $f2$:

$$F_{resistance} = f0 + f1 * v + f2 * v^2$$

The virtual vehicle in CarMaker is typically set up with unladen mass. As the coastdown test on real road requires a driver and measuring equipment, test vehicle mass will differ from unladen mass. For that reason, providing the experimental mass is mandatory before executing Coastdown Adaption.

Road load relevant effects from rotating components are considered by adding equivalent effective mass m_{rot} to test vehicle mass. This approach is relevant for all methods that are based on real road measurement according to ISO 10521-1. Inside the virtual vehicle in CarMaker there are several sub models for the rotating components. Each of these models require parameter(s) for rotational inertia. Consequently, the effect of inertia throughout a coastdown simulation is built-in. The equivalent effective mass has to be considered for the comparison between simulation and measurement, but not for the parametrization of the virtual vehicle itself. Providing m_{rot} will not affect the total mass of the virtual vehicle.

1.3 Features

The Coastdown Adaption tool offers a graphical user interface (GUI) to allow a fast parametrization for different use cases. In detail, the tool offers the following features:

- Manage configurations (input data). Configuration files will be saved in project folder path Data/Config/CDA/.
- Determining the longitudinal coefficients without performing an adaption is possible. There will be no changes at the vehicle itself in this case.
- Automated filename handling. Customizing filenames is supported.
 - Generated TestRuns inherit the vehicle name as suffix by default.
 - Generated vehicle and tires with suffix “_CDA” by default. Ask for overwriting permission in case of an already existing file.
 - Data structure with subfolders considered.
- Provide experimental mass as additional information.
 - Trim loads will be added when experimental mass is higher than vehicle mass.
 - Up to three categories are offered as additional trim load. Their geometrical coordinates are customizable:
 - Driver (default mass 75 kg) at estimated coordinate left-hand side
 - Co-Driver (default mass 75 kg) at estimated coordinate right-hand side
 - Measurement equipment or luggage in case of remaining mass at center of vehicle body
- A rotational mass can be optionally provided. This is only relevant when the rotational mass (equivalent effective mass) was used to calculate the coefficients f_0 , f_1 and f_2 according to ISO 10521-1.
- Changing units between km/h and m/s.
 - In analogy to ISO 10521-1 default unit is km/h.
 - Internal unit in CarMaker is m/s (SI-unit).
- Option to perform a lateral adaption. This feature can only be used in combination with RealTime Tire model. The lateral adaption calculates the resistance with a third order polynomial function.
- Electric and Hybrid vehicles will automatically change to StrategyMode_trg=3 (Coasting) and reduce the Load to 0. Therefore, the friction of the electric motors can be considered and no recuperation takes place.

1.4 Boundary Conditions

The Coastdown Adaption tool changes the tire model to a load and velocity dependent model if necessary. Constant or linear force deviations will be corrected by changing tire parameters. Deviations in the quadratic part of the polynomial function are corrected by adjusting the cross sectional area of vehicle aerodynamics. This method leads to the following constraints:

- Losses in differential, drivetrain or wheel bearings that differ from the vehicle parametrization can't be detected and changed, as no information about the ratio of these resistances is known. These resistances will be found in the coefficients of the tire.
- The virtual vehicle should be parametrized according to the testing conditions during the coastdown. For example, an electric vehicle without gearbox should not use regeneration throughout the simulated coastdown.
- If aerodynamic data was determined with high effort, the tool could overwrite these parameters.
- "1D Look-Up Table" needed as aerodynamic model.
- If tire data was determined with high effort, the automatic adjustment of the tire's parameters may overwrite these parameters.
- "RealTime Tire" or "Magic Formula Tire" is needed as tire model
 - The tire pressure which is used in the simulation is taken from the generated tires. If tire names are changed, it is possible that the tire pressure can't be identified.
 - In case of using Magic Formula Tires, only longitudinal coastdown adaption can be executed.
 - Mixing RealTime Tire and Magic Formula Tire in one vehicle will prevent Coastdown Adaption from executing.
- Existing trim loads in the virtual vehicle should not refer to mobile masses like driver, co-driver, measurement equipment or luggage.
- CarMaker and TruckMaker supported.

2 Installation Guide

Unpack the "CoastdownAdaption-<version>.zip". The following data in corresponding subfolders should be included:

- GUI/CMext-CoastDown.mod
- doc/CoastdownAdaption.pdf

Copy both files into your CarMaker installation path.

