Software User's Manual

Version 3

Tony Foale Designs © 2022

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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 there 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 lessor 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.

Version 3 adds many features for calculating optimum RPM for gear change points in each gear as well as extensive possibilities for optimising gearbox, primary drive and sprocket ratios.

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 performances 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.

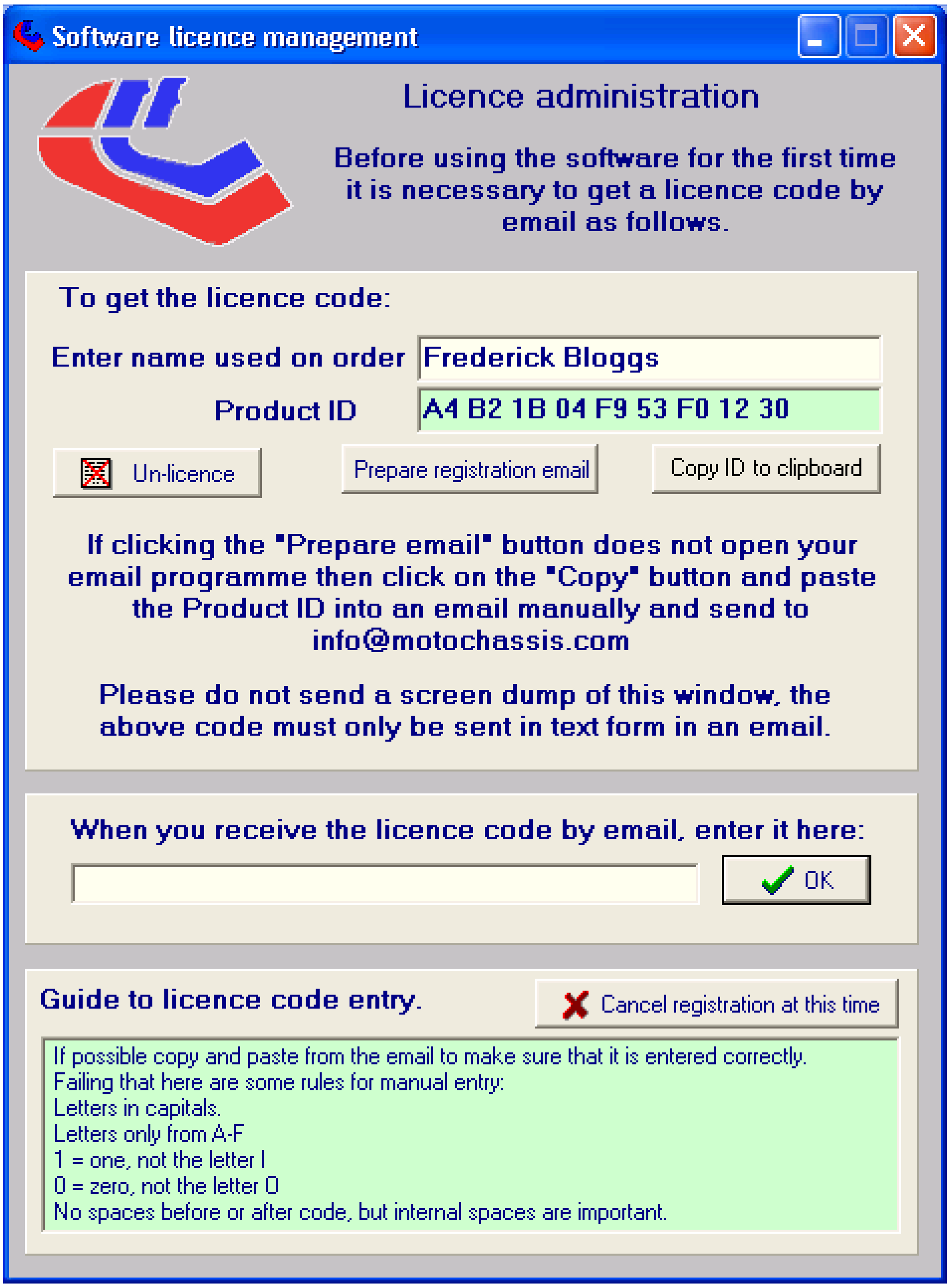
Tony Foale.

November 2007 & 2019

First time use.

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

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

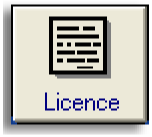


A licence code will be emailed back to you. When you receive this code, restart the software and enter the code where indicated. The software will then shut down and then function fully when restarted.

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

Procedure to transfer licence to another computer.

If you wish to change the computer on which you use the software, then firstly enter the above licence screen by clicking the



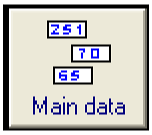
button on the opening window. (On the original computer.)

Then click the

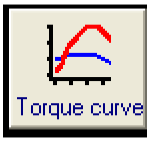
button. Make a note of the un-licence code that appears. Install the software on the new computer and email the customer number for that machine with the un-licence code from the first.

Initial screen

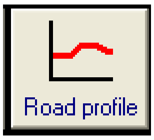
There are several speed buttons to access various areas of the software, as follows



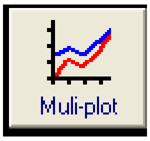
This is probably the most used button on the initial screen and it opens the main data entry screen.



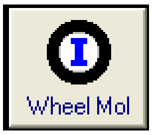
Takes you to the screen for entering the power or torque curve of the engine. Also accessible from the data entry screen.



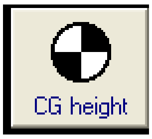
This opens a screen to enter the elevation of sections of the road or track. Not needed for a level horizontal surface. Also accessible from the data entry screen.



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

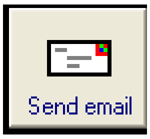


Opens a calculator for estimating the moments of inertia of the wheels and tyres. Using the default values will give good results.



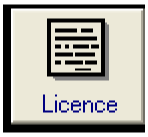
A calculator using an easy method to obtain CG height.

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



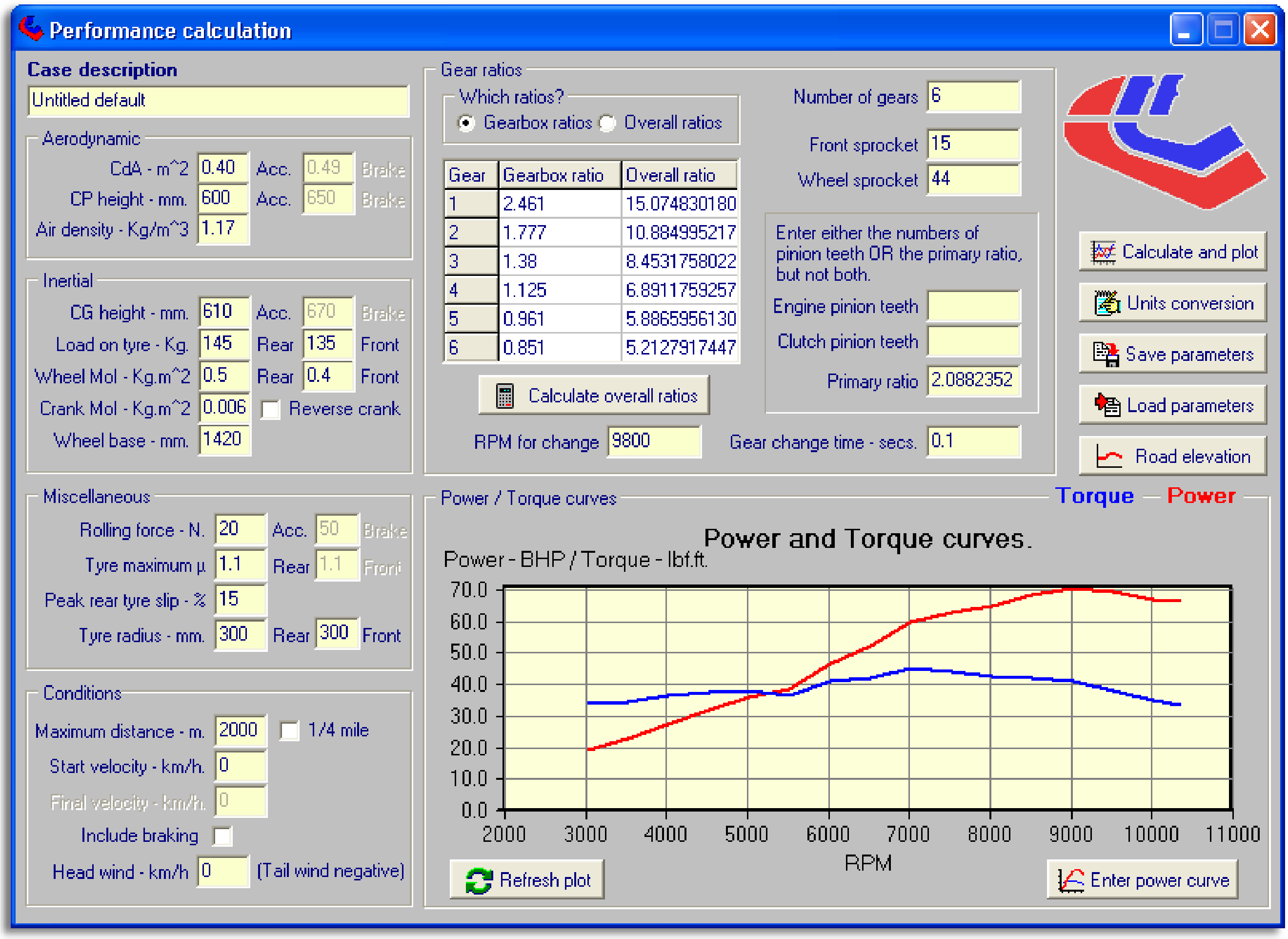
Sends an email to Tony Foale Designs. We welcome all comments about the software as well as suggestions to expand or improve it. *info@motochassis.com*

Connects to the Tony Foale Designs web site. *https://motochassis.com*



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

Main data entry screen



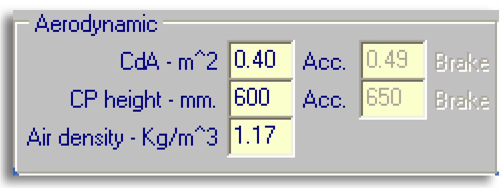
Note: This is the version1. screen. The version 3 additions are shown toward the end of this document.

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.

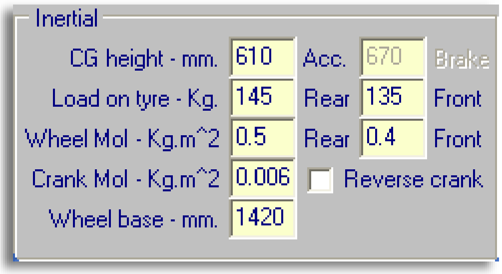
The data entry is divided into groups and the following will consider each group and data field in detail.



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.



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.

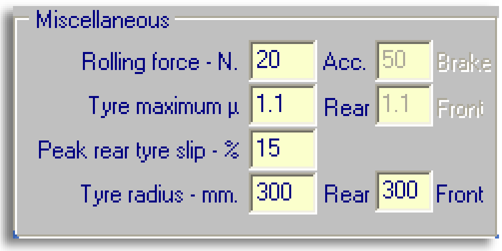
Load on tyre Simply the weight measured under each tyre of the fully loaded motorcycle.

Wheel MoI 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 MoI 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.



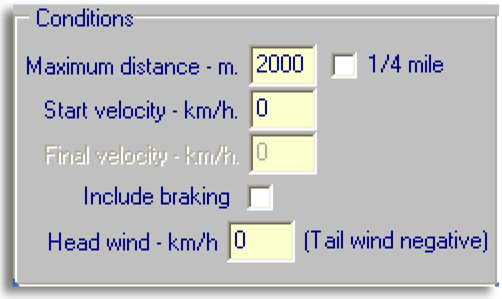
Rolling force Also known as rolling resistance. Another factor which is not always easy to specify and may be different between acceleration and braking. For example if the power characteristics were obtained using a rolling road dynamometer then the rolling force contribution from the rear will already 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 µ 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.



