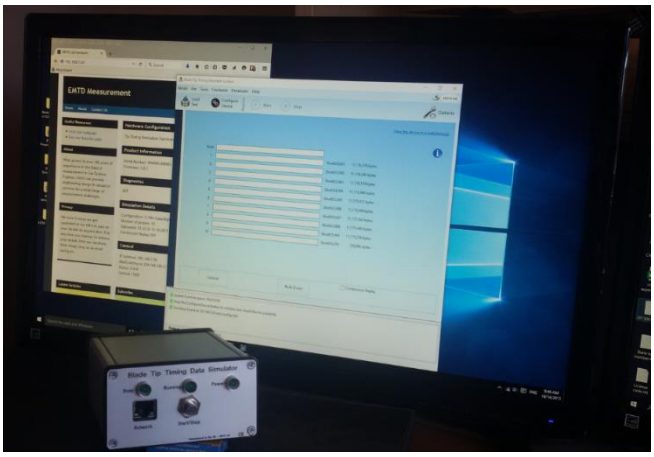
MultiTool Blade Tip Timing Acquisition, Analysis and Data Simulation Software

Analysis Manual



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1. MultiTool Analysis Mode

Some MultiTool features are licensed separately. If the analysis component of MultiTool has been licensed then it will be selectable from the Mode menu as shown in Figure 1. If this option is greyed and you believe that you have a valid license for analysis then please email support@emtd-measurement.com

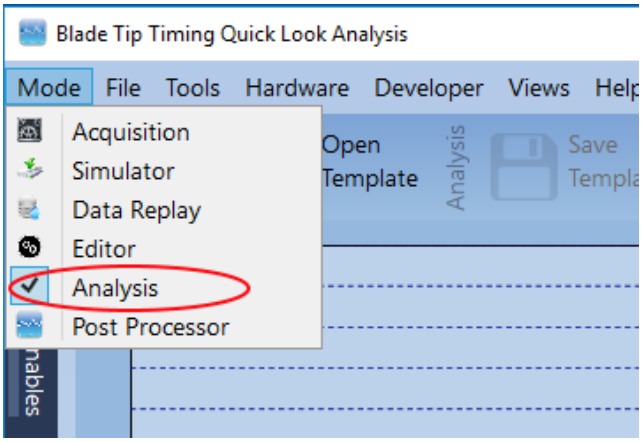


Figure 1 - Switching to Analysis mode

1.1. Loading a configuration file

In order to analyse a dataset a configuration file is required which describes the hardware configuration used to acquire the data. This must be a MultiTool standard configuration file and must be in the same directory as the data. If you don't already have one created then see creating a configuration file in the EM0100 Editor Guide.

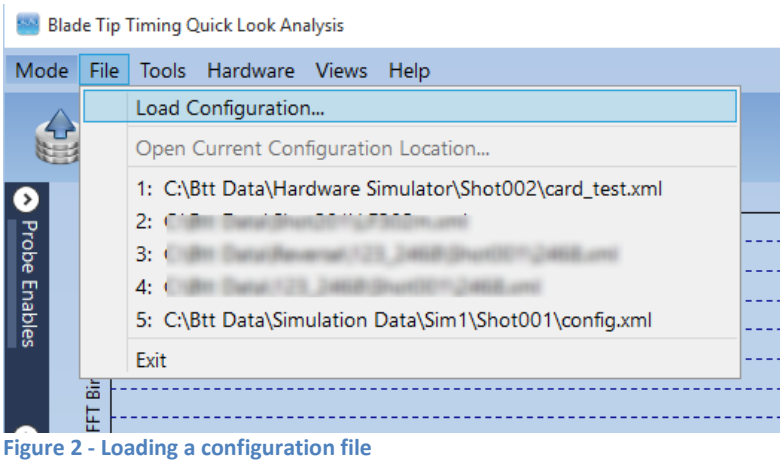


Figure 2 - Loading a configuration file

If the configuration file has been used before then it will appear in the recently used files list. Click on it to load. Note that the recent file list is different for each mode of the application so if you have loaded the file in the editor it will appear in the recent

list for the editor but won't appear in the analysis list until it has been loaded into the analysis system once.