- CMext-CoastDown.mod → <install path>/GUI/CMext-CoastDown.mod
- CoastdownAdaption.pdf → <install path>/doc/CoastdownAdaption.pdf

(Re-)Start CarMaker GUI.

3 Graphical User Interface

The graphical user interface (GUI) (see Figure 3-1) can be accessed via “Add-ons” → “Coastdown Adaption”. Several mouse over comments are available to give a fast overview on the functionality or content.

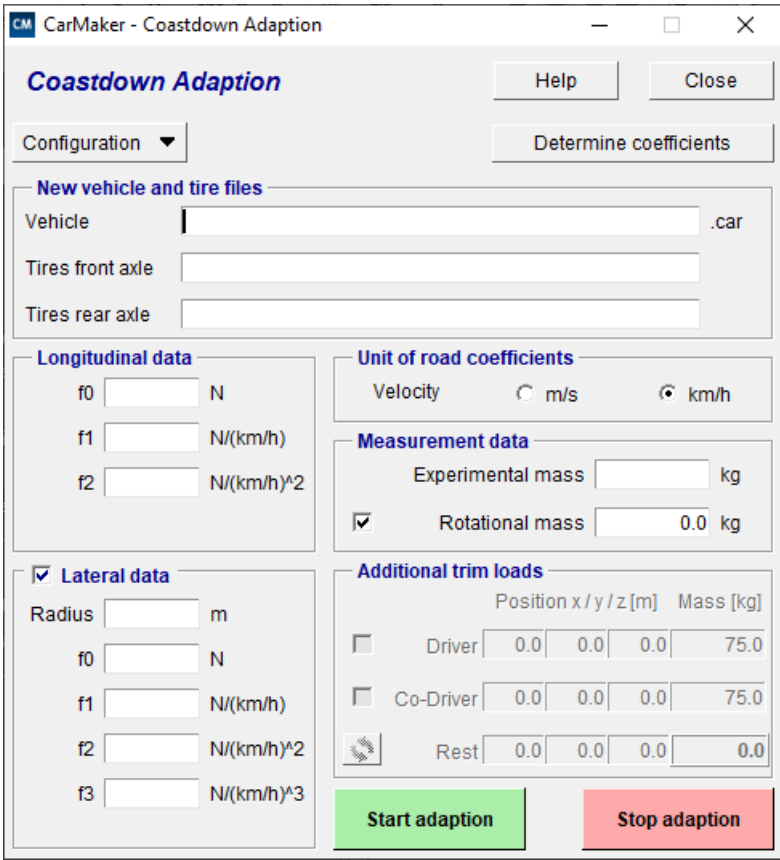


Figure 3-1: Graphical user interface (GUI) of the Coastdown Adaption add-on

The button *Configuration* allows for saving and (re-)loading different data sets. This is a comfortable option when the same data set is used several times.

Determine coefficients starts one single straight line coastdown TestRun with the vehicle, actually selected in the CarMaker Main GUI. Providing data in the entry fields is not necessary, the vehicle is simply referenced in a new TestRun without any modifications. The determined coefficients f_0 , f_1 and f_2 are printed to the CarMaker SessionLog at TestRun end.

Customizing the filenames of generated vehicle and tires is possible. Moreover, providing data for the adaption target is mandatory. The section *Additional trim loads* gets active as soon as a vehicle is selected in the CarMaker Main GUI. After providing a value for *Experimental mass* and deciding how to proceed with trim loads for *Driver* and *Co-Driver*, the *Update* button (circular arrow symbol) should be pressed once to calculate rest mass. Starting and stopping the adaption process can be triggered with the buttons *Start adaption* and *Stop adaption*.

4 Performing a Coastdown Adaption

Required data are described in chapter 4.1. A step by step introduction is given in chapter 4.2. For further information about the workflow of the Coastdown Adaption methodology refer to chapter 4.3, for results to chapter 4.4.

4.1 Preparation

Before performing a Coastdown Adaption, the following required data should be prepared:

- Vehicle infofile incl. appropriate tires
- Experimental mass (incl. driver, co-driver and measurement equipment)
- Rotational mass used for calculation of resistance force. Relevant when one of the real road measurement methods according to ISO 10521-1 was used to calculate the coastdown coefficients.
- Coefficients f_0 , f_1 and f_2 for straight line coastdown. Velocity unit either “m/s” or “km/h”.
- If lateral adjustment should be performed, the following data is needed (optional):
 - Radius of 360° turn
 - Coefficients f_0 , f_1 , f_2 and f_3

Due to a huge variety of conceivable coefficients of straight line coastdown, some hints on their effect are drawn out in Figure 4-1. In case of using positive values for all coefficients, driving resistance is a monotonic function in the range of positive velocity values. The minimum may be at zero velocity or below.