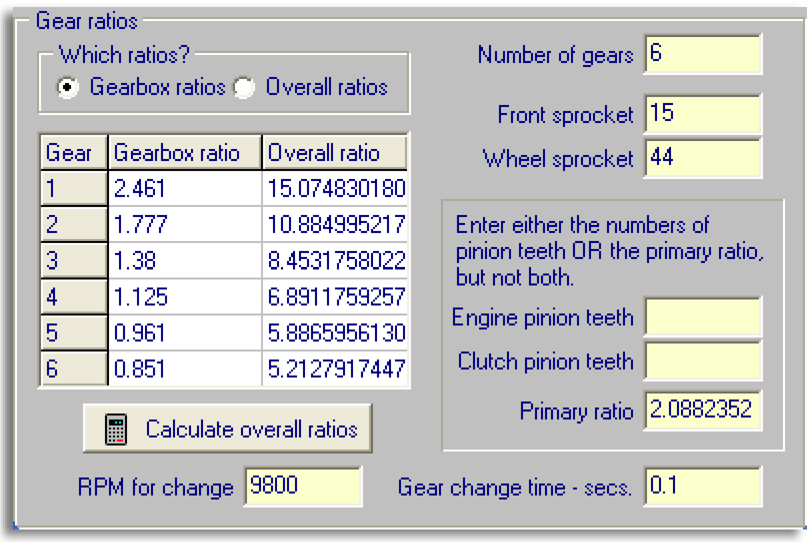
Maximum distance The calculations cease at this distance. If you tick the ¼ mile box then the maximum distance is set to 402 metres and the starting velocity to zero to enable calculation of standing start performance.

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.



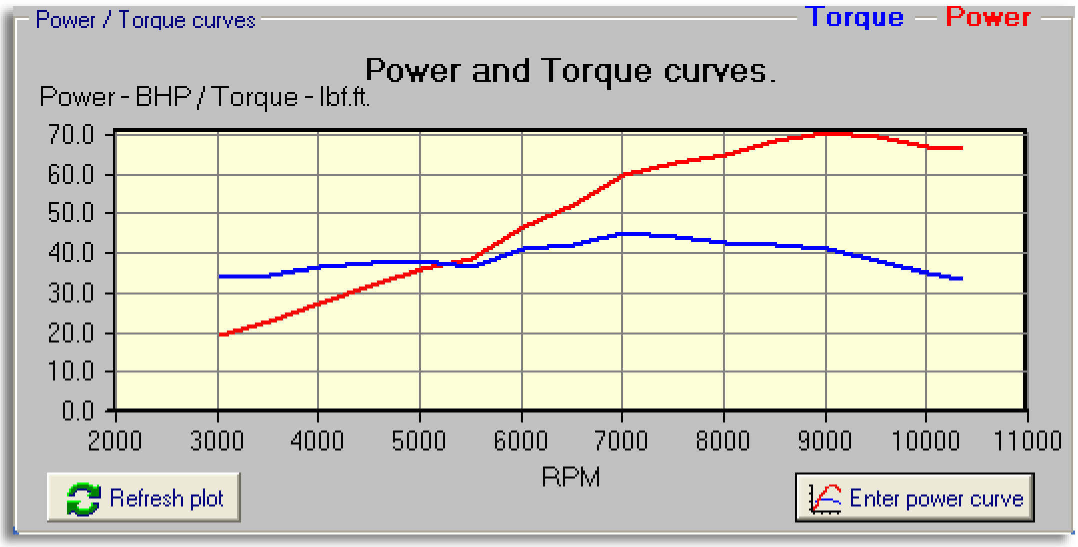
This group defines the transmission data etc. There are two options for data specification which are determined by the following selection:

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. Note: Version 3 permits different RPM for each gear.

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.

Note: There are additional buttons in version 3.

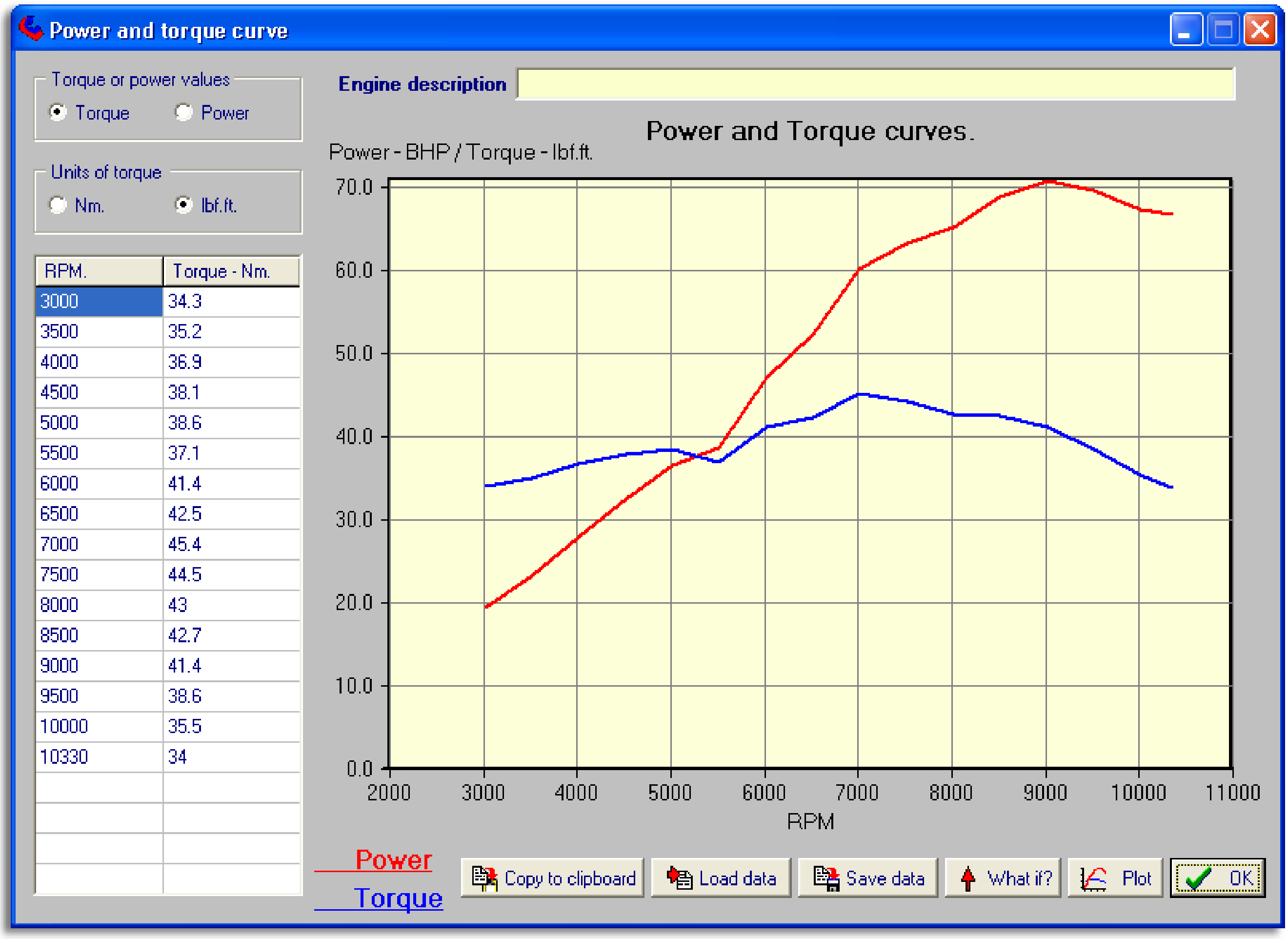
Click this when all data entry is done to pass to the screen for the graphical display of the calculation results.

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



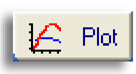
The data can be entered as either power or torques values against RPM. If "power" is selected then there is a units choice between BHP and kW, likewise if "torque" is the preferred input there is a choice of units between Nm and lbf.ft. All the internal calculations use Nm for torque but the conversion 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.

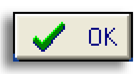
Copies the plot to the clipboard so that it can easily be copied into other documents, for example when illustrating a report.

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.

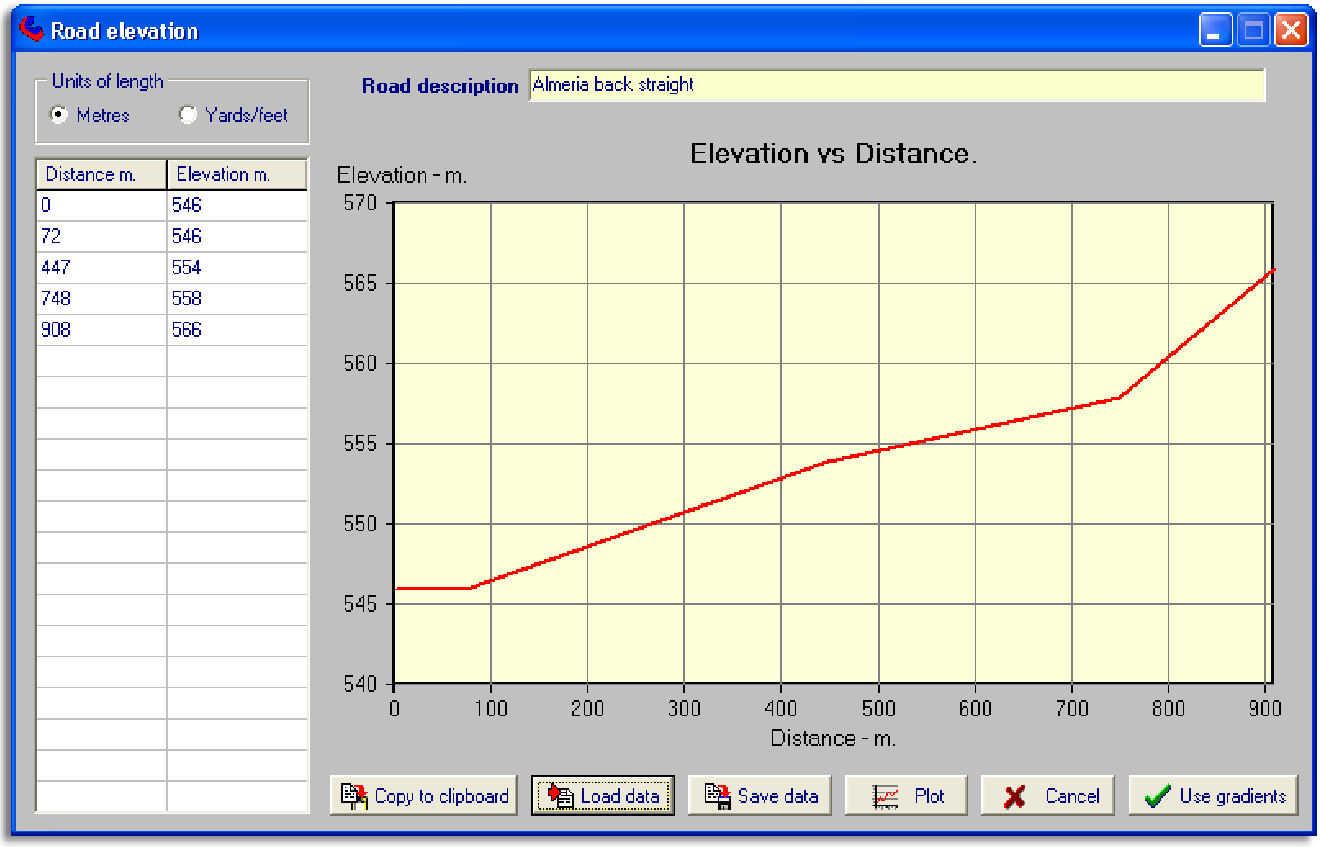


Refreshes the plot after entering or modifying the data grid.



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

Road elevation screen



Obviously not all roads nor tracks are flat and horizontal, and gradients affect performance. This screen allows the entry of road elevation data. Even though all internal calculations are done in metres, the data grid accepts units of metres or yards and feet. This makes data entry easier depending on the units of the track data. Elevation maps are available on the web sites of some tracks, the data for the back straight of the Almeria track in southern Spain, as shown above, came from such a site.