If the configuration file has not been loaded before then select *Load Configuration* from the file menu or click on the *Load Configuration* toolbar button. The dialog shown in Figure 3 – File Load, will allow you to navigate the disk to locate a configuration file.

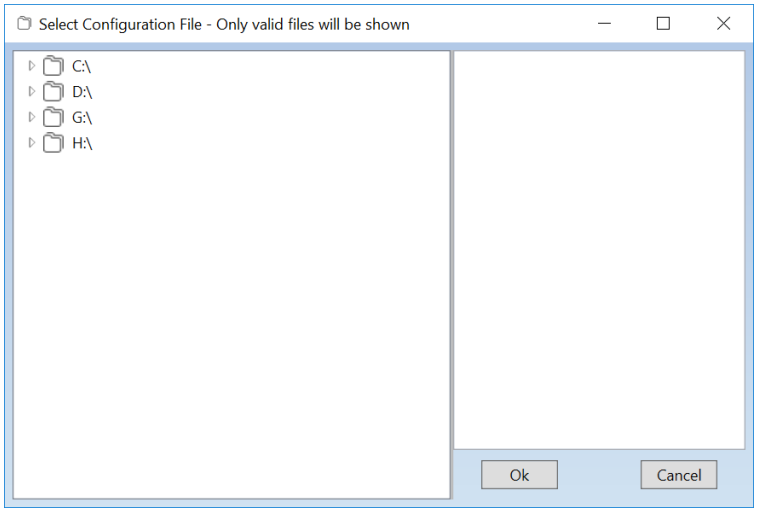


Figure 3 – File Load

Note. Only valid configuration files will be shown in the right hand pane and depending on the operating mode only configuration files located in the correct place will be shown.

Acquisition: Only shows valid configuration files that are in the root of a test folder. It will not show configuration files in shot directories. This is to avoid recursive data directories.

Replay and Analysis: Only shows valid configuration files that are in shot directories and not the root of a test folder. No data is associated with the root configuration file as each data directory has a local copy of the configuration the data was recorded against.

Editor: Shows any valid configuration file.

1.2. Data Validation

MultiTool will inspect the dataset and make sure it is good enough for analysis. Any problems found will be reported in the status area at the bottom of the display. While some issues may be minor and are for information only any major issues will halt the process and must be fixed before the data can be analysed. An example of a major issue would be the probe positions described in the configuration file do not match the positions calculated from the data.

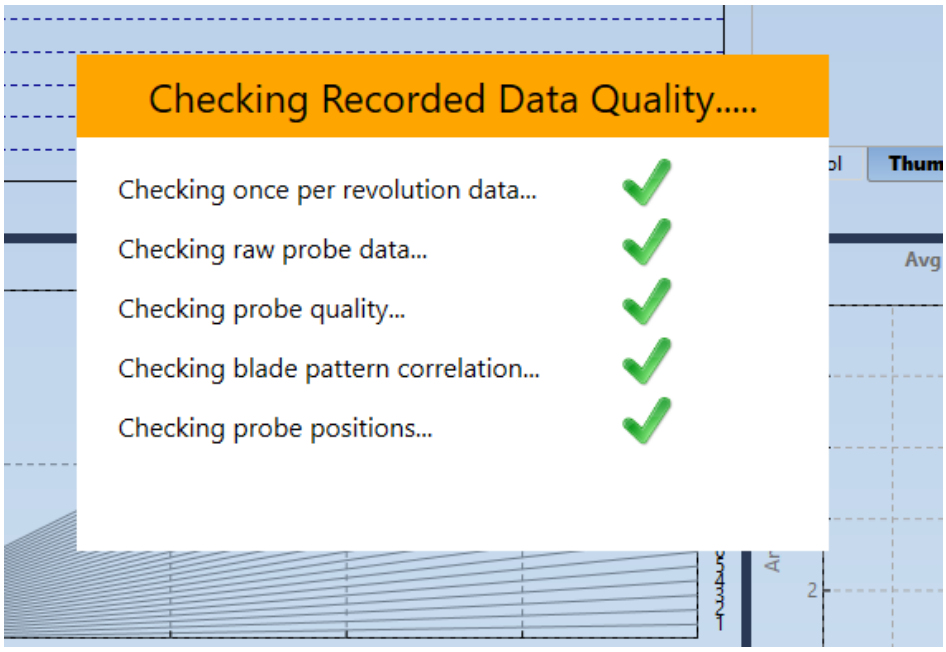


Figure 4 - Data Validation

This can take a little while depending on the size of the dataset.

