

MOTORCYCLE SETUP ANALYSIS

Version 1.05



Software User's Manual

Version 1.15

Tony Foale Designs © 2006-2007

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Introduction

During the past 3 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@tonyfoale.com describing the design. We will try and update the software to accommodate all systems that we regard of interest.

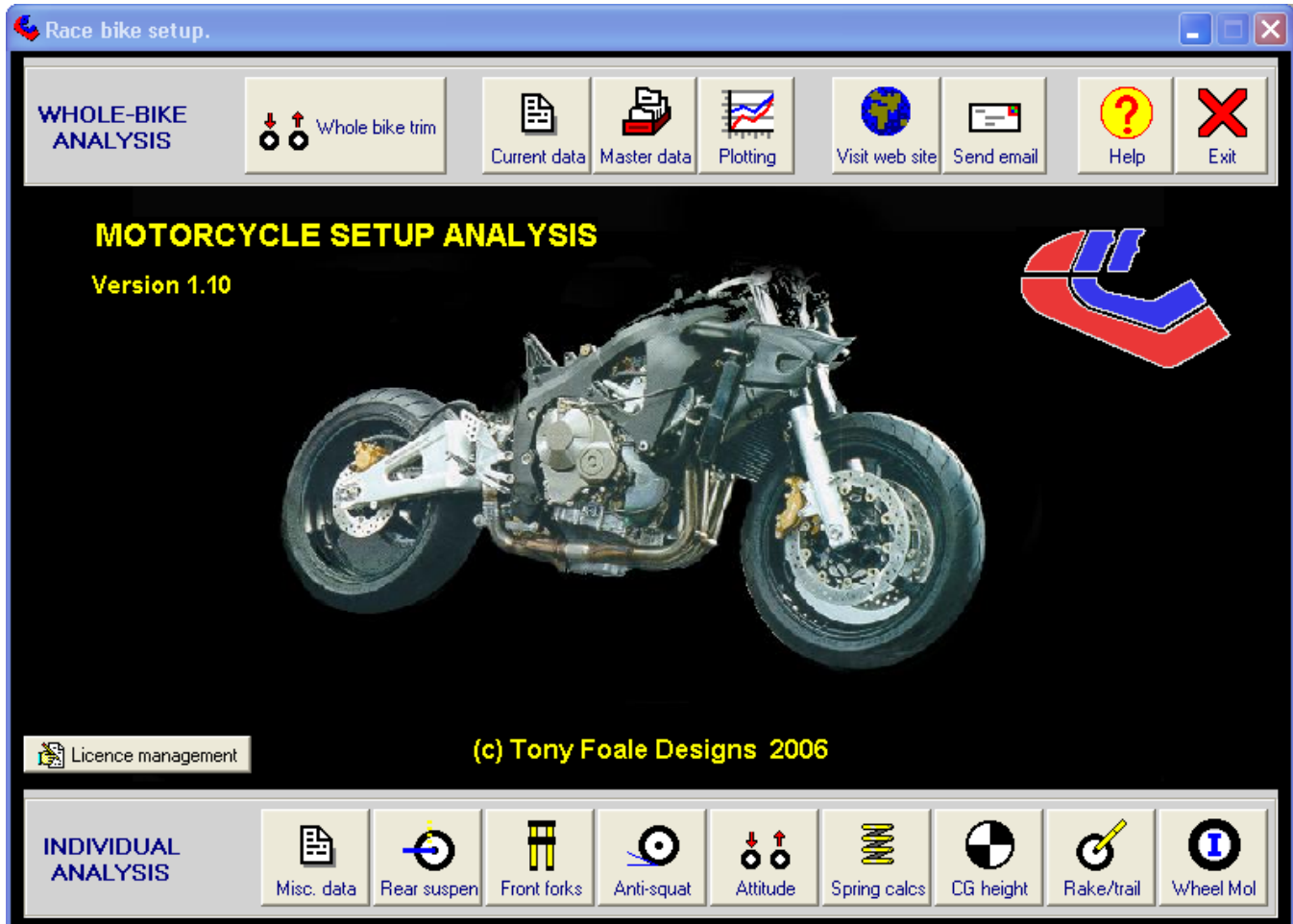
This software is currently limited to analyzing telescopic forks at the front. This does not prevent the overall analysis of a machine fitted with an alternative front end. The rear suspension, anti-squat and attitude calculations will still apply.

Foot note (Alternative front ends.)

For anyone interested in analyzing 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 analyze the new BMW duolever but not the older telelever which has sliding members. Email info@tonyfoale.com for further information.

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 brk 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.



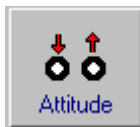
Selection screen for the type of rear suspension. There are three main classes of suspension configuration available, which cover almost all current designs. The BMW paralever and similar systems are not covered.



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.



Attitude

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.



Spring calcs

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.



CG height

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



Rake/trail

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.



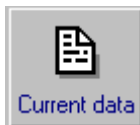
Wheel Mol

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



Who

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.



Current data

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.



Master data

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



Plotting

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.



Visit web site



Send email

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

Miscellaneous data		
Front wheel weight	10	Kgf.
Rear wheel weight	13	Kgf.
Front wheel Mol	-1	Kg.m ²
Rear wheel Mol	-1	Kg.m ²
Load on front tyre	125	Kgf.
Load on rear tyre	125	Kgf.
Y coord of CG	650	mm.
Front tyre radius	300	mm.
Rear tyre radius	300	mm.
Rake angle	25	deg.
Fork offset	36	mm.
Wheel base	1450	mm.
Y R ride height ref.	830	mm.
<hr/>		
Trail	100.2	mm.
Wt. balance % - F/R	50.0/50.0	
<input type="button" value="X Close"/> <input type="button" value="Update project"/>		

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

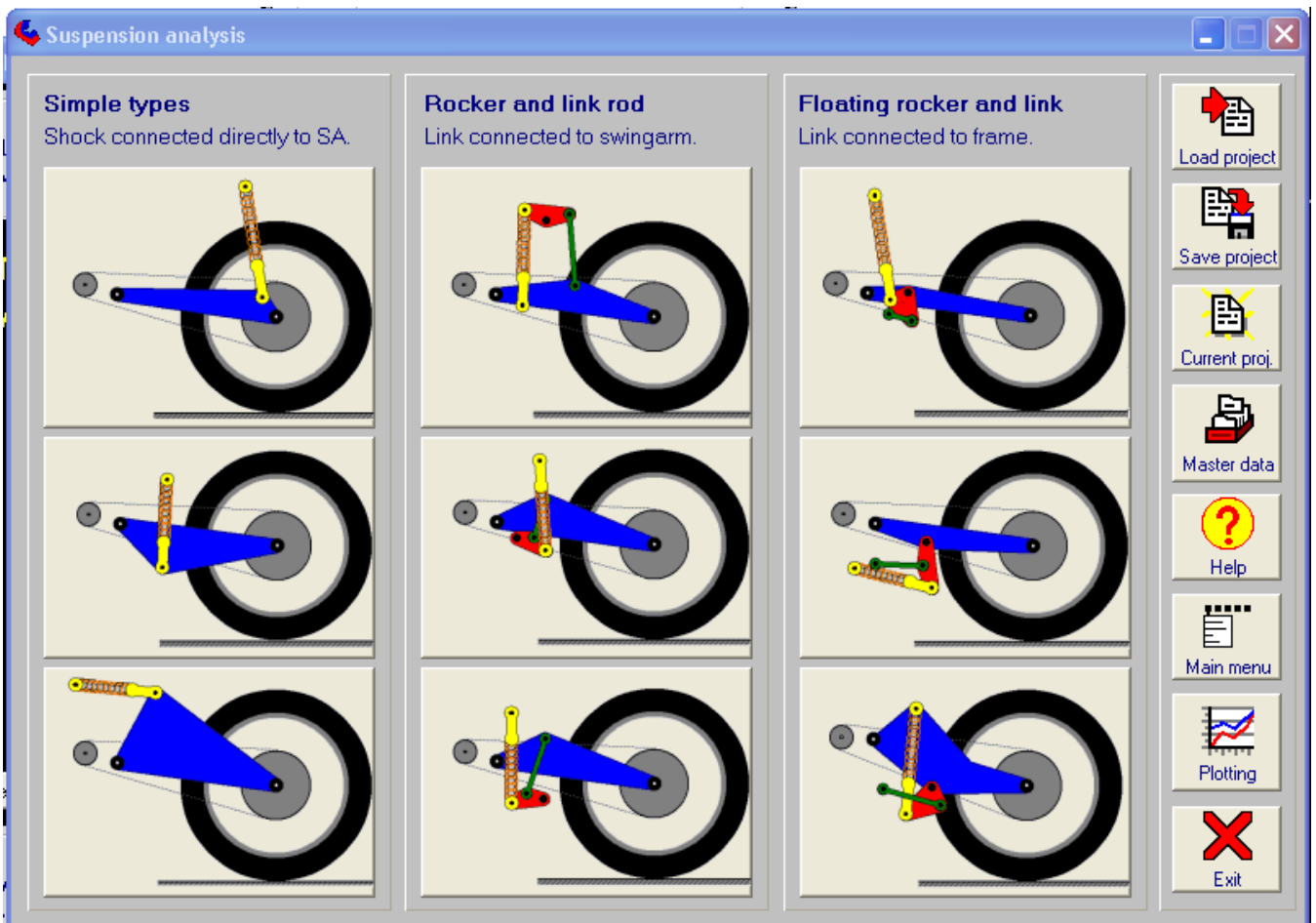
Chose a starting design, similar to that to be analyzed, from the following initial selection screen. If you have already selected or loaded a design and wish to return to that project the click on the “Current proj.” button.

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.



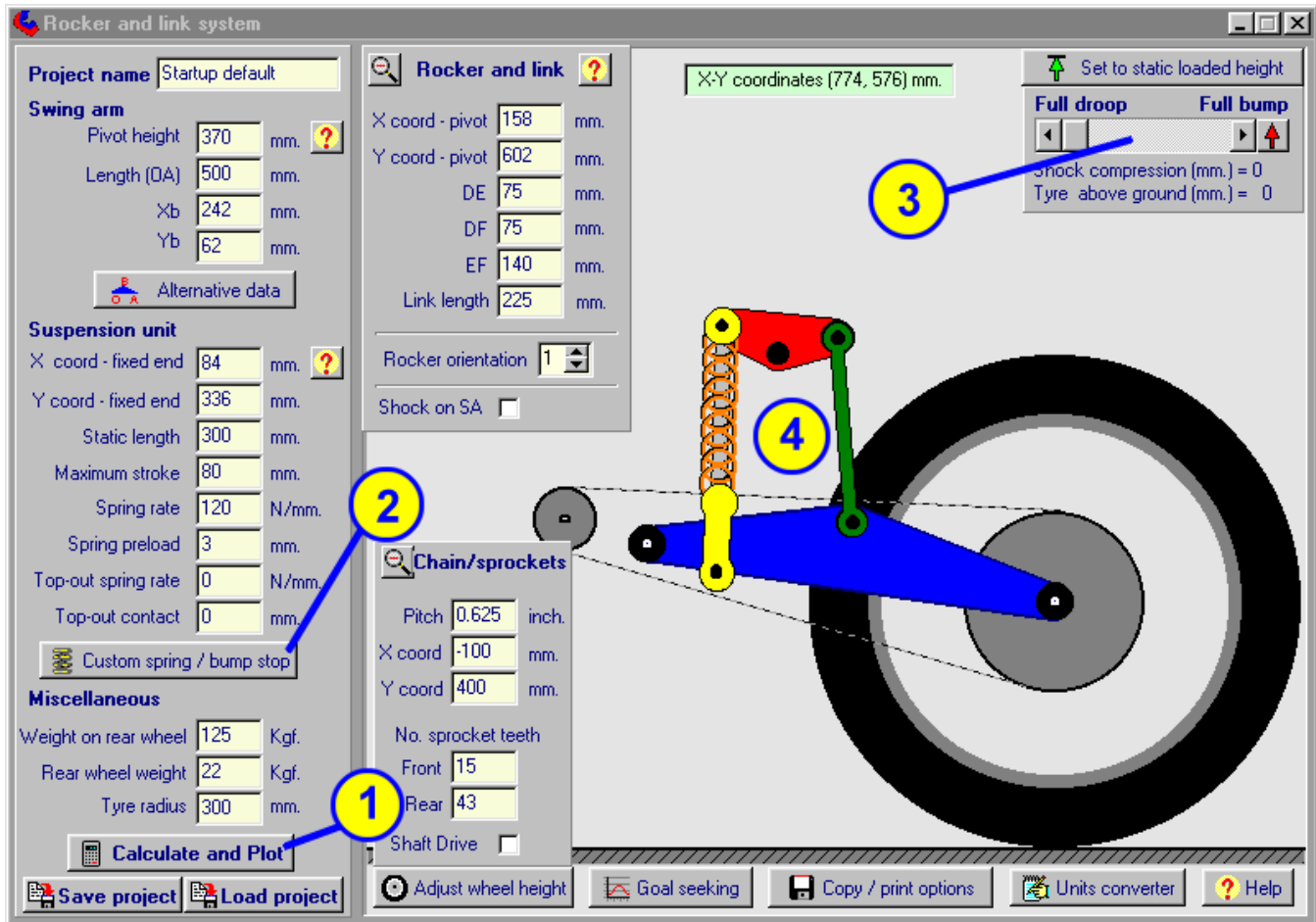
These classes are shown in the three on-screen columns.

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 shown in the detailed sections of this manual.

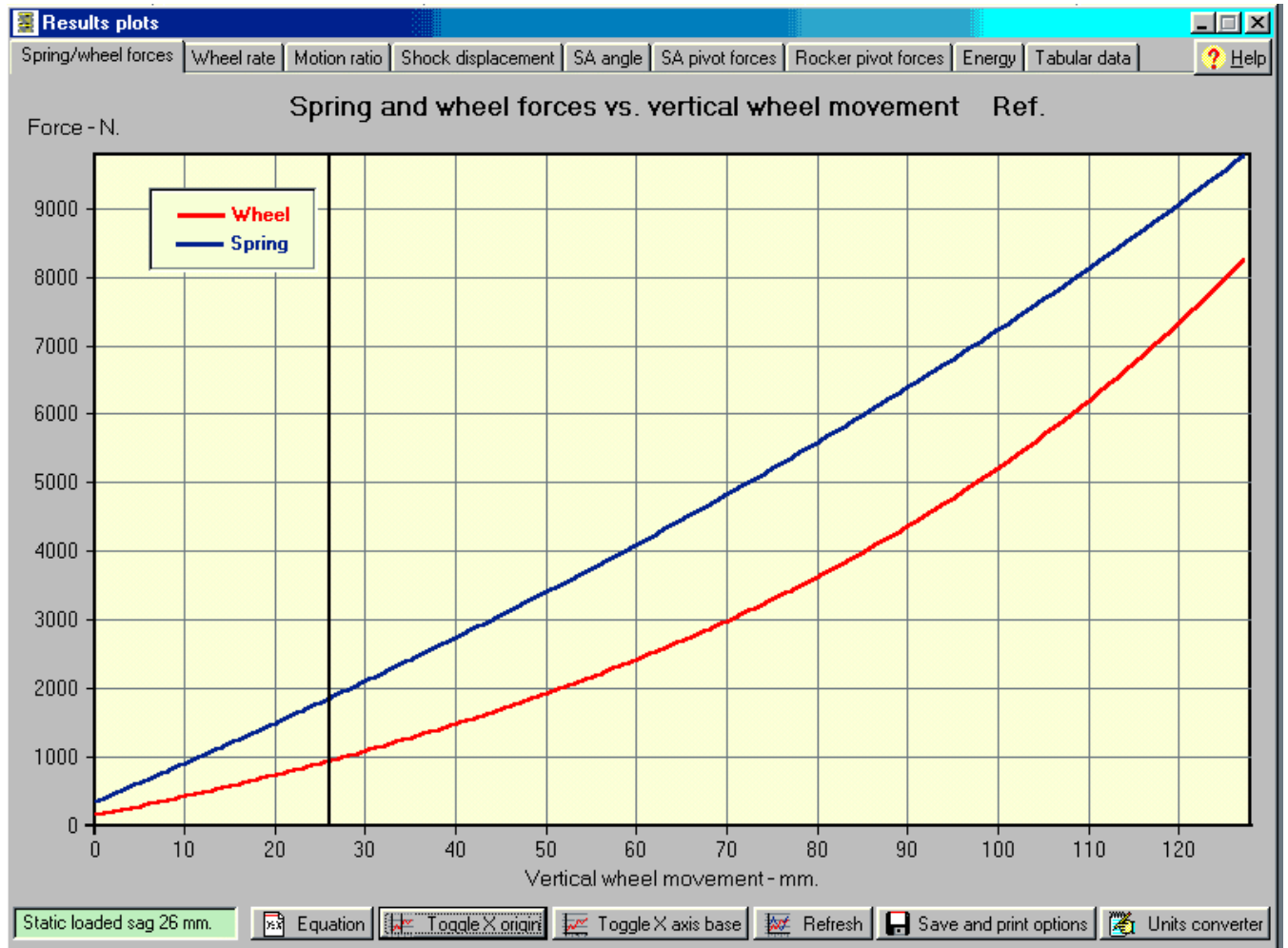
Data entry screen.



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.

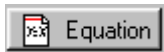
Swing-arm pivot forces – the horizontal, vertical and resultant forces at the swing-arm pivot point.

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:



Shows a polynomial equation of the data. Also plots a graph under the data graph to show degree of fit.



Toggles the origin of the X axis between full rebound position and static ride height.



Toggles between wheel movement and shock compression as X axis.



Redraws graphs, cleaning any user added lines or marks.



Print, save to file or copy graph to clipboard.



Conversion between metric and imperial units.

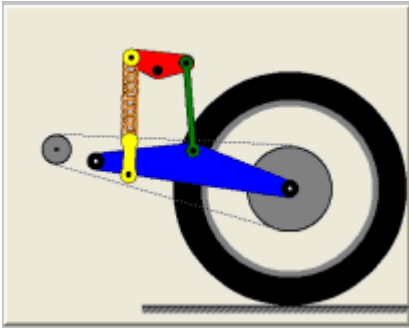
The best way to learn to use the programme is to play around. Enter various data and see what happens. The following section explains each feature in detail and there is a separate publication which explains the theory and practice of suspension systems in general.

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 be 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.



Load project

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



Save project

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.