This data can be saved and loaded later, so a library of track profiles can be built up. After entering or loading elevation data you can choose to use the data or ignore it in the performance calculations. If you exit this screen by clicking the **Cancel** button then no elevation data will be used. In other words the calculations are done using a horizontal road. If you click the **Use gradients** button then all calculations will use the elevation data until the **Cancel** button is clicked or the software restarted. When "***use gradients***" is active the following notice appears on the main data entry screen;

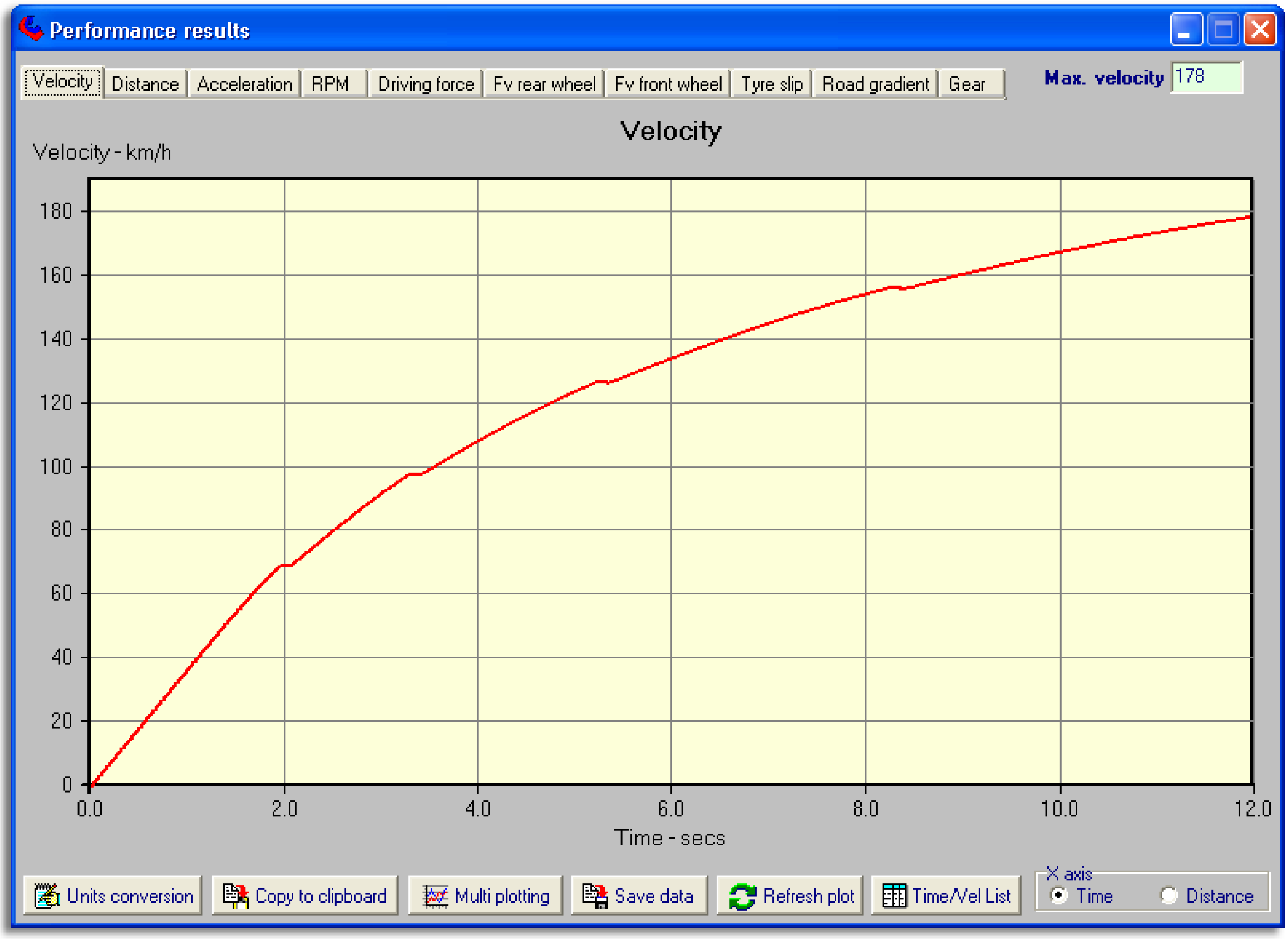
Notes on data:

The data entry allows considerable flexibility. The elevation values have an arbitrary reference and so can be entered in terms of elevation above sea level as in the above example. Alternatively, a zero reference level can be defined anywhere, say at the start of the run, in which case the above elevation values could be entered as:

0, 0, 8, 12, 20 instead of 546, 546, 554, 558, 566. The software only considers the relative values.

The distance data does not have to cover the whole length of a run. If the performance analysis continues outside of the range of the specified data the software assumes that the surface is horizontal outside of the elevation data range.

Results plots



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

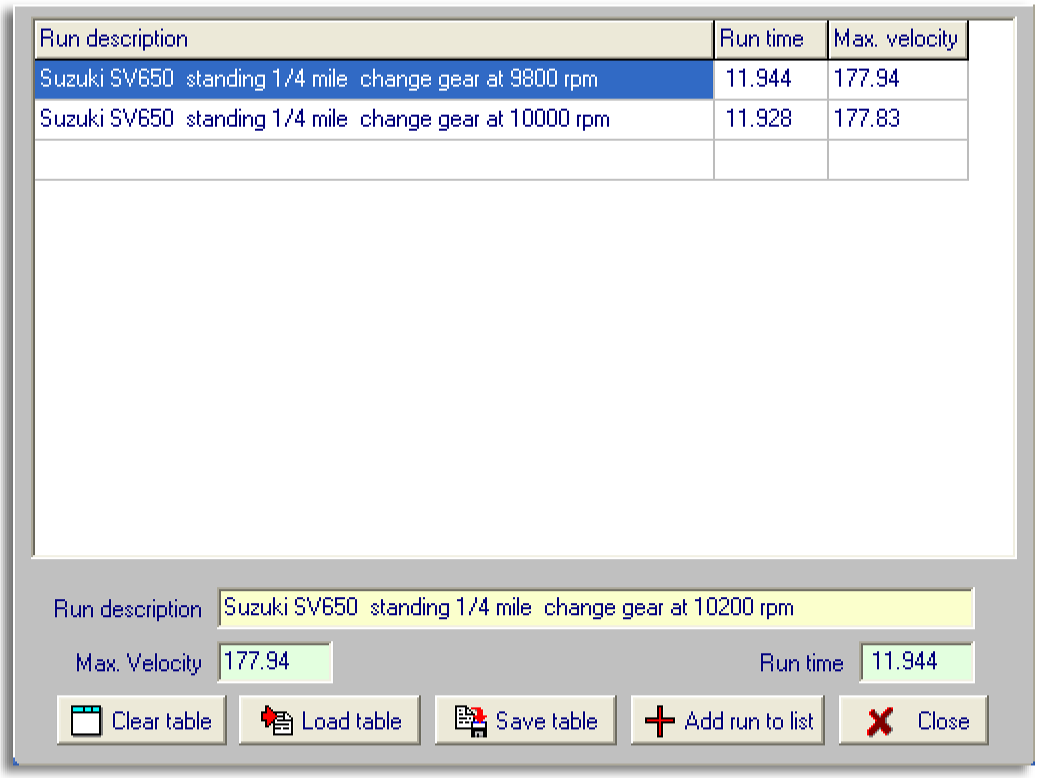
- X-hairs appear automatically showing the X-Y values.
- Marking points. To mark a point, just click and release without moving the mouse. This will mark a point on a graph and show the X-Y parameter values.
- Line drawing. To draw a line, click and hold at the start and release at the end. The slope 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.

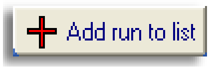
There are two functions in the software to enable quick comparisons between different cases:

and


This opens the following screen:

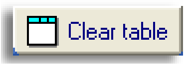


Above the buttons there are two data boxes with the time and velocity data for the last run, above that is a data entry box for entering a description of this case. If you want to add this run to the list click on:

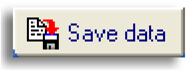


There are buttons to save an retrieve this table, which is useful if you want to add to it or refer to it at a later date.

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.



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.

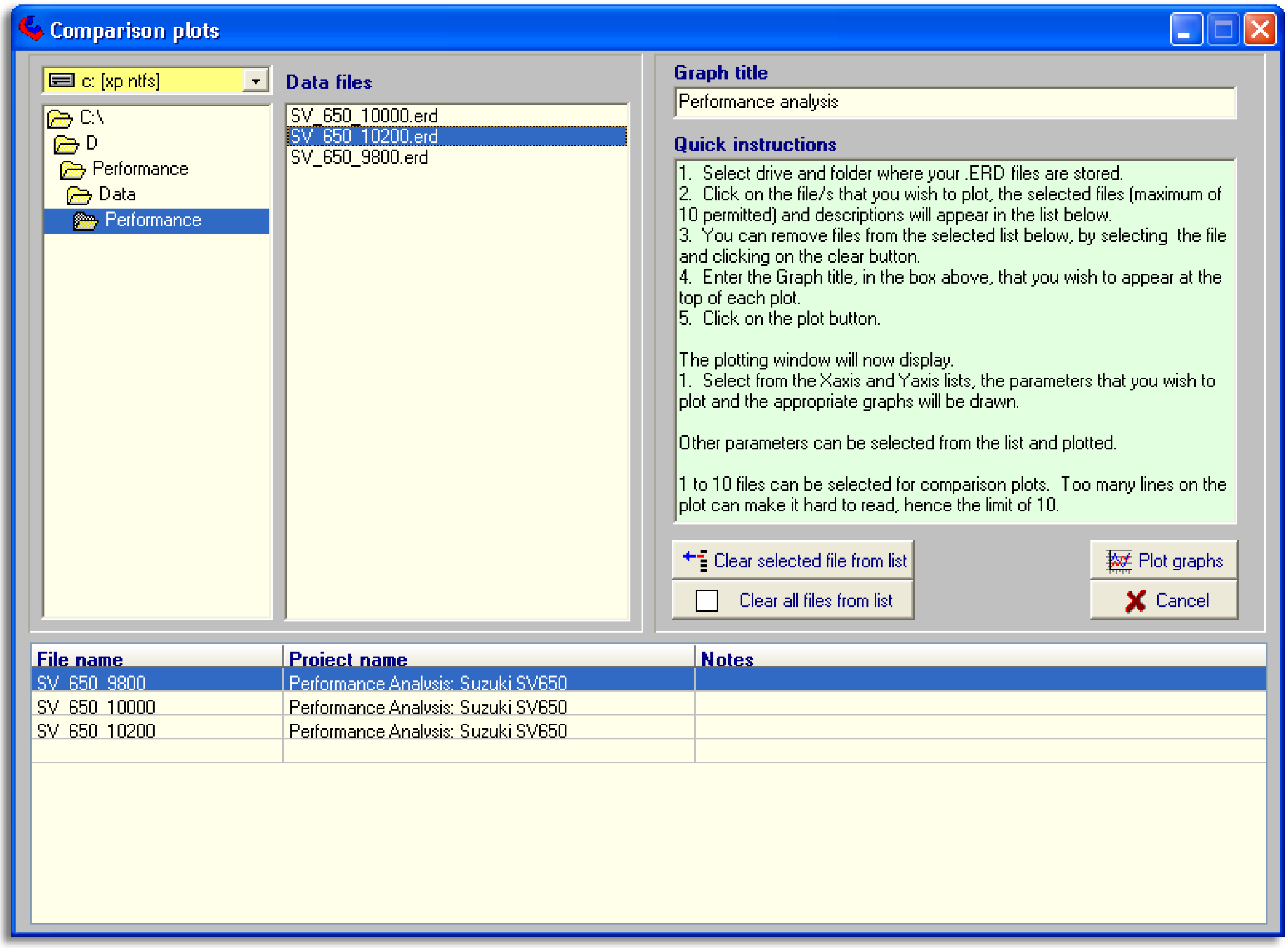
After saving several cases we can use this button to load up to ten cases for comparison on the same graph.

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.