Note: Any error message will be displayed in the status panel at the bottom with a red indicator.

1.3. Analysis Display Sections

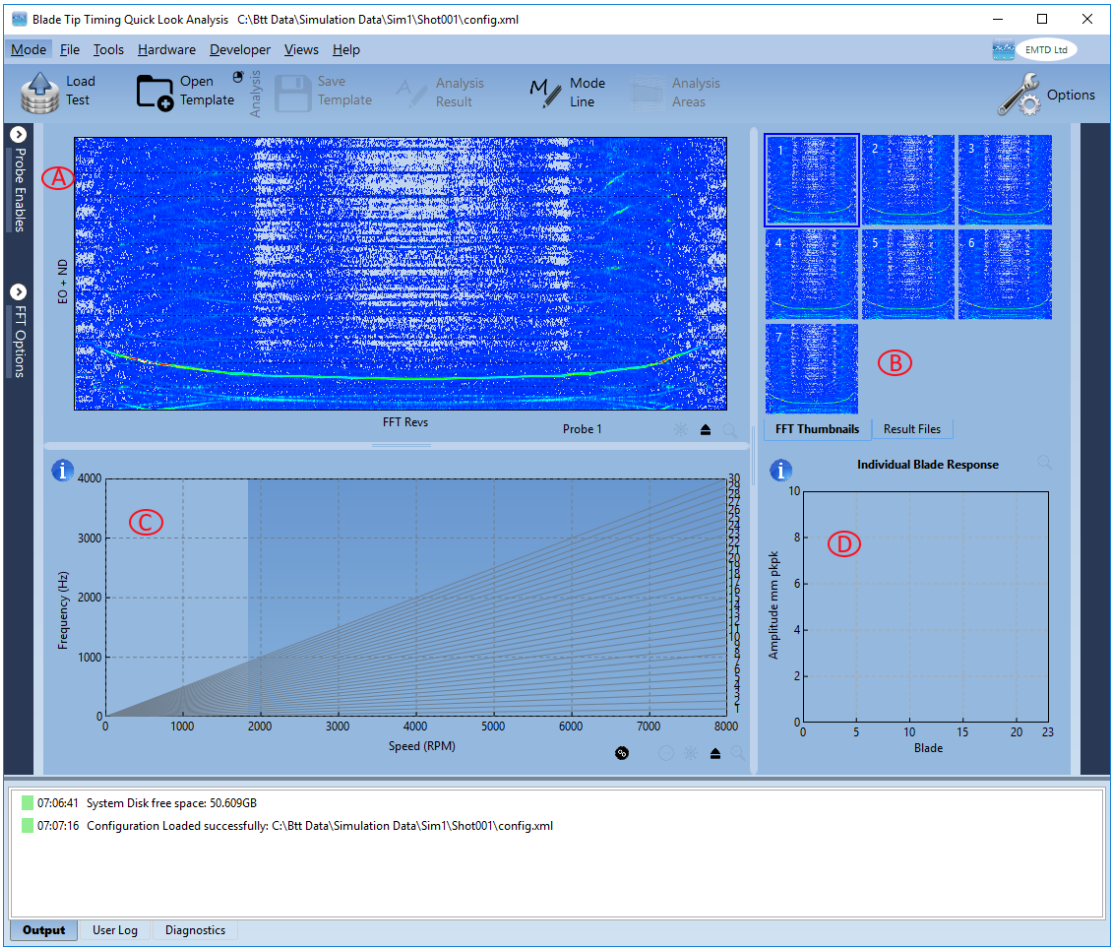


Figure 5 - Analysis Display Sections

Once the dataset has been loaded the display will update similar to that shown in Figure 5 .

