# GETTING STARTED WITH LOTUS CONCEPT CRANK TRAIN

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# WITH LOTUS CONCEPT CRANK TRAIN

VERSION 4.0

# Contents

# About This Guide

## Welcome to Lotus Engineering Concept Crank Train

Welcome to Lotus Engineering Concept Crank Train. This product will allow you to analyse and refine automotive style crankshafts for deflection, stress, fatigue, bearing loads, oil film thickness, balance and torsional vibrations. A 'drag and drop' interface allows you to build crankshafts connecting individual elements together, each element having it own unique set of properties.

## What You Need to Know

This guide assumes the following:

- Lotus Concept Crank Train is installed on your computer or network and you have permission to execute the relevant Lotus modules.
- The necessary password files are installed to allow you to run the necessary modules.

You have a basic understanding of engine crankshaft mechanisms, their loading regimes and functional operating requirements.

# 1 Introducing Lotus Concept Crank Train

## Overview

This chapter introduces you to the Lotus Concept Crank Train Analysis Tool and explains the normal uses for it. It also introduces the tutorials that we've included in this guide to get you started working with Lotus Concept Crank Train.

This chapter contains the following sections:

## What is Lotus Concept Crank Train?

Lotus Concept Crank Train is an analysis tool that can be used during the concept design phase of an engineering project. It combines a number of individual analysis tasks into one environment providing seamless use of data between these tasks. A ‘drag and drop’ interface allows the user to build complex multi-cylinder crankshafts up out of individual parts, such as webs and journals, in an intuitive user-friendly manner.

Created models can be reviewed through an animated 3d viewing module, that not only displays a scale wire frame display of the crankshaft, but also animates the results directly on to the model. This provides a user method for checking the model and visualising the results.

## Normal Uses of Lotus Concept Crank Train

The principal use of Lotus Concept Crank Train is to identify the critical material and dimensional requirements of an automotive style crankshaft. This is done by considering a range of analysis ‘tasks’. These ‘tasks’ include torsional vibration analysis, bending stress analysis, combined bending and torsional stress analysis to predict operating fatigue reserve factor values, bearing analysis for peak loads and minimum oil film thickness values.

Model properties such as bearing dimensions are changed until the calculated results conform to the required analysis targets. The underlying calculations are based on classical analysis techniques, with added algorithms based on findings from Finite Element analysis results and photo-elastic models.

## Overall Concepts

Concept Crank Train has a data entry phase, a solution phase and a post-processing phase. The data entry phase is the 2d layout of the elements using the builder interface. The solver phase is simply the move from the data entry phase into the 3D results viewer post-processing phase. Additional results display in the form of text listings and x-y plotting is also available as part of the post-processing.

Within the Builder environment the data is structure by component/type rather than analysis task into a series of modules. The current modules are;

| | |
|---|---|
| Crankshaft | Define and analyse the crankshaft model |
| Piston Pin | Define and analyse the piston pin |
| Bearings | Define and analyse crankshaft bearings |
| Material | Define Material properties |
| Loads | Define Load conditions |
| Lube Oil | Define Oil supply properties |

The data is structured such that information from one module is available in any relevant other module by reference to labels. This minimises data entry repetition and avoids typographical errors.

## About the Tutorials

The remainder of this guide is structured around a series of tutorials that introduce you to the features of Lotus Concept Crank Train. Each tutorial builds on what was learnt in those before it and are thus linked such that the user should work through them in the order presented.

- Getting Started – Inesothe layout of the application, teaches you how to load existing files and move between individual modules.
- Crankshaft Module as Dethe requirements for building a crankshaft model, working within the drag and drop environment and using data from other modules.
- Piston Pin Module ewsthe piston pin analysis module, its data requirements and analysis results.
- Bearings Module – sthe data entry for bearings, a look at the local analysis results and data values available for use in other modules.
- Materials Module – sadding, deleting and modifying the models local materials database that is accessed by the analysis modules.
- Loads Module – Detfining load points for use in the analysis modules. This includes various methods for defining FMEP.
- Lube Oil – Introducesethod for defining the oil properties as a function of engine speed. These are then referenced by the appropriate analysis modules.

# 2 Getting Started

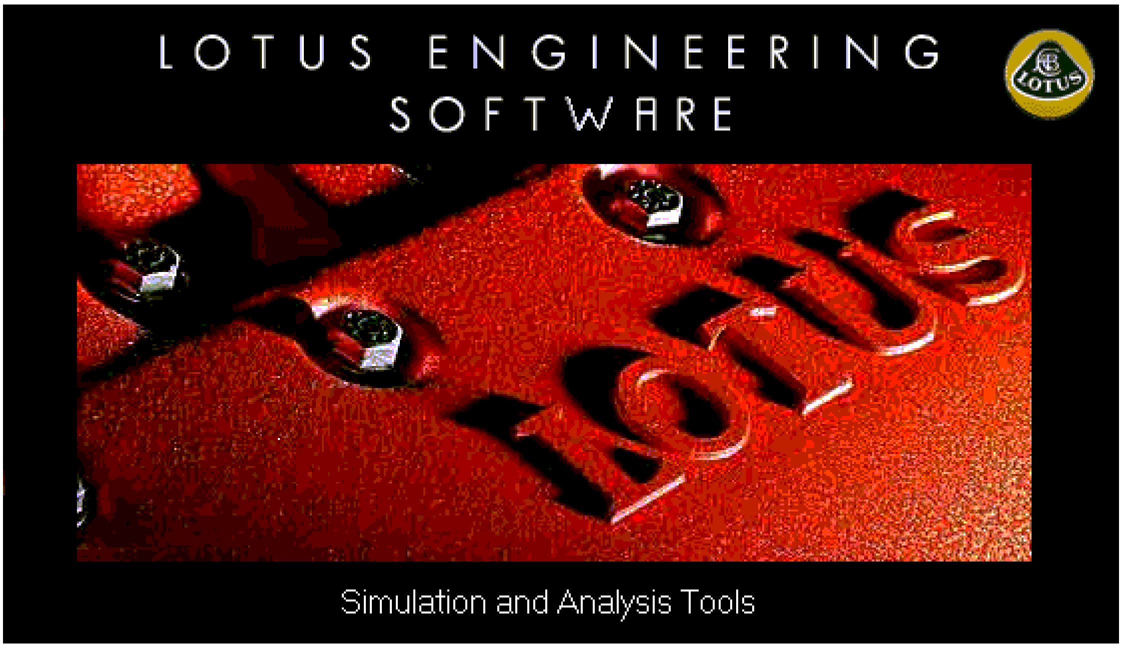
## Overview

This tutorial introduces the main visual features of the product, starting the application, the layout, opening and saving data files, moving between data modules and closing the application.

This chapter contains the following sections:

## Starting the Application

To start Lotus Concept Crank Train from the main **Start** menu point to **Programs** and then **Lotus Engineering Software** and then **Lotus Concept Crank Train**. If the program fails to start or the menu item is missing from your start menu, firstly confirm that the software has been installed correctly. You can browse for the application directly, the executable file name is *Leconcept3.exe*. As the program starts the start up 'splash' screen will be displayed, before the main application window is opened.

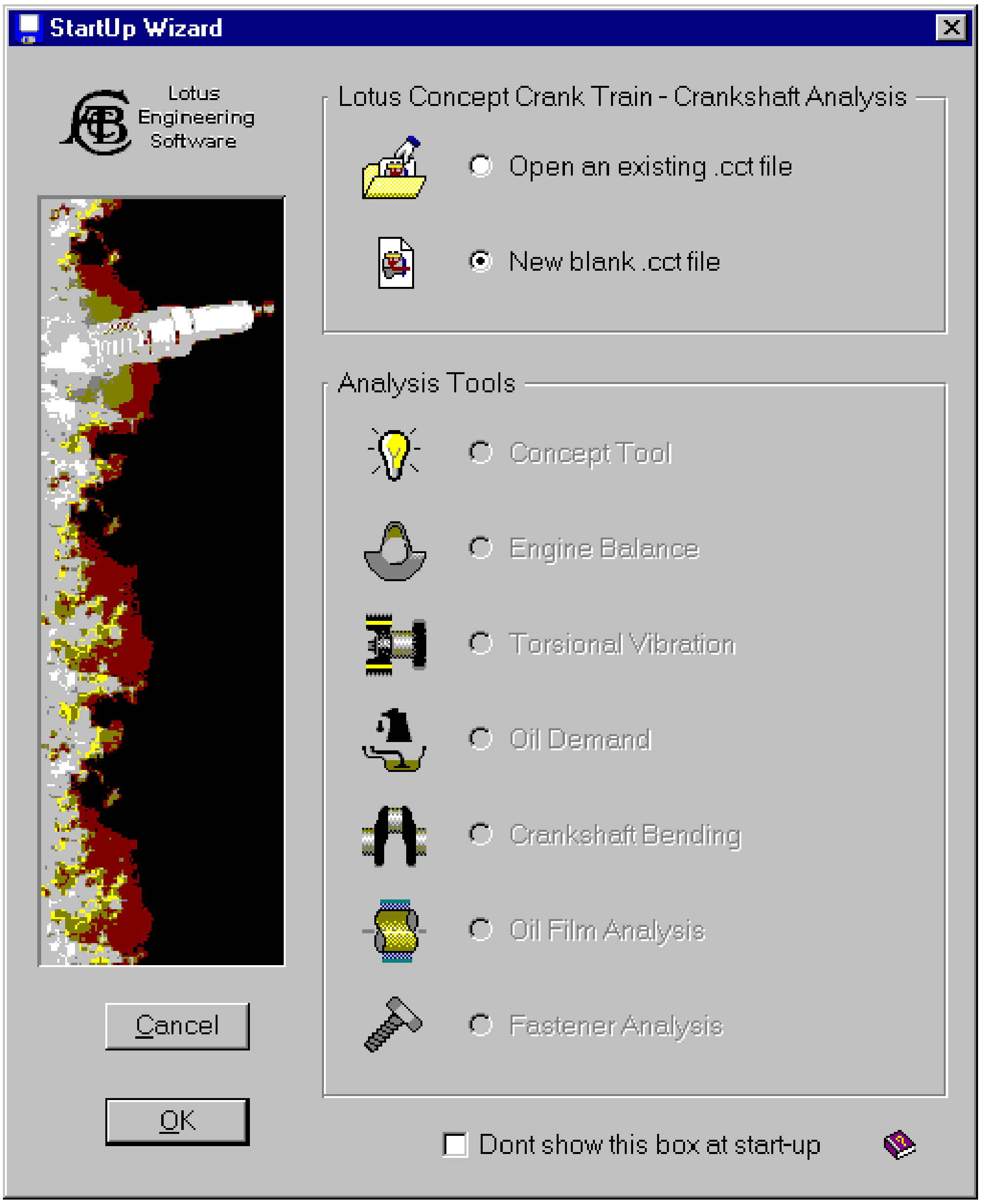



Start-up Splash Screen

## The Start-up Wizard

On start-up the application displays a Wizard' display. The functionality of this is currently limited to selecting either the opening an existing file, or starting with a new file. The remainder is reserved for future development and is not yet activated.

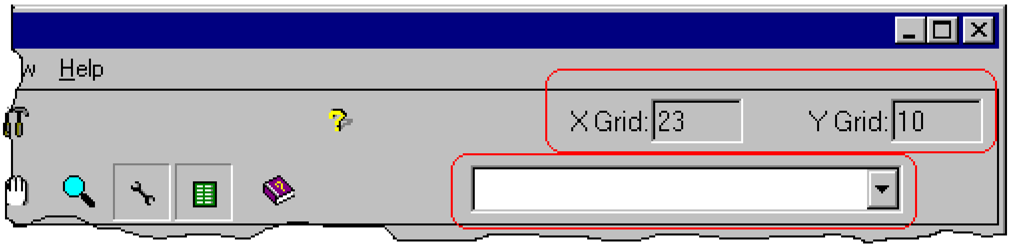
We will select **New Blank .cct file**, and then select **Ok.**




Start-up Wizard

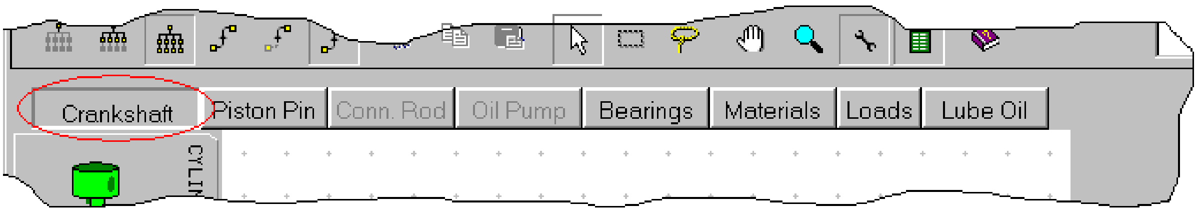
## The Application Layout

On start-up the application is in the 'Builder Interface' phase with the 'Crankshaft' being the currently selected module. The application has a main menu bar and collection of toolbars across the top of the main window. In addition the top region of the window contains two numerical display widgets that indicate the current screen position of the cursor. A selection box is also included in this region to allow selection of the model components by their assigned label.




Main Window Display, Selection box and co-ordinates indicated

Below the toolbar region is the main working area of the application. Here you will build the models, view data, and display results. Along the top of this region are a series buttons that are used to move between the separate modules. The one indented indicates the current module, which in our case is the 'Crankshaft' one.