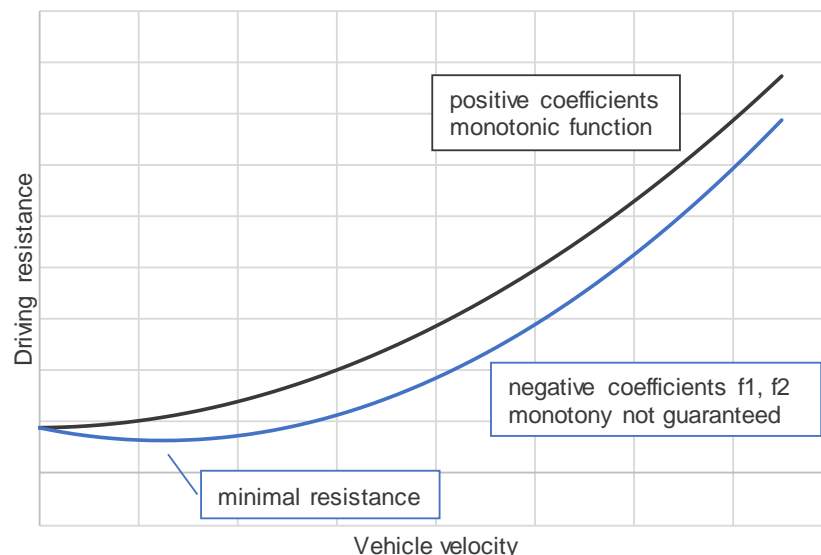


Figure 4-1: Effect of positive and negative coefficients for straight line coastdown

Using negative coefficients may lead to a minimum or even to an inverted function of driving resistance in the relevant velocity range. For this reason, negative values are highlighted in the Coastdown Adaption GUI and ask implicitly for attention by the user.

4.2 Instruction for Usage

Figure 4-2 shows a step by step instruction how to use the Coastdown Adaption tool. Coastdown Adaption uses the vehicle, that is currently selected (regardless of the one referenced in the current TestRun) and the corresponding tires. A new TestRun will be created, opened and started with the actually selected vehicle.

Please note, that Coastdown Adaption uses the tires that are referenced in the vehicle and not those referenced in the TestRun. In the case of "Magic Formula Tire", the corresponding ADAMS® tire property file should be imported in the tire infofile before starting the adaption.

In case the CarMaker session log is not opened yet, it will. During the adaption process, the actual progress and key data are logged. In the end, a summary of the process is pointed out.