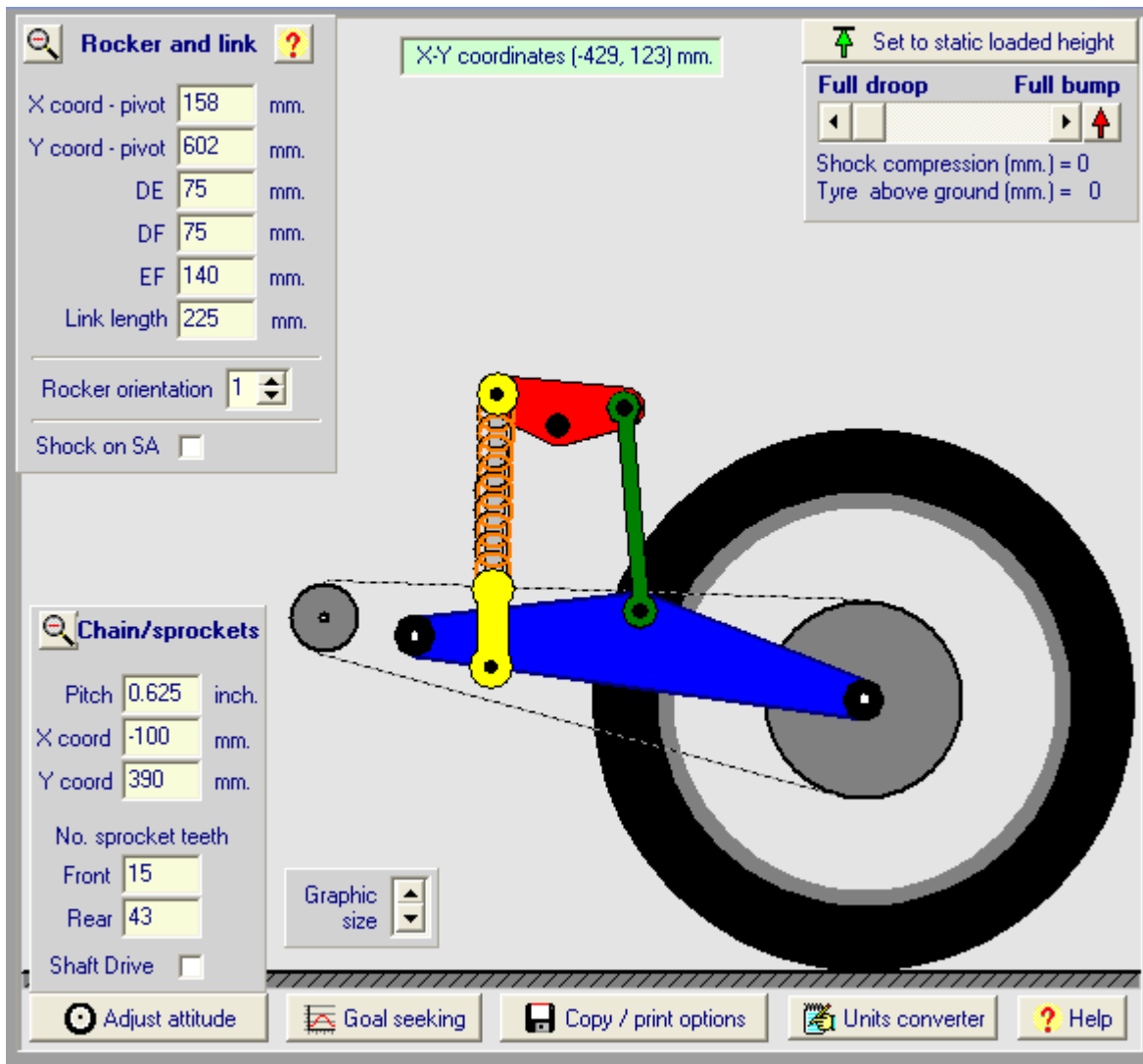
Help

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.

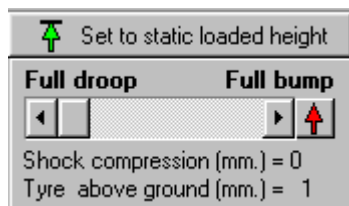
Animation and layout graphic




N.B. At times the image may disappear, a mouse click in this part of the screen will redraw it.

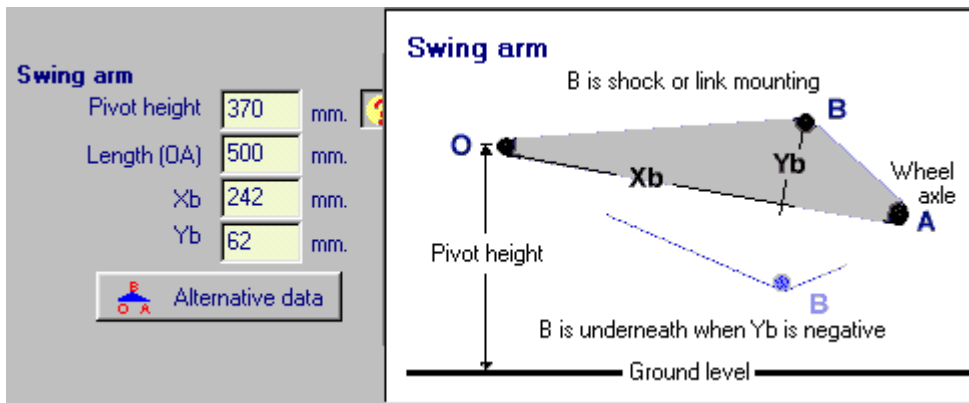
The layout graphic image serves a double purpose.

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.

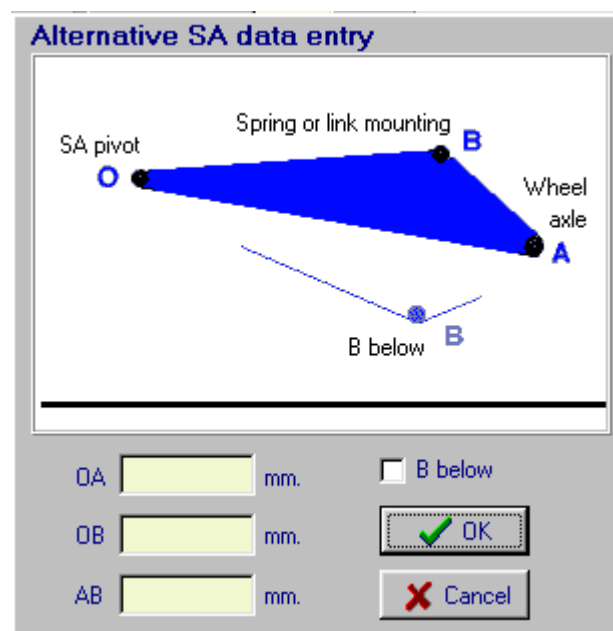
“O” – swing-arm pivot location.

“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.

Shock data

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 2nd 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.

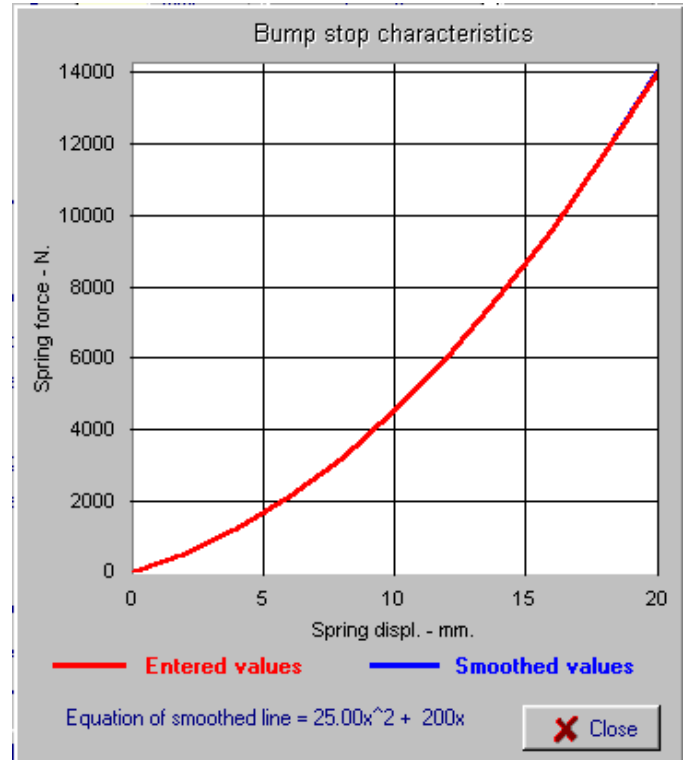
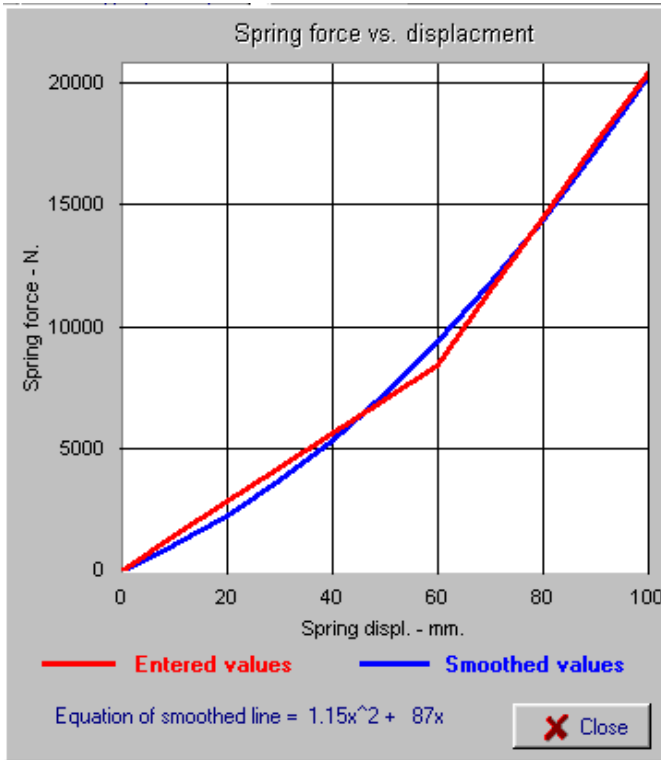
Make sure that the spring properties are entered to cover the maximum possible compression range. The displacement value for the final data point must be at least the maximum shock displacement plus the preload.

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.



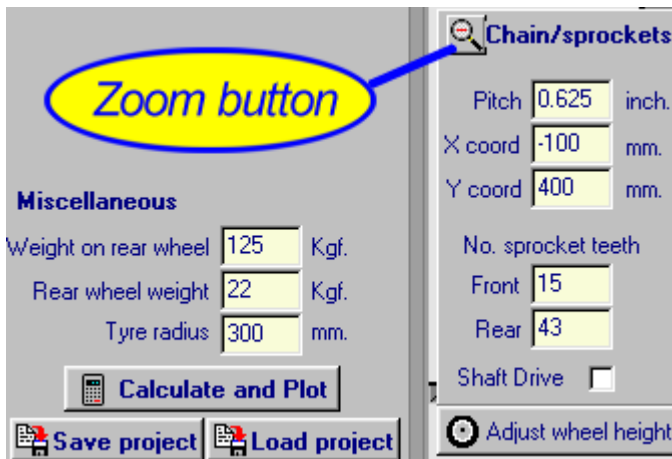
These buttons plot the custom spring/bump-stop characteristics. Both the smoothed and the entered curves are plotted and the equations of the smoothed characteristics are shown.



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.

The shaft drive 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 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.

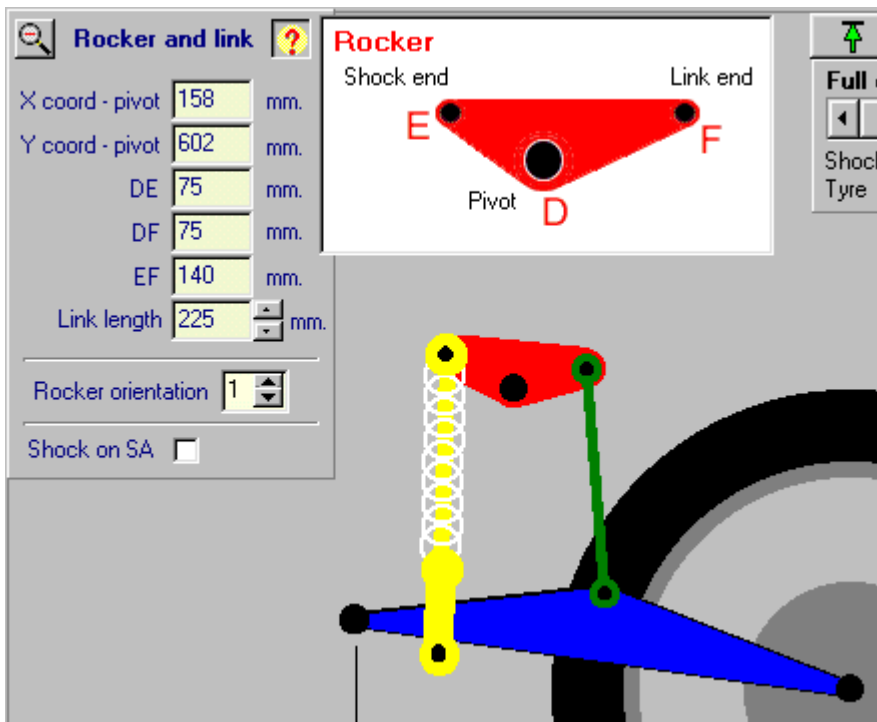


Print, save to file or copy the graphic to the clipboard.



Conversion between metric and imperial units.

Rocker and link

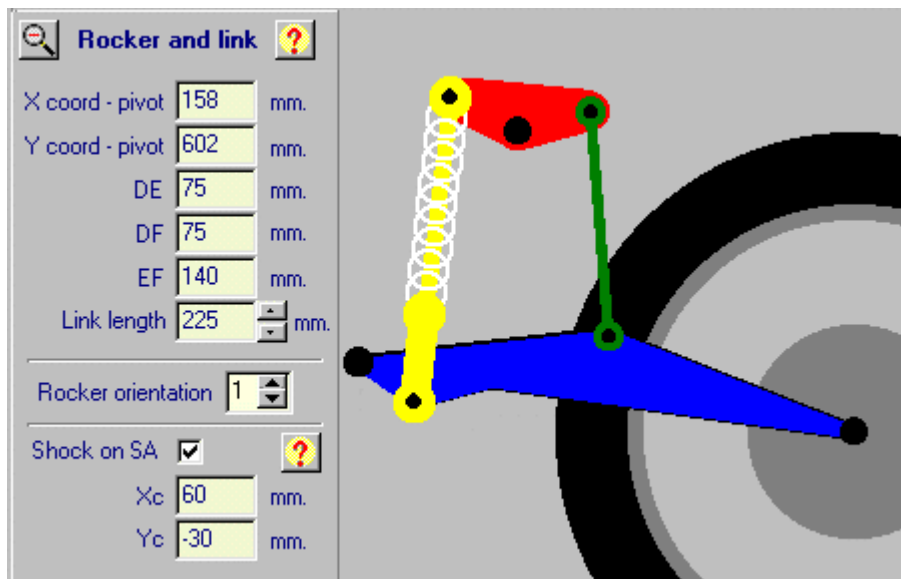


The fly-out help window shows the meaning of the various rocker dimensions.

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 coordinates.

Rocker orientation 4

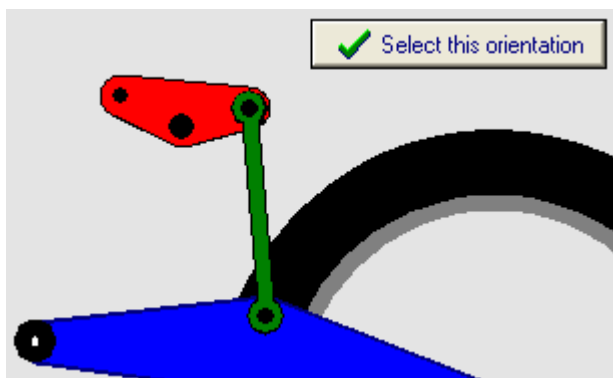
Rocker orientation

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.

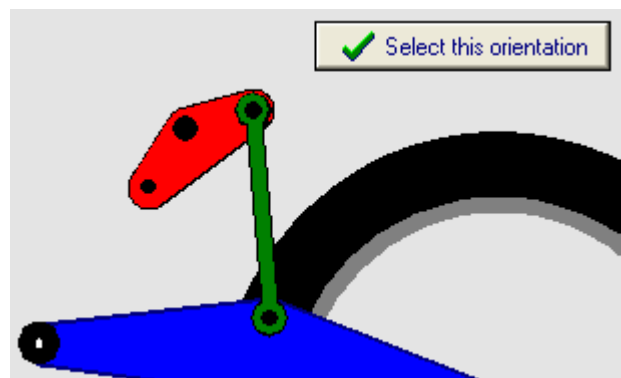
The following illustrations (which appear when the spin control is used) show the four alternative orientations for this particular design. The correct orientation is "1" as can be seen by reference to the graphics on the previous page. Some orientations lead to impossible physical layouts. To avoid 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.

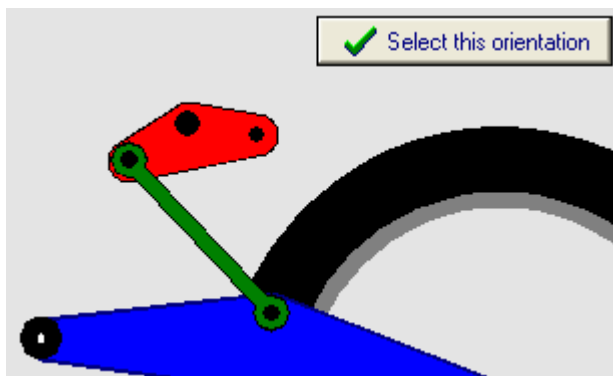
Orientation 1



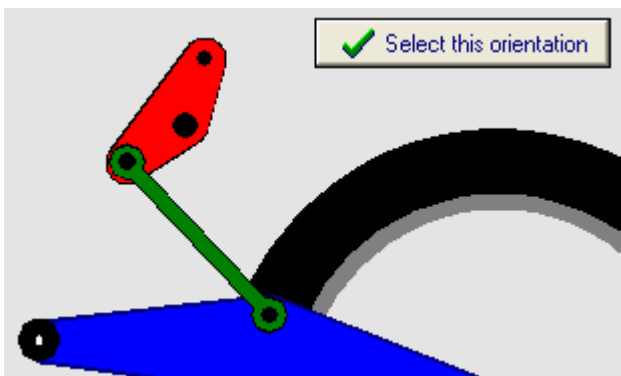
Orientation 2



Orientation 3



Orientation 4



Rocker and link ?

X coord - pivot 158 mm.

Y coord - pivot 602 mm.

DE 75 mm.

DF 75 mm.

EF 140 mm.

Link length 225 mm.

Rocker orientation 3

Shock on SA

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.

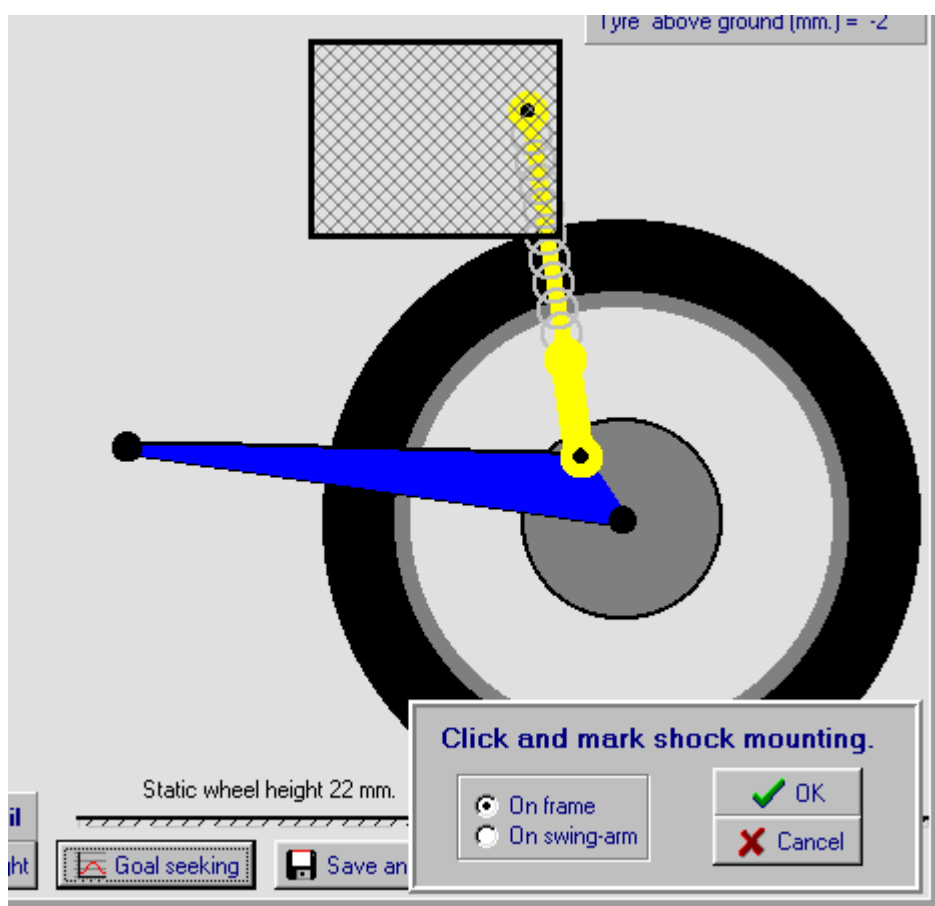


Within certain physical and kinematic limits, this feature will automatically adjust the selected dimensions to attempt to achieve a specified suspension characteristic. The desired characteristic can either be entered manually or be cloned from another bike. For example if the progressive characteristics 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.