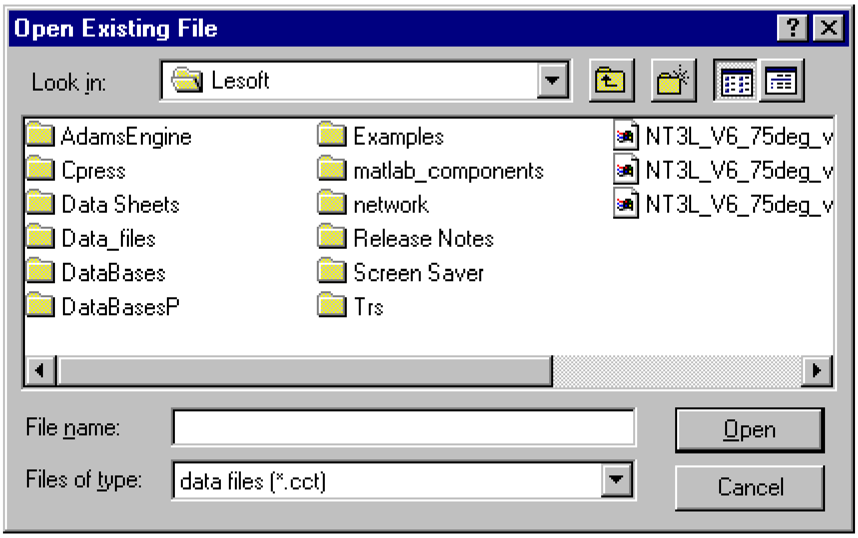

Main window Display, Module buttons indicated, Crankshaft selected

The appearance of the main working area will change slightly depending on which module you are in. The major difference is the inclusion of a panelled toolkit region to the left of the working area for the crankshaft module. This toolkit contains the standard building elements for our crankshaft module and is only relevant to this module.

The majority of the working area is given over to the graphical display region. On the far left is the property sheet region. Here the properties of the currently selected part, bearing, piston pin etc are listed. The actual content of the property sheet depends on the current module and also, for the crankshaft module, the current element type.

## Opening a Saved Data File

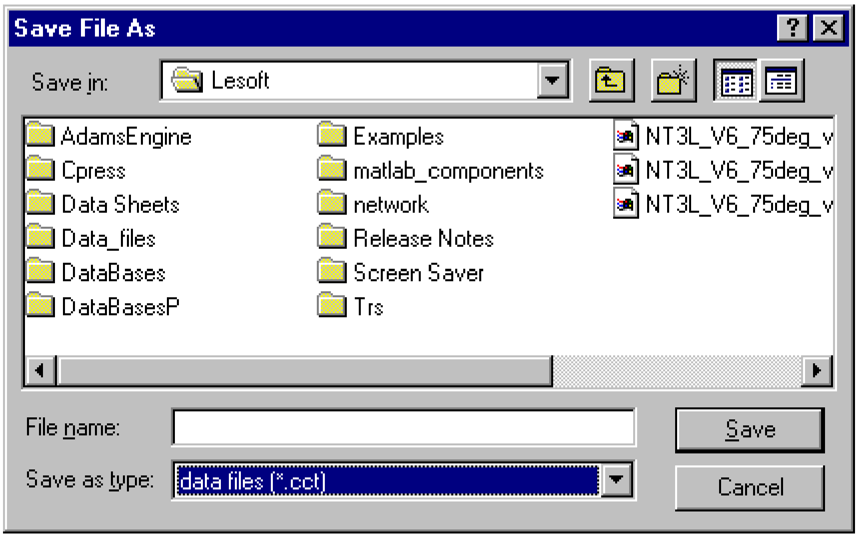
To open a saved data file select from the main menu the menu item, *File / Open*. This open the standard Windows© file browser. You would use his to browse for the target file, select this file and then select the **open** button. Note that if you have an existing model loaded you will be warned of potential data loss of the existing model and asked to confirm this action. The 'standard' file extension for Lotus Concept Crank Train data files is **.cct**.




File Open Browser

## Saving a Data File

Once we have created a model we will need to save it for possible future use. To save a model select the main menu item *File / Save As*. This will open the standard Windows© browser. In the normal way move to the required folder and enter the required file name. The standard concept crank train file extension of .cct will automatically be added if no file extension is given. The use of the 'standard' file extension is recommended as it aids recognition and assists loading since the browse 'filters' will correctly select out only the relevant files.



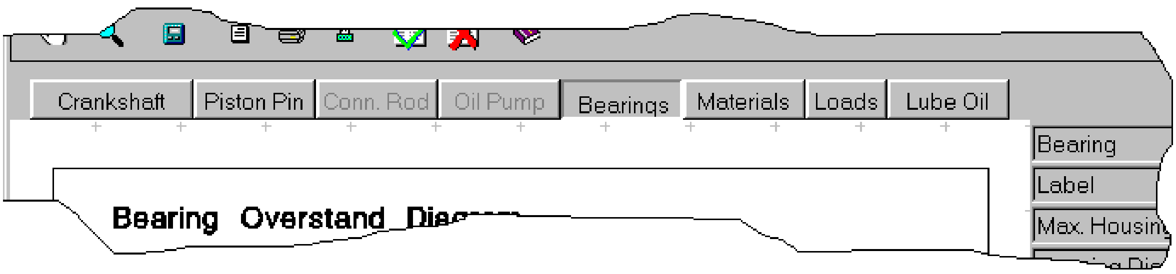

File 'Save As' Browser

## Moving Between Modules

To move between the separate modules, select the required module directly using the relevant module button. A number of the module buttons are 'greyed' out. These are reserved for future development.

As you select a module button the display will refresh to show the selected modules graphical display and relevant properties. No data is lost as you move between modules, each module retaining its own information independently of each other. The secondary tool bar icons will change to those specific to that module.

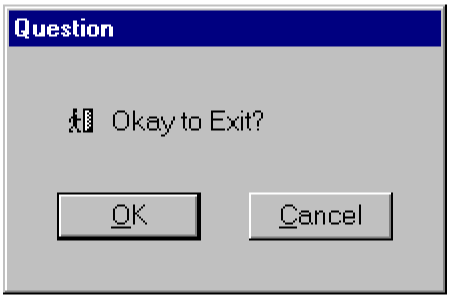
For now we are not specifically interested in the contents of each module only the method of moving between them. We will cover the contents of each and the moving of data between them in specific later tutorials.




Main Window, Module setting changed to 'Bearings'

## Closing the Application

To close the application either select the 'x' at the top right of the main display, or select the main menu item *File / Exit*. You will be asked to confirm this action to avoid accidental data loss. You should remember to save all work before exiting the application.



Exit, Action confirmation dialogue

# 3 Crankshaft Module

## Overview

This chapter describes the Crankshaft Module, how to build a model from components, use data from other modules, save the model, run the analysis and review the results.

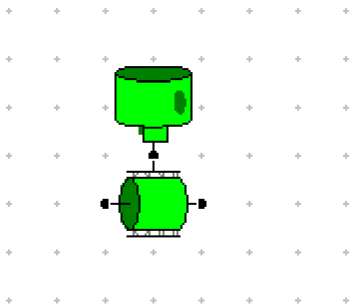
This chapter contains the following sections:

## Building the Model

We will build a sample in-line 4 cylinder crankshaft model. A useful feature of the builder environment is that all elements are added from the toolkit with their data fields fully populated. Thus we can initially concentrate on the process of building a model, and concern ourselves with data modification later. It is sufficient to note that an elements properties are displayed in the right-hand property sheet, when that element is 'in focus'.

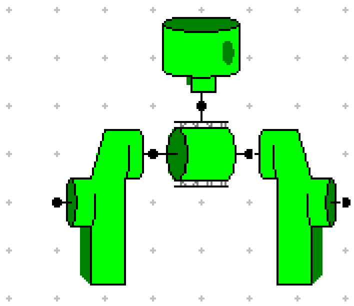
Start in the **Crankshaft** module, set to a new model ***File / new***. Select from the left-hand toolkit a cylinder element. To do this select the cylinder image with the left mouse button and either hold down and drag onto the workspace, or release move to the workspace and select position again with the left mouse button. Not that the cylinder added has a 'flashing' box around indicating that it is 'in-focus' and its properties are displayed in the right-hand property sheet.

Change the toolkit tab to **journal** by selecting the relevant tab area. We will now add a crankpin journal to our cylinder. Select the journal image with three connections from the toolkit with the left mouse and drag onto the workspace. Position such that the top connection is attached to the cylinder connection.



Cylinder and crankpin journal connected

Change the toolkit to the **webs** panel and select the top 'conventional' web element. Place <u>two</u> on to the workspace. Connect the first to the left-hand end of the journal. To connect the second to the other end we need to 'flip' its direction. To flip the second web select it so that it is in focus and either use the shortcut key **Ctrl+F** or pull up the right mouse menu and select **Flip Direction** from the menu. Now make the connection between this second web and the crankpin journal.

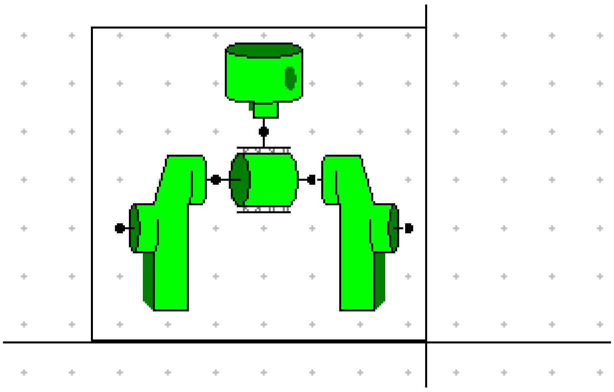


Webs added to crankpin

Note that you can move individual elements around the workspace by selecting them and using the ‘arrow’ keys to move up, down, left and right one grid point at a time. When you move an element it can either be moved individually or moved with its 1st children or the entire chain. See the ***Edit / Move By*** menu item for option setting.

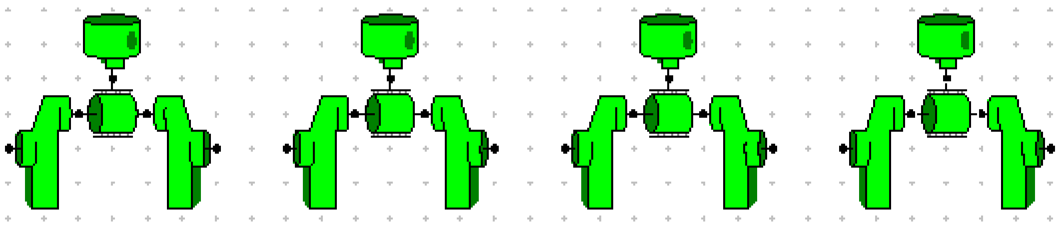
We could now repeat the above sequence of events to add the other three cylinder groups. To speed up the model building process we will use the cut and paste functionality.

To select a screen area rather than just a single element, select the menu option ***Edit / Pick Area***. Then use the left mouse button to ‘box in’ the current model components.



Selecting the model using the ‘Pick Area’ option

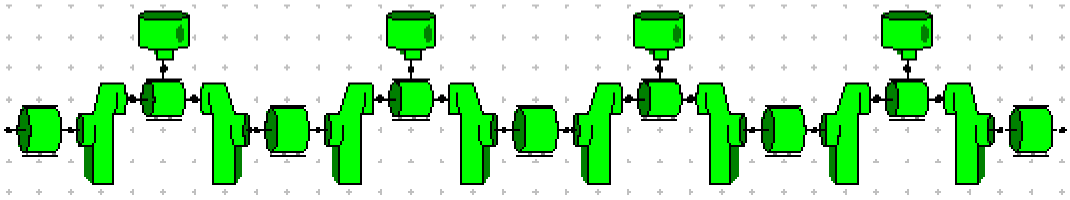
Once the elements are selected, use the menu items ***Edit / Copy*** and ***Edit / Paste*** to add a copy of our cylinder group onto the workspace. To move the pasted group select the new crankpin and drag it to the right-hand side of the original cylinder. (tip leave a couple of grids space for a main journal element). Repeat the paste and move operation twice more to complete our four cylinders.



Four cylinders after three pasting operations

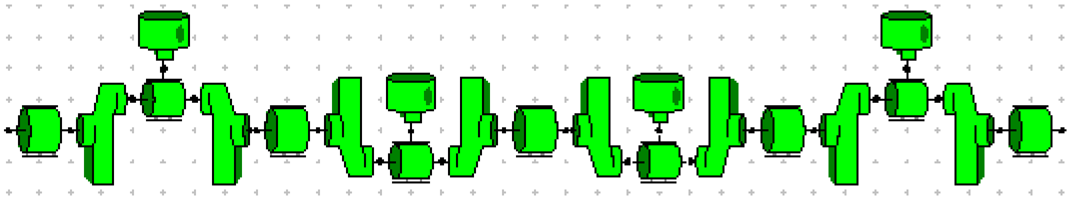
To manipulate the displayed view of the model, use the **View** menu to access the **Dynamic Translate** and **Dynamic Scale** options. It is useful to ensure that your cylinders are numbered left to right 1,2, 3 and 4. Whilst this is not a requirement it will avoid any potential for later confusion when setting individual properties.

Change the toolkit back to **Journals** and add five journals. In a similar vein to cylinders it is advisable to add them from left to right, such that number 1 is in front of the first web and the fifth is behind the last web.



Main journals added

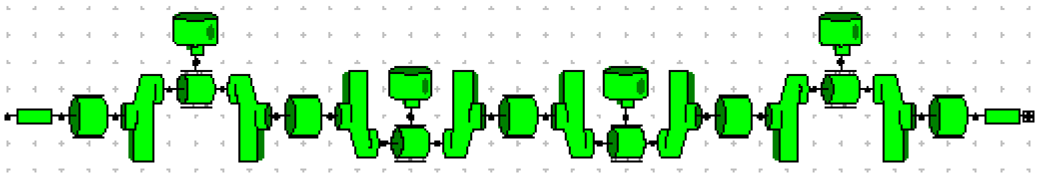
Before we add the elements representing the front and rear of the crankshaft we could rearrange some of the elements to visually appear more like our actual crankshaft form. The image below has used the element 'flip' and 'rotate' commands to reposition the middle pair of cylinders. Try and repeat the appearance of the model, (the rotate command can be founds on the elements right mouse menu).