Extra help is available throughout MultiTool wherever there is an information icon. Hover the mouse over these icons to display useful information.

1.3.1. Fast Fourier Transform (FFT) display (A)

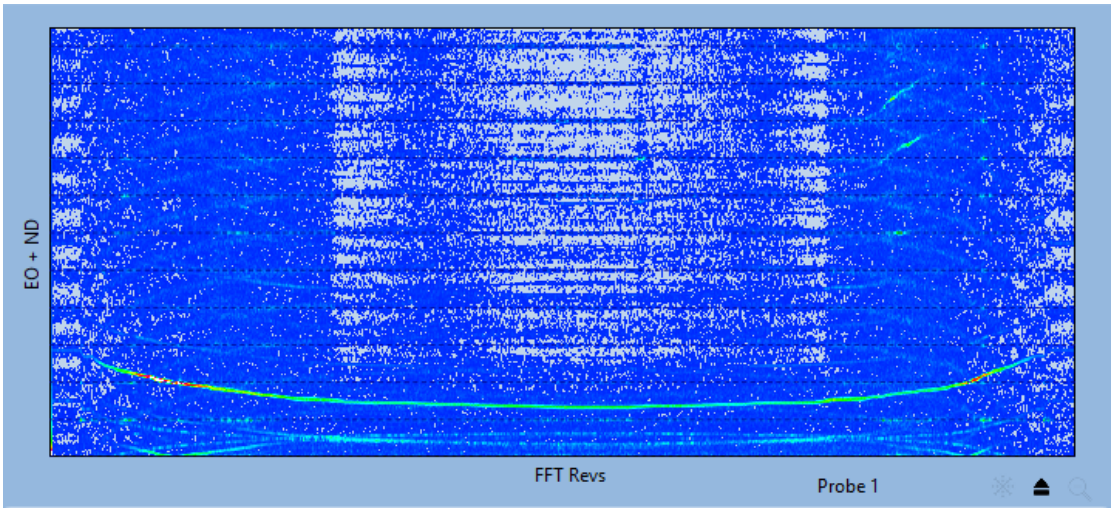
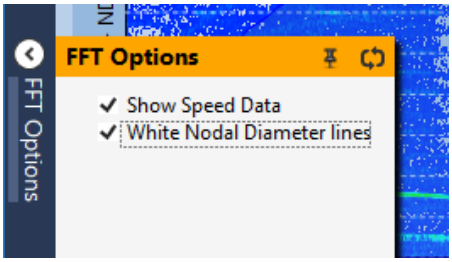
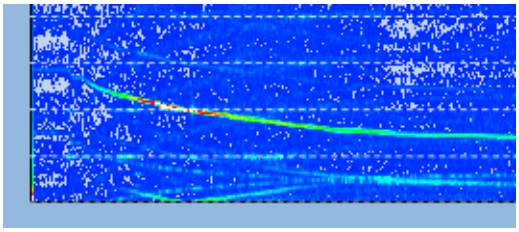


Figure 6 - FFT Display

This display shows the activity for all of the blades combined for a single probe. It is the best quick look method to determine if there are any responses in the data, where they are, and give an indication of amplitude. Moving the mouse over this display will cause the live cursor display to update with the revolution number, speed in RPM and percent plus overall amplitude. The full scale of the display can be changed using the mouse wheel. The resulting change depends on where the mouse is in the display. Fine changes occur to the left while there will be more coarse change with the mouse towards the right side of the display.



