CHAPTER 3:

SIMULATION PROGRAM

3. Simulation program

In chapter 1 the need for a two-dimensional vehicle simulation program was explained. Chapter 2 described the mathematical model for such a simulation program as well as the use of the LFOPC optimisation code, in conjunction with which the vehicle model is to be optimised with respect to certain vehicle parameters. In this chapter the simulation program Vehsim2d, that was developed to fulfil the first need, is described.

3.1 Introduction

A demonstration version of the program is included on compact disc in appendix B. The simulation program Vehsim2d is used to simulate two dimensional vehicle dynamics. The program is two-dimensional and can only simulate the pitch and bounce of the vehicle over symmetrical obstacles, i.e. the same route profile underneath the left and right wheels. The effect of different inputs under the left and right wheels as well as the effect of anti-roll bars cannot be simulated by Vehsim2d, and can only be done by using a three-dimensional vehicle dynamics program. It is proposed that Vehsim2d is to be used during the concept design phase and that a complete three-dimensional simulation be used during the detail design phase if necessary.

For Vehsim2d the individual suspension modules of a vehicle is broken up into a spring, damper, bump stop, suspension geometry and tyre characteristics. The suspension characteristic of a component is prescribed using a six piece-wise continuous linear representation of the stiffness versus deflection, or damping force versus deflection speed relationship. The wheels of the vehicle are modelled with a spring stiffness and damping which may both be non-linear. Two tyre models are also available; a point follower and a sector tyre model.

Coupled to Vehsim2d is the optimisation algorithm LFOPC. This algorithm can be used to optimise certain specified vehicle parameters or vehicle suspension characteristics, subject to certain constraints, through the minimisation of an appropriate objective function. The characteristics that need to be optimised as well as the objective function to be used can be prescribed by the user. The details of the optimisation module is described in the next chapter.

3.2 Vehsim2d simulation capabilities

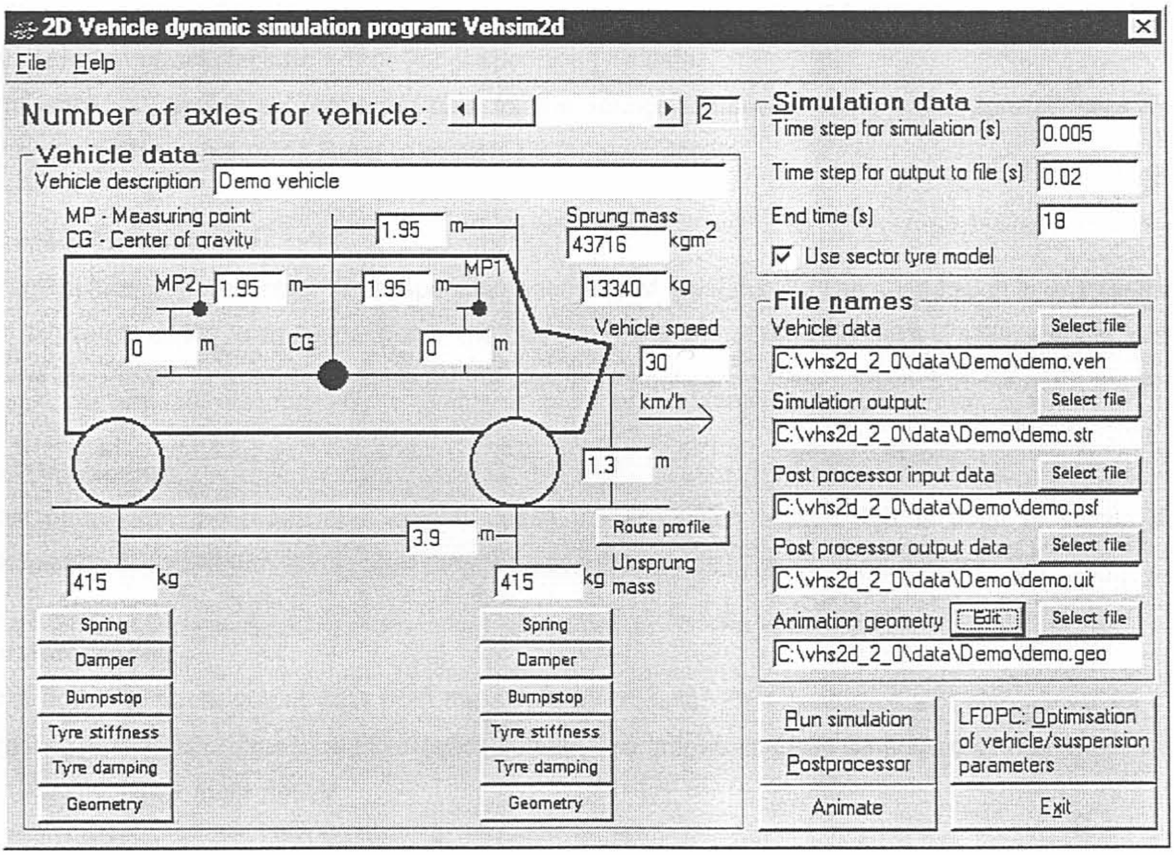
Vehsim2d is a two-dimensional vehicle simulation program and can be used to simulate the vehicle dynamics of a vehicle over symmetrical obstacles. The motion of the vehicle is simulated by prescribing the vehicle geometry, unsprung mass and inertia, the mass of the different sprung components and the suspension characteristics. The characteristics of the suspension components and the tyres may be non-linear and are prescribed using a six piece-wise continuous linear approximation for each component. The specific route profile and speed of the vehicle are also prescribed.

The dynamics of the vehicle over the specified route profile is solved during the simulations by the method detailed in chapter 2. The result of a simulation is stored and can then be analysed using a postprocessor. The postprocessor is also used to generate data for use in a coupled program, which is used to calculate ride comfort criteria for the simulation. An animation of the vehicle movement can also be done.

The constrained optimisation program LFOPC [51, 53-55] is also coupled to the program. This routine can be used to optimise user specified vehicle parameters or suspension characteristics through the minimisation of a user specified objective function. A typical example is the optimisation of the damper characteristics on specific axles in order to obtain the best ride comfort for the driver and rear passengers in the vehicle.

3.3 Program structure

Vehsim2d uses a graphical user interface (GUI) operating in a Microsoft Windows 95/98/2K/NT environment. It was developed using Microsoft Visual Basic 6.0 (Enterprise edition). Vehsim2d is divided into different functional subprograms that may be called by buttons on the main input screen of the program as shown in figure 3.1.



2D Vehicle dynamic simulation program: Vehsim2d

Number of axles for vehicle: 2

Vehicle data

Vehicle description: Demo vehicle

MP - Measuring point
CG - Center of gravity

MP2: 1.95 m, 0 m
MP1: 1.95 m, 0 m
1.95 m

Sprung mass: 43716 kgm^2, 13340 kg

Vehicle speed: 30 km/h

1.3 m

3.9 m

Unsprung mass: 415 kg, 415 kg

Simulation data
Time step for simulation (s): 0.005
Time step for output to file (s): 0.02
End time (s): 18
☑ Use sector tyre model

File names
Vehicle data: C:\vhs2d_2_0\data\Demo\demo.veh
Simulation output: C:\vhs2d_2_0\data\Demo\demo.str
Post processor input data: C:\vhs2d_2_0\data\Demo\demo.psf
Post processor output data: C:\vhs2d_2_0\data\Demo\demo.uit
Animation geometry: C:\vhs2d_2_0\data\Demo\demo.geo

Figure 3.1: Vehsim2d – Main Input Screen

Main input screen

The main screen is used to provide vehicle information relating to mass, inertia and geometry, number of axles, points of interest (measuring points), suspension components, simulation input data and relevant file names for simulation input and results. The execution of the various tasks: simulation, postprocessing, suspension optimisation, editing of the animation geometry and performing animation, are also available through the options and buttons displayed on the main input screen. The pull-down menu is used to open and save the vehicle files and to provide access to the help files. See 3.6 for more detail on the main input screen.

A short discussion of the main features available through interaction with the main input screen now follows.

Animation geometry editor

This editor is used to edit or create the vehicle geometry required for the animation. Only the geometry of the vehicle hull is required. See section 3.7 for more details.

Two dimensional data editor (for route profile data)

This editor is used to prescribe the data for the route profile used in the simulation. Route profile data is given as a two-dimensional data array with data sets for the distance and height of the road profile. Section 3.8 gives more details.

Suspension characteristic editor (for suspension/tyre data)

This editor is used to prescribe the data for the springs, dampers, bump stops, tyre stiffness and damping for the simulation. Refer to section 3.9 for more details.

Suspension geometry

This input screen prescribes the suspension geometry of the vehicle. The suspension is analysed as an equivalent trailing arm suspension. The position of the virtual reaction point is prescribed in terms of the distance in front and height above the relevant wheel centre. See section 3.10 for more details.

Run simulation

This button (on the main input screen) loads the simulation screen that is used to initiate the calculation of equilibrium and to start the simulation. Section 3.11 gives more details.

Postprocessor

This option extracts output data from the simulation results. The postprocessor also allows for the drawing of graphs of prescribed simulation output. The graphs can also be printed. Refer to sections 3.12 and 3.13 for more details.

Animate

The animation feature may be used to get a subjective feel of the simulation being performed. See section 3.14 for more details.

LFOPC: Optimisation of vehicle/suspension parameters

This button enables the selection of the design variables and appropriate objective function to be used by the optimisation algorithm LFOPC. Paragraph 3.15 gives more detail on the optimisation.

3.4 Simulations

A vehicle is modeled by prescribing the general vehicle characteristics, i.e. unsprung mass, unsprung pitch inertia, position of centre of gravity, number of axles and axle placement. Data for the springs, dampers, bump stops, tyre stiffness, tyre damping and suspension geometry of the different axles are also prescribed. The route profile, vehicle speed and simulation time steps are prescribed. Once all the required data is available the simulation can be performed. The entire vehicle, suspension and simulation data are saved in a vehicle file (*.veh). The first step during simulations is to perform the equilibrium calculations by means of which the equilibrium position of the vehicle is determined. Once equilibrium is obtained, the simulation can be commenced. With the forces known the accelerations are available and by using a fourth order Runga-Kutta technique the velocity and displacements of the different components are calculated at prescribed time instants during the ride. All these results are saved in a simulation output (.str) file.

Once the simulation is completed, the postprocessor can be used to extract the required simulation results and to write these to a postprocessor output (*.out) file. The required selection for output from the postprocessor is saved in a postprocessor input file (*.psf). The output of the postprocessor can be graphed using the graph option. The postprocessor can also be used to generate a file for ride comfort analysis (*.rcd) that can be used in performing ride comfort analysis with a separate module. Other buttons available on the postprocessor screen can be used for initiating the calculation of the root mean square, minimum and maximum values (*.rms) and the calculation of a vibration dose value (*.vdv).

An animation of the simulation can be done using the animator. For this purpose a geometry file (*.geo) is required which prescribes the geometry of the vehicle body. This animation geometry file can be compiled using the available geometry editor.

Optimising the suspension requires the selection of design variables, connecting vehicle/suspension characteristics to the design variables and specifying the objective function to be used. The input for the optimising algorithm is saved in the lfopc.dat, lfopc_fun.dat and lfopc_par.dat files. Once these values are prescribed the optimisation can be performed. This will automatically perform a simulation of the vehicle, run the postprocessor, draw graphs of the objective functions, change the design variables and the required vehicle characteristics and loop the simulation until the minimum objective function has been obtained within the constraints specified. Output for the optimisation process is written to the lfopc.out and lfopc.grf files.

3.5 Vehsim2d files

The program Vehsim2d uses default extensions to identify different files used during the simulations. The following tables give a summary of the files used.

Table 3.1: Vehsim2d files - Program files

File name	Extension	File type	Comments
Vehsim2d	.exe	Executable	The Vehsim2d executable file
Vehsim2d	.hlp	Help file	The Vehsim2d help file

Table 3.2: Vehsim2d files - Component, vehicle and output files

File name	Extension	File type	Comments
Vehicle	.veh	ASCII	Vehicle, suspension and simulation data
Vehicle	.str	Binary	Simulation output file
Vehicle	.out	ASCII	Output file for postprocessor
Vehicle	.psf	ASCII	Postprocessor input file
Vehicle	.geo	ASCII	Animation geometry data file
Vehicle	.rcd	ASCII	Output file for ride comfort analysis
Vehicle	.rms	ASCII	Output file for rms values
Vehicle	.vdv	ASCII	Output file for vdv values

Note: *The name "Vehicle" shown above is used for demonstration purposes, the actual name is given by the user during creation of the files.*

Table 3.3: Optimisation files – Input and output files

File name	Extension	File type	Comments
Lfopc	.dat	ASCII	Input file with optimisation variables and constraints
Lfopc_fun	.dat	ASCII	Input file with objective function data
Lfopc_par	.dat	ASCII	Input file with general optimisation data
Parameters	.lst	ASCII	File with vehicle parameters available
Fun_parameters	.lst	ASCII	File with objective function parameters available
Lfopc	.out	ASCII	Output file for optimisation algorithm
Lfopc	.grf	ASCII	Detail output file for optimisation algorithm and input for optimisation graphs

Note: *The file names shown above are fixed and will be overwritten each time input/output are changed.*

3.6 Main input screen

Via these sub frames the main input screen (see figure 3.1) is used to supply the following:

- vehicle data,
- simulation data, and
- file names.

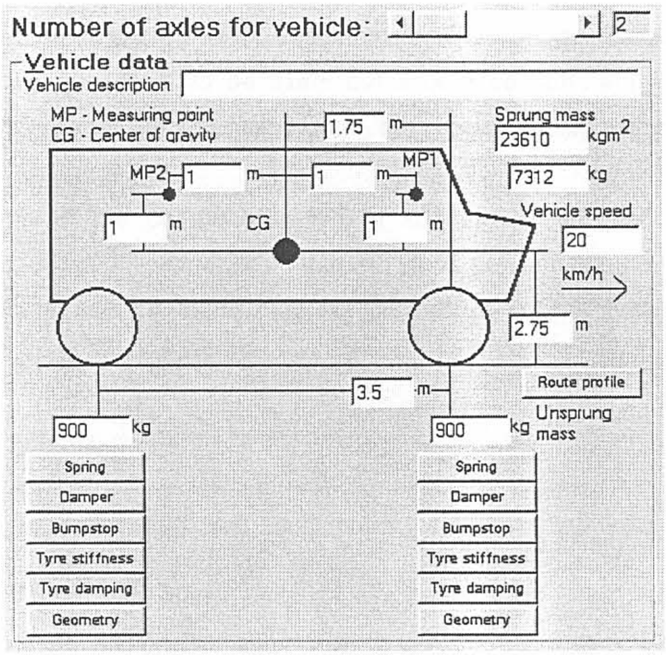
This screen is also used for the following:

- Saving and opening of vehicle files: use the "File" menu item and click on "File Open" or "File Save".
- Exit the program: use the "File" menu and click on "Exit" or click the "Exit" button. The user will be prompted to save the vehicle file before closing the program.
- Obtaining help: click on the "Help" menu item.

Note: *If calculation of equilibrium was performed with one of the options where the bump stop initial deflections were reset during equilibrium calculations then the calculated initial deflections for the springs will be saved in the vehicle when saving the vehicle file. For more details see Run simulation (Section 3.11)*

The respective sub frames introduced above are now individually dealt with below.

3.6.1 Vehicle data



Number of axles for vehicle: 2

Vehicle data

Vehicle description

Sprung mass 23610 kgm^2

7312 kg

Vehicle speed 20 km/h

Unsprung mass 900 kg (left), 900 kg (right)

Figure 3.2: Main Input Screen - Vehicle data

Number of axles:

Select the number of axles for the vehicle using the provided scroll bar. The number of axles that can be selected range between two and four.

Enter the general vehicle data:

- Unsprung mass.
- Pitch inertia of unsprung mass about the centre of gravity (CG) of the unsprung mass.
- Position of the CG: the horizontal position is prescribed as the distance between the front axle and the CG and the vertical position (height) is defined from the road surface.
- Positions of two measuring points, points of interest or monitoring points. The accelerations, velocities and displacements of these two points and that of the CG will be computed during the simulation and saved as simulation time histories. The two special points are usually situated at the driver and at the rear passenger seats.
- Axle placements as indicated. The distances between the axle centres are prescribed.
- Vehicle speed in km/h.
- Vehicle description in alphanumeric characters.

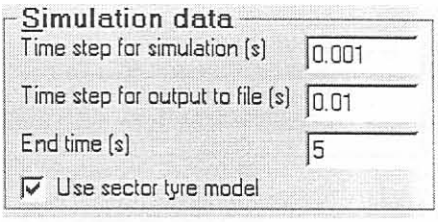
Click on the provided buttons to input data for the following:

- General and two-dimensional data for the springs, dampers and bump stops.
- General and two-dimensional data for the tyres.
- Suspension geometry.
- Route profile.