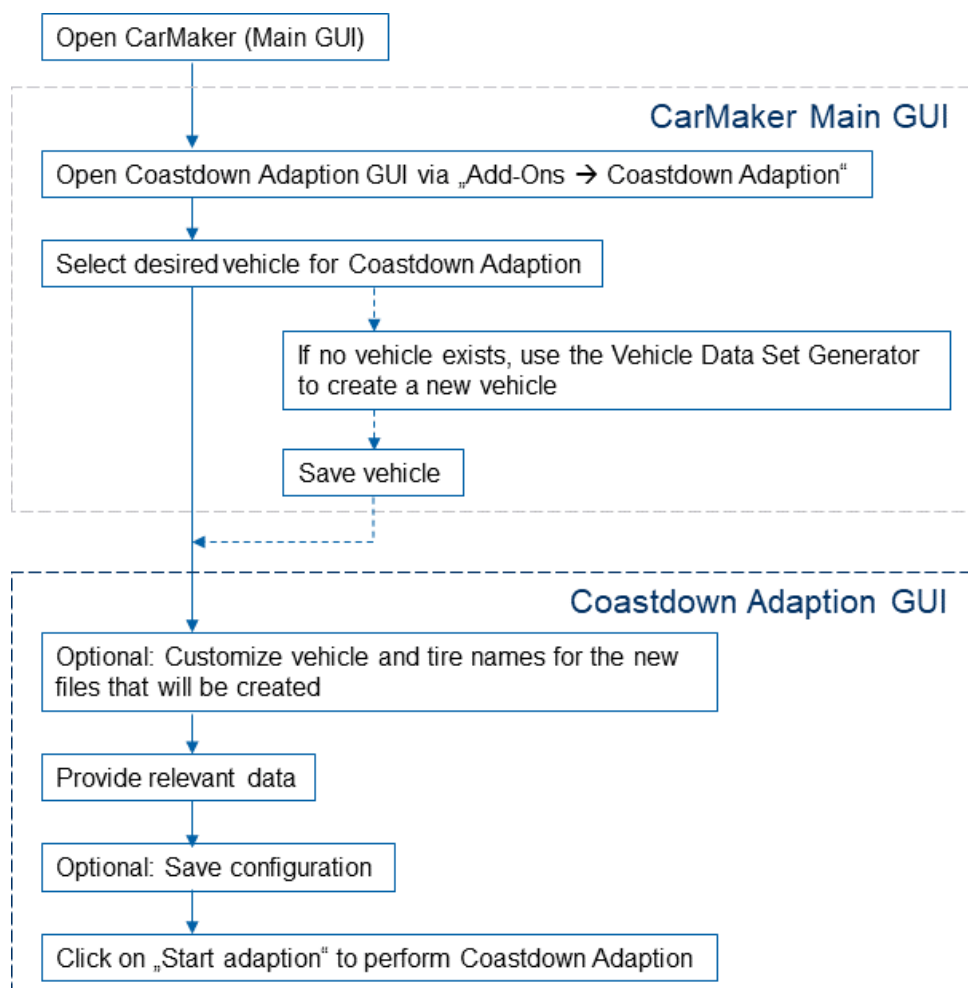


Figure 4-2: Step by step introduction how to use the Coastdown Adaption tool

The generated (and adjusted) vehicle and tire files can be used afterwards. The TestRun that is used to identify the vehicle's driving resistance is saved to TestRun folder of the actually selected CarMaker project directory.

4.3 Workflow of Coastdown Adaption Tool

The workflow of the adaption process is shown in Figure 4-3.