Model Image changed to reflect actual crankshaft form

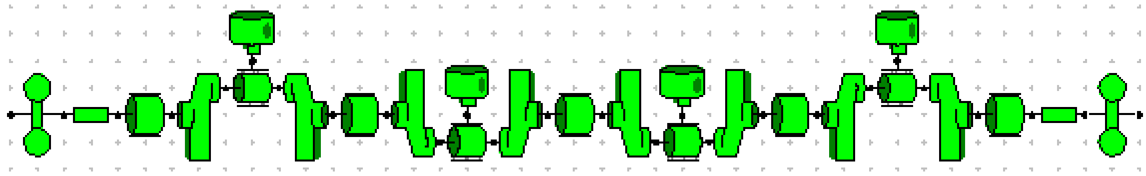
Change the toolkit to show **Shafts** by selecting the appropriate tab. As an aid to identifying the intended use of an element from the toolkit select it with the right mouse button. A short descriptive display of the element will be displayed

Use this facility to identify the **default front shaft** and add this to the front of the crankshaft. Add a **default rear shaft** to the rear main journal. The shafts are different to the other components we have used in that they are 'stretchable'. You position the first end then drag to the second end position.



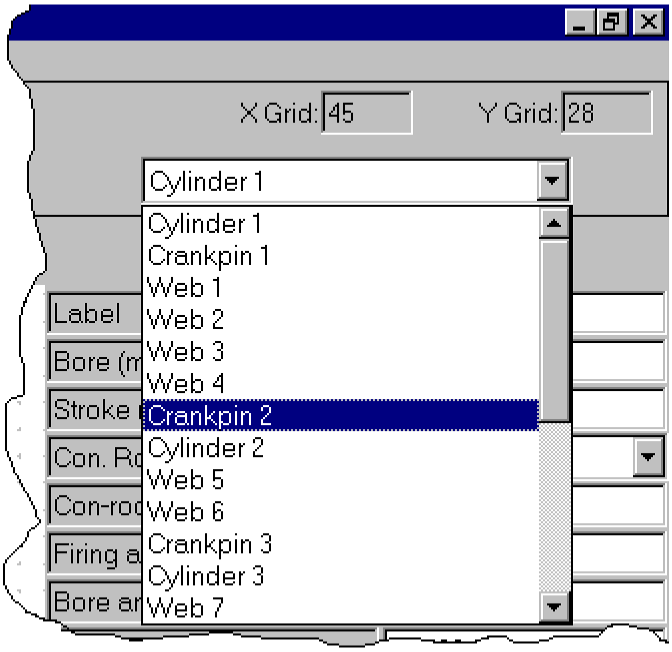
Default Shafts added to ends of model

Change the toolkit to **inertia's** add the **default pulley inertia** to the front of the crankshaft and the **default flywheel assmb** to the rear of the crankshaft.



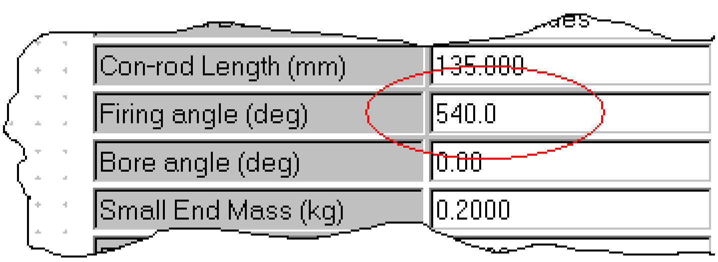
Finished model appearance, with default inertia's added

To illustrate the process of editing data we will correct the firing order to reflect the conventional 1-3-4-2 firing order. Select the second cylinder, (try using the selection box to pick it).




Picking the cylinder 2 element from the selection box

In the property sheet change its firing angle to **540** degrees. Repeat for cylinder 3, set its firing angle to **180** degrees and for cylinder 4 set its firing angle to 360 degrees.

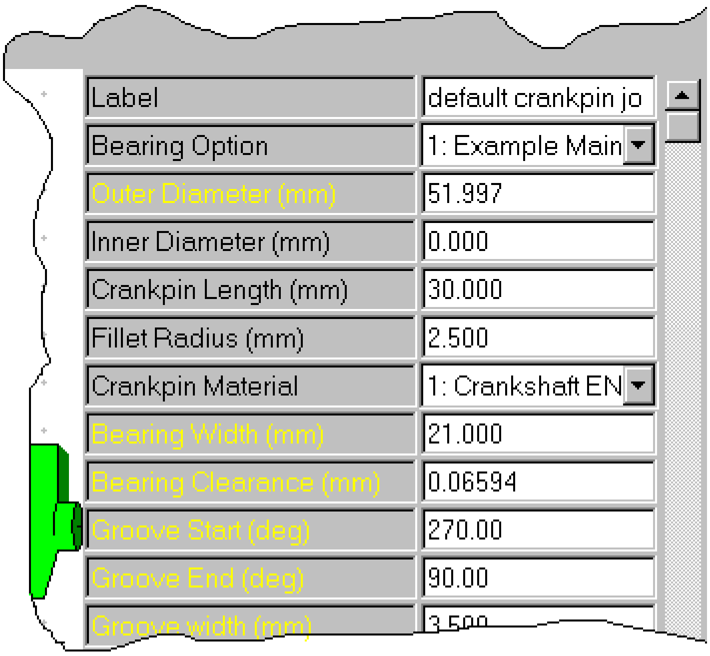



Editing Firing Order for Cylinder 2

## Data from Other Modules

Individual modules have common data requirements with other modules. Examples of this for our crankshaft module include bearing dimensions that are also required for the Bearings module. To share between modules enter the data in the 'origin' module, (in the case of the bearings dimensions this is 'bearings' module), then in the 'shared' module set the selection box to the required shared component.

When using 'shared' data the data field labels in the shared module are shown in yellow.

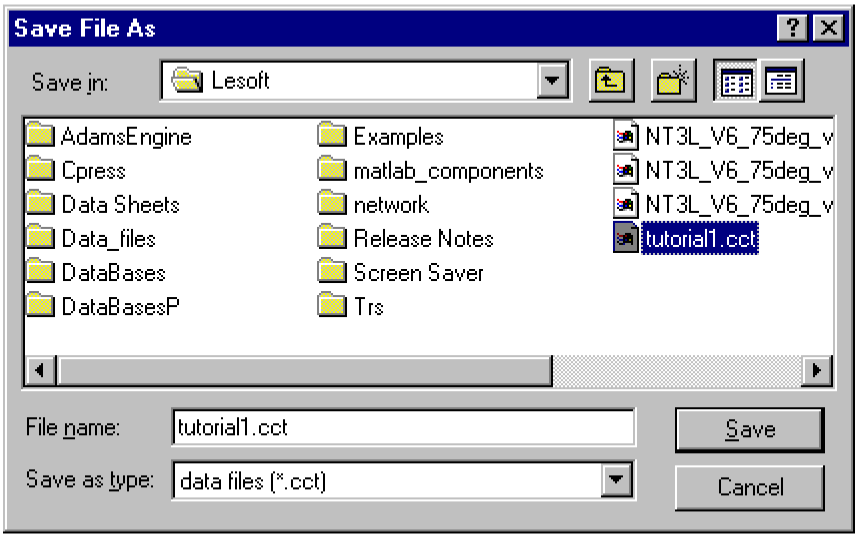



Bearing Component – using Bearings module data

A similar process is used in defining material properties for components in the crankshaft module, with the exception that no equivalent local data fields are available. This means that all material data is taken from the shared 'materials' module.

## Saving a Model

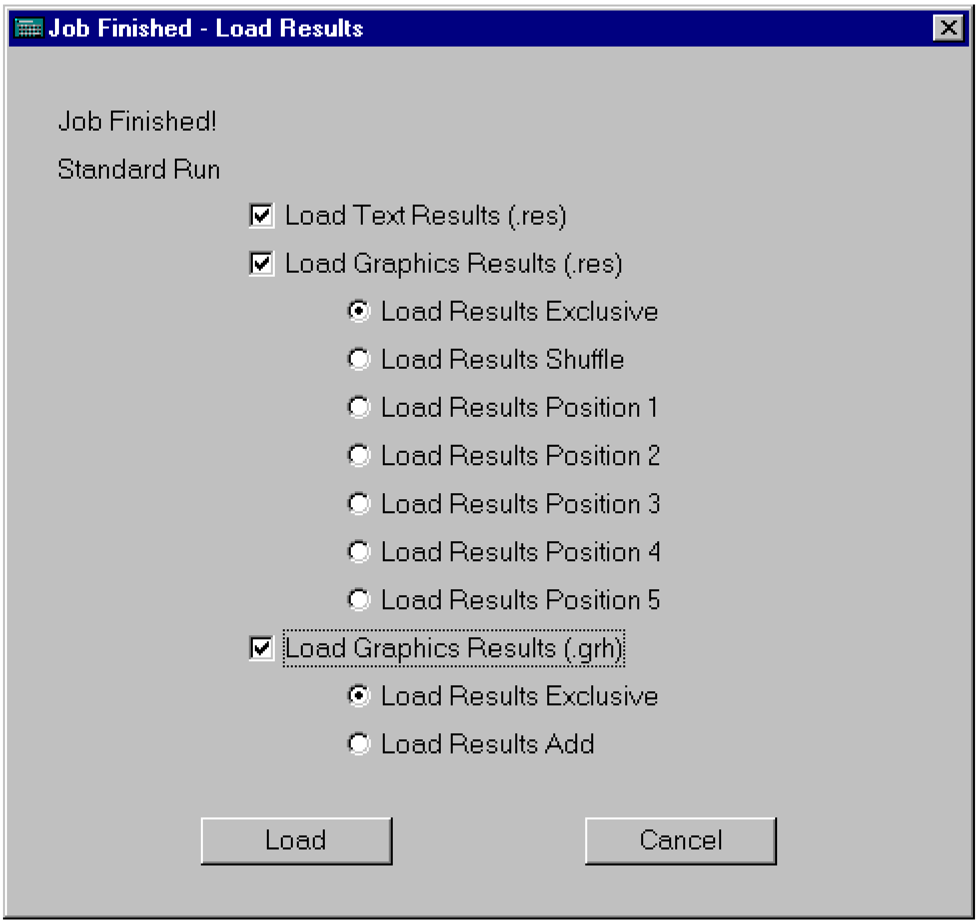
To save the model select the main menu *File / Save As*. The standard file browser shown below is displayed. Enter **tutorial1.cct** and select **Save**. Note that the default file extension for Lotus Concept Crank Train data files is .cct.



File Save As option – Save as Tutorial1.cct

## Running the Solver

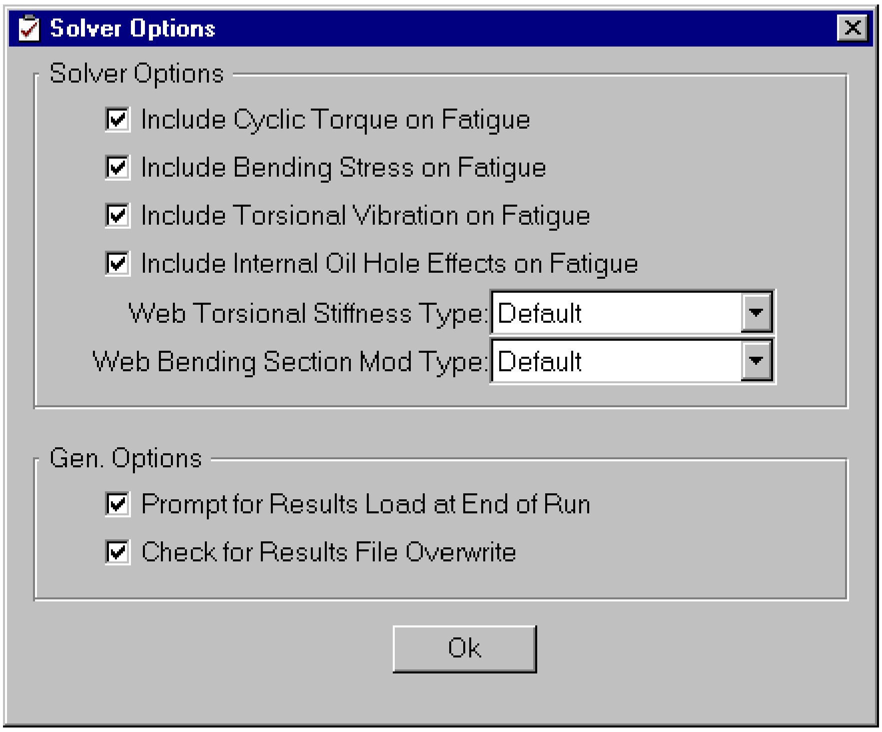
To run the solver select the menu option *Solve / Solve Update*. A progress bar will indicate the solution progress. Once the run is finished the user is presented with options to load the text and graphical results from the completed run.




Job Finished Banner

Check the boxes next to **Load Text Results (.res)** and **Load Results Exclusive** for the two Graphical results options. Select the **Load** button to load the selected results files. Before we review the results we will look at the solution settings.

