

# Software User's Manual

Version 1

Tony Foale Designs © 2007

Last revision 24/11/2007

## Introduction

Estimation of acceleration and top speed performance is often considered a simple matter. Multiply engine torque by the gear ratios and add aerodynamic drag and weight into the calculation mix and “hey presto” you have all the answers.

Reality is of course somewhat different. There are many more factors to take into account if you want to get as accurate a picture as possible. For example; CG height affects load transfer to the driven wheel as well as determining the tendency toward terminal wheelies. The height of the frontal aerodynamic centre of pressure also has a similar influence. Load transfer affects tyre slip which in turn affects the relationship between RPM and road speed, which in turn determines the power available at any particular road speed. Then there is the influence of the dead time between gear changes when no power is being transmitted.

This software takes all those factors, and more, into account and raises the bar of performance estimation to a new level for enthusiasts and racers of all levels. It is an invaluable tool to help with the proper evaluation of gearing strategies and gear change points.

### What will the software do?

Simply put, it will produce calculated estimates of the straight performance of a motorcycle. However, there is really a lot more to it than that and there are a lot of contributing factors to ultimate performance. When fed with the appropriate data this software uses most of these factors in the calculations.

The user can enter the power / torque curves of the engine. This information is much more readily available these days than it used to be and many people interested in performance will have their machines dyno tested.

Gear ratios, weight, drag, tyre properties, wheelbase and CG height are the other main factors which affect performance and the software accepts values for these parameters. Although of lesser importance, the values for wheel and crankshaft inertia can also be entered when known to further refine the results.

Outside of the motorcycle, performance is also affected by wind and the slope of the road surface, both of these values can be included. The web sites of many race tracks have data regarding road elevation which can be downloaded.

After the calculations have been made there are several graphical and tabular options for analysing the results, and comparing different cases. These comparisons can be used to optimise some of the contributing factors such as gear ratios, when to change gear, whether the CG is too high or too low, what effect would engine modifications have etc., etc. If required the results data can be exported for use in external software such as eXcel or other spreadsheets and calculation software.

### What it will not do.

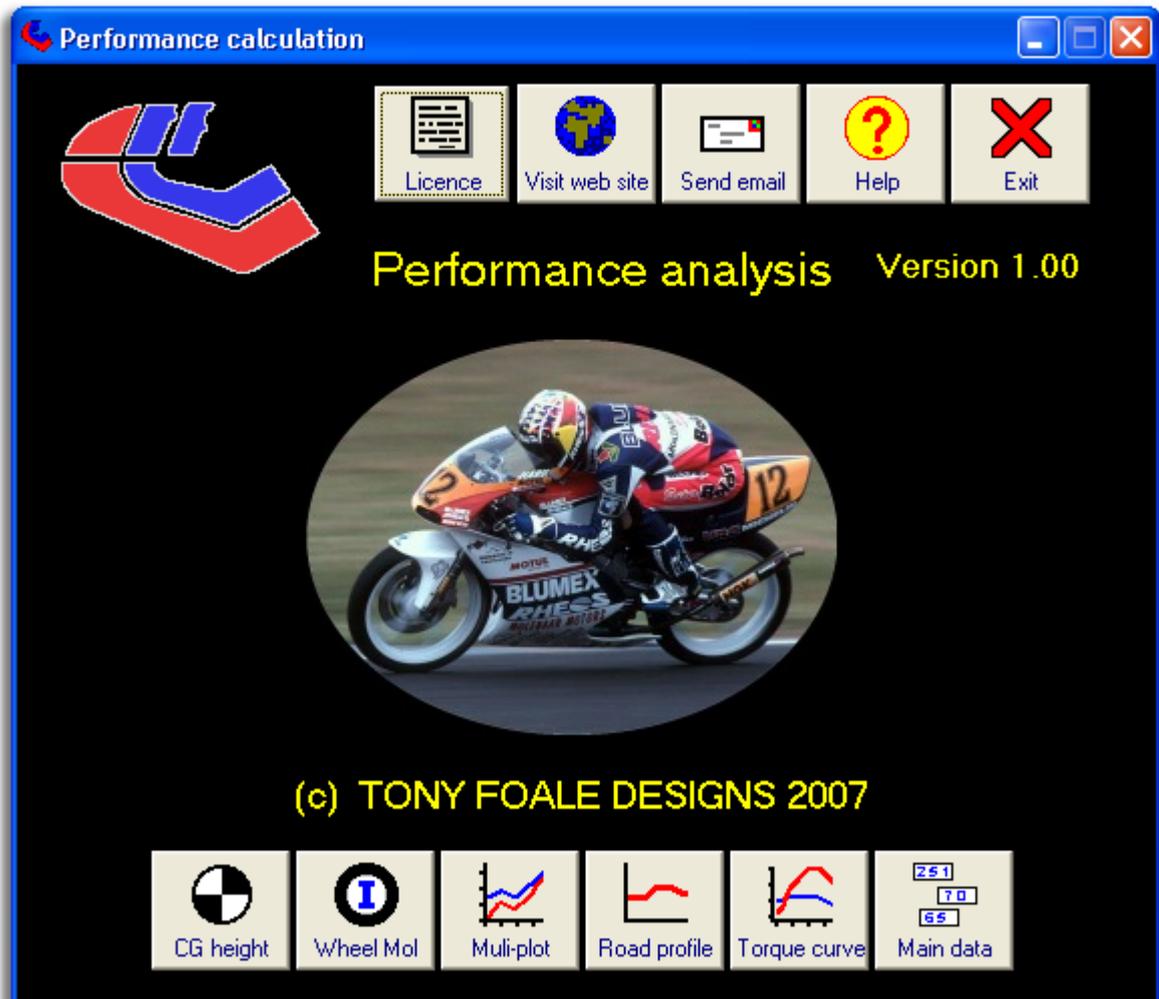
It will not substitute for lack of accurate input data.

In racing, success or failure is often measured in hundredths or even thousands of seconds after many minutes or hours of racing. Therefore the percentage difference involved is very, very small and calculations of performance are never going to achieve the same degree of accuracy. There are so many possibilities for errors in input data that are greater than the expected performance differences. For example, even if we had wind tunnel data for a motorcycle and rider, it is almost impossible to expect the rider's position to be exactly the same when actually riding. Maybe his elbow sticks out a bit more from one lap to another. No software can fully account for these variations. However, that is not always so important because we are usually more interested in the small differences rather than absolute values. This software will give results close to reality with a reasonable margin of error, but the differences between runs with different gearing or gear change RPM etc. should be much more representative of practice.

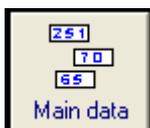
Tony Foale.

November 2007

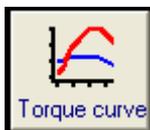
## Initial screen



There are several speed buttons to access various areas of the software, as follows



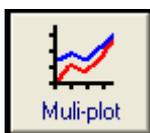
This is probably the most used button on the initial screen and it opens the main data entry screen.



Takes you to the screen for entering the power or torque curve of the engine. Also accessible from the data entry screen.



This opens a screen to enter the elevation of sections of the road or track. Not needed for a level horizontal surface. Also accessible from the data entry screen.



Enables the simultaneous plotting of up to 10 cases for comparison. Also accessible from the results display page.



Opens a calculator for estimating the moments of inertia of the wheels and tyres. Using the default values will give good results.



A calculator using an easy method to obtain CG height.



