
# Software User's Manual

**Version 2.0.4**

## Tony Foale Designs © 2006-2022

Last revision 29/07/2022

# Contents

# Introduction

During the past 4 decades there has been a proliferation of different rear suspension designs. Prior to this, with a few notable exceptions like the Vincent, most motorcycles used the traditional double shock system, with the shocks mounted approximately vertical towards the wheel end of the swing-arm. This gave almost linear effective wheel rates and the available wheel movement was limited to about 10 or 20% more than the shock stroke. Double springs or progressively wound springs were sometimes employed to give a progressive rate at the wheel.

The modern era was initiated when the Yamaha “cantilever” revived the Vincent system, and employed just one suspension unit – “monoshock”, although the original Vincent system used two shocks along side each other. Initially the Yamaha version was designed for moto-cross to extend wheel movement, and this led to a wide variety of alternative rear suspension systems by several manufacturers. These quickly spread into most other forms of motorcycling, including racing and road use. Many of these “new” designs also incorporated movement geometries that gave varying degrees of progression.

Whilst these progressive systems offer a much wider range of set-up options, they have also been the source of much confusion. Most people find it more difficult to understand the precise behaviour of the suspension action. It is usually necessary to go through awkward step by step physical measurement and tedious geometric plotting, to get an idea of the characteristics.

Along with improvements in rear suspension, as well as engine and tyre technology there has been an increased need to setup the overall configuration of sports and competition motorcycles to levels of refinement not seen in the past. Unfortunately the methods and tools to do this have not been generally accessible outside of the confines of the design departments of the motorcycle manufacturers.

This software is designed to make that job easy. It is only necessary to enter some dimensional data to automatically get detailed information about any suspension design, and setup configuration. It becomes a rapid exercise to investigate many different permutations of any design.

Indispensable for anyone involved in :

Designing or modifying a motorcycle.

Setting up sport or racing motorcycles.

Achieving improved comfort and handling.

Students.

Anyone wanting to better understand the workings of suspension systems and motorcycle setup.

Virtually all designs of current rear suspension systems can be analyzed by inputting appropriate data. The BMW paralever and similar designs are not presently supported.

However, designs are continually evolving and if you find it impossible to specify any particular layout with the existing programme then please send an email ***info@motochassis.com*** describing the design. We will try and update the software to accommodate all systems that we regard of interest.

This software is currently limited to analysing telescopic forks at the front. This does not prevent the overall analysis of a machine fitted with an alternative front end. The rear suspension, anti-squat and attitude calculations will still apply.

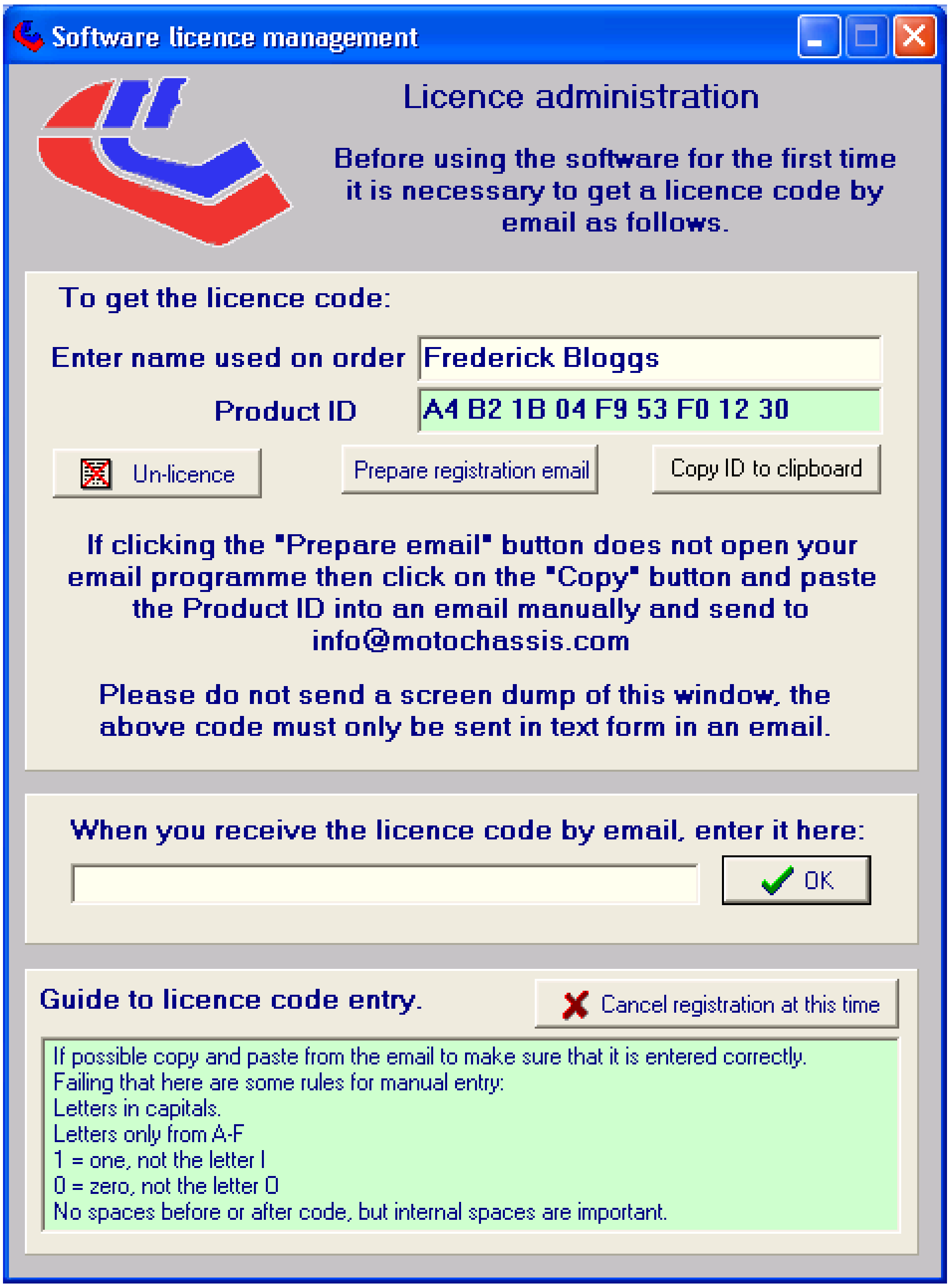
New features have been added to the end of this manual. Check that out for the latest.

**Foot note (**Alternative front ends.**)**
For anyone interested in analysing alternative front ends we have some stand alone software which may be of interest. This will calculate numerous parameters (such as anti-dive, rake and trail variation etc, etc.) of all known systems supported by arms and/or links. It does not handle any with sliding elements. For example it will analyse the new BMW duolever but not the older telelever which has sliding members. Email ***info@motochassis.com*** for further information.

# First time use.

When the software is started for the first time, you will be presented with the following licence screen. Fill in your name used for purchase and click on the "***Prepare registration email***" button. This will prepare an email in your default email client. If your email client does not respond then click on "***Copy ID to Clipboard"*** and then paste the ID manually into an email and send to *info@motochassis.com* If you do not use the computer for email then you can make a note of the customer code and send an email manually from another computer to *info@motochassis.com* You can then close the software.

Is important that the ID is in text form in the email, please do not send a screen print of this window.




A licence code will be emailed back to you. When you receive this code, restart the software and enter the code where indicated. The software will then shut down and then function fully when restarted.

It is important that you only use the licence code on the same computer that showed the emailed "Computer ID". Both of these codes are unique to each individual computer and will not work on another machine.

### Procedure to transfer licence to another computer.

If you wish to change the computer on which you use the software, then firstly enter the above licence screen by clicking the “Licence management” button on the opening screen on the original computer.

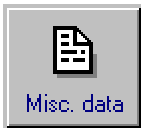

Then click the


button. Make a note of the un-licence code that appears.  Install the software on the new computer and email the computer ID number for that machine with the un-licence code from the first.

# Principal selection screen

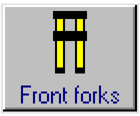
From the opening screen select the required action according to the function of each button. The lower row of buttons access various aspects of motorcycle setup in a separated manner. For example you can look at different front fork setups without reference to the rear suspension etc. On the other hand the upper row gives views of the whole bike data and characteristics.


## Button functions

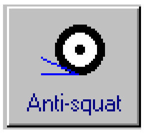



Accesses data that is common to all modules throughout the programme. This is the first data that needs to be entered or confirmed for each analysis project.

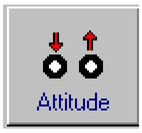

Selection screen for the type of rear suspension. There are three main classes of suspension configuration available, which cover almost all current designs. The BMW paralever and similar systems are not covered.




Analyses the front fork characteristics. Top-out springs can be specified when appropriate, as well as oil levels and gas pressures to show the effect on suspension action of the internal volume change with movement.

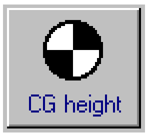



Allows for a very rapid assessment of the squat/anti-squat characteristics, and the effects of changing sprocket sizes and swing-arm angle etc.



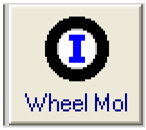

The effects of changing rear ride height and/or fork slider positions are calculated. After a change, the new weight distribution, rake, trail, CG position, swing-arm angle and wheelbase are shown. This is a very rapid way to see the global effects of attitude changes regardless of how those changes were made.


Calculates the spring rate from dimensional data of a spring. This is useful to get an estimate of the spring rate for those with no facilities to measure the rate directly. Suitable for linearly wound springs, it will in most cases provide reasonable accuracy for the starting rate only, of progressive springs. A built in help window gives instructions for use.

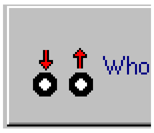



Shows one way to measure CG height and does the necessary calculations.

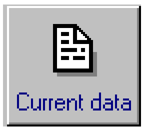

Evaluates the missing parameter in a set of four relating to steering geometry. Rake angle, wheel size, offset and trail are the 4 parameters. Enter any three of them and the fourth will be calculated.




Calculator for the moments of inertia of wheels and tyres. There are three different methods included.

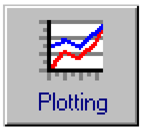



Complete attitude analysis of the whole bike. Calculates steady state attitude or trim parameters under static, braking and accelerating conditions. Shows load transfer and warns of wheelie or stoppie limits.

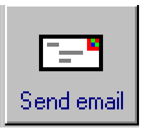



Lists all the input physical parameters used in the current project. Some of which can be changed from this screen whilst using the “Whole bike” analysis feature.


Centre for management of saved project data. Up to ten cases can be saved in the same project file.

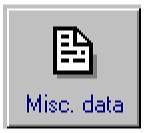



A plotting module which graphs up to ten examples of a selected parameter. This is very useful for comparing the results of different set-ups.

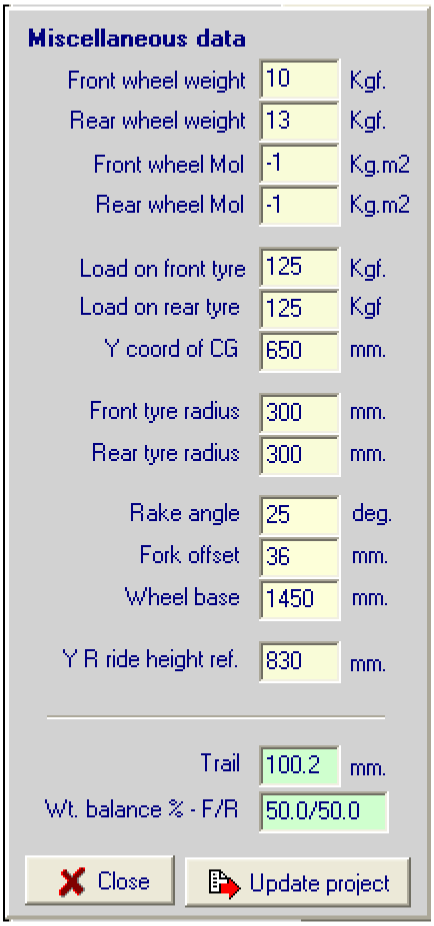



Updates to this and other software will be announced on our web site, so visit from time to time. We welcome feedback and suggestions about this programme and they can be sent by email.

# Full details of each feature




## Miscellaneous data




This is the source of data values used in various parts of the programme, but not specifically tied to the front forks nor rear suspension.

Where appropriate all data is taken from the reference attitude of the motorcycle. That is; both suspensions fully extended with the tyres just touching the ground.

If you do not have the values for the wheel moments of inertia, use the value –1, then default values based on wheel weight will be inserted in the calculations.

The loads on the tyres are the weights supported by each wheel under loaded conditions, i.e. with the rider on board.

Fork offset is the offset between the steering axis and the wheel axle. It is used to calculate trail.

Click on the “Update project” button when all the data has been entered correctly.


## Rear suspension

### Quick start

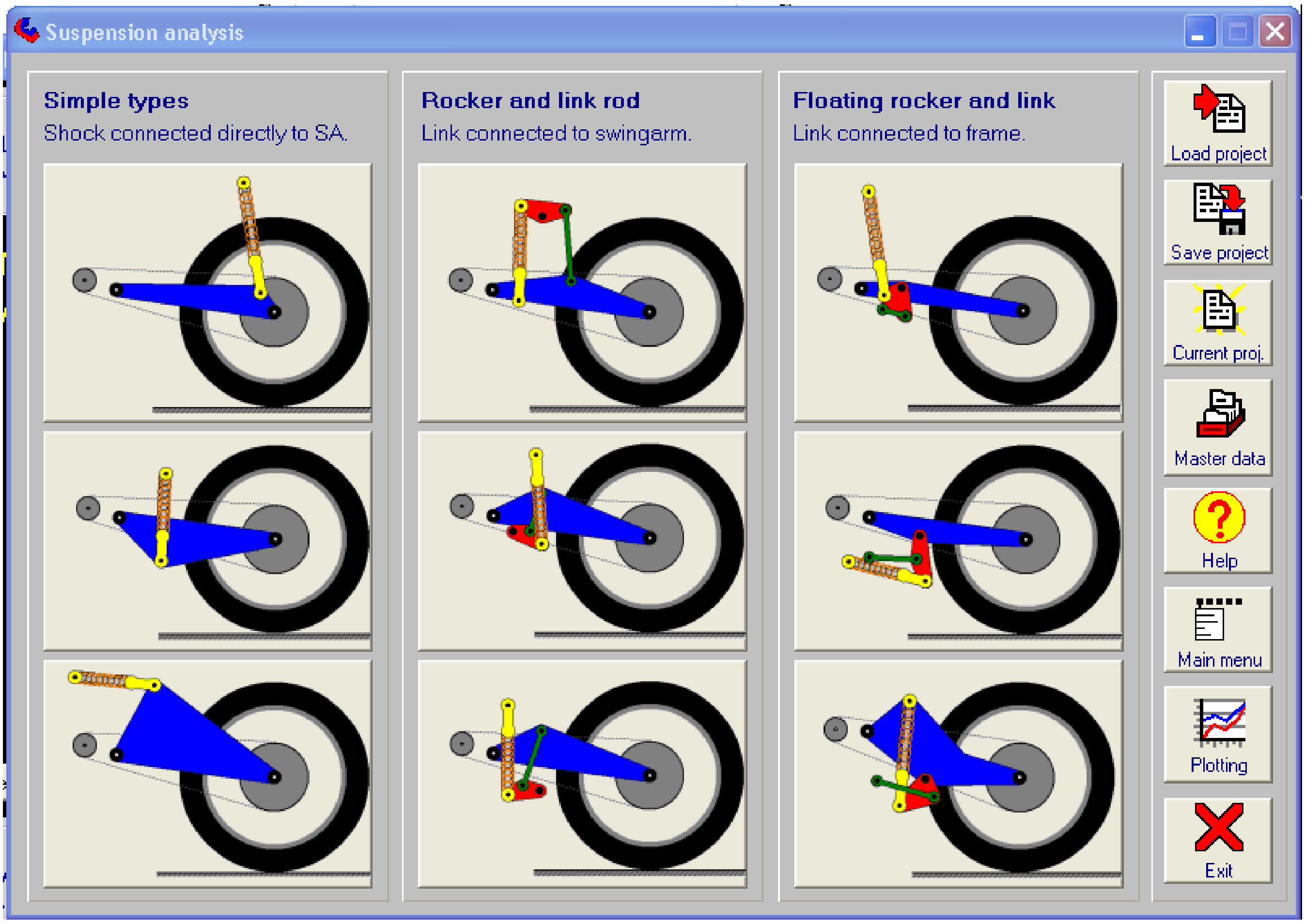
Chose a starting design, similar to that to be analyzed, from the following initial selection screen. If you have already selected or loaded a design and wish to return to that project the click on the “Current proj.” button.

There are three basic classes from which any other suspension designs can be input.

**Simple types** – Suspension unit connected directly.

**Rocker and link rod** – Link connected to swing-arm.

**Floating rocker and link** – Link connected to frame.



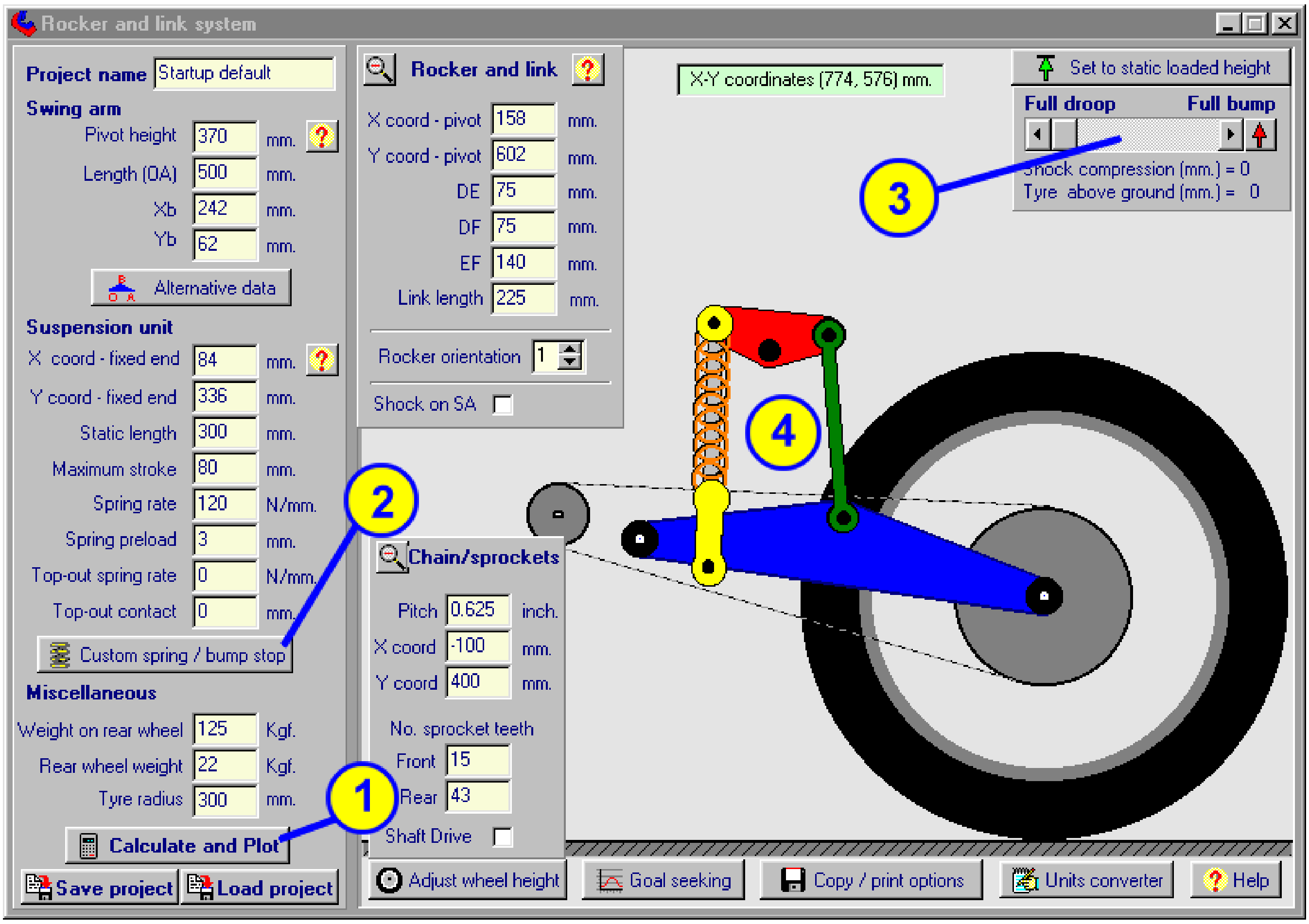

These classes are shown in the three on-screen columns.

It is important to select the correct class to describe any design that you wish to analyze, the programme uses different internal calculation algorithms for each class. However, it is relatively unimportant which example is chosen from within a particular class as the details can be changed through entered data on the following screen.

## Data entry

Dimensional data is entered numerically in the appropriate boxes. Mini fly-out context help screens are activated by pressing the ? buttons. Use these to get information about particular aspects of data entry. Full descriptions of all features on this screen are show in the detailed sections of this manual.

### Data entry screen.




Numbered features on this screen are:

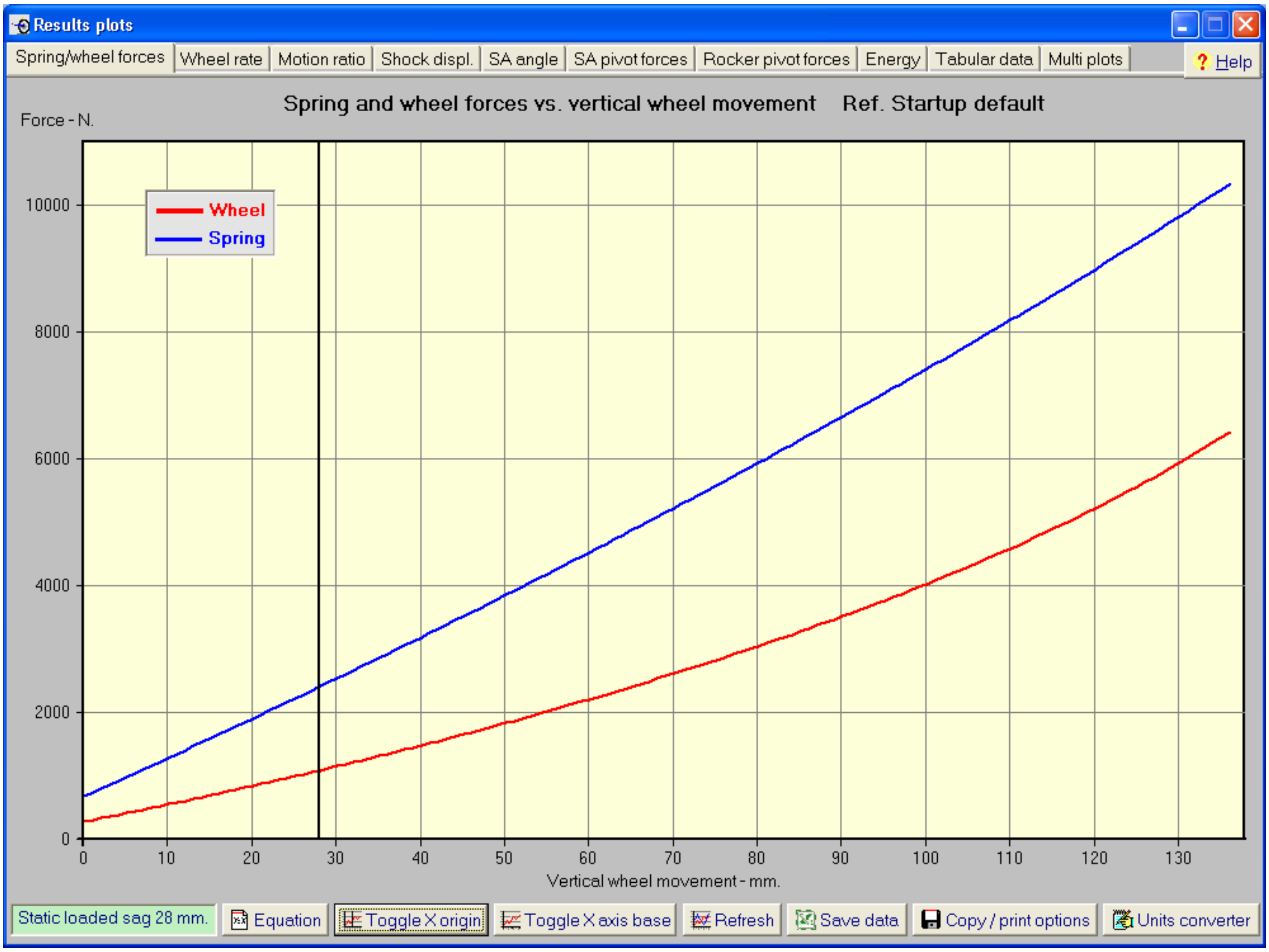
1 **Calculate and plot button.** – Click on this when data entry is complete to calculate and plot the results.

2 **Custom spring button.** – This opens a window to specify variable rate springs and/or bump rubbers.

3 **Animate** – The slider bar allows continuous animation of the suspension system graphic between full rebound and full bump. The ↑ button toggles between full rebound and full bump.

4 **Pictorial** representation of the suspension design as defined by the entered data. The illustration may disappear when returning from another screen, the screen saver or suspend mode, in which case clicking on the area of the graphic will cause it to be redisplayed.

## Results screens




The results are plotted on eight separate graphs each showing different characteristics of the suspension system being analyzed.

**Spring/wheel load** – (as illustrated above) the forces at the wheel contact patch and on the shock spring. These plots include the effects of variable rate spring and bump rubbers, if specified.

**Actual wheel rate** – the effective vertical spring rate as seen at the wheel plotted against wheel movement.

**Motion ratio** – the leverage ratio between shock and wheel.

**Shock compression** – this shows the relationship between the shock and wheel movements.

**Swing-arm angle** – the angle to the horizontal of the swing-arm throughout the range of wheel movement.

**Swing-arm pivot forces** – the horizontal, vertical and resultant forces at the swing-arm pivot point.

**Rocker pivot forces** - the horizontal, vertical and resultant forces at the rocker pivot, as well as the link force.

**Energy** - the energy stored in the compressed spring.

The results are also available in tabular form and can be printed or saved in various formats, allowing additional analysis or graphing possibilities.

There are  buttons on each plot page as follows:

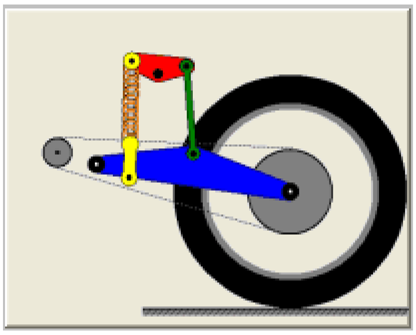
| | |
|---|---|
| Equation | Shows a polynomial equation of the data.  Also plots a graph under the data graph to show degree of fit. |
| Toggle X origin | Toggles the origin of the X axis between full rebound position and static ride height. |
| Toggle X axis base | Toggles between wheel movement and shock compression as X axis. |
| Refresh | Redraws graphs, cleaning any user added lines or marks. |
| Save and print options | Print, save to file or copy graph to clipboard. |
| Units converter | Conversion between metric and imperial units. |

The best way to learn to use the programme is to play around.  Enter various data and see what happens.  The following section explains each feature in detail and there is a separate publication which explains the theory and practice of suspension systems in general.

## Detailed description

The following explains all the features of the software on a window by window basis.


### Rear suspension

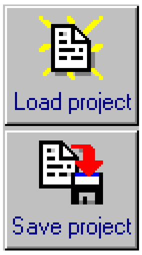


As shown in the ***Quick start*** section above this can used to select a starting type from a range of pre-defined designs.

The three columns of speed buttons (like that shown to the left) define three basic classes of suspension design.

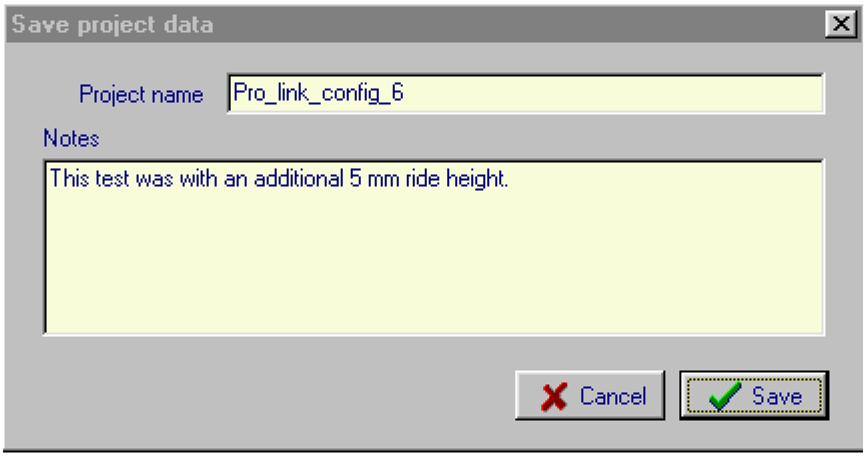
The three rows just predefine three separate examples within each class.

Within a particular class, the specific design is defined by manually entered data. The examples are just starting points.




The "Load" button retrieves previously saved designs from the hard disk. When a file is selected the notes are displayed to help chose the correct file. This feature is very helpful when you want to find a file some weeks after it was first saved.

Project data can be saved to a file for later retrieval. It is suggested that the file-name chosen helps to identify the design being saved, for example – "Yam_R1_3mm_preload". An option to enter some additional notes to help identify the suspension configuration is also available. See the separate chapter on saving projects.




The **"Save project"** screen, with sample examples of project name and notes.