Note*: The initial conditions for the vehicle model are specified as close as possible to static equilibrium. For simulation purposes initial deflection for the springs, bump stops and tyres are prescribed. These values need not to be exact but should be sufficiently realistic to aid in the calculation of equilibrium. Before the simulation is run, the precise equilibrium position is calculated.*

Warning*: Even if some of the components of the suspension are not used, data for those components must be specified. For example if no bump stops are simulated the bump stop data must contain a zero type characteristic, i.e. in this case the force will be 0 for all deflections.*

3.6.2 Simulation data



Simulation data

Time step for simulation (s) 0.001

Time step for output to file (s) 0.01

End time (s) 5

☑ Use sector tyre model

Figure 3.3: Main Input Screen - Simulation data

Enter the following:

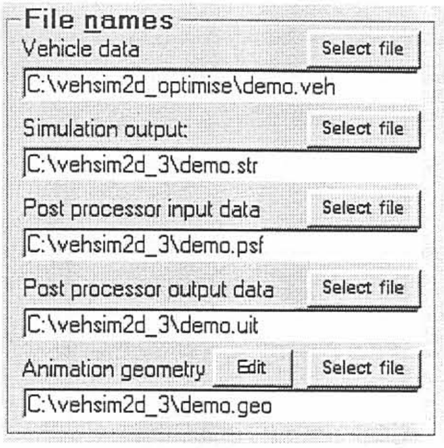
- Time step for simulations: The time step for solving the equation of motion for velocities and displacements during simulation. A fourth order Runga-Kutta technique is used for the numerical integration. In general the time step should be as small as possible for accuracy but this will have a detrimental effect on the time required to perform the simulation. A general guideline, obtained through years of vehicle simulation experience, is to allow for eight simulation steps for a specific obstacle in the route profile. For example, if a simulation over a 200 mm half round discrete obstacle is done at 18 km/h, a time step for every 25 mm of vehicle longitudinal movement is required. At 18 km/h the vehicle travels at 5.0 m/s. For 25 mm of travel a time step of 0.025 / 5 = 0.005 s is required. For a "smoother" route profile a longer time step may be used.
- Time step for output to file: this is the time interval at which the simulation results are to be saved to the output file (*.str). A maximum of 3800 saving steps per file are allowed.
- End time: The end time for the simulation.

Options:

Two tyre models are available in the program: A point follower model in which the tyre deflection is calculated at a single point vertically below the tyre centre. This tyre model is appropriate for simulation over smooth profiles where the obstacle "radius" is larger than two times that of the tyre radius. The second and default model is a tyre sector model that is used for more severe obstacles that have radii smaller than two times the tyre radius. In this model the tyre is divided into 40 sectors and the deflection and force for each sector is calculated and combined to obtain the resultant tyre force. The sector tyre model requires a longer computational time so, if appropriate, rather select the point follower model for faster running simulations. The point follower model is used by de-selecting the tyre sector model in the option box provided.

Note: *The selected tyre model is not saved with the vehicle file. Each time the program is started the tyre model will default to the sector model. Ensure that the required tyre model is selected before the simulation or optimisation is run.*

3.6.3 File names



File names

Vehicle data: C:\vehsim2d_optimise\demo.veh

Simulation output: C:\vehsim2d_3\demo.str

Post processor input data: C:\vehsim2d_3\demo.psf

Post processor output data: C:\vehsim2d_3\demo.uit

Animation geometry: C:\vehsim2d_3\demo.geo

Figure 3.4: Main Input Screen - File names

This frame groups the main input file names for the simulation:

Vehicle data

The file name for the vehicle data (*.veh). Selecting this file does not open the specific file, it only indicates the vehicle file name for saving the vehicle data when using the “File”, “File Save” pull-down menu item. Selecting a vehicle file will put default file names in the other file name text boxes if these were empty before selecting the vehicle file. To open a specific vehicle file, use the “File”, “File Open” pull-down menu item.

Simulation output

The name for the simulation output file (*.str). This can be an existing or new file.

Postprocessor input data

The postprocessor input data file (*.psf). This file indicates the required values to be extracted from the simulation output file during use of the postprocessor. This can be an existing or new file.

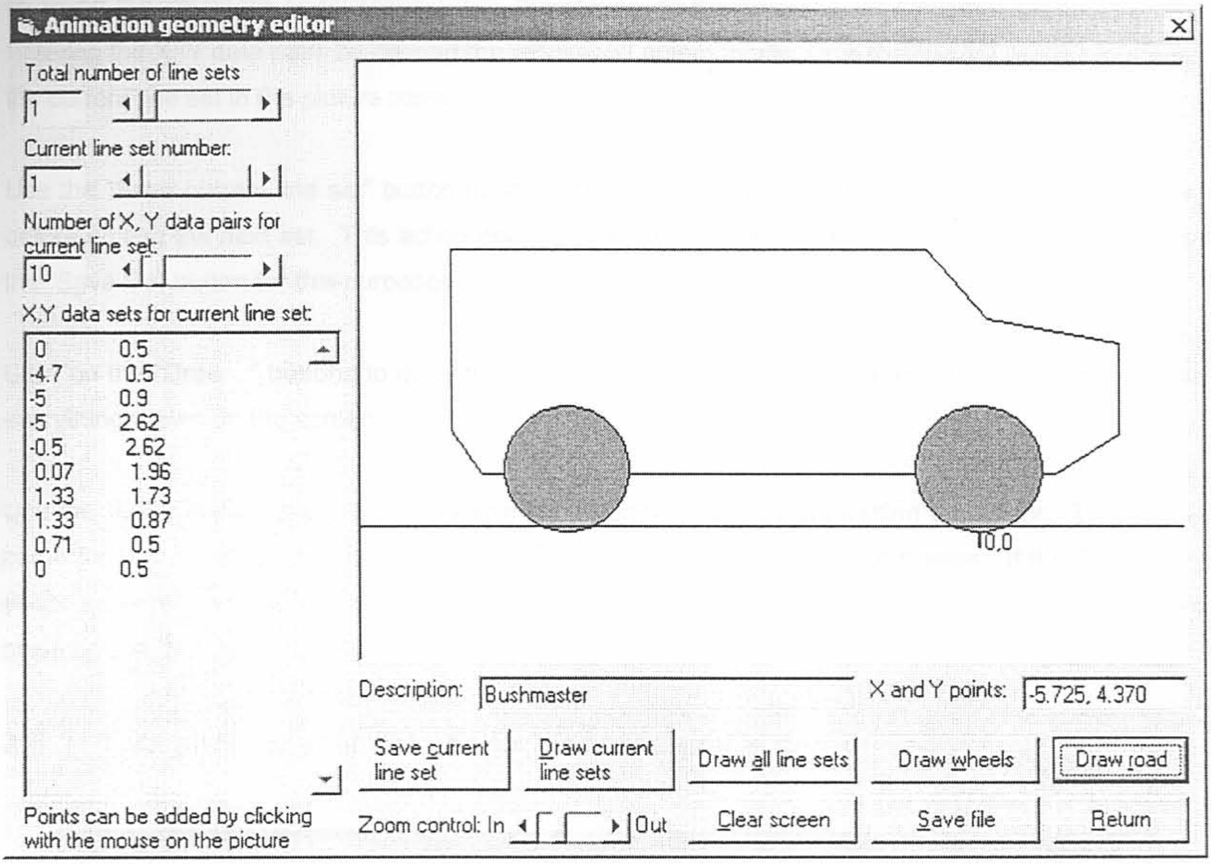
Post processor input data

The name for the postprocessor output file (*.out). This file will be used for saving the output of the postprocessor. An existing or new file can be selected.

Animation geometry

The animation geometry data file (*.geo). This file prescribes the geometry of the vehicle as drawn for the animations. Use the “Edit” button to edit / create this file.

3.7 Animation geometry editor



Animation geometry editor

Total number of line sets: 1

Current line set number: 1

Number of X, Y data pairs for current line set: 10

X,Y data sets for current line set:

0	0.5
-4.7	0.5
-5	0.9
-5	2.62
-0.5	2.62
0.07	1.96
1.33	1.73
1.33	0.87
0.71	0.5
0	0.5

Points can be added by clicking with the mouse on the picture

Description: Bushmaster

X and Y points: -5.725, 4.370

Figure 3.5: Animation geometry editor

The animation geometry editor is used to edit the prescribed geometry of the vehicle for the animation. In figure 3.5 the X,Y data pairs successively indicates the start and end co-ordinates of the lines, outlining the body of the vehicle. Point 0,0 is defined on the road surface below the front axle centre and the X-axis is horizontal and positive to the right. Y is the vertical axis and positive upwards.

The wheels of the vehicle are not prescribed in this file but are drawn by using the placement of the axles as prescribed on the Vehicle data frame on the main input screen. The tyre radii are as prescribed by using the "Tyre stiffness" or "Tyre damping" buttons.

Up to 20 line sets may be specified to represent the vehicle geometry. A line set is defined as a series of lines prescribed by X, Y data pairs. A line set is therefore a series of lines connecting the prescribed X, Y data pairs. Each line set can be defined by a minimum of 2 and a maximum of 100 X, Y data pairs.

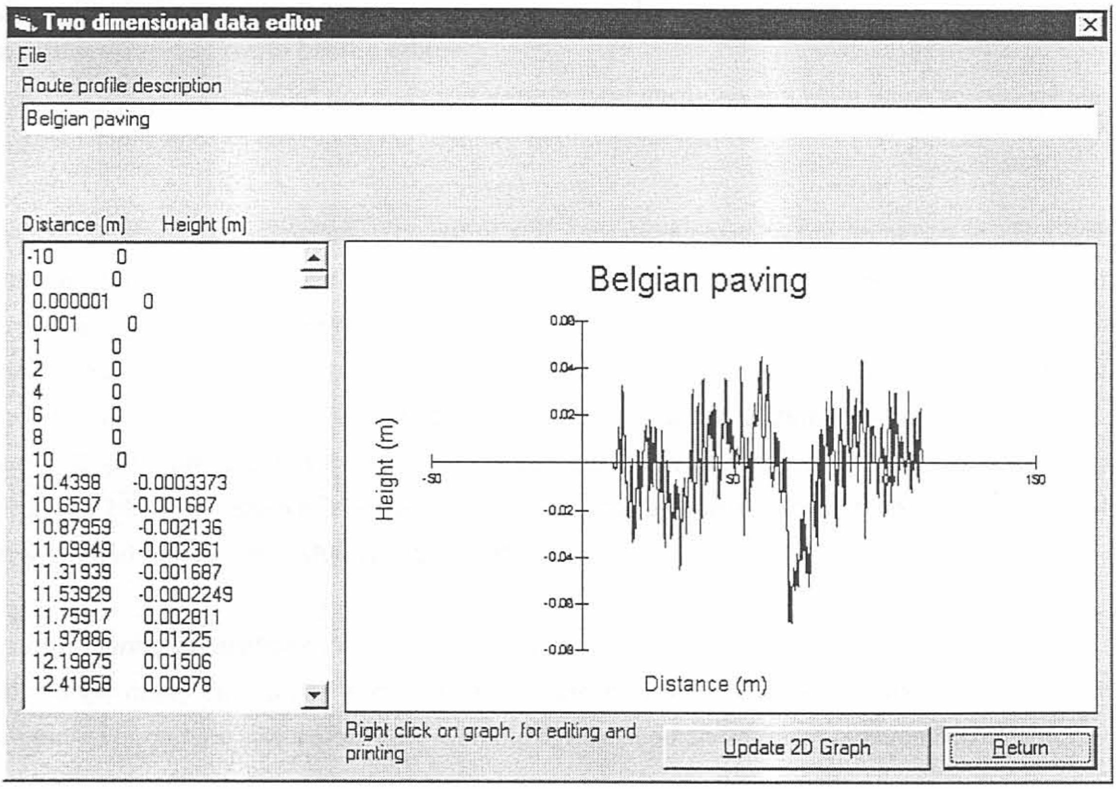
Use the scroll bars to select the total number of line sets, the current line set in edit and the number of X, Y data pairs for the current line set. The X, Y data pairs are entered into the X, Y data set text box by using the keyboard or by clicking with the mouse on the required X, Y point in the picture box. Entering the X, Y data pairs by clicking the mouse will automatically save the current line set and draw the current line set in the picture frame.

Use the "Save current line set" button to save the X, Y data pairs for the specific line set in memory before editing the next set. This action does not save the line set in the animation geometry file, use the "Save file" button for this purposes.

Click on the "Draw .." buttons to draw the indicated entities. Use the "Clear screen" button to delete everything drawn on the screen.

Use the "Save file" button to save the animation geometry file before exiting the editor. The default name for this file is prescribed on the File names frame on the main input screen. If the file already exists a warning will be displayed before overwriting the file. A new file name can be selected by pressing the "No" button on the overwrite warning and selecting a new file on the File dialog box.

3.8 Two dimensional data editor (for route profile data)



Route profile description: Belgian paving

Distance (m)	Height (m)
-10	0
0	0
0.000001	0
0.001	0
1	0
2	0
4	0
6	0
8	0
10	0
10.4398	-0.0003373
10.6597	-0.001687
10.87959	-0.002136
11.09949	-0.002361
11.31939	-0.001687
11.53929	-0.0002249
11.75917	0.002811
11.97886	0.01225
12.19875	0.01506
12.41858	0.00978

Figure 3.6: Two dimensional data editor for route profile data

This editor (as shown in figure 3.6) is used to edit the two dimensional data for the route profile.

General operation

The two dimensional data is entered in the text box displayed at the bottom left of the screen. Data is entered by specifying the X and Y values of successive points for the two-dimensional data pairs. X and Y values must be separated by one or more spaces or by a comma. Clicking the "Update 2D Data and graph" button will sort the data pairs in increasing X-values and display a graph. Identical X-values will be edited during this operation by adding a very small value to each identical X-value. The graph is drawn by cubic spline interpolation of the X, Y data set. For drastic changes in Y-values prescribe small X-value increments for accurate interpolation. A straight line is obtained by prescribing three data pairs. *A minimum of 3 data pairs and a maximum of 1000 data pairs are allowed.*

The two-dimensional data set can be saved to a file by using the "File", "Save data to a file" menu item on the pull-down menu. The "File", "Import data from a file" pull-down menu item can also be used to load previously saved data from an existing file. The file to be imported should be an ASCII text file with the X, Y data pairs in free format. *No default extensions are used for these files, the user can name these files using his own format for later identification.*

Right click on the graph to edit the graph to activate the Graph Control window in order to select the print option, change headings, etc. Detailed help on the Graph Control is available by clicking the "Help" button.

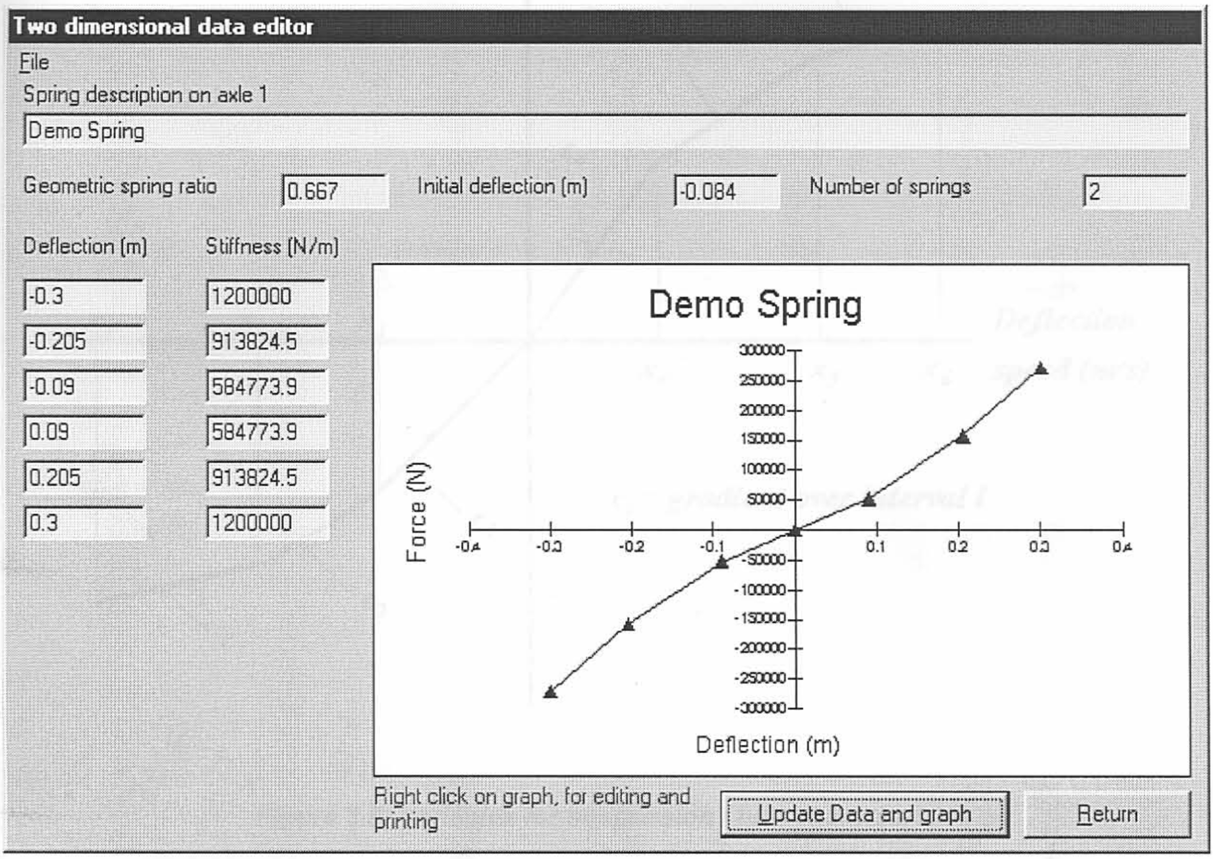
Detail description of route profile editor

Clicking on the "Route profile" button in the Vehicle data frame on the Main input screen will activate the editor. The following describes the input for the route profile:

Enter the route profile description. The set of X, Y data pairs describe the route profile. The point 0,0 is defined as a point at ground level underneath the front axle centre. The height of the front axle centre is equal to the tyre radius minus the tyre deflection plus the Y value. The X-value is the horizontal distance from 0 and positive in the direction of travel. The Y-data is positive for an increase in height. Remember to prescribe data points for the route profile underneath the vehicle at time = 0 s as well. Due to the fact that the point 0,0 is defined below the front axle the road below the other wheels will have a negative X-value. To aid the calculation of equilibrium prescribe a flat and horizontal road beneath the wheels at time = 0 s.