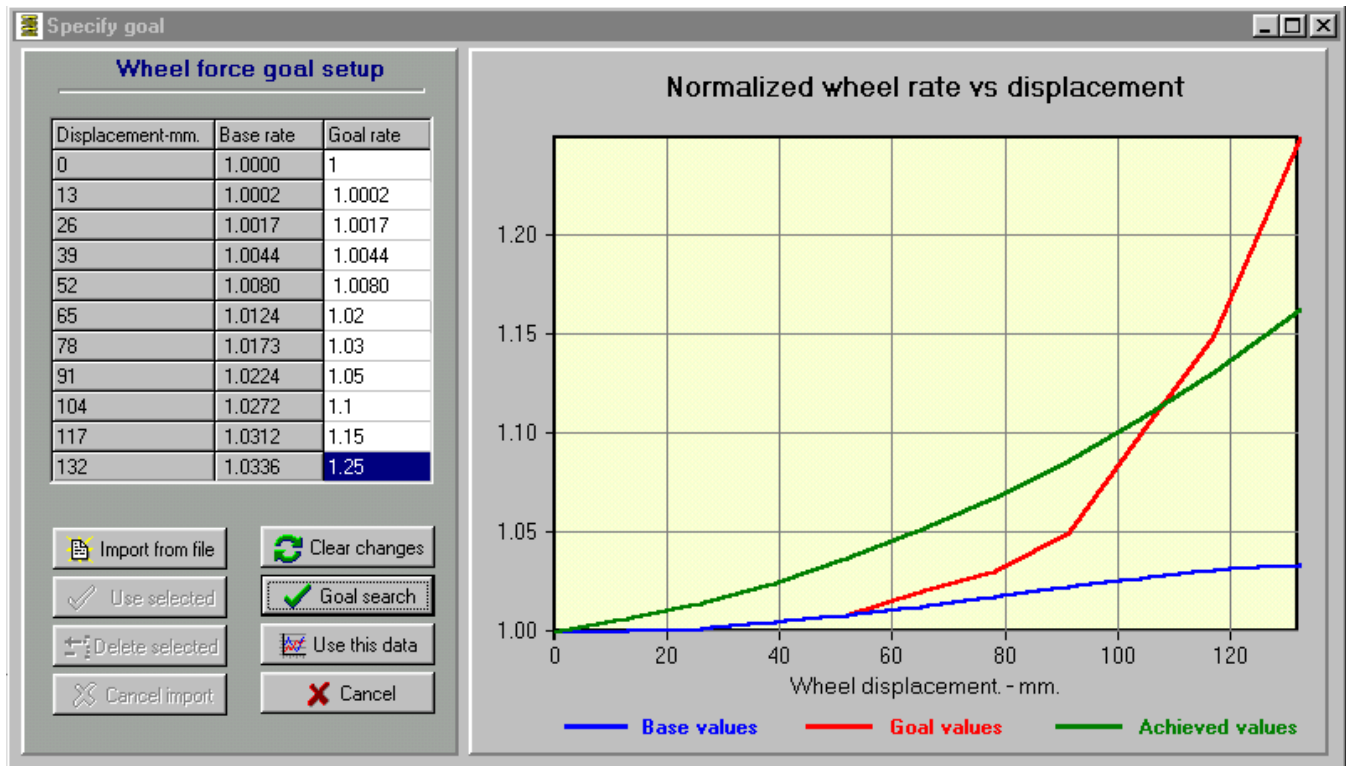


From the pop-up panel select the parameter to modify, in this example it is "On frame". Then, with a normal click and drag procedure, mark the limits as shown and click on the OK button when done.

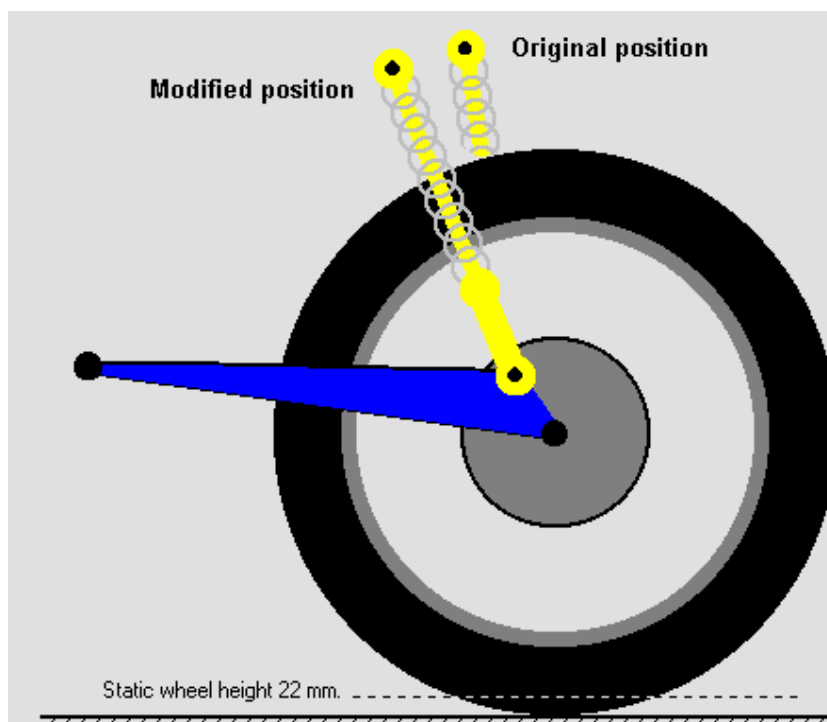
This will then pass on to a screen for entering the desired characteristic, which will show the unmodified characteristic as well as the achieved characteristic. The closeness of fit (least squared error) between the desired characteristic and that achieved will depend on how realistic the requested 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.



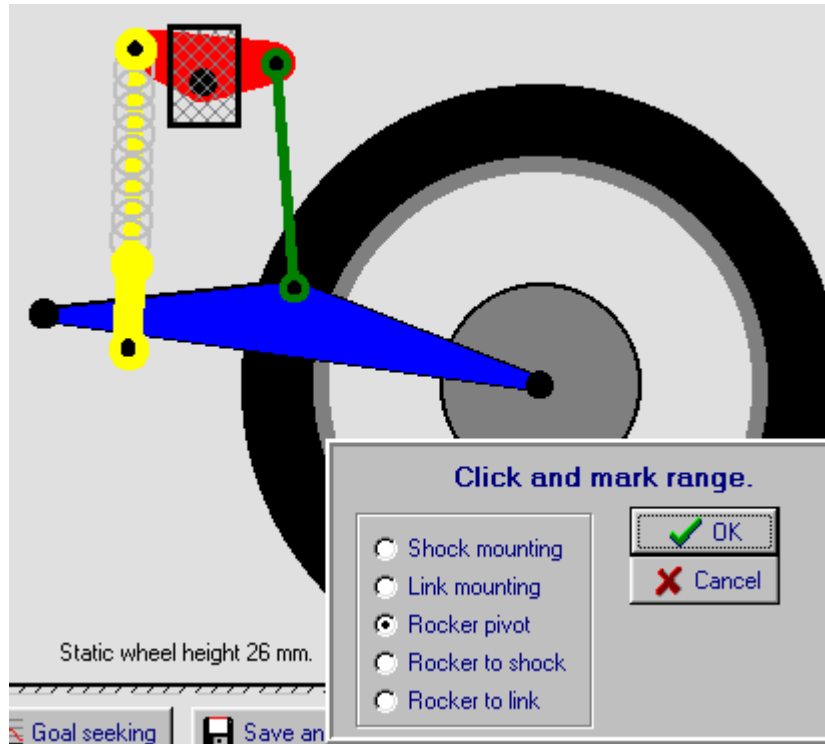
You can now either Cancel or elect to use the new layout. The new dimensions will be transferred back to the data entry screen automatically. The following picture shows how the frame to shock mounting has been moved forward to give the closest fit possible to our requirement. The shock movement will 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.



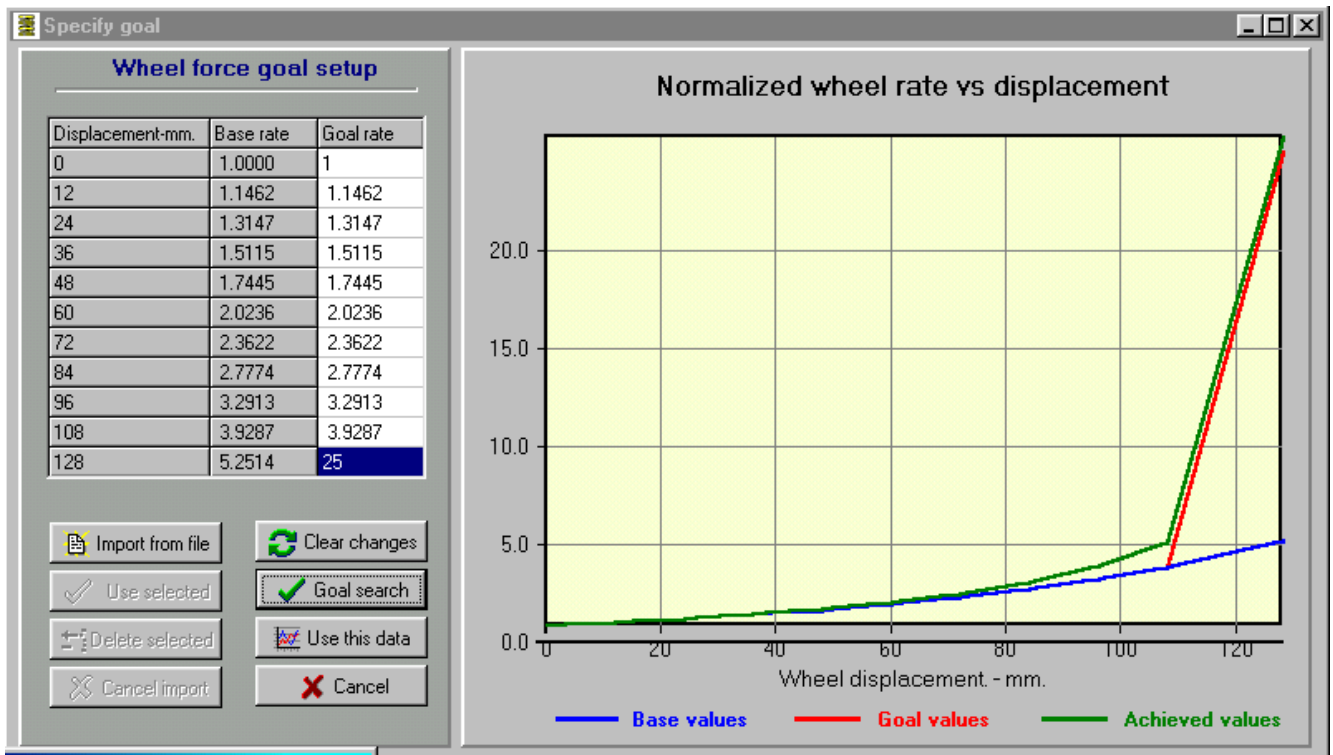
Rocker systems

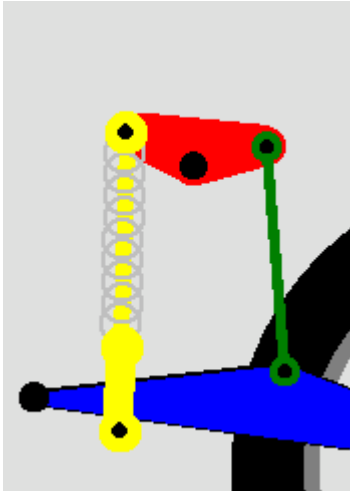
It is when we consider the rocker systems that the real power of this feature becomes more evident.

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

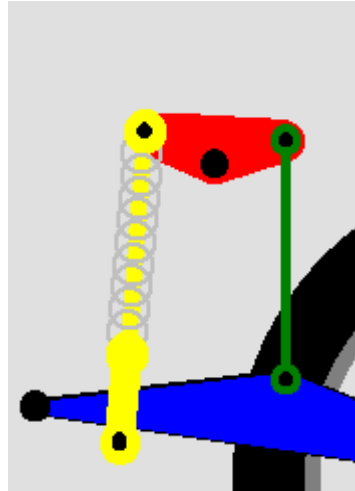


As shown below, the original maximum value of the normalized wheel rate was 5.2514. In this case we only want to increase the rate at the end of the wheel travel so only the last value of the goal rate was changed to 25. We can see that the achieved characteristic is very close to that requested. To 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.

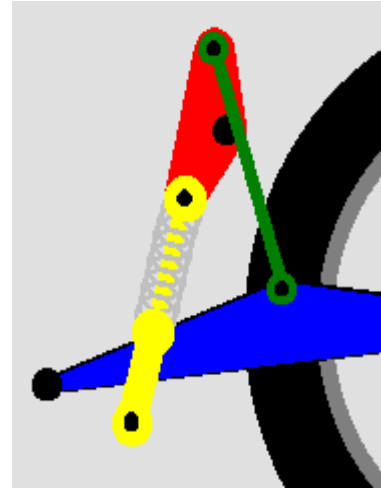




Original system fully extended.

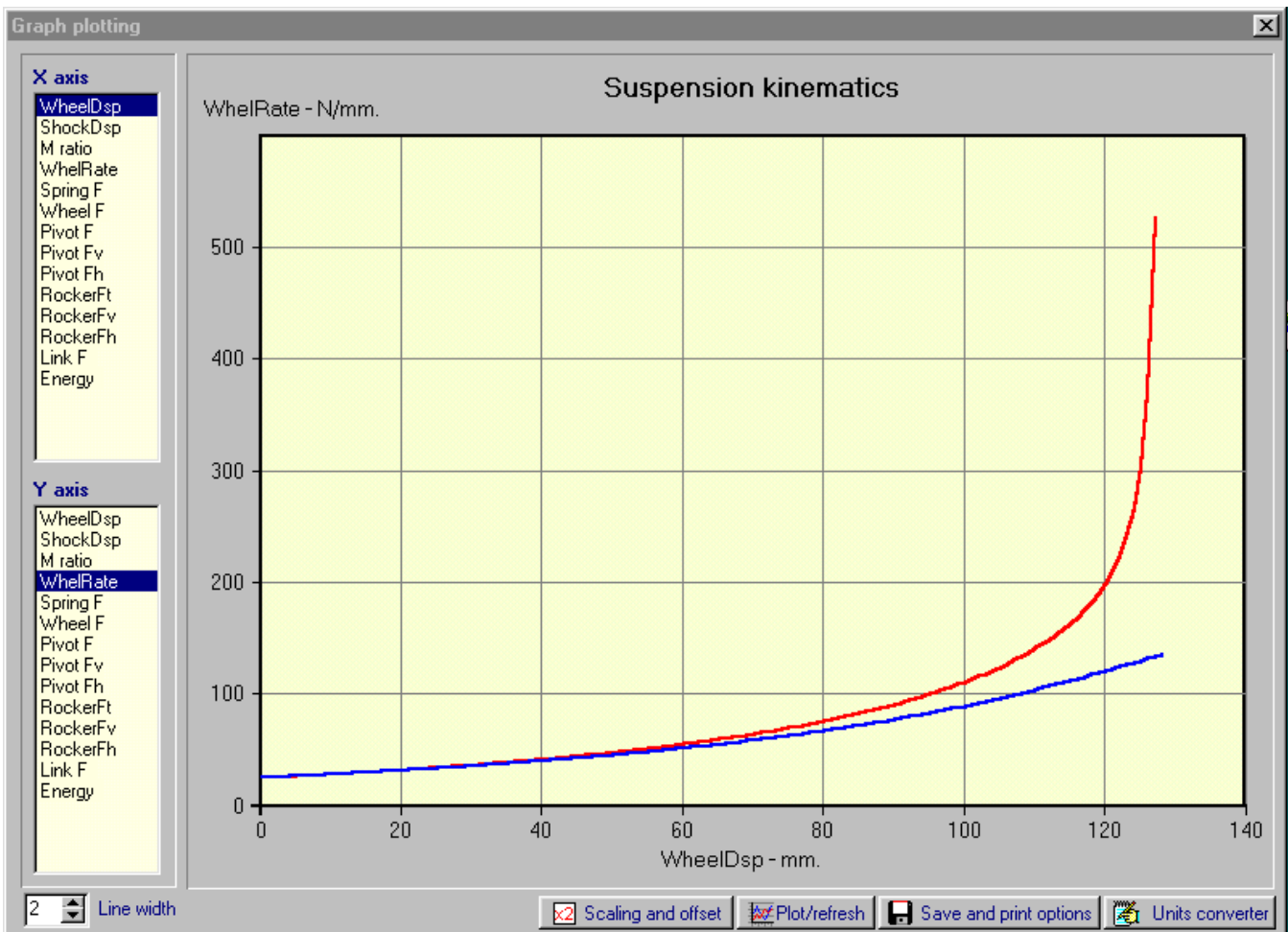


Modified design fully extended.



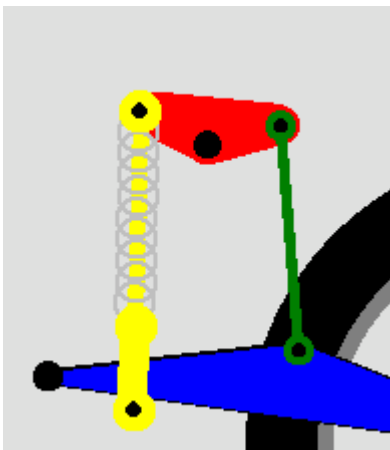
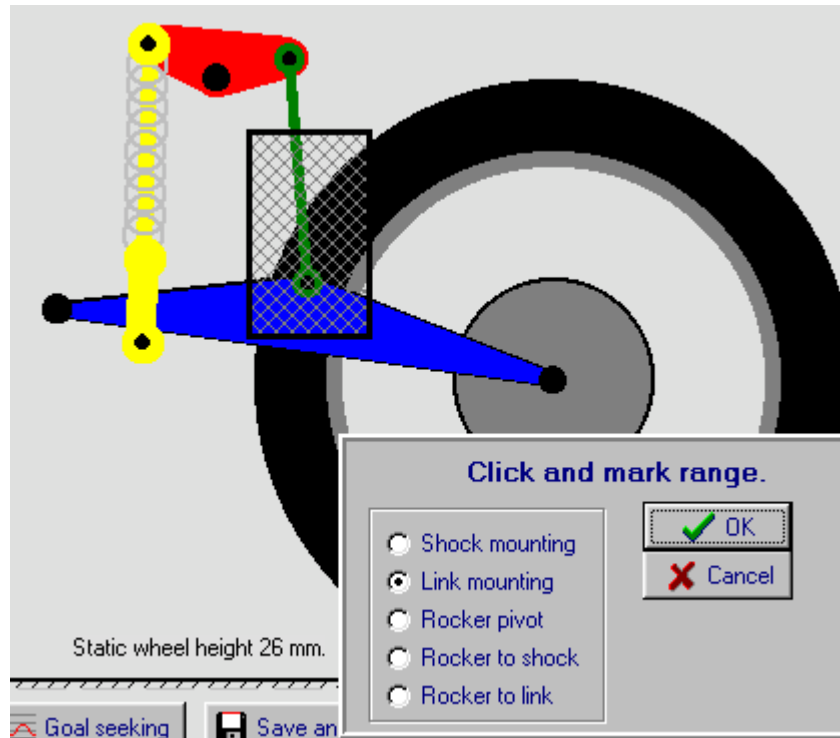
Modified design fully compressed. Note that more wheel displ. would cause a locked movement.