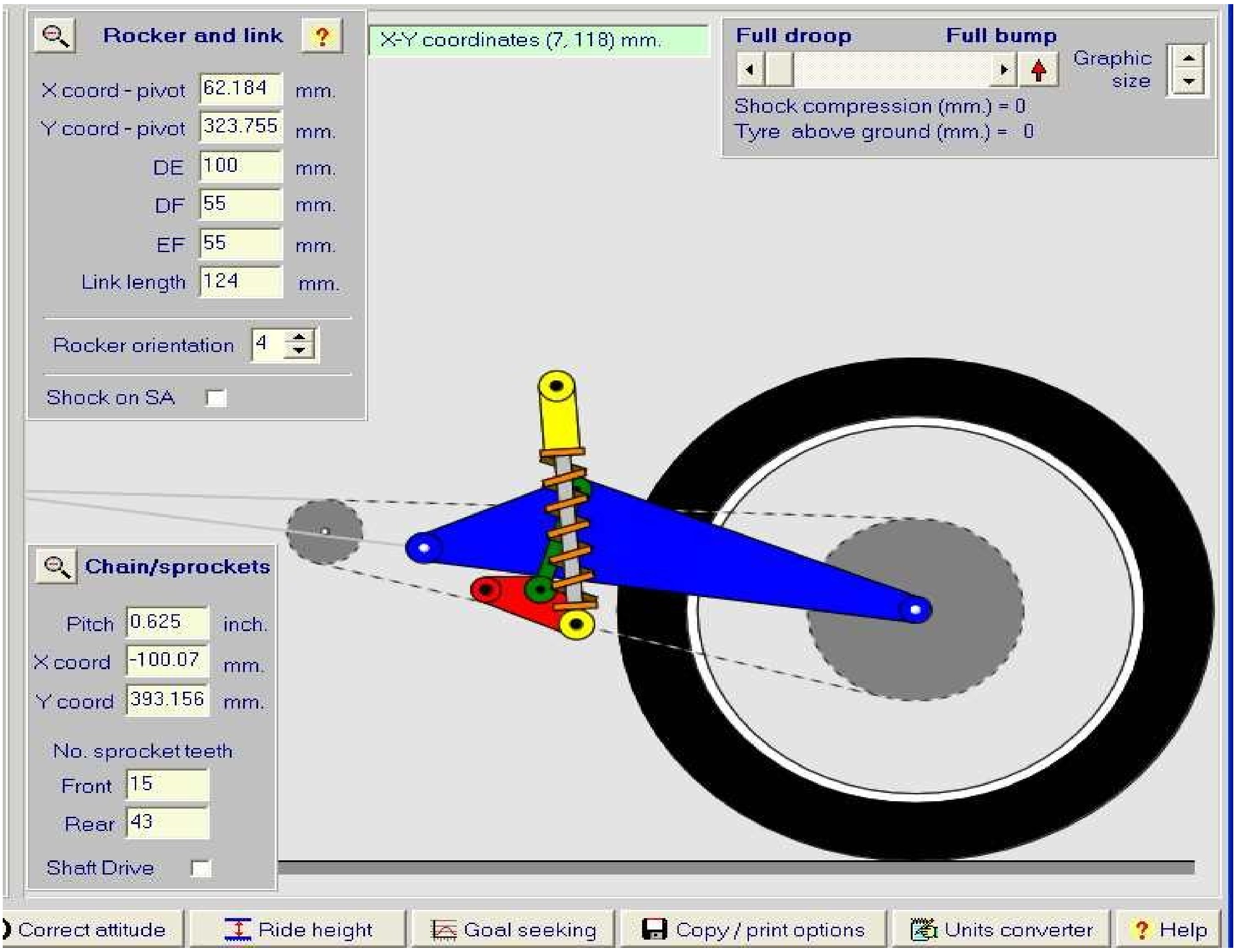
The filename defaults to the project name although that can be changed after clicking the save button.


This button opens a window to select this user manual in PDF format or to choose from a range of tutorial videos. It is highly recommended that you watch at least the basic tutorials before using the programme. Each one is only a few minutes long and it will speed the learning process greatly.

## Data entry screen

The full window is shown in the **Quick Start** section above. The following will look in detail at specific features of this screen.

**Animation and layout graphic**

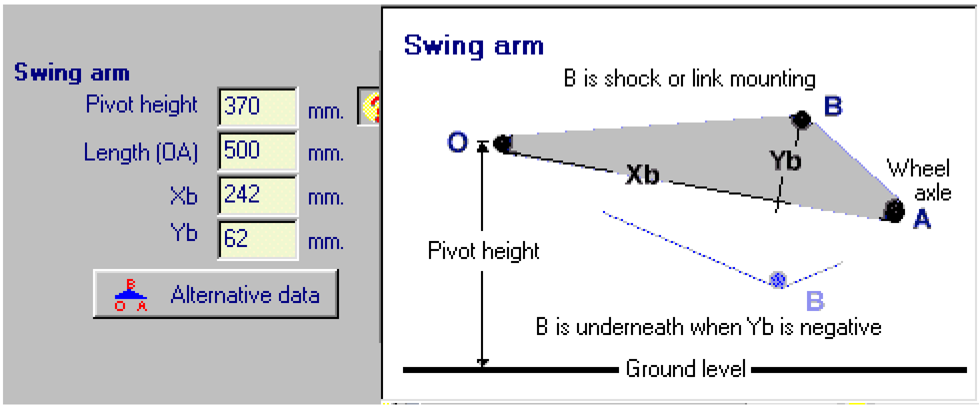



The layout graphic image serves a double purpose.

Firstly, it gives a visual check on the accuracy of the dimensional data that has been entered. If a mistake has been made during data specification then it will be quite obvious, as the graphic representation will differ from that expected. When any data item is changed then so too will it's representation.


Secondly, the image can be animated over the range of movement defined by the maximum stroke of the shock. The button will toggle between full rebound and full bump positions. The slider control allows a gradual animation over the same range. It is possible to specify a suspension design that becomes dimensionally incompatible over the full range of shock movement and the animation feature is very useful to see the cause of the problem. A typical cause might be that the length of a rocker is too small for the shock displacement specified.

## Swing arm data




There are two possible methods for entering the dimensions of the swing arm, the normal shown to the left.

The other is available after clicking the "Alternative data" button.

The standard method is much easier if you wish to enter different length swing-arms without changing other dimensions. For example to see the effect on suspension of chain adjustment.

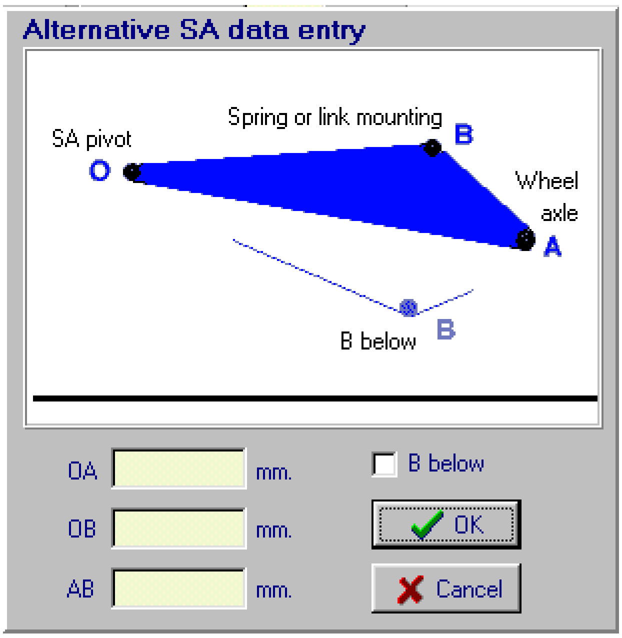
**"O"** – swing-arm pivot location.

**"A"** – wheel axle location.

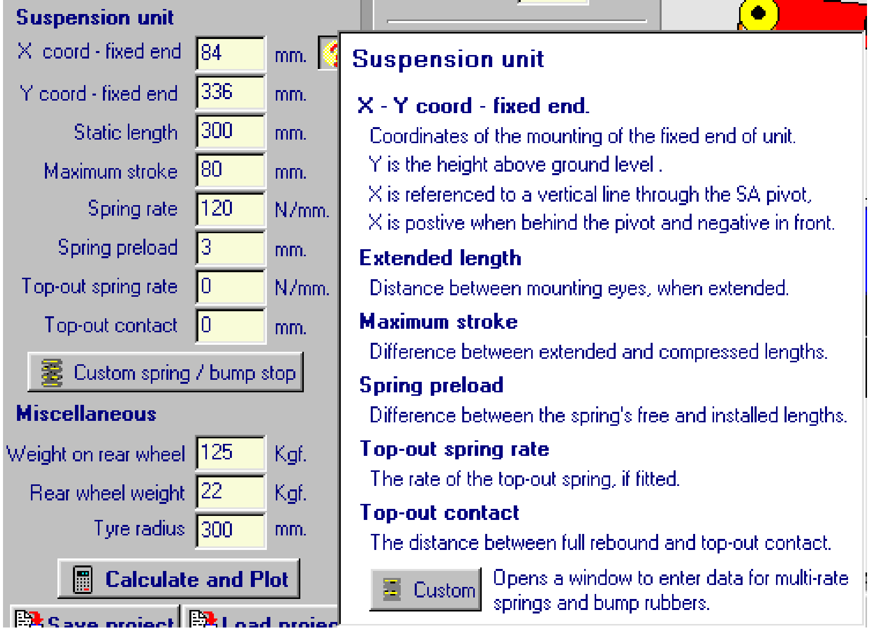
**"B"** – mounting point for shock or link.

? displays fly-out help screen.

## Alternative method

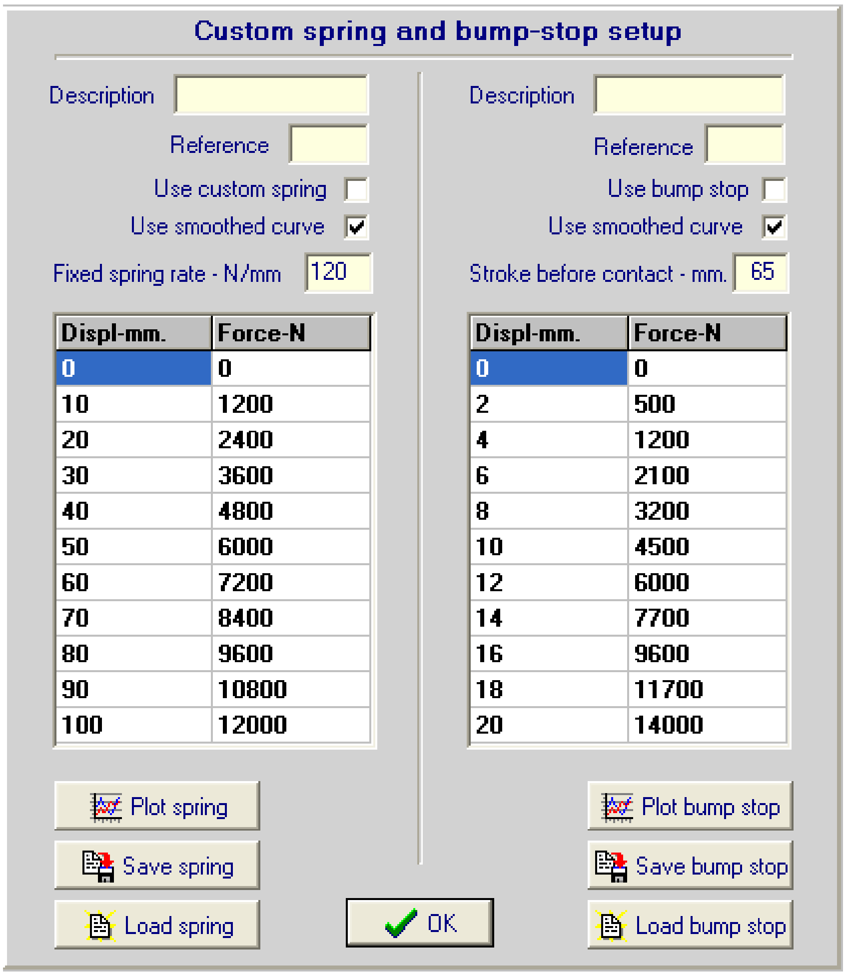



Sometimes it is more convenient to measure a swing-arm as shown above. Access to this screen is by clicking the "Alternative data" button.




The fly-out help screen shows the significance of the various shock parameters.

The **spring rate** and **preload** values are optional. The relationship between shock compression vs. wheel displacement and the motion ratio will be calculated without these data. If you don't know the spring rate it is suggested that you use a value such as 100 N/mm. and then the results based on forces will be shown in proportion to that value and can easily be extrapolated up or down.




Both variable rate spring and bump-stop data can be entered in force/displacement tables which accept 11 data points (10 points plus 1 for zero). It is not necessary to use equally spaced displacement intervals. The tables are initially filled with example data.

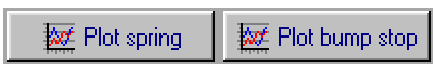
To smooth out measurement errors and fill in between data points, the data is converted to a smoothed 2$^{nd}$ order curve. In cases where a spring has basically 2 or 3 distinct rates, rather than a smooth transition, it is best to un-tick the **"Use smooth curve"** tickbox, this will then use the spring data as entered.

The **"Use custom spring"** tickbox toggles between using the custom spring or fixed rate data.

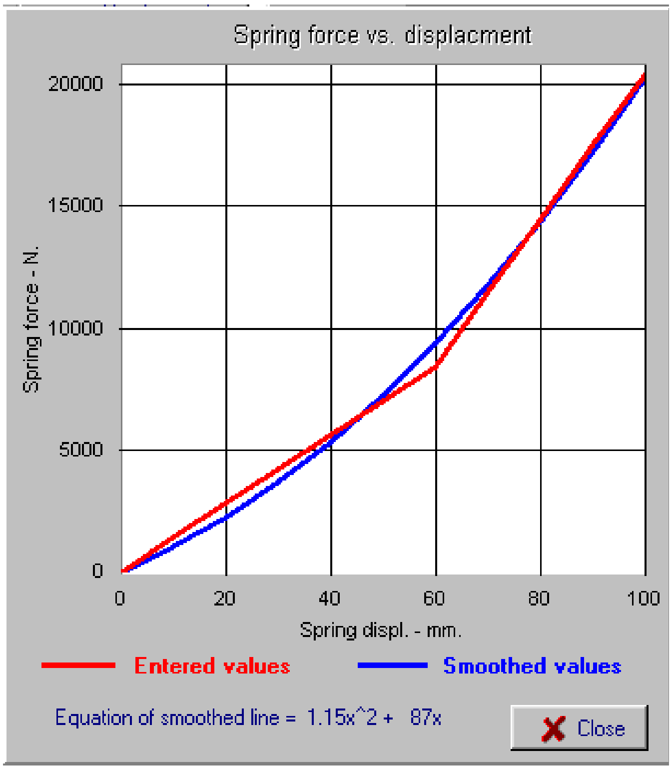
Make sure that the spring properties are entered to cover the maximum possible compression range. The displacement value for the final data point must be at least the maximum shock displacement plus the preload.

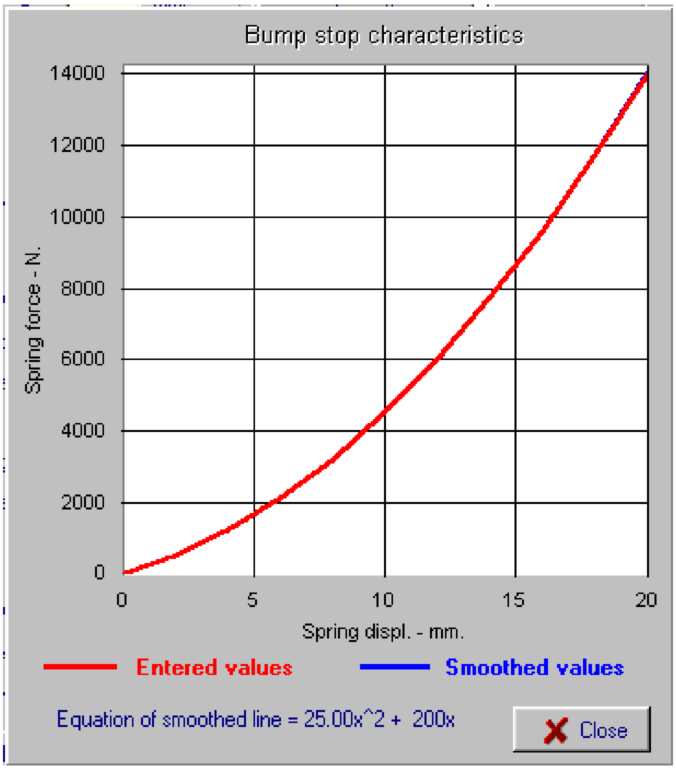
In the specification of the bump-stop, the **"Stroke before contact"** data is the amount of shock stroke before initial contact with the bump-stop.

Custom spring and bump-stop data can be saved separately to hard disk for later use. This makes it very easy to quickly calculate the effects of changing springs and/or bump-rubbers in any design.



These buttons plot the custom spring/bump-stop characteristics. Both the smoothed and the entered curves are plotted and the equations of the smoothed characteristics are shown.

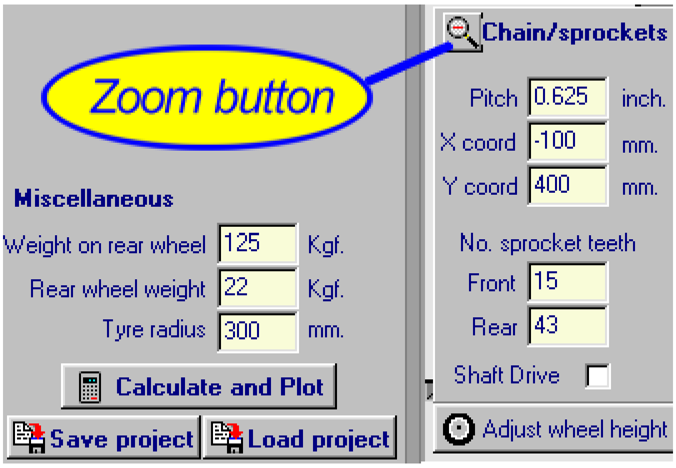



The sample spring data shown above is for a dual rate spring and the differences between the actual and smoothed curve can be clearly seen. In this example it would be best to un-tick the **"Use smooth curve"** tickbox, to use the spring data exactly as entered.

On the other hand, the smoothed example data fits the sample bump-stop data perfectly, and the blue curve is hidden behind the red. Bump rubbers are invariably smoothly progressive and are not designed to have 2 or 3 specific rates, but in practice some bump rubbers are difficult to match with a simple mathematical curve. In those cases where the smoothed and entered curves differ significantly it is best to untick the **"Use smoothed curve"** tickbox.

## Miscellaneous




The weight and tyre radius data should initially be entered in the Misc. data panel on the opening screen, but can also be changed here.

Tick the shaft drive box if you are analysing a non-linkage shaft drive such as the pre-paralever BMWs, also tick this for those scooters with the engine on the swing arm. This information is used in the calculation of the anti-squat characteristics.

Use the zoom button to expand or minimize the **"Chain/sprockets"** panel. Sometimes it is useful to minimize this window to avoid visual interference with the graphic of the suspension system. The panel can also be dragged to another part of the screen.


This button adjusts the pitch attitude by rotating the whole bike about the front axle to bring the rear tyre back to road level. For example, if you change some configuration data such as shock length then the rear wheel will not be at the correct height unless the attitude of the bike is corrected. Clicking this button will adjust data such as swing-arm pivot height and the co-ordinates of shock and rocker mountings.

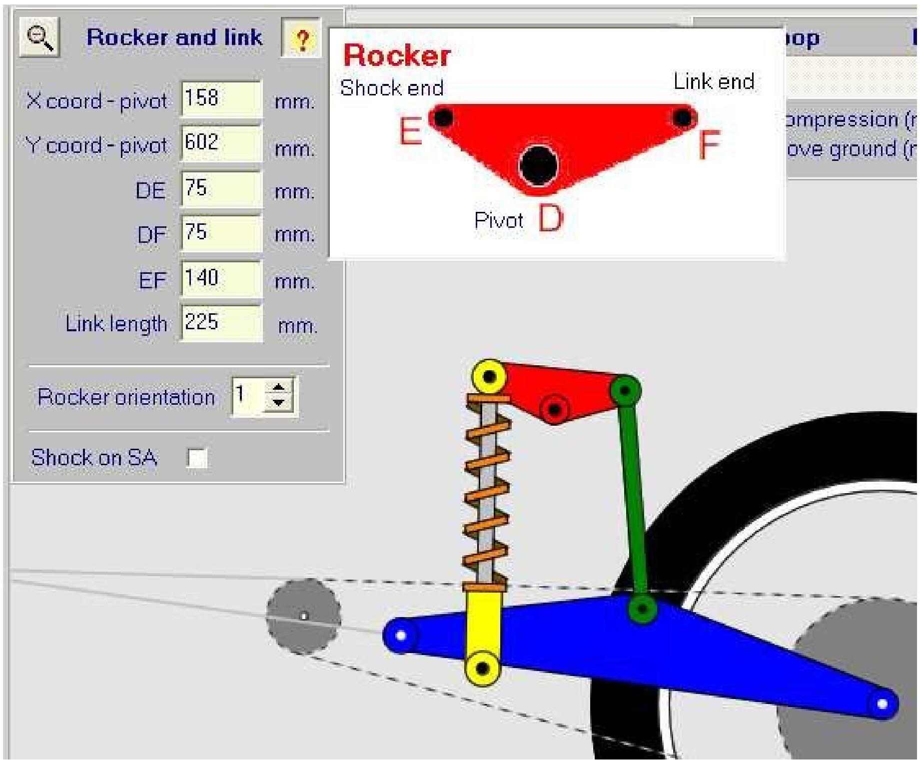
It is also useful to correct for measurement tolerances in the input data. These tolerances may indicate a small error (up to 5mm. or so) in the rear tyre height. In such cases, "adjusting attitude" will ensure mutually compatible dimensions.


This gives you a quick way to check the effects of changing the rear ride height by change to shock length, shock mounting position or change in link length on rocker type systems.


Print, save to file or copy the graphic to the clipboard.


Conversion between metric and imperial units.

## Rocker and link

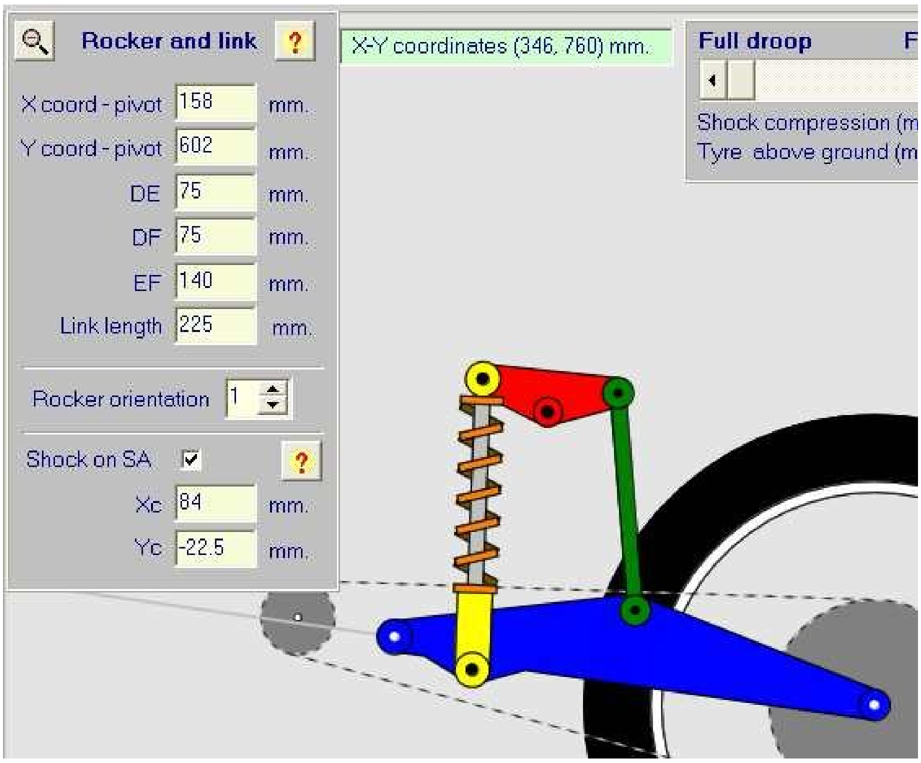



The fly-out help window shows the meaning of the various rocker dimensions.

The software does some error checking to try and ensure that the dimensions are physically compatible. For example **EF** must be less than or equal to **DE + DF.** **E** and **F** may both be on the same side of the pivot **D**, this is controlled by the length **EF**.

When the cursor hovers over the data entry window it is possible to drag that window to another part of the screen for those cases where it would otherwise obscure the graphic.

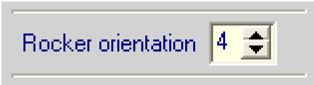
**IMPORTANT NOTE:** The letters E and F refer to the mounting points for the shock and link respectively, regardless of the orientation of the rocker. These letters DO NOT signify left nor right.




This is an example (similar to that shown above) but with the shock mounted on the swing-arm. Often called a "Fully floating" system.

The **"Shock on SA"** tickbox defines whether the shock is mounted on the chassis or fixed to the swing-arm. If this is ticked then additional data entry boxes are displayed to define the shock mounting points on the swing-arm, **Xc** and **Yc**.

The fly-out help screen (not shown) explains the significance of the additional swing-arm co-ordinates.

## Rocker orientation 

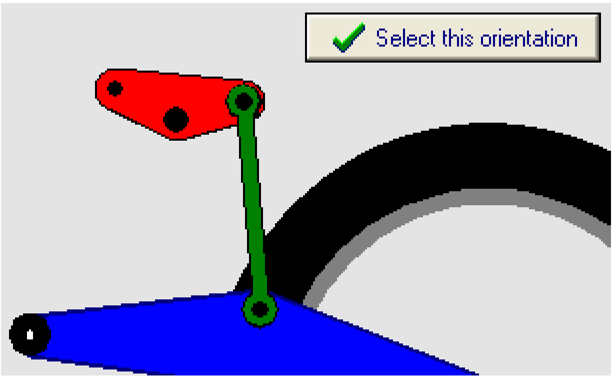

There are 4 possible orientations of the rocker. *(It can be flipped horizontally and/or vertically.)* The user can use the spin control to toggle through to the desired configuration.

The following illustrations (which appear when the spin control is used) show the four alternative orientations for this particular design. The correct orientation is “1” as can be seen by reference to the graphics on the previous page. Some orientations lead to impossible physical layouts. To avoid the inherent problems of trying to draw impossible layouts, the illustrations only show the wheel, swing-arm, rocker and link. An incorrect orientation is physically equivalent to an assembly error on the bike.

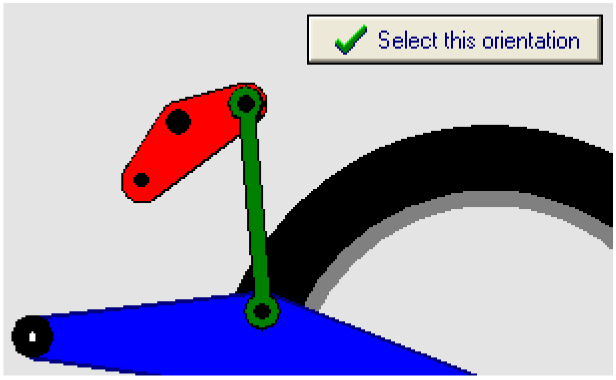
Click the 

button to select the correct layout.

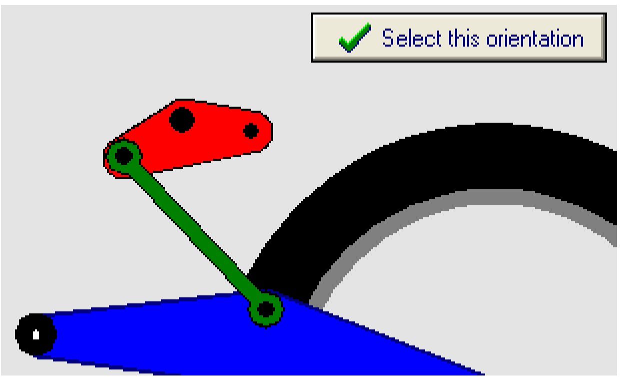
***Orientation 1***



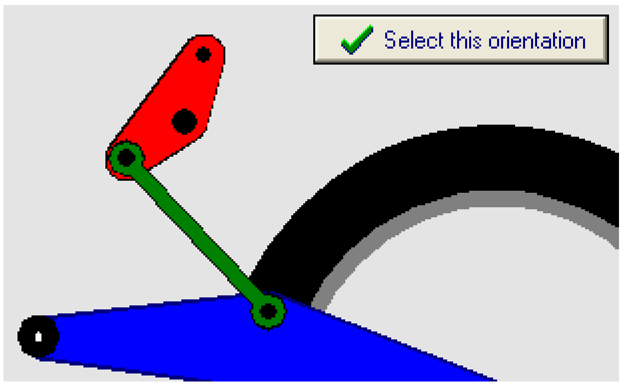

***Orientation 2***

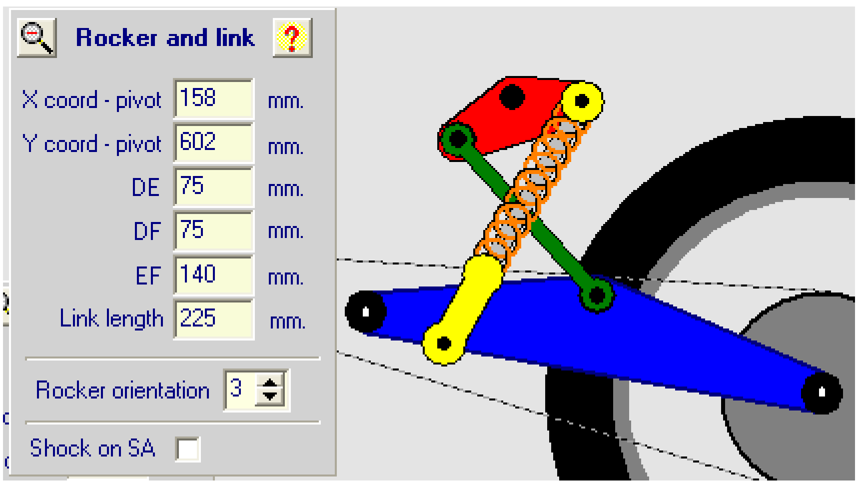



***Orientation 3***




***Orientation 4***




Here we see the effect of choosing an incorrect orientation of the system above. Orientation “3” instead of “1”. In this case the rocker is flipped both horizontally and vertically.