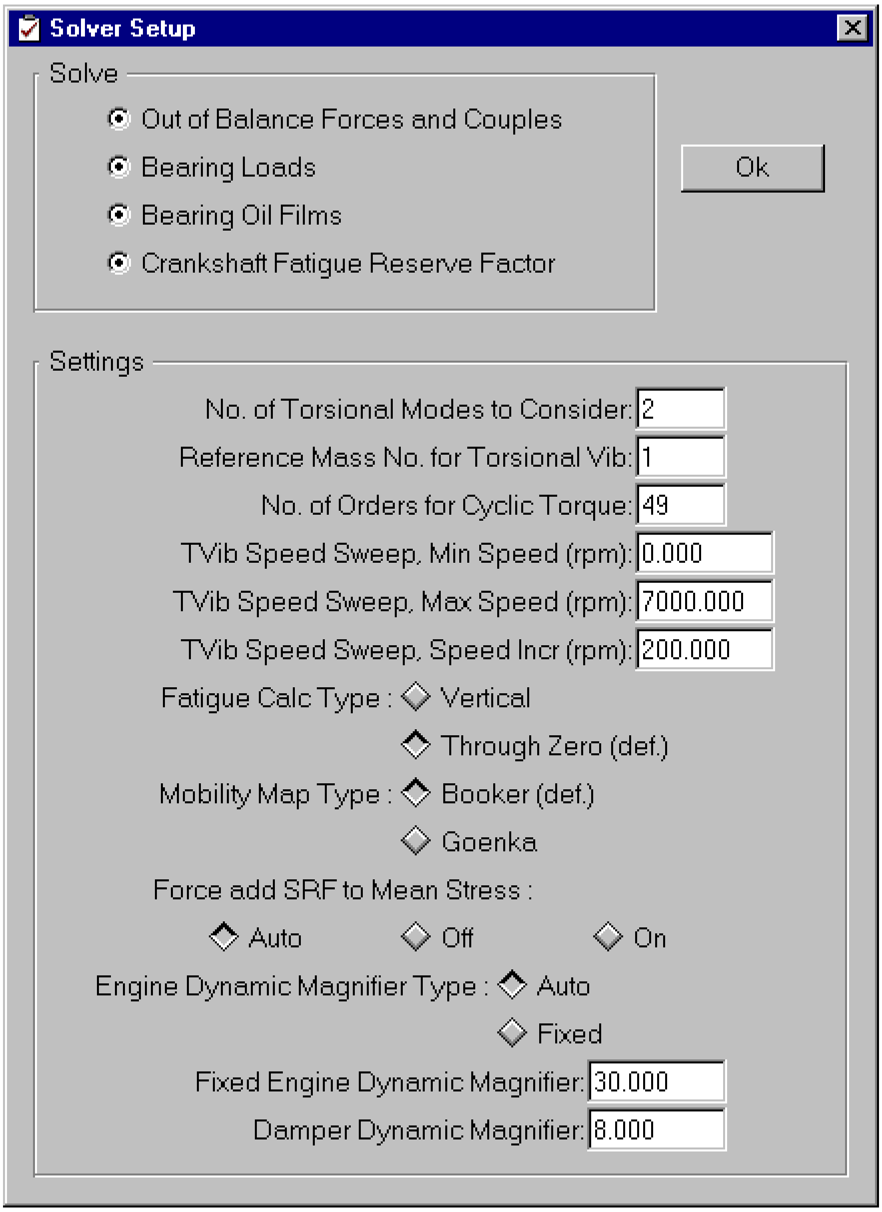
From the main menu select the menu *Solve / Solver Options* this will display the solver options dialogue box.



Solver options settings box

From this dialogue box we can switch different calculation sources ‘on’ and ‘off’ (i.e. Cyclic, bending and torsional contributions), set the calculation methods for web stiffness and web bending.

Additional solution control is available through the ‘solver set-up’ dialogue box. See *Solve / Solve Set-up* menu.



Solver Set-up dialogue box

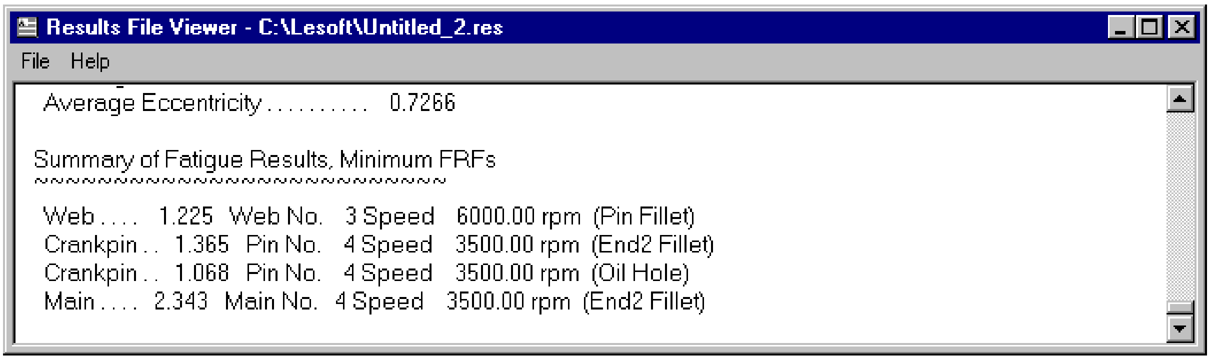
From this dialogue box it is possible to switch individual solution results ‘on’ and ‘off’ to speed up calculations. Torsional vibrations options are edited here. Fatigue reserve factor calculation type is also set here.

## Post Processing

Post processing allows us to review the analysis results in three distinct ways.

1) Textual Listing of Results, (*.res files)
2) Graphical x-y plotting of summary values, (*.res files)
3) 3d Viewing of model a results, (*.grh files)

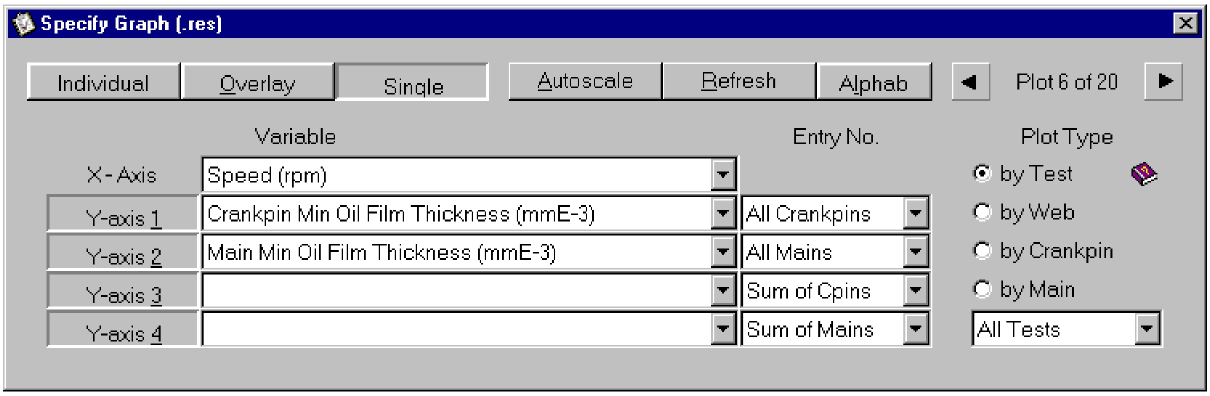
To view the previously loaded .res file as text results, open the scrollable text display via the *Results / .res Results / Results Viewer*. This lists an echo of the input deck and summary results for each analysis case and type. A useful summary of the minimum FRF's is given at the bottom of the text file, listing the minimum FRF for each section type, giving the location and load case.




Textual Results Summary – Min FRF's shown

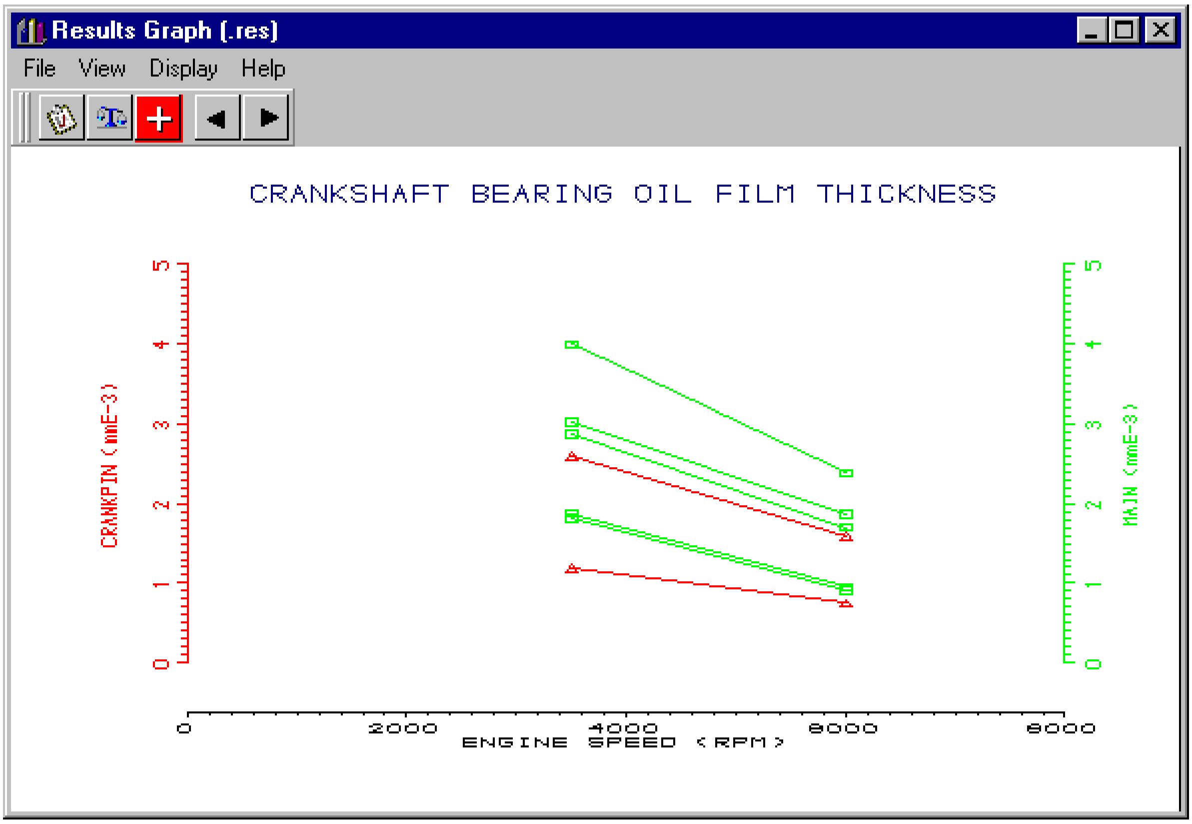
To view the previously loaded .res file as graph results, open the graphical display from *Results / .res Results / Results Graph*.

To change the graph displayed results, you can either use the toolbar arrow keys to move between the pre-defined graphs, (these include un-balanced forces and couples, peak bearing loads, oil film thickness, power loss and FRF's), or you can defined your own using the local *View / Specify Graph* menu.




Specify Graph – Default plot 6 shown

Cross plotting options existing to compare different runs on the x-y graphs together with the normal , print, copy and axis control.

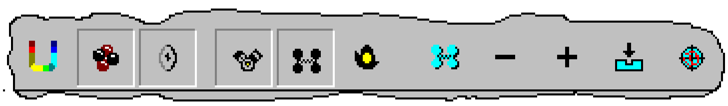



*.Res x-y graphical results display, Default plot 6 shown

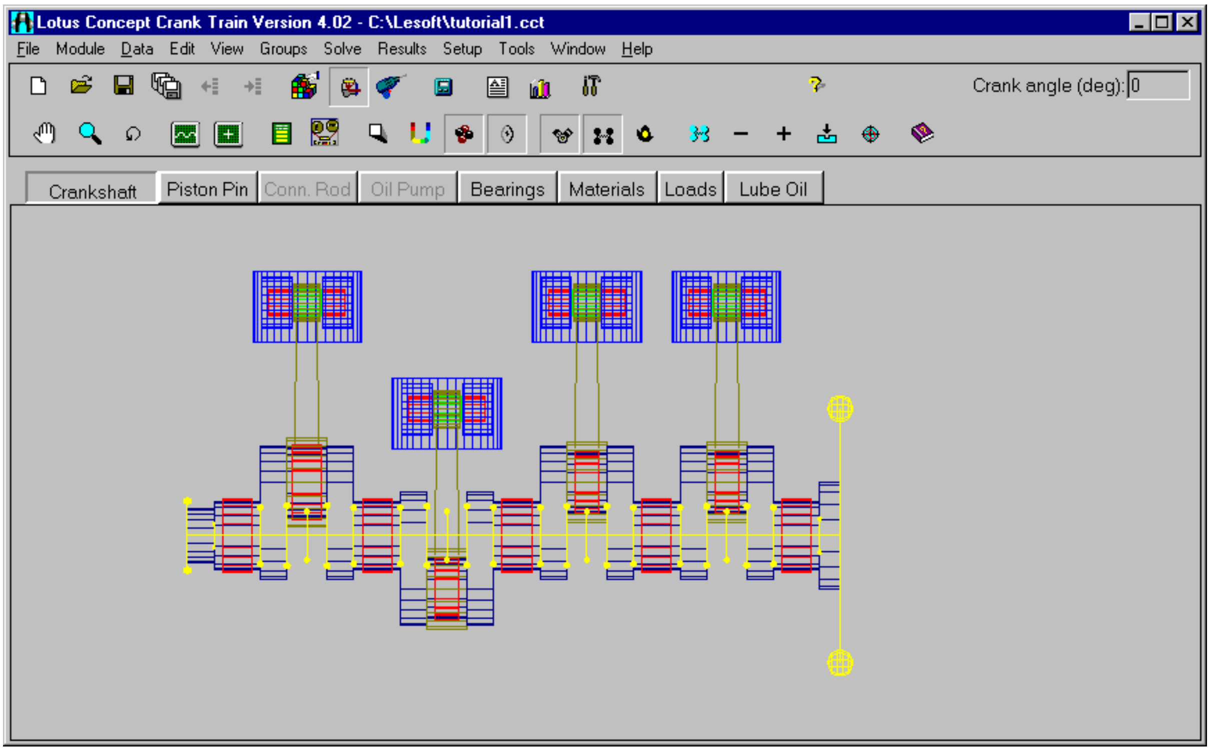
The third results viewing option is the 3D viewing. This uses the previously loaded .grh file to display not only the wire frame representation of the crankshaft, but also key results such as mode shapes and bearing loads actually on the crankshaft model. To change to the 3D view phase select the main menu item *Module / Results Viewer* (alternatively you can use the **Ctrl+F1** and **Ctrl+F2** to move between the model builder phase and the results viewer phase.