***Warning**: During simulations interpolation / extrapolation of the prescribed data is used. To avoid extrapolation make sure that the characteristics are prescribed for the complete range that will be experienced during the simulations. No warning is displayed should extrapolation be required.*

3.9 Suspension characteristics editor (for spring, damper, bump stop, tyre stiffness and tyre damping)



Spring description on axle 1: Demo Spring

Geometric spring ratio: 0.667

Initial deflection (m): -0.084

Number of springs: 2

Deflection (m)	Stiffness (N/m)
-0.3	1200000
-0.205	913824.5
-0.09	584773.9
0.09	584773.9
0.205	913824.5
0.3	1200000

Right click on graph, for editing and printing

Figure 3.7: Two dimensional data editor (for suspension components)

This editor is used to edit the data for the suspension and tyre characteristics.

General operation

The suspension and tyre characteristics are prescribed using a six piece-wise continuous linear approximation as shown in figure 3.8 for a typical damper characteristic. Data is entered by entering the abscissas x_1 to x_6 as well as the corresponding slopes or gradients c_1 to c_6 in the text boxes supplied to the left of the graph as shown in figure 3.7. The x_1 to x_6 and c_1 to c_6 values are entered from top to bottom. Clicking the "Update 2D Data and graph" button will sort the data pairs in increasing X-values and display a graph as shown. Identical X-values will be edited during this operation by adding a very small value to each identical X-value. *All six points must be prescribed. Also note that the characteristic must pass through the origin (0,0) as indicated.* Refer to section 2.1 for more details regarding this six piece-wise continuous linear approximation.

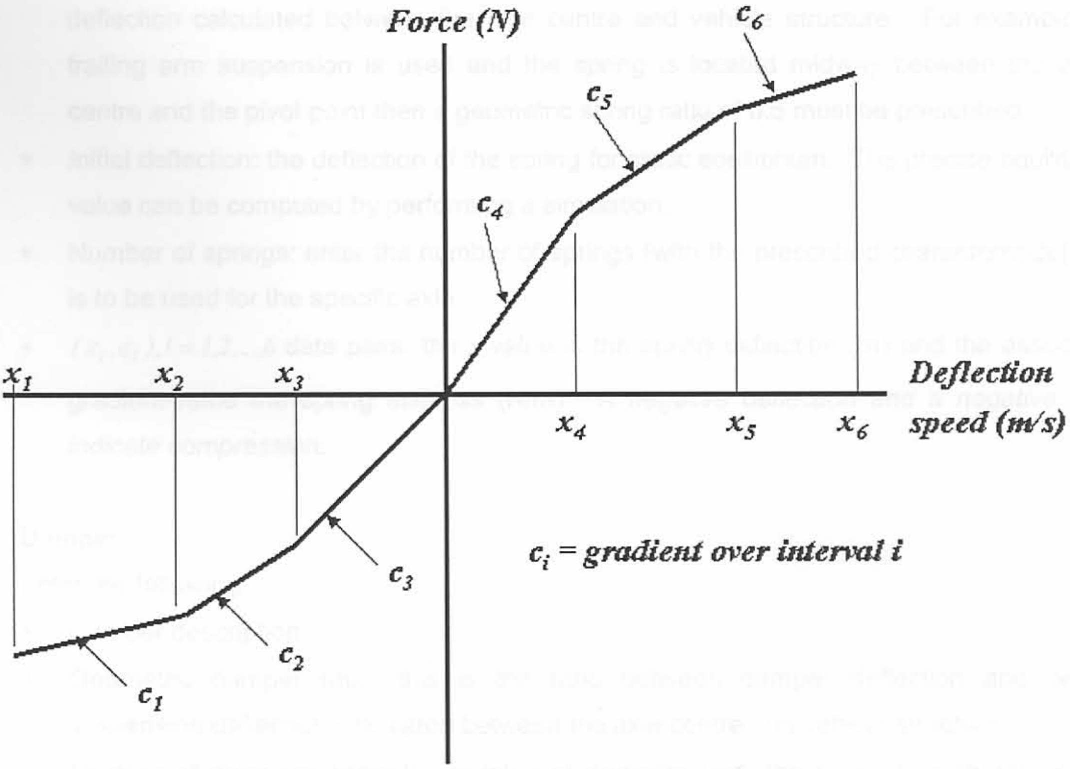


Figure 3.8: Variables for suspension / tyre characteristic

The data can be saved to a file by using the “File”, “Save data to a file” menu item on the pull-down menu. The “File”, “Import data from the file” pull-down menu item can also be used to load previously saved data from an existing file. The file to be imported should be an ASCII text file with the x_i, c_i data pairs in free format. *No default extensions is used for these files, the user can name these files using his own format for later identification.*

Right click on the graph to edit the graph to activate the Graph Control window in order to select the print option, change headings, etc. Detailed help on the Graph Control is available by clicking the “Help” button.

Detailed description of editor

Clicking on the different suspension and tyre buttons in the Vehicle data frame on the Main input screen will activate the editor. The input detail on the editor may change according to the specific button clicked. The following describe the input for the different buttons:

Spring

Enter the following:

* Spring description in alphanumeric characters.

- Geometric spring ratio: this is the ratio between spring deflection and vertical suspension deflection calculated between the axle centre and vehicle structure. For example if a trailing arm suspension is used and the spring is located midway between the wheel centre and the pivot point then a geometric spring ratio of 0.5 must be prescribed.
- Initial deflection: the deflection of the spring for static equilibrium. The precise equilibrium value can be computed by performing a simulation.
- Number of springs: enter the number of springs (with the prescribed characteristics), that is to be used for the specific axle.
- $(x_i, c_i), i = 1,2,\ldots,6$ data pairs: the x-value is the spring deflection (m) and the associated gradient-value the spring stiffness (N/m). *A negative deflection and a negative force indicate compression.*

Damper

Enter the following:

- Damper description.
- Geometric damper ratio: this is the ratio between damper deflection and vertical suspension deflection calculated between the axle centre and vehicle structure.
- Number of dampers: enter the number of dampers (with the prescribed characteristics) that is to be used for the specific axle.
- $(x_i, c_i), i = 1,2,\ldots,6$ data pairs: the x-value is the damper deflection rate (speed) (m/s) and the gradient-value the damper stiffness (damping coefficient) (Ns/m). *A negative speed and a negative force indicate compression.*

Bump stop

Enter the following:

- Bump stop description.
- Geometric bump stop ratio: this is the ratio between bump stop deflection and vertical suspension deflection calculated between the axle centre and vehicle structure.
- Initial deflection: the deflection of the bump stop for static equilibrium. The precise equilibrium value can be computed by performing a simulation. This value can be used to change the suspension travel without changing the bump data.
- Number of bump stops: enter the number of bump stops (with the prescribed characteristics) that is to be used for the specific axle.
- $(x_i, c_i), i = 1,2,\ldots,6$ data pairs: the x-value is the bump stop deflection (m) and the gradient-value the bump stiffness (N/m). *A negative deflection and a negative force indicate compression.*

Tyre stiffness

Enter the following:

- Tyre description.
- Unloaded tyre radius: this value is used for animation and calculation of tyre deflection.
- Initial deflection: the deflection of the tyre for static equilibrium. The precise equilibrium value can be computed by performing a simulation.
- Number of tyres: enter the number of tyres (with the prescribed characteristics) that is to be used for the specific axle.
- $(x_i, c_i), i = 1,2,\ldots,6$ data pairs: the x-value is the tyre deflection (m) and the gradient-value the tyre stiffness (N/m). *A negative deflection and a negative force indicate compression.* The deflection / force characteristic is that for deflection on a flat surface. The sector tyre model will estimate the deflection and force with for other types of obstacles.

Tyre damping

Enter the following:

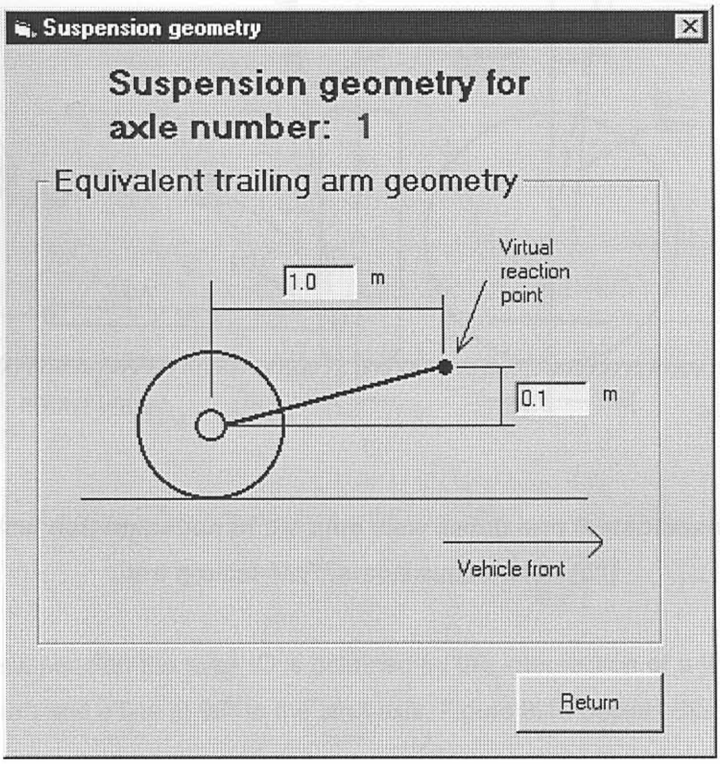
- Tyre description.
- Unloaded tyre radius: this value is used for animation and calculating tyre deflection.
- Initial deflection: the deflection of the tyre for static equilibrium. The precise equilibrium value can be computed by performing a simulation.
- Number of tyres: enter the number of tyres (with the prescribed characteristics) that is to be used for the specific axle.
- $(x_i, c_i), i = 1,2,\ldots,6$ data pairs: the x-value is the tyre deflection rate (speed) (m/s) and the gradient-value the tyre damping stiffness (coefficient) (Ns/m). *A negative deflection rate and a negative force indicate compression.* The deflection rate / force characteristic is that for deflection on a flat surface. The sector tyre model will estimate the deflection and force for other types of obstacles.

Warning:

During simulations interpolation / extrapolation of the prescribed data is performed. To limit extrapolation make sure that the characteristics are prescribed for the complete range that will be experienced during the simulations. No warning is displayed during extrapolation.

Even if some of the components on the suspension are not used, data for those components must be specified. For example, if no bump stops are to be simulated the bump stop data must contain a zero type characteristic, i.e. in this case the force will be 0 for all deflections.

3.10 Suspension geometry



Suspension geometry

Suspension geometry for axle number: 1

Equivalent trailing arm geometry

1.0 m

0.1 m

Figure 3.9: Input screen for the suspension geometry

The suspension is simulated by an equivalent trailing arm approximation (see section 2.1 for more details). For this purposes the virtual reacting point of an equivalent trailing arm is prescribed – see figure 3.9. Enter the relative co-ordinates (m) of this virtual reaction point in the appropriate text boxes. If an equivalent leading arm suspension is simulated, the horizontal distance must be entered as a negative value.

The virtual reaction point is also known as the side view swing arm instantaneous centre (svsa IC) [61]. Figures 3.10 to 3.13 show the determination of this point for some generally used suspension systems.

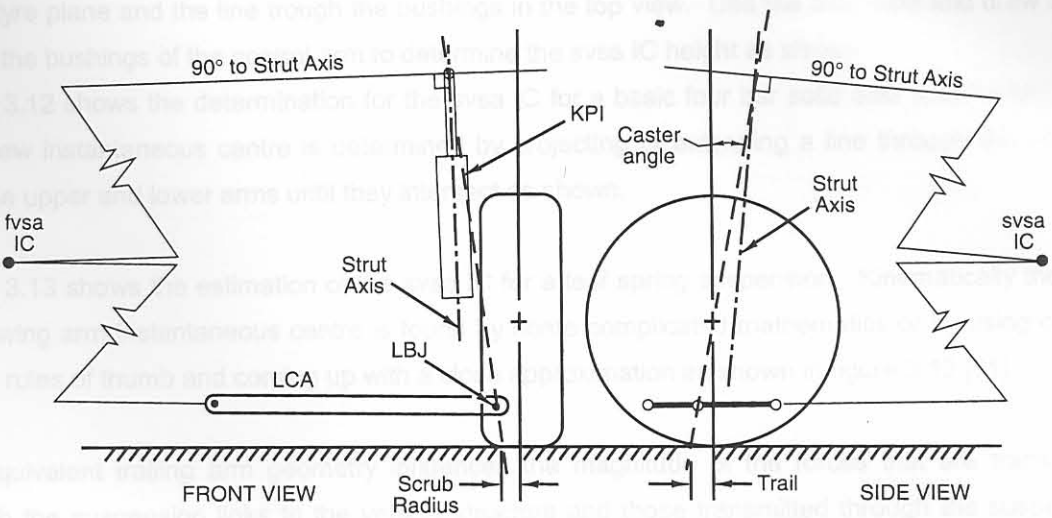


Figure 3.10: Graphical determination of the side view swing arm instantaneous centre (svsa IC) for a typical McPherson suspension [61]

For the McPherson suspension the svsa IC is obtained by the intersection of a line through the plane of the lower control arm and a line at 90º to the strut axis. Figure 3.10 depicts this construction.

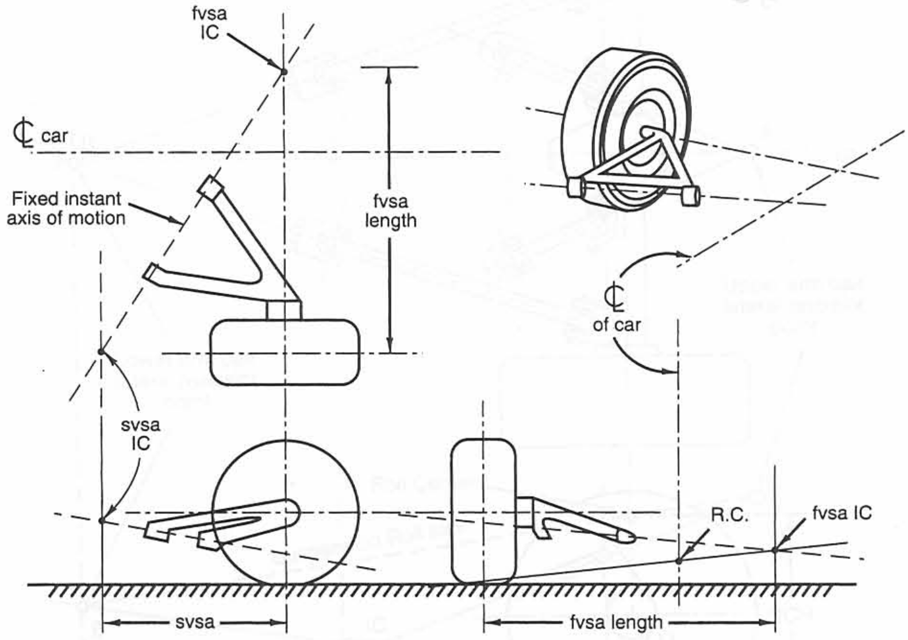


Figure 3.11: Graphical determination of the side view swing arm instantaneous centre (svsa IC) for a typical semi-trailing arm suspension [61]

The svsa IC for the semi-trailing arm is shown in figure 3.11. The svsa IC is determined by drawing a line through the swing arm bushings in a top view. The svsa length is determined by the intersection

of the tyre plane and the line trough the bushings in the top view. Use the side view and draw a line trough the bushings of the control arm to determine the svsa IC height as shown.
Figure 3.12 shows the determination for the svsa IC for a basic four bar solid axle suspension. The side view instantaneous centre is determined by projecting or extending a line through the ends of both the upper and lower arms until they intersect as shown.