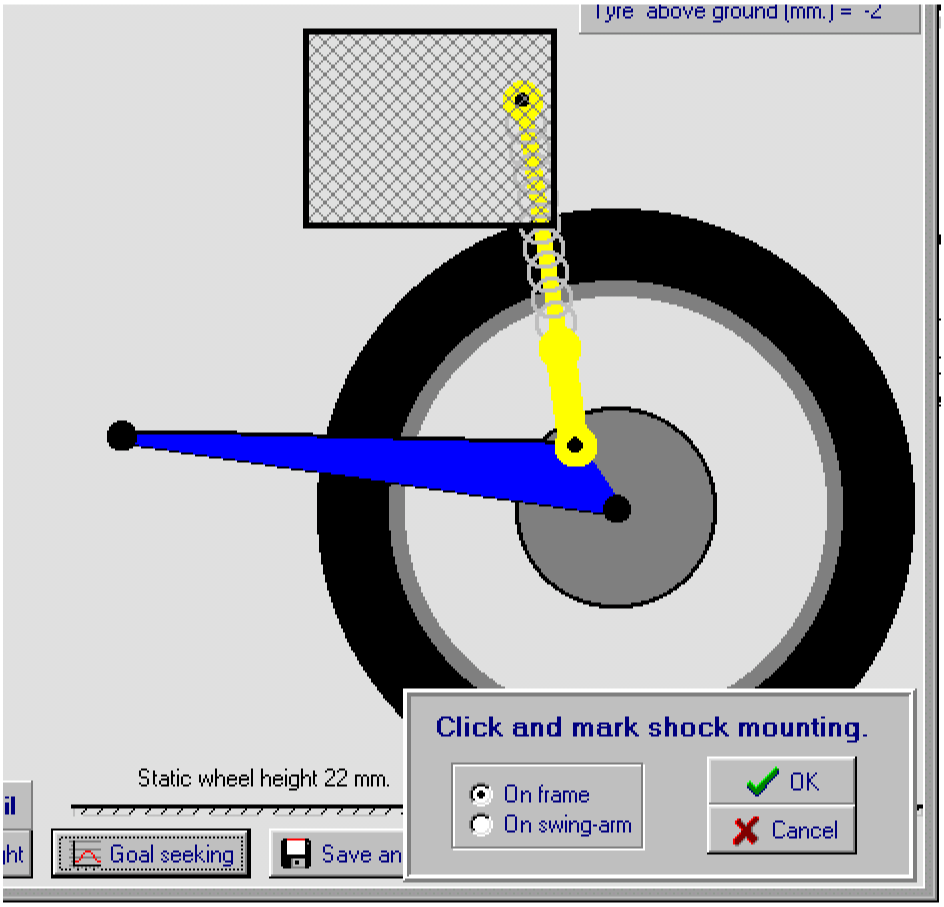
The user is encouraged to play with this control to get familiar with its effect.


Within certain physical and kinematic limits, this feature will automatically adjust the selected dimensions to attempt to achieve a specified suspension characteristic. The desired characteristic can either be entered manually or be cloned from another bike. For example if the progressive characteristics of a certain model motorcycle are deemed superior to those of a second bike then this feature will largely automate the process of calculating the modifications needed to apply those characteristics to the second machine.

The dimensions which can be physically adjusted depend on which class of suspension design is under consideration. For example, with the simple shock on swing-arm designs, we can either change the frame shock mounting or the swing-arm to shock mounting or both. Whereas, with a rocker system we have 5 possibilities plus combinations. This software only allows one set of dimensions to be changed at a time. Experiments during the development showed that multi-parameter searches were extremely slow and user control was lost.

Simple shock on swing-arm:

The following graphic shows how to select the dimensional limits of the parameter which we wish to alter to achieve a set characteristic. In this case the chosen variable is the frame to shock mounting coordinates. The selected limits might be determined by packaging constraints, for example.

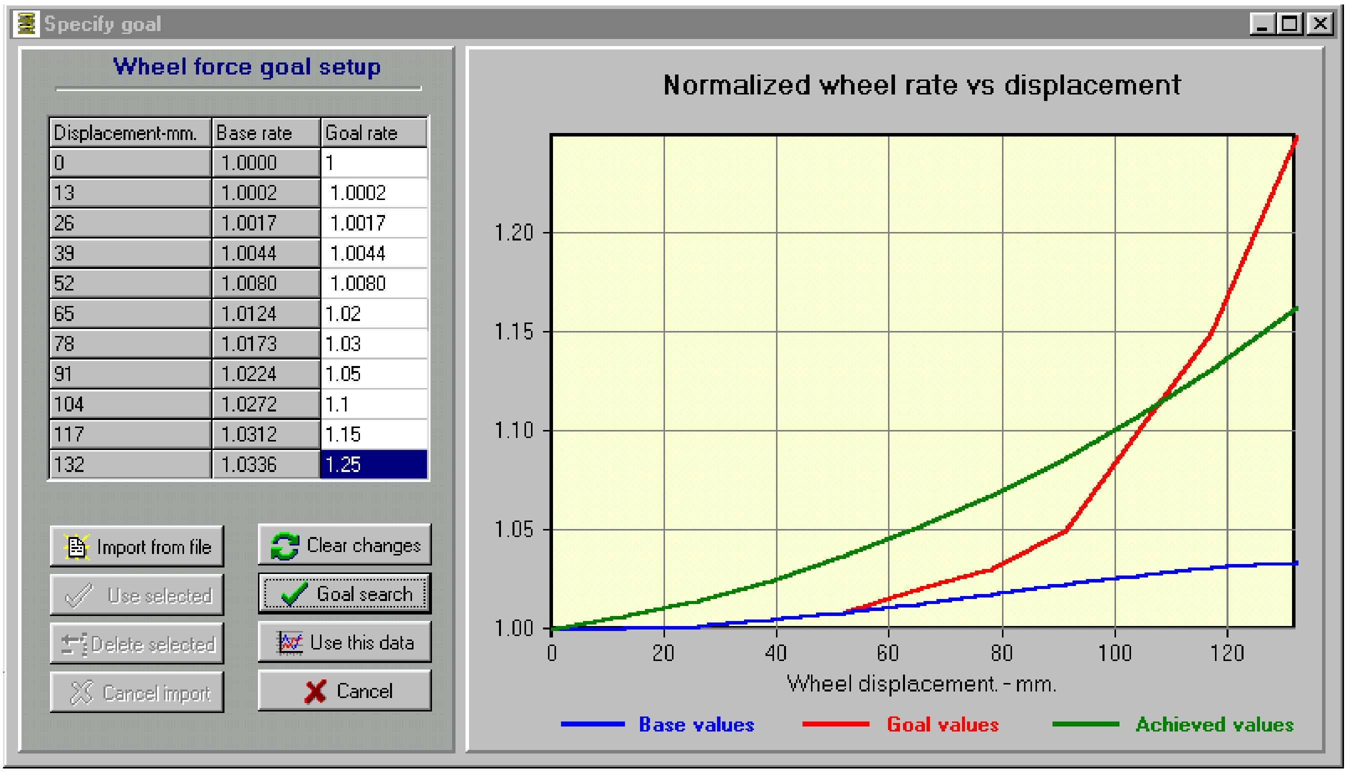



From the pop-up panel select the parameter to modify, in this example it is “On frame”. Then, with a normal click and drag procedure, mark the limits as shown and click on the OK button when done.

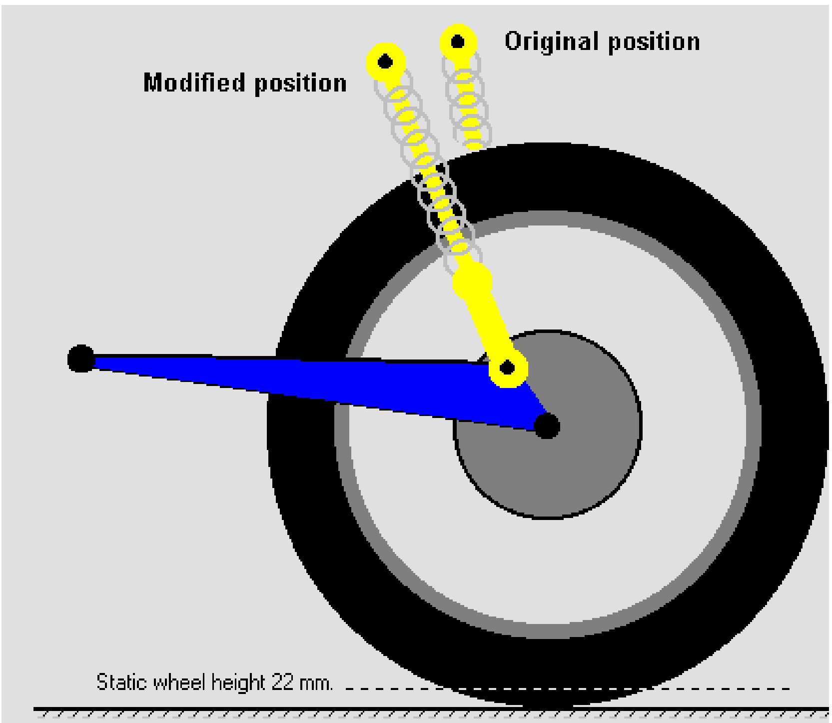
This will then pass on to a screen for entering the desired characteristic, which will show the unmodified characteristic as well as the achieved characteristic. The closeness of fit (least squared error) between the desired characteristic and that achieved will depend on how realistic the requested requirement was and the sensitivity to the modified parameter. For example, asking for a 2:1 wheel rate progression with a simple twin shock layout is not generally realistic. Depending on wheel movement etc., 1.1 to 1.2 is the maximum obtainable.

In the case shown below, the required degree of progressiveness is beyond that which the simple layout can provide and so the achieved result only goes part way to satisfy the unrealistic requirement. This example was chosen for illustrative purposes, to show that not all requirements can be physically achieved.

On entry to this screen we see a table and graph of the unmodified layout, the characteristic chosen for comparison is the normalized value of the wheel rate, this allows comparison between different layouts and bike models, on an equal footing. In this example the “Goal rate” was entered manually to request a design with a total of 25% progression, not a lot for a rocker system but quite high for this simple design, which achieved 16%. When the goal is entered, click on the “Goal search” button and the achieved values will be plotted.



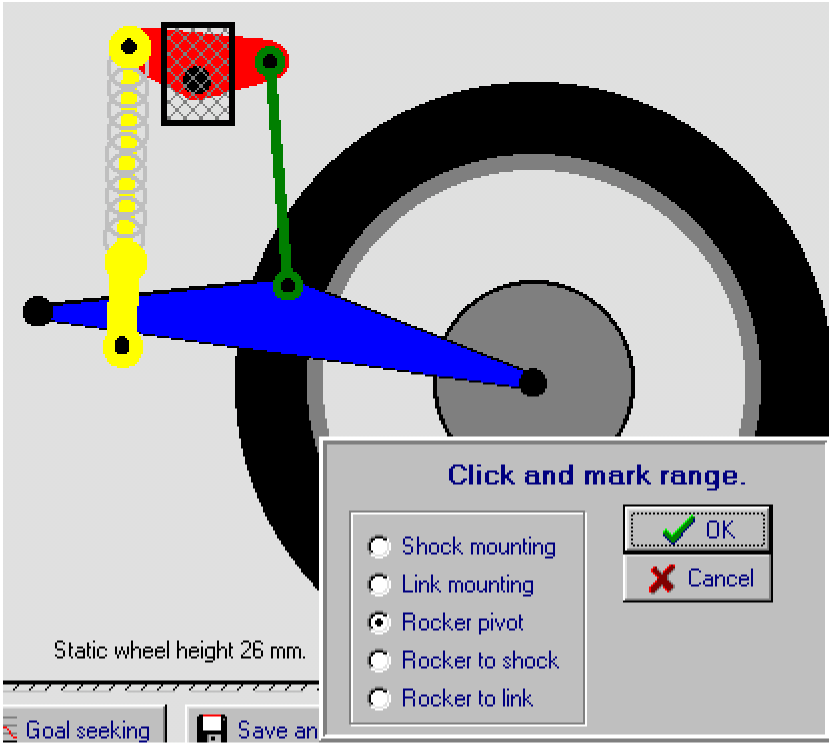

You can now either Cancel or elect to use the new layout. The new dimensions will be transferred back to the data entry screen automatically. The following picture shows how the frame to shock mounting has been moved forward to give the closest fit possible to our requirement. The shock movement will also be adjusted to keep the original maximum wheel displacement. Spring rate and spring preload will be automatically adjusted also, to maintain the same initial wheel rate and wheel preload, these parameters may need further manual adjustment to get the overall effect desired.



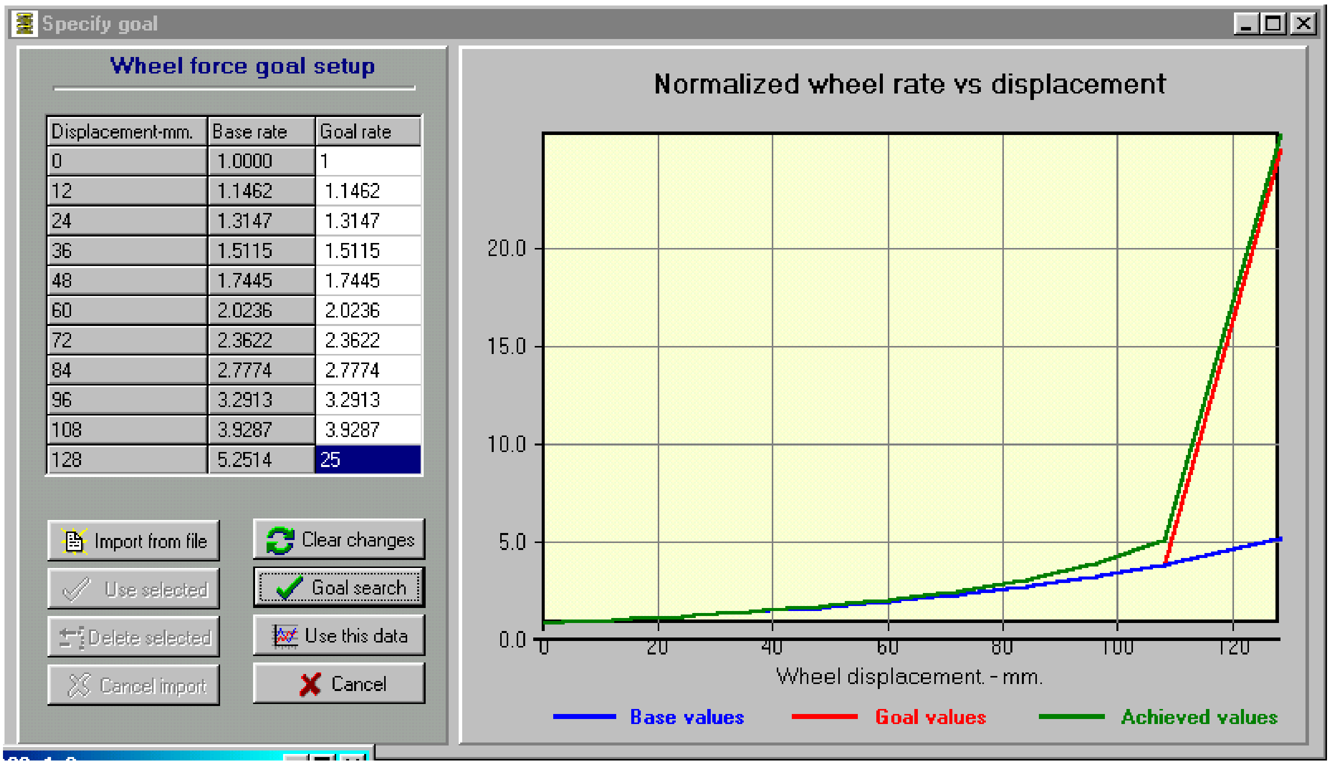
## Rocker systems

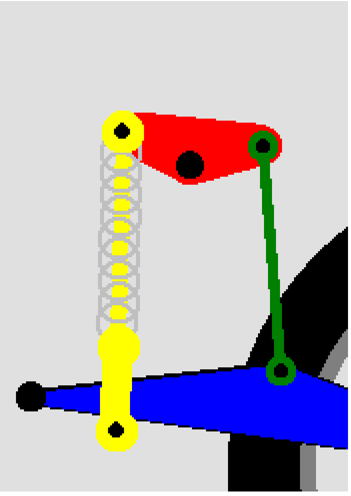
It is when we consider the rocker systems that the real power of this feature becomes more evident.

The next example shows what can happen when we allow changes to the rocker pivot position as below;

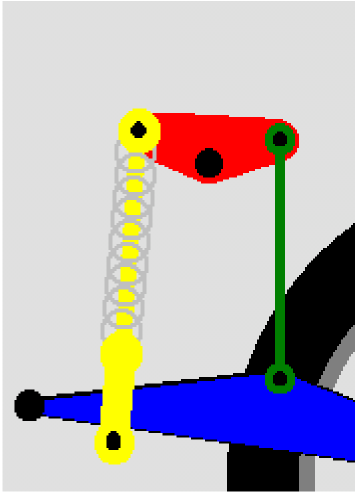



As shown below, the original maximum value of the normalized wheel rate was 5.2514. In this case we only want to increase the rate at the end of the wheel travel so only the last value of the goal rate was changed to 25. We can see that the achieved characteristic is very close to that requested. To get that change the X coordinate of the rocker pivot changed from 158 to 175 and the Y coordinate from 602 to 605. Link length changed from 225 to 231.3 to maintain the starting wheel position.

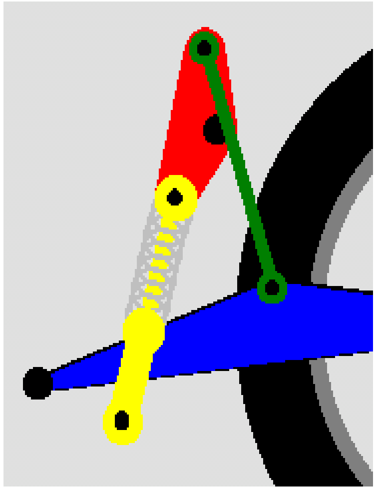




**Original system fully extended.**

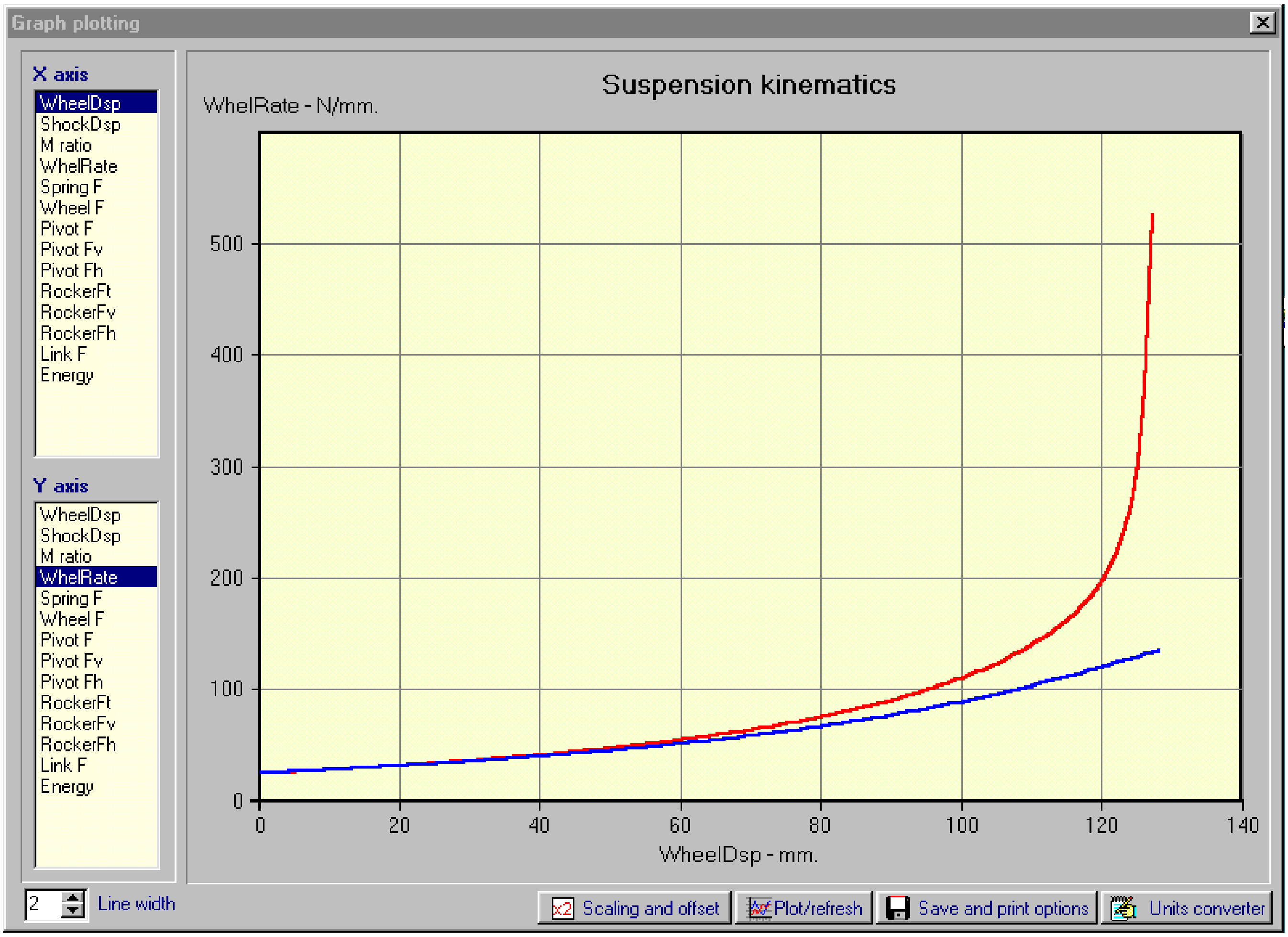


**Modified design fully extended.**



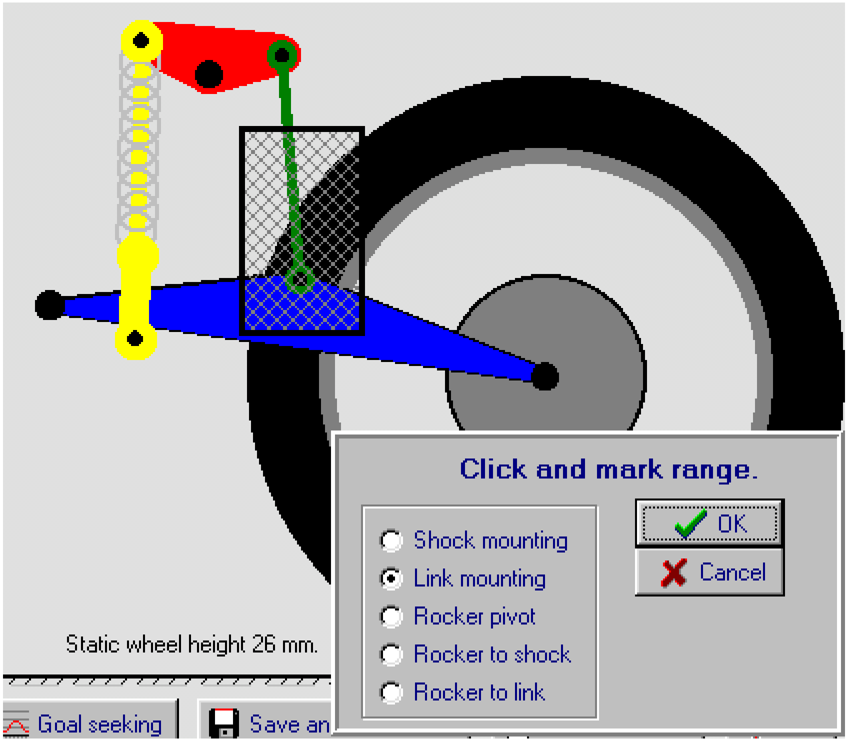
**Modified design fully compressed. Note that more wheel displ. would cause a locked movement.**

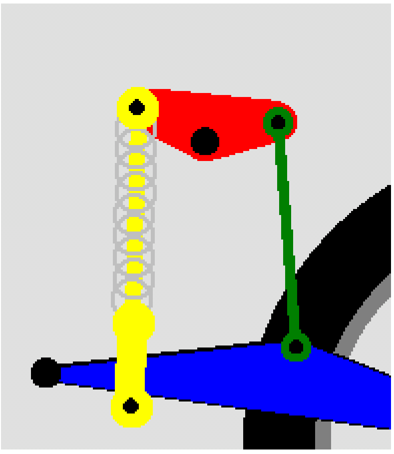
**Word of warning.** Although we have achieved the wheel rate range that we sought, we have created a design that is very close to a lock condition (as explained in the Kinematics booklet) at full compression, as we can see from the above graphics. We can also see how the characteristics have changed by comparing the real wheel rates (not the normalized values) of the two designs in the following plot. Note how the rate of the modified design increases rapidly toward full compression, as the lock state is approached.



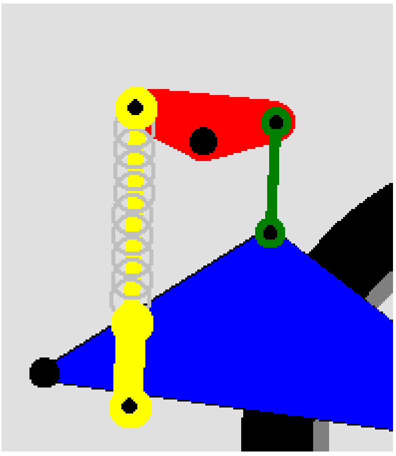
This does not mean that all layouts which give nearly a 25:1 wheel rate range will tend to this potential lock problem. Even higher ranges can be achieved with other design options. The above example was chosen to illustrate that whilst a goal searching feature can be extremely useful, the resulting design and characteristics must be scrutinized carefully to make sure that it satisfies all requirements.

The next example starts with the same basic design but instead of goal searching on relocating the rocker pivot, the search was done for moving the link to swing-arm dimensions. As follows:

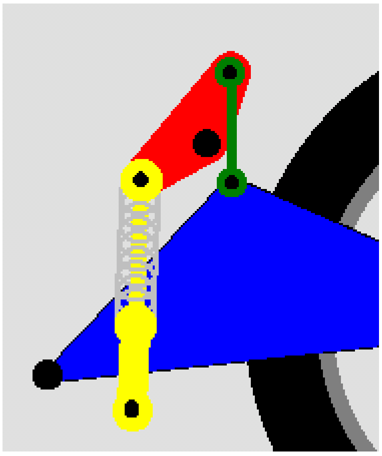


**Original system fully extended.**

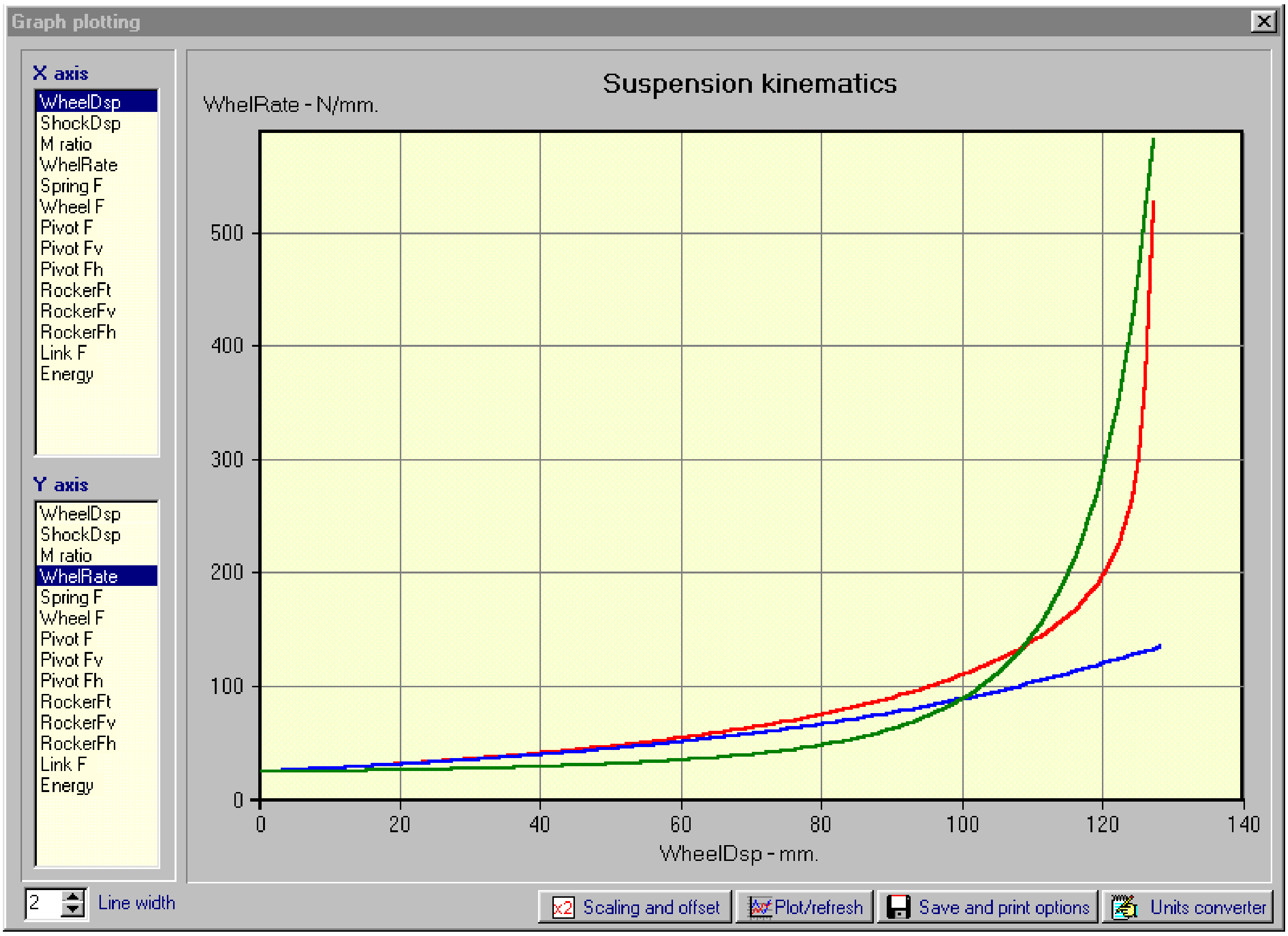


**Modified design fully extended.**



**Modified design fully compressed. This design has a greater margin before reaching an "over centre" condition.**

We can see that even though the normalized wheel rate range was a bit greater than in the previous example, there is a greater margin before the lock condition. The plot of the wheel rate also shows how the rate increases at a slower rate as full bump position is approached.




**Important note:** When marking the range within which you allow the specified dimension to be modified, do not follow the temptation to make the range too large without considering if such dimensions are physically possible. It is very easy to specify a range in which a lock may occur or perhaps cause the shock to go "over centre". In most cases the software will simply ignore these "rogue" dimensions and eliminate them from the results of a goal search. However, it is possible that occasionally a combination of dimensions will cause an error message to be displayed.