We can use the 3D viewer to display the wire frame representation of the crankshaft, we can overlay on this the internally calculated model of the mass elastic system for the torsional vibration analysis and the internally calculated model of the unbalanced masses for the calculation of un-balanced forces and couples.

The switches for these visibility's is set via the relevant toolbar icons.



Visibility Icons




3D Viewer Screen Shot, Mass Elastic Model Shown overlayed.

The 3D view can be changed using the dynamic view modes of, translate, rotate and scale. Remember that the rotate mode has two styles depending whether you pick towards the centre of the display or the edge.

## Exercise 1 - Problem

For our example we require to display the bearing loads on the 3D wire frame. Find the relevant switches and animate the display. Manipulate the view to look along the crankshaft axis.

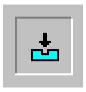
What is our current models $1^{St}$ and $2^{nd}$ torsional natural frequency? (hint, either use the text file or switch the torsional amplitudes on in the 3D viewer).

What is the current Minimum Fatigue reserve factor?

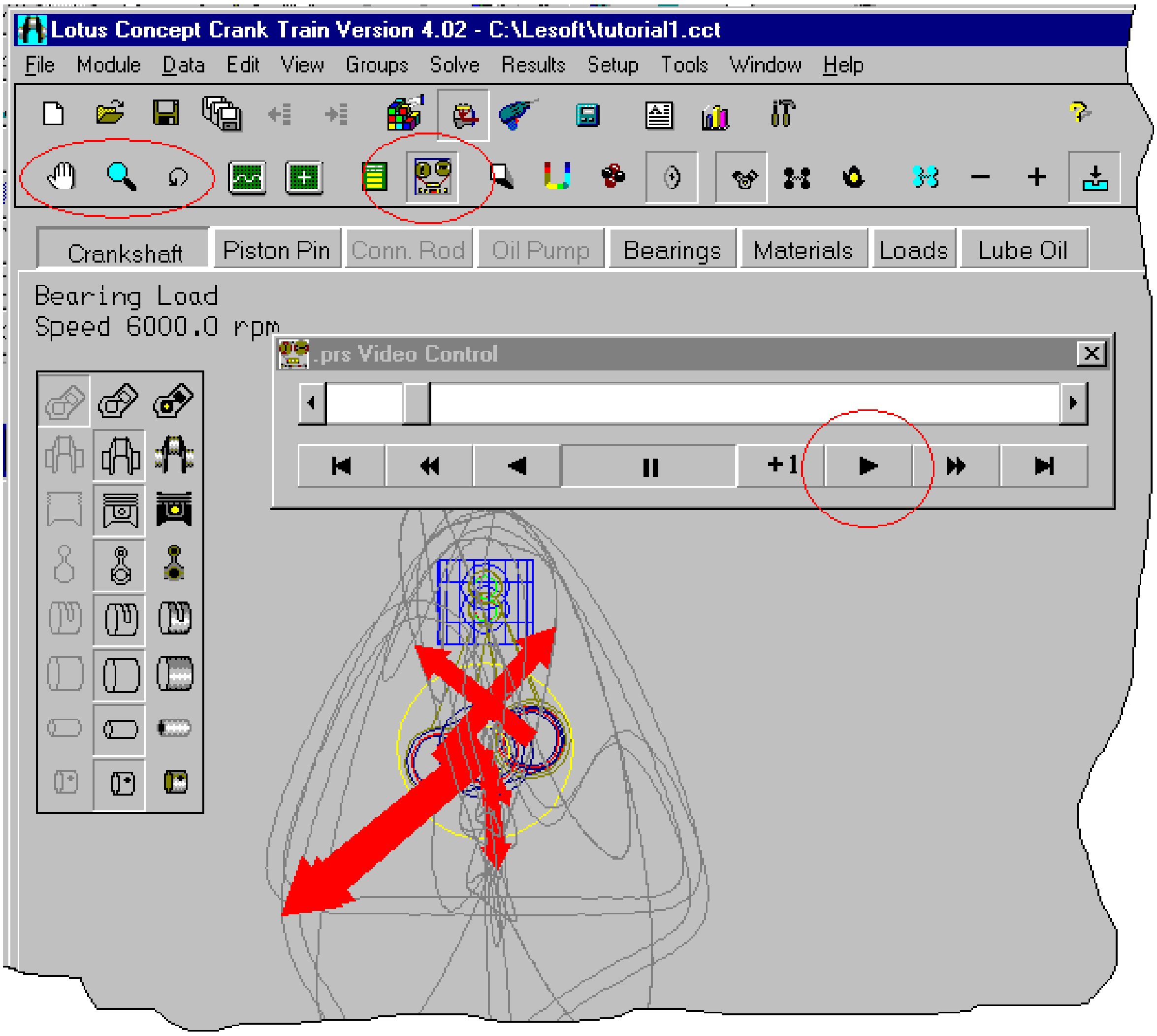
What happens to the Minimum Fatigue reserve factor if we increase the crakpin diameter to 48 mm?

## Exercise 1 – Solution

To switch on the bearing loads display in the 3D viewer select the icon indicated below.



Bearing Loads Visibility Icon




View along Crankshaft, animating display, relevant icons ringed

The first torsional mode is at 367 Hz whilst the second is at 1016 Hz.

The current minimum FRF is 1.076 at the oil hole of crankpin No. 4 for the 3500 rpm case.

At 48 mm the minimum FRF is increased to 1.286 at the same location and speed.

# 4 Piston Pin Module

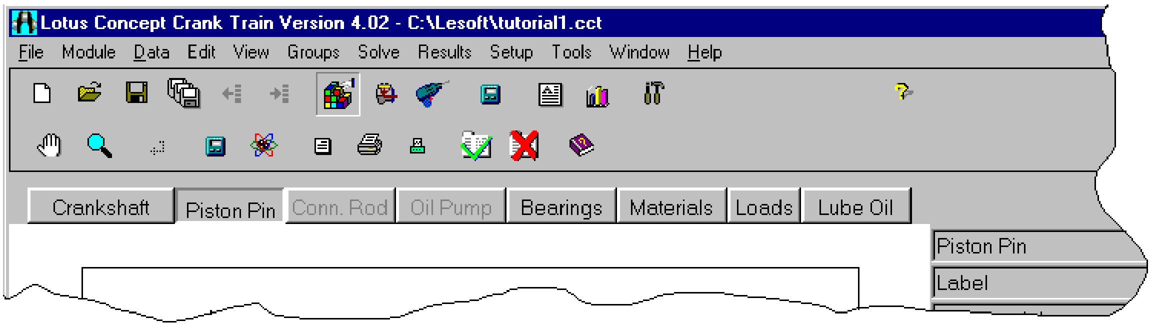
## Overview

This chapter describes the Piston Pin Analysis Module. The majority of this module is identical to the previous standalone program ‘Gopher’. The integration of this module into Lotus Concept Crank Train has allowed for data commonality on data fields such as loading pressure and results such as pin mass.

This chapter contains the following sections:

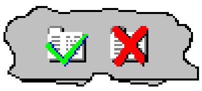
## Piston Pin Data Fields

Change to the Piston Pin module by selecting the relevant component tab.



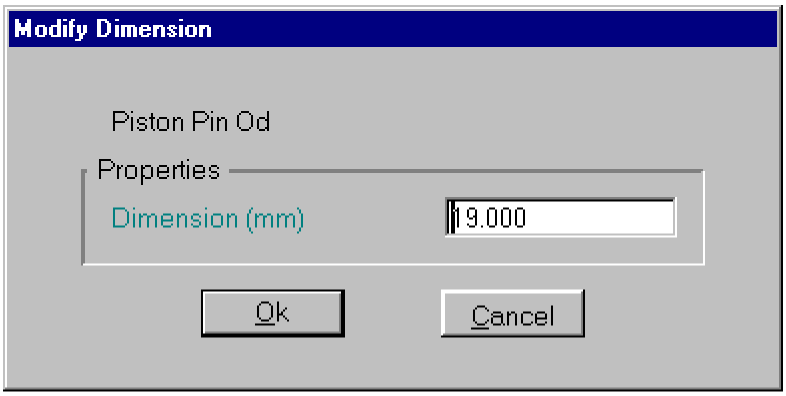

Piston Pin Module Tab Selected

By default an example piston pin component is already included in the dataset. You can either manipulate the data fields for this one or add additional piston pins and define the properties for these. To add a new piston pin pick the relevant icon.



Icons for adding and deleting Piston Pin Components

The data values can either be edited in the property sheet display or by selecting the relative value on the graphical display with the left mouse button.



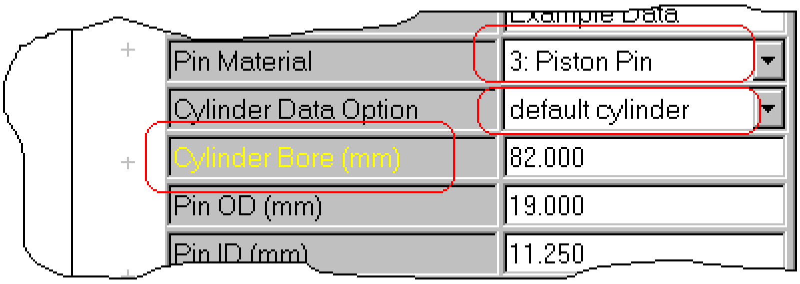

Data Value Editing – Selecting from display

## Shared Data Fields

As with other modules in Lotus Concept Crank Train common data requirements can be shared between modules. Normally one module will be considered the 'source' for a particular shared value, with the others being considered potential 'receivers' of the shared data. A potential receiver module may be forced to use the shared data, (as in the case of material properties), or it may have its own local value option The Piston Pin module receives compulsory material property data from the *Materials* module, and receives optional 'Cylinder bore' data from the *Crankshaft* module.

An option has yet to be added to allow the Piston Pin module to receive optional data from the Connecting rod module. This will be enabled once this module has been added from CROWS.

The Piston Pin analysis results of 'mass' is available to the crankshaft module as an optional data value.




Data Recievers and shared data indicators

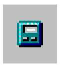
## Adding a New Piston-Pin Component

To add a new piston pin component select the ‘add piston pin’ icon as indicated previously. This will increment the number of piston pin components by 1, display the new piston pin, with all data local fields set to zero. To aid identification you should give the new component a unique label.


New piston pin component message

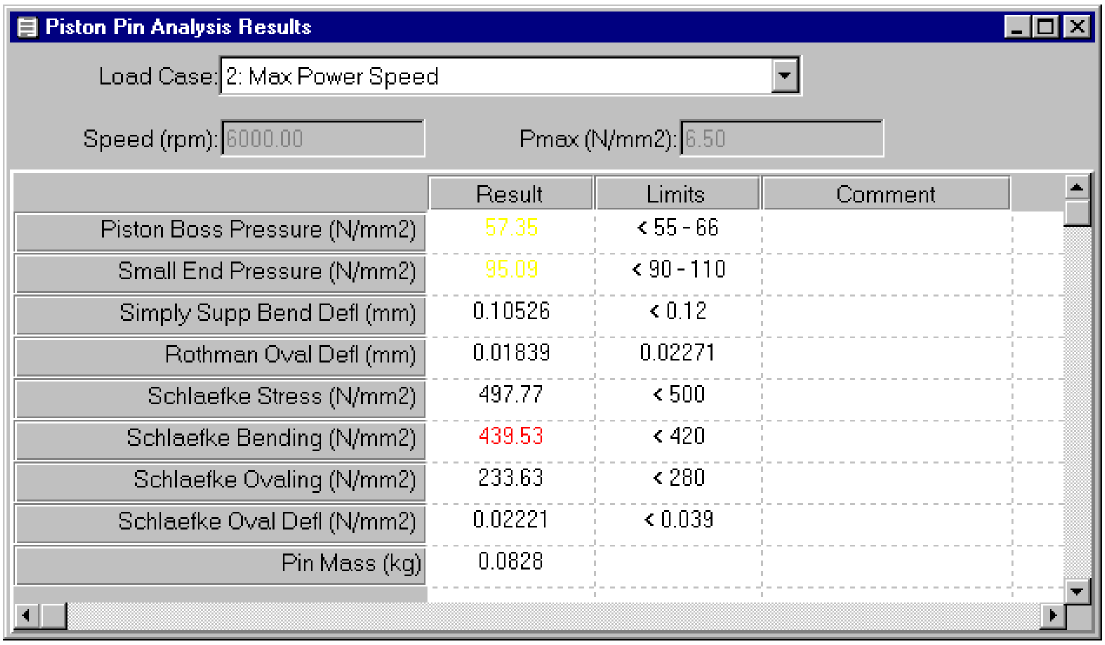
## Running the Piston Pin Solver

To run the solver for the current displayed piston pin component, select the ‘calculate’ icon. This will extract the current data, perform the calculations and open the results display.