Figure 3.13 shows the estimation of the svsa IC for a leaf spring suspension. Kinematically the side view swing arm instantaneous centre is found by some complicated mathematics or by using certain simple rules of thumb and coming up with a close approximation as shown in figure 3.13 [61].

The equivalent trailing arm geometry influences the magnitude of the forces that are transmitted through the suspension links to the vehicle structure and those transmitted through the suspension components (springs, dampers, etc) – refer to section 2.1 for more detail on the mathematical vehicle model. The geometry will also influence the accelerations that are experienced by the vehicle when hitting a severe obstacle such as a bump. For example, think of the difference between pulling and pushing a wheel burrow over an obstacle.

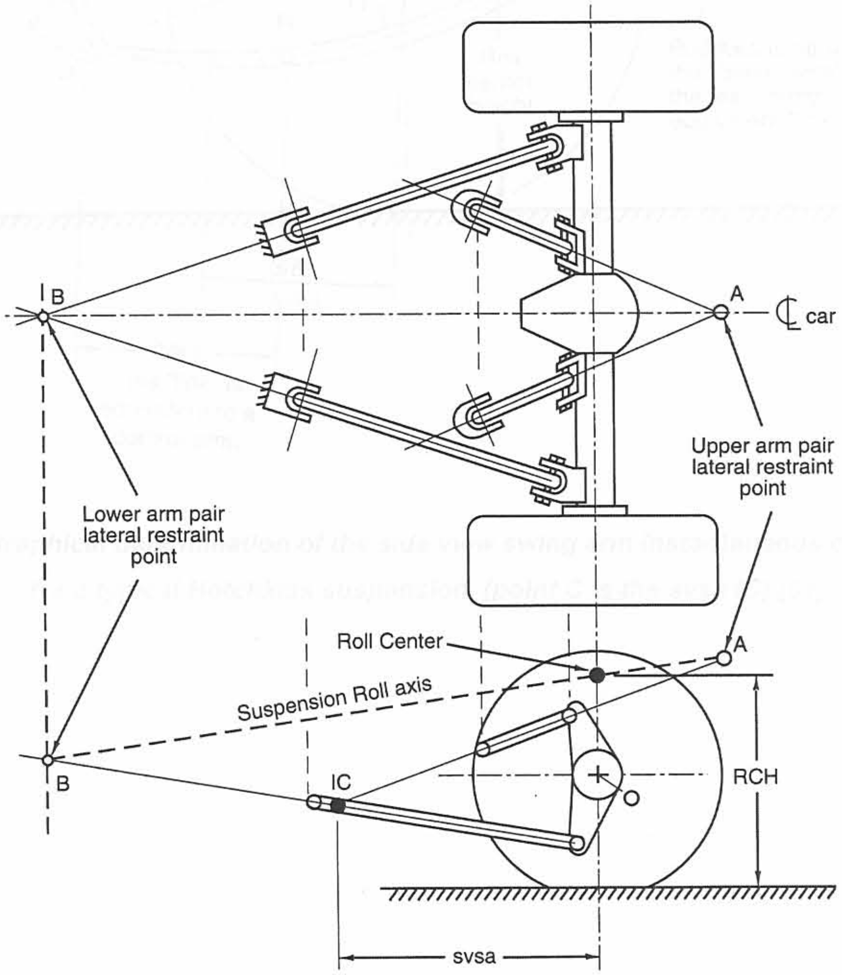


Figure 3.12: Graphical determination of the side view swing arm instantaneous centre (svsa IC) for a typical basic 4 bar suspension (point IC is the svsa IC) [61]

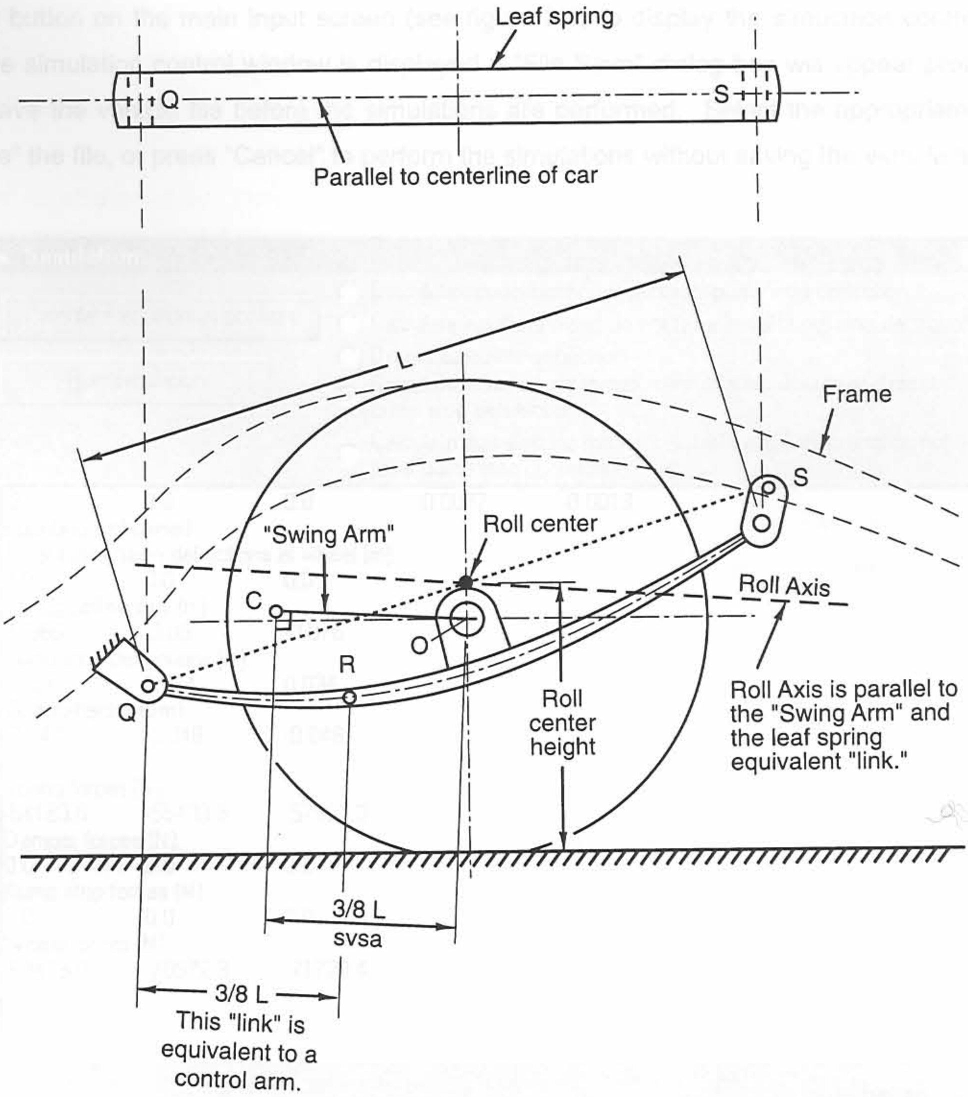
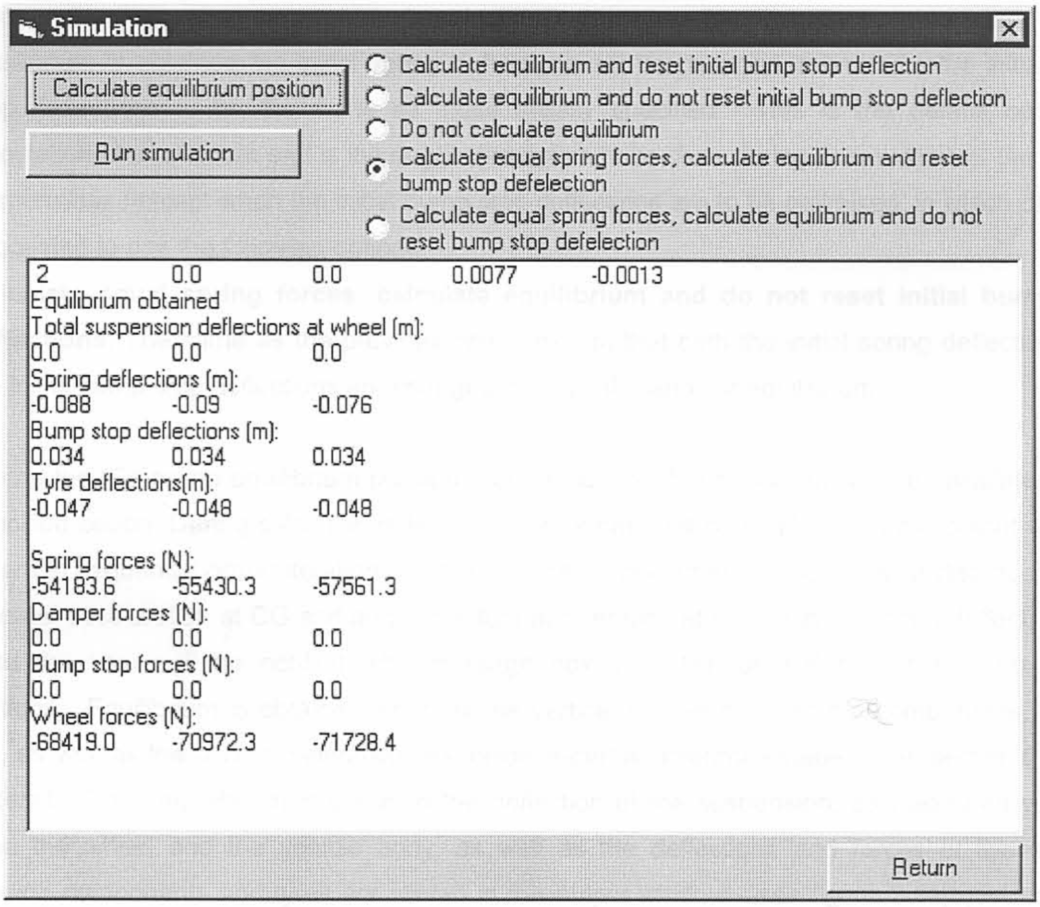


Figure 3.13: Graphical determination of the side view swing arm instantaneous centre (svsa IC) for a typical Hotchkiss suspension (point C is the svsa IC) [61]

3.11 Run simulation

Click this button on the main input screen (see figure 3.1) to display the simulation control window. Before the simulation control window is displayed a "File Save" dialog box will appear prompting the user to save the vehicle file before the simulations are performed. Select the appropriate file name and "Save" the file, or press "Cancel" to perform the simulations without saving the vehicle file.



○ Calculate equilibrium and reset initial bump stop deflection
○ Calculate equilibrium and do not reset initial bump stop deflection
○ Do not calculate equilibrium
● Calculate equal spring forces, calculate equilibrium and reset bump stop defelection
○ Calculate equal spring forces, calculate equilibrium and do not reset bump stop defelection

```
2          0.0        0.0        0.0077     -0.0013
Equilibrium obtained
Total suspension deflections at wheel (m):
0.0        0.0        0.0
Spring deflections (m):
-0.088     -0.09      -0.076
Bump stop deflections (m):
0.034      0.034      0.034
Tyre deflections(m):
-0.047     -0.048     -0.048

Spring forces (N):
-54183.6   -55430.3   -57561.3
Damper forces (N):
0.0        0.0        0.0
Bump stop forces (N):
0.0        0.0        0.0
Wheel forces (N):
-68419.0   -70972.3   -71728.4
```

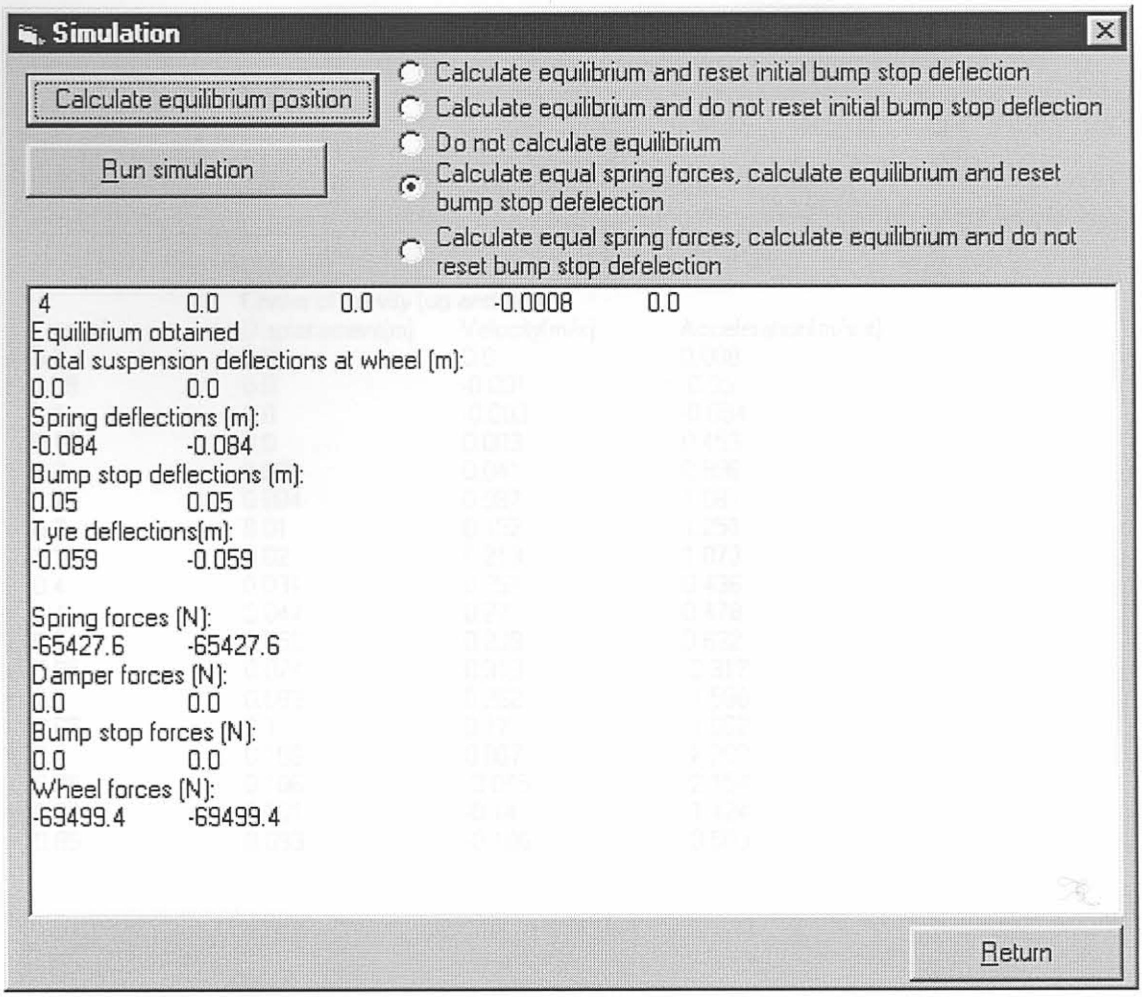
Figure 3.14(a): Simulation control

The first step is to calculate the equilibrium position. The following options for the calculation of equilibrium is available:

- **Calculate equilibrium and reset initial bump stop deflections**: This option will calculate equilibrium from the initial prescribed position (refer to section 2.1 for more detail) as specified in the vehicle file. Once equilibrium is obtained the initial spring deflections will be changed in order to keep the initial bump stop deflections the same as those initially specified – see section 3.9. This process will continue until the initial spring deflections are such that the initial bump stop deflections are the same as those initially specified. This option can be used where the exact bump stop deflection or bump stop clearance in static equilibrium is known.

- **Calculate equilibrium and do not reset initial bump stop deflections**: Equilibrium will be calculated from the initial prescribed position as specified in the vehicle file.
- **Do not calculate equilibrium**: No equilibrium position will be calculated and the simulation will start from the initial prescribed position as specified in the vehicle file.
- **Calculate equal spring forces, calculate equilibrium and reset initial bump stop deflection**: This option will start by calculating the initial spring deflections in order to obtain equal spring forces on all the axles. These equal forces are determined by the sprung weight and number of axles. Starting with the calculated spring deflections equilibrium will be calculated. Once equilibrium is obtained the initial spring deflections will be changed in order for the initial bump stop deflections to be the same as those initially specified. This is the default option for calculation of equilibrium and is the suggested option to be used during optimisation of the vehicle suspensions (except when the initial bump stop deflections are to be optimised, in which case it is suggested to use the following option).
- **Calculate equal spring forces, calculate equilibrium and do not reset initial bump stop deflections**: The same as the previous option except that both the initial spring deflections and the initial bump stop deflections are changed during calculation of equilibrium.