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.

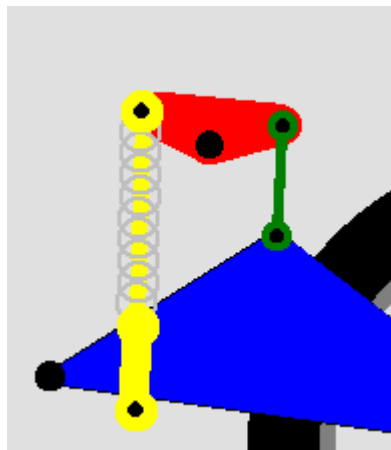


This does not mean that all layouts which give nearly a 25:1 wheel rate range will tend to this potential lock problem. Even higher ranges can be achieved with other design options. The above example was chosen to illustrate that whilst a goal searching feature can be extremely useful, the resulting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

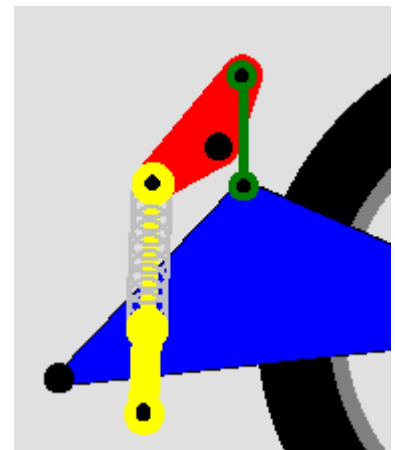
The next example starts with the same basic design but instead of goal searching on relocating the rocker pivot, the search was done for moving the link to swing-arm dimensions. As follows:



Original system fully extended.

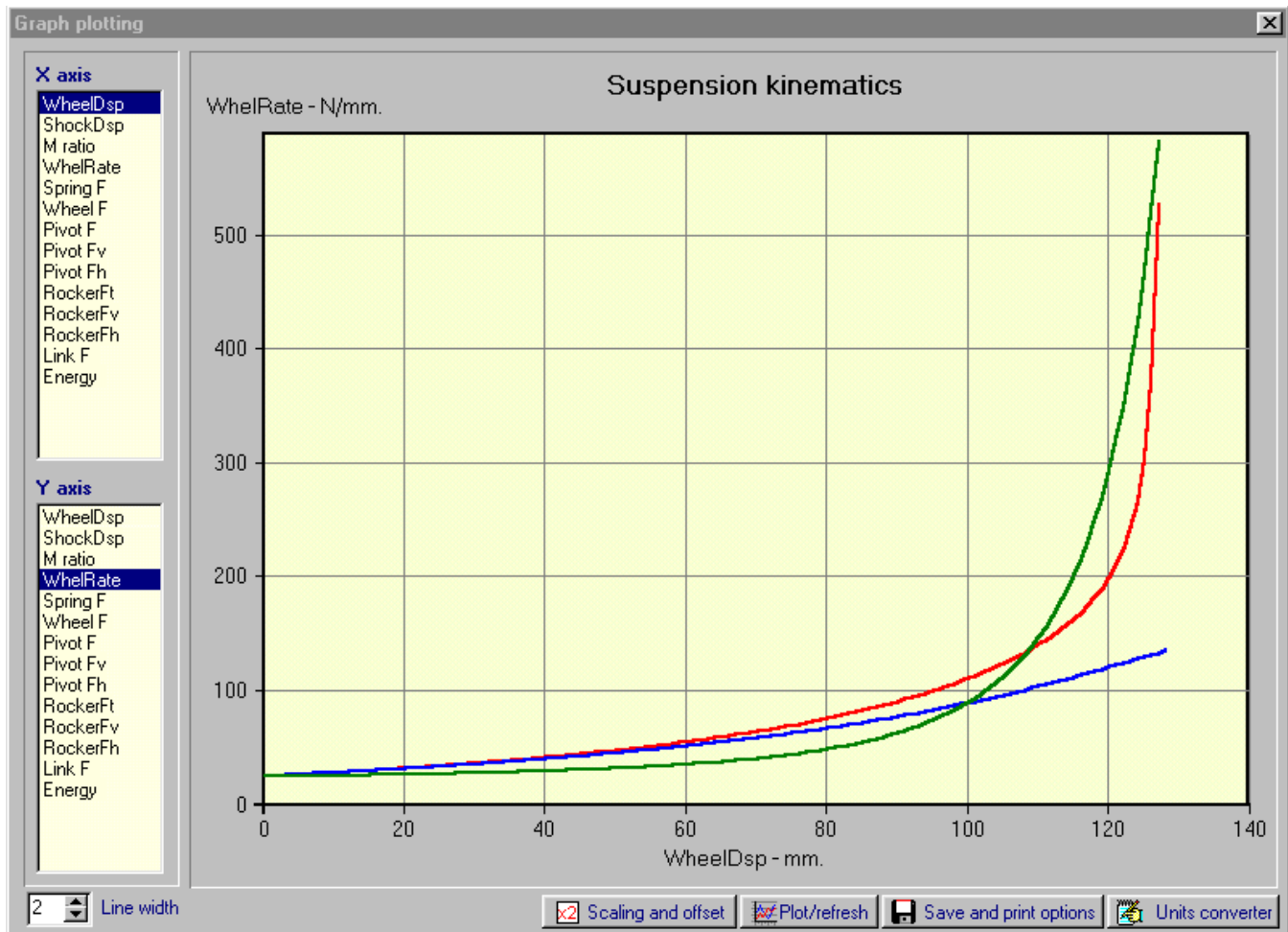


Modified design fully extended.



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:

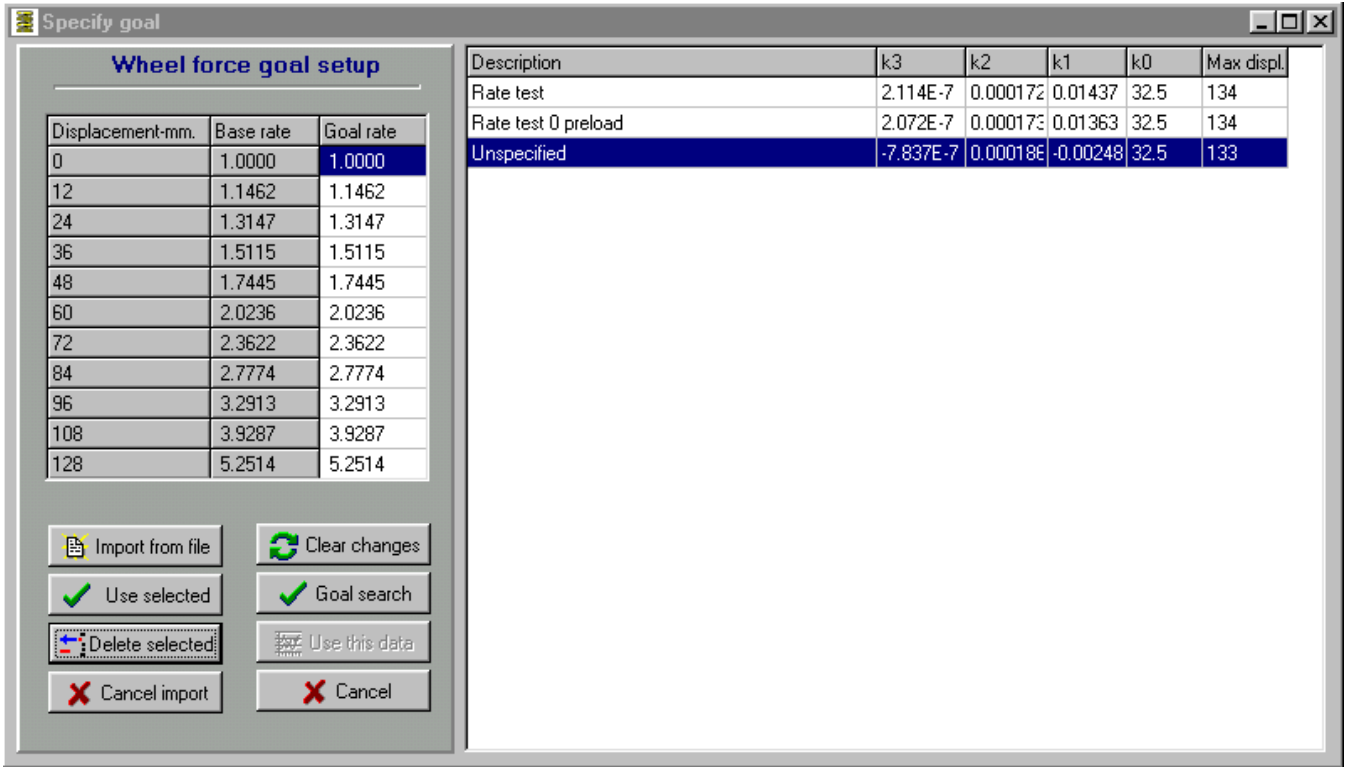
- Enter the data or load it from file for the bike to be cloned.
- Click the “Calculate and plot” button and select the “Wheel rate” page.
- Click the “Save and print options” button and select “Save eqn. to file”.

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.

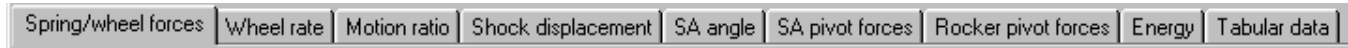
When using a donor design it is quite likely that the range of wheel displacement will be different from the receiving design. In that case the software will automatically impose the donor range of wheel rate values onto the receiving design.

Results screens

Calculate and Plot

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

Results plots										
Spring/wheel forces Wheel rate Motion ratio Shock displacement SA angle SA pivot forces Rocker pivot forces Energy Tabular data										Help
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

Static loaded sag 26 mm. [Save data] [Print data] [Units converter]

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:

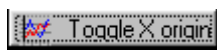
- *.ERD – For use with the internal multi-plotter and WinEP (Windows Engineering Plotter)
- *.XLS – For use with MS excel and compatible programmes.
- *.SLK – General purpose spreadsheet format. Loads with excel and many other spreadsheets.
- *.TXT – TAB delimited file. Can be imported into spread sheets 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 26 mm.. In other words, under initial static loading the sag at the wheel will be 26 mm. 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.

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 on the blue curve.

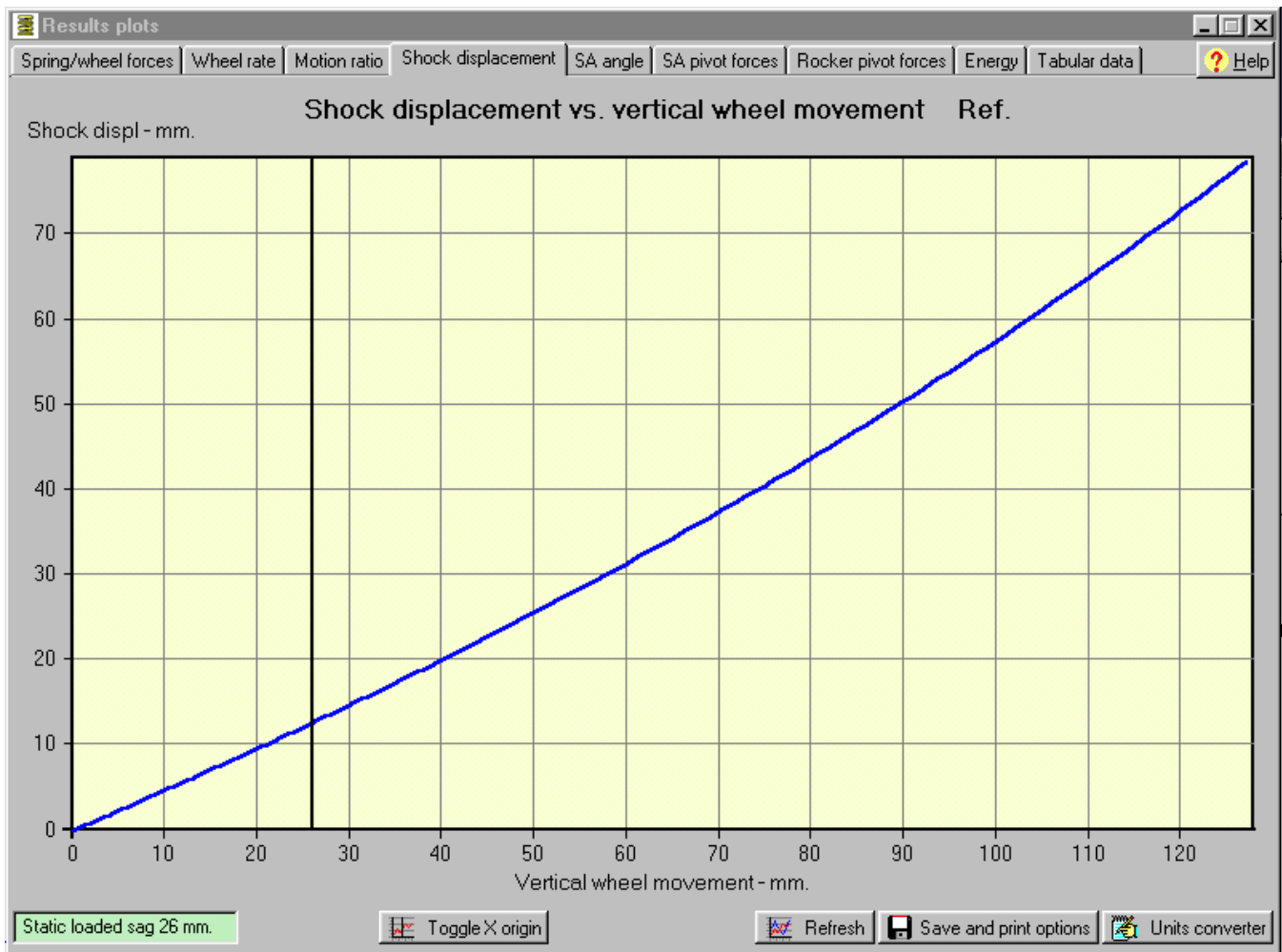
Lines can be drawn by dragging with the mouse and holding the LHS button, on release the slope of the line will be shown, this is shown on the red curve.

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

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

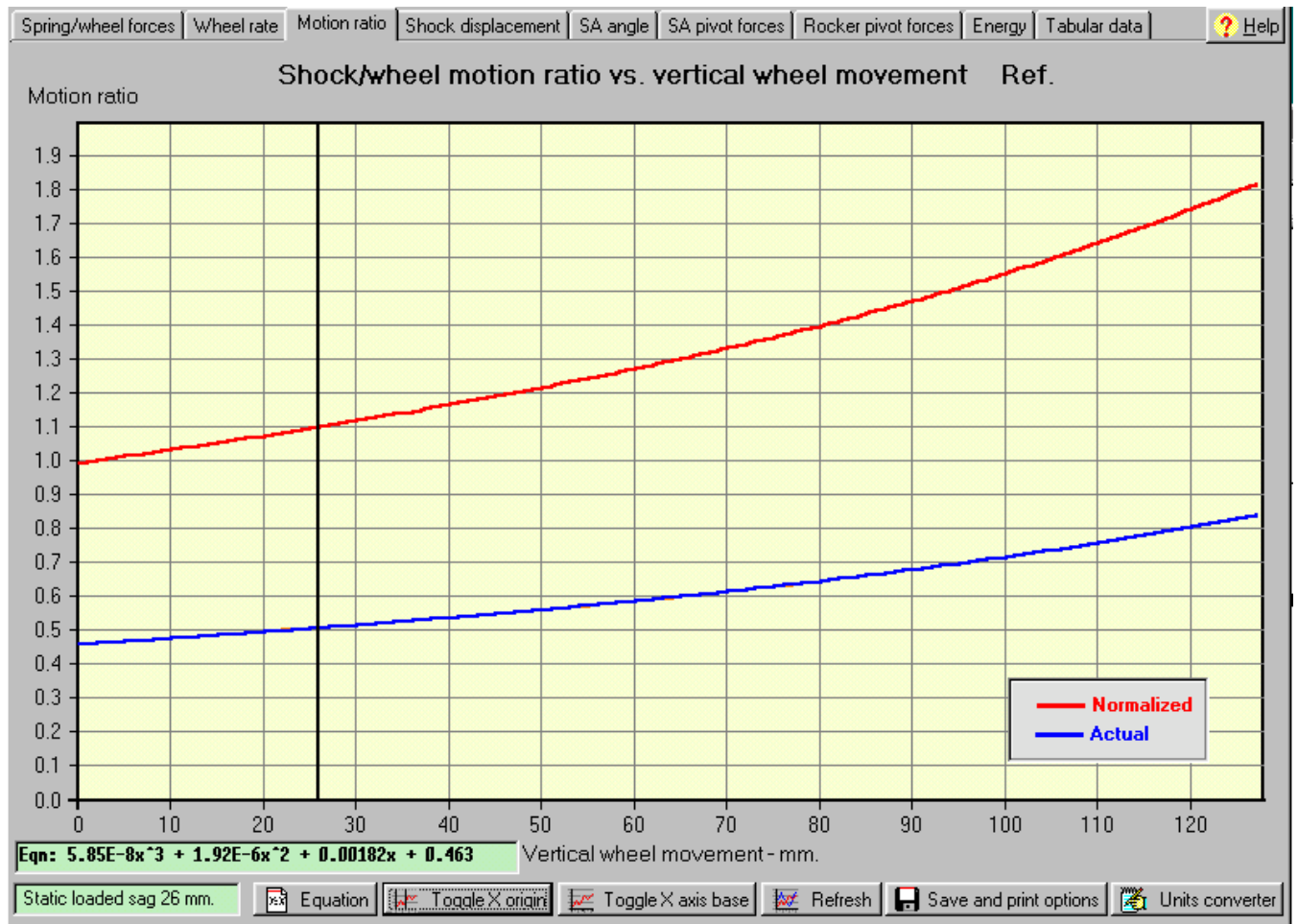
The  button toggles between using the wheel motion or shock compression as the values for the X axis. The line equation will automatically change to reflect the new axis.