Gives access to this user manual as well as the tutorial videos



Sends an email to Tony Foale Designs. We welcome all comments about the software as well as suggestions to expand or improve it. [info@tonyfoale.com](mailto:info@tonyfoale.com)



Connects to the Tony Foale Designs web site. [www.tonyfoale.com](http://www.tonyfoale.com)



As explained in the section on first use this button opens the licence management window.

## Main data entry screen

**Performance calculation**

**Case description**  
 Untitled default

**Aerodynamic**  
 CdA - m<sup>2</sup> 0.40 Acc. 0.49 Brake  
 CP height - mm. 600 Acc. 650 Brake  
 Air density - Kg/m<sup>3</sup> 1.17

**Inertial**  
 CG height - mm. 610 Acc. 670 Brake  
 Load on tyre - Kg. 145 Rear 135 Front  
 Wheel Mol - Kg.m<sup>2</sup> 0.5 Rear 0.4 Front  
 Crank Mol - Kg.m<sup>2</sup> 0.006  Reverse crank  
 Wheel base - mm. 1420

**Miscellaneous**  
 Rolling force - N. 20 Acc. 50 Brake  
 Tyre maximum  $\mu$  1.1 Rear 1.1 Front  
 Peak rear tyre slip - % 15  
 Tyre radius - mm. 300 Rear 300 Front

**Conditions**  
 Maximum distance - m. 2000  1/4 mile  
 Start velocity - km/h. 0  
 Final velocity - km/h. 0  
 Include braking   
 Head wind - km/h 0 (Tail wind negative)

**Gear ratios**  
 Which ratios?  
 Gearbox ratios  Overall ratios  
 Number of gears 6  
 Front sprocket 15  
 Wheel sprocket 44  
 Enter either the numbers of pinion teeth OR the primary ratio, but not both.  
 Engine pinion teeth  
 Clutch pinion teeth  
 Primary ratio 2.0882352  
 Calculate overall ratios  
 RPM for change 9800 Gear change time - secs. 0.1

Gear	Gearbox ratio	Overall ratio
1	2.461	15.074830180
2	1.777	10.884995217
3	1.38	8.4531758022
4	1.125	6.8911759257
5	0.961	5.8865956130
6	0.851	5.2127917447

**Power / Torque curves**  
 Torque — Power  
 Power - BHP / Torque - lb.ft.  
 70.0  
60.0  
50.0  
40.0  
30.0  
20.0  
10.0  
0.0  
 2000 3000 4000 5000 6000 7000 8000 9000 10000 11000  
 RPM  
 Refresh plot Enter power curve

Calculate and plot  
 Units conversion  
 Save parameters  
 Load parameters  
 Road elevation

Except for the power and torque curves of the engine and the elevation of the road surface all the necessary data is entered on this screen. Perhaps complex at first sight but in reality quite simple. Some of the data fields may ask for data which you don't have. In most cases if you use the default values the final results will not be in error by much. For example most people will not know the "Moments of Inertia" of the crankshaft assembly, in practice this has only a small influence in most cases and only in the lower gears anyway. Data like this is included in the software only for those situations where it is available to add a little refinement to the calculations.

The factors which have the biggest influence over performance are weight, aerodynamic drag, gear ratios and engine characteristics. Of these it is the aerodynamic drag which is the least available but if you know the top speed of the motorcycle being analyzed then the software can help determine the drag. Power and torque curves can easily be obtained by testing the machine on a rolling dynamometer, or failing that, there are many sources for such information on the internet. Many aftermarket exhaust manufacturers have this data on their websites.

Road surface elevation data is also available, for many race tracks, on the official websites.

The data entry is divided into groups and the following will consider each group and data field in detail.

**Aerodynamic**

CdA - m<sup>2</sup> 0.40 Acc. 0.49 Brake  
 CP height - mm. 600 Acc. 650 Brake  
 Air density - Kg/m<sup>3</sup> 1.17

**CdA** This is the value of the drag coefficient multiplied by the frontal area in sq.metres. This value will vary depending on whether the rider is laying down on the tank for acceleration or sitting up for braking. Therefore there are two data fields, although the one for the braking value is only enabled when the "Include braking"

feature is active. In the section on using the software, it will be explained how to use the software to get this value.

**CP height** Normally this value is only available from wind tunnel testing or CFD calculation. Except at very high speeds this value is not of major importance for the acceleration phase and the default value will give good results. As this also varies with rider position there are data fields for acceleration and braking

**Air density** Varies depending on ambient temperature, barometric pressure and humidity. There are many sources for this information on the internet. Use the default value if you don't have other data for this.

Inertial				
CG height - mm.	610	Acc.	670	Brake
Load on tyre - Kg.	145	Rear	135	Front
Wheel Mol - Kg.m <sup>2</sup>	0.5	Rear	0.4	Front
Crank Mol - Kg.m <sup>2</sup>	0.006	<input type="checkbox"/>	Reverse crank	
Wheel base - mm.	1420			

**CG height** These values are for the fully loaded motorcycle with rider and all liquids. Two data fields for the two rider postures. These values can be determined by weighing the machine with one wheel raised onto a block. This parameter affects load transfer under both acceleration and braking and so it is important when we are operating near to the traction limit of the tyres. It also controls the acceleration at which a wheelie or stoppie will occur which is another limiting factor on acceleration.

**Load on tyre** Simply the weight measured under each tyre of the fully loaded motorcycle.

**Wheel Mol** The Moment of Inertia of each wheel about its rotational axis. Methods for measuring these values are given elsewhere but in most cases the default values will work OK.

**Crank Mol** This data is not generally available without calculation or direct measurement. Such measurements are not difficult but require stripping the engine. In any case this value is generally only significant in first gear and even then is of minor importance.

**Reverse crank** This is a tick box to indicate the direction of rotation of the crankshaft. Leave it unticked for an engine which rotates in the same direction as the wheels and tick it for one that runs "backwards".

**Wheelbase** is the horizontal distance between front and rear axles.

Miscellaneous				
Rolling force - N.	20	Acc.	50	Brake
Tyre maximum $\mu$	1.1	Rear	1.1	Front
Peak rear tyre slip - %	15			
Tyre radius - mm.	300	Rear	300	Front

**Rolling force** Also known as rolling resistance. Another factor which is not always easy to specify and may be different between acceleration and braking. For example if the power characteristics were obtained using a rolling road dynamometer then the rolling force contribution from the rear will already be accounted for, to some extent, in the torque figures. In which case it will be the front tyre drag plus bearing friction and brake drag which will be the main contributor. On the other hand if the power values are obtained from an engine or gearbox driven dynamometer then we need to consider the extra drag from the rear and the chain.

Under braking it is very hard to estimate a value and it will depend on many things, some rider controlled. If the bike has a slipper clutch or electronically controlled fly-by-wire throttle the value will be quite different from that obtained with heavy engine braking which in turn is affected by which gear the rider has selected.

**Tyre maximum  $\mu$**  Coefficient of friction. For modern tyres this is likely to be in the range of 1.0 to 1.2 on a good dry surface. May be different between front and rear. The front value is only necessary if we are using braking.

**Peak rear tyre slip** All tyres slip to some extent when driving or braking and we get the maximum driving force when the tyre is slipping by about 10 to 20%. This varies with the particular tyre and surface. Slip affects the

relationship between road speed and RPM under acceleration, and so controls the power available at any road speed. In the absence of proper tyre data it is suggested to leave the value at the default 15%. The slip value is not so important when calculating braking and there is no provision for entering the front value.

**Tyre radius** The rolling radii of the tyres when loaded.

Conditions

Maximum distance - m.   1/4 mile

Start velocity - km/h.

Final velocity - km/h.