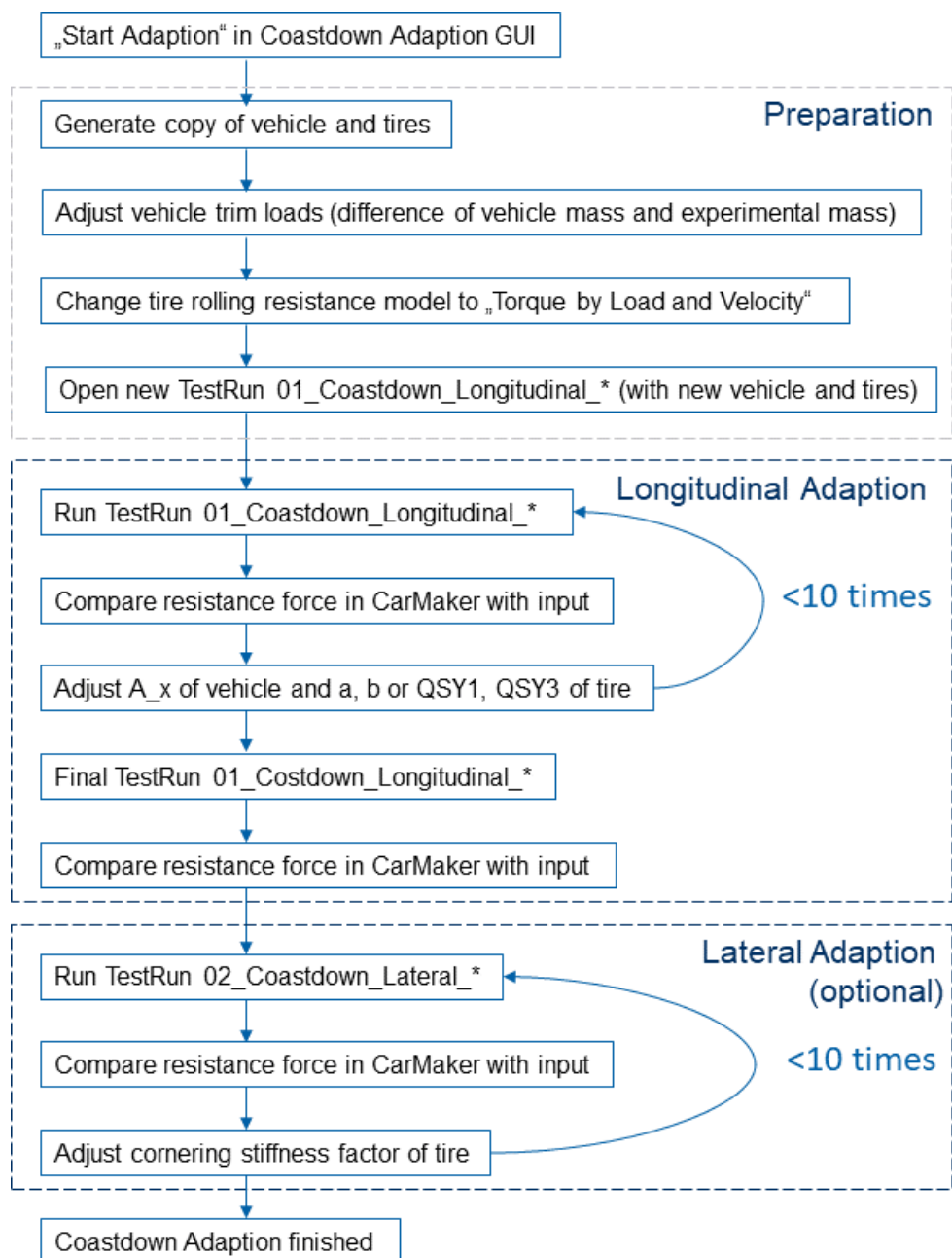


Figure 4-3: Workflow of the Coastdown Adaption tool

4.4 Results of Coastdown Adaption Tool

After performing a Coastdown Adaption, the following files are available:

- New vehicle infofile based on the originally selected vehicle with...
 - ... custom filename or a "_CDA" suffix
 - ... adjusted cross sectional area (see "Aerodynamics" section in vehicle)
 - ... added or adjusted trim loads for matching the correct experimental mass
 - ... different tire references (see below)
- New tire infofile(s) based on the originally referenced tires with...
 - ... rolling resistance model "Torque by Load and Velocity"
 - ... adjusted tire parameters "a" and "b" in the case of "RealTime Tire" or "Roll.QSY1" and "Roll.QSY3" in the case of "Magic Formula Tire"
 - ... adjusted cornering stiffness factor (if lateral adaption was performed with RealTime Tire)
- Copy of the Coastdown Adaption TestRun(s) with the generated vehicle referenced

By simply choosing the generated vehicle in your TestRuns, you can perform your simulations with the adjusted resistance according to the coastdown measurement.

5 Accuracy

As the Coastdown Adaption tool is not adding a polynomial resistance function, but changing parameters of the vehicle and tire, there will be a small difference between measurement and simulation.

The deviation between the determined polynomial function in the simulation and the measurement for straight line coastdown is usually within a range of < 1 N. Consequently, a relative accuracy better than 1 % is typically achievable.

For the longitudinal adaption, this small deviation is determined within several adjustments steps of three parameters. The parameter changes coming from the add-on are limited to the third decimal place. More decimal places would lead to slightly better results on the paper, but would suggest an accuracy that is not realistic.

For the lateral adaption the stiffness factor of the lateral force is adjusted to achieve better results. As this is a very simplified approach and kinematics and suspension setup have a big influence on the rolling resistance (e.g. ackermann, camber, toe-in, etc.), the accuracy will not be as good as for longitudinal adaptations. The influence of kinematic parametrization and suspension can be up to 10 %. Additionally, there is some kind of cross influence between the parameters that are modified during the longitudinal adaption and the cornering resistance.

6 Release History

6.1 Version 1.20

New Features

- Trim loads for driver and co-driver are now considered as user option. Rest mass remains mandatory in case of difference between experimental mass and vehicle mass. The amount of rest mass must be calculated by pressing the *Update* button before starting adaption.
- The user may now define geometrical coordinates for driver, co-driver and rest mass. Initial values are estimated based on vehicle dataset.
- The user may now define driver and co-driver mass. Default value for each is 75 kg.

Changes

- Bugfix: The sum of rotational mass and experimental mass was used to calculate additional trim loads for the vehicle. Now only the experimental mass is used to calculate trim loads. Rotational mass should be specified when user input coefficients f_0 , f_1 and f_2 are based on an approach that requires equivalent effective mass for rotational components of the powertrain (see ISO 10521-1). Coastdown Adaption will consider rotational mass for road load comparison.
- Existing trim loads in the vehicle dataset will not be changed any more. In previous versions an existing trim load could be modified in certain situations.