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



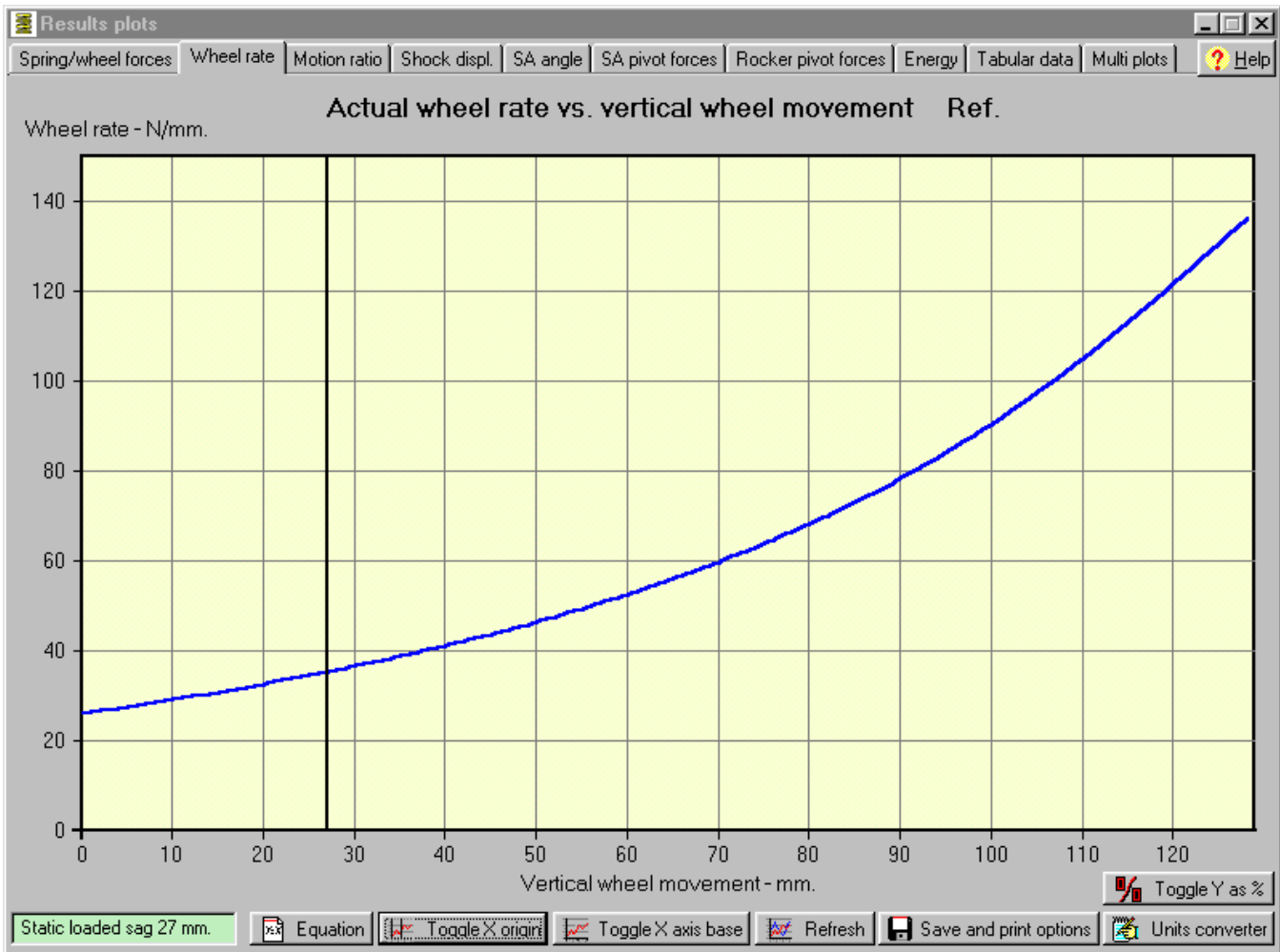
The motion ratio is also called leverage ratio, velocity ratio and mechanical advantage. As plotted it shows the shock velocity in terms of the vertical wheel velocity. In this example, we can see that at full rebound the motion ratio is around 0.46 which means that the wheel is moving upward at a rate 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.

It is usual that this ratio is always 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 but no current designs are known where the motion ratio is greater than 1.0.

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.

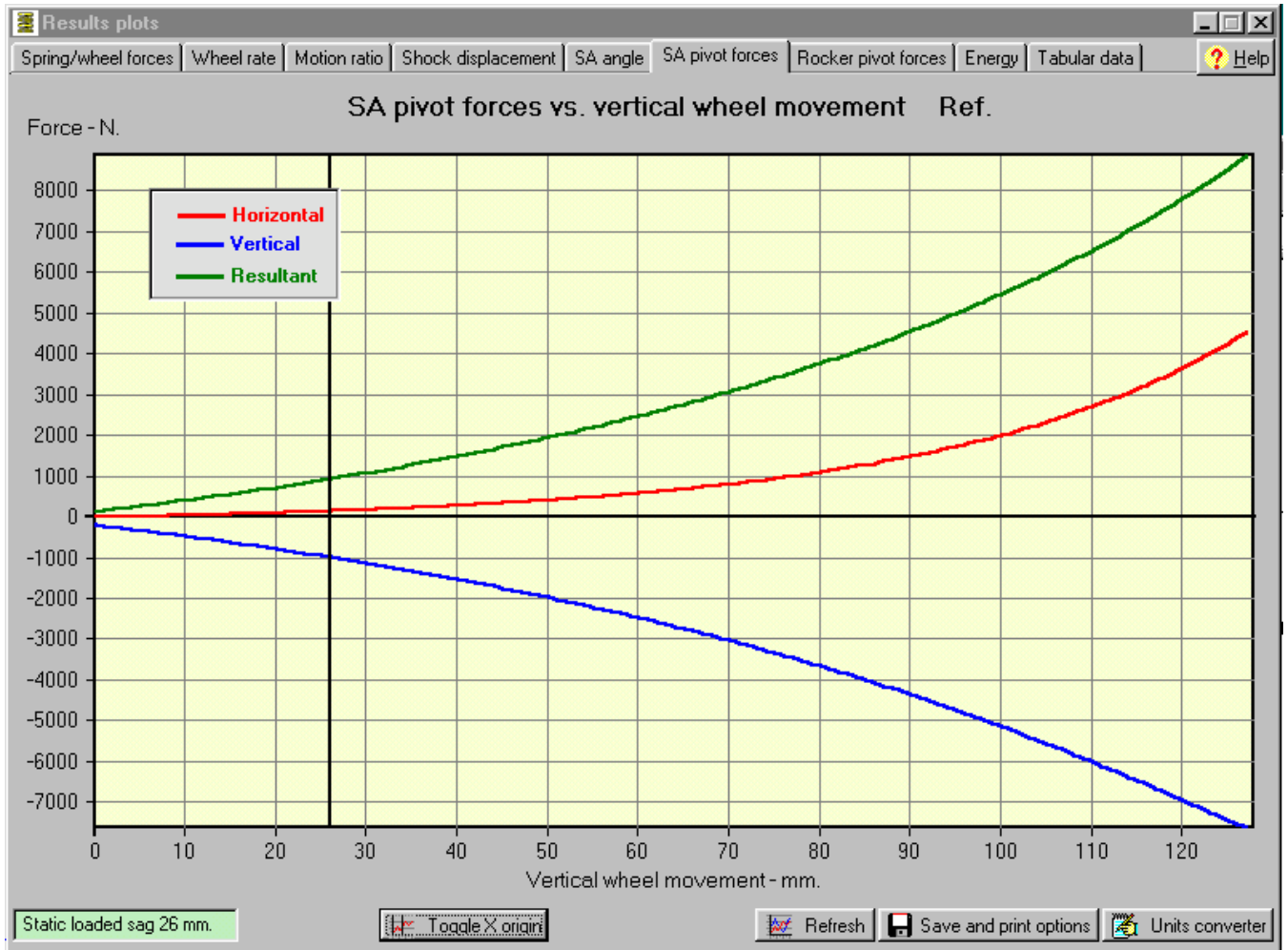
At any point in the movement range the wheel rate is defined as the extra vertical force, at the tyre/road interface, needed to produce a small unit vertical displacement of the wheel. This software calculates this in steps of 1.0 mm. of wheel movement.

This curve will also show the effects of specifying a bump stop, 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



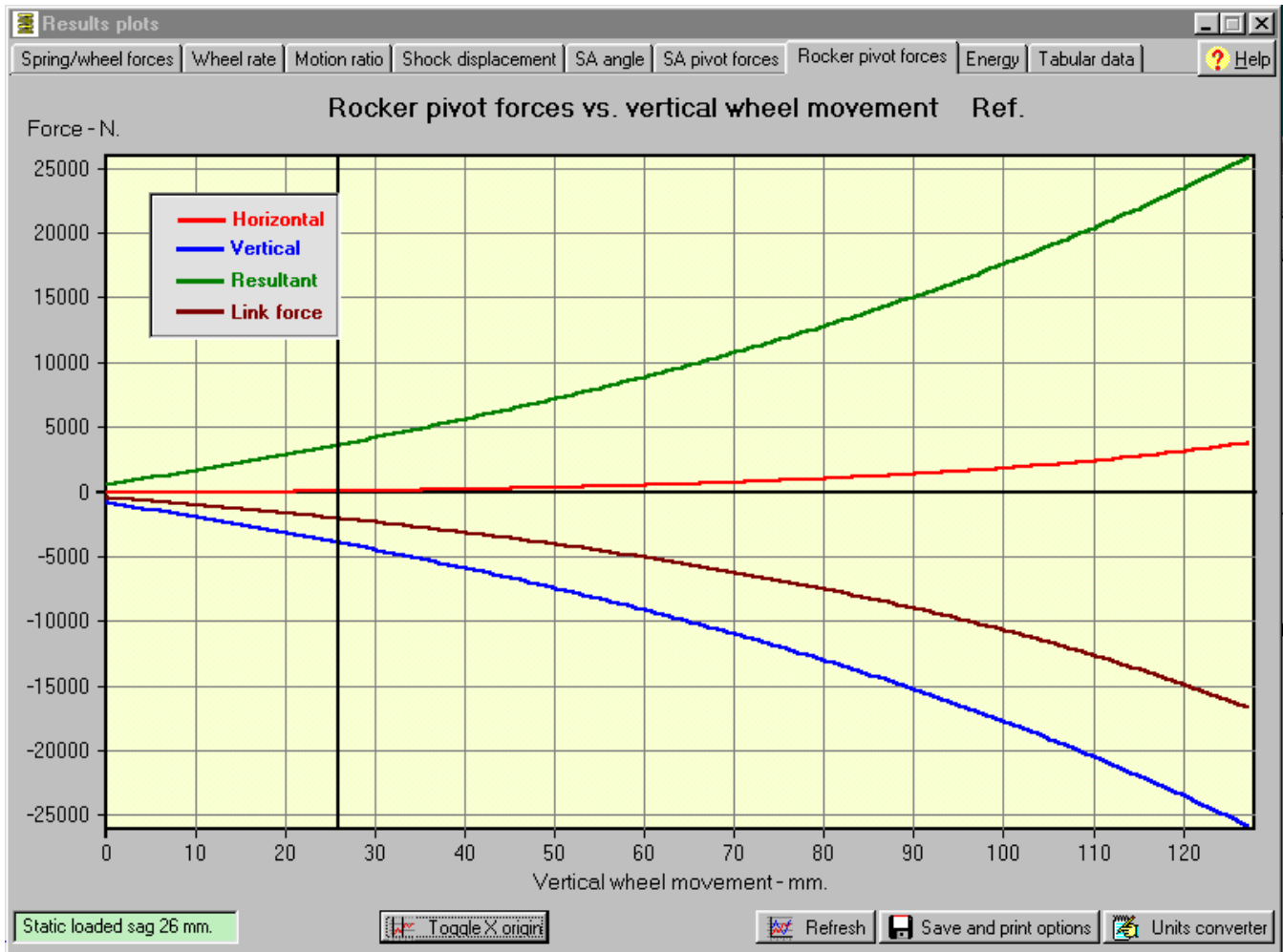
The advent of modern suspension systems, with high leverage, has resulted in higher loading in the swing-arm pivot bearings. Due account must be taken of this in the selection of the bearings and the structural properties of the swing-arm and frame supporting points.

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

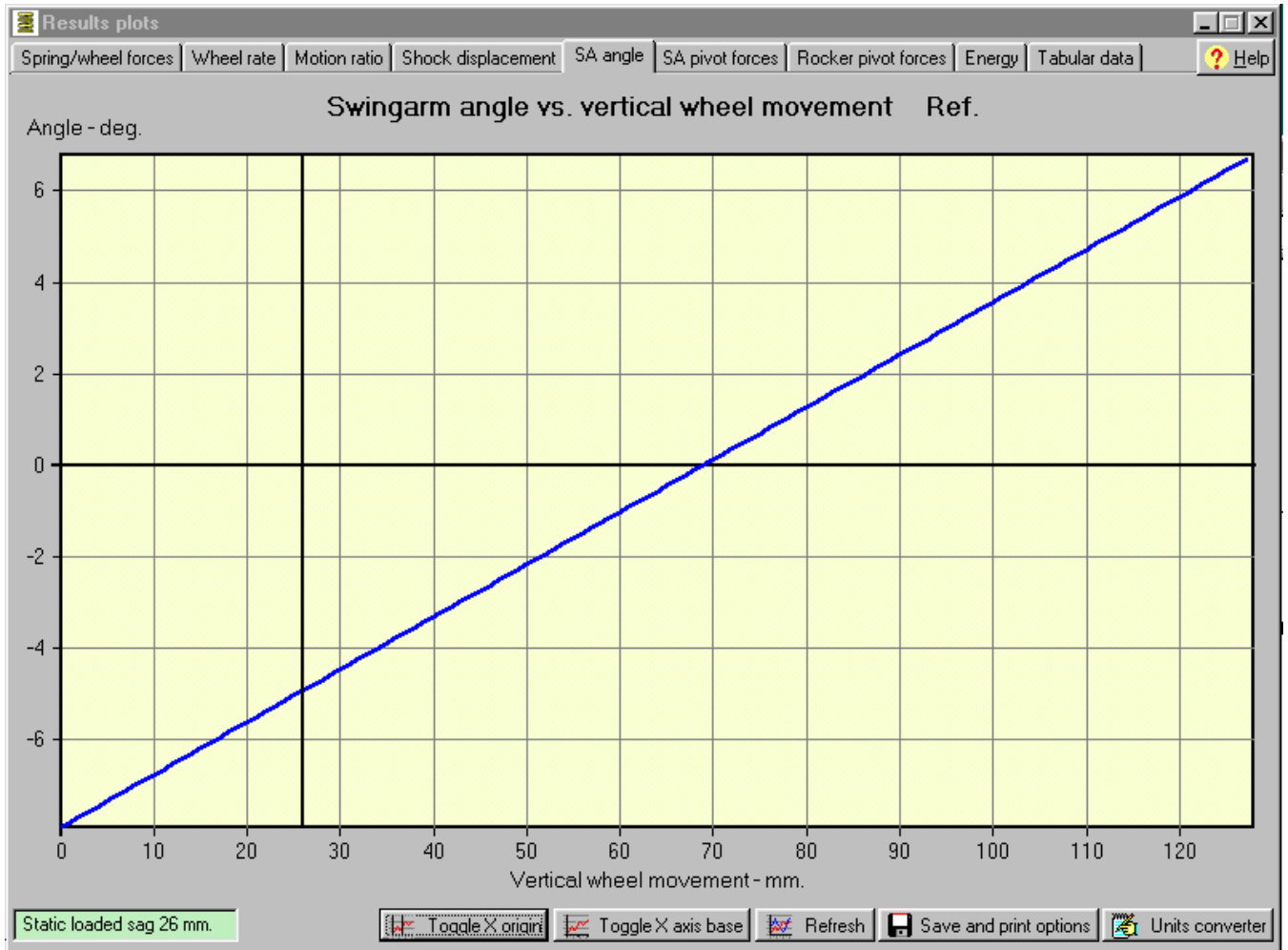


In many designs using a rocker and link system the forces at the rocker pivot can be substantial. As with the previous plot these curves show the total and its horizontal and vertical components. Also shown is the force in the link, tension is shown as negative and compression as positive.

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

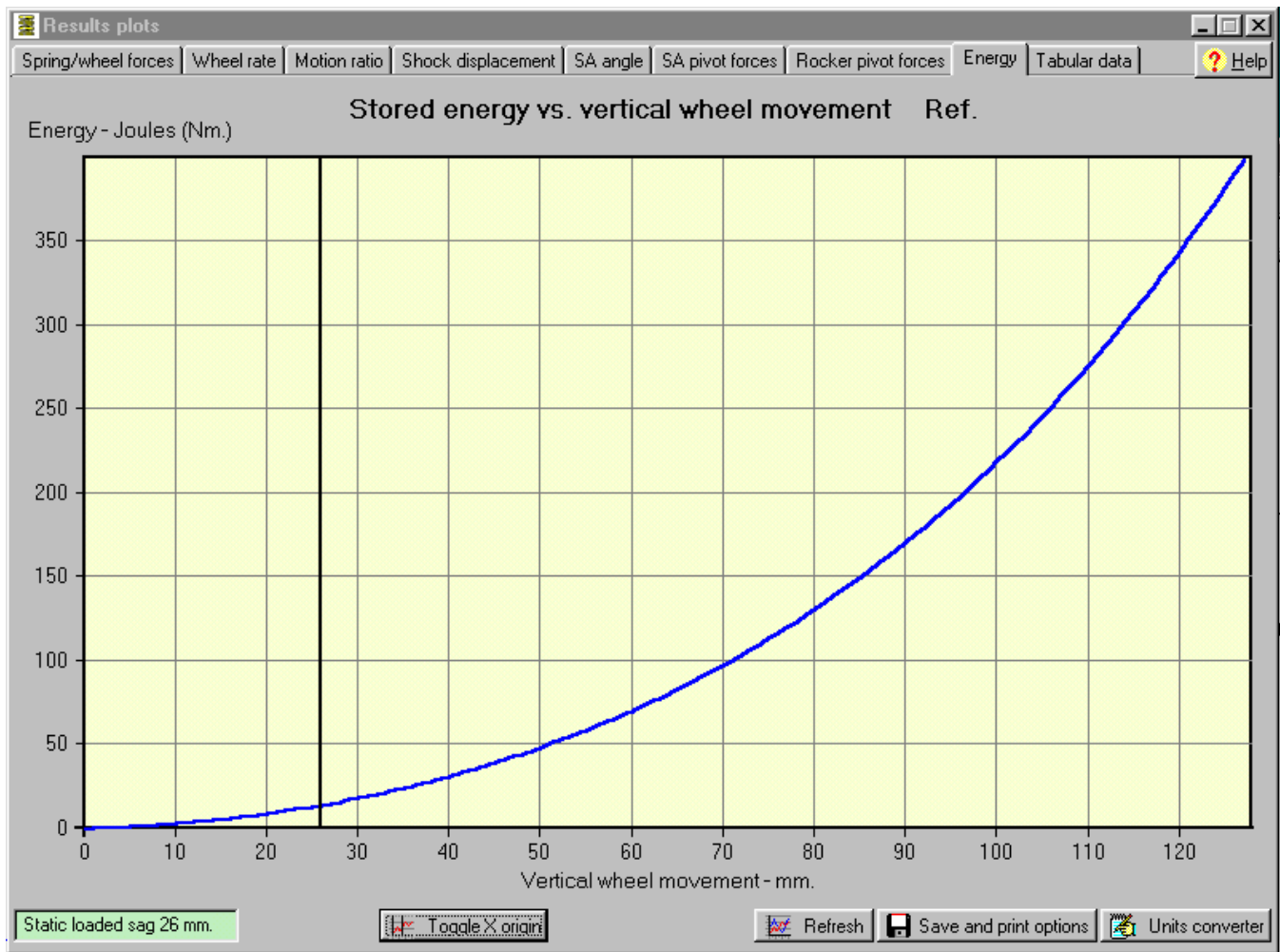
N.B. Remember that this does not include the effects of damping forces which may easily double these values in some cases.