Include braking

Head wind - km/h  (Tail wind negative)

**Maximum distance** The calculations cease at this distance. If you tick the ¼ mile box then the maximum distance is set to 402 metres and the starting velocity to zero to enable calculation of standing start performance.

**Start velocity** The performance calculations begin with this velocity. The software automatically selects which gear is engaged at this speed. This may be the velocity at which the bike exits a turn and begins accelerating down a straight.

**Final velocity** This is only enabled when the “include braking” tick box is ticked. It will normally be zero if you are interested in coming to a complete stop within the maximum distance specified or more likely it will be the corner entry speed for a turn at the end of the straight.

**Include braking** Tick this if you wish to include braking within the specified maximum distance. Use this when you know the distance from one corner exit to the next corner entry point as well as the exit and entry speeds. This will help optimise performance from one corner to another.

**Head wind** Performance is affected by wind and here we can enter wind data. Use positive values for a head wind and negative values for a tail wind.

Gear ratios

Which ratios?  
 Gearbox ratios  Overall ratios

Gear	Gearbox ratio	Overall ratio
1	2.461	15.074830180
2	1.777	10.884995217
3	1.38	8.4531758022
4	1.125	6.8911759257
5	0.961	5.8865956130
6	0.851	5.2127917447

Number of gears

Front sprocket

Wheel sprocket

Enter either the numbers of pinion teeth OR the primary ratio, but not both.

Engine pinion teeth

Clutch pinion teeth

Primary ratio

RPM for change  Gear change time - secs.

This group defines the transmission data etc. There are two options for data specification which are determined by the following selection:

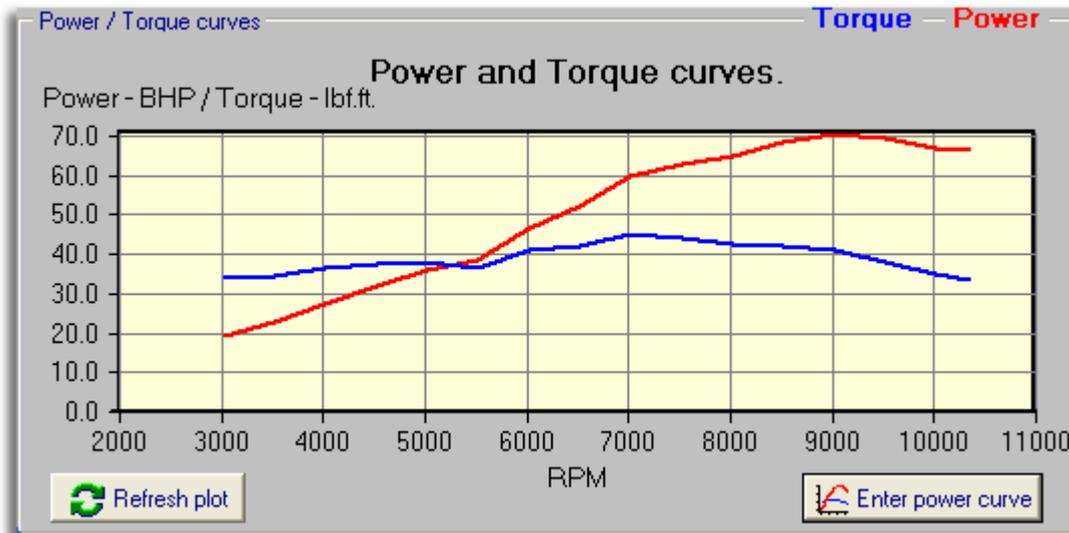
Which ratios?  
 Gearbox ratios  Overall ratios

If **Gearbox ratios** is selected then you must enter the actual gearbox ratios plus the sprocket teeth and the primary or clutch reduction ratio. After data entry click on the **Calculate overall ratios** button to produce the overall ratios.

If **Overall ratios** is chosen then just enter the overall ratios where indicated.

**RPM for change** This is simply the RPM to change gear at.

**Gear change time** is the dead time during gear changing when there is no power being applied to the wheel. This varies a lot between riders and also depends on whether some form of quick shifter is employed. Is likely to be in the range of 0.1 to 0.3 seconds in a racing environment.



This section of the screen simply reproduces the power – torque curves for information. To enter or modify these curves click on the **Enter power curve** button to access the appropriate window.

The remaining controls on this screen are the buttons on the right hand side as follows.



Click this when all data entry is done to pass to the screen for the graphical display of the calculation results.



Converts between metric and imperial units of measure.

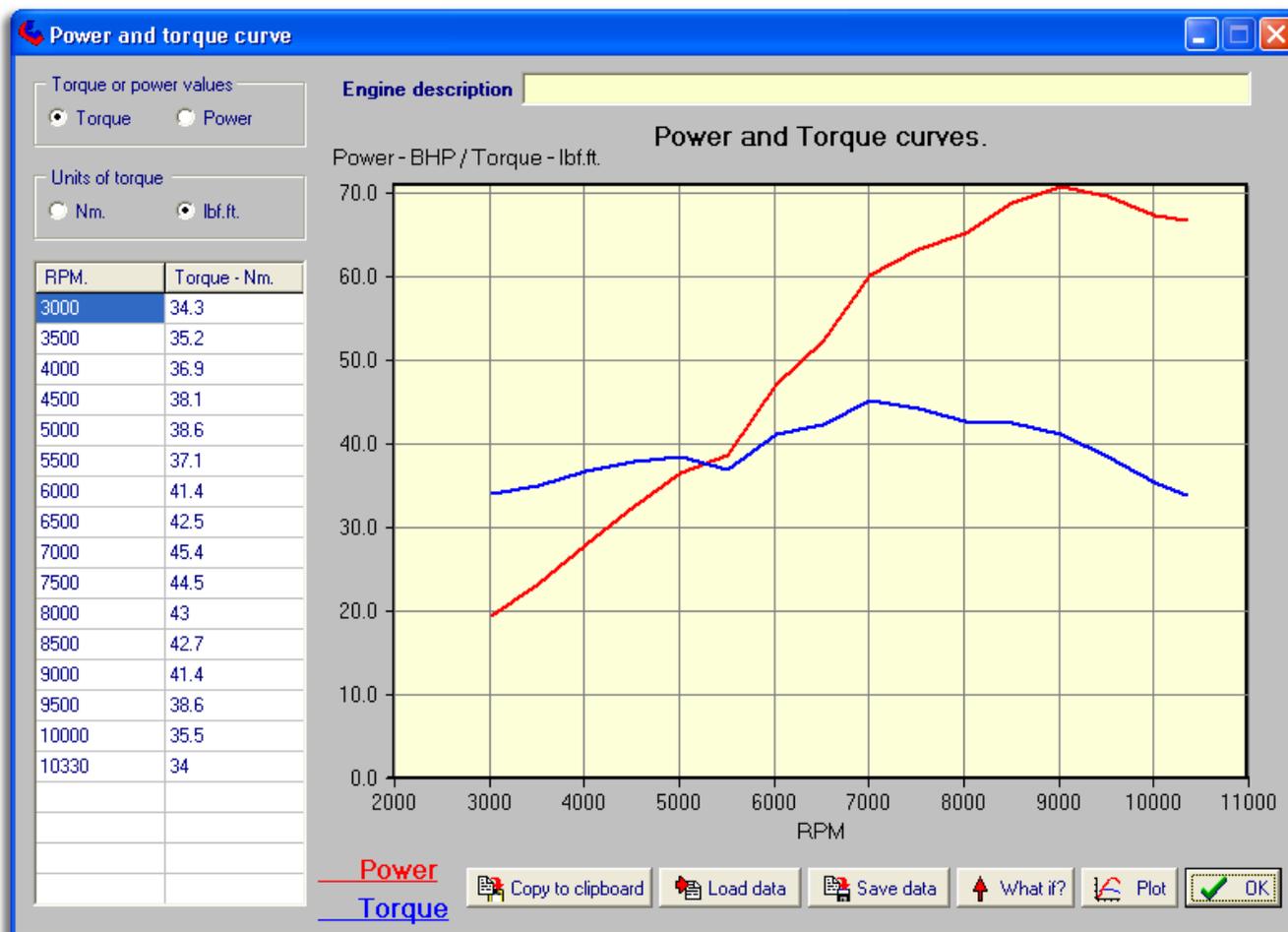


Allows the saving and later loading of the motorcycle data. The data in the “Conditions” group is not saved because this refers to the test conditions and not the motorcycle.