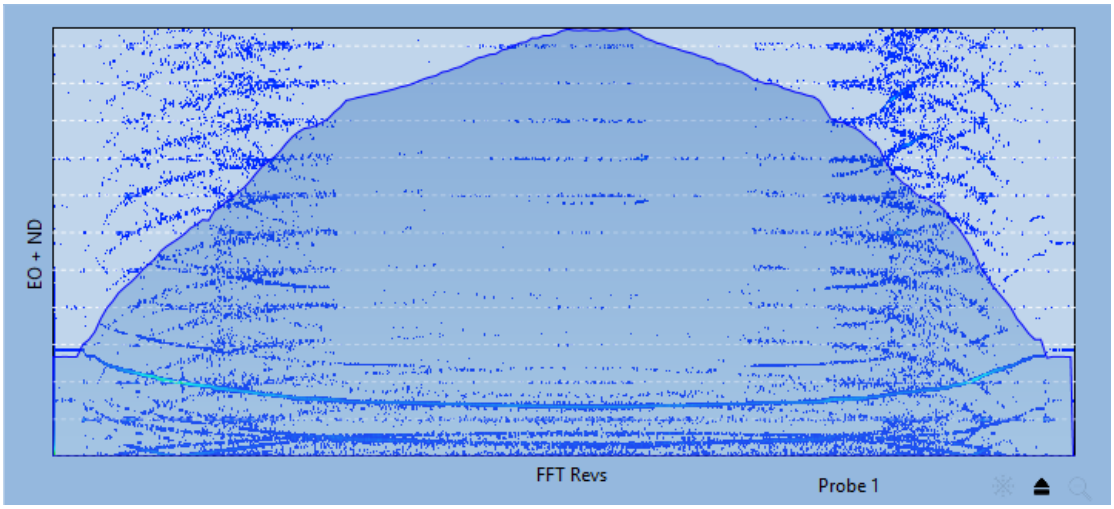


The horizontal dotted lines each represent a nodal diameter (ND) where the number of nodal diameters is equal to the number of blades divided by 2. Depending on the contents of the FFT and the current full scale these lines may not be very clear. From the FFT Options expander white ND lines can be selected to provide more contrast.

The speed profile of the dataset can be superimposed onto the FFT by selecting the Show Speed Data option. The full scale may have to be adjusted with the mouse wheel to make this more visible.

Where a response seems to have occurred at multiple nodal diameters is useful to ascertain if this is the case or if there is more than on response. To help with this if the control key is held down while clicking on the display all of the nodal diameter lines will be shifted and baselined on the mouse click point. Any activity on a ND line

will be part of the response under the mouse point. Any activity not on a ND line will be due to a separate response.



 The display can be zoomed, and re-zoomed, with the left mouse button. To reset the display use the reset button on the bottom right of the display.

 The display can be detached in order to make it easier to view and manipulate the data. Pressing this button will pop out the display into a new container. To put it back again close the new display.

1.3.2. Individual Probe FFT Display (B)

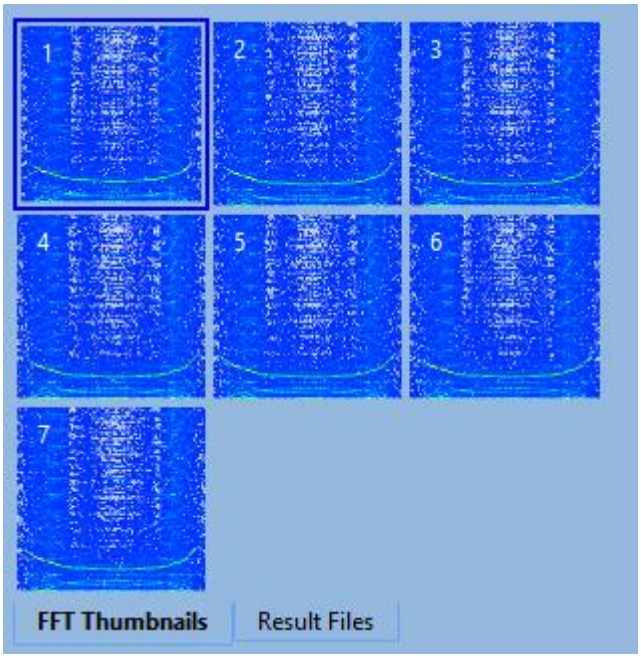


Figure 7 - Individual Probe FFT display.

A thumbnail view of each probes data is shown in this display. Clicking on one of these FFT thumbnails will put that probe on to the main display. If any of the probes contain bad data or other issues then it will be apparent from this display. If any probes need to be removed from the analysis this can be done using Disabling Probes for Analysis. Disabled probes will have a greyed out appearance. Again the full scales can be adjusted with the mouse wheel.