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

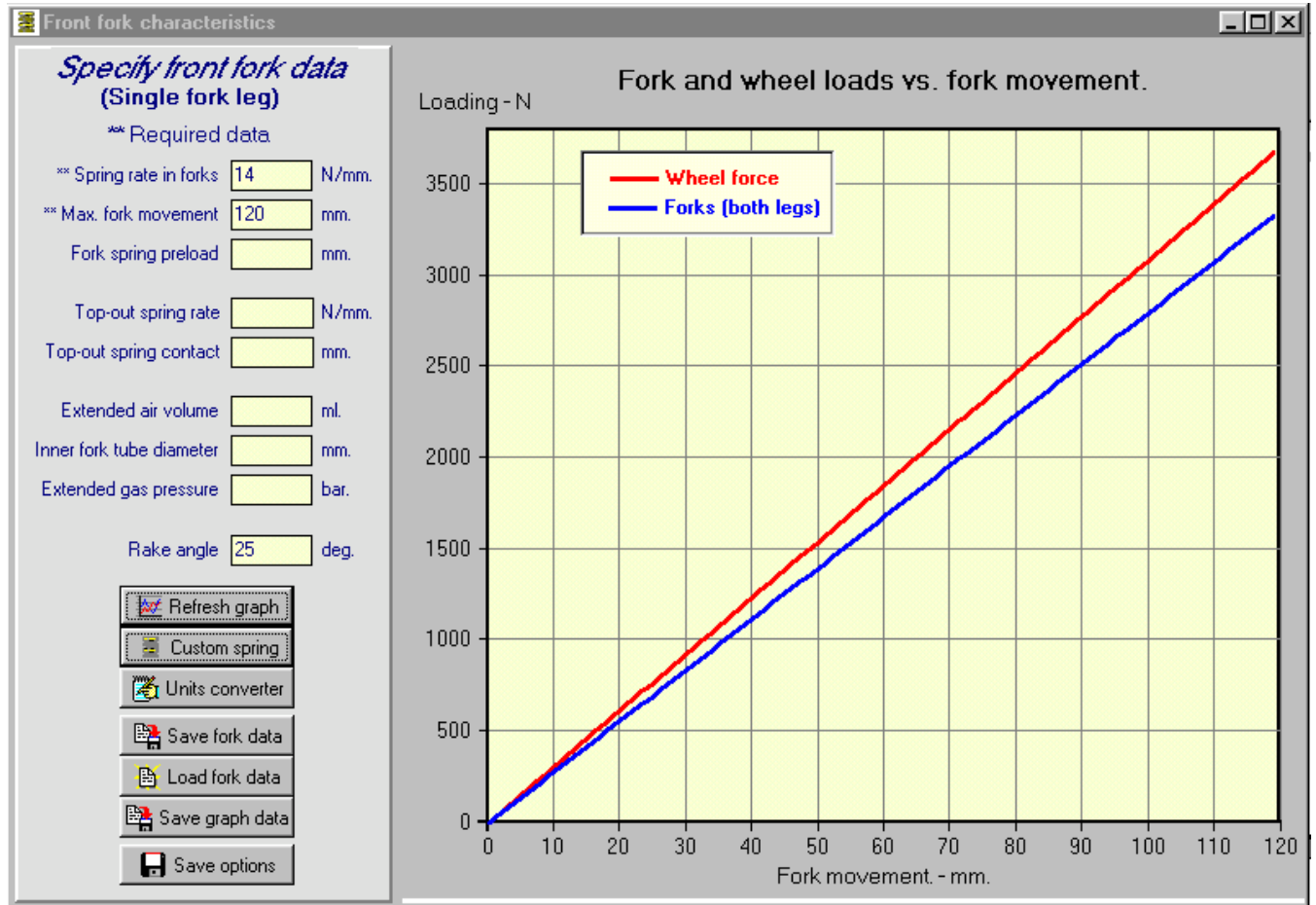


This shows the energy stored in the spring at varying displacements. This energy is an important parameter when considering suspension in impact situations, such as a motoX bike landing after a high jump. Of most interest is the value at the maximum compression point.



Front forks

The data entry fields accept the data for one fork leg, but 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.



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.

- **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.

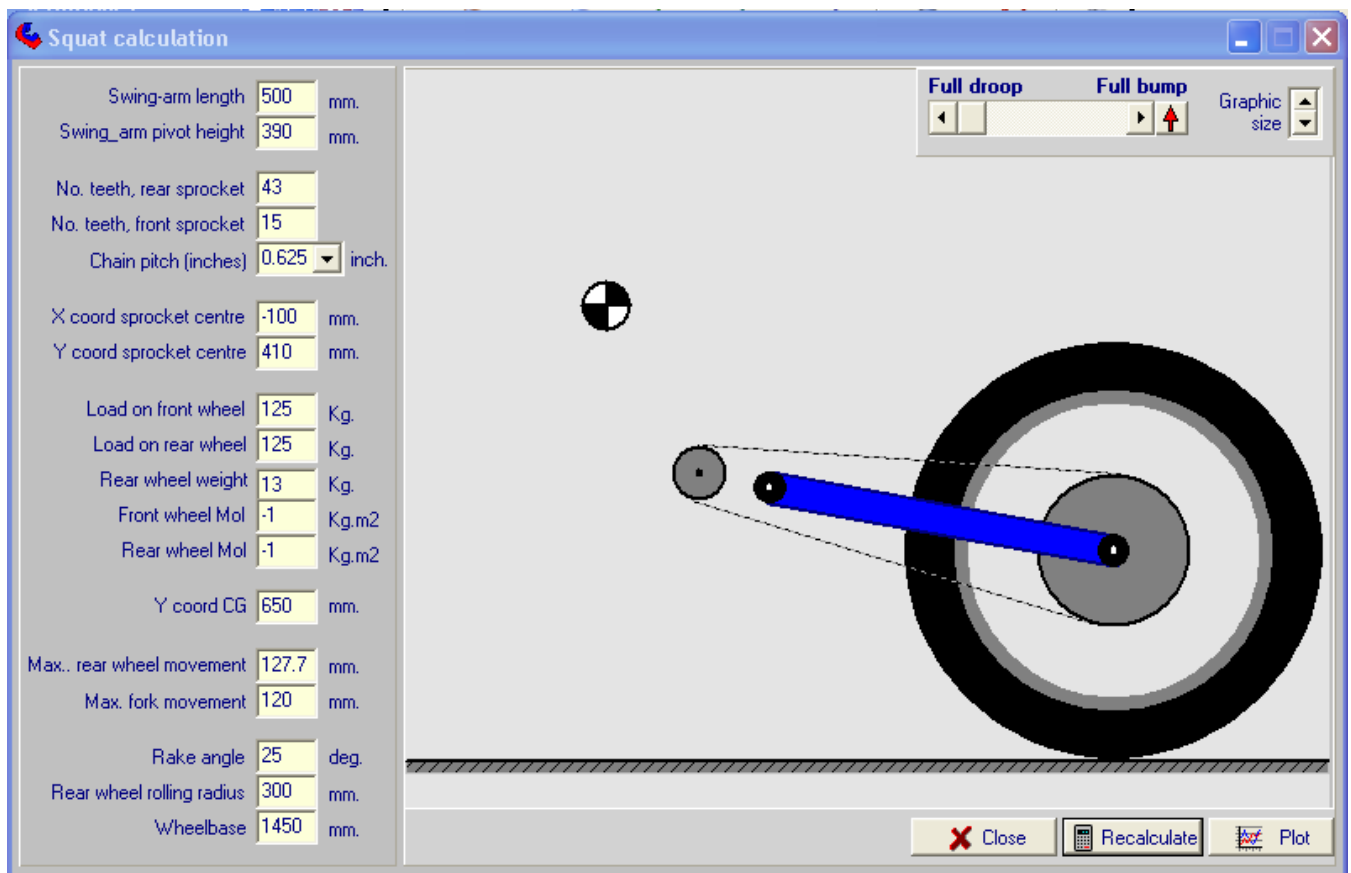


Anti-squat

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.

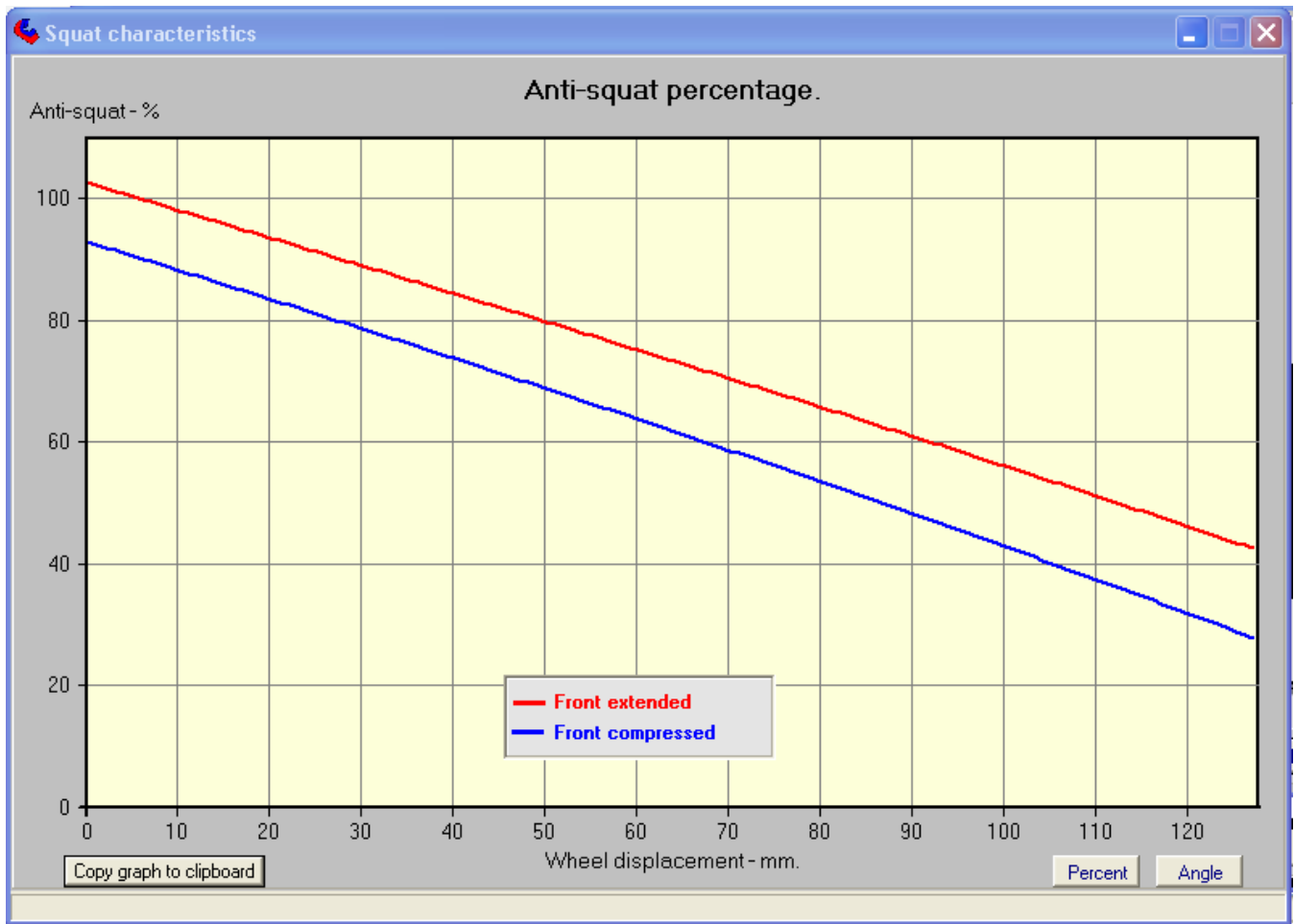
Click the recalculate button to refresh the graphic after changing some data.



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.





Attitude calculation

The purpose of this function is to quickly analyze the effects on the attitude, of changes to up to four setup parameters. Attitude changes are compared to the base setup. The four setup parameters are: Rear ride height, fork sliders position, chain link addition or subtraction and fork clamp offset.

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.

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.

The screenshot shows the 'Static attitude calculation' software interface. The main window displays a motorcycle with various dimensions and parameters labeled. A 'Base case' table and a 'Changed case' table are visible on the right side of the window.

Base case	
% Front / rear	50.00 / 50.00
Front load	125.0
Rear load	125.0
CG height	650.0
Wheel-base	1450.0
SA angle	8.0
Rake angle	25.0
Trail	100.2

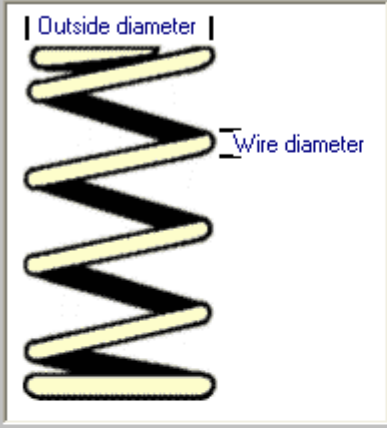
Changed case	
% Front / rear	50.54 / 49.46
Front load	126.3
Rear load	123.7
CG height	651.0
Wheel-base	1465.7
SA angle	8.0
Rake angle	24.9
Trail	93.6



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.

Coil spring calculator
✕



Units

 mm. + N.
 inches + lbf.

Material

 Spring steel
 Titanium

Outside diameter mm.

Wire diameter mm.

Number of turns

Spring rate N/mm.

End coil factor turns

Enter data into any three of the upper four data entry boxes and the programme will calculate the missing value. This allows you to calculate the spring rate but also to work backwards from the spring rate to calculate one of the other parameters. Note that spring design is a specialist task and this is only meant as a rough guide. The number of turns to be entered should be counted from tip to tip.

All good quality suspension springs are flattened and ground on their ends. This has the effect of making the ends of a spring less compliant than the centre section. Experimental results show that an average value for the number of active coils can be found by deducting 1.75 turns from the total number. This value is usually quite close for front fork springs, but will probably need reducing for springs with few turns as typified by mono-shock rear springs. This calculator uses 1.75 turns end coil factor by default, but this can be changed by the user as necessary.



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.

CoG calculator

This calculates the CoG location of a motorcycle.

It is required that the weight on front and rear wheels be measured with the bike on a horizontal surface, and again with one wheel lifted onto a block. The higher this block the better the accuracy.

IT IS VERY IMPORTANT THAT THE WEIGHT DATA IS TAKEN WITH THE WHEELS FREE TO ROTATE. THE BRAKES MUST NOT BE APPLIED.

Data required:
 Radius of each wheel.
 Wheelbase.

Weight distribution

Front	50.0	%
Rear	50.0	%

CG position

Front lifted
 Rear lifted

CG height 603.1

CG from rear axle 725.0

Calculate



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.

Motorcycle front geometry calculator. ✕

This is to calculate the missing value in a set of four, given the other three.

The castor/rake angle must be entered in degrees from the vertical (not radians).

The linear dimensions can be in any units, as long as all three use the same. (e.g. all in mm. or all in inches, etc.)

To use, just enter values for the three known parameters, and then press the calculate button. The missing value will then be entered by the computer.

If you enter all four parameters then an error message will be displayed. Be sure to leave one entry box completely empty. A zero is not the same as empty.

There are two trail values (real and ground). The "real trail" is not available as input.

Castor angle (deg.)

Yoke offset

Tyre rolling radius

Ground Trail

Real Trail



Wheel moment of inertia calculator

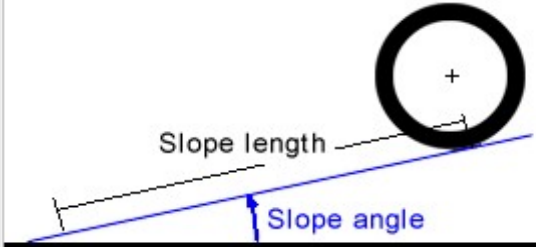
The wheel moments of inertia are used in the calculation of the squat and dive characteristics, and the sag etc. under braking and acceleration.

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

The period is the time for the wheel to traverse the slope length, starting with the wheel stationary.



	Front	Rear
Wheel weight- Kgf.	<input type="text"/>	<input type="text"/>
Slope length - m.	<input type="text"/>	<input type="text"/>
Total period - secs.	<input type="text"/>	<input type="text"/>
Slope angle - deg.	<input type="text"/>	<input type="text"/>
<hr/>		
Moment of Inertia - Kg.m ²	<input type="text"/>	<input type="text"/>

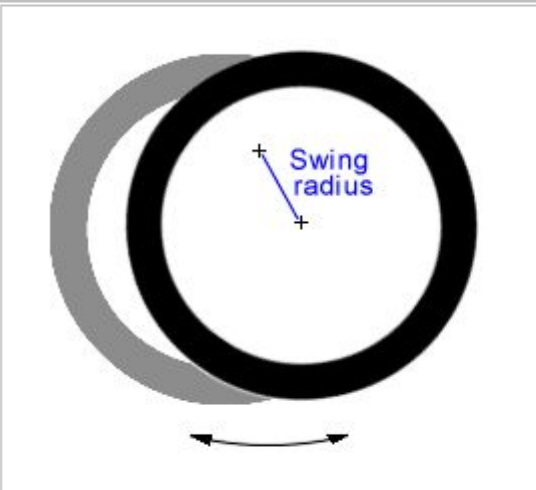
QUICK HELP.

This calculator determines the polar moment of inertia of the wheels and tyres, by any one of the 3 methods described in the User's Manual.

1. Let the wheel swing like a pendulum and measure the time for several complete swings, say 20 for example.
2. Let the wheel roll down an incline of about 10 to 15 degrees, and measure the time to traverse a known distance, starting from stationary.
3. Fix a small pulley to the wheel and use a known weight on the end of thin cable to accelerate the wheel. Measure the time period to complete 2 or 3 complete revolutions, starting from stationary.

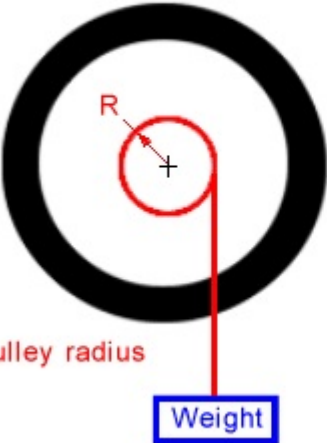
The results are expressed in Kg.m²

Wheel Moment of Inertia calculator



	Front	Rear
Wheel weight- Kgf.	<input type="text"/>	<input type="text"/>
Number cycles	<input type="text" value="20"/>	<input type="text" value="20"/>
Total period - secs.	<input type="text"/>	<input type="text"/>
Swing radius - mm.	<input type="text"/>	<input type="text"/>
<hr/>		
Moment of Inertia - Kg.m ²	<input type="text"/>	<input type="text"/>

Wheel Moment of Inertia calculator



R = Pulley radius

Weight

	Front	Rear
Weight - Kgf.	<input type="text"/>	<input type="text"/>
Number revolutions	<input type="text"/>	<input type="text"/>
Total period - secs.	<input type="text"/>	<input type="text"/>
Pulley radius - mm.	<input type="text"/>	<input type="text"/>
<hr/>		
Moment of Inertia - Kg.m ²	<input type="text"/>	<input type="text"/>



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.