By clicking the "Calculate equilibrium position" button the equilibrium position will be calculated using the specified option. During calculations five columns of data will be displayed in the output window. These are in sequential order: iteration number, vertical displacement of CG, angular displacement of CG, vertical acceleration at CG and angular (pitch) acceleration at CG. If initial spring deflections are changed the user will be notified with message boxes. Click on OK to continue equilibrium calculations. Equilibrium is obtained when all the vertical accelerations of the components and the vehicle, as well as the pitch acceleration, are below a certain tolerance value – see section 2.1.2 for more detail. Once equilibrium is obtained the deflection of the suspension, as measured vertically between the wheel and the vehicle body, as well as the deflections and forces of the different suspension components and tyres are shown in the output window - see figure 3.14(b). Use these values to check that the vehicle is being simulated correctly by interpreting values for the suspension travel, static wheel loads, etc. The calculated equilibrium deflections can also be used to change the suspension component data for initial deflections closer to the required value to ensure that the vehicle is modelled close to static equilibrium – see section 3.9 for input of these initial values. When using one of the options where the initial spring deflections are changed during equilibrium calculations, saving the vehicle file will automatically store the new values to the vehicle file. ***It is necessary to perform the equilibrium calculation before each simulation run.***



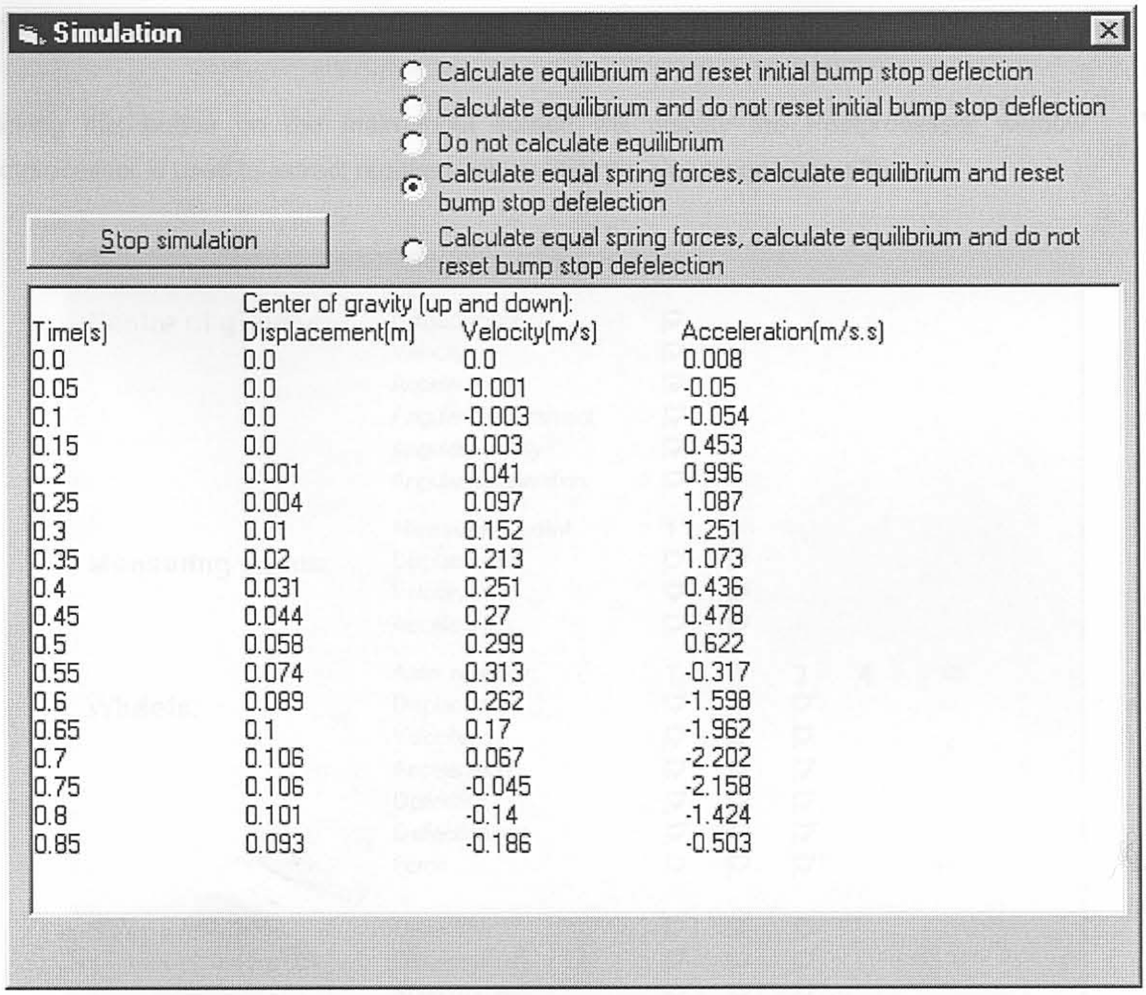
○ Calculate equilibrium and reset initial bump stop deflection
○ Calculate equilibrium and do not reset initial bump stop deflection
○ Do not calculate equilibrium
● Calculate equal spring forces, calculate equilibrium and reset bump stop defelection
○ Calculate equal spring forces, calculate equilibrium and do not reset bump stop defelection

```
4           0.0         0.0         -0.0008         0.0
Equilibrium obtained
Total suspension deflections at wheel (m):
0.0         0.0
Spring deflections (m):
-0.084      -0.084
Bump stop deflections (m):
0.05        0.05
Tyre deflections(m):
-0.059      -0.059

Spring forces (N):
-65427.6    -65427.6
Damper forces (N):
0.0         0.0
Bump stop forces (N):
0.0         0.0
Wheel forces (N):
-69499.4    -69499.4
```

Figure 3.14(b): Equilibrium obtained

Click the "Run simulation" button to start the simulation. Simulation results for the movement of the centre of gravity at the specified output time intervals will be displayed on the screen – see figure 3.15. Once the simulation is started the "Stop" button will be available and can be used to stop the simulation prematurely. Results up to the time at which the simulation was stopped will be available in the output file (*.str). Alternatively, when the end time is reached, the simulation will stop and the "Return" button will be available.



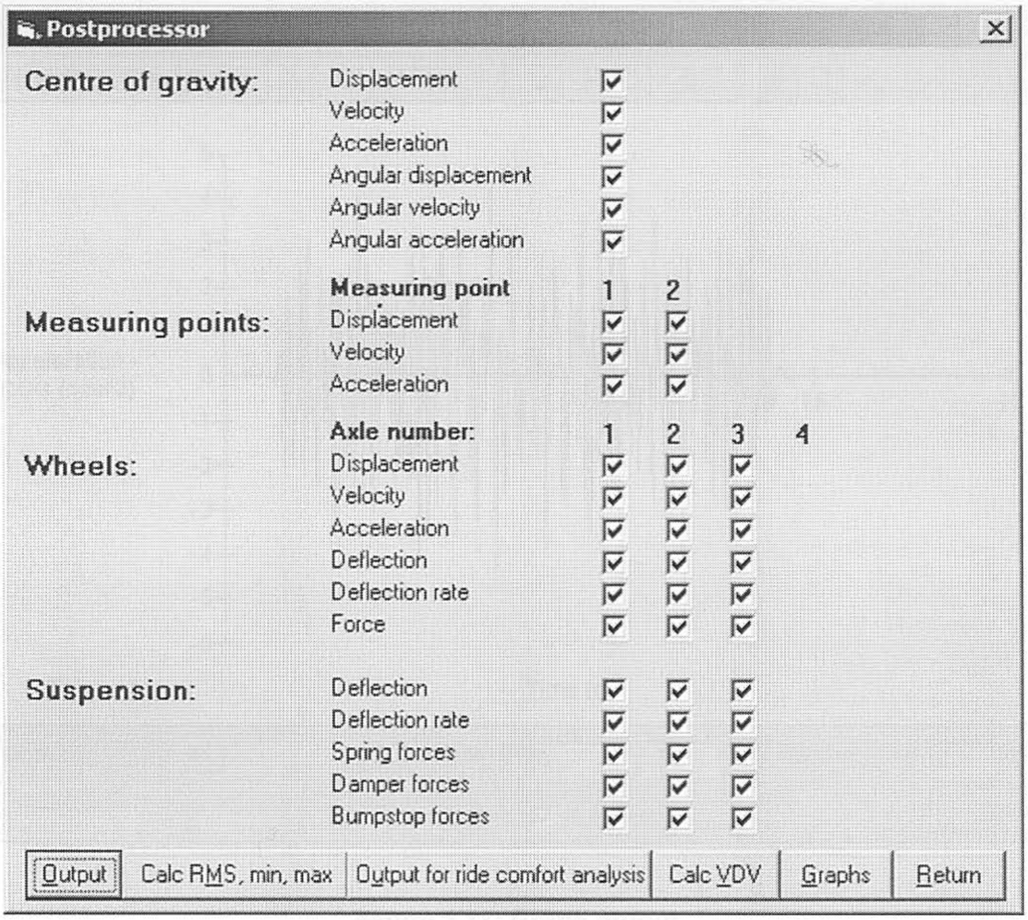
○ Calculate equilibrium and reset initial bump stop deflection
○ Calculate equilibrium and do not reset initial bump stop deflection
○ Do not calculate equilibrium
● Calculate equal spring forces, calculate equilibrium and reset bump stop defelection
○ Calculate equal spring forces, calculate equilibrium and do not reset bump stop defelection

```
           Center of gravity (up and down):
Time(s)    Displacement(m)   Velocity(m/s)   Acceleration(m/s.s)
0.0        0.0               0.0             0.008
0.05       0.0               -0.001          -0.05
0.1        0.0               -0.003          -0.054
0.15       0.0               0.003           0.453
0.2        0.001             0.041           0.996
0.25       0.004             0.097           1.087
0.3        0.01              0.152           1.251
0.35       0.02              0.213           1.073
0.4        0.031             0.251           0.436
0.45       0.044             0.27            0.478
0.5        0.058             0.299           0.622
0.55       0.074             0.313           -0.317
0.6        0.089             0.262           -1.598
0.65       0.1               0.17            -1.962
0.7        0.106             0.067           -2.202
0.75       0.106             -0.045          -2.158
0.8        0.101             -0.14           -1.424
0.85       0.093             -0.186          -0.503
```

Figure 3.15: Performing simulations

3.12 Postprocessor

Clicking this button on the main input screen will display the Postprocessor window. The postprocessor is used to extract required values from the simulation output file.



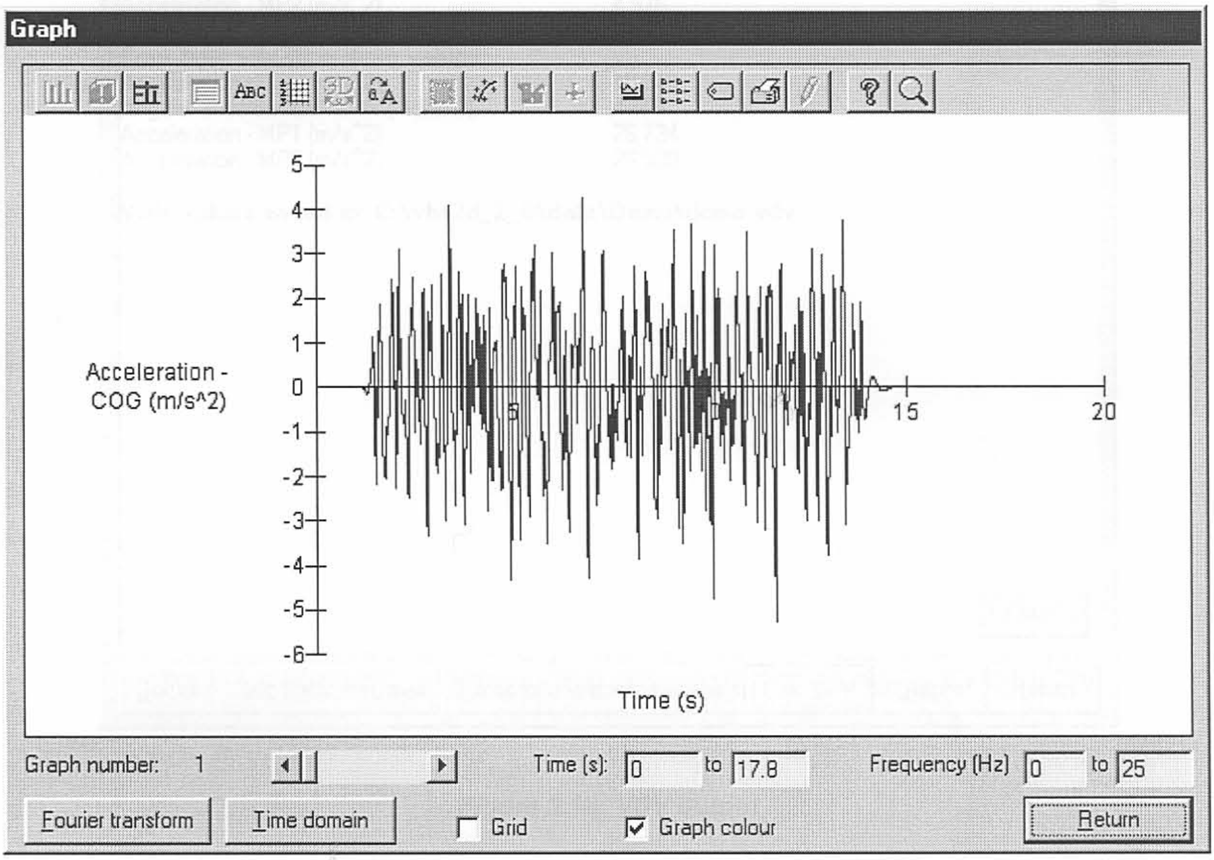
Centre of gravity:	Displacement	☑			
	Velocity	☑			
	Acceleration	☑			
	Angular displacement	☑			
	Angular velocity	☑			
	Angular acceleration	☑			
	Measuring point	1	2		
Measuring points:	Displacement	☑	☑		
	Velocity	☑	☑		
	Acceleration	☑	☑		
	Axle number:	1	2	3	4
Wheels:	Displacement	☑	☑	☑	
	Velocity	☑	☑	☑	
	Acceleration	☑	☑	☑	
	Deflection	☑	☑	☑	
	Deflection rate	☑	☑	☑	
	Force	☑	☑	☑	
Suspension:	Deflection	☑	☑	☑	
	Deflection rate	☑	☑	☑	
	Spring forces	☑	☑	☑	
	Damper forces	☑	☑	☑	
	Bumpstop forces	☑	☑	☑	

Figure 3.16 Postprocessor input

Select the required values for output by using the option boxes available. Selections as previously used and stored in the postprocessor file (*.psf) will be selected when the postprocessor is activated. The selection will automatically be saved to this file when the postprocessor is closed. The selection made here will not influence the output created during optimisation. In this instance all the available output will be written to the output files.

Click on the "Output" button to extract the required values. This will also save the extracted data to the postprocessor output file (*.out). Once these extractions are completed the "Graph", "Calc RMS,min,max", "Output for ride comfort analysis" and "Calc VDV" buttons will be available for the user.

The "Graphs" button is used to display graphs of the postprocessor output. Help on the graph is available by using the buttons at the top of the graph. These buttons can both be used to change the appearance of the graph and for printing the graph (use the "System" button for printing). For more details see section 3.13.