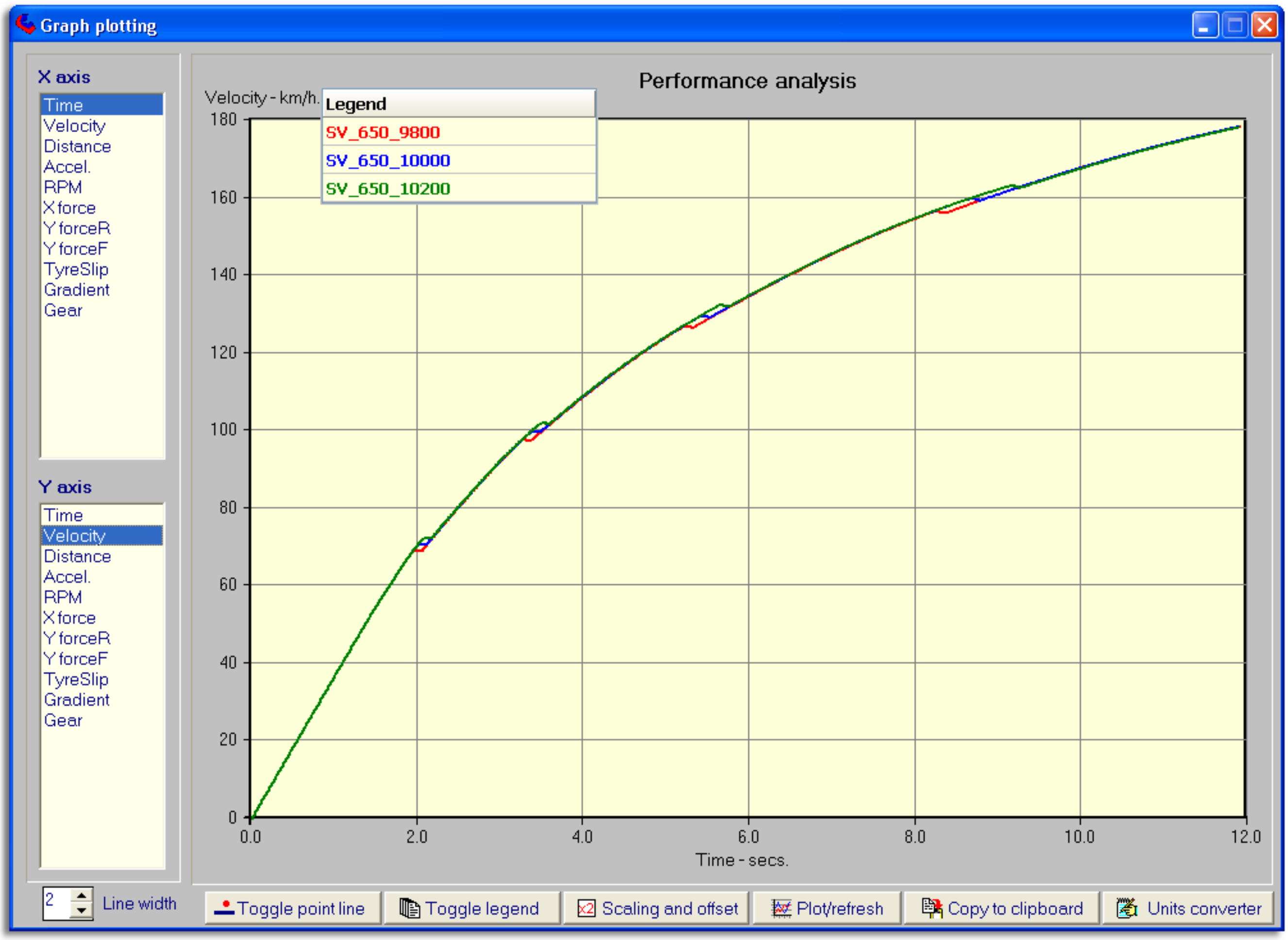
The plotting window, shown next, has 3 areas.

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.

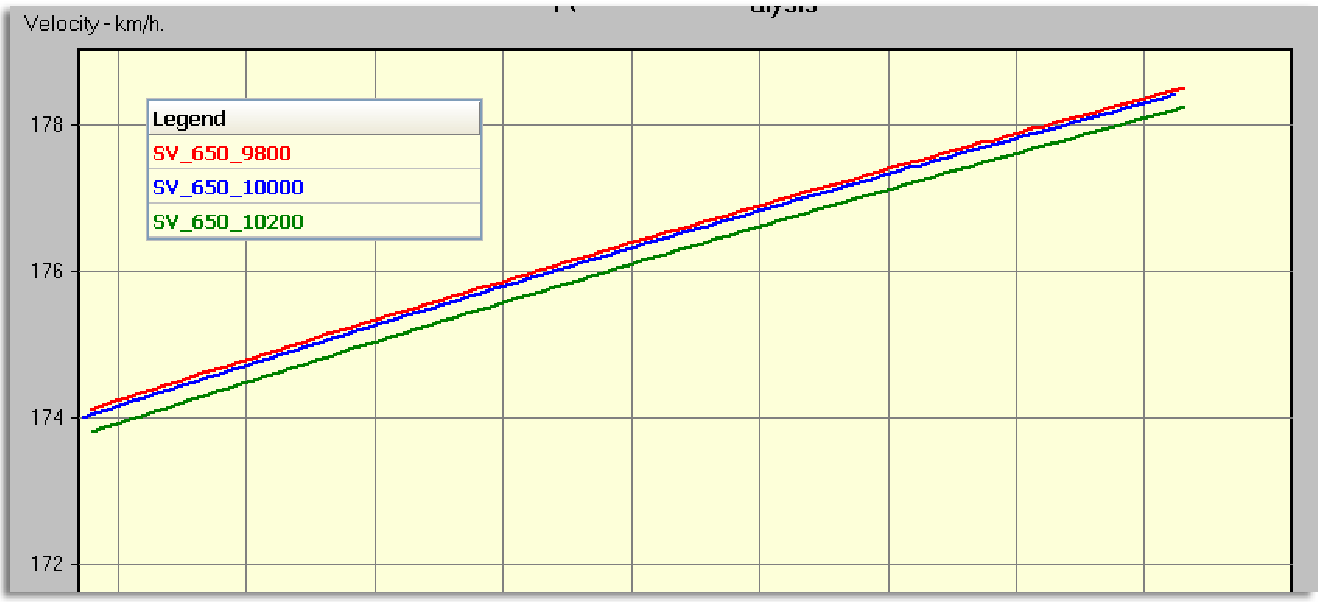
Along the bottom of the window, are some buttons with fairly obvious significance, except perhaps for the "Scaling and offset". Occasionally it is useful to be able to scale or offset the data before plotting.

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

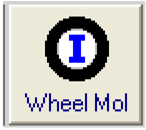
On the plotting window, below, the area to the left shows that time has been chosen for the X axis and velocity for the Y axis. The 3 graphs show this parameter pair for the 3 files selected from the previous screen.



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 by dragging with the mouse holding the left button down. Release the mouse button 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.

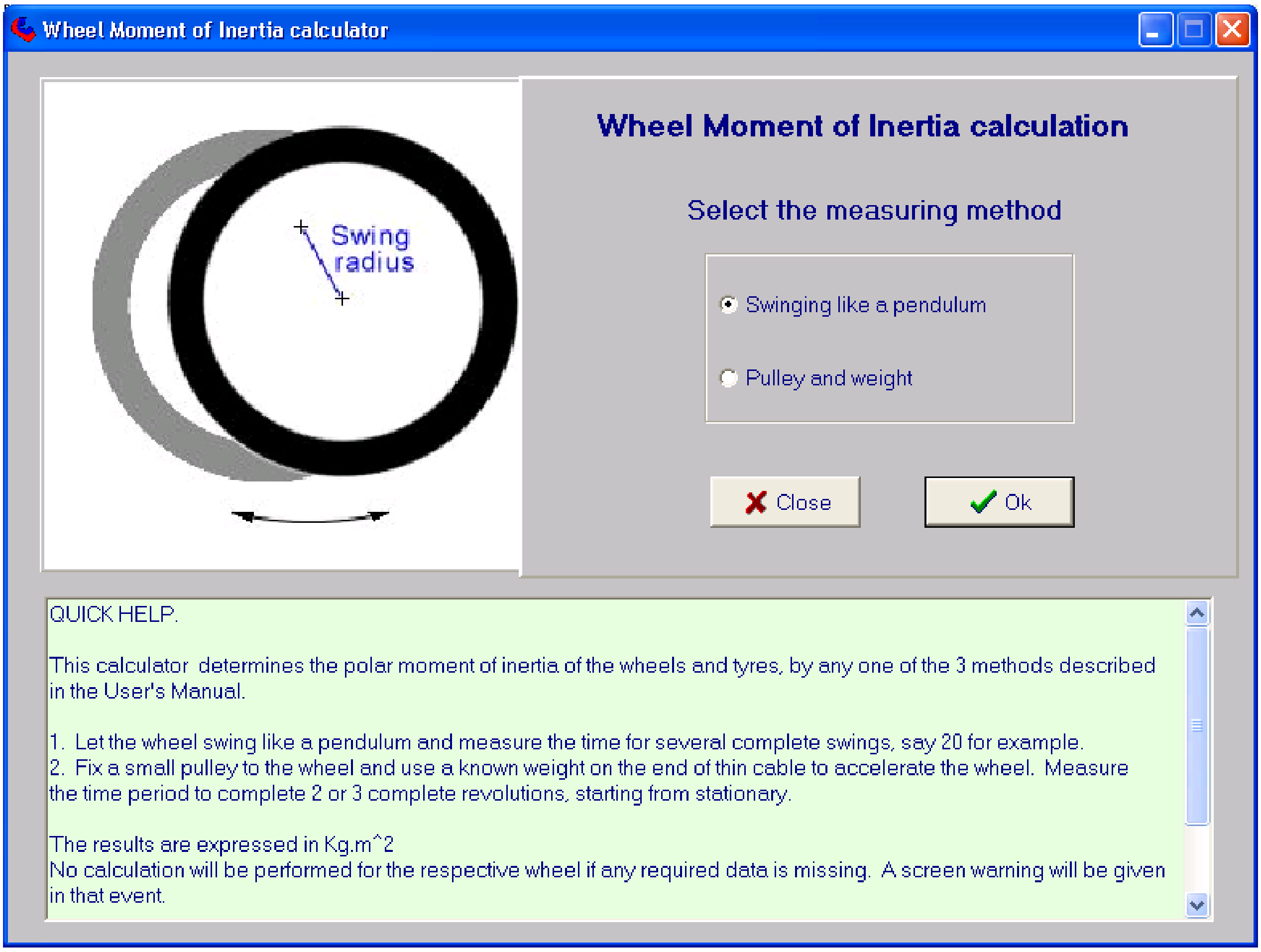


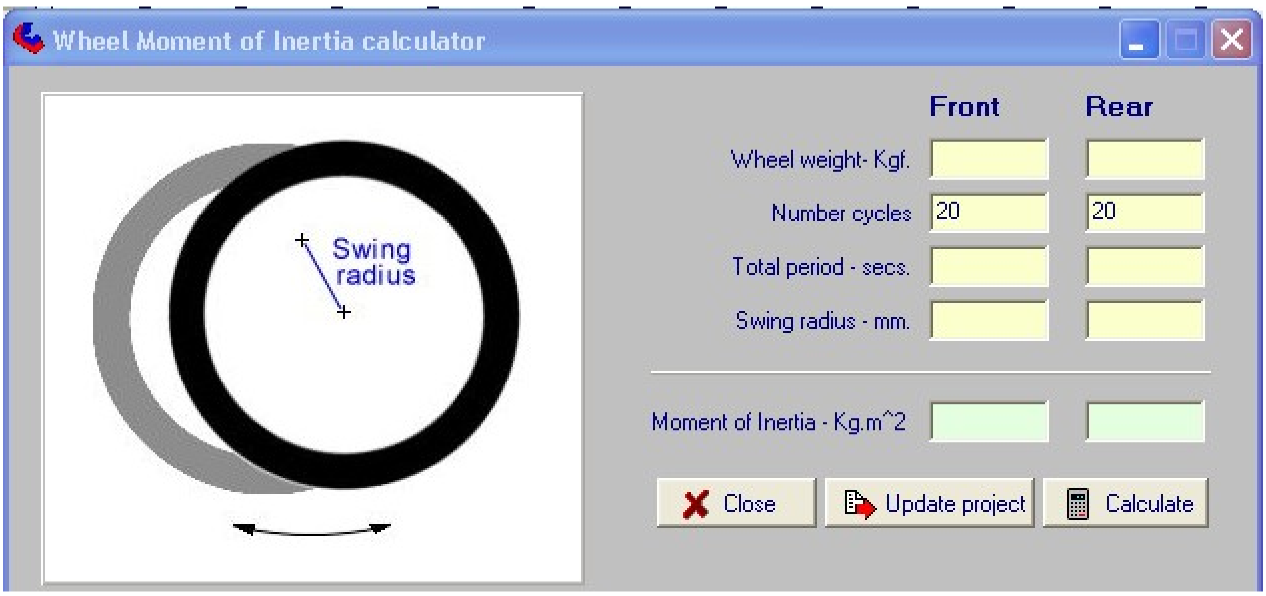
Now we can quite clearly see the differences between the 3 cases. A discussion of what the differences mean and how to interpret them will be included in the document on making use of the software.