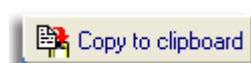
Opens a screen for the entry of data related to the elevation of the road – track surface. This data is sometimes available from the websites of race tracks. Not needed for a level horizontal surface. Also accessible from the initial opening screen.

## Power and torque entry



The data can be entered as either power or torques values against RPM. If “power” is selected then there is a units choice between BHP and kW, likewise if “torque” is the preferred input there is a choice of units between Nm and lbf.ft. All the internal calculations use Nm for torque but the conversion is taken care of inside the software. If you enter power data then the torque data will be calculated and vice versa.

There is a maximum of 20 data points, but it is not necessary to use them all, nor is it necessary to use constant RPM increments. You can use more points in parts of the curve that change quickly.



Copies the plot to the clipboard so that it can easily be copied into other documents, for example when illustrating a report.



Saves and loads data for specific engines or different states of tune. Does not save the other motorcycle data.



Opens a window in which to enter a percentage value to increase or decrease the power and torque. Useful to quickly see the effect of a global power change on performance.



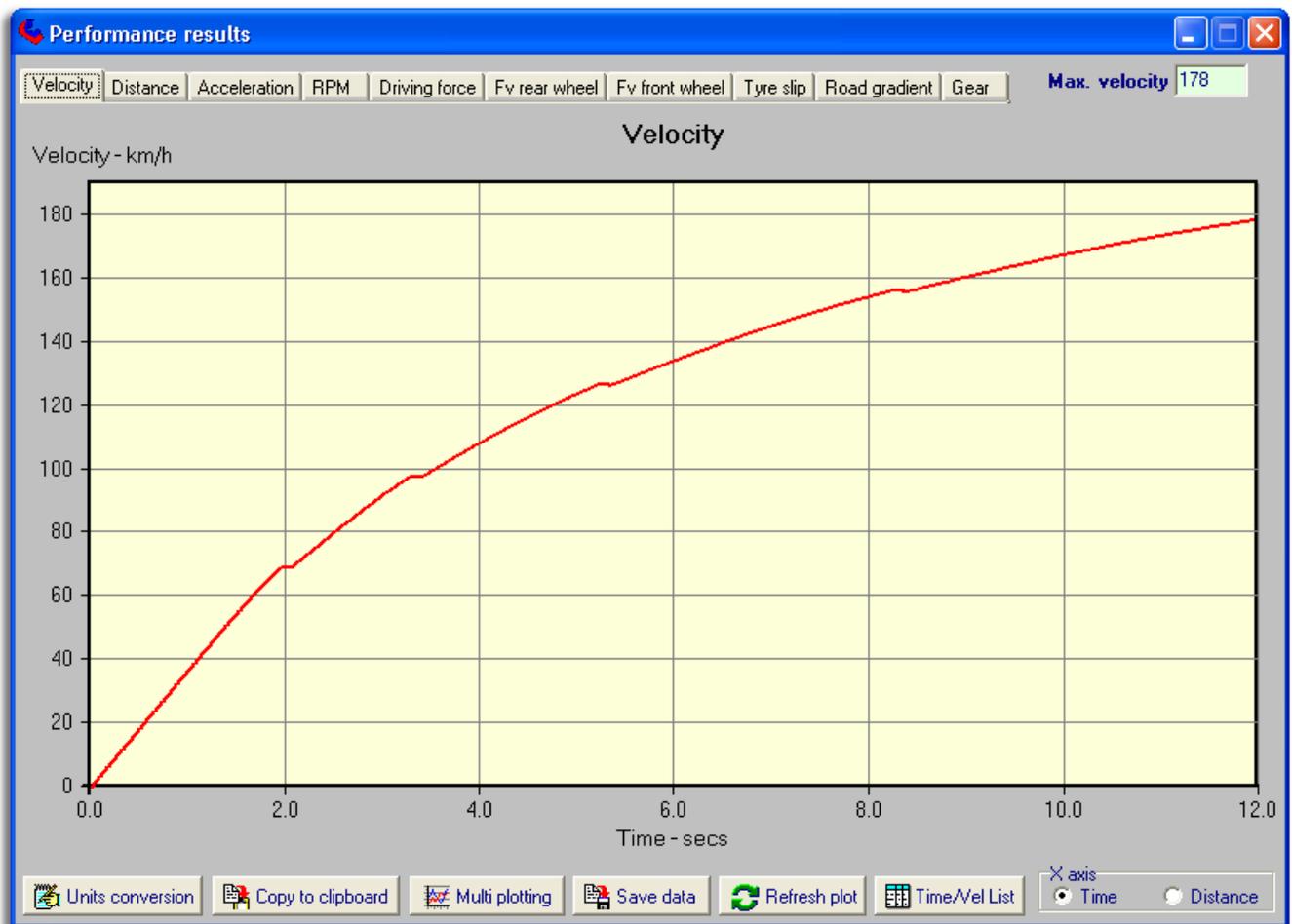
Refreshes the plot after entering or modifying the data grid.



Returns to the main data entry screen with the power curve selected.



## Results plots



There are some special features available when the mouse pointer passes over the graph area.

- X-hairs appear automatically showing the X-Y values.
- Marking points. To mark a point, just click and release without moving the mouse. This will mark a point on a graph and show the X-Y parameter values.
- Line drawing. To draw a line, click and hold at the start and release at the end. The slope of the line will be calculated and displayed.
- Changing graph pages will remove the marks and lines.
- The graph data can be saved in numeric form to a file, which can be later be used in the multi-plotting feature to compare multiple cases.
- The graph window can be saved to the clipboard and subsequently pasted into other software for creating reports etc.

Several pre-defined plots are available and can be selected from the tabs at the top of the graph area. These plots can be viewed against time or distance. Although these plots provide interesting and useful information they only refer to the latest analysis. The real power of the software is in the ability to compare small differences in the results of different cases. We can do this by saving the results of each scenario which can be differences in gearing, just looking at different RPM for gear changes or seeing the effects of engine modifications etc.

There are two functions in the software to enable quick comparisons between different cases:





This opens the following screen:

Run description	Run time	Max. velocity
Suzuki SV650 standing 1/4 mile change gear at 9800 rpm	11.944	177.94
Suzuki SV650 standing 1/4 mile change gear at 10000 rpm	11.928	177.83

Run description:

Max. Velocity:  Run time:

Above the buttons there are two data boxes with the time and velocity data for the last run, above that is a data entry box for entering a description of this case. If you want to add this run to the list click on:

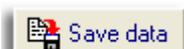


There are buttons to save or retrieve this table, which is useful if you want to add to it or refer to it at a later date. Without saving this table, it only remains active until you either close the programme or click on:



This feature is the quickest way to get a comparison of the two main performance indicators – time and velocity.