Graph number: 1

Time (s): 0 to 17.8

Frequency (Hz) 0 to 25

☐ Grid

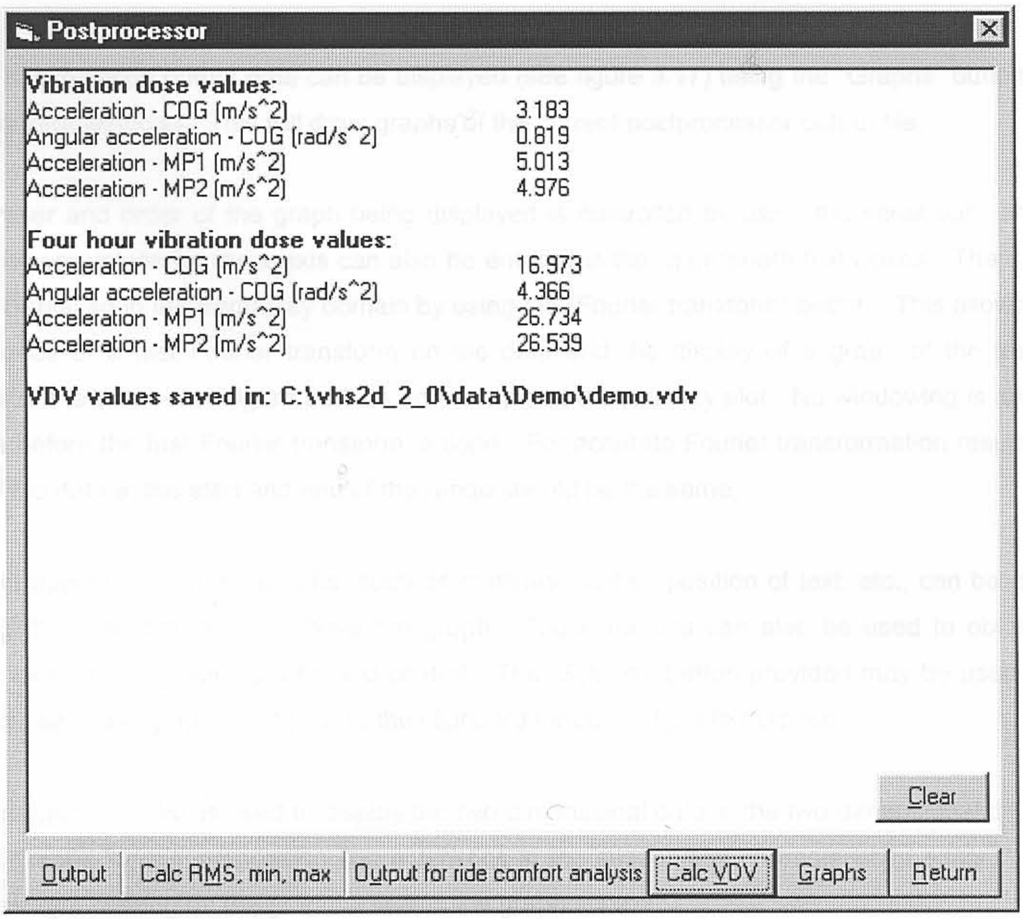
☑ Graph colour

Figure 3.17: Graph output

The "Calc RMS, min, max" button is used to calculate these values for the selected output. The results are also stored in a file (*.rms).

Clicking the "Output for ride comfort analysis" button will create a file (*.rcd) for use with a separate module to calculate the ride comfort of the vehicle according to different criteria. This file contains column data for time, CG vertical acceleration, CG pitch acceleration, vertical acceleration at position MP1 (monitoring point 1) and vertical acceleration at position MP2 (monitoring point 2).

The "Calc VDV" button can be used to calculate the vibration dose values for the simulation performed – see figure 3.18 for an example of calculated VDV values. This calculation is not as comprehensive as that used by the separately available ride comfort analysis program and must only be use for estimation purposes or optimisation. Again it is emphasized that for more accurate values the separately available ride comfort program should be used.



```
Vibration dose values:
Acceleration - COG [m/s^2]                   3.183
Angular acceleration - COG [rad/s^2]         0.819
Acceleration - MP1 [m/s^2]                   5.013
Acceleration - MP2 [m/s^2]                   4.976

Four hour vibration dose values:
Acceleration - COG [m/s^2]                   16.973
Angular acceleration - COG [rad/s^2]         4.366
Acceleration - MP1 [m/s^2]                   26.734
Acceleration - MP2 [m/s^2]                   26.539

VDV values saved in: C:\vhs2d_2_0\data\Demo\demo.vdv
```

Figure 3.18: VDV output

Warning

If the postprocessor output file (.out) already exist when the postprocessor is activated the "Graphs" button will be available in the postprocessor window. If a new simulation was performed, first click on the "Output" button to update the postprocessor output file before using the "Graph" button*

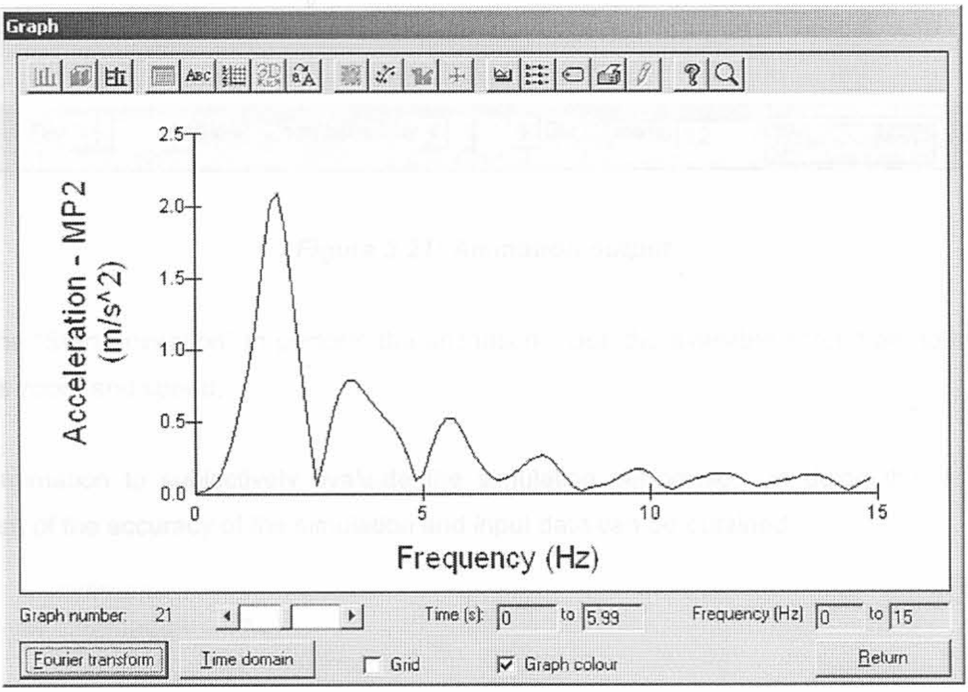
3.13 Graphs

Graphs of simulation output data can be displayed (see figure 3.17) using the "Graphs" button on the postprocessor windows. This will draw graphs of the current postprocessor output file.

The number and order of the graph being displayed is controlled by using the scroll bar. Minimum and maximum values for the x-axis can also be entered in the appropriate text boxes. The data can also be displayed in the frequency domain by using the "Fourier transform" button. This allows for the performance of a fast Fourier transform on the data and the display of a graph of the frequency contents of the data – see figure 3.20 as an example of a frequency plot. No windowing is applied to the data before the fast Fourier transform is done. For accurate Fourier transformation results the y-value of the data at the start and end of the range should be the same.

Details in appearance of the graphs, such as gridlines, scales, position of text, etc., can be changed by using the available buttons above the graph. These buttons can also be used to obtain more detailed help on the graph options and control. The "System" button provided may be used to print the graph, save the graph to a file or to the clipboard for cut and paste purposes.

The same graph control is used to display the two-dimensional data in the two-dimensional data editor and the graphs for the suspension characteristics in the suspension characteristics editor. In these instances right clicking on the graph activates the graph control.



Graph number: 21

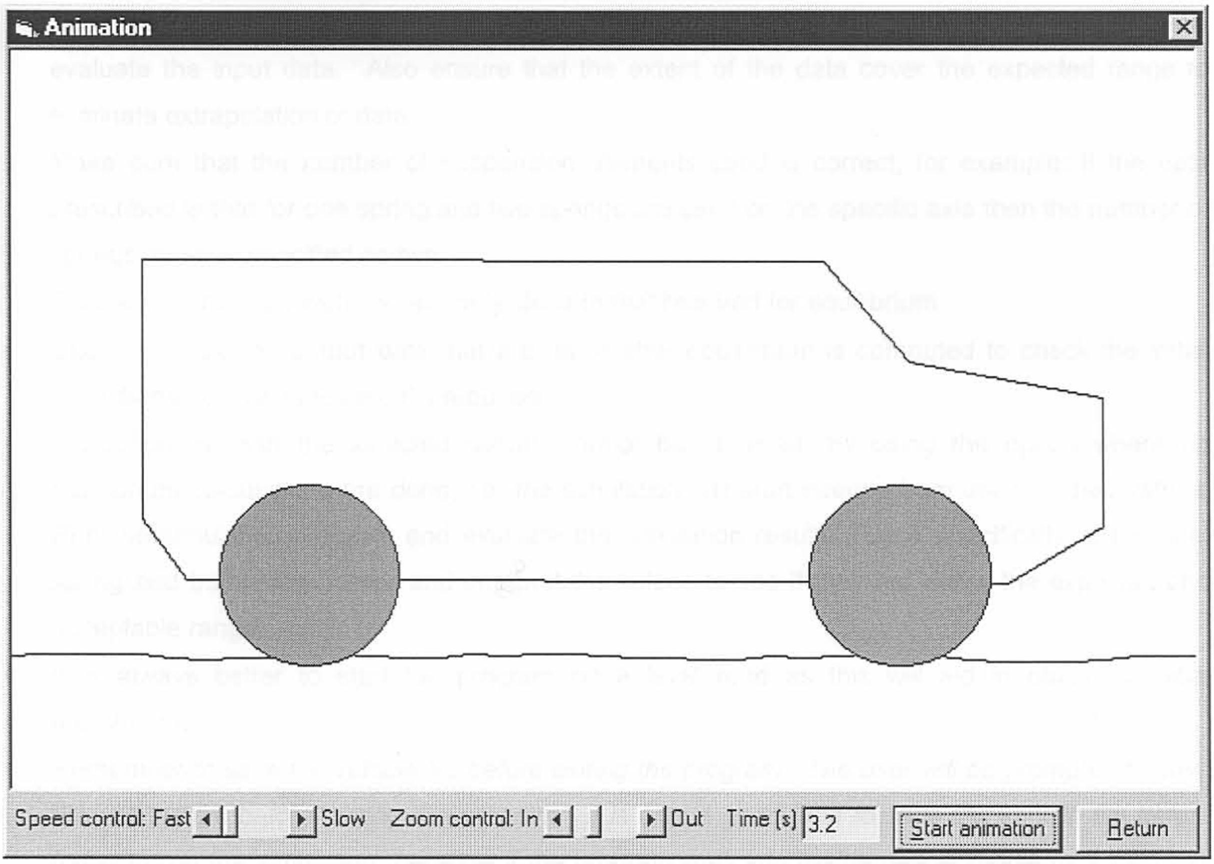
Time (s): 0 to 5.99

Frequency (Hz) 0 to 15

Figure 3.20: Graph output (frequency plot)

3.14 Animation

Use the "Animate" button on the main input screen (see figure 3.1) to perform animations of the simulation results. *Before animations can be performed the animation geometry must be created by clicking the "Edit" button on the File names frame on the main input screen to activate the animation geometry editor.* Figure 3.21 shows a snap shot of the animation at a particular instant in time.



Time (s) 3.2

Figure 3.21: Animation output

Click on the "Start animation" to perform the animation. Use the available scroll bars to change the animations zoom and speed.

Use the animation to subjectively evaluate the simulation performed. In doing this a subjective assessment of the accuracy of the simulation and input data can be obtained.

3.15 Simulation hints

The critical steps in building the vehicle model are the following:

- Geometry: make sure that all the geometrical specifications of the vehicle, i.e. position of CG, placements of axles, etc. are supplied correctly (all units are in SI units, i.e. m, kg, kgm^2, etc.)
- Ensure that the suspension/tyre data is correct and that the sign convention is applied correctly. Negative for compression (jounce) and positive for rebound. Use the graph option to subjectively evaluate the input data. Also ensure that the extent of the data cover the expected range to eliminate extrapolation of data.
- Make sure that the number of suspension elements used is correct, for example: if the data prescribed is that for one spring and two springs are used on the specific axle then the number of springs must be specified as two.
- Choose the initial deflections relatively close to that required for equilibrium.
- Use the simulation output data that are given after equilibrium is computed to check the initial deflections. Correct the model if required.
- If equilibrium, with the selected option, cannot be obtained, try using the option where no equilibrium calculations are done, i.e. the simulation will start directly from the specified values. Run the simulation program and evaluate the simulation results. Look specifically at the tyre, spring and bump stop forces and interpret the values to see if they are within the expected and acceptable range.
- It is always better to start the program on a level road as this will aid in obtaining initial equilibrium.
- *Remember to save the vehicle file before exiting the program. The user will be prompted to save the vehicle file before exiting the program. It is also a good idea to save the vehicle file before trying to run the simulation, because if the program runs into mathematical problems it may exit due to a program error and the data will be lost.*

3.16 Example Simulation

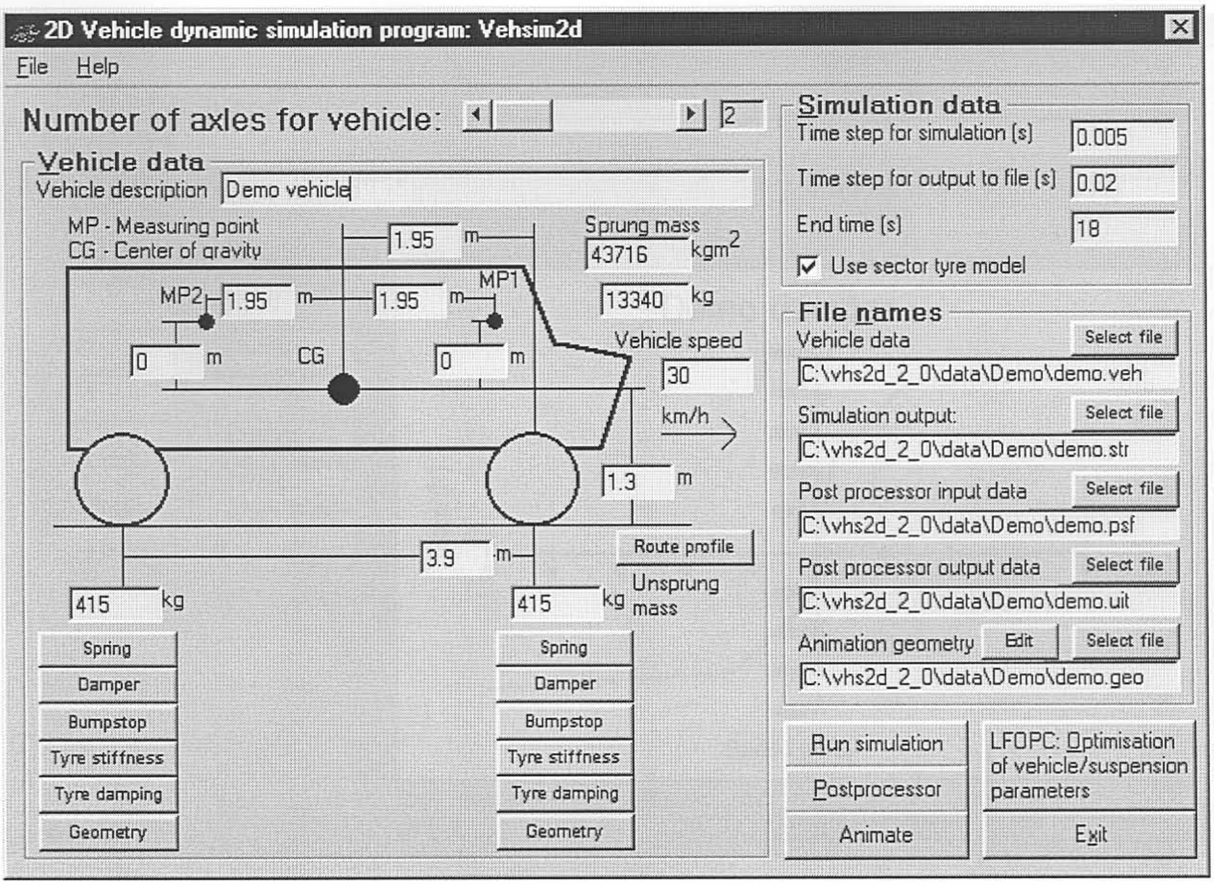
An example simulation is installed in the /data/demo directory of the installation directory as part of the installation process. The vehicle file, demo.veh, in this directory is for an example vehicle. If the program was installed into a different drive or directory, ensure that all files are specified correctly in the "File names" frame group on the main input screen after opening the vehicle file. Use the "Select file" button to select the required files. The correct files are named DEMO.*

The demo files installed are for a typical four wheel vehicle as shown in figure 3.22:

Figure 3.22: Vehicle model for the example simulation

3.16.1 Running the example

Open the vehicle file DEMO.VEH using the "File", "File Open" menu item on the pull-down menu. Once the vehicle file is opened the main input screen will be similar to figure 3.23.