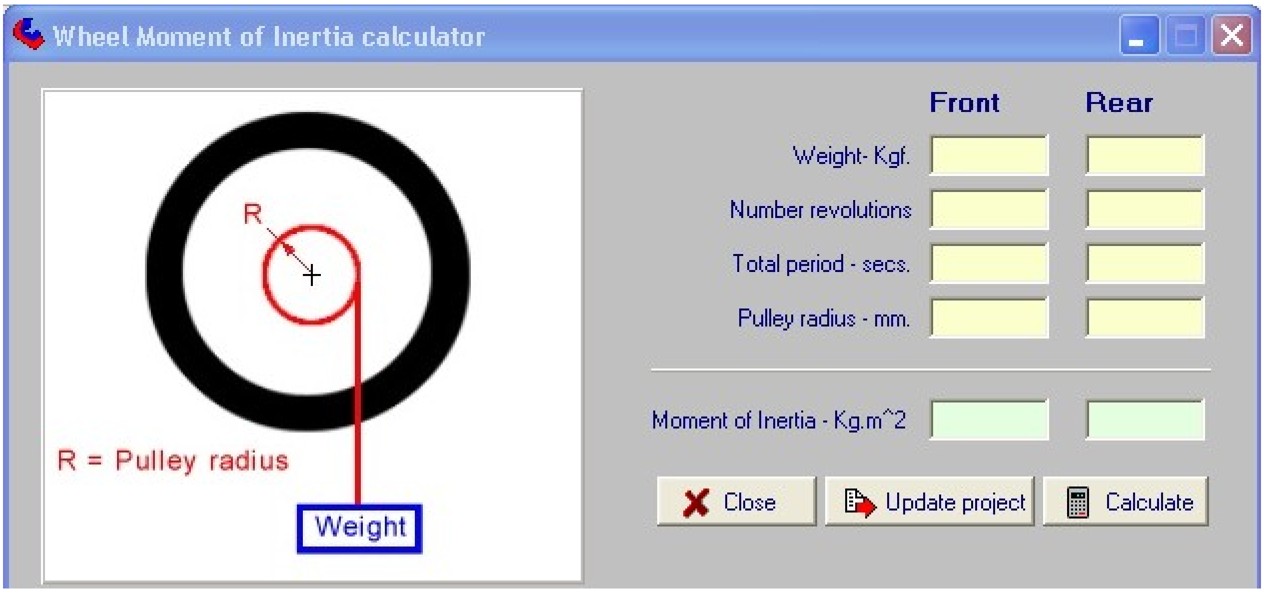


Wheel moment of inertia calculator

This calculator is really two in one. It can calculate for two different methods of physical measurements. This theme is covered in more detail in the following.







Moments of Inertia of the wheels and tyres

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

1. Swinging pendulum
2. Pulley and weight

These methods will be described in detail.

Swinging pendulum

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

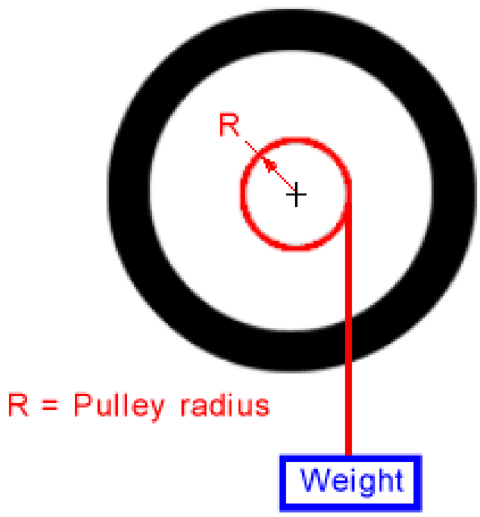
The distance between the swing axis and the axle centre needs to be measured. The wheel should be slightly displaced to one side and allowed to swing back and forth like a pendulum. Measure the time required to complete a number of complete cycles, 20 for example to reduce the effect of timing errors.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

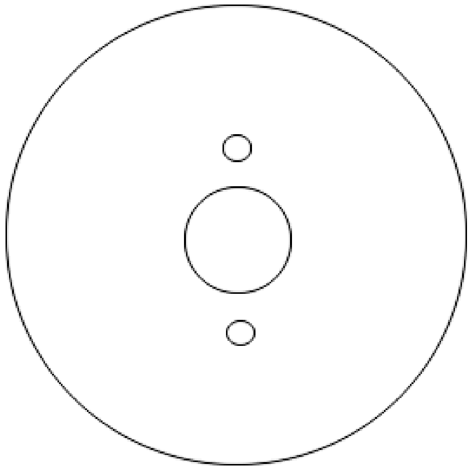
Pulley and weight

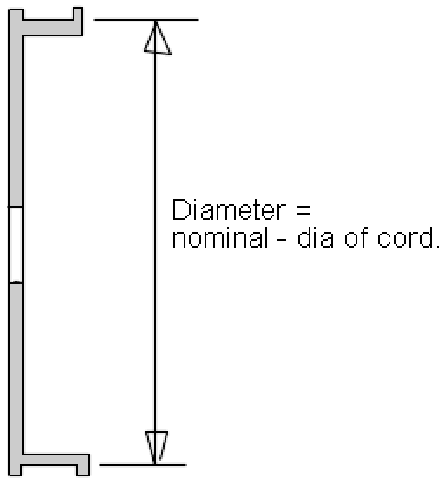
This is probably the most accurate method of the two, but requires a little more preparation. A small pulley (about 100 mm. diameter is ideal) needs to be made that can be attached to the wheel concentric with its spin axis. Some thin cord or flexible cable is wound around the pulley and the free end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

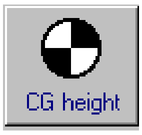
The pulley should be a light as possible so that it contributes a minimum to the MoI of the wheel, although in most cases it will be a simple matter to calculate its own MoI and subtract from the overall value, but this is usually not necessary.



Possible pulley design.





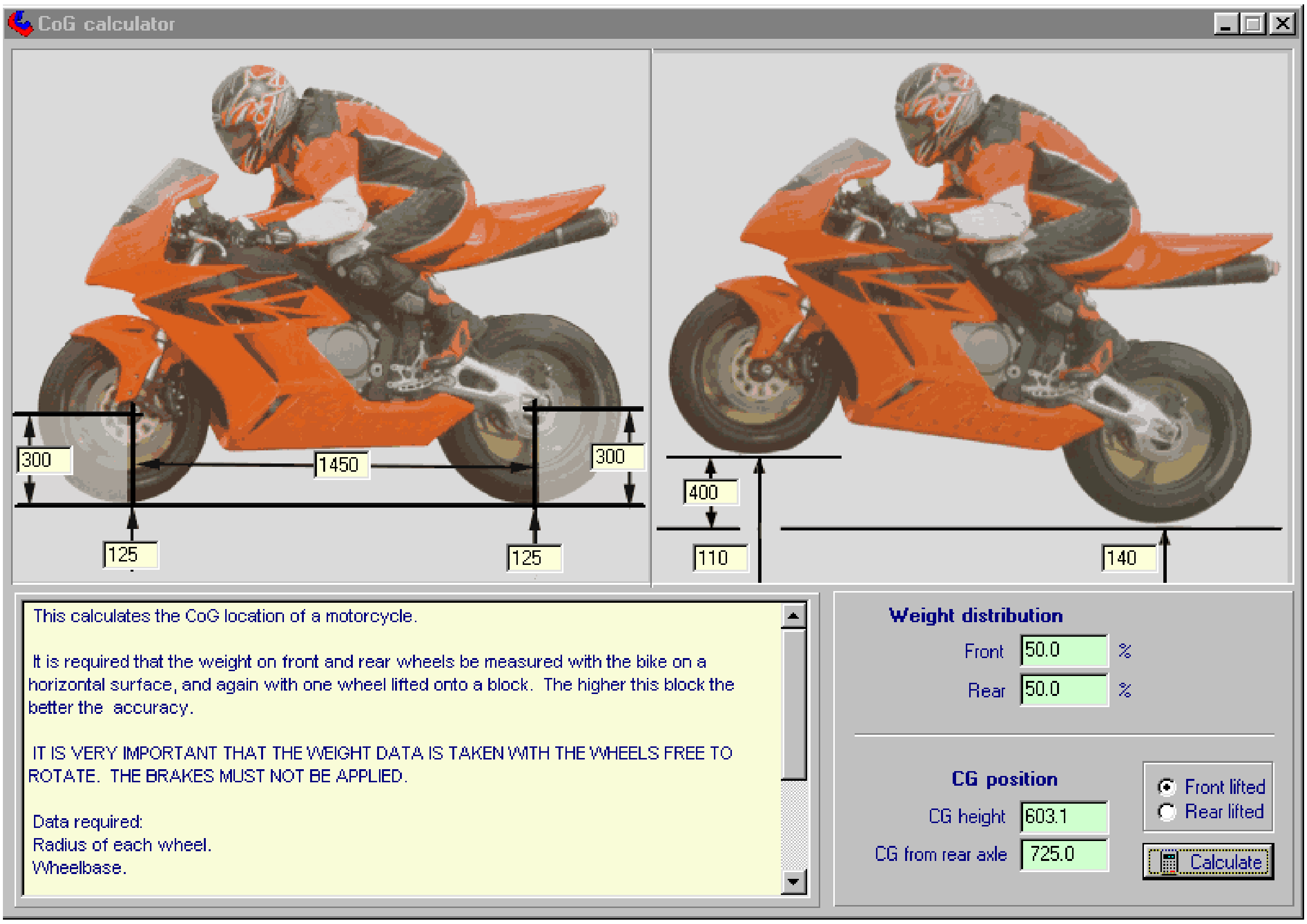


Centre of Gravity height

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.



Notes on input data & accuracy

GIGO is a well used acronym in the computer world. **I**t stands for "**G**arbage **I**n **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 so critical. The crankshaft moment of inertia (MoI) 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
Yamaha Venture		*0.75*
Honda V65 Magna		*0.61*
Honda Blackbird	*0,44 / 0,49*	*0,72 / 0,81*
Honda VF1000F	*0.40*	*0.46 / 0.45*
Aprilia Mille	*0,52*	*0,61*
Ducati 916	*0,49 / 0,57 / 0,53*	*0,61 / 0,69 / 0,61*
BMW R1100 RT	*0,53*	*0,97*
BMW K100RS	*0.40*	*0.43*
Yamaha R1 (1998)	*0,57*	*0,62*
Yamaha FJ1100	*0.43*	*0.48*
Kawasaki GPZ900R	*0.36*	*0.43*
Suzuki GSX1100EF	*0.41*	*0.44*
Suzuki GSXR750	*0.32*	
Suzuki Hayabusa	*0.31*	
Kawasaki ZX-12R	*0.34*	
Yamaha OW69	*0.32*	
Honda 1996 RS125	*0.20*	
Honda 1990 RS125	*0.19*	
Honda RS500	*0.24*	
Rifle faired Yamaha	*0.15*	

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. This value varies with altitude, temperature and humidity. Air density will have an effect on engine power as well as its aerodynamic effects, but these two effects partiallycancel out.