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In addition to the default file format used internally (\*.ERD) there are options to export the results in .SLK or comma delimited .TXT format. Both these formats can be imported directly into most spread sheets including MS eXcel.



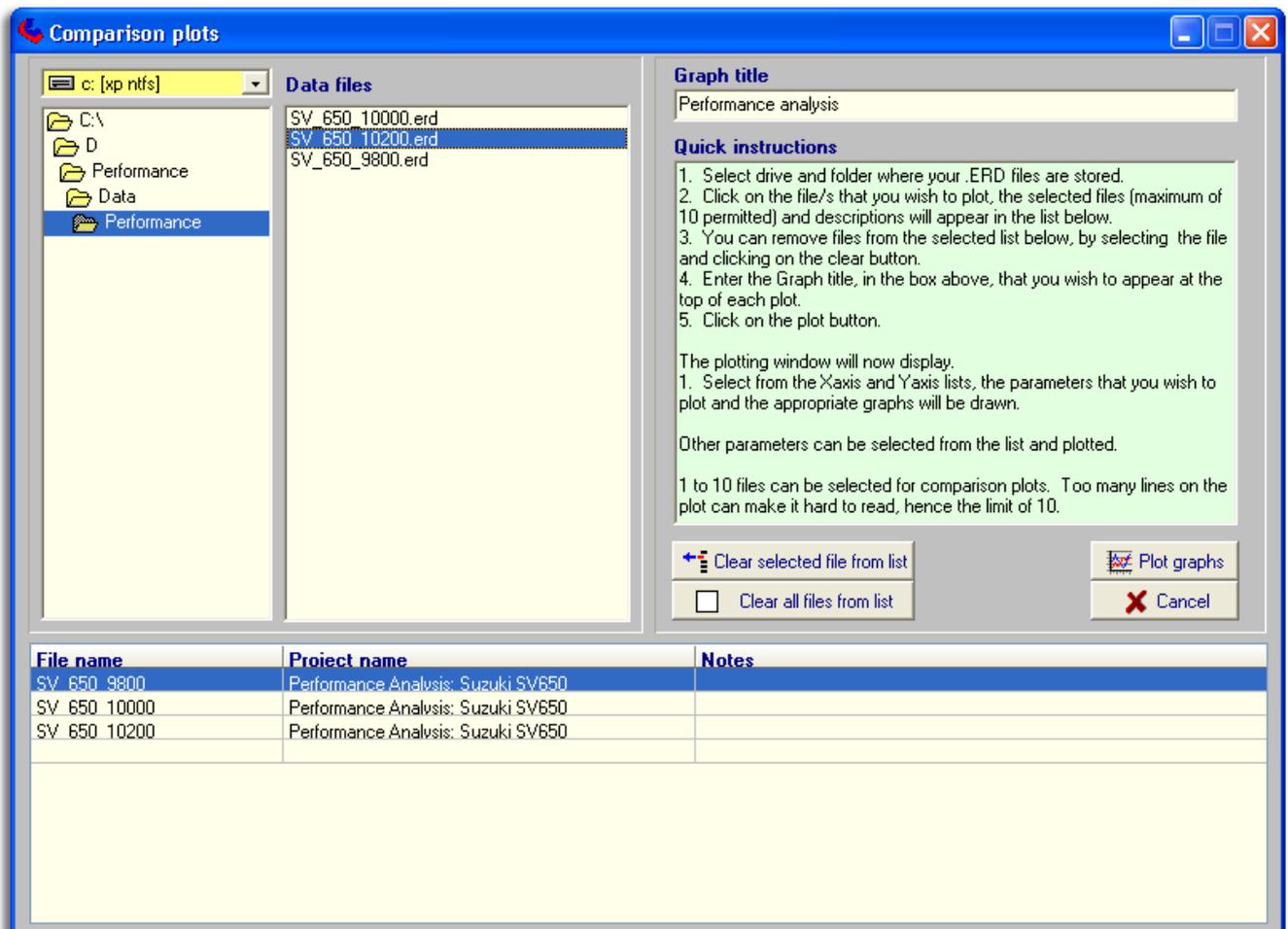
After saving several cases we can use this button to load up to ten cases for comparison on the same graph.

## Multi-plotting

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

The window will initially open into the default file save directory. You can navigate to other directories if you saved the files elsewhere

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.



In this case there are 3 example runs over a standing quarter with a standard SV650 Suzuki, the difference between the runs is the RPM at which to change gear. They are 9,800, 10,000 and 10,200 RPM.

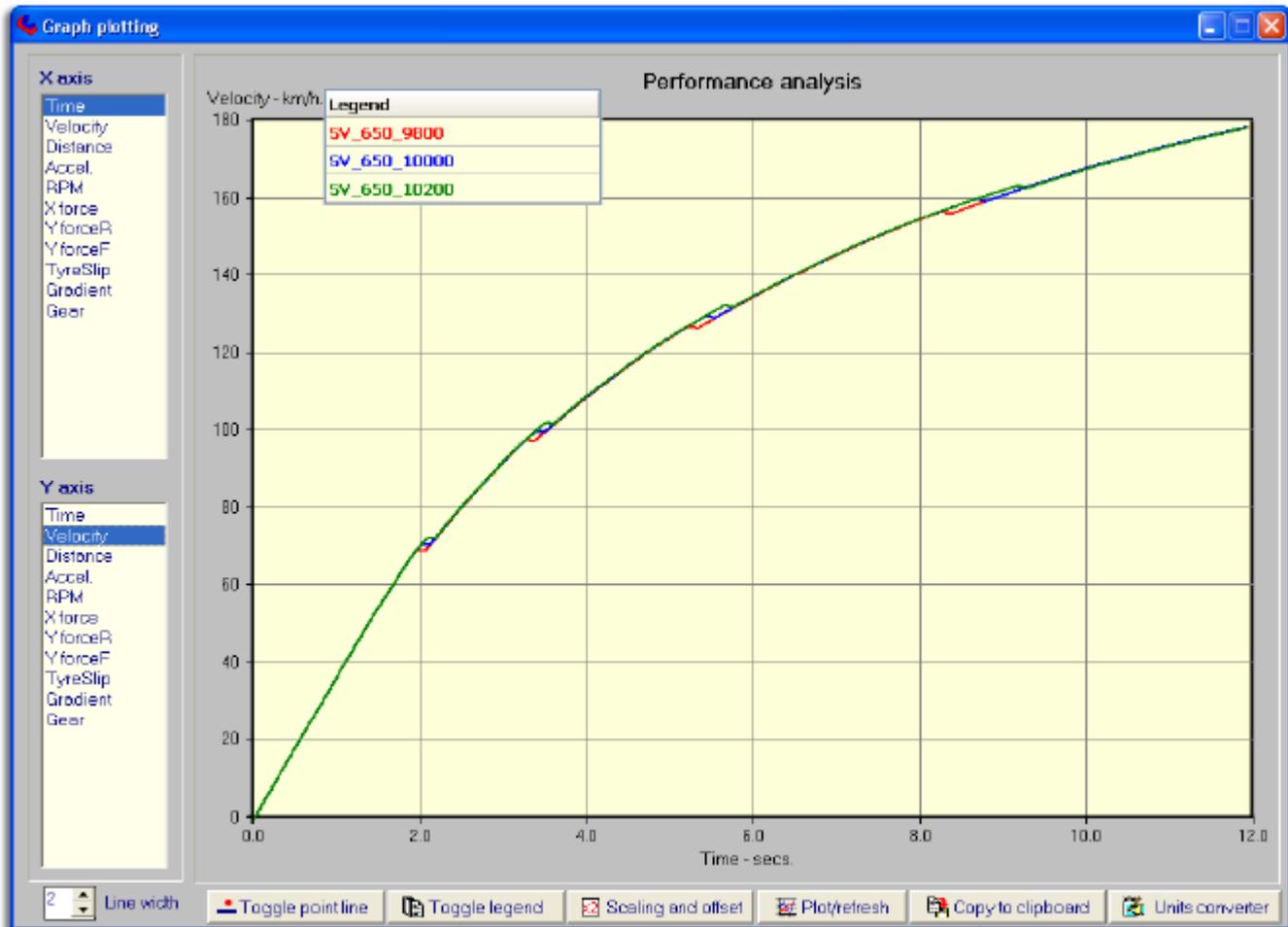
The plotting window, shown next, has 3 areas.