2D Vehicle dynamic simulation program: Vehsim2d

Number of axles for vehicle: 2

Vehicle data
Vehicle description: Demo vehicle
MP - Measuring point
CG - Center of gravity
Sprung mass: 43716 kgm^2, 13340 kg
Vehicle speed: 30 km/h
MP2: 1.95 m, 0 m
MP1: 1.95 m, 0 m
CG: 1.95 m
1.3 m
3.9 m
Unsprung mass: 415 kg, 415 kg

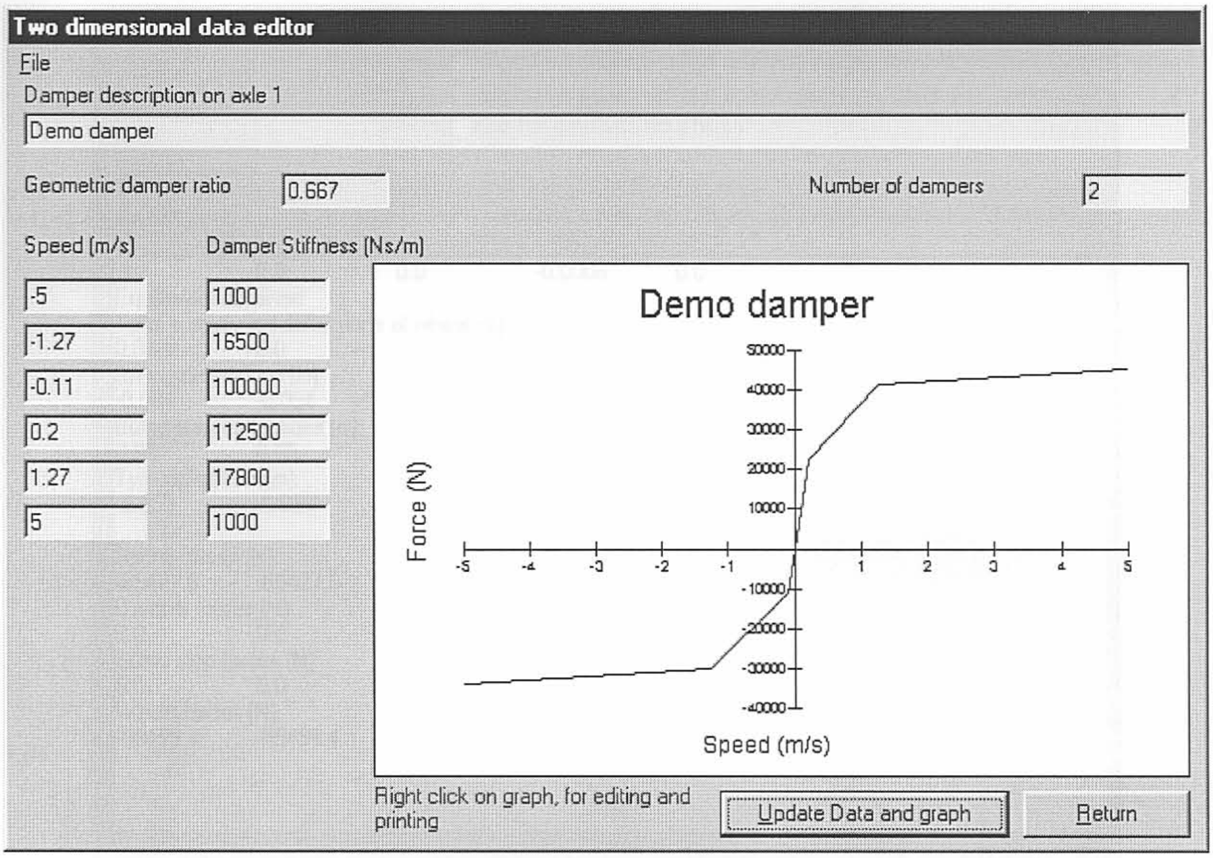
Simulation data
Time step for simulation (s): 0.005
Time step for output to file (s): 0.02
End time (s): 18
☑ Use sector tyre model

File names
Vehicle data: C:\vhs2d_2_0\data\Demo\demo.veh
Simulation output: C:\vhs2d_2_0\data\Demo\demo.str
Post processor input data: C:\vhs2d_2_0\data\Demo\demo.psf
Post processor output data: C:\vhs2d_2_0\data\Demo\demo.uit
Animation geometry: C:\vhs2d_2_0\data\Demo\demo.geo

Figure 3.23: Vehicle data for demonstration vehicle

Ensure that the other file names for the simulation are specified correctly by looking at the File names frame on the main input screen. Select the correct files named demo.* by using the "Select file" buttons provided.

The buttons below the wheels can be used to inspect the data for the different components. For example, the spring characteristic for the front axle dampers, is as displayed in figure 3.24.



Two dimensional data editor

Damper description on axle 1: Demo damper

Geometric damper ratio: 0.667

Number of dampers: 2

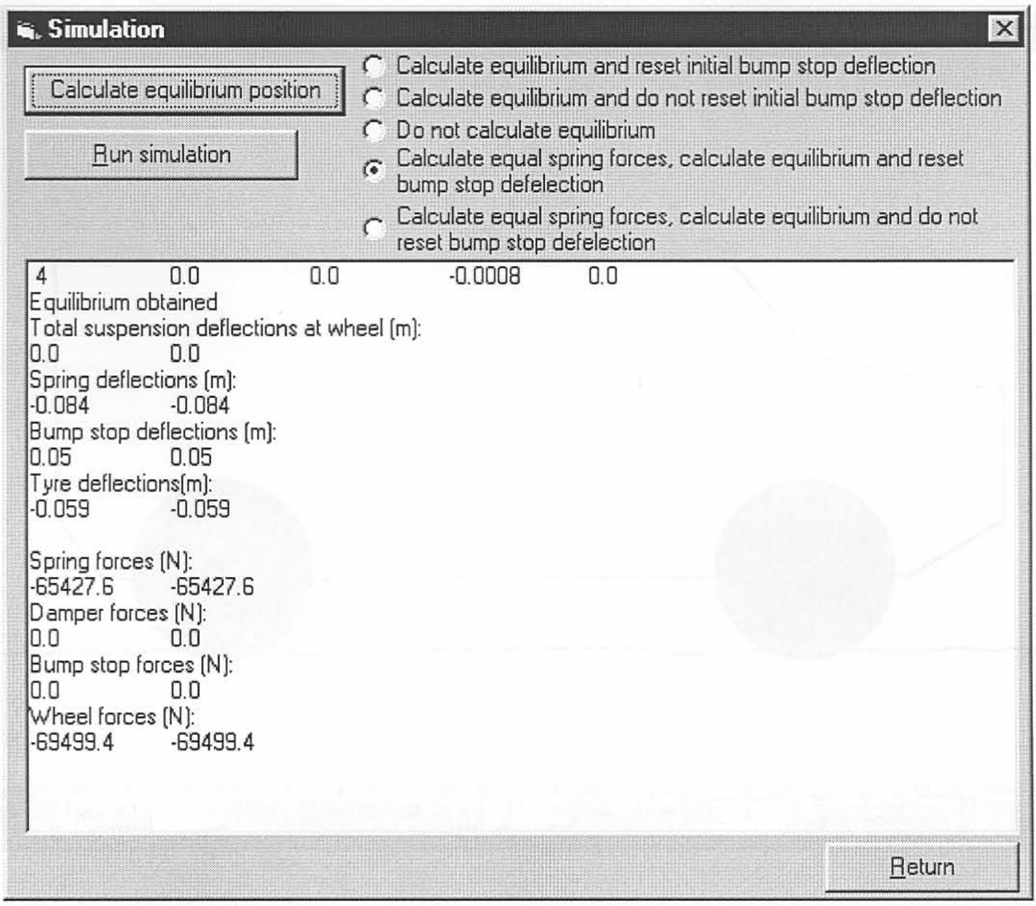
Speed (m/s)	Damper Stiffness (Ns/m)
-5	1000
-1.27	16500
-0.11	100000
0.2	112500
1.27	17800
5	1000

Right click on graph, for editing and printing

Figure 3.24: Damper data for demonstration vehicle

Use the "Update data and graph" button on the data editor to draw graphs of the characteristics.

Click on the "Run simulation" button to obtain the simulation control window. Click on the "Calculate equilibrium" button to calculate the static equilibrium for the vehicle. The results may be inspected in the window shown in figure 3.25.



○ Calculate equilibrium and reset initial bump stop deflection
○ Calculate equilibrium and do not reset initial bump stop deflection
○ Do not calculate equilibrium
● Calculate equal spring forces, calculate equilibrium and reset bump stop defelection
○ Calculate equal spring forces, calculate equilibrium and do not reset bump stop defelection

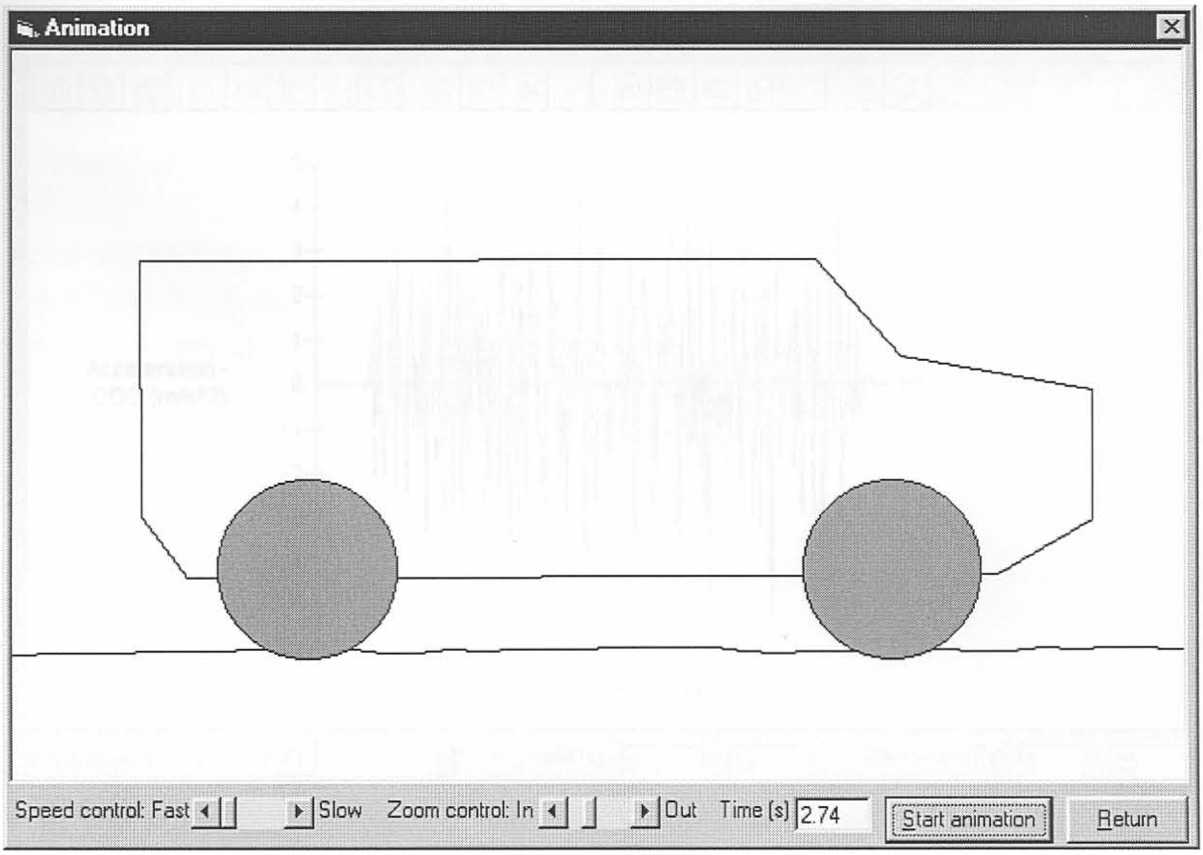
```
 4          0.0           0.0            -0.0008       0.0
Equilibrium obtained
Total suspension deflections at wheel (m):
0.0         0.0
Spring deflections (m):
-0.084      -0.084
Bump stop deflections (m):
0.05        0.05
Tyre deflections(m):
-0.059      -0.059

Spring forces (N):
-65427.6    -65427.6
Damper forces (N):
0.0         0.0
Bump stop forces (N):
0.0         0.0
Wheel forces (N):
-69499.4    -69499.4
```

Figure 3.25: Equilibrium calculations for demonstration vehicle

Once equilibrium is obtained click on the "Run simulation" button to start the simulation. After completion of the simulation, click on the "Return" button to return to the main input screen.

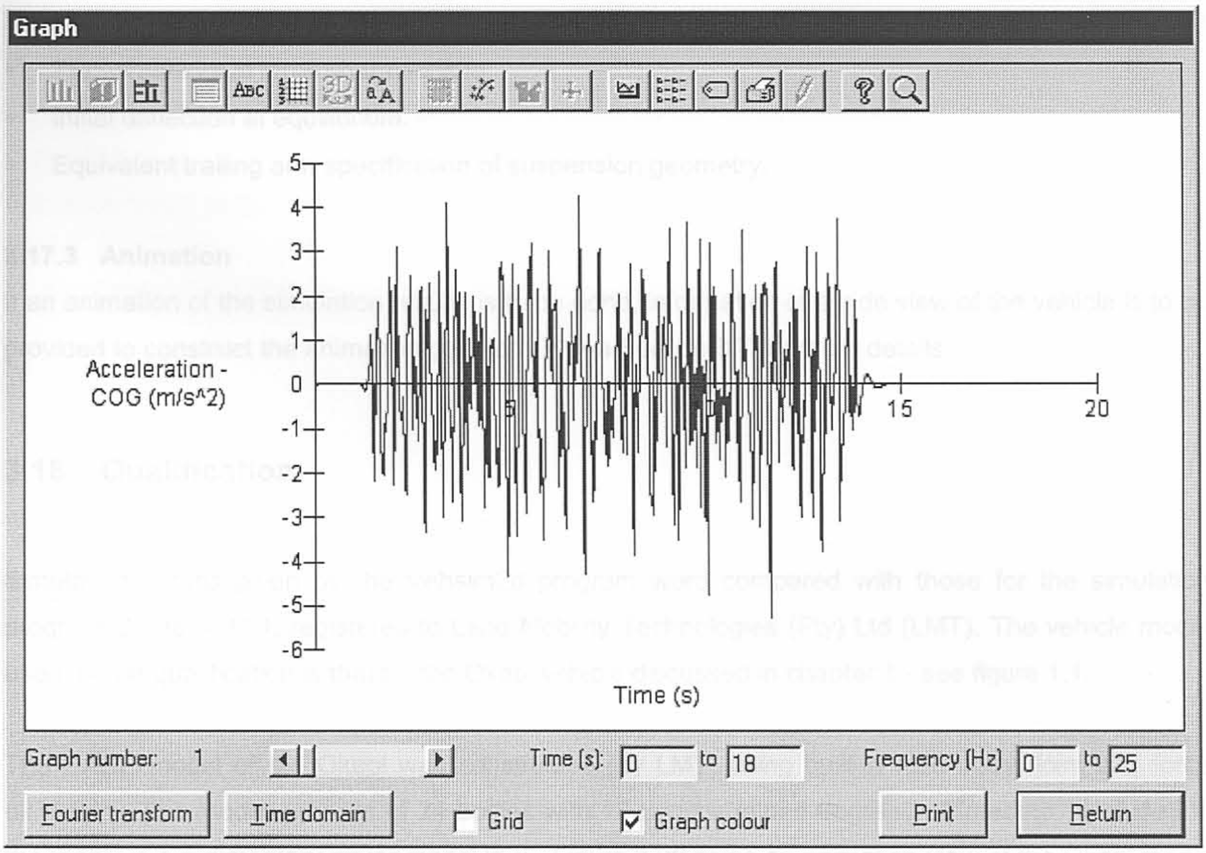
Click on the "Animate" button to perform an animation of the simulation. Figure 3.26 shows a snapshot of the animation for a particular time step.



Time (s) 2.74

Figure 3.26: Animation snapshot of demonstration vehicle

On the main input screen click on the "Postprocessor" button to activate the postprocessor. Then select the required output options and click the "Output" button to extract the output. The "Graphs" button can now be used to graph the simulation results, as shown for the example in figure 3.27.



Graph number: 1

Time (s): 0 to 18

Frequency (Hz) 0 to 25

☐ Grid

☑ Graph colour

Figure 3.27: Simulation results for demonstration vehicle

Click on the graph number scroll bar to view the graphs for the other selected outputs. Use the icons on top of the graph to configure the graph display, etc.

On the postprocessor use the other buttons to analyse the results, etc.

For a more detailed description of the different options and windows, refer to the required sections in the help file.

3.17 Summary of input data required

3.17.1 Vehicle

* Number of axles.
* Position of Centre of gravity.
* Axle placement.
* Unsprung mass and unsprung pitch inertia.
* Placement of required measuring points.

3.17.2 Suspension data (for each suspension component)

- Two dimensional force characteristic.
- Initial deflection at equilibrium.
- Equivalent trailing arm specification of suspension geometry.

3.17.3 Animation

If an animation of the simulation results is to be done, information of a side view of the vehicle is to be provided to construct the animation geometry – see Section 3.7 for more details.