Inertial

CG height. This parameter controls load transfer under acceleration and so also tyre slip and maximum grip. It is of lessor 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 MoI – (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 MoI. 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 MoI 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 μ - (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.

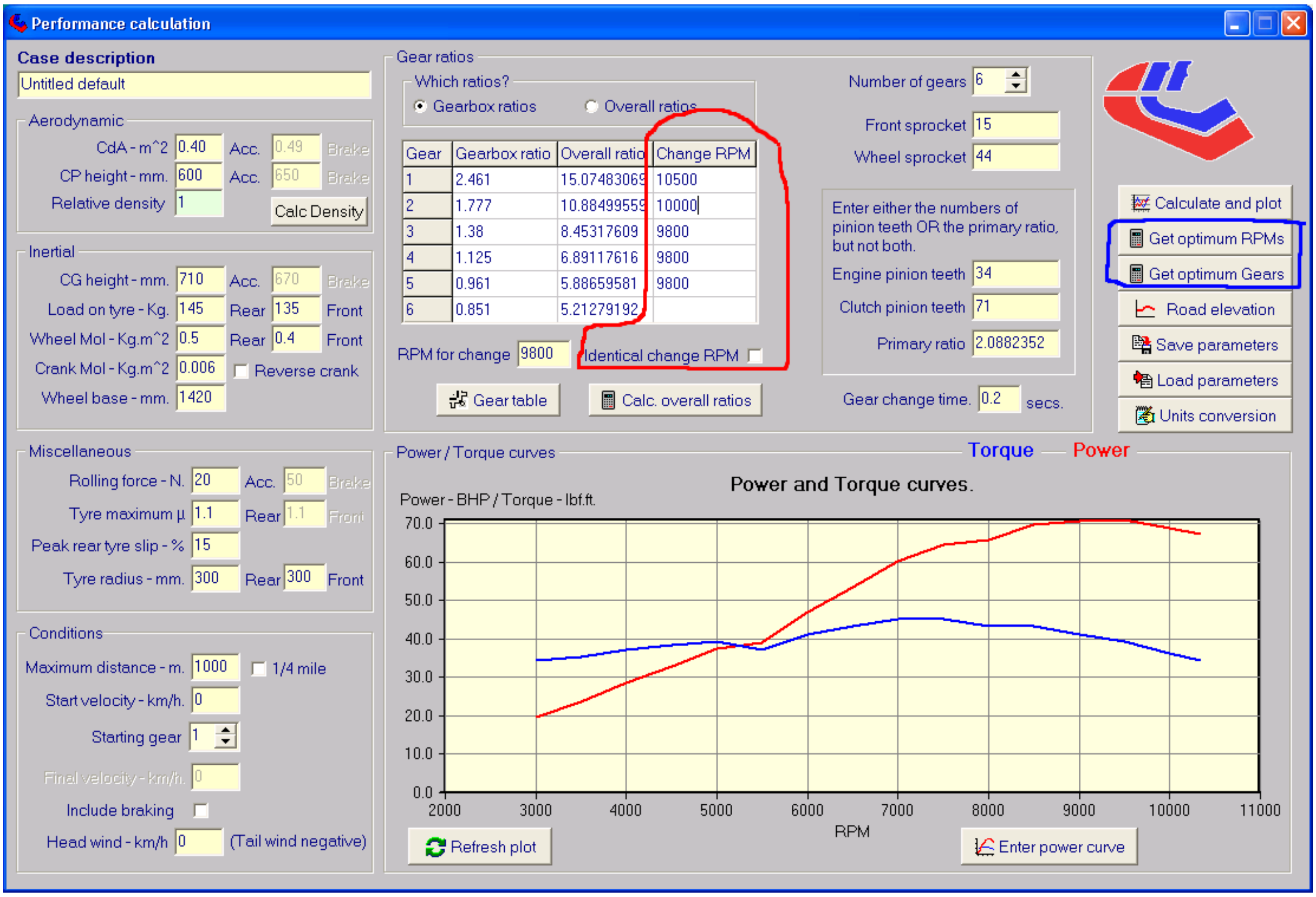
The peak driving force which can be generated occurs when the tyre circumference is travelling somewhat faster than the road speed. That is, the tyre is slipping. If we had the Pacejka coefficients then the degree of slip for a given tyre would be defined by the “magic formula”. The slip characteristics 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.

Changes and additions up to Version 3.0.7

There are changes which see the introduction of extra features designed to make optimising gear ratios and RPM change points as easy as pressing a button.

Let us look at the "***Main data***" window.



The red border shows an additional column which allows for different gear change RPMs in different gears and there is a tick box to fill the column with equal values for all gears.

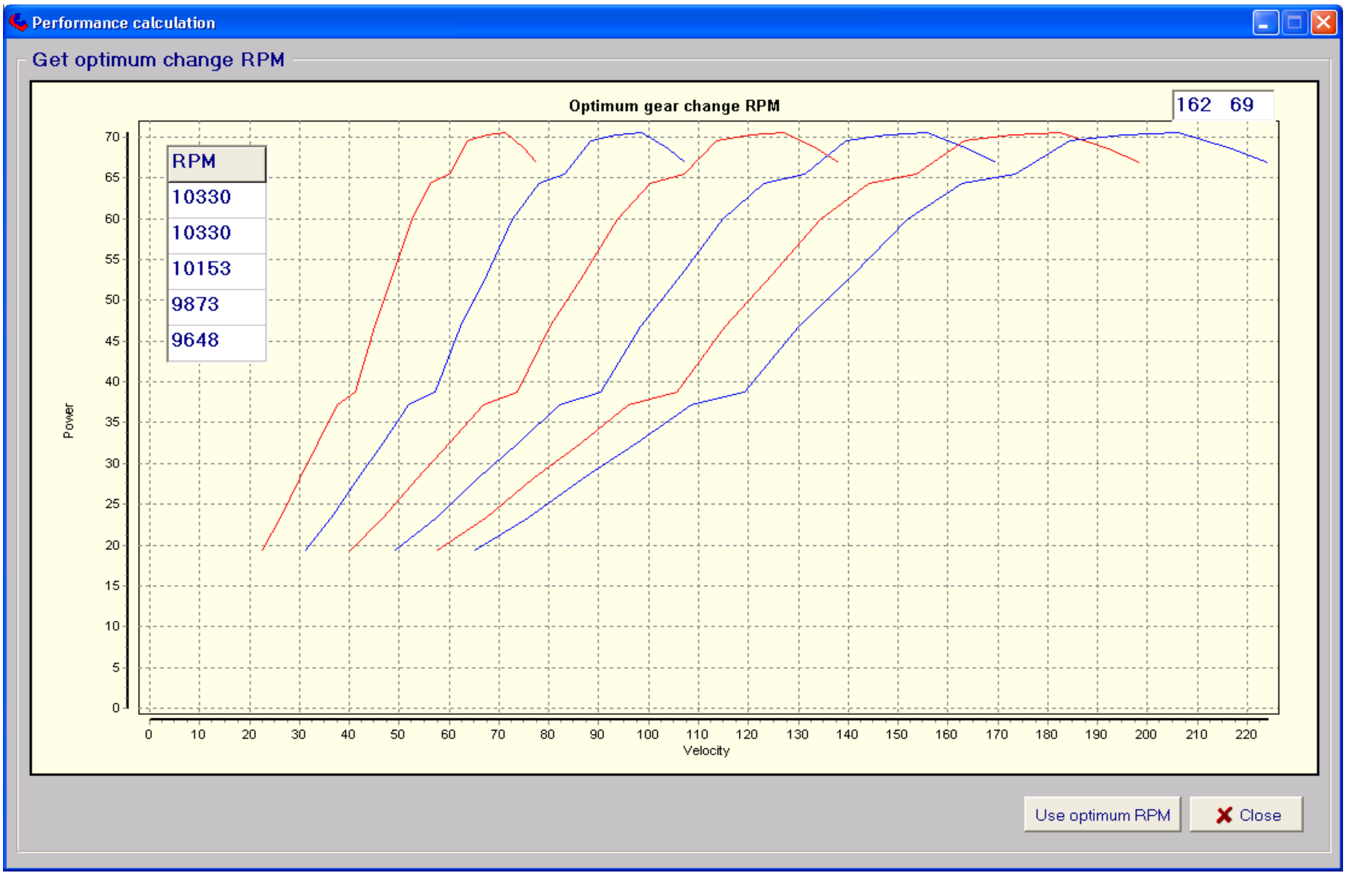
The blue border encircles two new buttons.

The first "***Get optimum RPMs***" opens a window, shown below, which calculates the optimum RPM at which to change gear to suit the power/torque of the engine and the gear ratios. It may come as a surprise to some people that although close this optimum RPM is not the same between all gears.

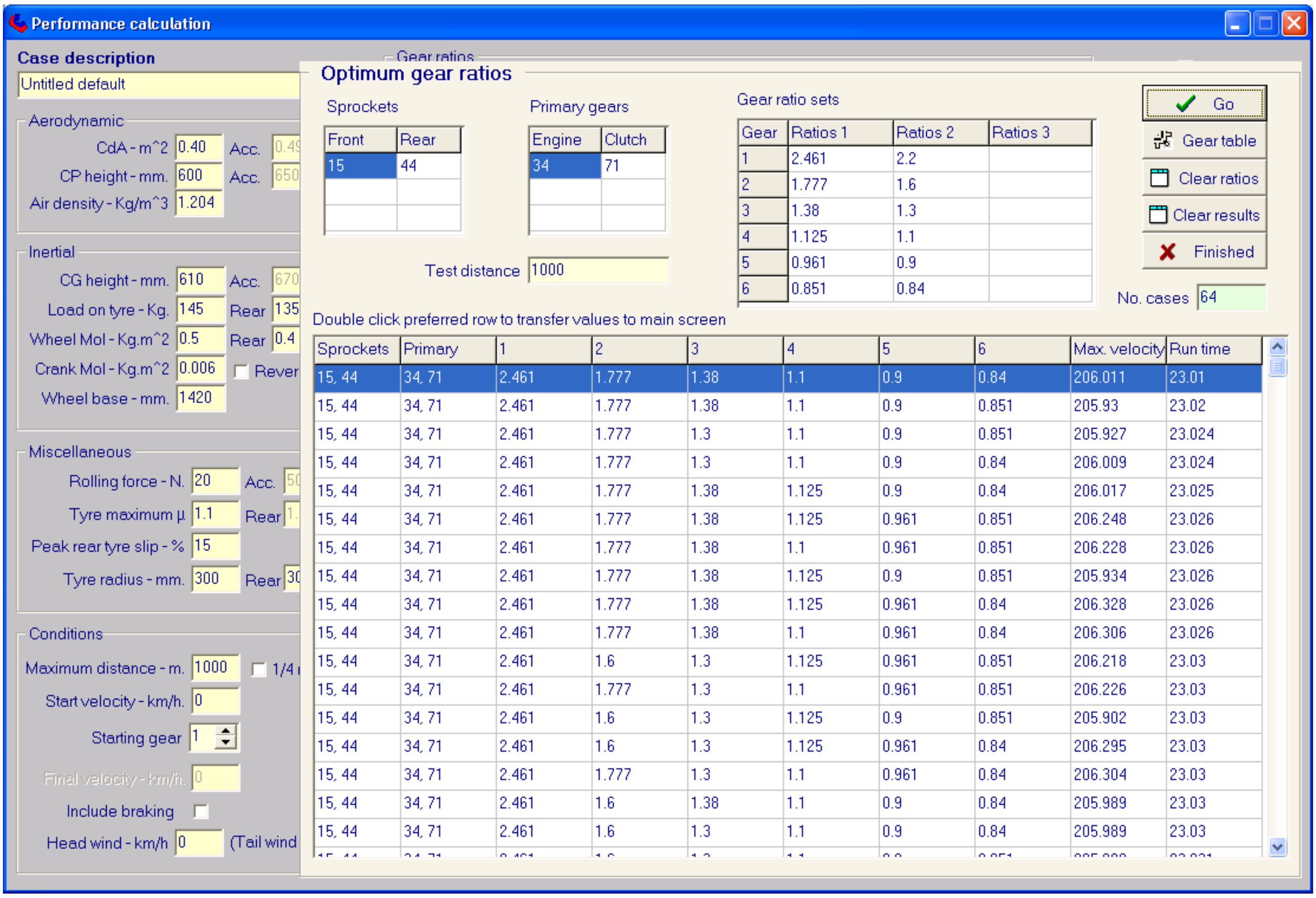
These optimum change RPM values are shown in the table to the upper left. The top value is for the change from 1st to 2nd gear.