## Cloning a design

In addition to entering the desired wheel rate values by hand we can clone the characteristics from another model as follows:

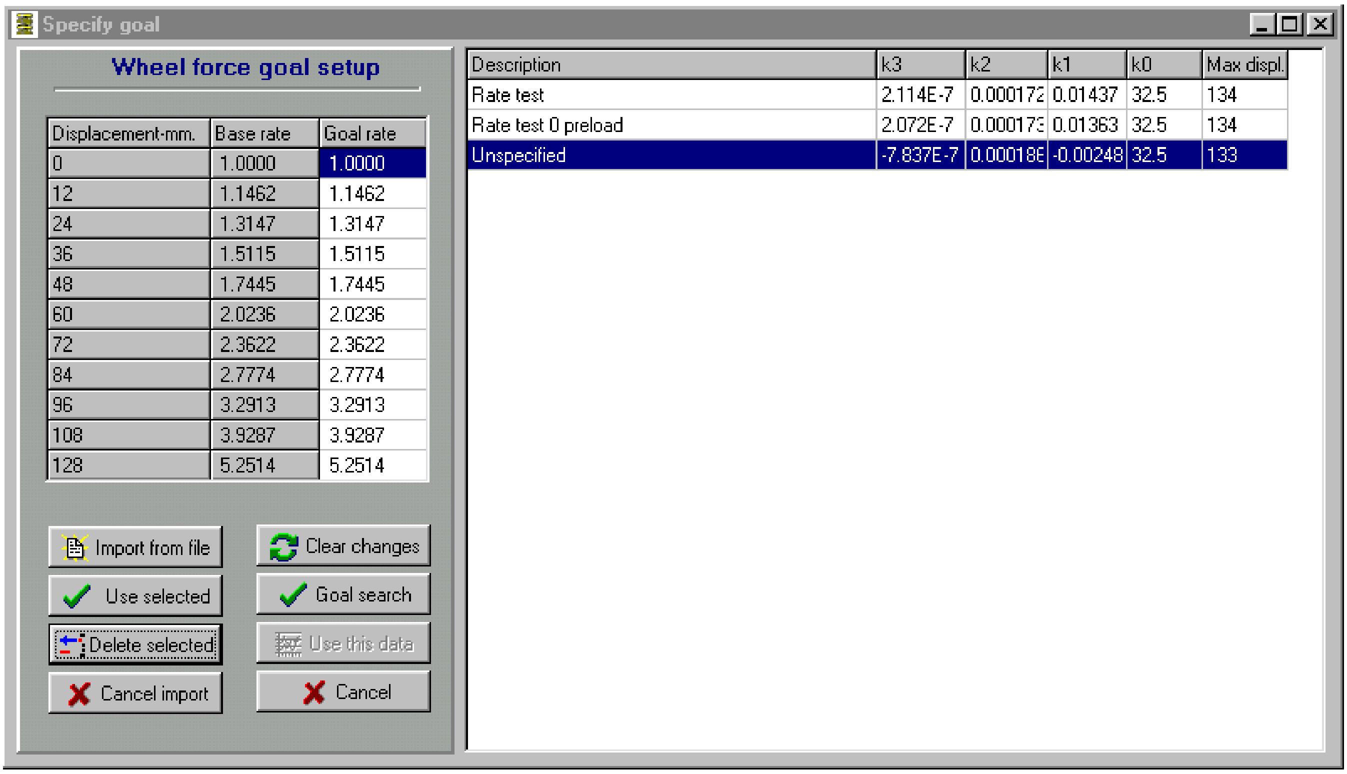
- Enter the data or load it from file for the bike to be cloned.
- Click the "Calculate and plot" button and select the "Wheel rate" page.
- Click the "Save and print options" button and select "Save eqn. to file".

The data from the bike to be cloned will be put in a file with any others that you may have already saved to be cloned.

Now load the data for the design which you wish to modify, as above, and select the parameter to do the goal search with, from the goal search panel, as in the examples above.

From the goal search screen:

- Click on the "Import from file" button.
- Select the required design from the list.
- Click on the "Use selected" button.




The data from the donor will be loaded into the “Goal rate” table and then you can proceed with the goal search as in the previous examples.

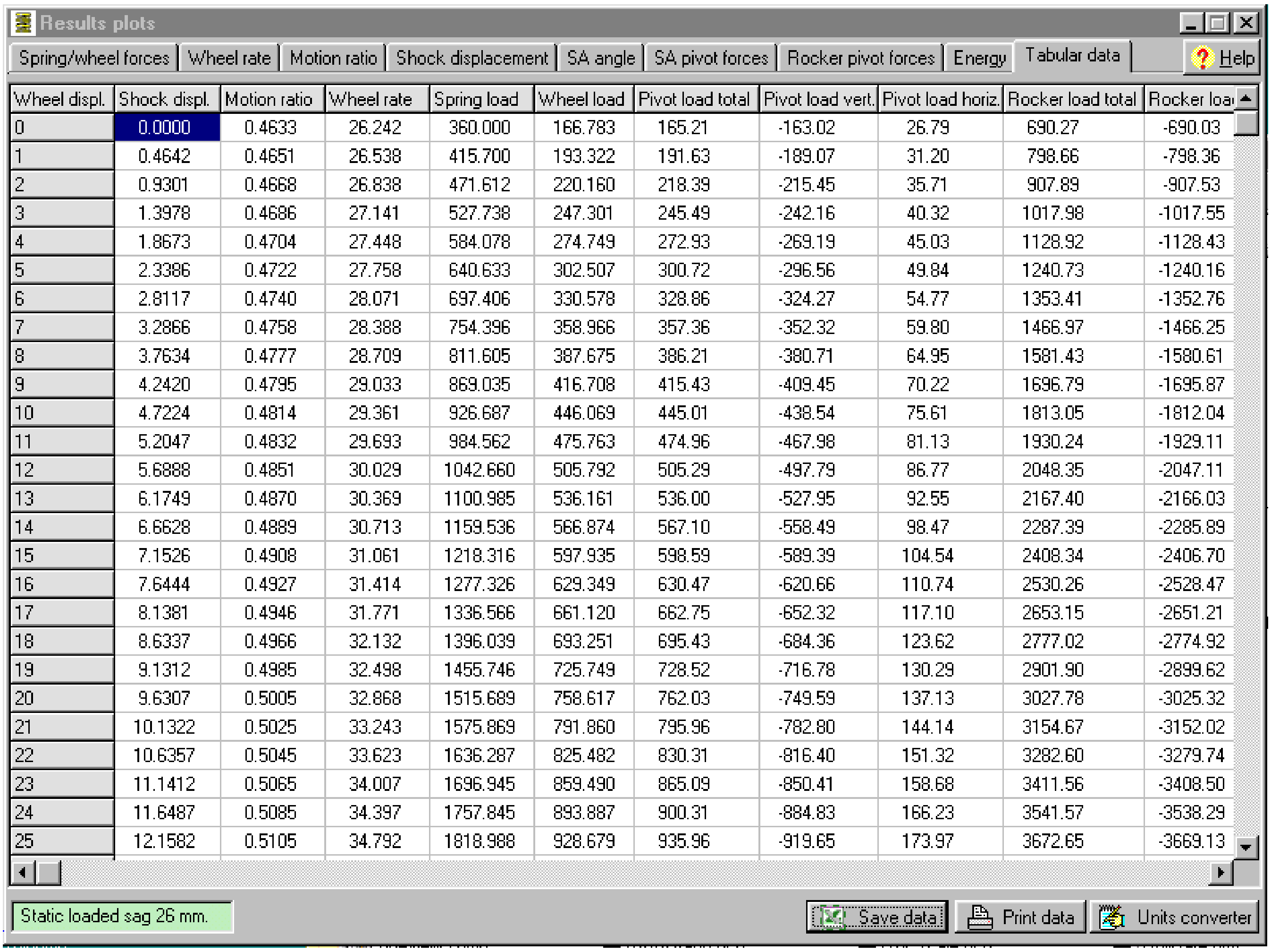
When using a donor design it is quite likely that the range of wheel displacement will be different from the receiving design. In that case the software will automatically impose the donor range of wheel rate values onto the receiving design.

## Results screens


There are several pre-defined screens with graphs plotted of various sets of calculated data. One screen contains the calculated data in tabular form, which can be exported in eXcel spread sheet, as well as other, formats for additional analysis or charting.

All of these results screens can be printed separately. The results screens display automatically after clicking on the button, and are selected by the following page tabs.


### Tabular view




| Wheel displ. | Shock displ. | Motion ratio | Wheel rate | Spring load | Wheel load | Pivot load total | Pivot load vert. | Pivot load horiz. | Rocker load total | Rocker loa |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.0000 | 0.4633 | 26.242 | 360.000 | 166.783 | 165.21 | -163.02 | 26.79 | 690.27 | -690.03 |
| 1 | 0.4642 | 0.4651 | 26.538 | 415.700 | 193.322 | 191.63 | -189.07 | 31.20 | 798.66 | -798.36 |
| 2 | 0.9301 | 0.4668 | 26.838 | 471.612 | 220.160 | 218.39 | -215.45 | 35.71 | 907.89 | -907.53 |
| 3 | 1.3978 | 0.4686 | 27.141 | 527.738 | 247.301 | 245.49 | -242.16 | 40.32 | 1017.98 | -1017.55 |
| 4 | 1.8673 | 0.4704 | 27.448 | 584.078 | 274.749 | 272.93 | -269.19 | 45.03 | 1128.92 | -1128.43 |
| 5 | 2.3386 | 0.4722 | 27.758 | 640.633 | 302.507 | 300.72 | -296.56 | 49.84 | 1240.73 | -1240.16 |
| 6 | 2.8117 | 0.4740 | 28.071 | 697.406 | 330.578 | 328.86 | -324.27 | 54.77 | 1353.41 | -1352.76 |
| 7 | 3.2866 | 0.4758 | 28.388 | 754.396 | 358.966 | 357.36 | -352.32 | 59.80 | 1466.97 | -1466.25 |
| 8 | 3.7634 | 0.4777 | 28.709 | 811.605 | 387.675 | 386.21 | -380.71 | 64.95 | 1581.43 | -1580.61 |
| 9 | 4.2420 | 0.4795 | 29.033 | 869.035 | 416.708 | 415.43 | -409.45 | 70.22 | 1696.79 | -1695.87 |
| 10 | 4.7224 | 0.4814 | 29.361 | 926.687 | 446.069 | 445.01 | -438.54 | 75.61 | 1813.05 | -1812.04 |
| 11 | 5.2047 | 0.4832 | 29.693 | 984.562 | 475.763 | 474.96 | -467.98 | 81.13 | 1930.24 | -1929.11 |
| 12 | 5.6888 | 0.4851 | 30.029 | 1042.660 | 505.792 | 505.29 | -497.79 | 86.77 | 2048.35 | -2047.11 |
| 13 | 6.1749 | 0.4870 | 30.369 | 1100.985 | 536.161 | 536.00 | -527.95 | 92.55 | 2167.40 | -2166.03 |
| 14 | 6.6628 | 0.4889 | 30.713 | 1159.536 | 566.874 | 567.10 | -558.49 | 98.47 | 2287.39 | -2285.89 |
| 15 | 7.1526 | 0.4908 | 31.061 | 1218.316 | 597.935 | 598.59 | -589.39 | 104.54 | 2408.34 | -2406.70 |
| 16 | 7.6444 | 0.4927 | 31.414 | 1277.326 | 629.349 | 630.47 | -620.66 | 110.74 | 2530.26 | -2528.47 |
| 17 | 8.1381 | 0.4946 | 31.771 | 1336.566 | 661.120 | 662.75 | -652.32 | 117.10 | 2653.15 | -2651.21 |
| 18 | 8.6337 | 0.4966 | 32.132 | 1396.039 | 693.251 | 695.43 | -684.36 | 123.62 | 2777.02 | -2774.92 |
| 19 | 9.1312 | 0.4985 | 32.498 | 1455.746 | 725.749 | 728.52 | -716.78 | 130.29 | 2901.90 | -2899.62 |
| 20 | 9.6307 | 0.5005 | 32.868 | 1515.689 | 758.617 | 762.03 | -749.59 | 137.13 | 3027.78 | -3025.32 |
| 21 | 10.1322 | 0.5025 | 33.243 | 1575.869 | 791.860 | 795.96 | -782.80 | 144.14 | 3154.67 | -3152.02 |
| 22 | 10.6357 | 0.5045 | 33.623 | 1636.287 | 825.482 | 830.31 | -816.40 | 151.32 | 3282.60 | -3279.74 |
| 23 | 11.1412 | 0.5065 | 34.007 | 1696.945 | 859.490 | 865.09 | -850.41 | 158.68 | 3411.56 | -3408.50 |
| 24 | 11.6487 | 0.5085 | 34.397 | 1757.845 | 893.887 | 900.31 | -884.83 | 166.23 | 3541.57 | -3538.29 |
| 25 | 12.1582 | 0.5105 | 34.792 | 1818.988 | 928.679 | 935.96 | -919.65 | 173.97 | 3672.65 | -3669.13 |

All calculated values are available in this table. The data is shown at increments of 1 mm. of vertical wheel movement, ranging from zero up to the maximum permitted by the maximum shock stroke.

Vertical and horizontal scroll bars allow access to the whole table.

The full table can be printed and or saved in various formats. Viz:

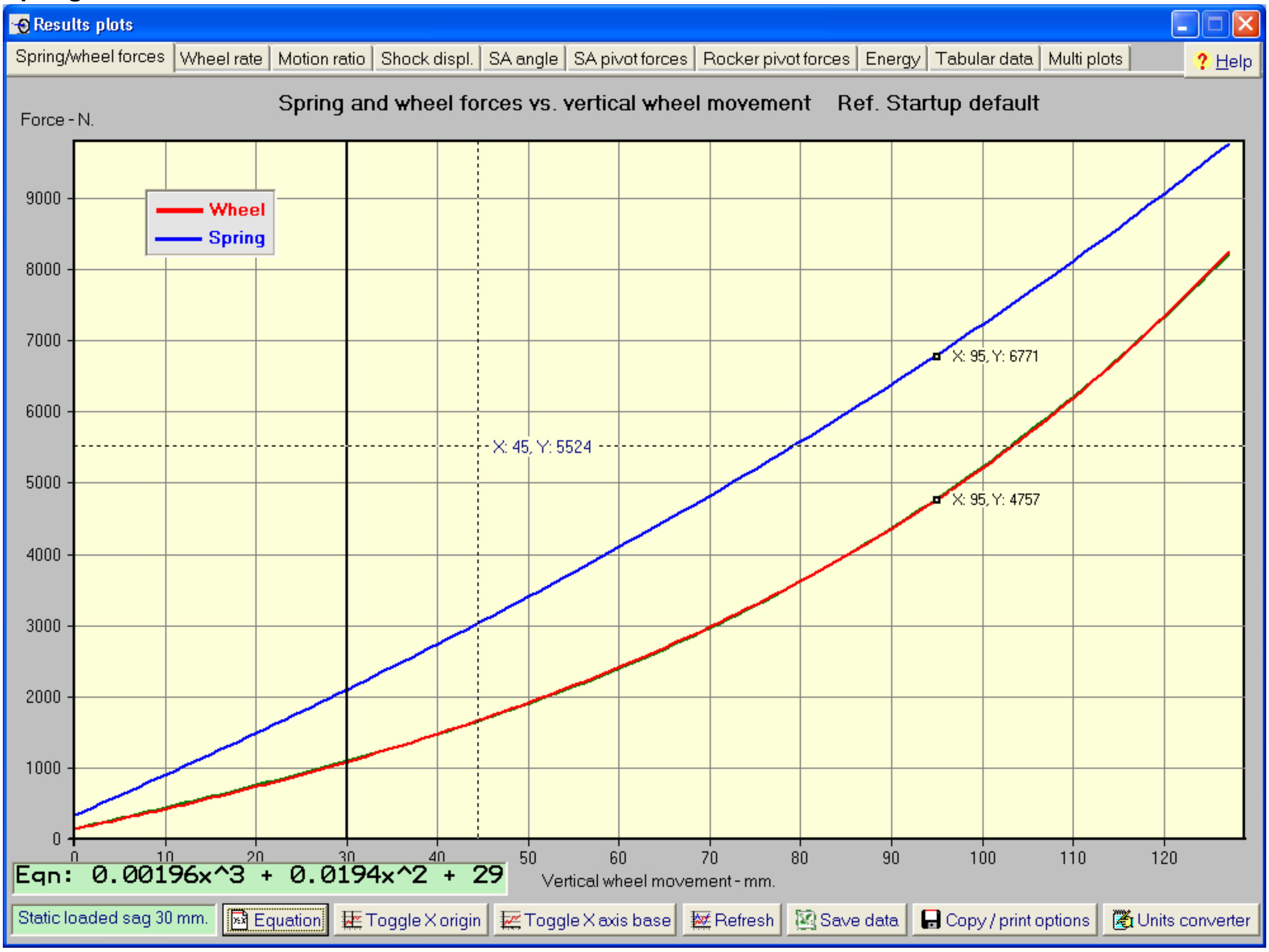
*.TFD – For use with the internal multi-plotter.

*.XLS – For use with MS excel and compatible programmes.

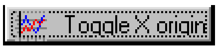
*.SLK – General purpose spreadsheet format. Loads with excel and many other spreadsheets.

*.TXT – TAB delimited file. Can be imported into spread sheets and other software.

## Spring and wheel loads

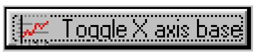



These curves show the actual forces experienced by the wheel and shock spring, over the range of wheel movement. In actual use there will be additional forces due to damping, but these vary with shock velocity and so cannot be calculated in a static analysis such as this. These curves and that of the actual wheel rate are probably the most important in any suspension analysis. If specified, the effects of a bump-stop rubber will be shown in these plots.

The vertical heavy black line is the static sag position, in this case it is 30mm.. In other words, under initial static loading the sag at the wheel will be 30mm. The origin of the X axis can be toggled to be either at the fully extended position or at the static sag position by using the 

button. The above graph shows the origin at the default full rebound position.

When the origin is at the ride height positive wheel movement values indicate compression from the static position and negative values show the sag. The wheel load graph, as shown later, illustrates the origin when set to the ride height.

The 

button toggles between using the wheel motion or shock compression as the values for the X axis. The line equation will automatically change to reflect the new axis.

Other features shown on this graph are:

Equation of a 3rd order polynomial fit to the wheel load graph.

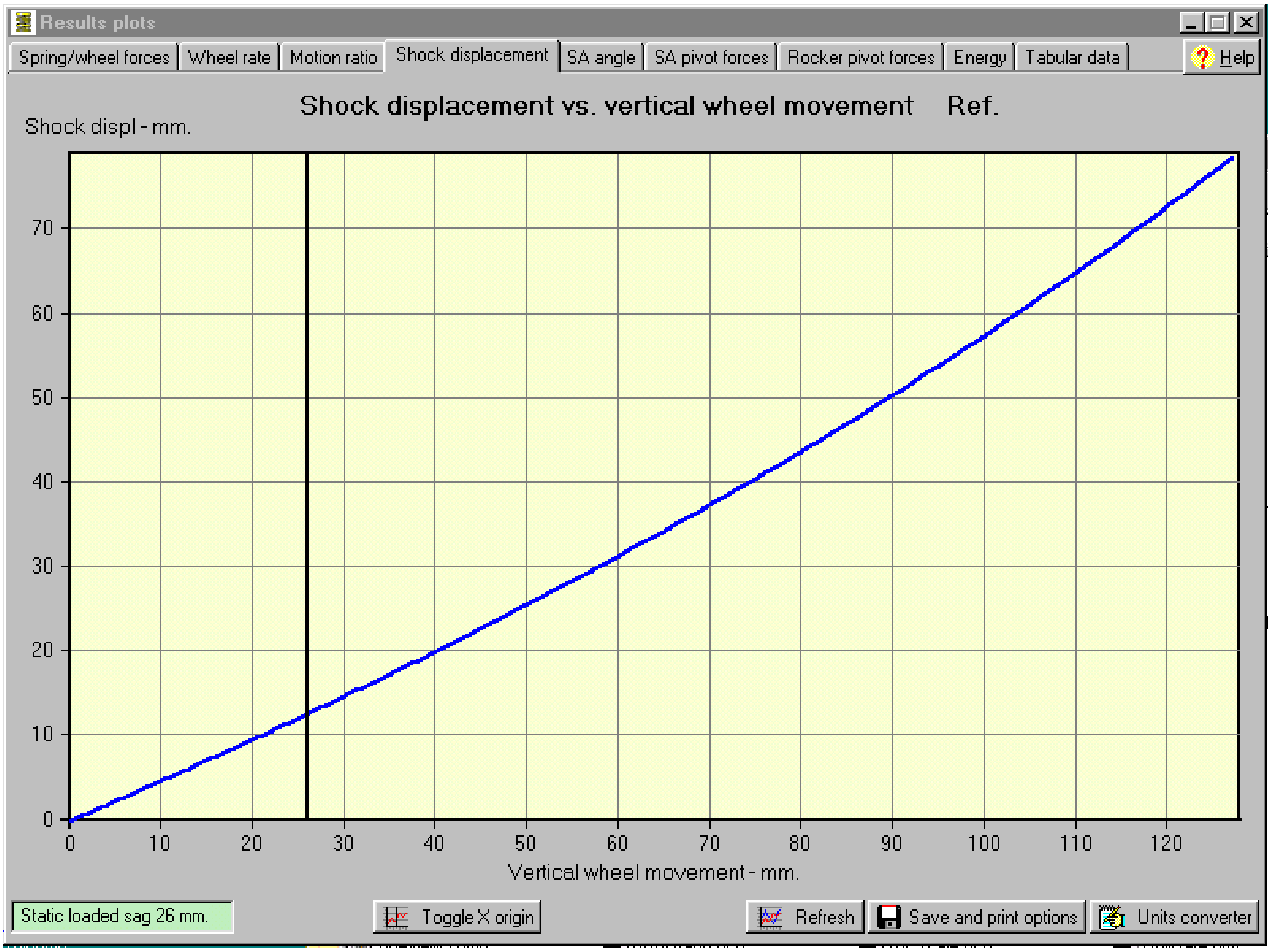
Points can be marked with X-Y coordinates, by pressing and releasing the LHS mouse button without moving the mouse, as shown above at a displacement of 95mm.

As you move the mouse over the graph, cross hairs will be displayed with the X-Y values.

Clicking the Refresh button will redraw the curves with any marks and zooming cleaned off.

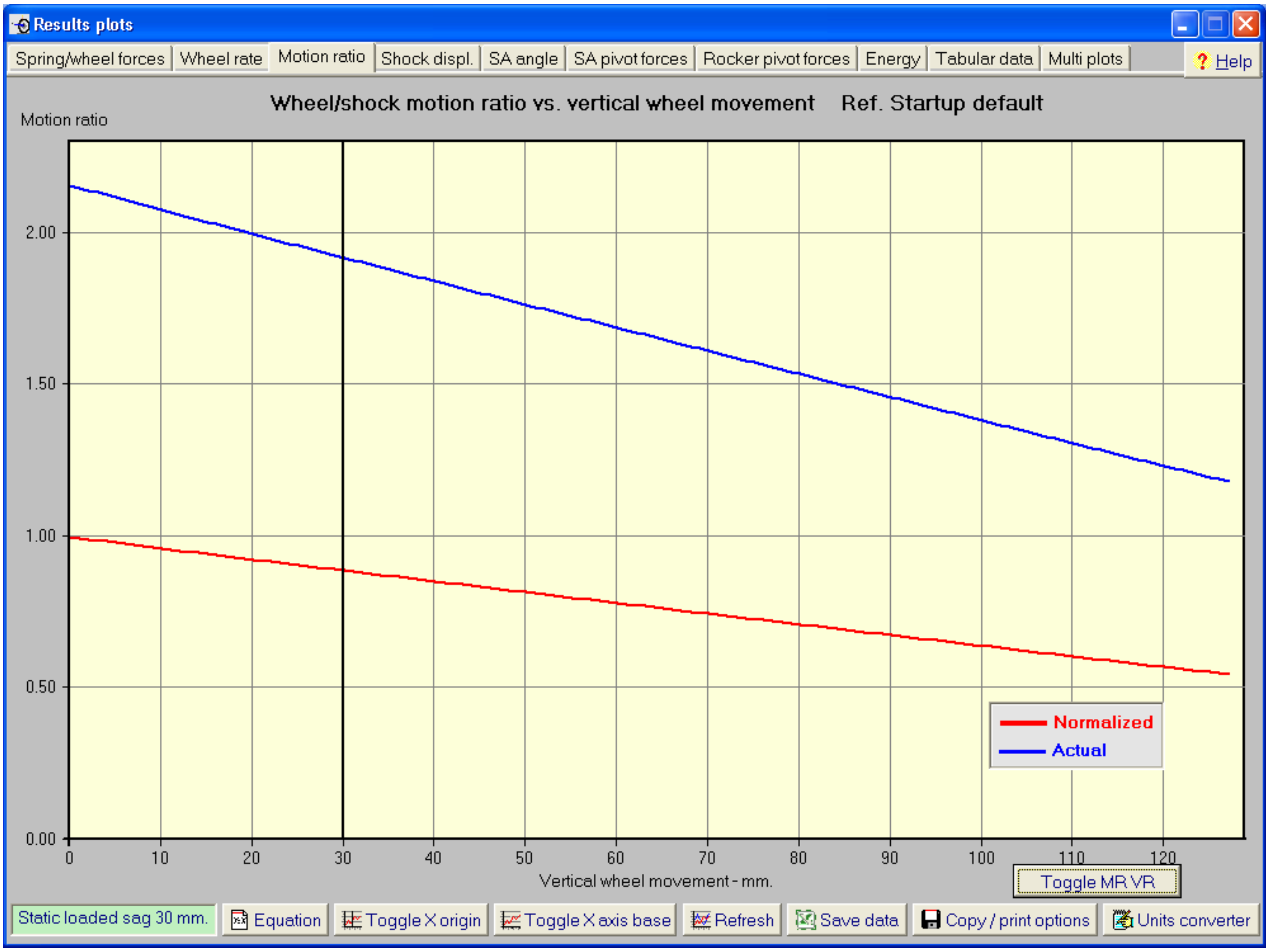
To zoom use the LHS mouse button and draw a rectangle around the area to be zoomed in a downward and right motion. To unzoom, drag the mouse upward and to the left.

## Shock displacement




This plot shows the relationship between the shock compression and vertical wheel movement. In this example, nearly 130 mm. of total vertical wheel movement causes almost 80 mm. of shock compression.

## Motion ratio




The motion ratio is also called leverage ratio, velocity ratio and mechanical advantage. The default plot shows the shock velocity in terms of the vertical wheel velocity. Clicking the "Toggle MR VR" button inverts the ratio to show the wheel velocity in terms of the vertical shock velocity. It is a matter of personal preference which to use

In this example, we can see that at full rebound the motion ratio is around 0.46 which means that the wheel is moving upward at a rate of over double the compression rate of the shock. Hence the leverage between the wheel and shock is 2.17 so the wheel rate is softer than the shock rate. At full compression, this ratio is just above 0.8, which represents a lower leverage of 1.25 and hence a stiffer suspension rate.

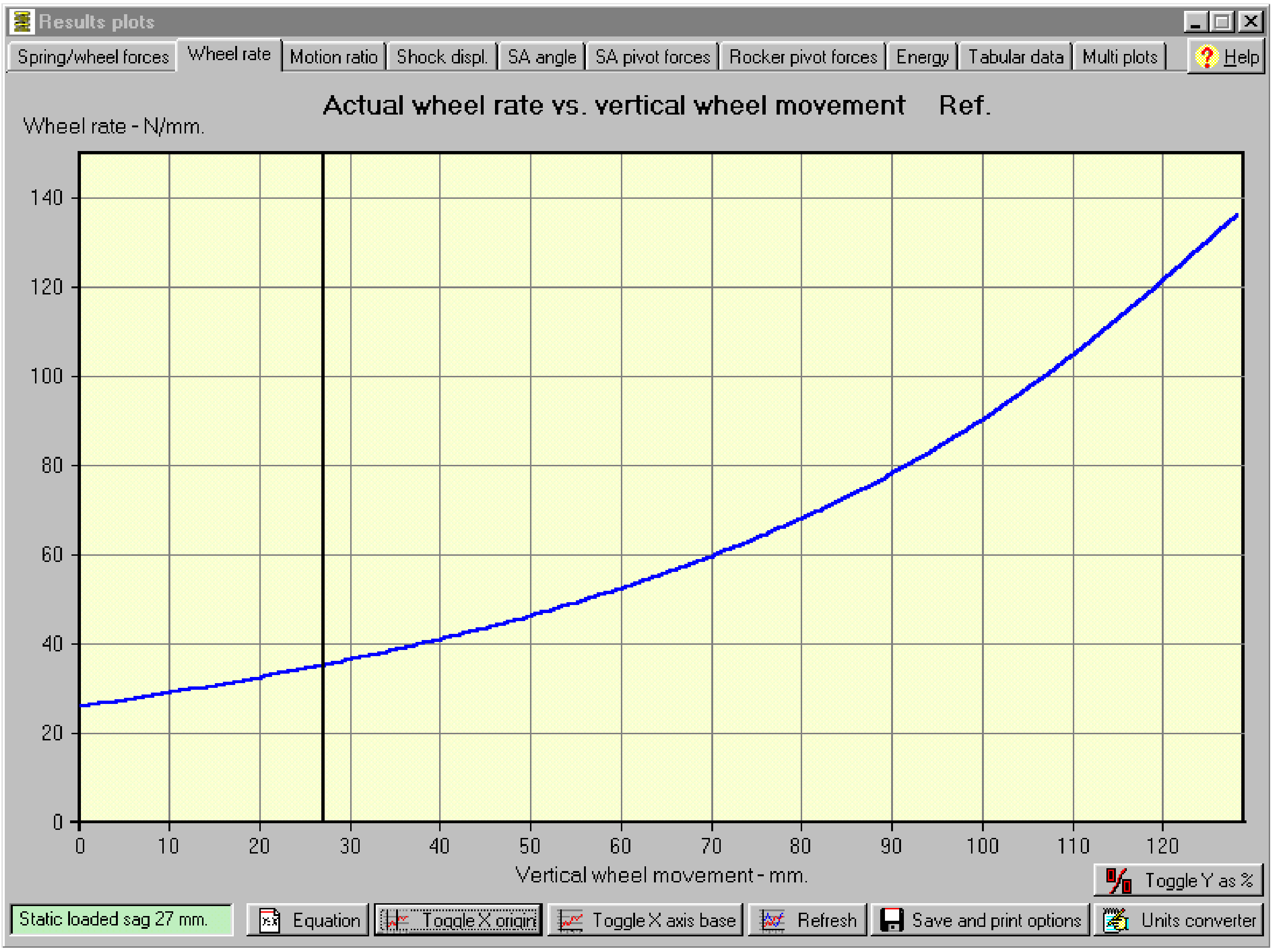
This example is of a progressive suspension geometry. A completely fixed single rate design would be represented by a constant motion ratio over the full range of suspension movement.

The default ratio is usually less than 1.0, that is; the shock moves slower than the wheel. The total movement of the shock is less than that of the wheel. This is not a physical requirement and some scooters have a shock mounted behind the wheel spindle for packaging reasons. A downward slope of the plot lines indicates a progressive suspension characteristic.