Calculate Icon

The results are displayed for the first load case. To change to any other defined case, use the top selection box. Results are shown compared to the typical result limits. Colours are used to indicate which results exceed the normal limits.




| | Result | Limits | Comment |
|---|---|---|---|
| Piston Boss Pressure (N/mm2) | 57.35 | < 55 - 66 | |
| Small End Pressure (N/mm2) | 95.09 | < 90 - 110 | |
| Simply Supp Bend Defl (mm) | 0.10526 | < 0.12 | |
| Rothman Oval Defl (mm) | 0.01839 | 0.02271 | |
| Schlaefke Stress (N/mm2) | 497.77 | < 500 | |
| Schlaefke Bending (N/mm2) | 439.53 | < 420 | |
| Schlaefke Ovaling (N/mm2) | 233.63 | < 280 | |
| Schlaefke Oval Defl (N/mm2) | 0.02221 | < 0.039 | |
| Pin Mass (kg) | 0.0828 | | |

Example Results –Colours Indicate >Limits

## Reviewing the Results

Results are listed for a number of analysis types. These include deflection stresses and projected pressures. The techniques are primarily classical techniques with empirically derived targets. The targets listed are standard Gasoline Automotive, and users should confirm the suitability of these to their particular application.

Where a range is given in the limit this is due to either the inclusion of design features increasing the limit, i.e. Piston Pin profiling or Side relief in the piston pin bore. A range can also be to the two distinct types of piston pin, fixed or fully floating. The small end pressure for a fixed pin tends to be smaller than for a floating pin. Again if in doubt refer to component supplier.

An optimise facility is included that allows the user to define the target pressures and the application will then identify the minimum mass solution that achieves the design targets.

## Exercise 2 – Problem

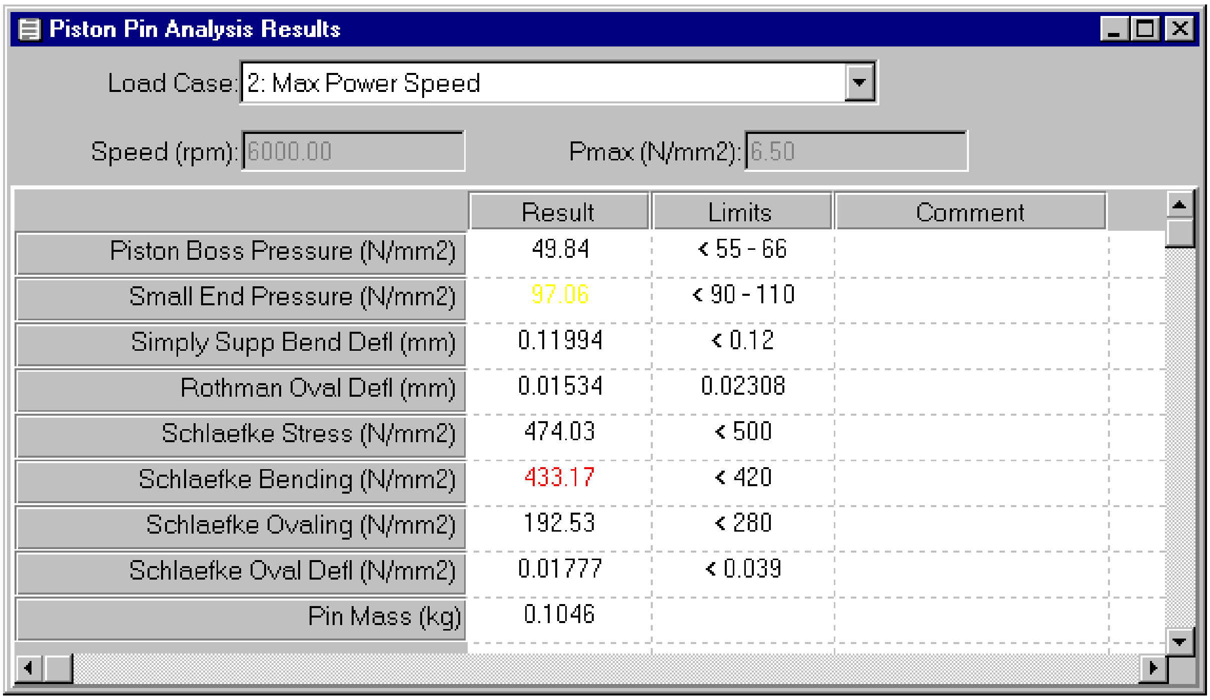
Create a new model with the following dimensions for a floating steel pin.
Cylinder bore = 85 mm
Piston Pin Od = 20 mm
Piston Pin Id = 10 mm
Total Pin Length = 63 mm
Piston Boss Span = 23 mm
Small End Width = 20 mm
Pin End Chamfer = 1.0 mm
Piston Boss Chamfer = 0.5 mm
Small End Chamfer = 0.5 mm

Peak Cylinder Pressure = 6.5 N/mm2  (existing load cases)

What pin Id is required to achieve the ‘standard’ targets.

## Exercise 2 – Solution

The pin Id could be increased to 11.4 mm and achieve all the 'standard' targets.




Sample solution for exercise 2. 11.4mm Id

# 5 Bearings Module

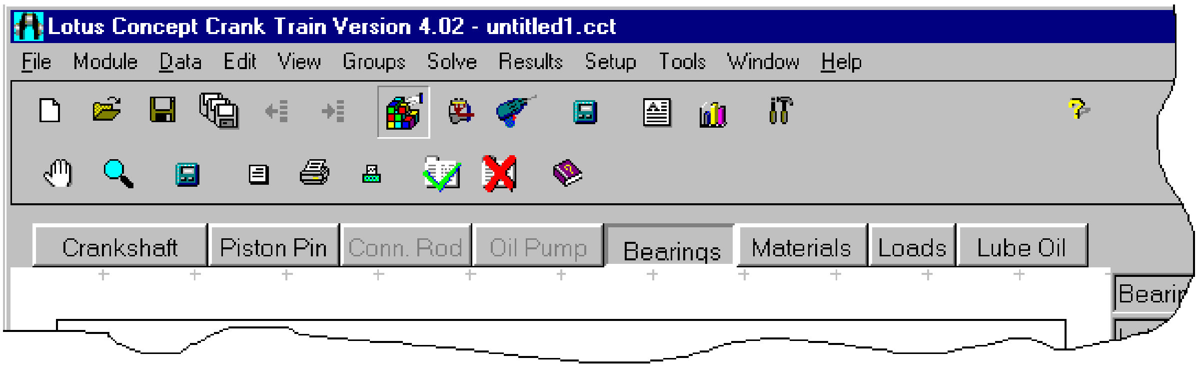
## Overview

This chapter describes the Bearing Fit Analysis Module. The majority of this module is identical to the previous standalone program ‘BEES’ (a sub set of BATS). The integration of this module into Lotus Concept Crank Train has allowed for data commonality on data fields such as bearing diameter and length and results such as bearing running clearance.

This chapter contains the following sections:

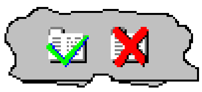
## Bearing Data Fields

Change to the Bearing module by selecting the relevant component tab.



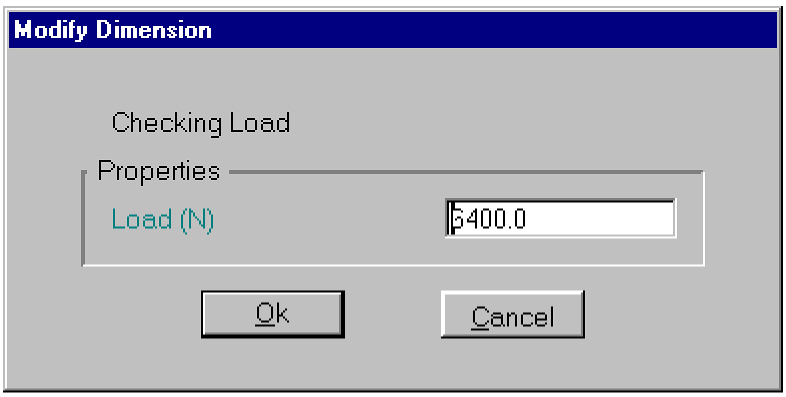

Bearing Module Tab Selected

By default two example bearings are already included in the dataset, one as an example of a crankpin the other as an example of a main bearing. You can either manipulate the data fields of these or add additional bearings and define the properties for these. To add a new bearing pick the relevant icon.



Icons for adding and deleting Bearing Components

The data values can either be edited in the property sheet display or by selecting the relative value on the graphical display with the left mouse button.

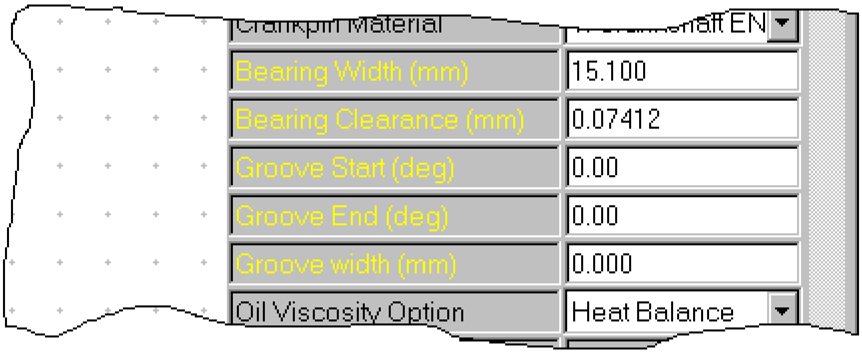



Data Value Editing – Selecting from display

## Shared Data Fields

As with other modules in Lotus Concept Crank Train common data requirements can be shared between modules. Normally one module will be considered the 'source' for a particular shared value, with the others being considered potential 'receivers' of the shared data. A potential receiver module may be forced to use the shared data, (as in the case of material properties), or it may have its own local value option The Bearing module receives a number of compulsory material property data settings from the *Materials* module.

The Piston Pin analysis results of 'clearance' is available to the crankshaft module as an optional data value, along with the bearing dimensional data of length and diameter.




Data Recievers and shared data indicators. Crankshaft Element Using Bearing

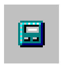
## Adding a New Bearing Component

To add a new Bearing component select the ‘add bearing’ icon as indicated previously. This will increment the number of bearing components by 1, display the new piston pin, with all data local fields set to zero. To aid identification you should give the new component a unique label.

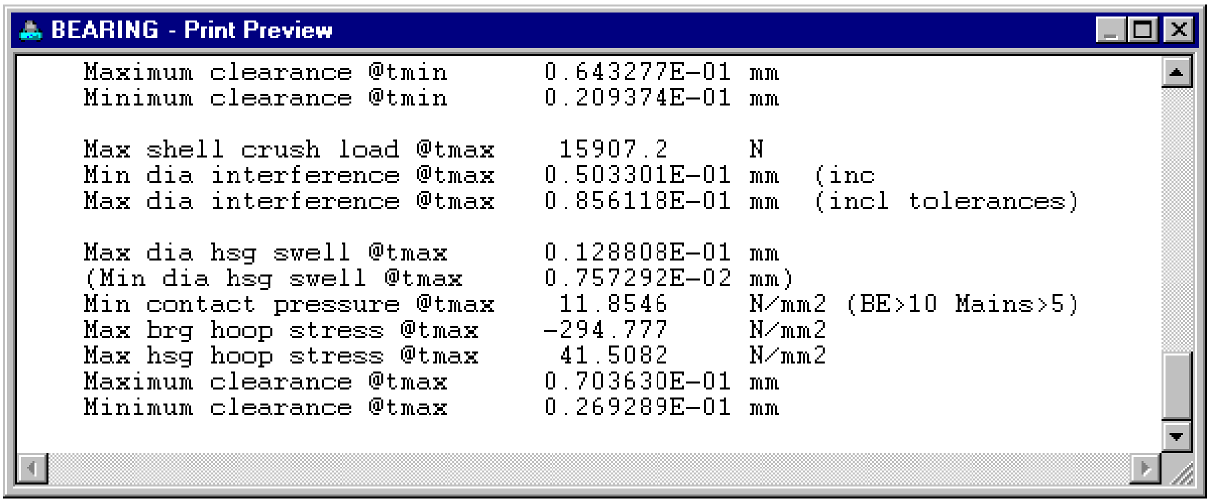
New Bearing Component Message

## Updating the Bearing Solver

To run the solver for the current displayed bearing, select the ‘calculate’ icon. This will extract the current data, perform the calculations and open the results display.


Calculate Icon

The results are displayed in a spread sheet form (opened automatically) and also a scrollable text form, (open using the print preview icon).



Example Results – Print Preview Display

## Reviewing the Results

Results are listed for a number of conditions. These include a nominal build temperature, a minimum operating temperature and a maximum operating temperature. The results calculated include contact pressures between bearing and housing and the clearance between bearing and journal. Thick cylinder theory is used to determine the 'housing swell' and provide a more realistic prediction of running clearance.

Typical design limits are given for the target minimum contact pressure between bearing and housing.