The graph shows the power curve plotted against velocity for all gears.

Towards the lower left of the window is a button labelled "***Use optimum RPM***", clicking this will copy these optimum values into the main window and will be used in the on road calculations.



The “***Get optimum Gears***” button opens a window which allows for huge numbers of gear and sprocket ratio permutations to be calculated in only a few seconds.

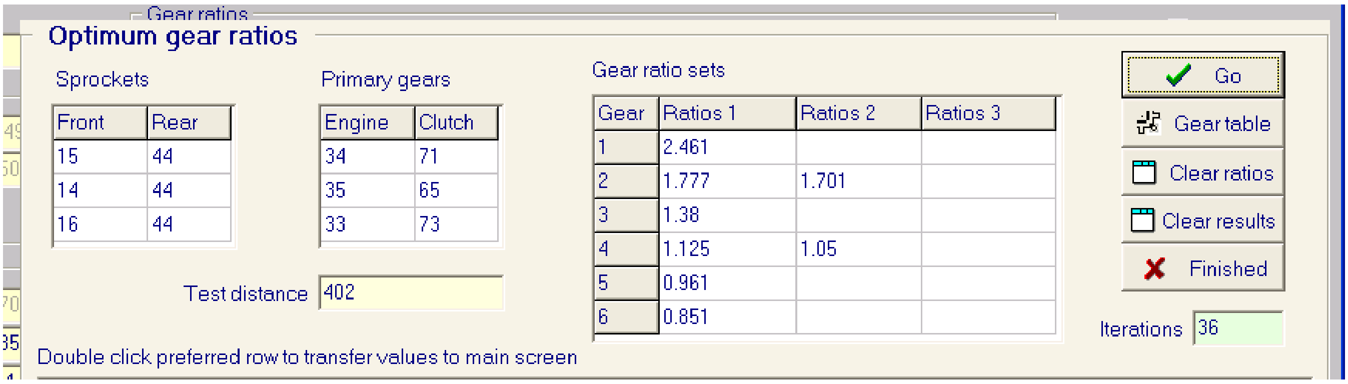


Gear	Ratios 1	Ratios 2	Ratios 3
1	2.461	2.2	
2	1.777	1.6	
3	1.38	1.3	
4	1.125	1.1	
5	0.961	0.9	
6	0.851	0.84	

Sprockets	Primary	1	2	3	4	5	6	Max. velocity	Run time
15, 44	34, 71	2.461	1.777	1.38	1.1	0.9	0.84	206.011	23.01
15, 44	34, 71	2.461	1.777	1.38	1.1	0.9	0.851	205.93	23.02
15, 44	34, 71	2.461	1.777	1.3	1.1	0.9	0.851	205.927	23.024
15, 44	34, 71	2.461	1.777	1.3	1.1	0.9	0.84	206.009	23.024
15, 44	34, 71	2.461	1.777	1.38	1.125	0.9	0.84	206.017	23.025
15, 44	34, 71	2.461	1.777	1.38	1.125	0.961	0.851	206.248	23.026
15, 44	34, 71	2.461	1.777	1.38	1.1	0.961	0.851	206.228	23.026
15, 44	34, 71	2.461	1.777	1.38	1.125	0.9	0.851	205.934	23.026
15, 44	34, 71	2.461	1.777	1.38	1.125	0.961	0.84	206.328	23.026
15, 44	34, 71	2.461	1.777	1.38	1.1	0.961	0.84	206.306	23.026
15, 44	34, 71	2.461	1.6	1.3	1.125	0.961	0.851	206.218	23.03
15, 44	34, 71	2.461	1.777	1.3	1.1	0.961	0.851	206.226	23.03
15, 44	34, 71	2.461	1.6	1.3	1.125	0.9	0.851	205.902	23.03
15, 44	34, 71	2.461	1.6	1.3	1.125	0.961	0.84	206.295	23.03
15, 44	34, 71	2.461	1.777	1.3	1.1	0.961	0.84	206.304	23.03
15, 44	34, 71	2.461	1.6	1.38	1.1	0.9	0.84	205.989	23.03
15, 44	34, 71	2.461	1.6	1.3	1.1	0.9	0.84	205.989	23.03

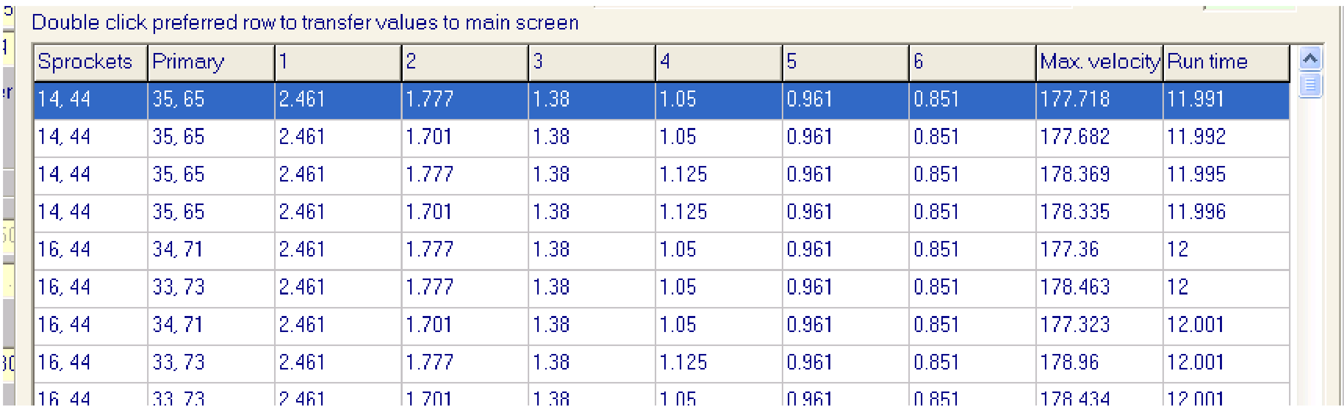
In the above screen shot there has been only two sets of gear ratio options entered and one each of sprocket and clutch ratios. Clicking the "***Go***" button will run all possible combinations and that is 64 runs through the performance software to make up the table which is ordered by the elapsed time to cover the specified distance. Shortest time at the top of the list.

With three sets of data each for sprocket ratio, primary ratio and three full sets of gears the number of iterations goes up to nearly 7000, this can take some time to execute depending on the speed of the computer. However, in practice it would be unlikely that we would want to run this maximum number of cases. It would be more likely that we might look at say three gearbox options with just one primary ratio and one sprocket combination, This would bring the number of iterations down to 759. If we just want to investigate the effects of three different sprocket and three different primary ratios with a single set of gearbox ratios then 9 iterations is all that is required.



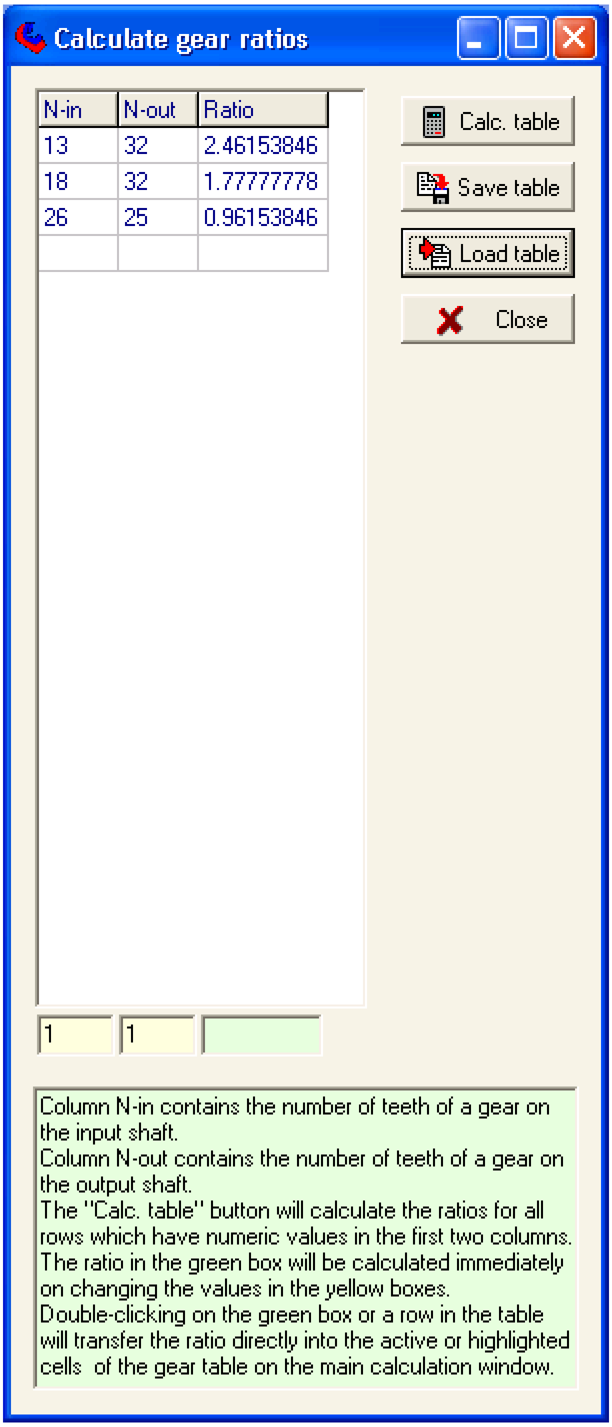
Often we might only have a limited choice of alternative gearbox ratios available as shown above. Here we only have alternatives for 2nd and 4th gears. The software was designed to handle such cases and it is very flexible in this regard.

Once we have completed our optimisation of our gearing options we can see the relative performances of all ratio combinations in the following table. From this we can select one combination which we decide to use, if we double click on the row containing that combination then the gearing data will be entered into the main calculation window for further analysis and plotting.


Double click preferred row to transfer values to main screen

Sprockets	Primary	1	2	3	4	5	6	Max. velocity	Run time
14, 44	35, 65	2.461	1.777	1.38	1.05	0.961	0.851	177.718	11.991
14, 44	35, 65	2.461	1.701	1.38	1.05	0.961	0.851	177.682	11.992
14, 44	35, 65	2.461	1.777	1.38	1.125	0.961	0.851	178.369	11.995
14, 44	35, 65	2.461	1.701	1.38	1.125	0.961	0.851	178.335	11.996
16, 44	34, 71	2.461	1.777	1.38	1.05	0.961	0.851	177.36	12
16, 44	33, 73	2.461	1.777	1.38	1.05	0.961	0.851	178.463	12
16, 44	34, 71	2.461	1.701	1.38	1.05	0.961	0.851	177.323	12.001
16, 44	33, 73	2.461	1.777	1.38	1.125	0.961	0.851	178.96	12.001
16, 44	33, 73	2.461	1.701	1.38	1.05	0.961	0.851	178.434	12.001

Clicking on the "***Gear table***" button will bring up a small window as shown next. Here we can enter the number of teeth on any pair of gears to calculate the ratio. This is useful to enter all the gear ratios available which can then be saved to files and reloaded when necessary. Double clicking on any particular row will enter that ratio into the active cell in the main table of gearbox ratios, so it becomes very quick to virtually build up a gearbox without re-typing each ratio. Different files could be saved for different motorcycles.



Environmental conditions

Air density affects both engine power and aerodynamic drag proportionally and so the effects of density change is partially cancelled out. So at first sight we might think that we could ignore changes. Unfortunately it is not that easy because other factors such as rolling resistance and mass are not affected by density and so the balance is upset.

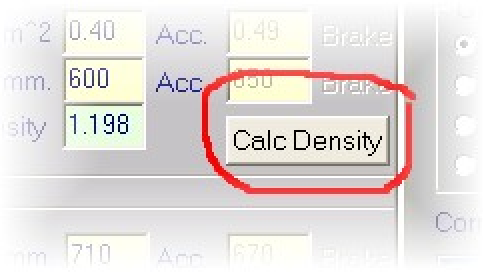
In previous versions of the software there was single piece of input data, the density of the air. Version 3 has made this easier by doing the calculations for you based on temperature, barometric pressure and relative humidity. The automotive industry has various standards for calculating the change in engine output depending on environmental conditions. When engines are dyno tested the results should be corrected to one of these standards.