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

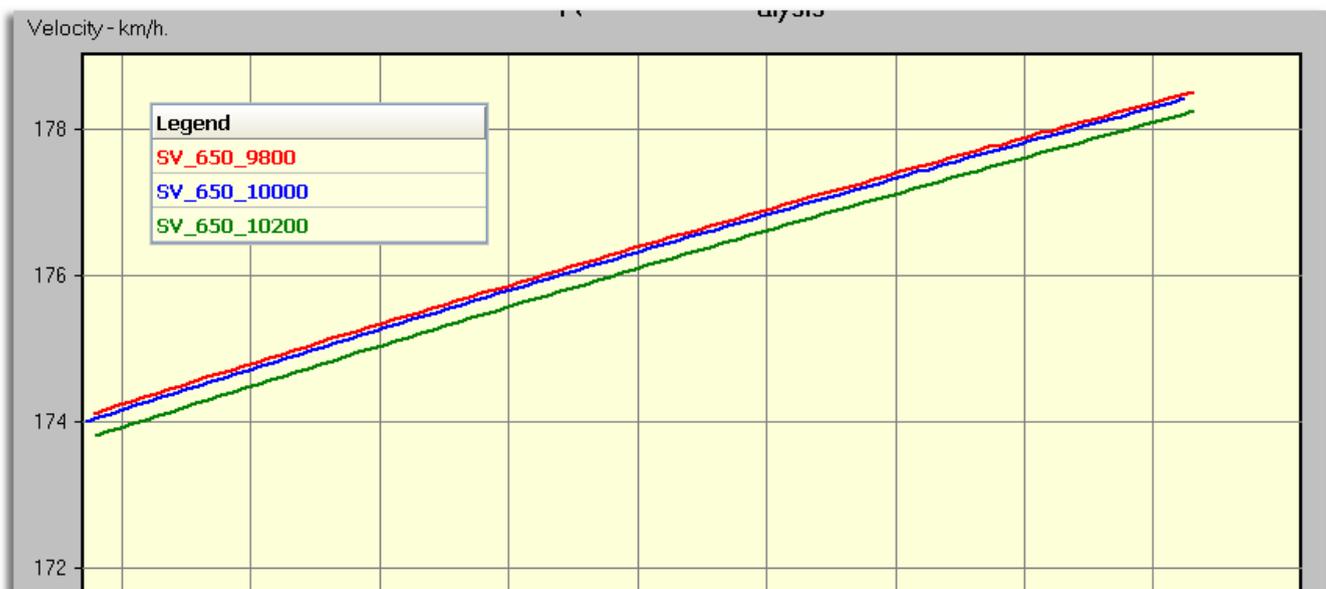
Along the bottom of the window, are some buttons with fairly obvious significance, except perhaps for the "Scaling and offset". Occasionally it is useful to be able to scale or offset the data before plotting.

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, below, the area to the left shows that time has been chosen for the X axis and velocity for the Y axis. The 3 graphs show this parameter pair for the 3 files selected from the previous screen.



In racing we are often looking for very small differences and the plot above is not very useful to distinguish which gear change option was best. However, we can zoom in to very small areas of the graph to get a much closer look. To do this, select a small area near the end of the run using the Ctrl key while dragging with the mouse holding the left button down. Release the mouse and Ctrl buttons when the required area is selected inside a dotted line box. The selected area will now zoom to fill the plot area. If necessary you can repeat the zoom again on the zoomed graph. Click on the **Plot refresh** button to remove zooming. The following shows the result of zooming on the above.



Now we can quite clearly see the differences between the 3 cases. A discussion of what the differences mean and how to interpret them will be included in the document on making use of the software.

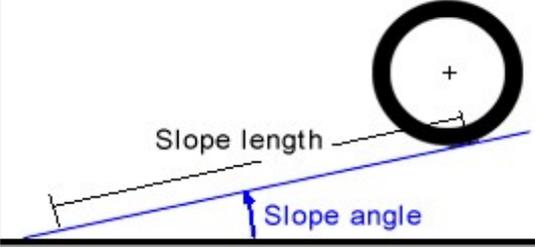


## Wheel moment of inertia calculator

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 following.

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"/>
Moment of Inertia - Kg.m <sup>2</sup>		
<input type="text"/>		

Close Update project Calculate

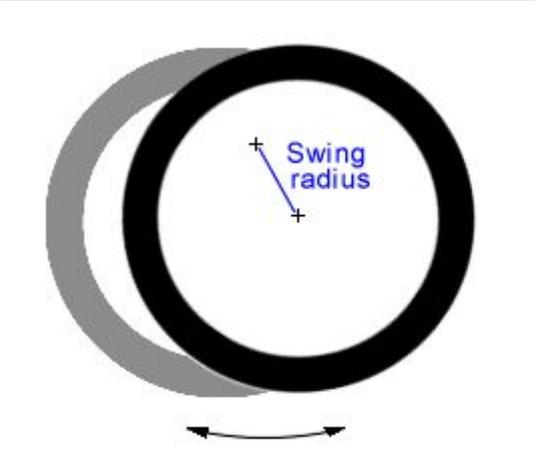
QUICK HELP.

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.

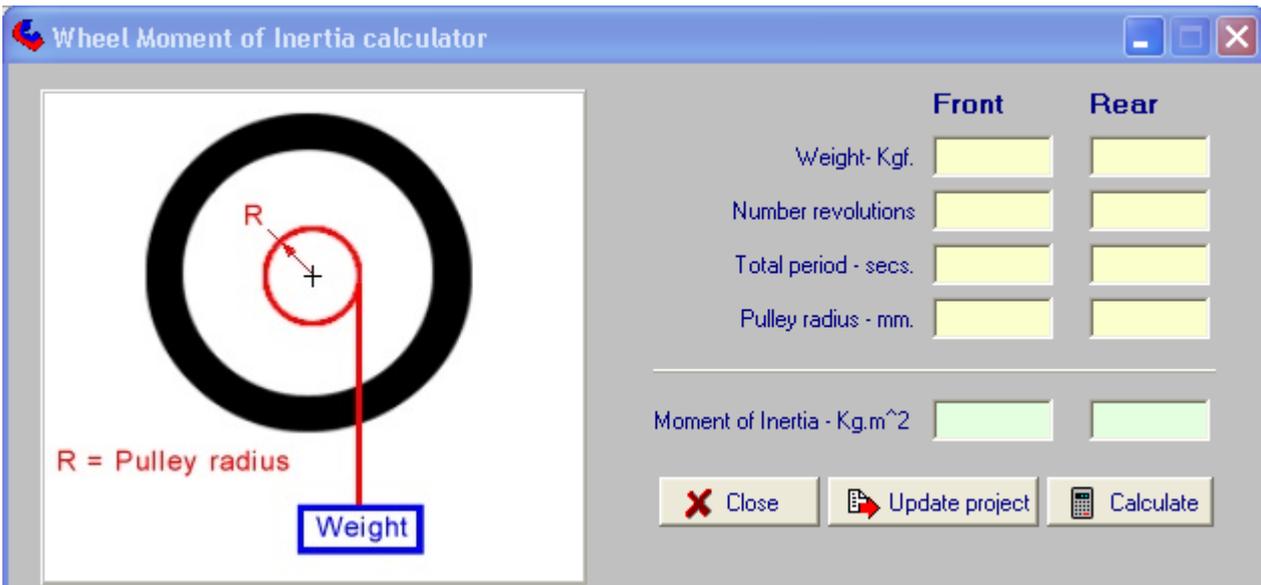
The results are expressed in Kg.m<sup>2</sup>