3.18 Qualification

Simulation results given by the Vehsim2d program were compared with those for the simulation program DADS v 9.51, registered to Land Mobility Technologies (Pty) Ltd (LMT). The vehicle model used for the qualification is that for the Okapi vehicle discussed in chapter 1 - see figure 1.1.

The DADS model of the Okapi was constructed (by LMT) using built-in rigid body, joint and force elements. The model consists of 24 bodies with 18 unconstrained degrees of freedom. Included in the model is a rudimentary driver model [62]. Figure 3.28 gives an animation view of the Okapi model in DADS.

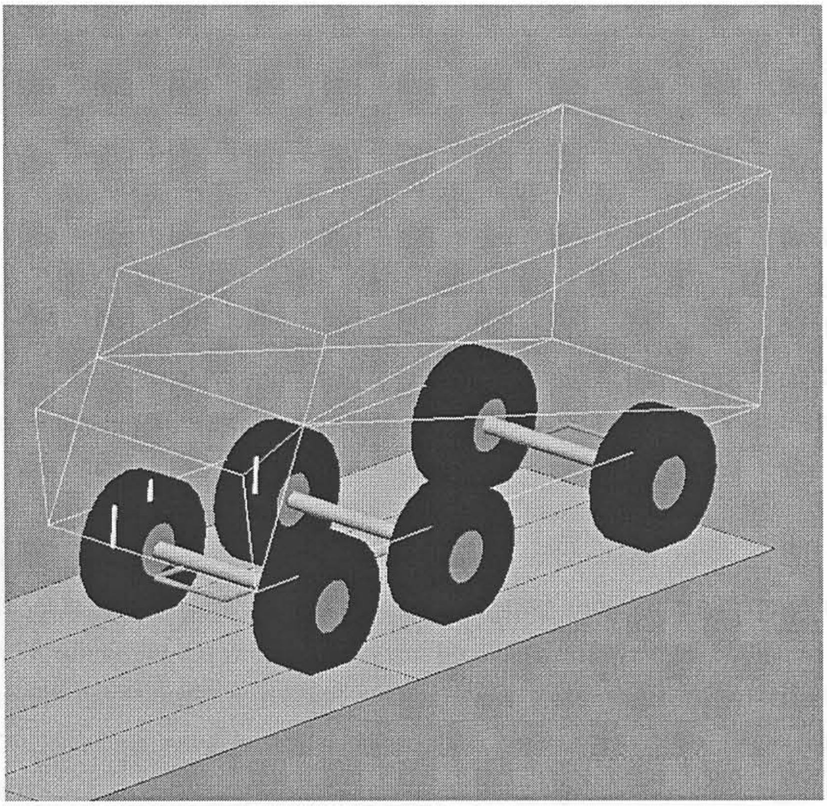
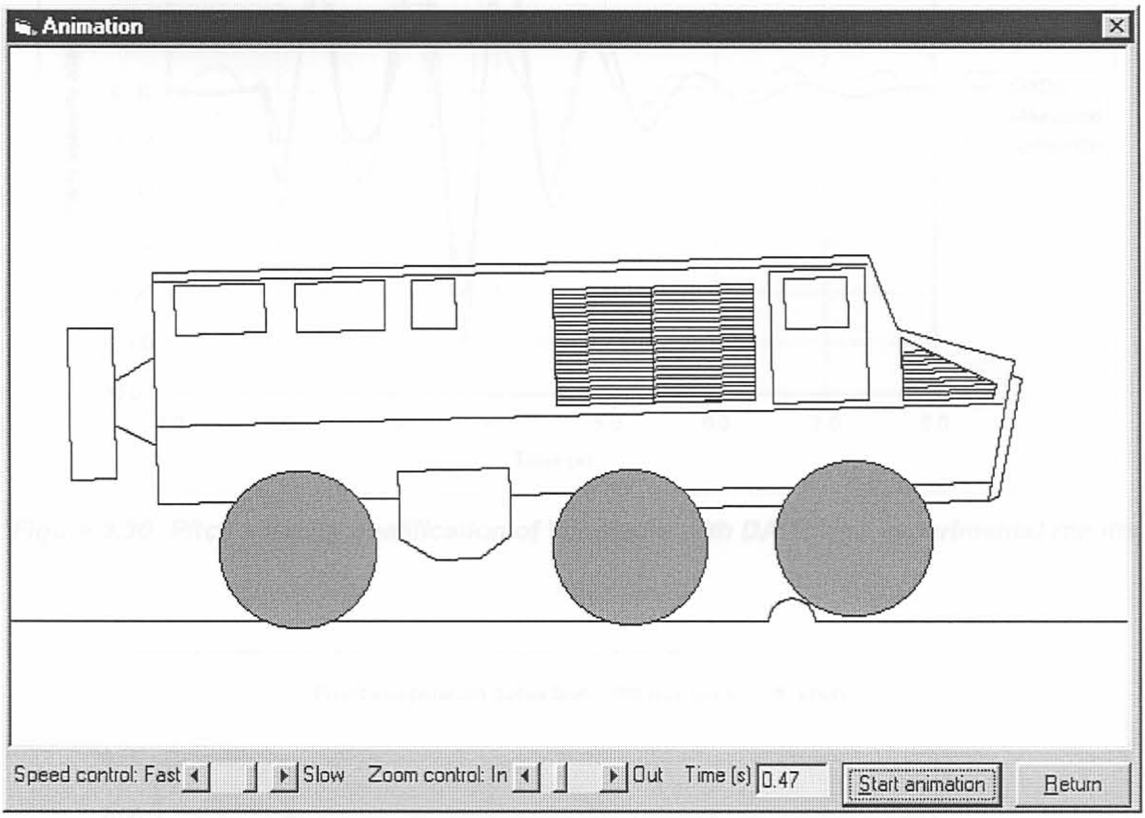


Figure 3.28: Animation view of Okapi model in DADS [62]

The vehicle model for the Okapi vehicle in Vehsim2d consists of four bodies and the suspension components. No anti-roll bars, as can be seen in figure 3.28 for the DADS model, can be simulated in Vehsim2d. Due to the fact that Vehsim2d is limited to two-dimensional simulation, qualification was performed over a symmetrical obstacle, namely a 200 mm half round bump. Figure 3.29 shows an animation frame of the Okapi model in Vehsim2d during the qualification run.



Time (s) 0.47

Figure 3.29: Animation view of Okapi model in Vehsim2d

Experimental measurements were done on the Okapi vehicle during actual crossing of the same 200 mm half round obstacle at the Gerotek vehicle testing track (http://www.gerotek.co.za/, Pretoria, South Africa). LVDT (displacement transducer) measurements were taken of the suspension deflections between front axle and the body, and between the second axle and the body. A gyroscope was also used in the vehicle body to measure the pitch velocity of the vehicle.

Figures 3.30 to 3.32 show comparisons of the simulation results of Vehsim2d and DADS with the experimentally measured values. Very good correlation is obtained between the measured and simulated results. It is also evident that the simulation models' motions are damped out quicker than is experimentally observed for the vehicle. This can be attributed, amongst others, to the fact that the suspension compliance (damper's rubber bushes) was not modelled. Modelling suspension compliance in DADS would have greatly increased the complexity of the simulation model, with a corresponding increase in the computational time, without significantly affecting the quality of the simulation [62].

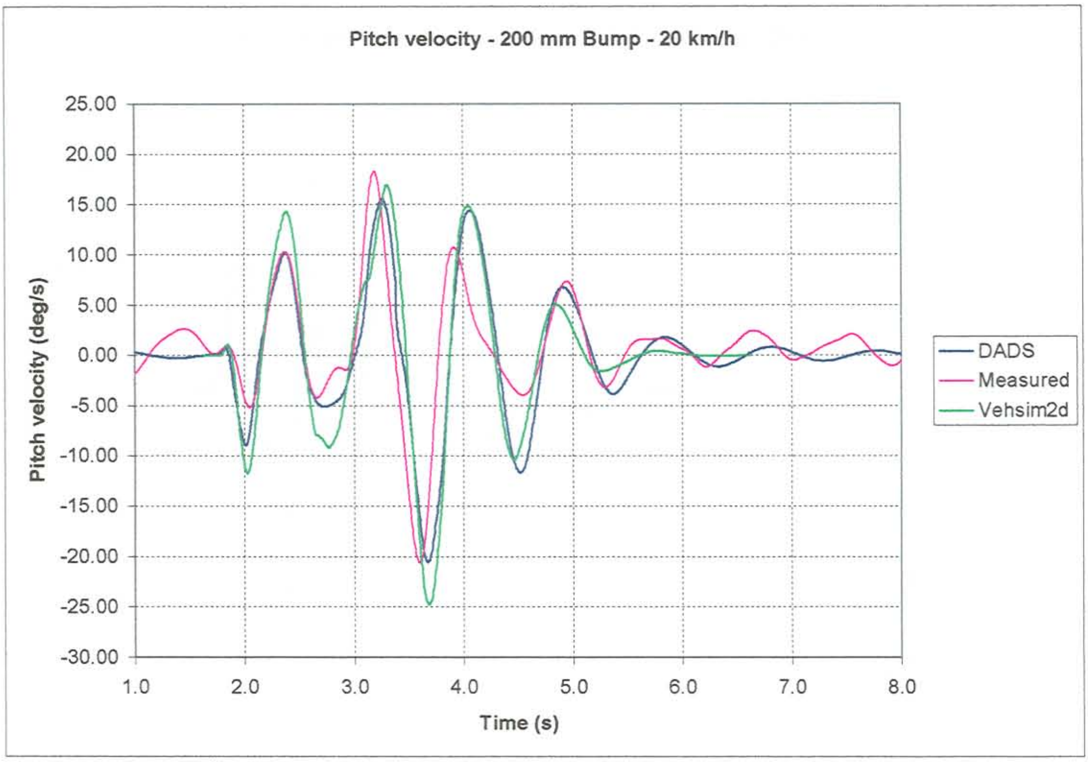


Figure 3.30: Pitch velocity qualification of Vehsim2d with DADS and experimental results.

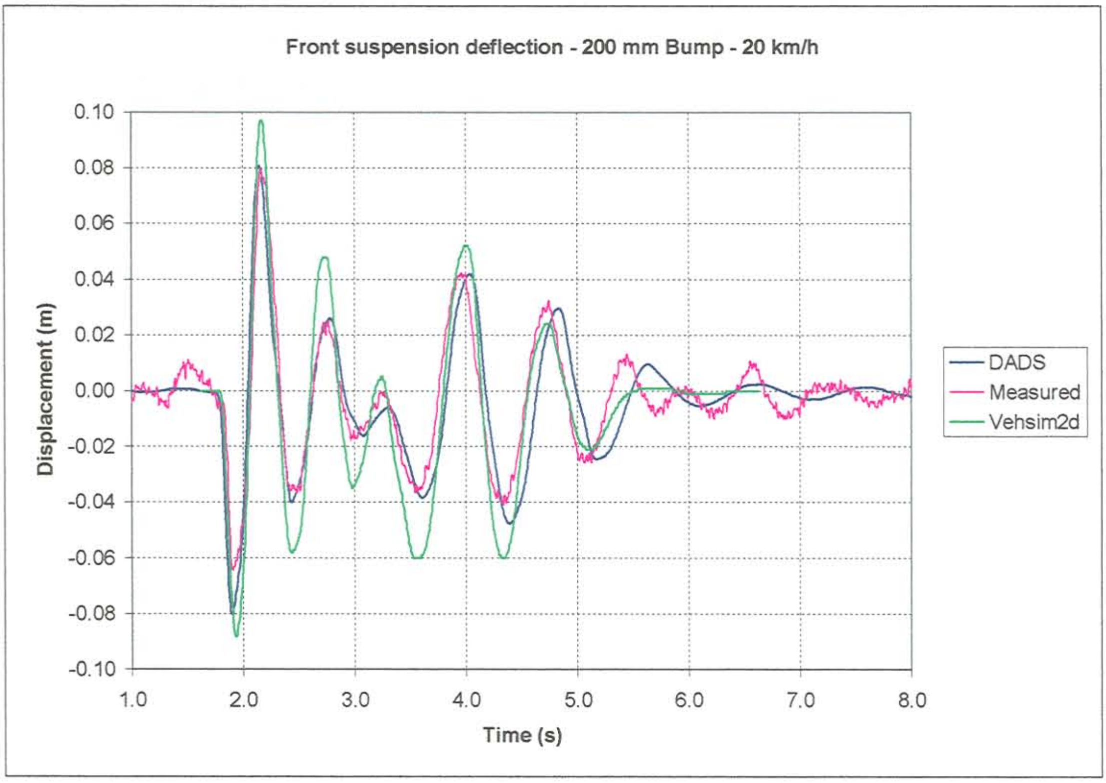


Figure 3.31: Front axle suspension deflection qualification of Vehsim2d with DADS and experimental results.

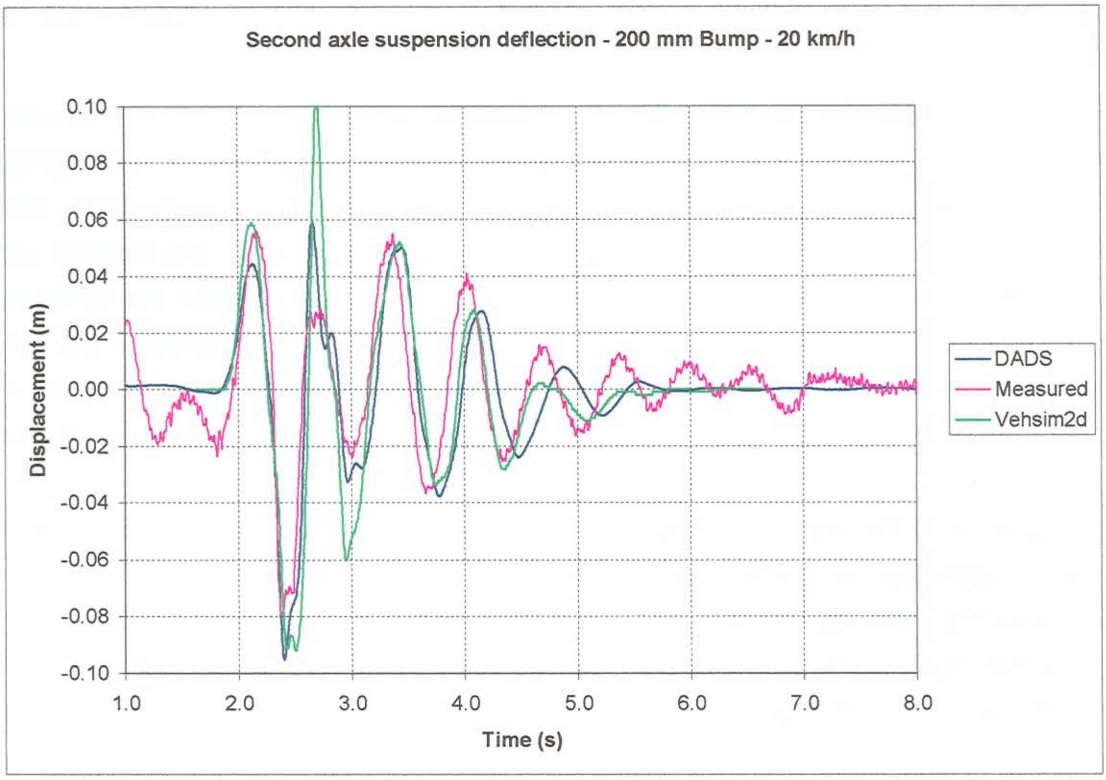


Figure 3.32: Second axle suspension deflection qualification of Vehsim2d with DADS and experimental results.

From the qualification results obtained it is concluded that the relative simple two-dimensional program Vehsim2d gives realistic results and is therefore a valid simulation program. This program may be used with confidence during vehicle concept design to model vehicle dynamics.

3.19 Summary

The program Vehsim2d was developed as a two-dimensional simulation program for analysis of vehicle dynamics during the concept design phase. The input for the program is kept as basic as possible. The suspension of the vehicle is modelled using an equivalent trailing arm approach and springs, dampers and bump stops are the basic of components of the suspension system. The tyres of the vehicle are modelled by both spring and damping characteristics. Two tyre models, a point follower and a sector tyre model are available. The suspension and tyre characteristics are prescribed by using six piece-wise continuous linear approximations, each using twelve parameters to describe the normally non-linear characteristics.

To qualify the simulation program Vehsim2d, both the simulation program DADS and experimental measurements were used. For qualification purposes the Okapi vehicle, as described in chapter 1, was actually driven over a 200 mm half round bump at a speed of 20 km/h and experimental measurements were made. The motion for the same route was simulated using both Vehsim2d and DADS. Comparison between simulated and measured data showed good correlation. From this qualification it was concluded that the simulation program Vehsim2d gives realistic results and can be successfully used as a simulation program during vehicle concept design.