Although similar these standards vary slightly with regard to what each considers the "standard" conditions. The software has four main standards built in which cover the more important standards, these are:

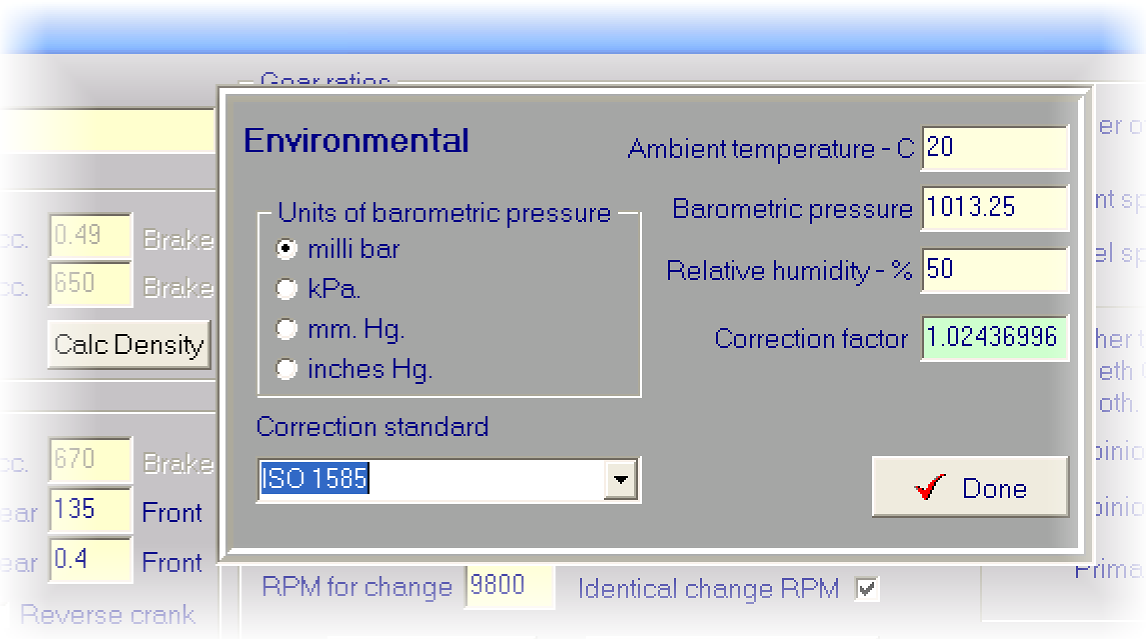
SAE J1349, ISO 1585, JIS D1001 and DIN 70020.

Note that the DIN standard does not take relative humidity into account.

Not only do these different standards use different base values for the standard temperature, pressure and humidity, they calculate the correction factors differently.

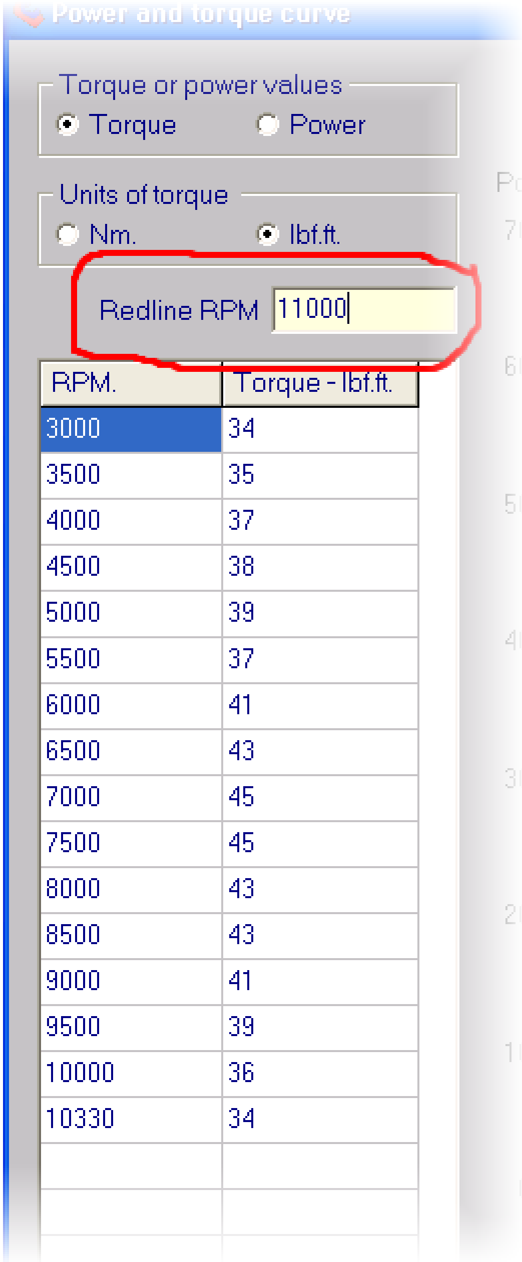


There is a new button on the main screen labelled "***Calc Density***" which opens a panel for the entry of the environmental data.



There is a choice of units for the barometric pressure with milli-bars being the default. This can be changed and the appropriate value for pressure entered to the right. The standard to which your dyno results were corrected can be chosen from the drop down box. If that is unknown, use the default SAE. Enter the three environmental variables which match the conditions which you want to simulate and click on the "***Done"*** button. This will calculate a correction factor which is applied to both the aerodynamic drag and the power/torque values. Note that the table and graphs of engine power remain the same as the originally entered data, as the base reference. Only the internal calculations use the corrected values. Values of the correction factor outside the range of say 0.8 to 1.2 are indicative of an incorrect data value. Lower values may be OK at high altitudes though.

RPM limit



Version 3 has a new data box on the power curve window labelled ***"Redline RPM"*** which allows entry of an RPM limit which is not exceeded in the performance calculations. In the table shown above the maximum RPM entered in the table is 10330 but the redline is entered as 11000. The value entered in the table takes priority and when either the ***"Plot"*** or ***"OK"*** buttons are clicked the redline will be adjusted down to 10330. If the redline value is less than the table maximum then the redline value will be used.

If the RPMs set for gear changing on the main window are higher than the redline, then when the "***Calc overall ratios***" or "***Calculate and plot***" buttons are clicked those RPMs will be adjusted down to the redline.

The redline value acts as if it was a rev-limiter, that is the RPM and hence the velocity will remain constant and acceleration will be zero.

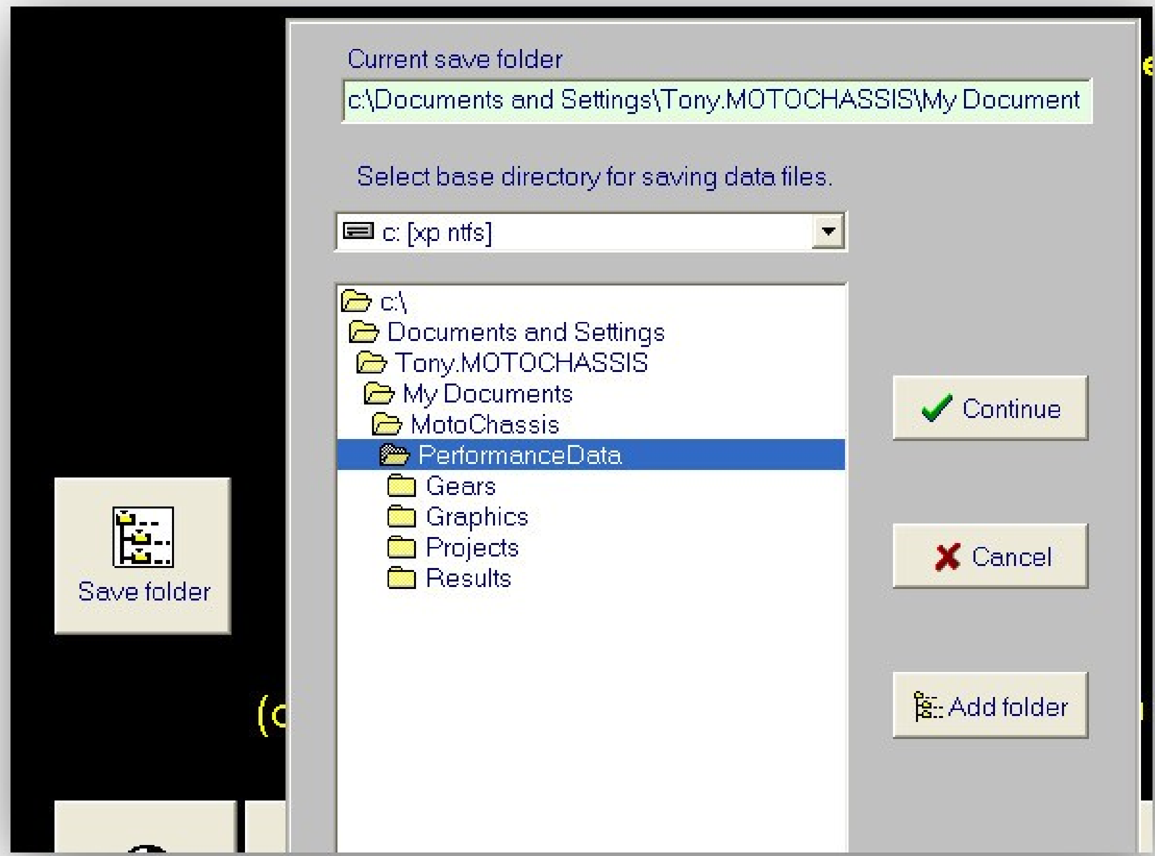
The redline value does not influence the calculation of the optimum gear change values because if these are higher than the redline it will show the potential in raising the redline where mechanically prudent.

Additions in v 3.0.7

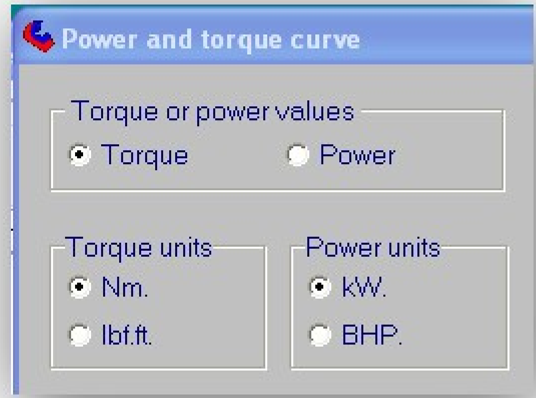
Save directory.

A new button has been added to the left of the opening window, labelled **"Save folder".** This opens up the option to select where you want to save files. This selects the base folder and the software creates sub-folders within this for the different types of files.

If this is an update installation and you have files saved elsewhere then if you select a different base folder then you will have to manually move your files from the old to the new folder.



Additional selection on torque curve window.



The torque and power units selection have been separated and allow metric and imperial units to be mixed for display. These settings only affect the values on the plot and in the data table. Internal calculations are always done using torque in Nm, but this is transparent to the user.

The “Torque or power” selection should only be set once for any particular power/torque curve. This setting specifies whether your input values are torque or power in the units specified in the units selection.

For example if you select “Power” and then enter power values, everything will be fine. However, if you then change the setting to “Torque”, the software assumes that your input was torque and will calculate erroneous values for power.

So, if your data is torque then select “Torque” as your first action and do not change it, likewise if you select “Power” be sure to enter data in power values. Whichever type of input data you use be sure to set the appropriate units. When you have finished the data entry you can freely change the units and the graph will respond with the new values. The data that the user entered in the data table never changes under software control, it always remains as the user entered it, so it is important that the torque and power units are correct before proceeding to the performance calculations.

The above behaviour is pretty much as it was in previous versions, but some users found it confusing and the above is to add some clarity.

REMEMBER: The data in the table always remains as the user entered it, the units and type of data that is plotted and passed into the performance calculations is controlled by the three settings in the screen snippet above.