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"/>
Moment of Inertia - Kg.m <sup>2</sup>		
<input type="text"/>		

Close Update project Calculate



## Moments of Inertia of the wheels and tyres

It is not difficult to measure the actual moments of inertia with 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.

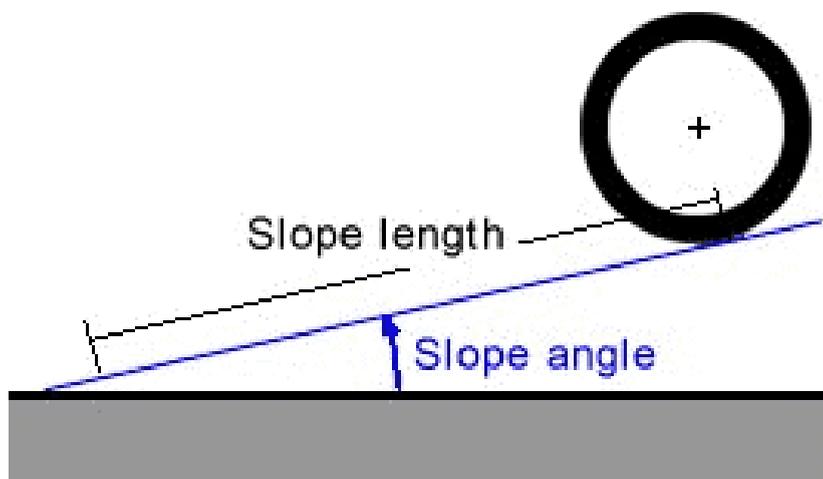
The distance between the swing axis and the axle centre needs to be measured. The wheel should be slightly displaced to one side and allowed to swing back and forth like a pendulum. Measure the time required to complete a number of complete cycles, 20 for example to reduce the effect of timing errors. A swing amplitude of  $\pm 5$  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.

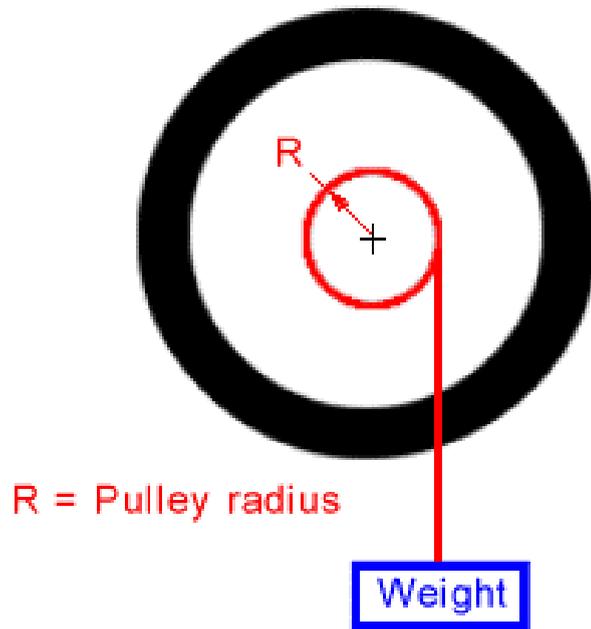


### Pulley and weight

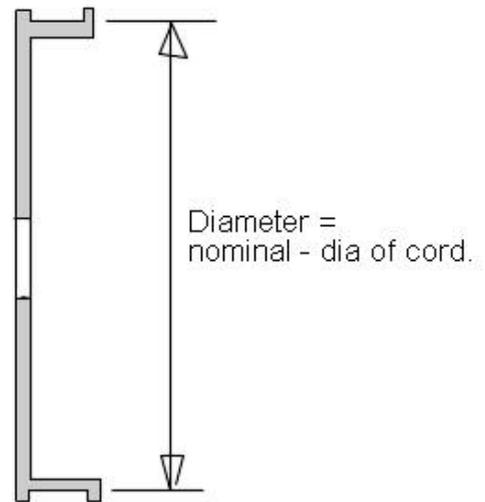
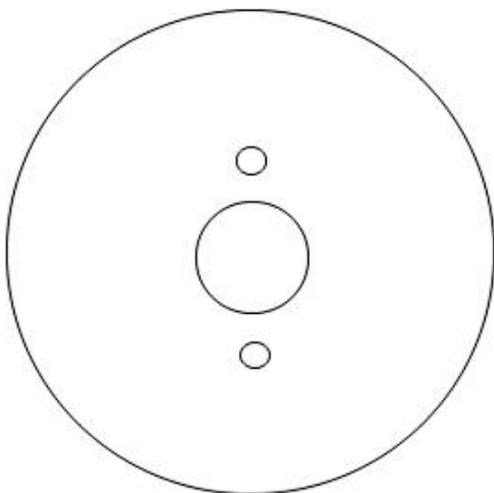
Probably the most accurate method of the three, but requires a little more preparation. A small pulley (about 100 mm. diameter is ideal) needs to be made that can be attached to the wheel concentric with its spin axis. Some thin cord or flexible cable is wound around the pulley and the free end attached 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 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.





### Centre of Gravity height

The CG height is an important parameter because it affects whether acceleration is limited by wheelies and it controls load transfer which is important for getting the maximum grip from the tyres. There are various ways to measure the CG height but many 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.

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**

CG height	603.1
CG from rear axle	725.0

Front lifted  
 Rear lifted

Calculate

## Notes on input data & accuracy

**GIGO** is a well used acronym in the computer world. It stands for “**G**arbage In **G**arbage **O**ut”. What this means is that we can’t expect to get better quality results than the quality of the data that we input. Having said that it is true that some parameters only have a small influence on the performance and so the accuracy of those parameters is not critical. The crankshaft moment of inertia (Mol) is likely to be in that category, for example. Some of the required input data is easy to come by but other data may be difficult. The internet, magazine road tests and manufacturer’s manuals are a good source of some data. The following will consider each piece of data individually and discuss its importance and availability.

### Aerodynamic

**CdA.** In general this needs wind tunnel facilities or sophisticated CFD analysis to determine. Few of us have access to such facilities but there are other ways to get reasonable data. Magazines sometimes publish such figures and the following table gives some typical values collected from various sources.