## Exercise 3 – Problem

Given the example data below revise the bearing overstand data to achieve acceptable level of minimum contact pressure at the Tmax condition. You must keep the 0.03 tolerance range on overstand. Target min contact pressure is 10 N/mm2

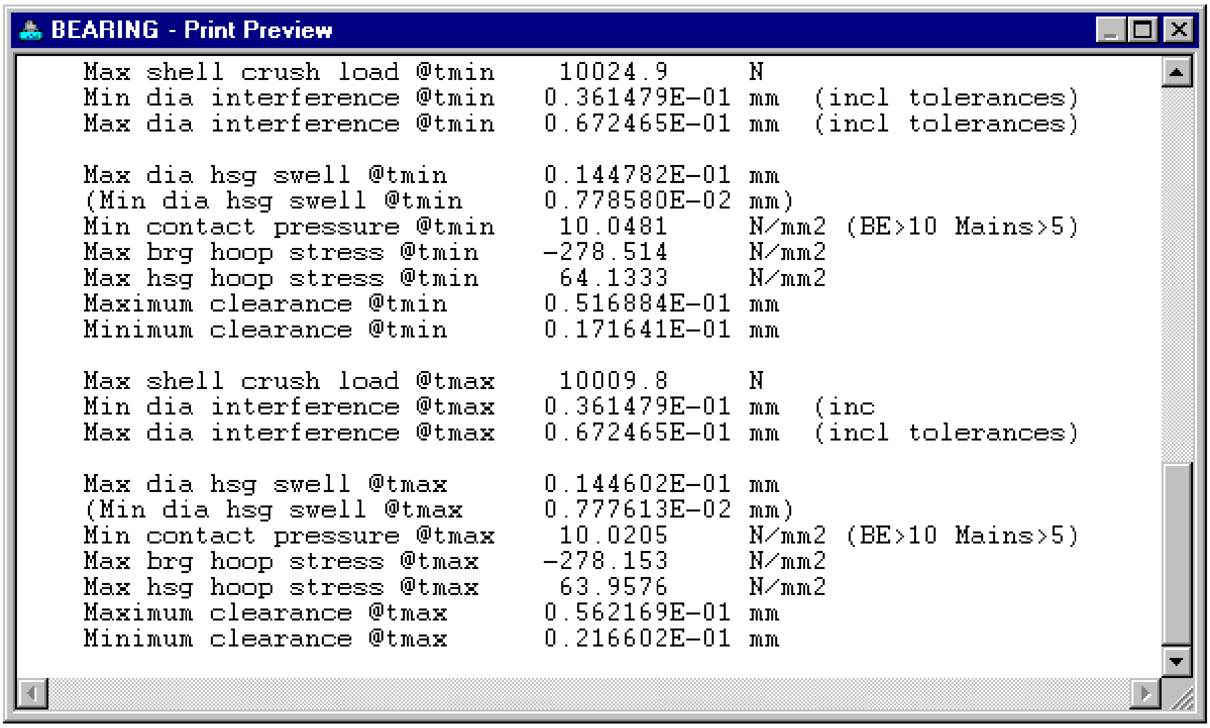
For an example enter the following;

Max Housing Diameter = 43.00, tol = 0.012 mm
Max Journal Diameter = 39.98, tol = 0.011 mm
Max wall Thickness = 1.5 mm, tol = 0.005 mm
Max Steel Thickness = 1.15 mm
Keep Default Crankpin Material Types
Bearing Width 18.0 mm
Checking load = 3500 N, Diameter = 43.012 mm
Min Overstand = 0.02 mm , Max Overstand = 0.05
Outer Multiplier = 1.35

Note that the material properties will be set by the materials module, whilst the operating temperature range is set by the loads module.

## Exercise 3 – Solution

To achieve the contact pressure at Tmax we can either decrease the overstand values, (retaining the range) or decrease the checking load. We would need to decrease the checking load to 1700 N.




Exercise 3 Solution – Checking Load reduced to 1700 N

# 6 Materials Module

## Overview

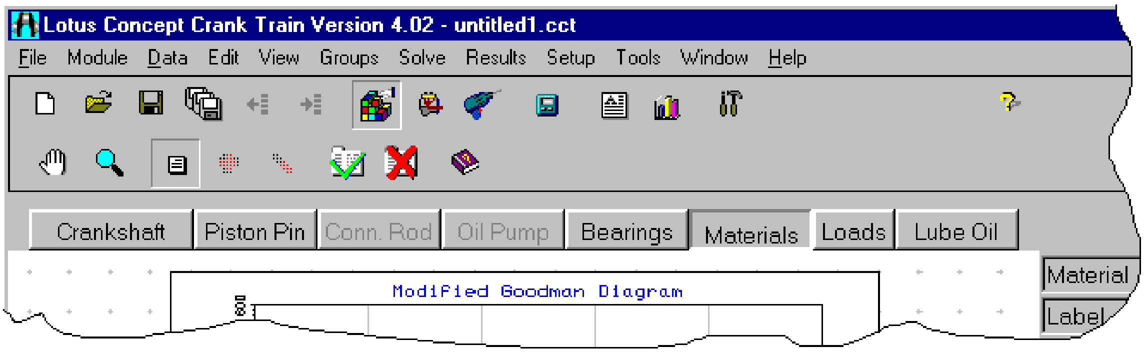
This chapter describes the Materials Module. This module provides a single point of entry for all material related properties. A number of materials are defined each being identified by a unique label. The analysis modules that require material properties then select a material by label and the analysis module uses the relevant data fields as required.

This chapter contains the following sections:

## Material Data Fields

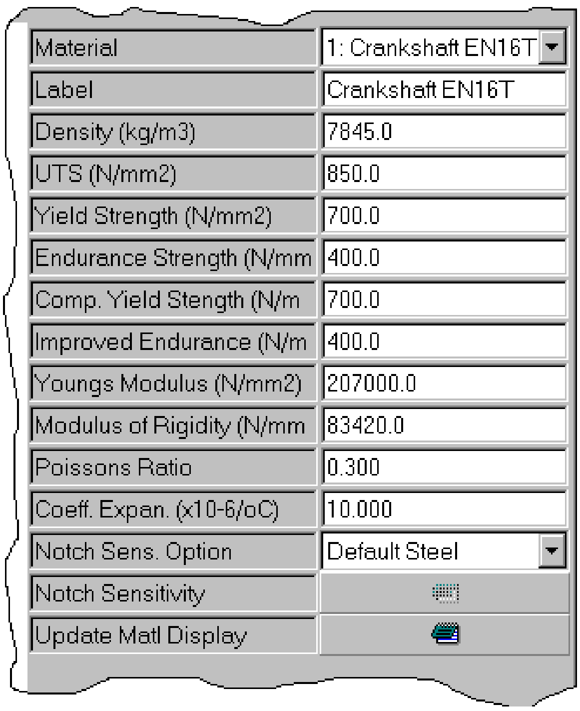
Change to the Materials module by selecting the relevant top button. By default a number of materials are already added into the models dataset. No guarantee is given as to the relevance of the default material properties for a specific component. Users should ensure the correct properties are entered.

Note that not all fields are used by each analysis module but will be referenced somewhere within Lotus Concept Crank Train.




Module Changed to Materials

As with the other modules each entry into the dataset is selected from the top selection box. Its properties are then listed in the property sheet fields. The majority of the fields are self-explanatory. The improved endurance refers to the possible improvement of the Endurance Strength in treated areas such as the fillet region.



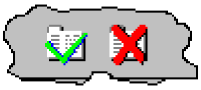

Sample Data Material Fields

The Notch sensitivity deals with how a geometric stress concentration factor is modified by the materials notch sensitivity to produce a local strength reduction factor. This is applied to the calculated nominal stress value, rather than factor down the local endurance strength. The option is provided to define a user specified notch sensitivity curve.

Graphs are shown for the Goodman Diagram and the Notch Sensitivity. The definition values for which can also be edited through the graphs, (see later section).

## Adding a New Material

To add a new material, (rather than modify an existing one), select the add material icon.



Adding a new Material Icon

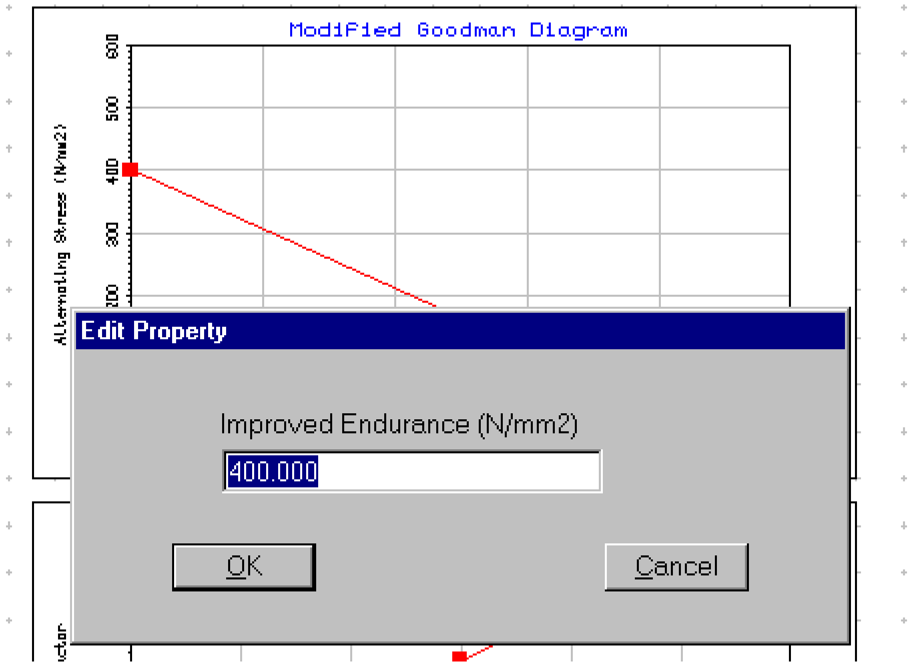
This will increase the number of materials in the dataset, sets the display to the new entry and sets all data fields to zero. You will be informed that this has been added


New material Prompt

You should now enter a unique description and define the displayed data fields.

## Graphical Data Editing

The graphs of the Goodman diagram and the Notch sensitivity can be edited through the graphical display. You can only edit the Goodman diagram once the values are populated, since all values will be located at 0. In a similar restriction you can only edit, add or delete points on the notch sensitivity curve if you are using a user defined curve.




Graphical Editing of Goodman diagram.

# 7 Loads Module

## Overview

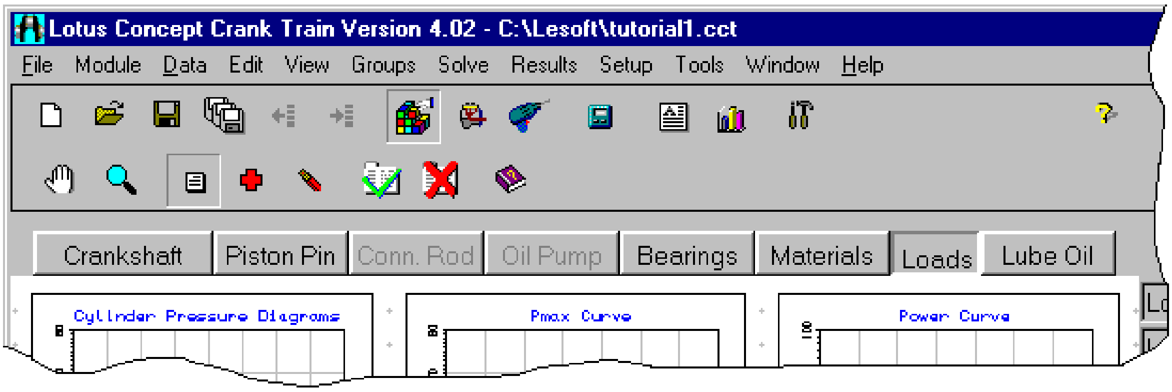
This chapter describes the Loads Module. This module provides a single point of entry for all load related properties. A number of load conditions are defined each being identified by a unique label. The analysis modules that require load properties then select a load by label and the analysis module uses the relevant data fields as required.

This chapter contains the following sections:

## Loads Data Fields

Change to the Loads module by selecting the relevant top button. By default two load case are already added into the models dataset. A notional max. torque speed point and a max. power speed point.

The loads Module uses 'standard' cylinder pressure files loaded as part of the program install. Two sets of files are used a naturally aspirated set and a turbo-charged set. These 'sets' are scaled by the application to derive the defined test points.

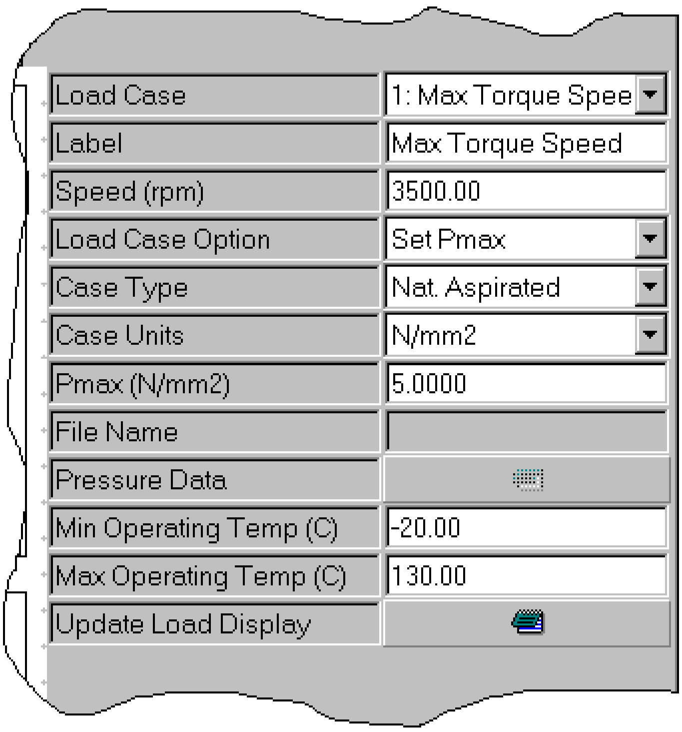



Module Changed to Loads

A load case consist of a speed value, a cylinder pressure diagram and minimum and maximum operating temperatures. The cylinder pressure diagram can be defined in a number of different ways. The simplest method is to use a single point definition. Single point definition interpolates between the previously mentioned cylinder pressure files, scaling them to achieve the specified value. You can specify peak any one from pressure, power, torque, BMEP or IMEP. The alternative method is define the cylinder pressure file directly either as a pre-stored file, or entered directly into the application.

To view/edit a particular load point select it from the list in the selection box at the top of the property sheet. The load data is shown graphically in the six x-y plots presented. The significance of the filled vs hollow symbols is that the filled point is the 'definition' variable, i.e. for the default load cases the Pmax curve has solid symbols.