When the inverted ratio is used then the opposite applies, i.e. the ratio is usually greater than 1.0 and an upward slope of the plot lines indicates a progressive suspension characteristic.

The red curve shows the same curve but normalized such that the starting value is equal to 1.0 and other values have been increased proportionally. This gives a curve which is useful for comparison with other designs.

## Wheel rate



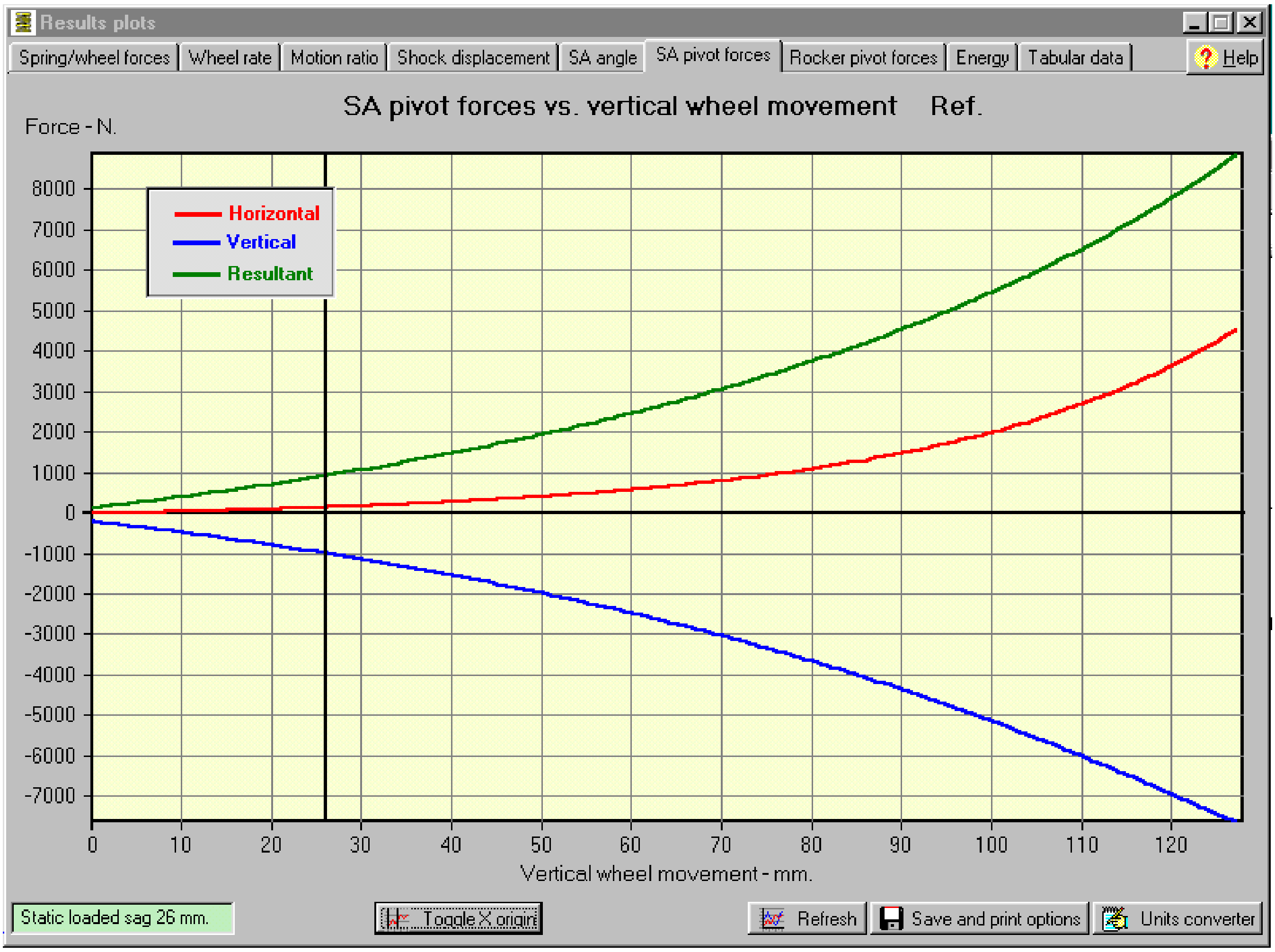

The effective wheel spring rate is the vertical rate as seen by the wheel and is usually lower in value than the rate of the spring itself.

At any point in the movement range the wheel rate is defined as the extra vertical force, at the tyre/road interface, needed to produce a small unit vertical displacement of the wheel. This software calculates this in steps of 1.0 mm. of wheel movement.

This curve will also show the effects of specifying a bump stop and/or top out spring, although that was not done in this example, which is highly progressive just by the nature of the geometric layout. The rate at full bump is over 5 times that at full rebound. Compare this graph with that of the shock compression. The compression graph can be very misleading to a casual glance, it looks almost linear in this example, but as we can see it is far from that.


This button toggles the display between showing the actual wheel rate, as in the graphic above, and showing the same data as a percentage of the starting wheel rate. The percentage display is useful as a comparison with other setups and designs because it is independent of the rate of the suspension spring. The actual wheel rate display will change according to the specified spring rate.

## Swing-arm pivot forces



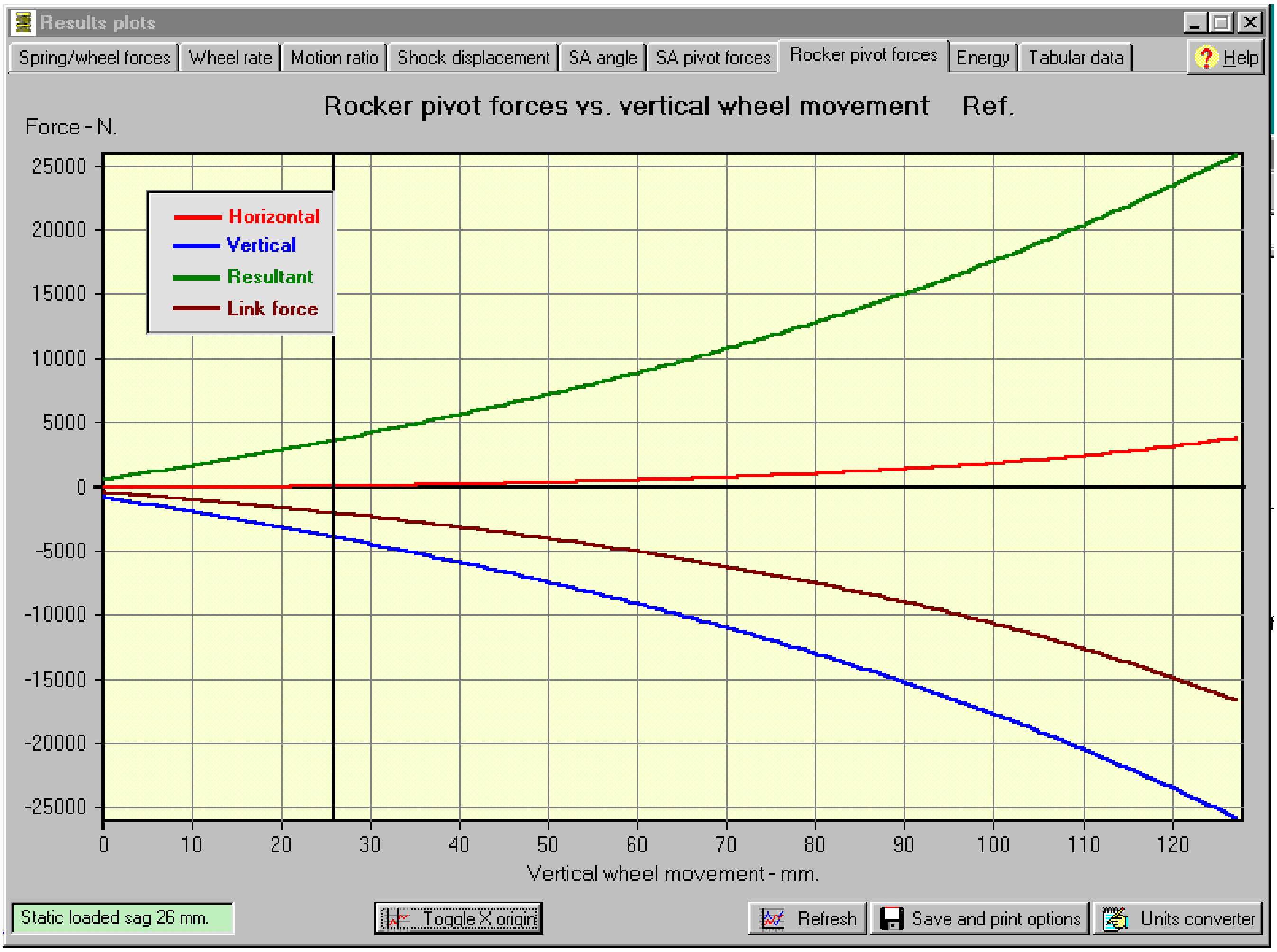

The advent of modern suspension systems, with high leverage, has resulted in higher loading in the swing-arm pivot bearings. Due account must be taken of this in the selection of the bearings and the structural properties of the swing-arm and frame supporting points.

These graphs show the total or resultant force, together with the horizontal and vertical components.

If specified, the effects of a bump-stop rubber will be shown in these plots.

***N.B.*** Remember that this does not include the effects of damping forces which may easily double these values in some cases.

## Rocker pivot forces

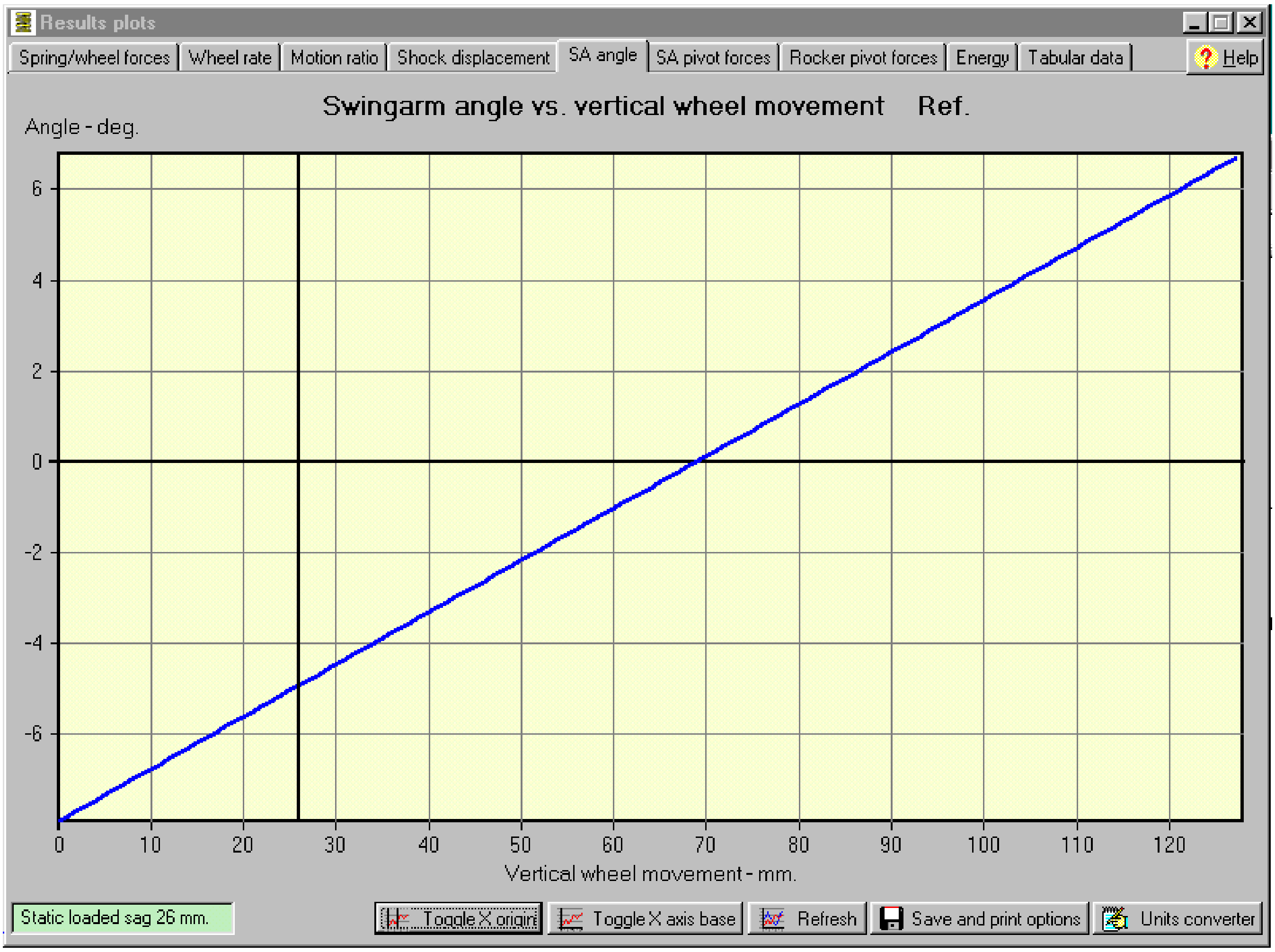



In many designs using a rocker and link system the forces at the rocker pivot can be substantial. As with the previous plot these curves show the total and its horizontal and vertical components. Also shown is the force in the link, tension is shown as negative and compression as positive.

If specified, the effects of a bump-stop rubber will be shown in these plots.

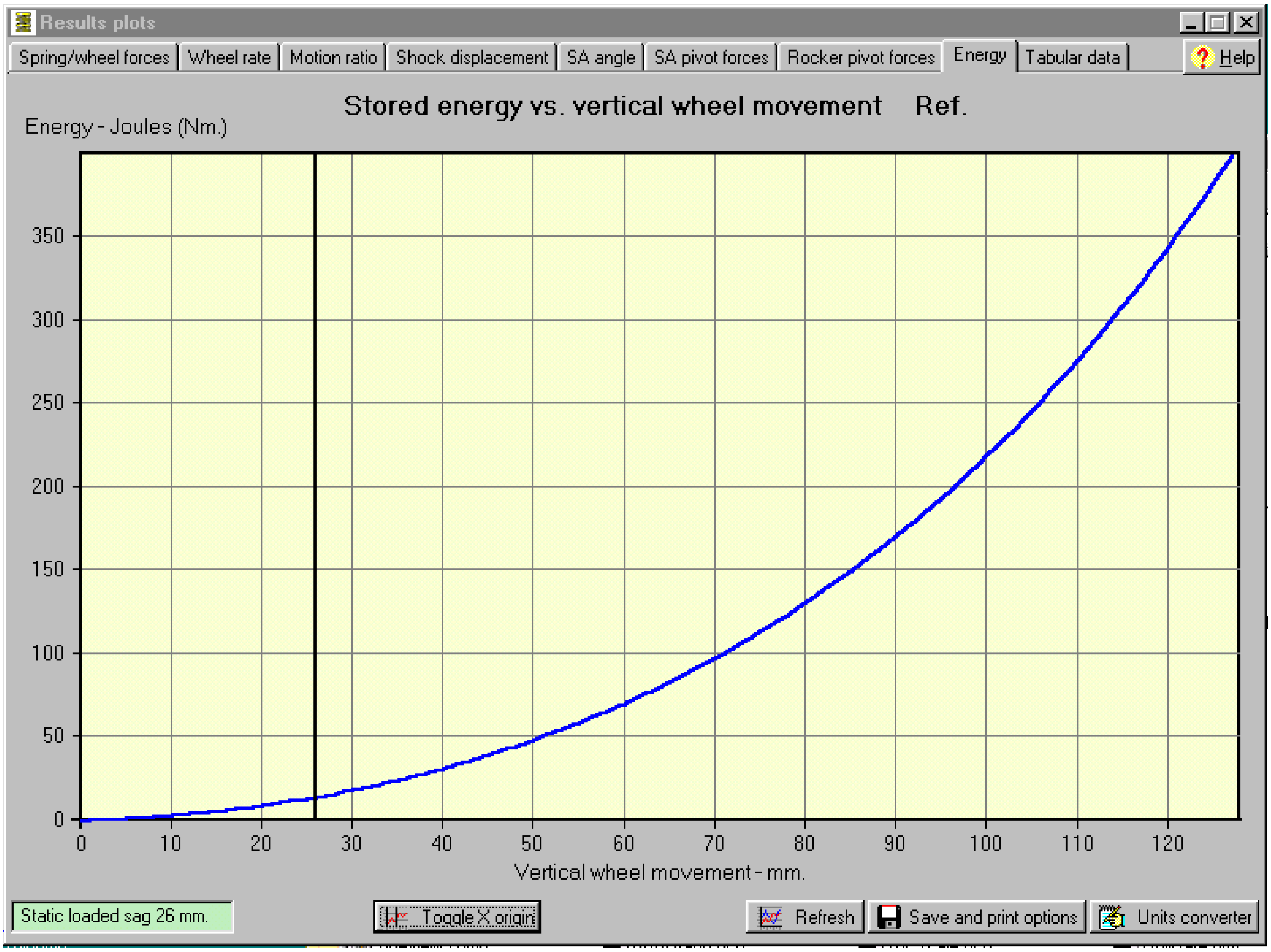
***N.B.*** Remember that this does not include the effects of damping forces which may easily double these values in some cases.

## Swing-arm angle

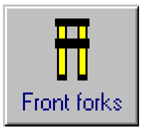



This shows the angle of the swing-arm to the horizontal, over the range of wheel movement. The swing-arm angle is defined as the angle between the horizontal and the line drawn through the swing-arm pivot and the rear wheel axle. A negative value occurs when the swing-arm slopes downward toward the rear.

## Energy

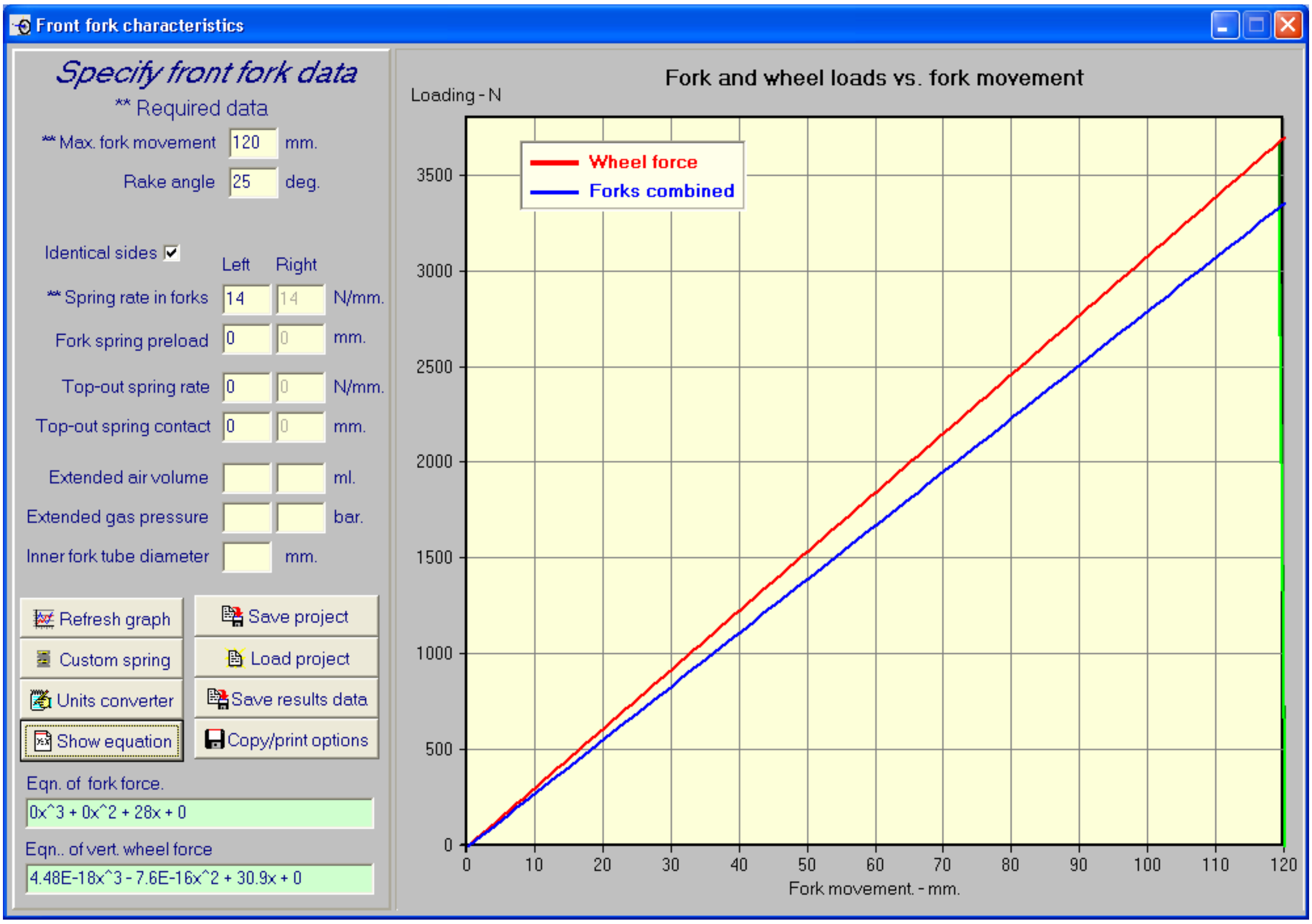



This shows the energy stored in the spring at varying displacements. This energy is an important parameter when considering suspension in impact situations, such as a motoX bike landing after a high jump or road bike hitting a roadside curb head on. Of most interest is the value at the maximum compression point.




## Front forks

The data entry fields accept the data for each fork leg separately to allow for different rate springs in each side, if the “Identical sides” box is ticked then data for a single side will automatically be inserted for the other leg. The graphs show the combined results of the complete fork. As with the rear suspension there is the option to enter data for a custom or multi-rate spring and top-out springs.




The only data that is additional to that entered for the rear are the three parameters related to the compression of air in the forks. The significance of which follows:

- **Extended air volume.** This is the air volume above the oil in a fork leg in the fully extended position. The spring must also be in place. It is usual to set the oil level purely as a linear measurement but the calculation of the free air volume is not straight forward from that data. Allowance must be made, not only for the tube diameter, but also for the volume of some spring coils.

  Probably the easiest and most accurate way to measure this is with the aid of a fork cap that has been drilled. Then fill the fork completely with oil. Suck some oil out into a bottle and then remove the cap. Suck out more oil until the desired level is reached. The volume of oil that has been sucked out will be the free air volume.

  It is important to make this measurement as carefully as possible because in some cases a small error can have a large effect on the results of the fork force calculation at or near full compression. See note below.

- **Inner fork tube diameter.** This is the external diameter of the inner fork tube.

- **Extended gas pressure.** Some forks are pressurized with air or nitrogen. This parameter is relative to atmospheric pressure and entered as bar. One bar is approx. 100 kpascal or 14.5 psi.

Pressurizing forks has several effects, viz:

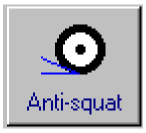
**Pre-load** – similar to adding pre-load to the spring.

**Seal pressurization** – aids sealing but increases friction.

Reduces **cavitation** in the oil.

Increases **progressive rate** tendencies near full compression.

NOTE: The option to enter air volume was incorporated mainly for traditional “right way up forks” which are relatively easy to measure. Some modern USD cartridge forks and those fitted with gas reservoirs can be difficult to get appropriate data.

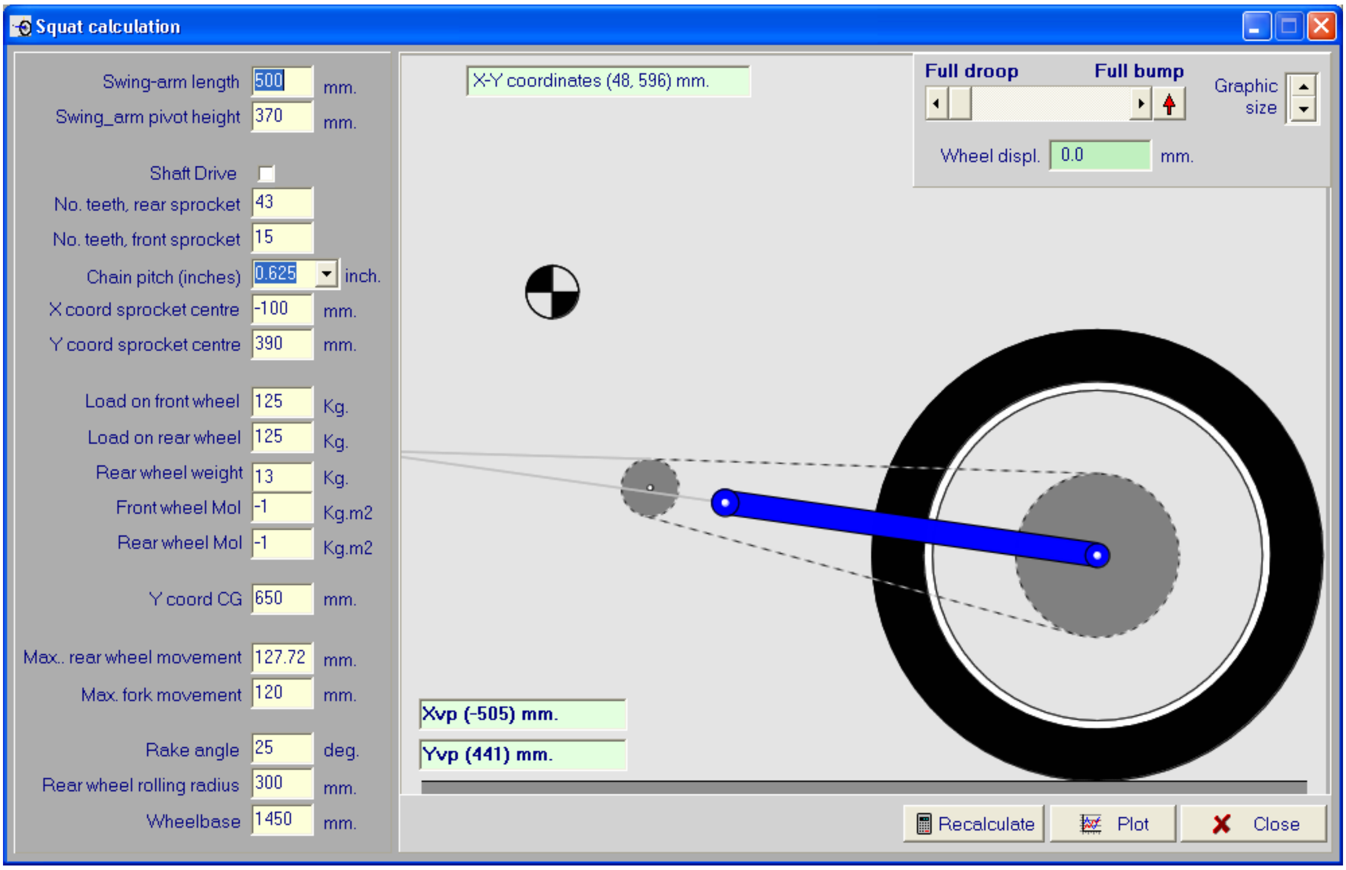



## Anti-squat

On first entry this window is loaded with some default data, which must be adjusted to the dimensions of the bike being analyzed. If you have previously entered data into the rear suspension module and plotted the results then the parameters of that case will be the default.

The graphic is kept simple and does not show details of the type of suspension system in use because that has no effect on the anti-squat properties. The graphic can be exercised over the specified range of wheel movement, the main purpose for this is to visually see the proximity of the chain run to the swing arm pivot.

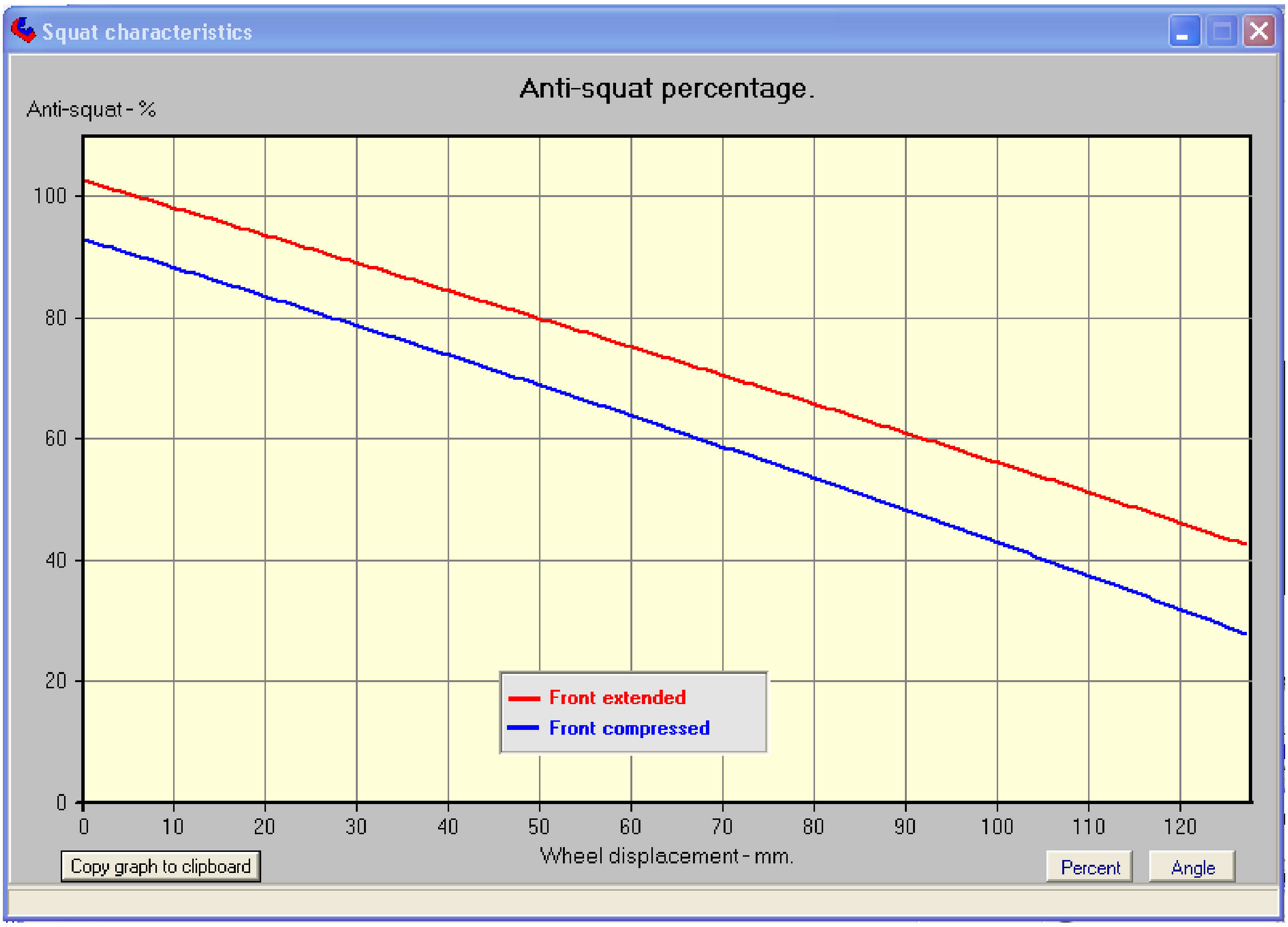
Click the recalculate button to refresh the graphic after changing some data.