Description of bike	Rider prone	Rider sitting
<i>Yamaha Venture</i>		<i>0.75</i>
<i>Honda V65 Magna</i>		<i>0.61</i>
<i>Honda Blackbird</i>	<i>0,44 / 0,49</i>	<i>0,72 / 0,81</i>
<i>Honda VF1000F</i>	<i>0.40</i>	<i>0.46 / 0.45</i>
<i>Aprilia Mille</i>	<i>0,52</i>	<i>0,61</i>
<i>Ducati 916</i>	<i>0,49 / 0,57 / 0,53</i>	<i>0,61 / 0,69 / 0,61</i>
<i>BMW R1100 RT</i>	<i>0,53</i>	<i>0,97</i>
<i>BMW K100RS</i>	<i>0.40</i>	<i>0.43</i>
<i>Yamaha R1 (1998)</i>	<i>0,57</i>	<i>0,62</i>
<i>Yamaha FJ1100</i>	<i>0.43</i>	<i>0.48</i>
<i>Kawasaki GPZ900R</i>	<i>0.36</i>	<i>0.43</i>
<i>Suzuki GSX1100EF</i>	<i>0.41</i>	<i>0.44</i>
<i>Suzuki GSXR750</i>	<i>0.32</i>	
<i>Suzuki Hayabusa</i>	<i>0.31</i>	
<i>Kawasaki ZX-12R</i>	<i>0.34</i>	
<i>Yamaha OW69</i>	<i>0.32</i>	
<i>Honda 1996 RS125</i>	<i>0.20</i>	
<i>Honda 1990 RS125</i>	<i>0.19</i>	
<i>Honda RS500</i>	<i>0.24</i>	
<i>Rifle faired Yamaha</i>	<i>0.15</i>	

Whilst the value of the Cd is useful for comparing the relative drag qualities of different shapes, it is not so useful for comparing different bikes. It ignores the other main ingredient of drag - frontal area. This table shows the value of the Cd multiplied by the area, this parameter is known as the CdA and is the best way of relating the drag performance of diverse machinery. The lower this value, the lower will be the power needed to produce a given speed. This data has been compiled from various sources and so should only be considered as a guide because there is bound to be variation from measurements made at different sites. Rider size and clothing may be different for example.

Multiple values in the table indicate that data for these machines was available from multiple sources.

Note the differences between sitting up and laying on the tank. Use the prone values for acceleration calculations and the sitting values for braking.

The last machine in the list was especially prepared for a fuel economy contest.

The values for the R1 Yamaha look suspiciously high and should be treated with caution.

Consider these values purely as a starting point for a similar type of motorcycle. We can refine these numbers using the software. If we know the top speed of a particular machine, either from magazine road tests or own testing then we can alter the CdA value until the software calculates the same top speed. This will then give us a value suitable for the overall performance calculations with different gearing scenarios etc.

**CP height.** This really is a value that is difficult to estimate without the proper facilities but fortunately in most cases it will not have a large influence on performance. Load transfer at high speed is affected by this parameter, which in turn affects tyre slip and grip. Tyre grip is usually only a limiting factor at relatively low speeds and is affected much more by CG height rather than CP height. Errors in the calculation of tyre slip at high speed only produce relatively small errors in the performance calculation. In the absence of real data use a value somewhere in the region of the CG height, and it won't be far wrong.

If you have data acquisition fitted to the front forks then it might be possible to get an idea of the CP height by looking at the variation of fork extension against speed.

**Air density.** There are many sources for this data (many on the internet) which varies with altitude, temperature and humidity. However, using the default value of 1.17 Kg/m<sup>3</sup> will generally give sufficient accuracy for comparison scenarios.

## Inertial

**CG height.** This parameter controls load transfer under acceleration and so also tyre slip and maximum grip. It is of lesser importance on low powered machines where performance is not limited by wheelie or tyre grip issues. On the other hand it affects the initial acceleration to a large extent on powerful machines when doing a standing start. This value will vary between the cases of a prone and sitting up rider posture and so different values can be entered for braking and acceleration.

There is a CG height calculator built into the software.

**Load on the tyres.** The sum of the front and rear gives the all up weight of the machine and rider. Acceleration throughout the speed range is directly related to this important parameter and so the user should strive for an accurate a value as possible. Fortunate this is easily done by weighing each end of the loaded bike. If this is done one wheel at a time then chock up the other wheel to the same height as the scales so that the machine remains horizontal during the measuring process.

**Wheel Mol – (Moment of Inertia).** In performance terms these values (front and rear) act as if the motorcycle was more massive than its weight would indicate. Possibly by around 5% depending on all the various physical parameters. These values also have a small effect on the effective CG height, lowering it somewhat. In the absence of real data use the default values, although it is not difficult to measure this reasonably accurately and a calculator is included in the software.

**Crank Mol.** This has two effects, firstly it acts like the wheels in effectively adding mass to the motorcycle to accelerate it and secondly there is an inertia reaction in the opposite direction to its rotation which adds to or subtracts from the load transfer, depending on its direction of rotation. This parameter is generally not very significant and only in the lower gears anyway. The difference in calculated performance is very little between using a value of zero and the correct value. If you have a drawing of the crankshaft in a CAD programme then many of these will calculate the Mol for you.

Note. Motorcycles with longitudinal engines like BMW boxers, MotoGuzzi and Gold Wings do not cause a longitudinal load transfer under acceleration.

**Wheelbase.** This is another parameter which affects load transfer but is easy to measure accurately.

## Miscellaneous

**Rolling force.** There are two sources of drag on a wheeled vehicle. Aerodynamic which is proportional to the square of velocity and everything else is usually lumped together under the term rolling force or rolling resistance. This comprises drag from a number of sources such as wheel bearing friction, tyre drag, residual brake drag etc. Although in reality this force varies in a complex manner with velocity it is usually considered as a constant value, as it is in this software. Without proper testing facilities it is difficult to accurately determine these values, and so it is fortunate that usually they are low enough in proportion to acceleration and aerodynamic forces to be of minor importance only. The software allows for different values under acceleration and braking. If the power values were measured at the rear wheel then the rolling resistance from the rear (chain, transmission, tyres etc.) will

have been accounted for in the power and torque figures and so we would only need to use the contribution of the front wheel to rolling resistance. Under braking we need to account for the rolling resistance of each end.

**Tyre maximum  $\mu$  - (maximum co-efficient of friction) & Peak rear tyre slip.** The nature of tyre grip is very complex and depends on load, road surface, tyre construction and tread compounds. In handling calculations, in general, it is quite common for to use an empirical expression know as the Pacejka “magic formula”. This formula gives grip values for different conditions of loading etc. and different tyres and surfaces are accounted for by using different coefficients in the formula. Unfortunately, the values of these coefficients are not readily available outside of the research departments of tyre companies. Therefore it is not easy to gain access to accurate tyre data. The most important component of the total tyre data that we need is the peak co-efficient of friction, which with modern tyres is likely to be within the range of 1.0 to 1.2.

The peak driving force which can be generated occurs when the tyre circumference is travelling somewhat faster than the road speed. That is, the tyre is slipping. If we had the Pacejka coefficients then the degree of slip for a given tyre would be defined by the “magic formula”. The slip characteristics are important in performance calculations because they affect the relationship between RPM and road velocity in a given gear, in turn this affects the wheel torque available at any given road speed, and the road speed at which gear changes occur. Fortunately, as long as the torque curve doesn’t change quickly with RPM then the inaccuracies introduced by the absence of full tyre data will not be great. This is further helped because maximum slip only occurs when we are operating close to the limit of the tyres. In the absence of better data it is suggested that the default value of 15% peak slip is used. Those with data acquisition fitted to the motorcycle can compare measured values of slip and adjust the software input to best match those measured values. A graph of calculated slip values is provided to help with this adjustment to the data.

**Tyre radius.** This is the rolling radius of the tyre when loaded with the static weight of motorcycle, liquids and rider. The software implicitly assumes that this radius remains constant and does not vary with load transfer under acceleration. The error introduced by this assumption is small.