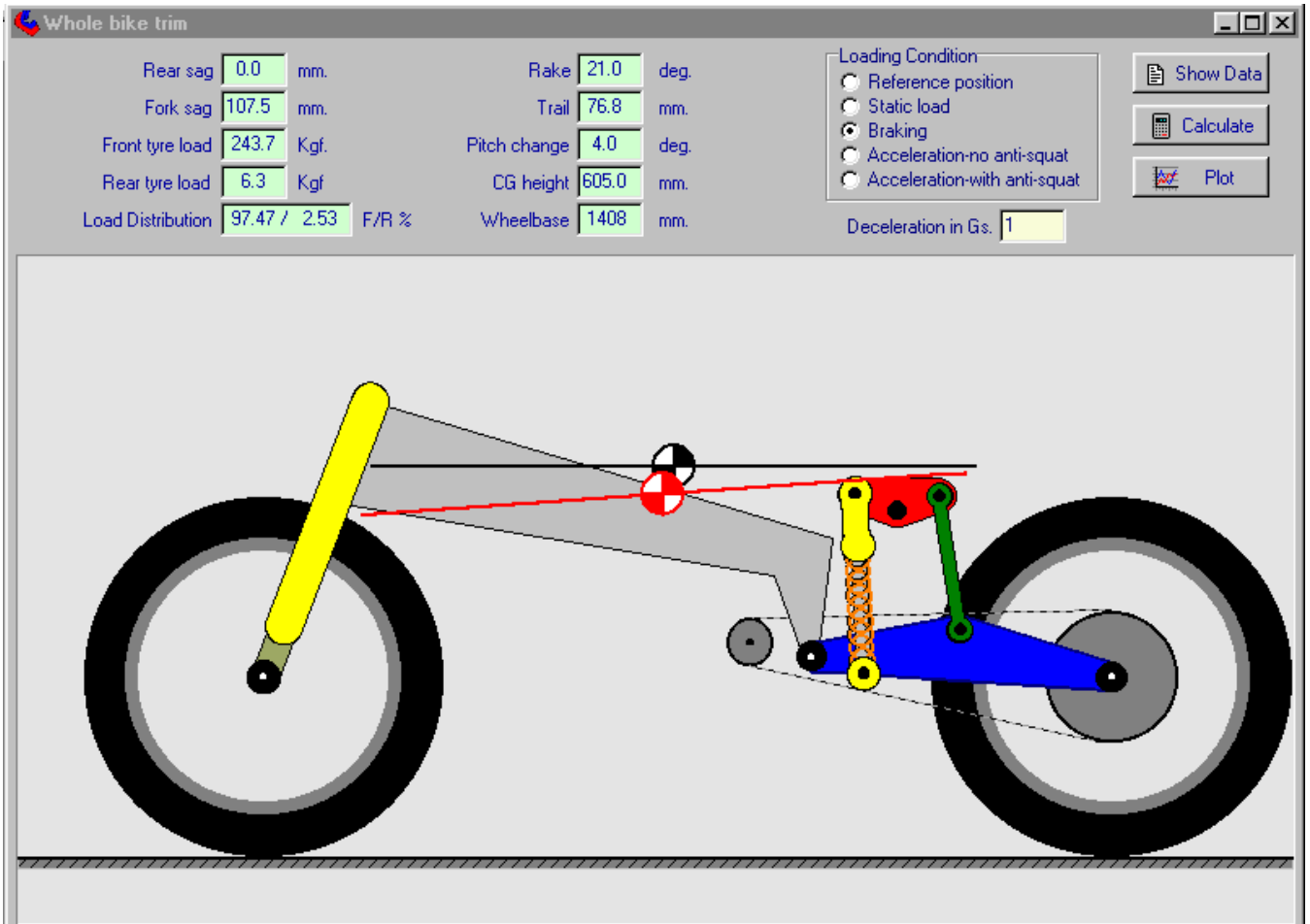
The initial data is loaded from the Misc data window on the opening screen, and the rear suspension and front suspension windows (any changed data in the squat and attitude screens is ignored). Clicking the Show data button shows all the data in use and lets you change some, as described in the next 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 5 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 fourth case, "Acceleration with no anti-squat" effect is only included for reference, it does not represent a realistic case, but shows just what effect the anti-squat has when compared with the real case.

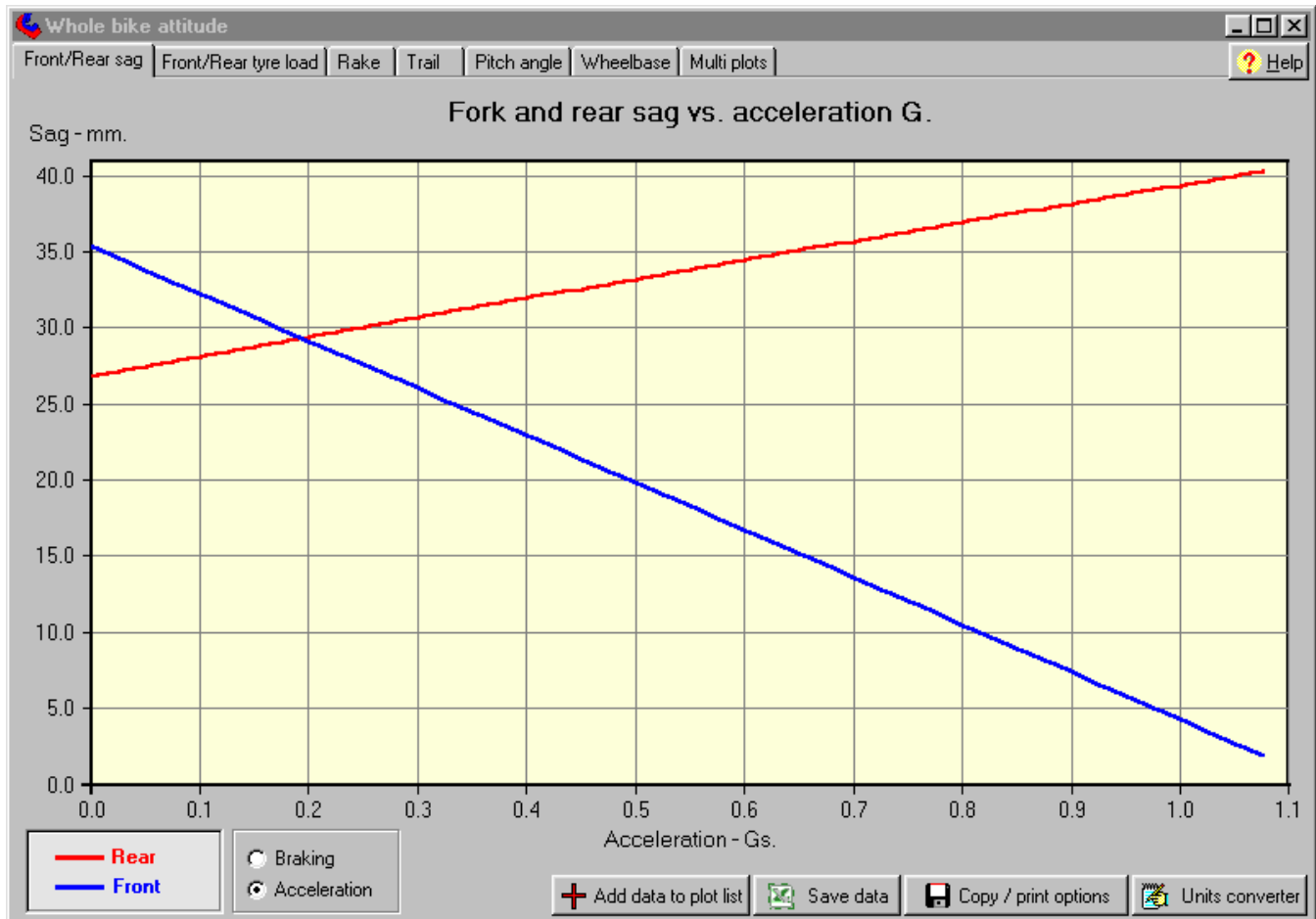
The attitude calculations assume a perfectly smooth road and are for low speed acceleration and braking. At higher speeds the attitude is affected by the aerodynamic drag value and general aerodynamic properties of the machine which are not usually known.

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 .ERD file to be saved which can be viewed and compared in the multi-plotting feature or the programme WinEP.



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 changable on that screen. Yellow is changable.

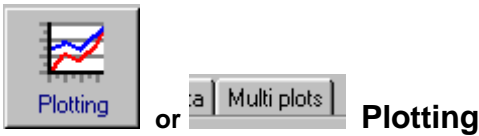
Some data on this screen is made read-only because it needs to be checked for integrity by the appropriate parts screen. For example; changing some rear suspension dimensions can only be done on the rear suspension screen because it is very easy to change data elsewhere which might lead to an impossible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

Current case data

Project name: Startup default

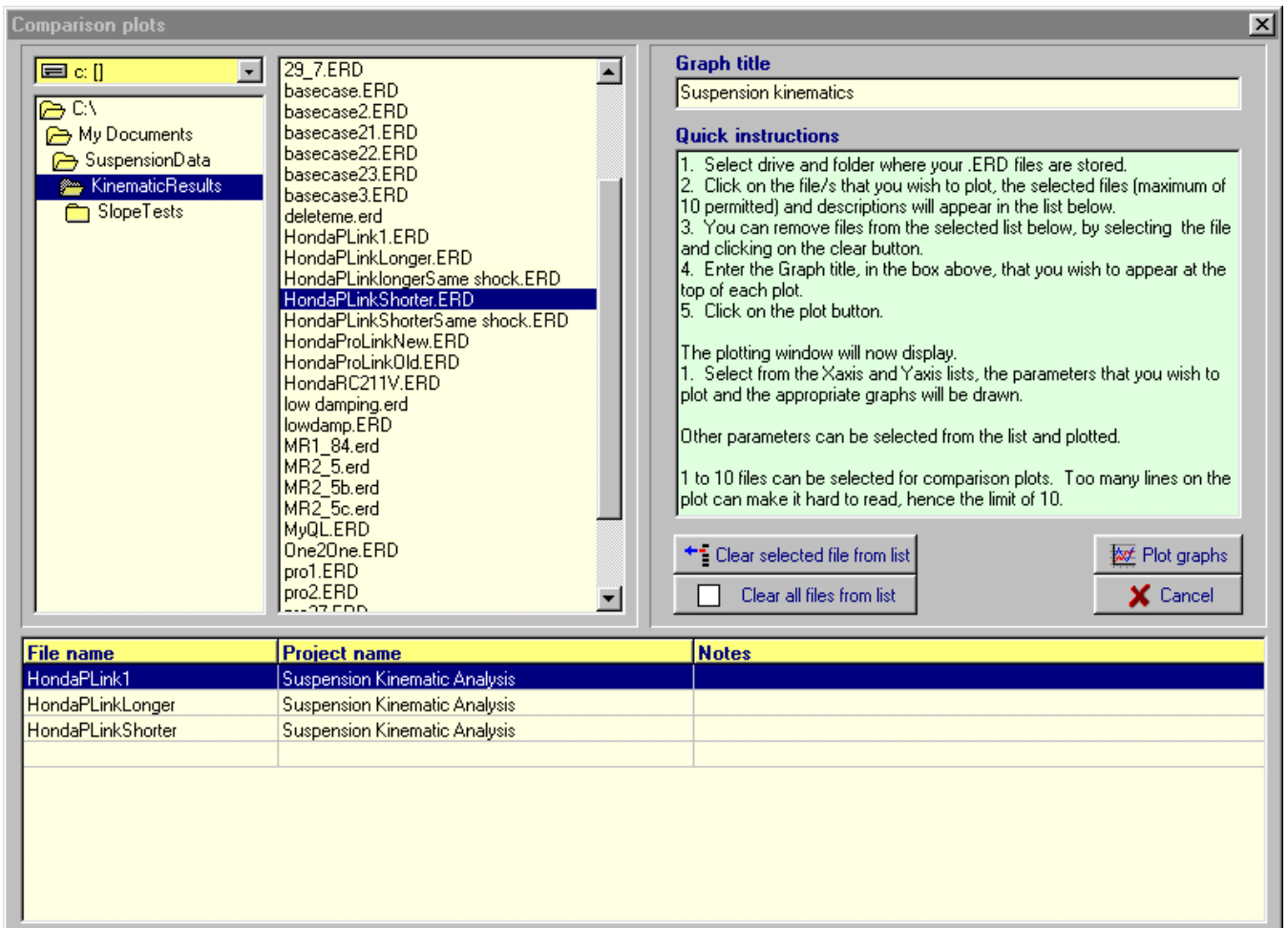
Miscellaneous	Rear suspension type	Rocker and link	Front fork (single leg)
Front wheel weight: 15 Kgf.	Rocker and link system	X coord - pivot: 157.96 mm.	Spring rate in forks: 14 N/mm.
Rear wheel weight: 22 Kgf.	Swing arm	Y coord - pivot: 602.21 mm.	Max. fork movement: 120 mm.
Front wheel Mol: -1 Kg.m ²	Pivot height: 370.18 mm.	DE: 75 mm.	Fork spring preload: 0 mm.
Rear wheel Mol: -1 Kg.m ²	Length (OA): 500 mm.	DF: 75 mm.	Top-out spring rate: 0 N/mm.
Load on front tyre: 125 Kgf.	Xb: 242 mm.	EF: 140 mm.	Top-out spring contact: 0 mm.
Load on rear tyre: 125 Kgf.	Yb: 62 mm.	Link length: 225 mm.	Extended air volume: ml.
Y coord of CG: 650 mm.	Suspension unit	Rocker orientation: 1	Inner fork tube diameter: mm.
Front tyre radius: 300 mm.	X coord - fixed end: 84.01 mm.	Shock on SA: <input type="checkbox"/>	Extended gas pressure: bar.
Rear tyre radius: 300 mm.	Y coord - fixed end: 336.20 mm.	Xc: 0 mm.	Custom spring ref.
Rake angle: 25 deg.	Static length: 300 mm.	Yc: 0 mm.	
Fork offset: 36 mm.	Maximum stroke: 80 mm.	Chain/sprockets	Case notes
Wheel base: 1450 mm.	Spring rate: 120 N/mm.	Pitch: 0.625 inch.	
X R ride height ref.: 325 mm.	Spring preload: 3 mm.	X coord: -100.0 mm.	
Y R ride height ref.: 750 mm.	Top-out spring rate: 0 N/mm.	Y coord: 400.43 mm.	
Trail: 100.2 mm.	Top-out contact: 0 mm.	No. sprocket teeth	
Wt. balance % - F/R: 50.0/50.0	Custom spring ref.	Front: 15	
	Bump stop ref.	Rear: 43	

Refresh data | Update project | Save project | Load project



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"***

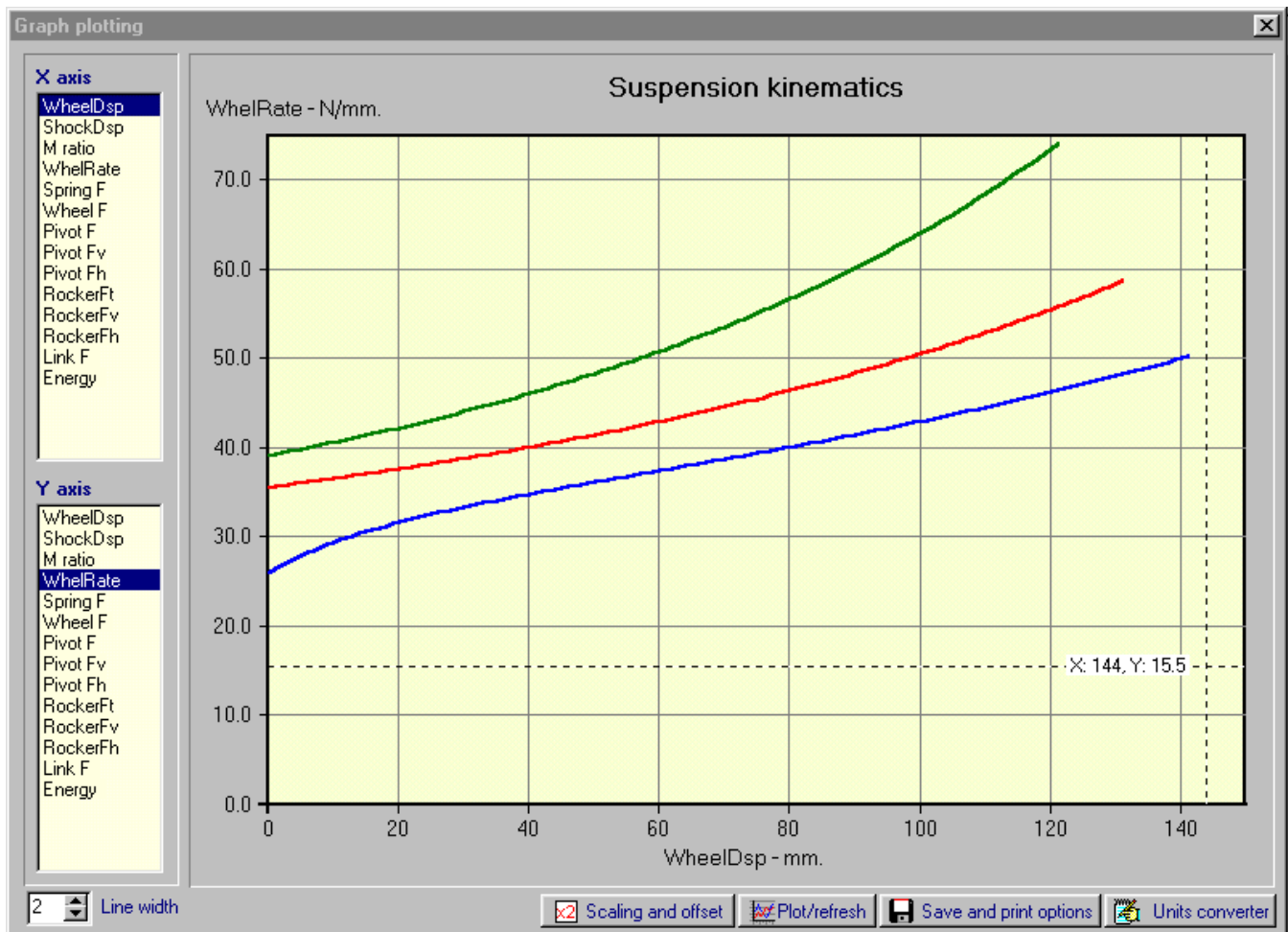
The second column will display a list of saved files. Click on those which you wish to compare (up to a maximum of 10), and they will appear in the plotting list across the bottom. There are buttons to remove files from this list or clear it altogether. Click on the "Plot graphs" button when you have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

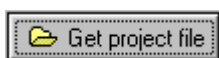
There are times when you will only be working on, say the rear suspension and will not specify any front fork parameters, in such cases a set of default data will be saved for the forks. The reverse is true when you are only working with the front, a simple default rear layout will be saved.

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.

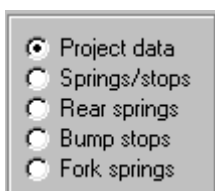
When saving to a project file you will be prompted to write some case notes to describe each case. Make a good job of that because it’ll be a big help when you come back to load a design a few weeks or months later. Choose a column in which you want to save the current project data and double click in 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.

Master data list

Case notes: Similar to base case. Fixed rate spring and shorter link.

Project data
 Springs/stops
 Rear springs
 Bump stops
 Fork springs

File name: C:\My Documents\SuspensionData\Manual.dat
 Project name: Test case for manual
 Suspension type: Rocker and link Get project file

Double click on a column to load that case.

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.