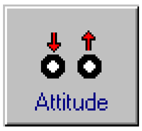



The “Plot” button opens the following screen which plots the anti-squat percentage over the specified range of wheel movement. The calculated values of anti-squat percentage are dependent on the accuracy of the entered CG height. As an option, it is possible to toggle between displaying the results as a percentage or as the anti-squat angle. This angle is not dependent on the CG height value.

In either case there are two lines plotted, one shows the anti-squat performance with the front suspension extended and the other shows it with the front suspension compressed. Therefore these two lines define the full range of possible anti-squat values. Under hard acceleration the front will be, at least, near to the full extension condition.

The legend box can be dragged out of the way of the curves, where necessary, by using standard Windows dragging methods.


Squat characteristics
Anti-squat percentage.
Anti-squat - %
100
80
60
40
20
0
0
10
20
30
40
50
60
70
80
90
100
110
120
Front extended
Front compressed
Wheel displacement - mm.
Copy graph to clipboard
Percent
Angle




## Attitude calculation

The purpose of this function is to quickly analyze the effects on the attitude, of changes to several setup parameters. Attitude changes are compared to the base setup. The changeable setup parameters are: Rear ride height, swing-arm pivot height, fork sliders position, fork clamp offset, front and rear sprocket teeth number and chain link addition or subtraction.

On first entry this window is loaded with default data, which must be adjusted to the dimensions of the bike being analyzed.

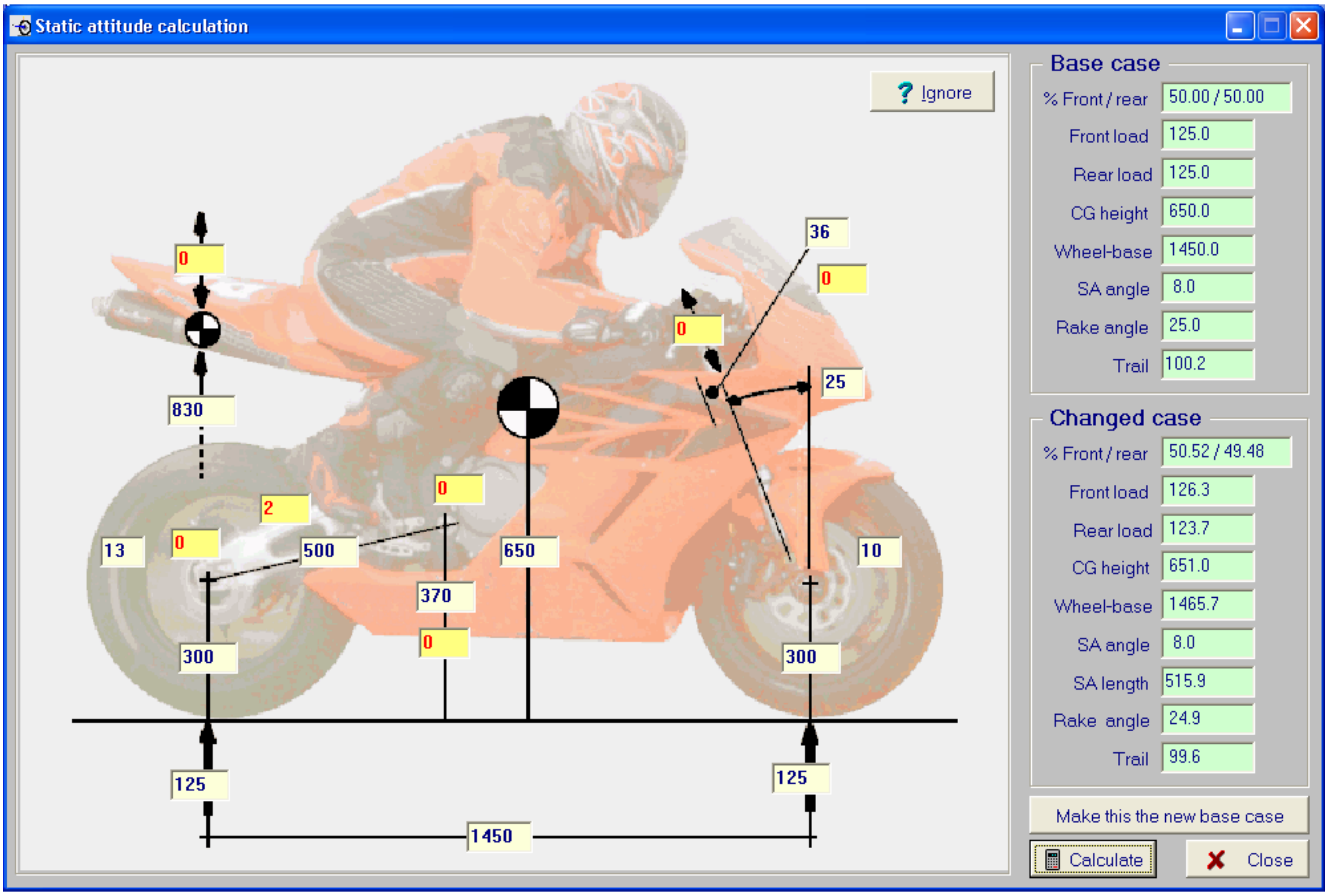
The basic physical parameters of the motorcycle are entered into the data fields lightly shaded in yellow. This data defines the static loaded condition of the machine. All data entry boxes have fly-out hint messages to describe each parameter, although in most cases their meaning is obvious from their location on the graphic. Additionally, there is a small help window available by clicking the "Help" button.

Changes are entered in the bright yellow edit boxes. Enter the change in value from the base value, DO NOT enter the actual required values here. Rear ride height changes (as measured vertically above the rear axle) and adjustment to the fork sliders position can be entered into the bright yellow fields. A positive value at the rear represents an increased ride height setting. A positive value at the forks represents the fork sliders being raised in their clamps. Therefore, positive values for either value lead to a pitched forward change of attitude.

There are addition bright yellow fields for the addition or removal of chain links and also for changes to fork clamp offset.

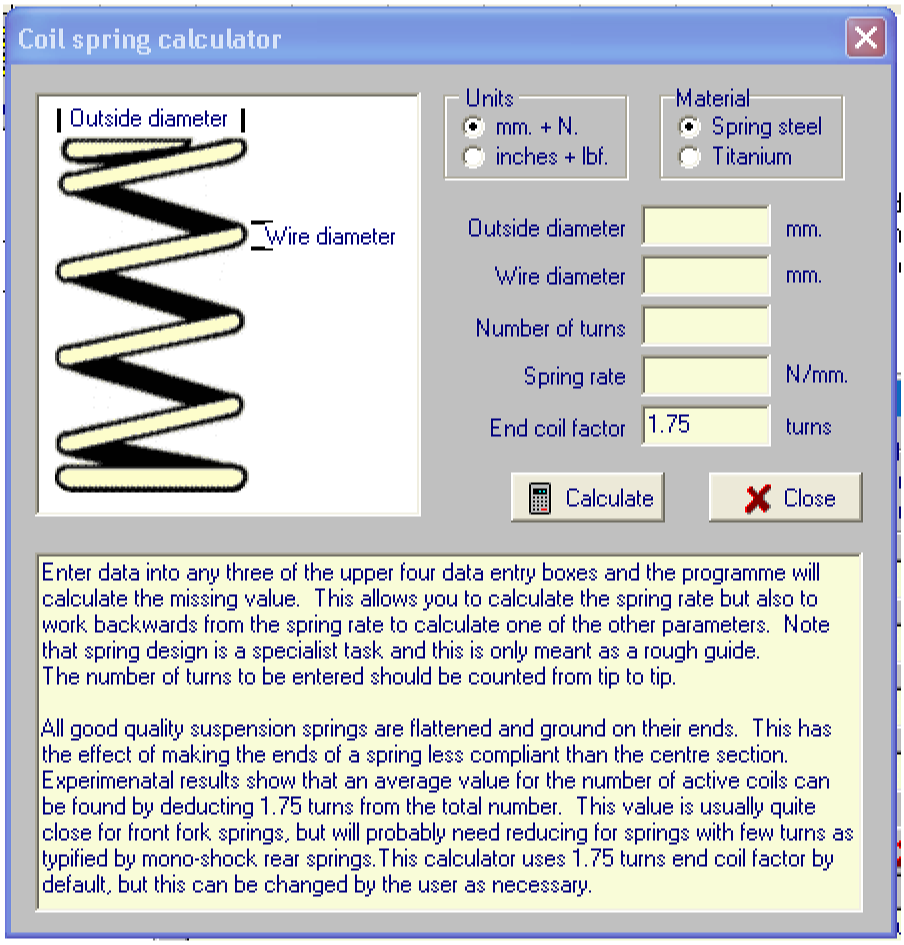
On clicking the "Calculate" button various parameters are shown to the right. Both the base values and the values with the ride height changes made are displayed.

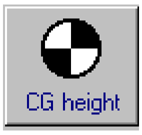
The following illustration shows the effects of adding 2 links to the chain, which requires a lengthened swingarm.




## Spring calculator

This utility is to help calculate the spring rate when only the dimensional data is known. It makes these calculations for the two most common spring materials, spring steel and titanium. The calculation of spring rates is dependent on the accuracy of the allowance for the end coils and so any calculation should only be regarded as an approximation. Where possible it is always preferable to measure the rate physically.



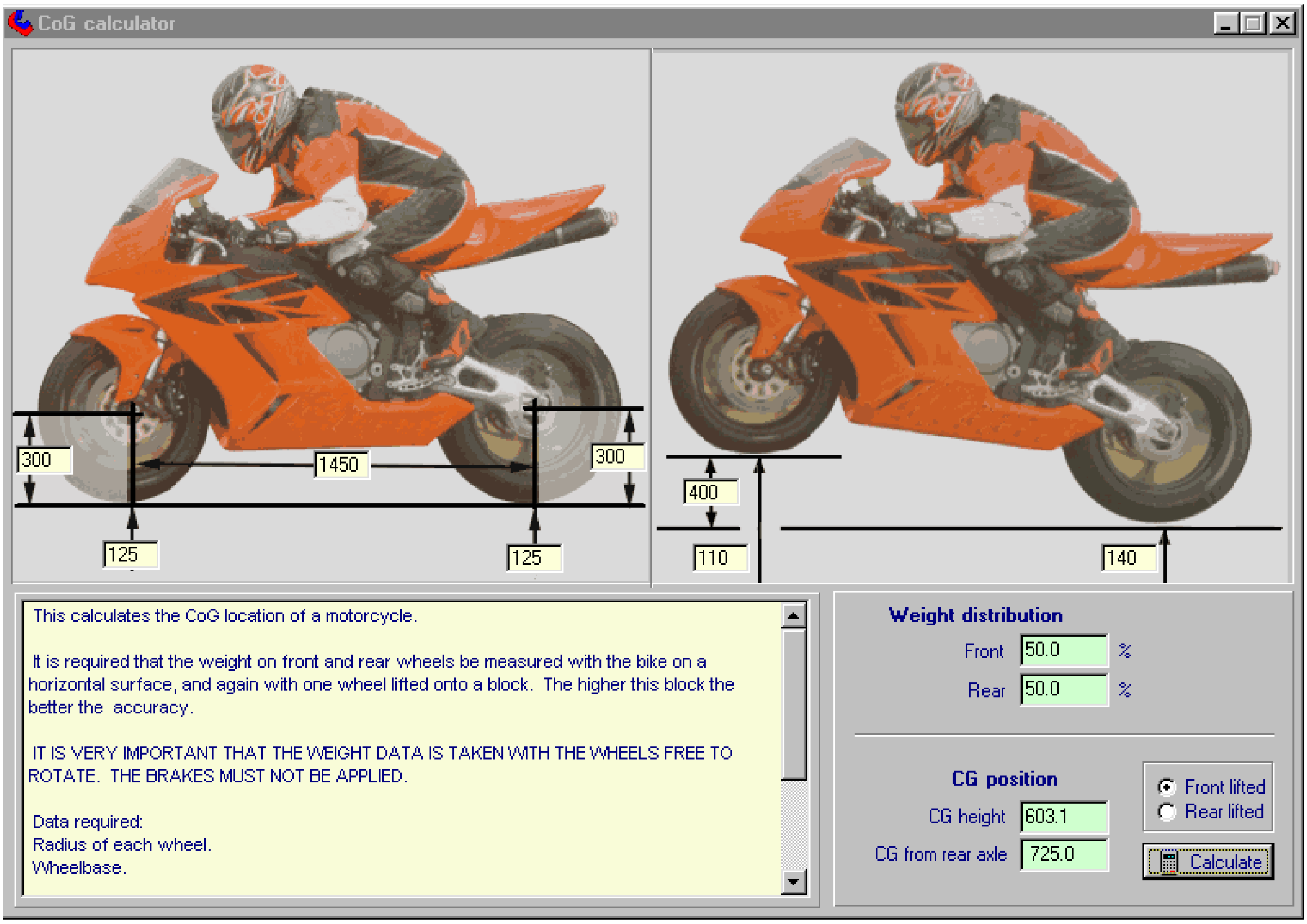


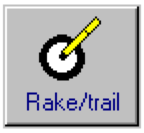

## Centre of Gravity height

The CG height is an important parameter needed for the analysis of motorcycle setup. There are various ways to measure this but most need facilities outside of those readily available.

The simplest is to weigh each end of the machine when level and when lifted onto a block at one end. This calculator will then calculate the CG position. You can toggle the calculator depending on whether you raise the front or rear of the motorcycle. It is usually easier for the rider to raise the front end.

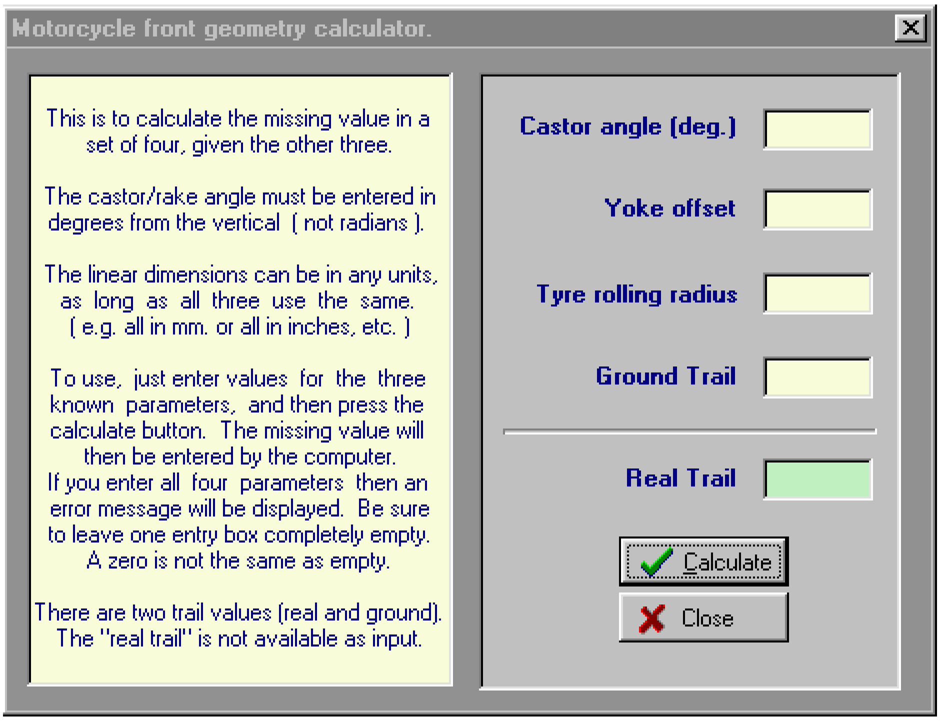
A help window is built into the screen, and warnings are given if input data is not mutually compatible.

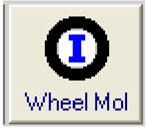





## Rake and trail calculator

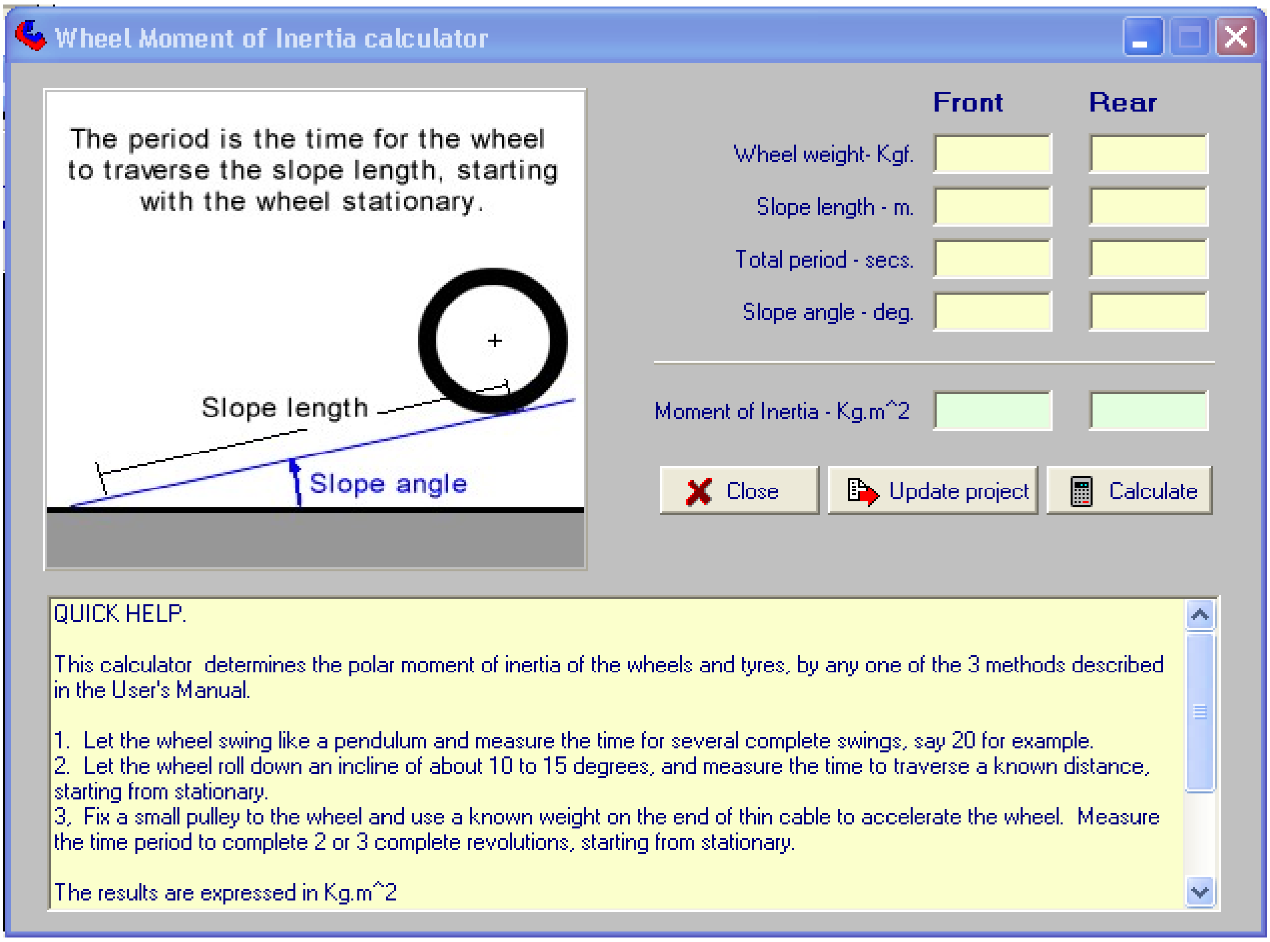
Enter data into any three of the four data entry boxes, click on “Calculate” and it will calculate the fourth parameter. For example, if you know the required rake and trail values and wheel size then it will calculate the required offset necessary to give those values.

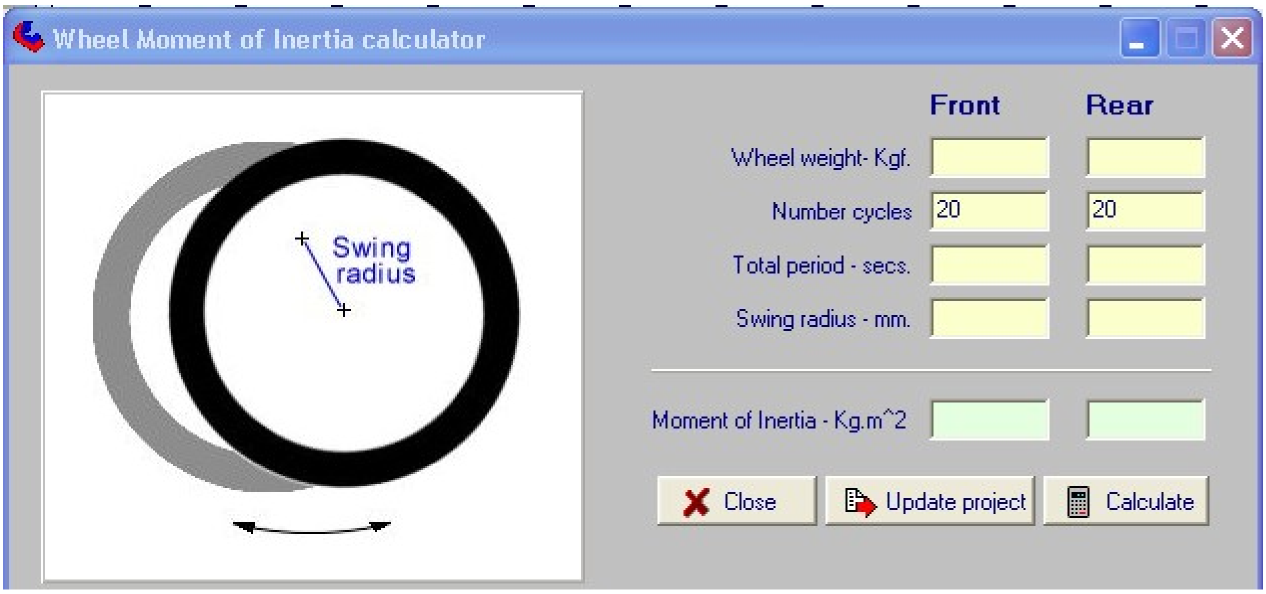


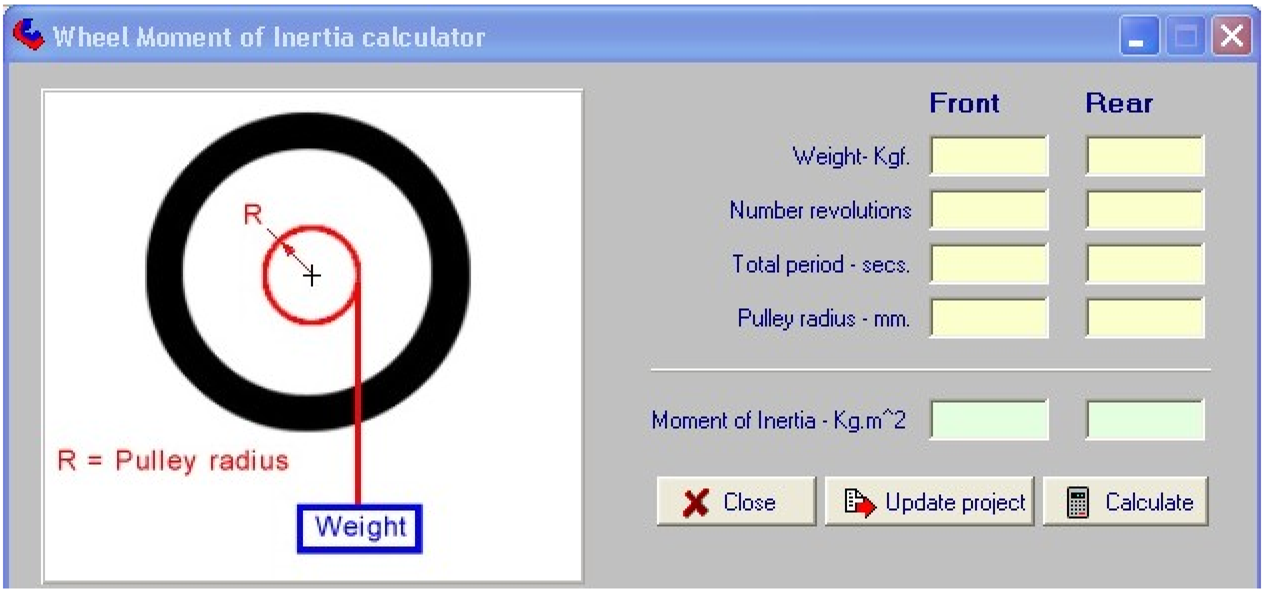


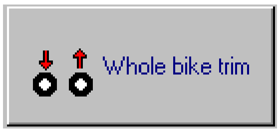

## Wheel moment of inertia calculator

The wheel moments of inertia are used in the calculation of the squat and dive characteristics, and the sag etc. under braking and acceleration.
This calculator is really three in one.  It can calculate for three different methods of physical measurements. This theme is covered in more detail in the section on measuring the motorcycle.




Wheel Moment of Inertia calculator
R
R = Pulley radius
Weight
Front
Rear
Weight- Kgf.
Number revolutions
Total period - secs.
Pulley radius - mm.
Moment of Inertia - Kg.m^2
Close
Update project
Calculate




## Whole bike trim

This feature brings the front and rear suspensions into a complete motorcycle for analysis. Various loading conditions can be tested and the steady state trim calculated.

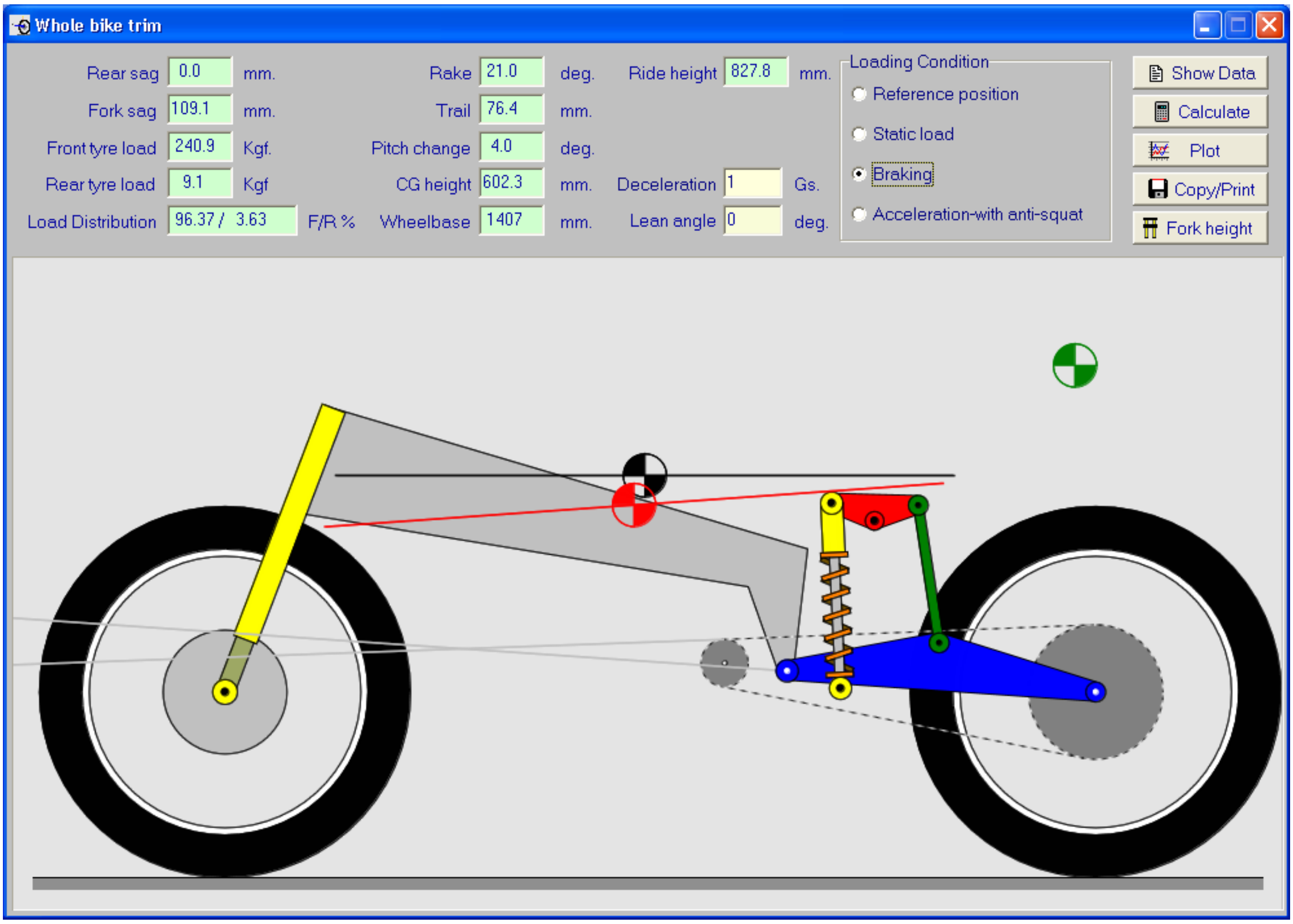
The initial data is loaded from the Misc data window on the opening screen, and the rear suspension and front suspension windows (any changed data in the squat and attitude screens is ignored). Clicking the Show data button shows all the data in use and lets you change some, as described in the next section.

The data entry method for the rear suspension shows the rear wheel off/under the ground level if there is some tolerance or error in the dimensional data. In the whole bike analysis the fixed coordinates (SA pivot height and frame mtg. of shock and rocker etc.) are adjusted to place the wheel on the ground. These coordinates will remain changed when you return to the rear suspension screen.

The whole bike graphic is drawn for 4 selectable conditions, in order to help visualize the attitude change the CG position and a line showing pitch angle is superimposed over the same for the reference position which is wheels just on ground with both suspension fully extended.