6.2 Version 1.19

New Features

- CarMaker 11 supported

6.3 Version 1.18

New Features

- The filenames of all generated files are customizable. In previous versions, only the filename of the vehicle could be adapted. Now the filenames for the generated tires are customizable as well. Assuming identical tires for left and right side of an axle, editing the filenames independently for up to four axles in case of using TruckMaker is possible.
- Determining the longitudinal coefficients for a straight line coastdown without performing an adaption is now supported. This feature takes the vehicle selected in the CarMaker Main GUI to perform a longitudinal coastdown. Providing values in the entry fields of the Coastdown Adaption GUI is not necessary. The vehicle itself does not change. The calculated coefficients are printed to the session log.

Changes

- The template TestRun for a lateral coastdown with CarMaker 10 has changed. Now the vehicle starts on a straight road and subsequently enters the 360° turn tangentially. This

setup allows for executing the TestRun under various conditions (e.g. non-default steering model or a large z-coordinate of CoG).

- The initial velocity for the lateral coastdown now differs between two vehicle categories. In case of CarMaker the initial velocity is calculated with a maximum lateral acceleration of 6 m/s², in case of TruckMaker it's 3 m/s².
- After a successful adaption a comparison of newly calculated vehicle and tire parameters with those of the starting configuration is pointed out in the session log. Moreover, the generated files are listed. Consequently, the final popup window, known from previous versions of Coastdown Adaption, is not necessary any more.
- In case of errors during the execution of the coastdown TestRuns, the generated files are now deleted.
- During the vehicle parameter evaluation the aerodynamics table is checked for providing data for pure frontal incident flow.

6.4 Version 1.17

New Features

- CarMaker 10 supported

6.5 Version 1.16

New Features

- Magic Formula Tire supported for longitudinal coastdown adaption. However, mixing RealTime Tire and Magic Formula Tire on one vehicle is not supported.

Changes

- Negative coefficients f0, f1, f2 for longitudinal coastdown are now highlighted with yellow background color in CDA GUI. Nevertheless, it is possible to start the adaption.
- In case of providing non-numeric values for f0, f1 or f2, the "Start adaption" button is disabled.
- The description of all generated vehicle and tire files contain information about time, date and version of an executed adaption.

6.6 Version 1.15

Changes

- Negative coefficients f0, f1, f2 for longitudinal coastdown can result in model parameters that are out of valid range (especially tire model). In previous versions of CDA, the execution of the adaption was aborted in these cases. Now CDA is trying to go ahead with simulation and finally will ask the user if storage of results should be carried out.
- Negative coefficients f0, f1, f2 for longitudinal coastdown are now highlighted in CDA GUI. Nevertheless, it is possible to start the adaption.

6.7 Version 1.14

New Features

- CarMaker 9 supported

6.8 Version 1.13

New Features

- Electric (and hybrid) vehicles now automatically switched to StrategyMode_trg=3 (Coasting) and PT.Control.Motor.Load is set to 0. Therefore friction of the electric motor is considered, but without recuperation.

Changes

- Maneuver 2 changed to manual pedal positions
- Vehicle is only saved between TestRuns if changes are applied.

6.9 Version 1.12

New Features

- CarMaker 8 supported

6.10 Version 1.11

New Features

- Masses defined in powertrain bodies supported

6.11 Version 1.10

Changes

- Bugfix: CarMaker Main GUI could freeze in some cases

6.12 Version 1.9.9

Changes

- Bugfix: Opening a configuration dialog which is already opened lead to a tcl error

6.13 Version 1.9.8

New Features

- CarMaker 7 supported

6.14 Version 1.9.7

Changes

- Acceleration maneuver in TestRuns deleted to support usage of trucks
- Bugfix: Wrong vehicle mass was calculated when twin tires were used

6.15 Version 1.9.6

Changes

- Usage of no aerodynamic model or wrong mass ($m_{\text{exp}} < m_{\text{vehicle}}$) avoided
- If tire files should be overwritten, user will be asked in advance
- TestRun files now included in CoastDown.mod file

6.16 Version 1.9.5

New Features

- Already existing trim loads now recognized

Changes

- Bugfix: If stop button was pressed the adaption did not fully stop in some cases

7 Abbreviations

Abbreviation	Description
CDA	Coastdown Adaption
CoG	Center of gravity
GUI	Graphical User Interface

Table 7-1: Used Abbreviations