Master data list

Description: Short stop

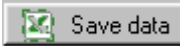
Project data
 Springs/stops
 Rear springs
 Bump stops
 Fork springs

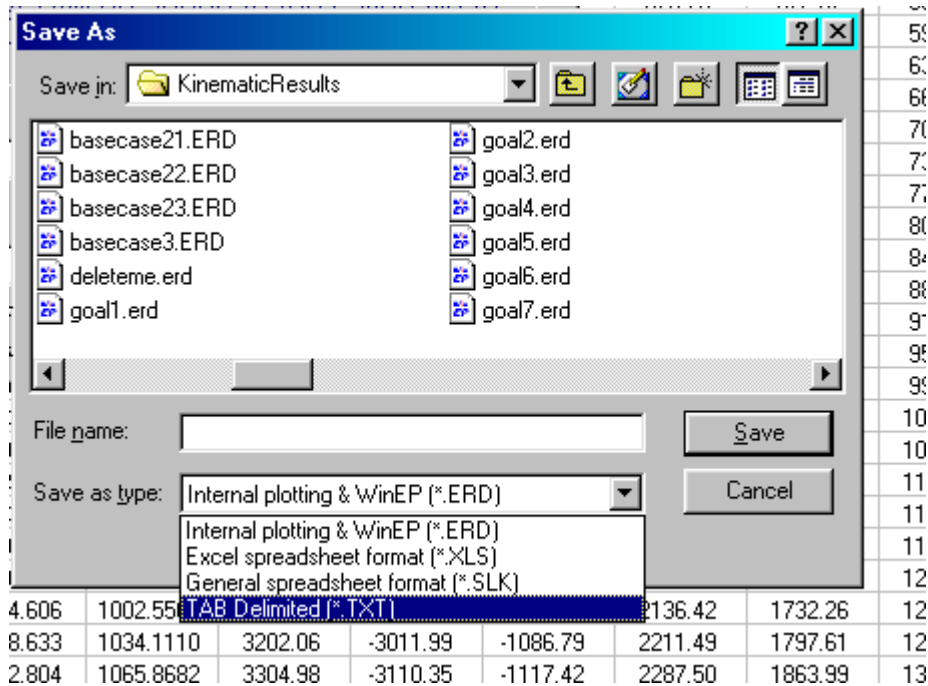
File name:
 Project name: Springs and bump stops file.
 Suspension type: All springs/bumpstops. Delete selected item

Double click on a row to load that spring or stop.

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	100,14000
S-489	test2	false	0,0	10,1400	20,2800	30,4200	40,5600	50,7000	60,8400	70,9800	80,11200	90,12600	100,14000
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	100,15000

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 .erd, which is the required format for the internal multi-plotting feature as well as WinEP.

ERD files

This is the file format for the freeware programme WinEP (Windows Engineering Plotter). Which is included on the distribution CD for the suspension software. WinEP is an excellent and flexible plotter for XY data, which allows the concurrent plotting of data from several files. This is particularly useful for overlaying the results of different suspension set-ups for comparison purposes. Scaling and zooming are easily accomplished. This can be done with Excel but it is much more tedious. A PDF user's manual for WinEP is included in the Docs folder.

After saving data to an ERD file, it is only necessary to double click on the required ERD file to open it into WinEP. The opening screen shows a list of output parameters which can be plotted. Select those required and select "plot". Consult the WinEP PDF manual for more advanced features.

WinEP can be used to analyze data from other sources also. It is only necessary to create an ERD file in the format described in the manual.

WinEP is freeware and is now included in the install package as a service to users purely on an "As-Is" basis and does not form part of the paid-for content, no responsibility is accepted for any incorrect functioning. It is being distributed with the permission of the authors at the University of Michigan. The latest version should always be available at www.trucksim.com/winep/winep.zip

The in-built graphing module for comparing the results from different configurations largely supersedes the need for WinEP in this application. However, it is included as a useful tool.

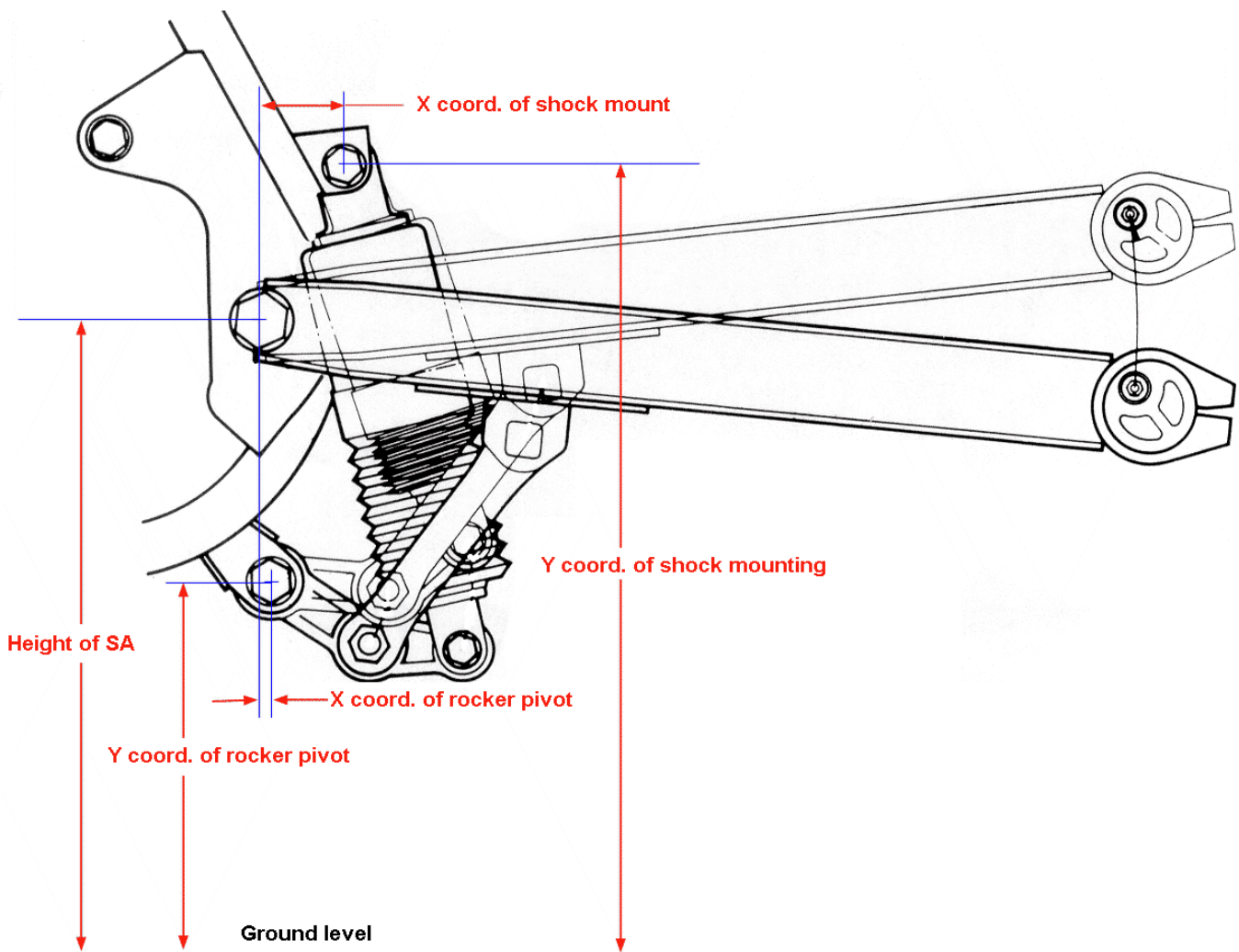
Measuring the motorcycle

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.

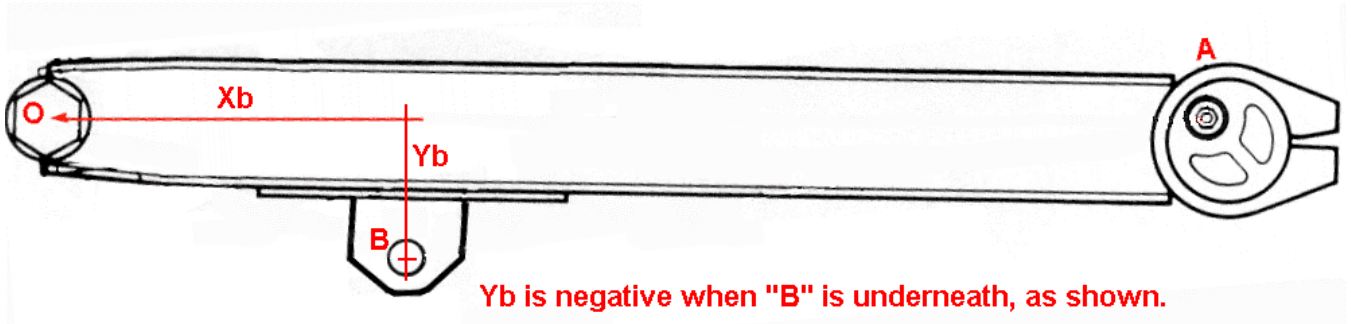
The sketch shows the significance of the co-ordinates required by the software. These dimensions should be measured with the motorcycle supported such that both front and rear suspensions are extended and with the tyres just touching the road surface.

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.

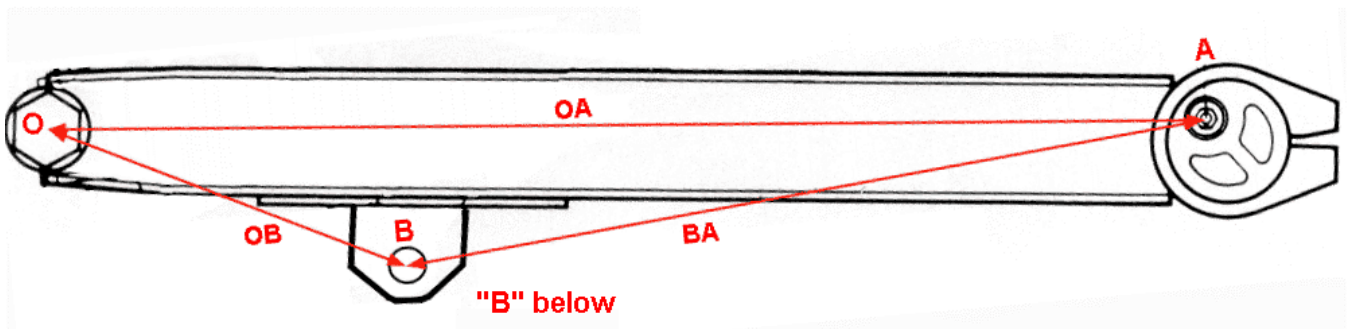
Components

Swing-arm

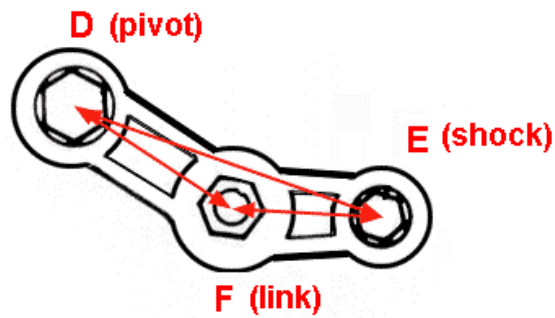


Using the Uni-trak example from above, this sketch shows how the swing-arm is measured as a separate component to get the data for entry into the programme. In those cases with a rocker system, and where the shock also mounts on the swing-arm, there will be an additional point on the swing-arm to specify. 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 Mol 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 Mol 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 three in one Mol 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 three simple methods of measurement. They can be described as:

1. Swinging pendulum
2. Rolling down an incline
3. 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.

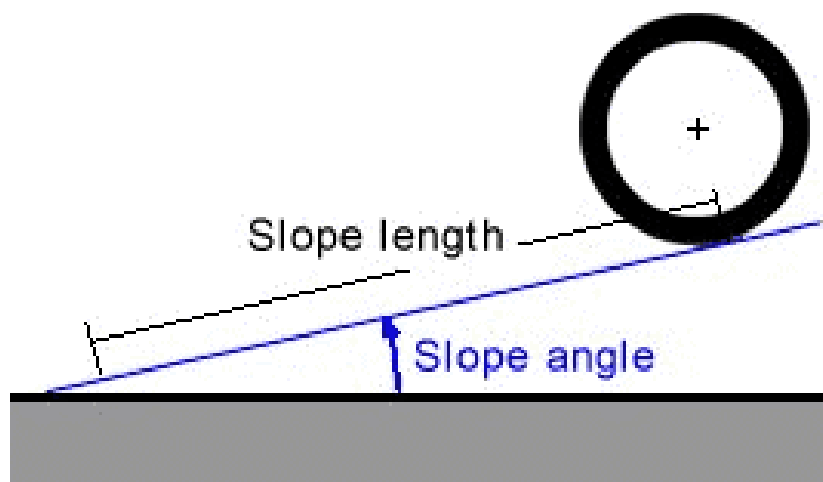
The distance between the swing axis and the axle centre needs to be measured. The wheel should be slightly displaced to one side and allowed to swing back and forth like a pendulum. Measure the time required to complete a number of complete cycles, 20 for example to reduce the effect of timing errors. 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 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.

Rolling down an incline

In this case the longer the slope the better, and an incline angle of greater than 15 degrees is preferable. If the incline is too flat the wheel will not accelerate quickly and will often tend to run to one side, particularly rear wheels with the lateral weight offset of the sprocket and cush-drive assembly. It is possible to make a simple incline from wooden board thick enough not to bend under the weight of the wheel, but 2 metres length at an incline of 10 degrees is about the minimum necessary to achieve sufficient timing accuracy. 3 metres at 15 degrees would give approximately equal transit times but with greater directional stability.

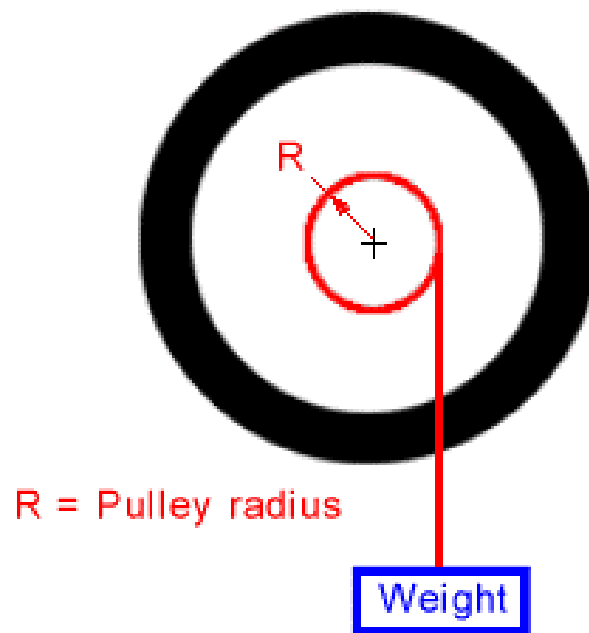
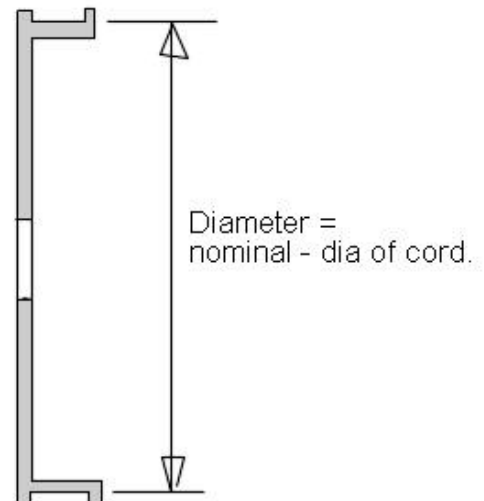
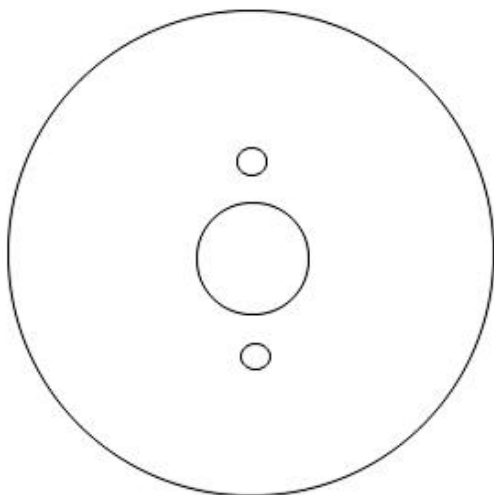
Mark out a defined distance along the slope. Hold the wheel at the higher mark and start timing at the moment of freeing the wheel, stop the clock as it passes the second mark. Repeat this several times and average the times. This method is very sensitive to timing errors and is the hardest to get good timing because, unless a long incline is available, the time intervals are quite short – 1.5 seconds and up.



Pulley and weight

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

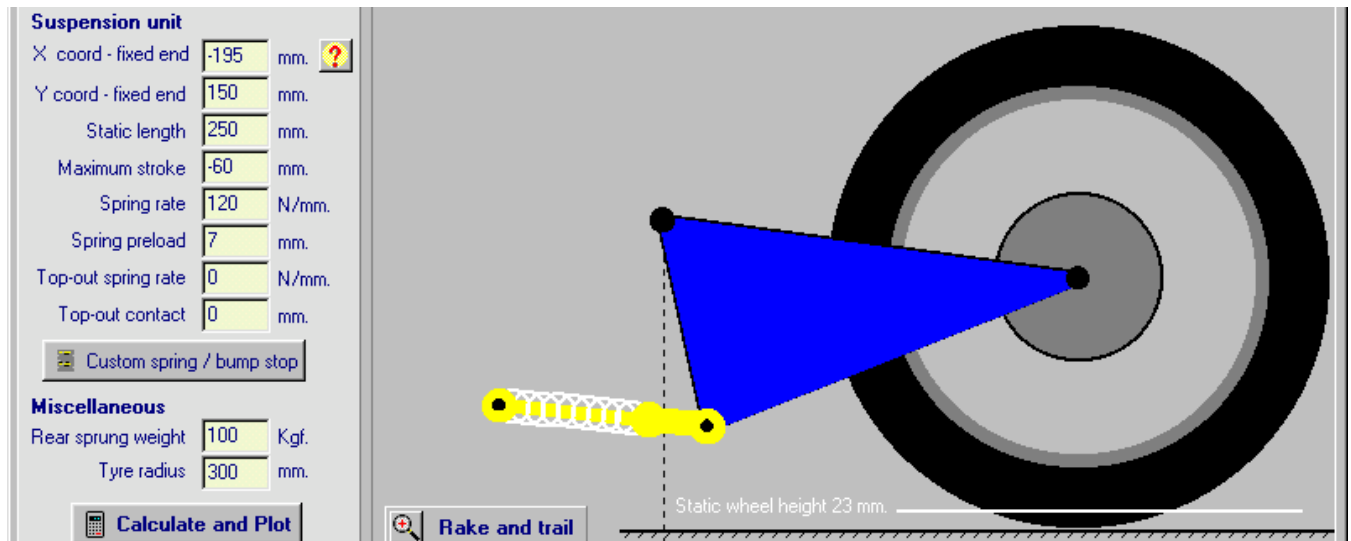
Layout of pulley and wheel**Possible pulley design.**

Special notes

Extension shocks

Shocks that are arranged to extend rather than compress when loaded. Some Harley-Davidson 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.



Multi-lingual features

From version 4.10, the software structure incorporates features to allow translation into any number of languages. Although it has not been tested with alternative character sets, such as those used in various Asian languages.

The translation files are in text format and are external to the software itself, this makes it very easy to add more translations and enables users to make their own translation files if required. The base software remains the same, regardless of the language in use. As few or as many language files, as required, can be present in a single installation of the software and switching between languages can be done with the programme running.

If no language files are present then the programme will display all text in English. If one language file is present then the translations in that file will be loaded without user action. When two or more language files exist in the same directory as the software, then a drop-down list will be displayed as follows, in the lower right hand side of the opening screen:



Anyone interested in creating a translation for a particular language should send an email to info@tonyfoale.com and we'll provide all the information necessary.

At time of writing a partially complete Spanish translation file exists in addition to the default English. These are available at no cost by emailing to info@tonyfoale.com.

Currently, we have no plans on translating this user's manual into other languages, but that may change if sales volume to a particular country warrant the work involved.