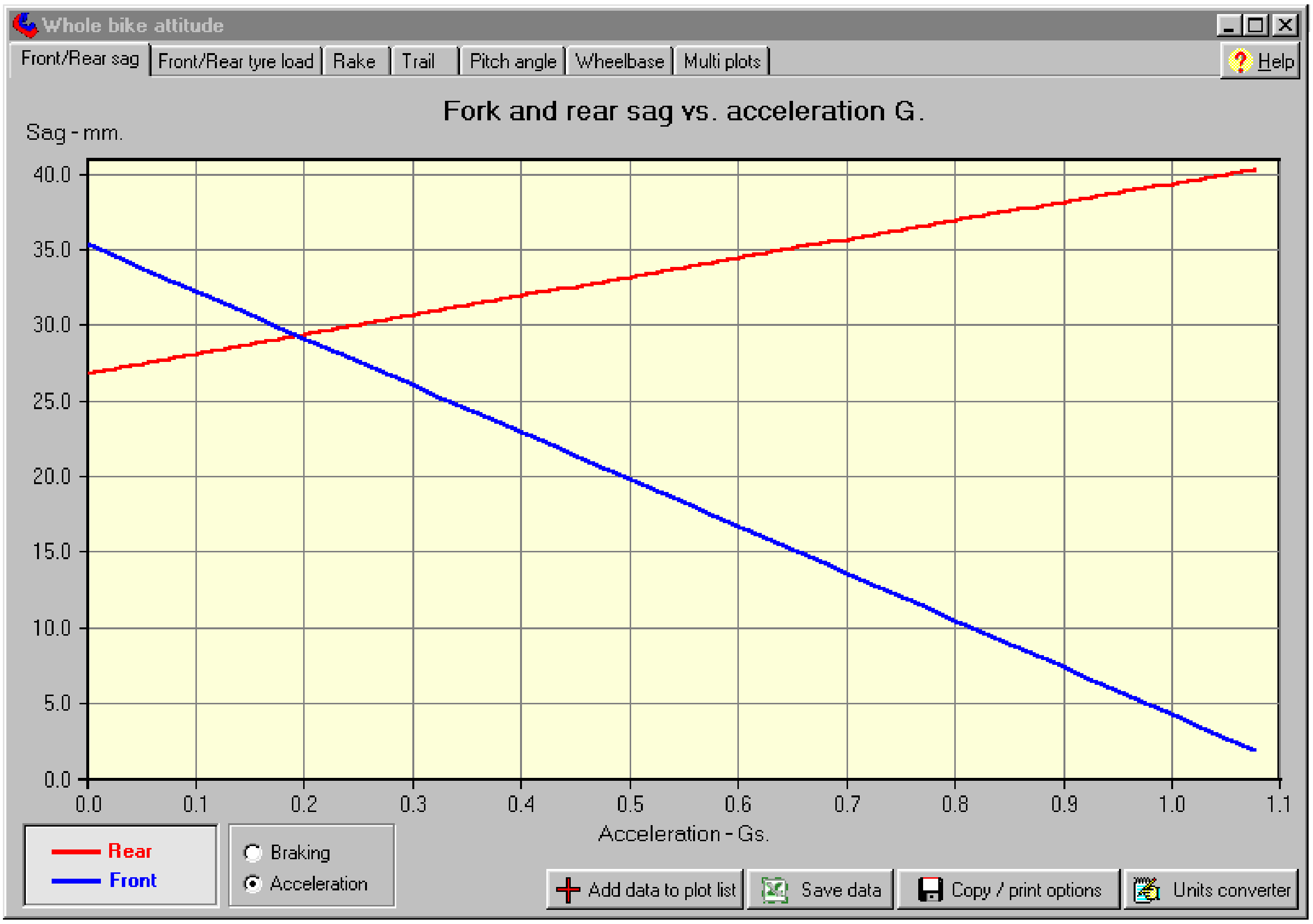
The attitude calculations assume a perfectly smooth road and are for low speed acceleration and braking. At higher speeds the attitude is affected by the aerodynamic drag value and general aerodynamic properties of the machine which are not usually known.

Warnings are given if the setup being analyzed cannot withstand the specified acceleration/braking level without looping. There are additional warnings to let you know when the shock/forks have reached the maximum bump level of their travel.

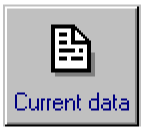



Plots are available showing various parameters plotted against braking and acceleration G. The maximum value of G plotted is the limit at which looping will occur unless the rider reduces the braking or acceleration. In general this limit will be slightly different for the braking and acceleration cases. The looping limit is reached when all load has been transferred off one tyre.

The rear sag value is that for a point vertically above the rear axle. The front sag is that of the forks themselves. A sag value of zero indicates that the suspension has topped out.




The “Save data” button will allow an .TFD file to be saved which can be viewed and compared in the multi-plotting feature at a later date.



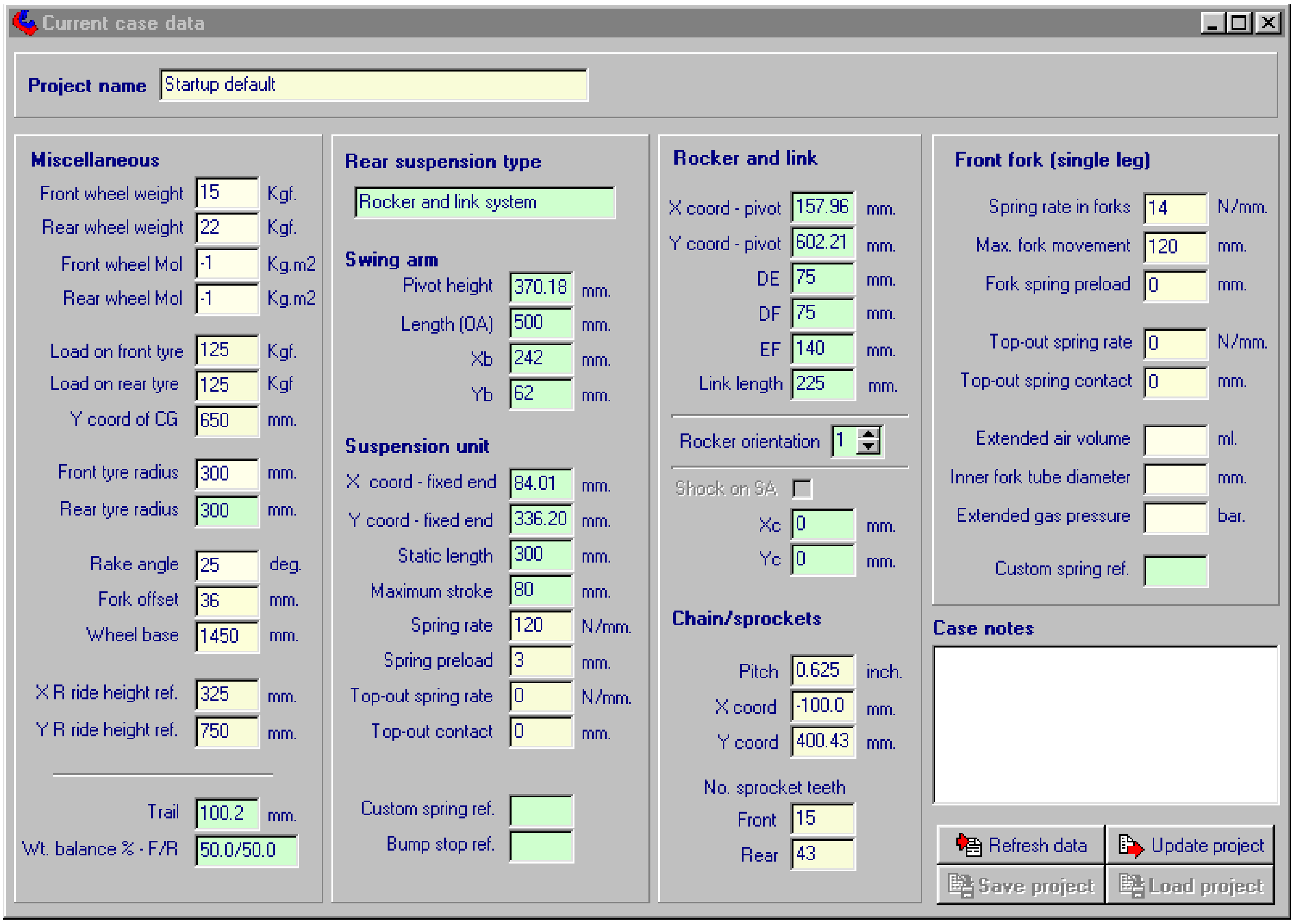
or

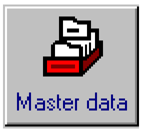


# Current data

All of the current project data can be seen in one place by clicking on the “Current data” (also “Show data” from within the whole bike screen) button. Where some data is show in green and some in yellow. Throughout this software, data in green is read-only and not changeable on that screen. Yellow is changeable.

Some data on this screen is made read-only because it needs to be checked for integrity by the appropriate parts screen. For example; changing some rear suspension dimensions can only be done on the rear suspension screen because it is very easy to change data elsewhere which might lead to an impossible system.



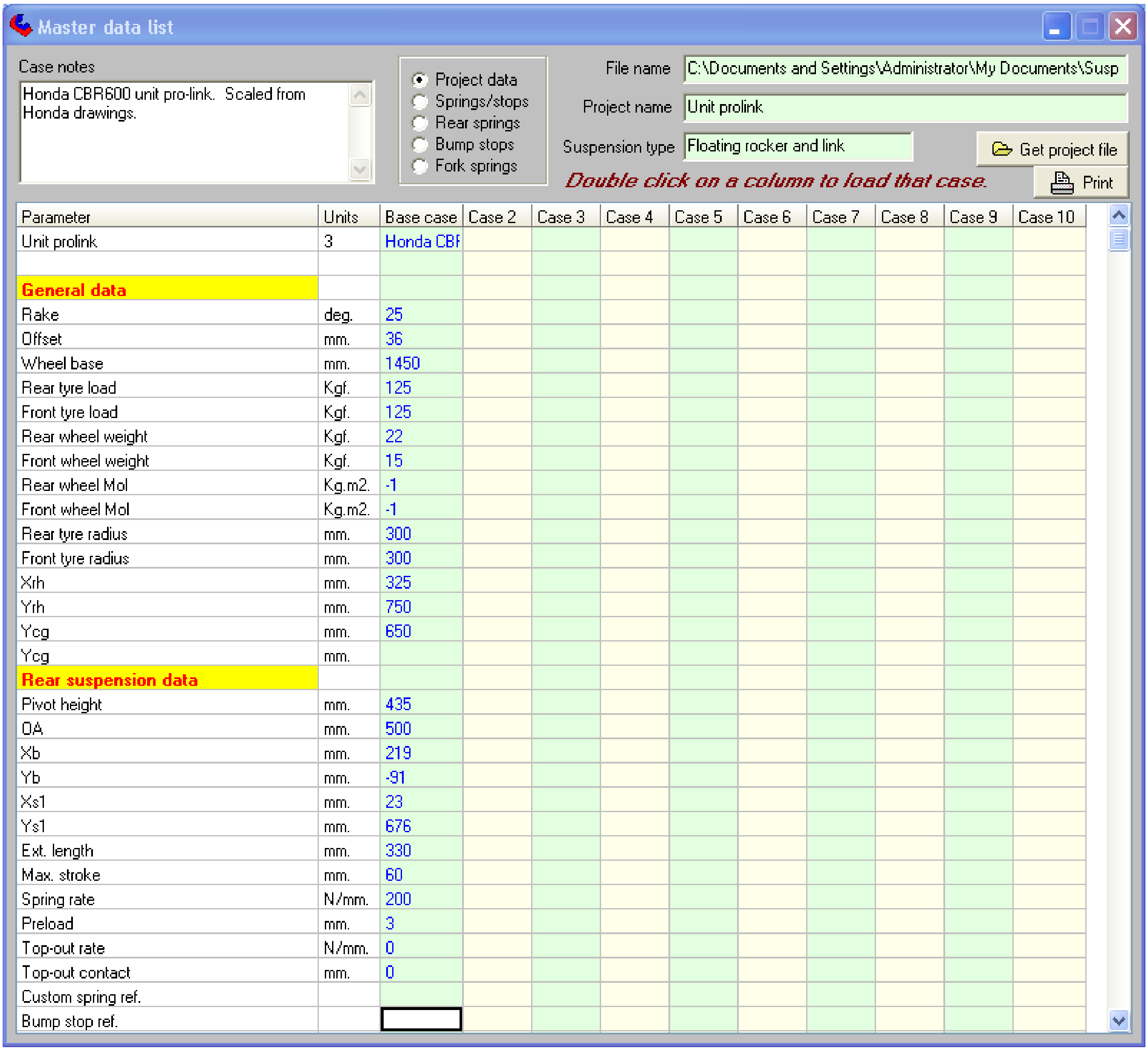



## Master data

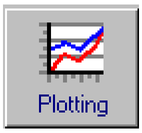
The purpose of this is fully described in a following section on saving data, and is not repeated here.

The 

button enables printing of the data entered into the grid, but also blank data entry sheets, one each for the three different classes of rear suspension system. These sheets are useful for manual entry of measured data when actually measuring in the workshop.




| Parameter | Units | Base case | Case 2 | Case 3 | Case 4 | Case 5 | Case 6 | Case 7 | Case 8 | Case 9 | Case 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Unit prolink | 3 | Honda CBF | | | | | | | | | |
| | | | | | | | | | | | |
| **General data** | | | | | | | | | | | |
| Rake | deg. | 25 | | | | | | | | | |
| Offset | mm. | 36 | | | | | | | | | |
| Wheel base | mm. | 1450 | | | | | | | | | |
| Rear tyre load | Kgf. | 125 | | | | | | | | | |
| Front tyre load | Kgf. | 125 | | | | | | | | | |
| Rear wheel weight | Kgf. | 22 | | | | | | | | | |
| Front wheel weight | Kgf. | 15 | | | | | | | | | |
| Rear wheel MoI | Kg.m2. | -1 | | | | | | | | | |
| Front wheel MoI | Kg.m2. | -1 | | | | | | | | | |
| Rear tyre radius | mm. | 300 | | | | | | | | | |
| Front tyre radius | mm. | 300 | | | | | | | | | |
| Xrh | mm. | 325 | | | | | | | | | |
| Yrh | mm. | 750 | | | | | | | | | |
| Ycg | mm. | 650 | | | | | | | | | |
| Ycg | mm. | | | | | | | | | | |
| **Rear suspension data** | | | | | | | | | | | |
| Pivot height | mm. | 435 | | | | | | | | | |
| OA | mm. | 500 | | | | | | | | | |
| Xb | mm. | 219 | | | | | | | | | |
| Yb | mm. | -91 | | | | | | | | | |
| Xs1 | mm. | 23 | | | | | | | | | |
| Ys1 | mm. | 676 | | | | | | | | | |
| Ext. length | mm. | 330 | | | | | | | | | |
| Max. stroke | mm. | 60 | | | | | | | | | |
| Spring rate | N/mm. | 200 | | | | | | | | | |
| Preload | mm. | 3 | | | | | | | | | |
| Top-out rate | N/mm. | 0 | | | | | | | | | |
| Top-out contact | mm. | 0 | | | | | | | | | |
| Custom spring ref. | | | | | | | | | | | |
| Bump stop ref. | | | | | | | | | | | |

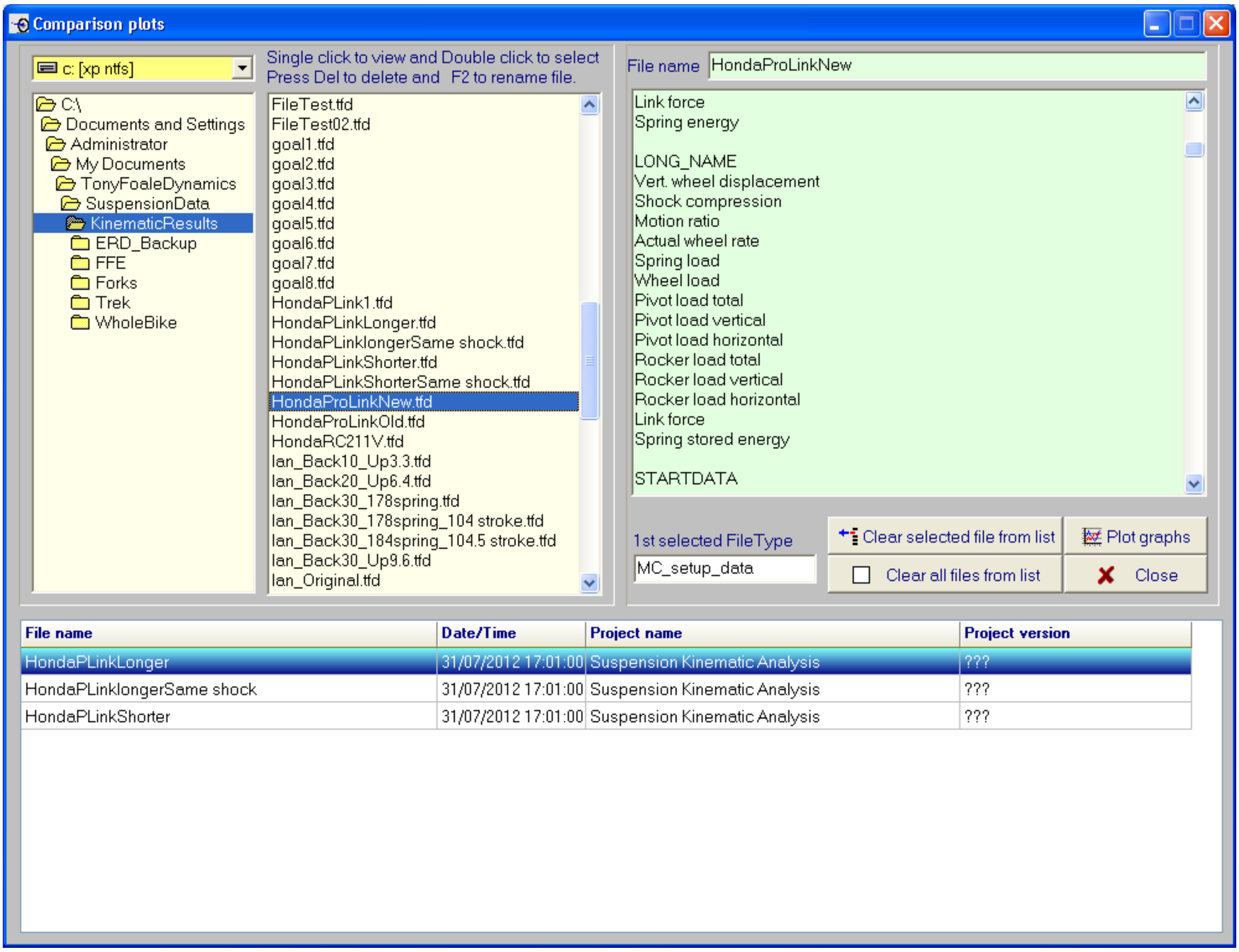



or 


## Plotting

This opens a selection screen for choosing up to ten saved results files for comparative plotting.

The files must first be saved from the tabular values on the results pages, in ERD format (see following section on saving data).




The window will initially open into the default file save directory. You can navigate to other directories if you saved the files elsewhere. Default is ***"My Documents\SuspensionData\KinematicResults"***

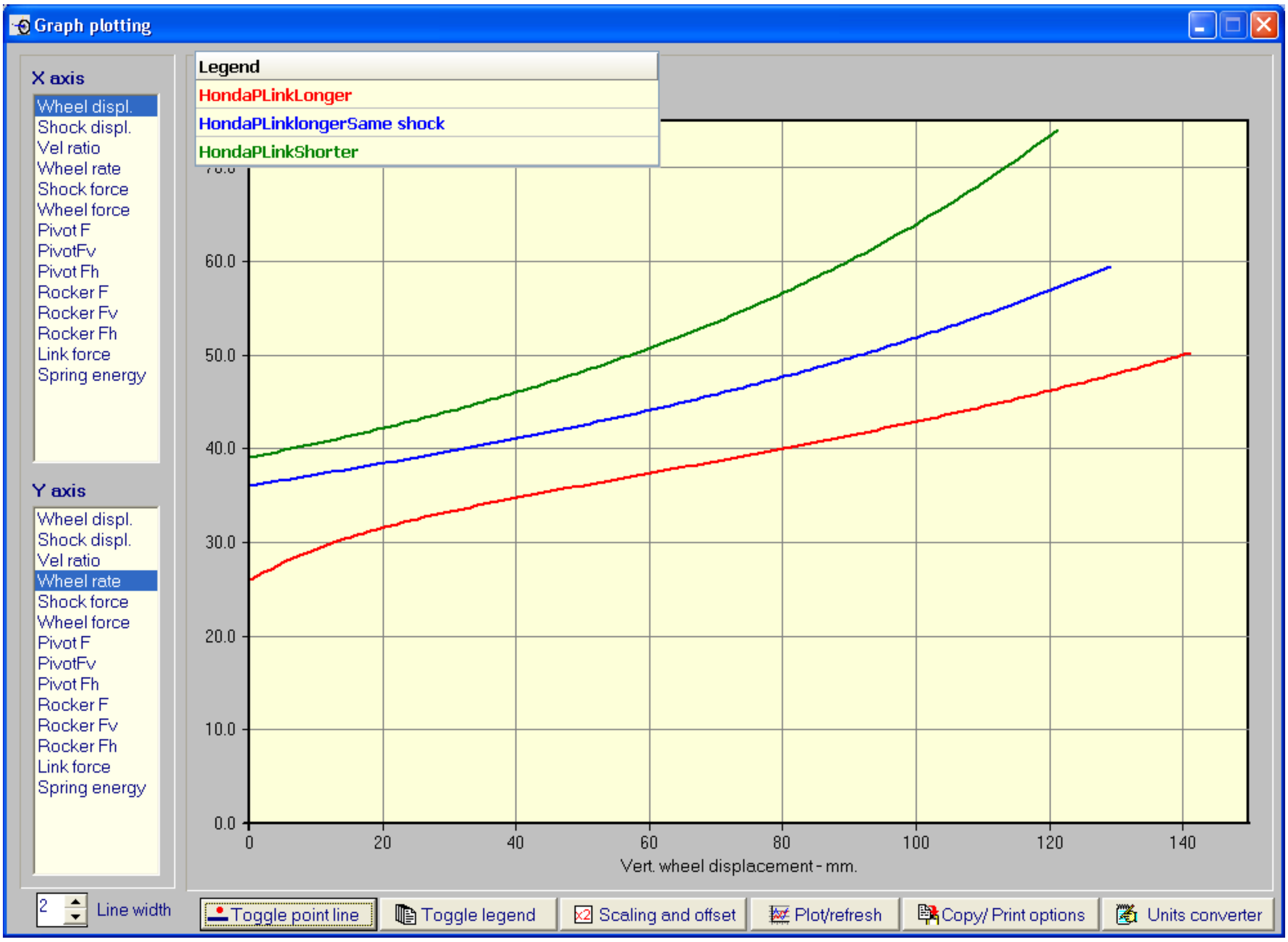
The second column will display a list of saved files. Click on those which you wish to compare (up to a maximum of 10), and they will appear in the plotting list across the bottom. There are buttons to remove files from this list or clear it altogether. Click on the "Plot graphs" button when you have listed the files of interest, 3 in this example.

The plotting window, shown next, has 3 areas.

On the left are 2 lists of the parameters which can be plotted. The top one selects the parameter for the X axis, usually the Wheel displacement or Shock compression. The lower one selects the Y axis. The graphs will change dynamically as you select different plotting parameters.

Along the bottom of the window, are some buttons with fairly obvious significance, except perhaps for the "Scaling and offset". Occasionally it is useful to be able to scale or offset the data before plotting. For example, if you wanted to see the wheel force curves for different strength springs, normally you would have to change the data and rerun the analysis. With the scaling you could simple scale the plot in the proportion as the rate of the various springs.

The main area on this window is the plotting area which graphs a single parameter from each of the selected files.




On the plotting window, above, the area to the left shows that the wheel displacement has been chosen for the X axis and the wheel spring rate for the Y axis. The 3 graphs show this parameter pair for the 3 files selected from the previous screen.

This multi-file plotting feature is extremely useful and is also very fast and easy to use.

## Saving and loading data

There are two types of data that can be saved in the software.

Parametric (project data).

Calculated results.

The parametric data refers to the physical parameters of the motorcycle. For example, rocker dimensions, wheel size, spring rates etc. This data has been centralized under the “Master data” option.

The calculated results are the characteristics of the systems being analyzed such as wheel rate, forces, motion ratio etc.

## Parametric (project data)

The data is stored using the concept of a “project” . A project represents all the parametric data for a particular motorcycle layout, consisting of front fork, rear suspension and rake, wheelbase data including any custom springs or bump-stop rubbers used. Up to 10 different configurations of a basic project can be stored in one project file. This is useful, for example, if you analyze the same basic setup with different ride height settings. The parameters for all the settings can be kept together in one file.

There are times when you will only be working on, say the rear suspension and will not specify any front fork parameters, in such cases a set of default data will be saved for the forks. The reverse is true when you are only working with the front, a simple default rear layout will be saved.

## Master data window.

There are buttons to save a project on each the front and rear suspension windows and the initial selection screen. If the data to be saved was originally entered by choosing the front suspension option or that for the rear suspension from the main menu then a new file (new project) will be created, after prompting for a filename and some notes to help with later selection. However, if the project was originally loaded from an existing project file from the “Master data” centre then you will have the option to save as a new project or add the current layout to the existing project – up to a maximum of 10 cases per project file.

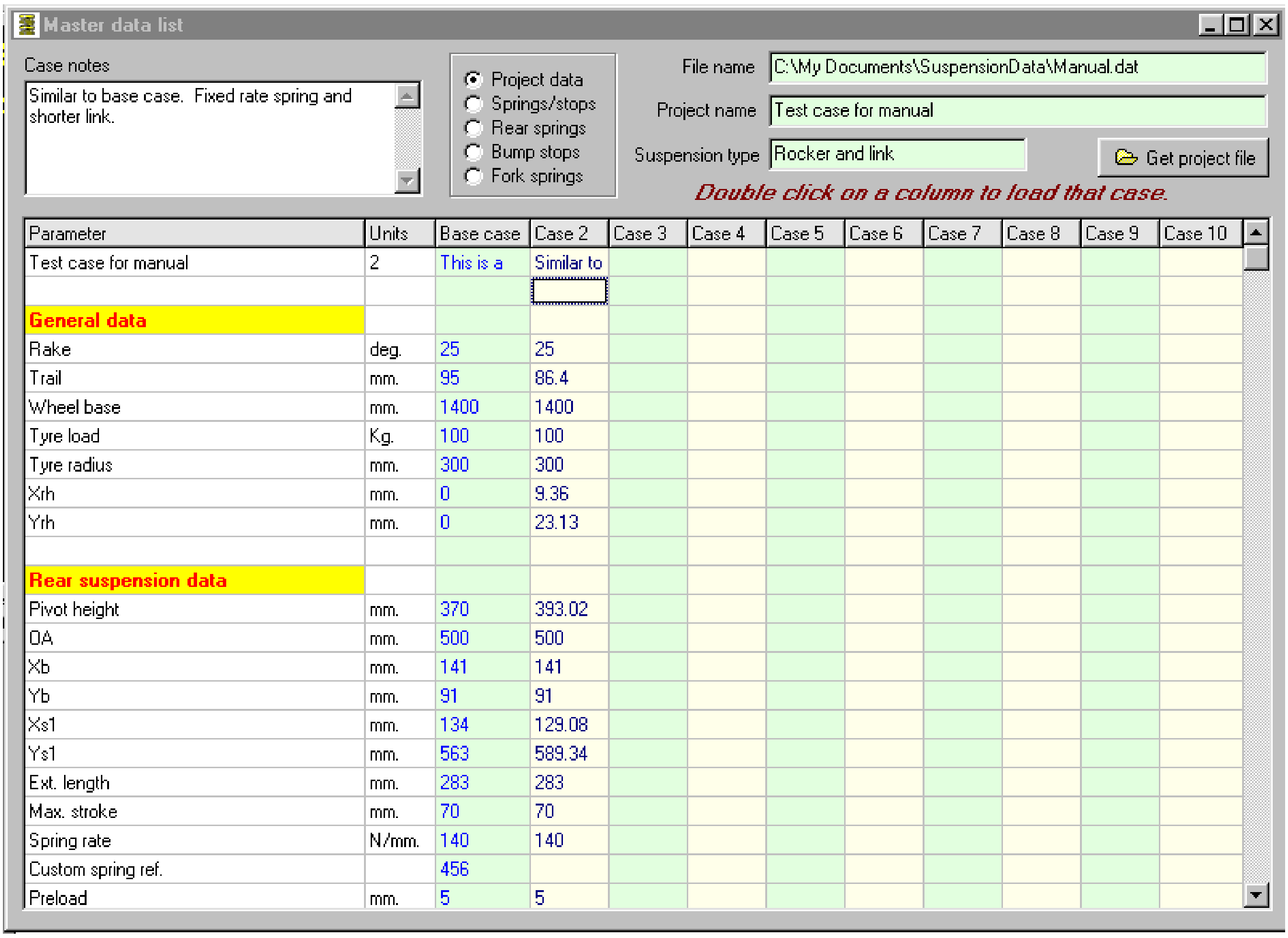
When saving to a project file you will be prompted to write some case notes to describe each case. Make a good job of that because it’ll be a big help when you come back to load a design a few weeks or months later. Choose a column in which you want to save the current project data and double click in that column. If the column is not empty then you will be asked if you wish to overwrite the existing data.

You can activate the Master data window for loading projects from buttons on the main menus and front fork window.


Click here to select a project file to open. Simply double click on the column which contains the desired case to load and the data for that case will be entered into the system.