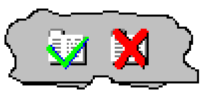
Note that the minimum and maximum temperature data fields are common to all test points.




Loads Data Fields

## Adding a New Load

To add a new load, (rather than modify an existing one), select the add load icon.



Adding a new Load Icon

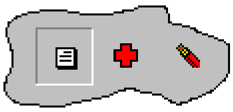
This will increase the number of loads in the dataset, sets the property sheet display to the new entry and sets all data fields to zero. You will be informed that this has been added.


New load Prompt

You should now enter a unique description and define the displayed data fields. The alternative way of adding new points is through the graphical display, (see next section).

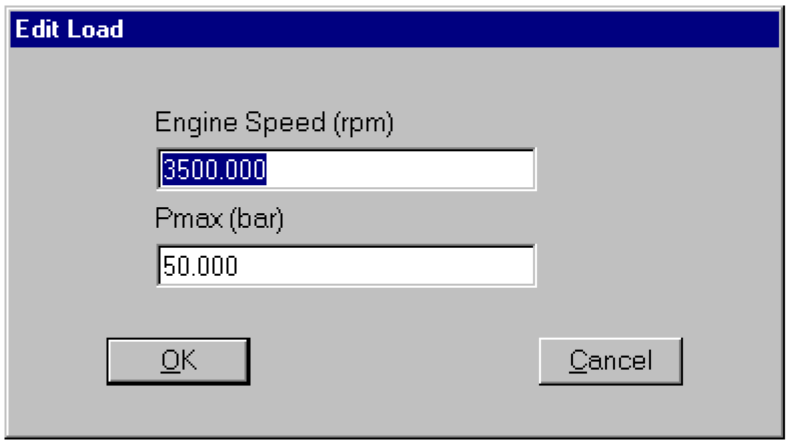
## Graphical Data Editing

The graphical displays can be used not only for viewing the data entered via the property sheet, but also as a means of editing the loads data. This includes adding and deleting load points. The edit, add, delete mode is controlled by the three icons on the toolbar.



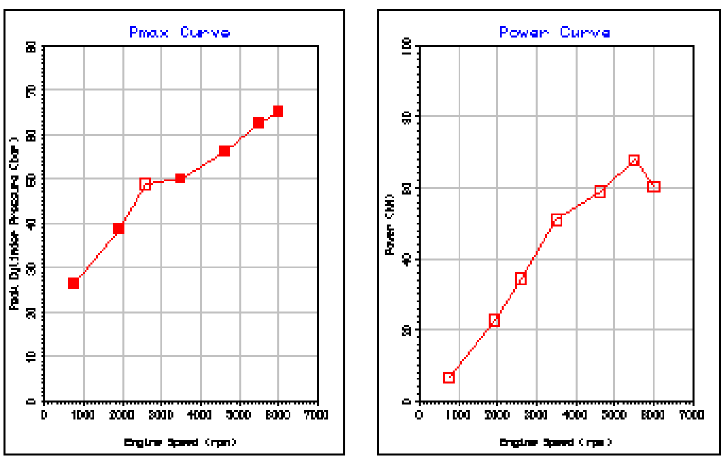
Edit, Add and Delete icons for graphical editing

In edit mode selecting a point on the graph will bring up a standard edit box to allow you to change the speed and value, (note that the cylinder pressure graph is display only). Editing in this way will change the single point definition method to whichever one you define the value in.




Data Point Edit

In add mode you can select a point on any of the five single point definition graphs. A new load point will be added at the selected point, (i.e. both speed and value). The selected curve will also be the definition curve. Load points are automatically shuffled based on ascending speed value as they are entered.




Edited curve, Data added to Pmax

# 8 Lube Oil Module

## Overview

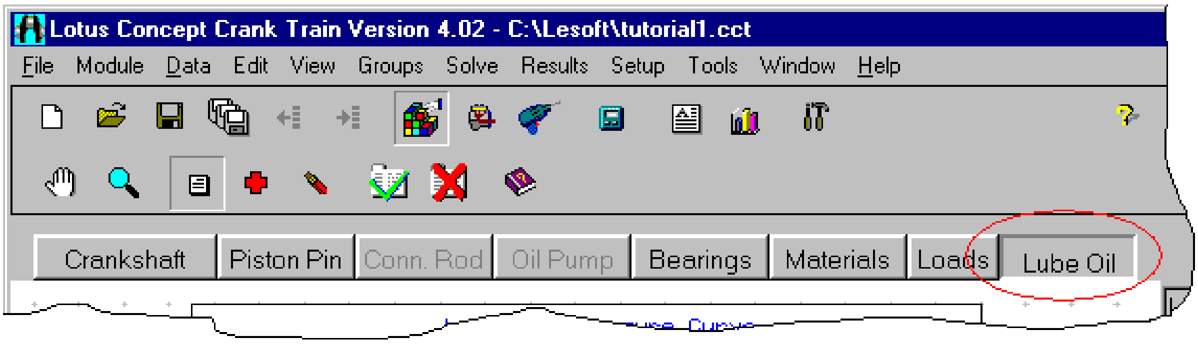
This chapter describes the Lube Oil Module. This module provides a single point of entry for all oil related properties. A number of individual lubricants can be defined. A single default lubricant is added to the dataset for new models. The analysis modules that require lubricant properties then select a lubricant by label and the analysis module uses the relevant data fields as required.

This chapter contains the following sections:

## Lubricant Data Fields

Change to the Lubricant module by selecting the relevant top button. By default a single lubricant is already added into the models dataset.

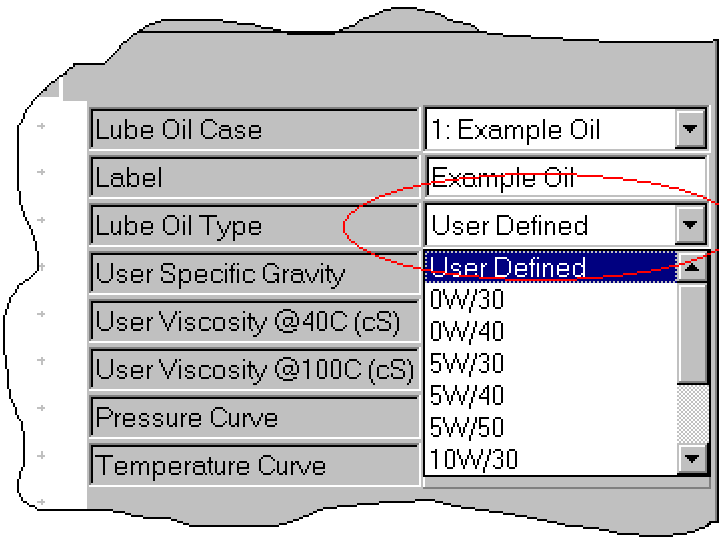
The lubricant module uses ‘standard’ oil types to define the operating viscosity curve. The user can select one of these standard types or define their own multigrade by two viscosity points.




Module Changed to Lube Oil

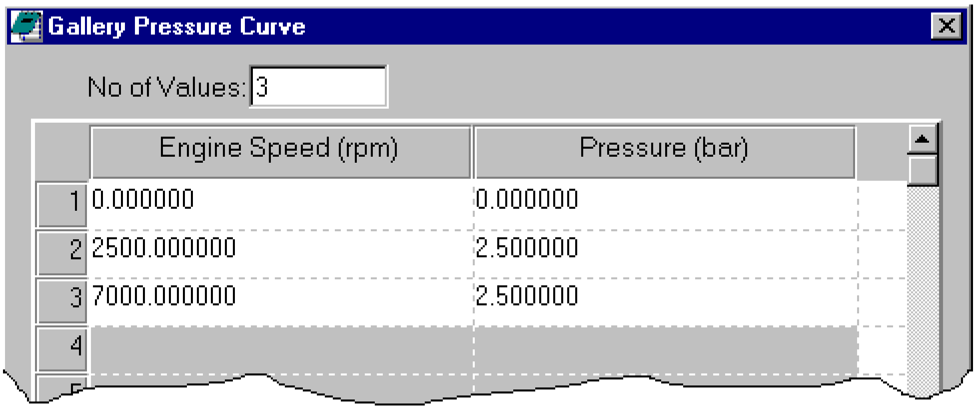
A lubricant data set consists of a viscosity classification, a supply pressure vs speed curve and a supply temperature vs speed curve. The curves are defined by a series of paired (x,y) values.

The lubricant type is set by a selection list in the property sheet that includes the most common multi-grade specifications. If the required oil type is not listed you can use the ‘User Defined’ option. You will then need to enter values for Specific Gravity and Viscosity at two temperature points.




Setting a User Defined Oil Grade

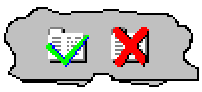
The pressure vs speed curve and the temperature vs speed curve can be edited in through the text entry dialogue box opened from the property sheet. Alternatively they can be edited through the graphical display, (see later section).




Textual editing of the Curve Data

## Adding a New Lubricant

To add a new lubricant, (rather than modify an existing one), select the add lubricant icon.



Adding a new Lubricant Icon

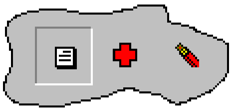
This will increase the number of lubricants in the dataset, sets the property sheet display to the new entry and sets all data fields to zero. You will be informed that this has been added.


New Lubricant Prompt

You should now enter a unique description and define the displayed data fields. The alternative way of adding new points is through the graphical display, (see next section).

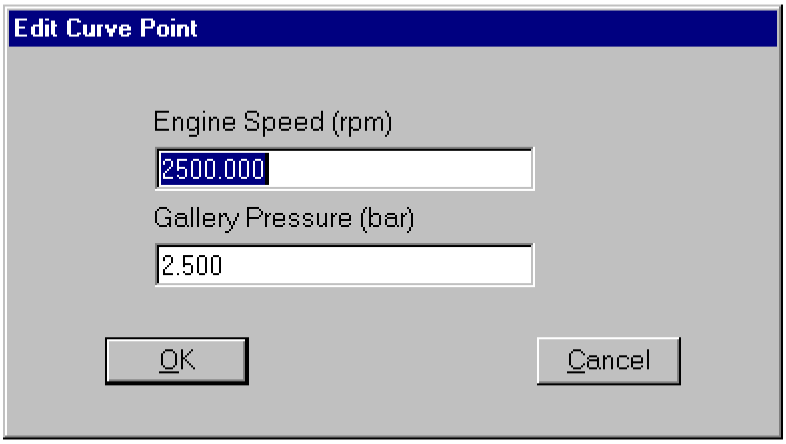
## Graphical Data Editing

The graphical displays can be used not only for viewing the data entered via the property sheet, but also as a means of editing the lubricant curve data. This includes adding and deleting points into the pressure and temperature curves. The edit, add, delete mode is controlled by the three icons on the toolbar.



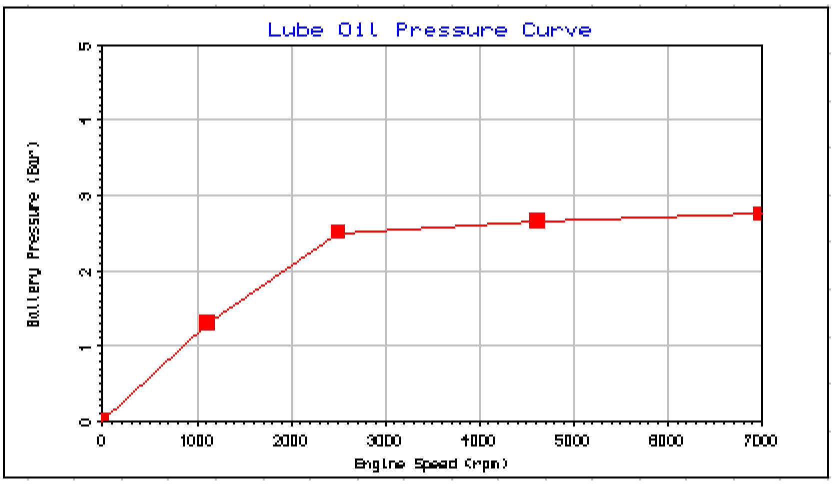
Edit, Add and Delete icons for graphical editing

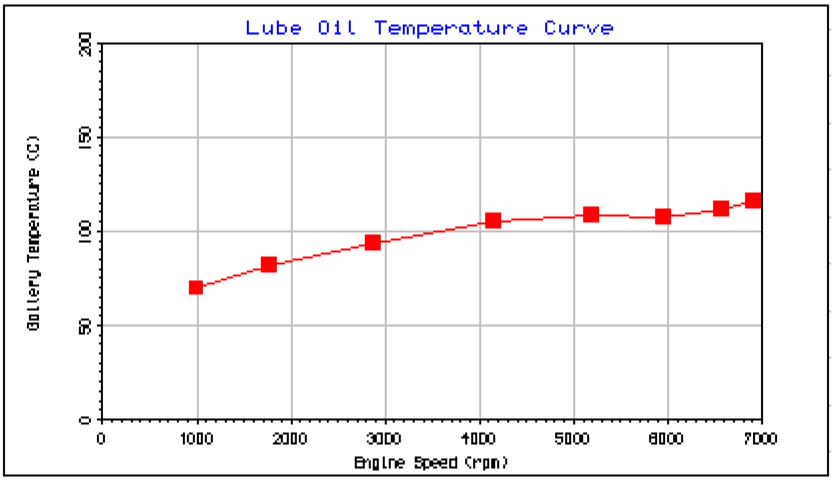
In edit mode selecting a point on the graph will bring up a standard edit box to allow you to change the speed and value.




Curve Data Point Edit

In add mode you can select a point on either the pressure curve or the temperature curve. A new data point will be added at the selected point, (i.e. both speed and value). Data points are automatically shuffled based on ascending speed value as they are entered.




Edited curve, Data added to Pressure and Temperature

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