### Data display

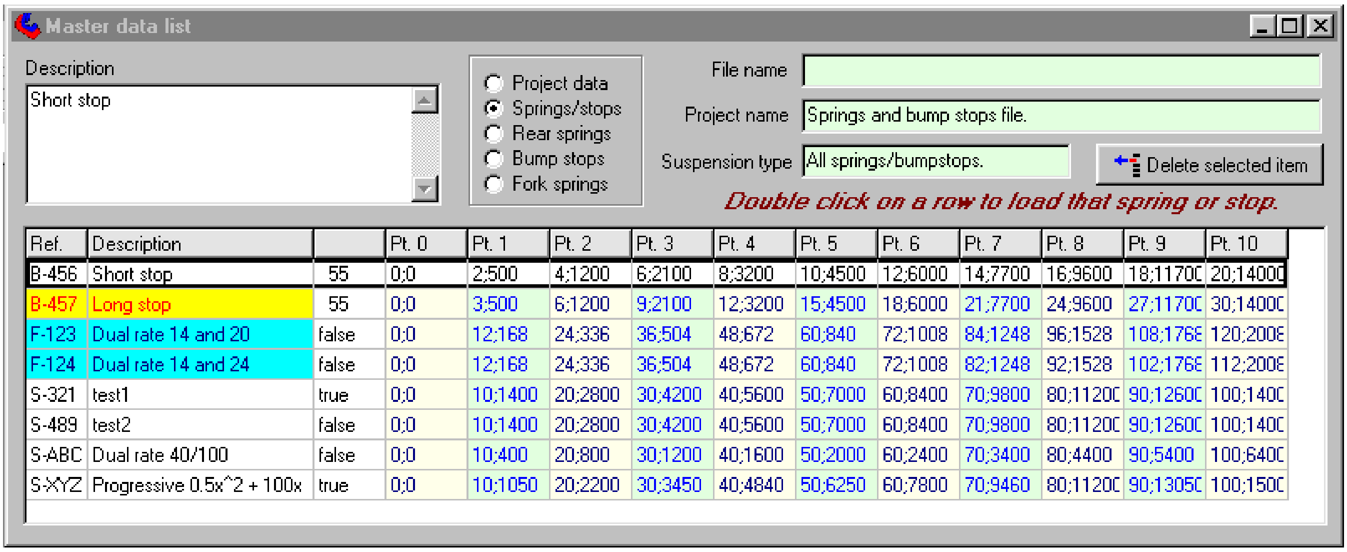

The data display can be toggled between the project data and a list of custom springs and bump stops. “Springs/stops” shows a full list of front and rear custom springs as well as any bump-stops. They are colour coded and grouped to help identification as shown below. Bump-stop rubbers are pre-fixed with a “B”, fork springs with “F” and rear springs with “S”. The remaining options show those components separately. Double click on any item to load it into the current project.




| Parameter | Units | Base case | Case 2 | Case 3 | Case 4 | Case 5 | Case 6 | Case 7 | Case 8 | Case 9 | Case 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Test case for manual | 2 | This is a | Similar to | | | | | | | | |
| | | | | | | | | | | | |
| General data | | | | | | | | | | | |
| Rake | deg. | 25 | 25 | | | | | | | | |
| Trail | mm. | 95 | 86.4 | | | | | | | | |
| Wheel base | mm. | 1400 | 1400 | | | | | | | | |
| Tyre load | Kg. | 100 | 100 | | | | | | | | |
| Tyre radius | mm. | 300 | 300 | | | | | | | | |
| Xrh | mm. | 0 | 9.36 | | | | | | | | |
| Yrh | mm. | 0 | 23.13 | | | | | | | | |
| | | | | | | | | | | | |
| Rear suspension data | | | | | | | | | | | |
| Pivot height | mm. | 370 | 393.02 | | | | | | | | |
| OA | mm. | 500 | 500 | | | | | | | | |
| Xb | mm. | 141 | 141 | | | | | | | | |
| Yb | mm. | 91 | 91 | | | | | | | | |
| Xs1 | mm. | 134 | 129.08 | | | | | | | | |
| Ys1 | mm. | 563 | 589.34 | | | | | | | | |
| Ext. length | mm. | 283 | 283 | | | | | | | | |
| Max. stroke | mm. | 70 | 70 | | | | | | | | |
| Spring rate | N/mm. | 140 | 140 | | | | | | | | |
| Custom spring ref. | | 456 | | | | | | | | | |
| Preload | mm. | 5 | 5 | | | | | | | | |

**Custom springs (front and rear) and bump-stop rubbers (rear only)**

The custom springs and bump stops are all stored together in one file, allowing this to be scrolled as a list for easy selection.

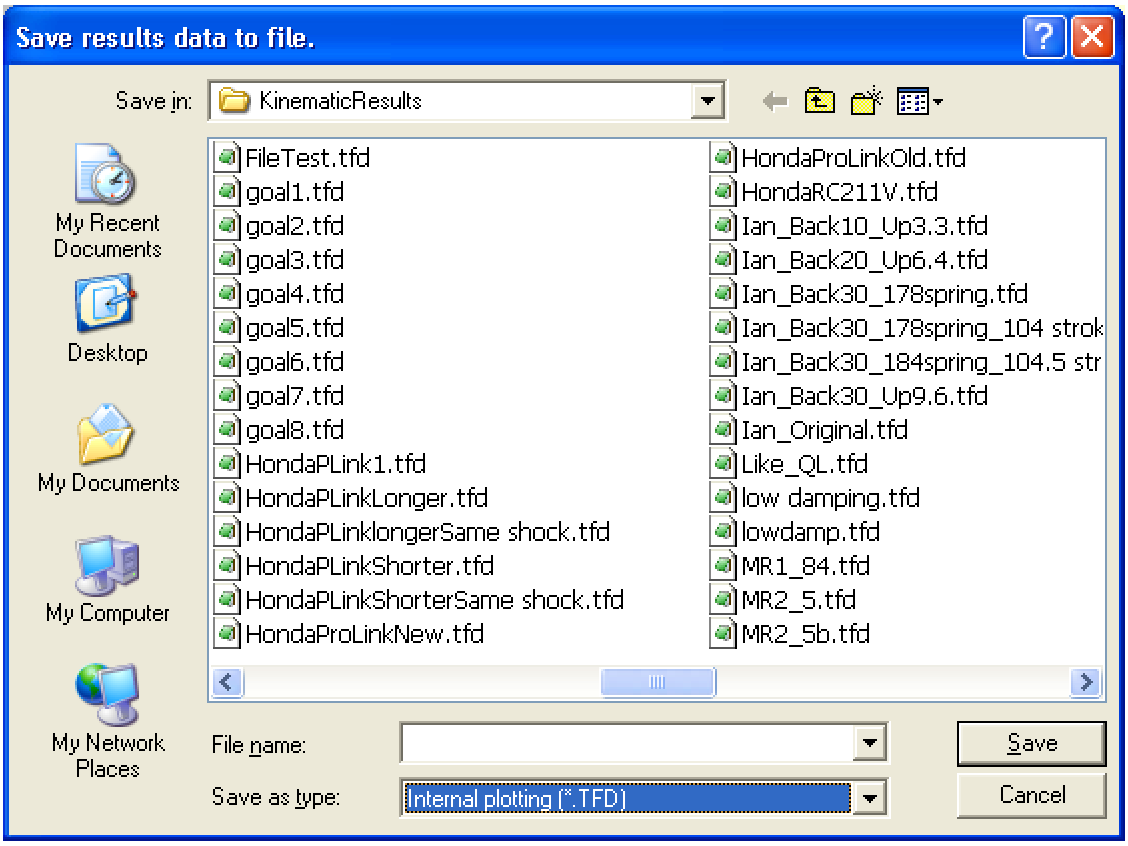



| Ref. | Description | | Pt. 0 | Pt. 1 | Pt. 2 | Pt. 3 | Pt. 4 | Pt. 5 | Pt. 6 | Pt. 7 | Pt. 8 | Pt. 9 | Pt. 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B-456 | Short stop | 55 | 0;0 | 2;500 | 4;1200 | 6;2100 | 8;3200 | 10;4500 | 12;6000 | 14;7700 | 16;9600 | 18;11700 | 20;14000 |
| B-457 | Long stop | 55 | 0;0 | 3;500 | 6;1200 | 9;2100 | 12;3200 | 15;4500 | 18;6000 | 21;7700 | 24;9600 | 27;11700 | 30;14000 |
| F-123 | Dual rate 14 and 20 | false | 0;0 | 12;168 | 24;336 | 36;504 | 48;672 | 60;840 | 72;1008 | 84;1248 | 96;1528 | 108;1768 | 120;2008 |
| F-124 | Dual rate 14 and 24 | false | 0;0 | 12;168 | 24;336 | 36;504 | 48;672 | 60;840 | 72;1008 | 82;1248 | 92;1528 | 102;1768 | 112;2008 |
| S-321 | test1 | true | 0;0 | 10;1400 | 20;2800 | 30;4200 | 40;5600 | 50;7000 | 60;8400 | 70;9800 | 80;11200 | 90;12600 | 100;1400 |
| S-489 | test2 | false | 0;0 | 10;1400 | 20;2800 | 30;4200 | 40;5600 | 50;7000 | 60;8400 | 70;9800 | 80;11200 | 90;12600 | 100;1400 |
| S-ABC | Dual rate 40/100 | false | 0;0 | 10;400 | 20;800 | 30;1200 | 40;1600 | 50;2000 | 60;2400 | 70;3400 | 80;4400 | 90;5400 | 100;6400 |
| S-XYZ | Progressive 0.5x^2 + 100x | true | 0;0 | 10;1050 | 20;2200 | 30;3450 | 40;4840 | 50;6250 | 60;7800 | 70;9460 | 80;11200 | 90;13050 | 100;1500 |

## Saving calculated results

These can be saved by clicking on the 

buttons which are accessible at the bottom of the tabular data page on the rear suspension results window and also the plotting window of the whole bike trim feature.




There is a choice of file formats available, allowing the data to be imported into spread sheets or other external analysis programmes when thought necessary. The default file extension is .tfd, which is the default and required format for the internal multi-plotting feature.

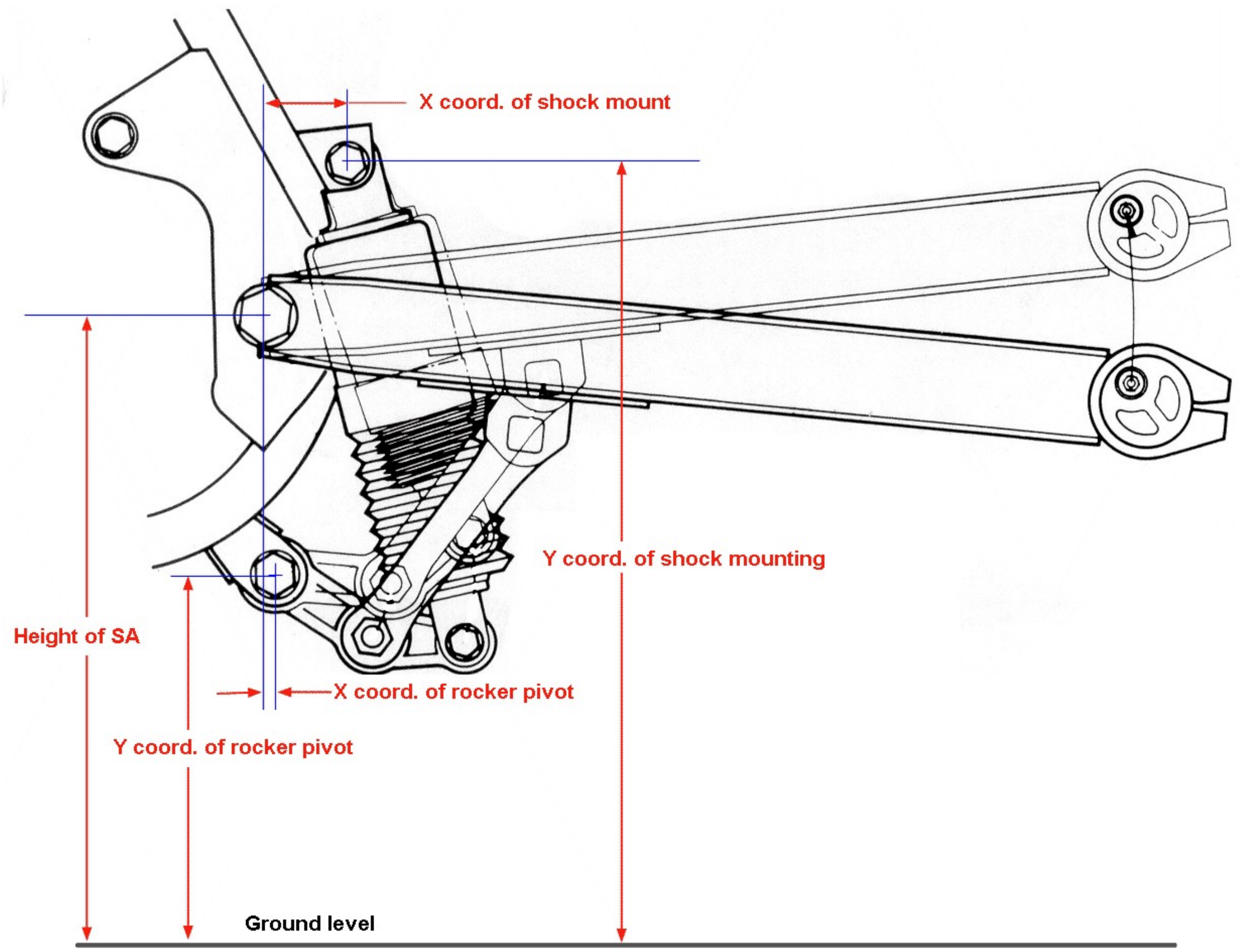
## Measuring the motorcycle

Before we can analyze anything we have to make a few measurements. There are several methods that could be used to do this, but this software employs a measurement philosophy that reflects the physical reality and tends to show up measurement errors and mis-typing of the input data.

### Measurement reference

With any vehicle set-up measurements, it is necessary to have a reference base. Some people recommend the static loaded position, but this cannot be considered as a fixed reference because it will vary depending on rider weight and fuel load just to mention 2 variables. This software is based around the reference being with the suspension fully extended at both ends of the bike, with the tyres just touching the ground. The calculated output data are considered as being relative to this initial reference position.

The mounting points on the main frame are regarded as fixed and are entered as **X** and **Y** co-ordinates. The ground is taken as the origin for the **Y** co-ordinate, and the vertical line through the swing-arm pivot is taken as the **X** origin. Points to the rear of the pivot are positive and those to the front are negative. The other suspension components, such as the shock, link and rocker are considered as separate pieces and are input as such without regard to their final co-ordinates, which are calculated internally.




The example above of a Kawasaki Uni-trak has three mounting points on the frame.

- Swing-arm pivot.
- Top mounting of shock.
- Rocker pivot.

The sketch shows the significance of the co-ordinates required by the software. These dimensions should be measured with the motorcycle supported such that both front and rear suspensions are extended and with the tyres just touching the road surface.

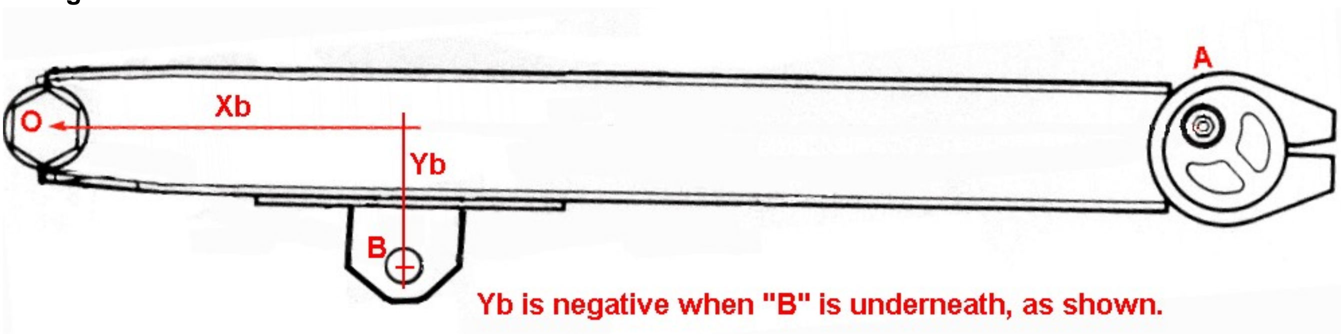
The other components, such as swing-arm, shock, rocker and link are regarded as free pieces and their dimensions are entered without regard to their co-ordinates when fitted to a motorcycle.

Therefore, unless all entered dimensions are compatible, the rear tyre will not appear to be on the ground. This immediately signals an error in the data. If the error in tyre position is small, say less than 2 mm., this probably indicates that the error is just measurement tolerances, in which case the use of the 

button, as explained earlier, is the simplest way to bring everything into line. The static height of the rear tyre is shown numerically on the lower part of the animation control area, when the image is shown at full droop.

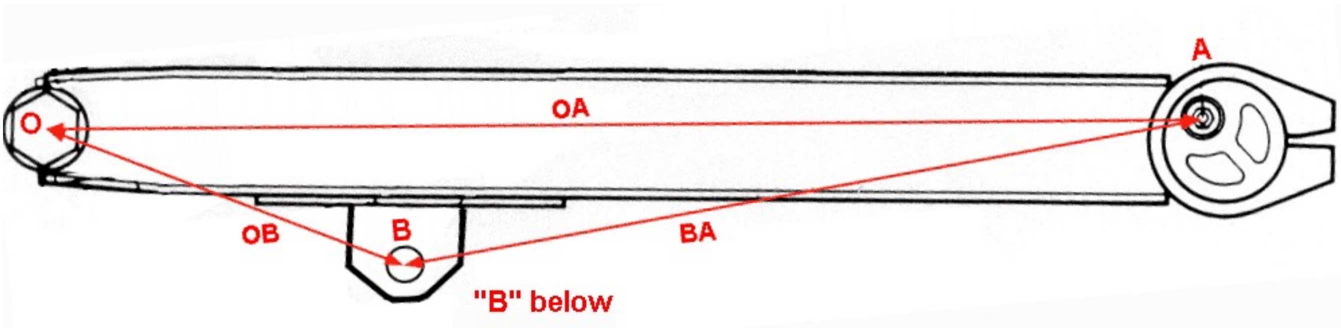
## Components

### Swing-arm

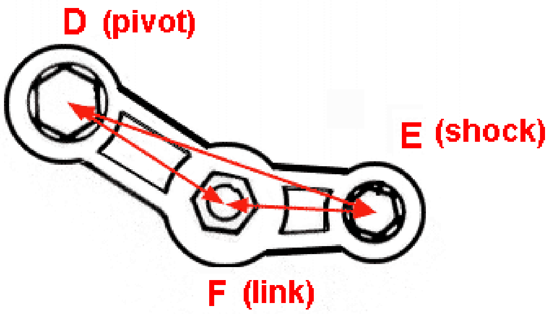



Using the Uni-trak example from above, this sketch shows how the swing-arm is measured as a separate component to get the data for entry into the programme. In those cases with a rocker system, and where the shock also mounts on the swing-arm, there will be an additional point on the swing-arm to specify. The fly-out help screens show how this is done.

The following sketch shows the “Alternative” method of measuring. In some cases this may be the easiest way to measure but requires additional measurements if you wish to try the suspension calculations with the wheel position altered for chain adjustment.



**Rocker**




The rocker from the same example. Also measured as a separate component.

The shock and link are characterized by their length only, which is self evident and not shown here.

## Moments of Inertia of the wheels and tyres

These values are used in the calculation of the squat and sag values, under acceleration and braking conditions. The accuracy of the MoI values do not have a large effect on the squat and sag values, they are just a refinement to the calculations not a major part. In many cases the MoI values will not be available, if you do not have this information, use the value –1, which loads default values into the calculations based on typical wheels according to their weight. These default values will normally be sufficient.

It is not difficult to measure the actual moments of inertia and there is a two in one MoI calculator built into the software. There are many different ways of doing these measurements depending on the facilities available, but these calculators do the hard work for two simple methods of measurement. They can be described as:

1. Swinging pendulum
2. Pulley and weight

These methods will be described in detail.

**Swinging pendulum**

The previous photos show how the wheel needs to be mounted off centre such that it can swing from side to side about an axis defined by the supporting bar. In cases where there is no convenient symmetrical supporting locations (rear wheels and single disc fronts), the wheel can be supported by the bar just under the rim section.

The distance between the swing axis and the axle centre needs to be measured. The wheel should be slightly displaced to one side (in the plane of the wheel) and allowed to swing back and forth like a pendulum. Measure the time required to complete a number of complete cycles, 20 for example to reduce the effect of timing errors. A swing amplitude of +/- 5 degrees is quite sufficient.

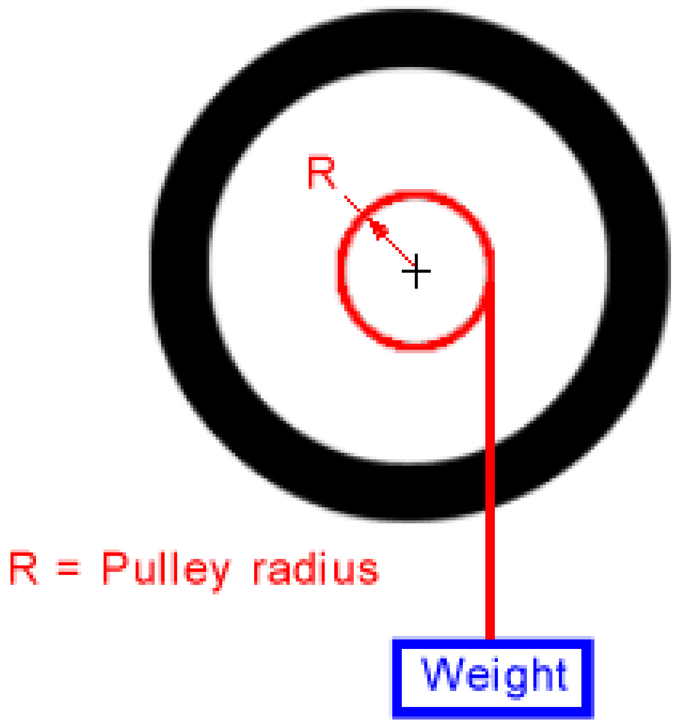
This method has the advantage that only the minimum of equipment is needed to do the measurements. Apart from a stop watch, weighing scales and a ruler or vernier calipers, a bar strong enough to support the wheel without excessive flex (10 mm. diameter is usually sufficient) and some means of supporting the bar horizontally is all that's necessary.

**Pulley and weight**

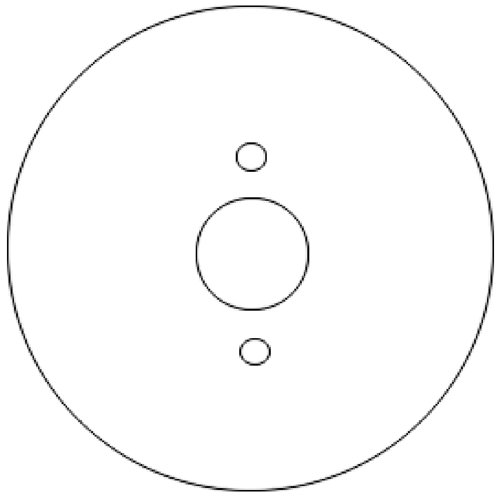
Probably the most accurate method of the two, but requires a little more preparation. A small pulley (about 100 mm. diameter is ideal) needs to be made that can be attached to the wheel concentric with its spin axis. Some thin cord or flexible cable is wound around the pulley and the free end attached to a known weight (2 kg. for example). Using this method the wheel can be supported with its own axle, which must be mounted sufficiently high to allow the weight to fall the equivalent of 2 or more wheel revolutions. Using a pulley of 100 mm. diameter, the weight will fall just over 0.3 metres for each revolution.

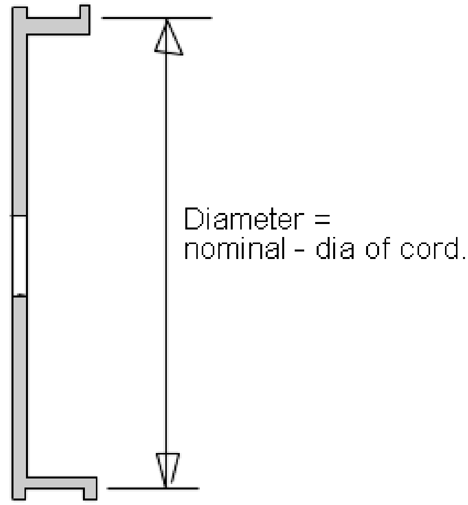
The pulley should be a light as possible so that it contributes a minimum to the MoI of the wheel, although in most cases it will be a simple matter to calculate its own MoI and subtract from the overall value, but this is usually not necessary.

**Layout of pulley and wheel**




**Possible pulley design.**



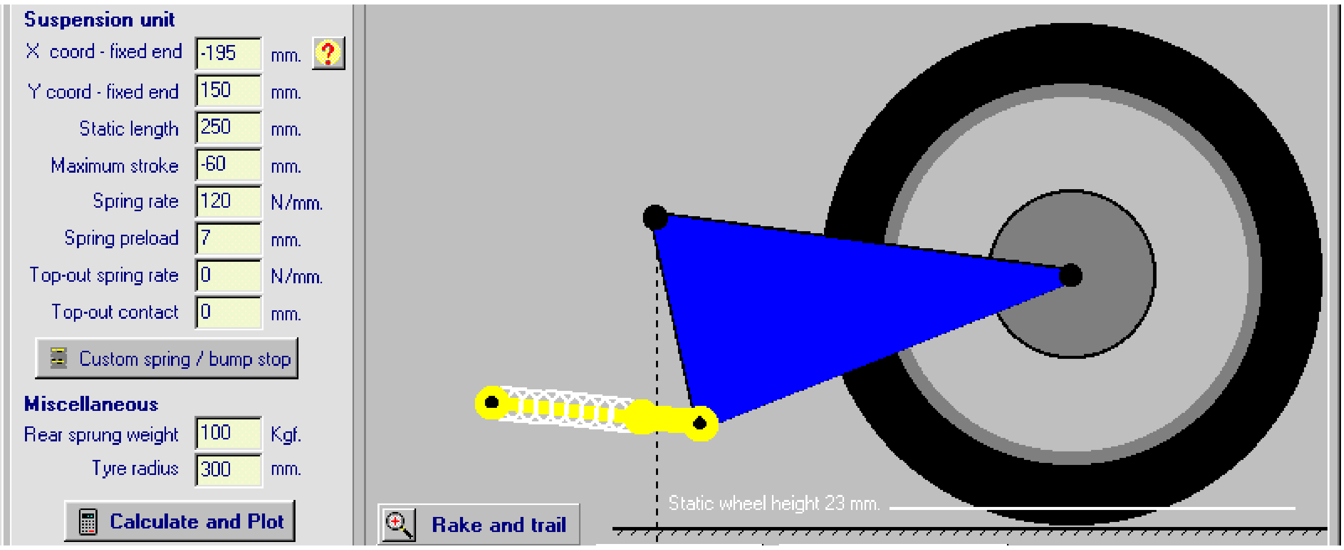

Diameter =
nominal - dia of cord.

# Special notes

## Extension shocks

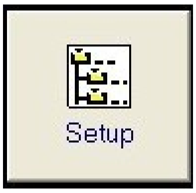
Shocks that are arranged to extend rather than compress when loaded.  Some Harley-Davison models use these. To model these in this software it is necessary to specify the “Maximum stroke” as a negative value as shown below.

In the software it is only the “simple shock on swing-arm” designs that accept a negative “Maximum stroke” value.

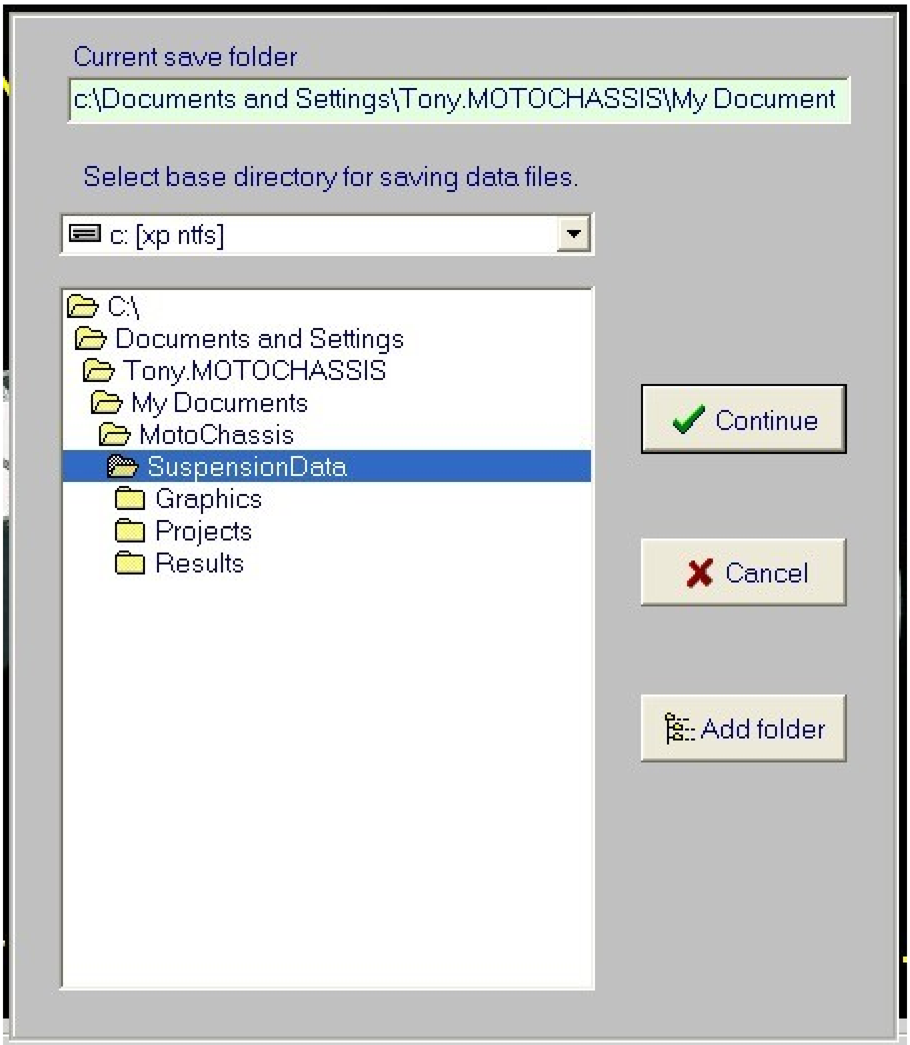



# New features.

On the opening screen there is a new button labelled “Setup” which opens an options box to allow a choice between setting or creating a directory for saving your files, and screen scaling.




**Directory setting**




Set or create a default directory for saving your project and data files. You can change the folder for individual files at the time of saving, as usual.

### Screen scaling

When this software was first written,  800 x 600 and 1024 x 768 were considered hi-res monitors.  Since then resolutions have increased considerably.  Automatic scaling features were added to the programme but with the wide variation in available resolutions the automatic scaling does not suit everybody nor all monitors.  It is now possible to choose one of these three options, viz:

1. No scaling.  This gives a maximum window size of 800 x 600.
2. Automatic scaling which is the same as the previous “no choice” scaling, and is set as the default.
3. Custom scaling, which allows any user specified scaling, but there are  limits of 100% to 200%.  Scaling is specified as a % .  100% is the same as no scaling.  Scaling is acumulative whilst being changed.  For example if you were using the auto scaling of say 130% then if you change to a custom 120% you would be presented with a scaling of 120% of 130 or 156%.  Therefore it is recommended to close the programme and restart after making scaling changes.