1.3.3. Analysis Results Viewer (B)

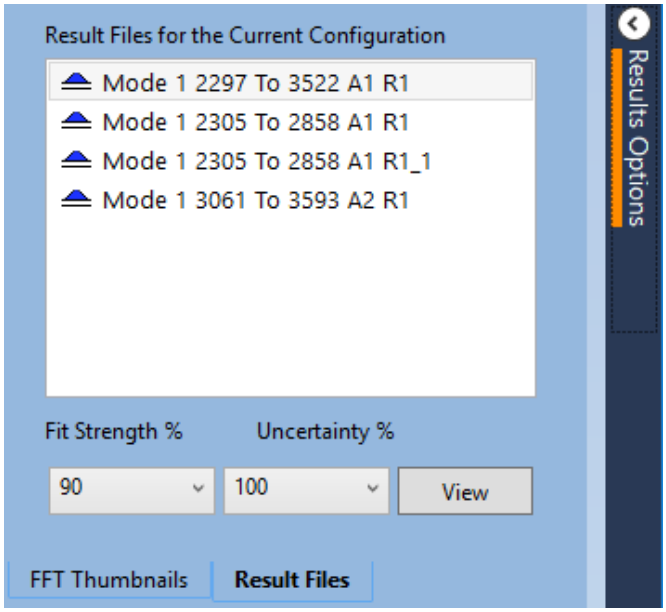


Figure 8 Analysis Results Viewer

The Results tab shown in Figure 8 Analysis Results Viewer allows the viewing of the results of an analysis. As new analysis is performed the list will be updated with the file. The symbol next to each file indicates whether the manoeuvre is an acceleration ramp, deceleration ramp or a more complex manoeuvre.

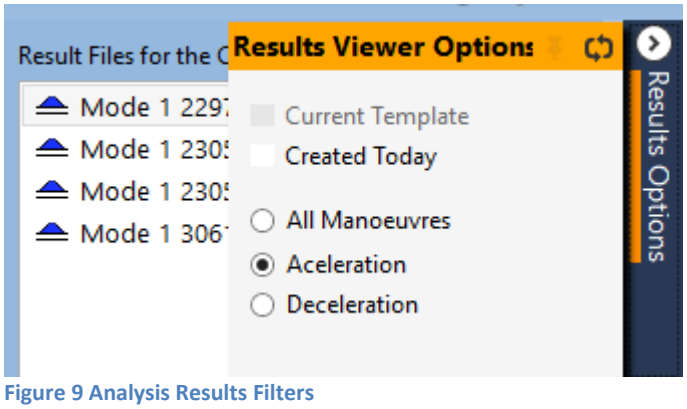


Figure 9 Analysis Results Filters

Where there are many results the view can be filtered so only a subset of results are displayed. These options are.

Current Template: Only show results of an analysis performed with the currently loaded analysis template.

Created Today: Only show results created since midnight.

Acceleration: Only show results from manoeuvres that are acceleration ramps.

Deceleration: Only show results from manoeuvres that are deceleration ramps.

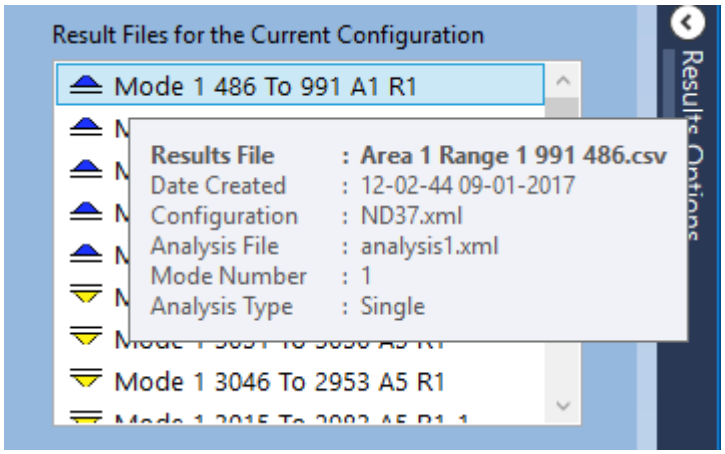
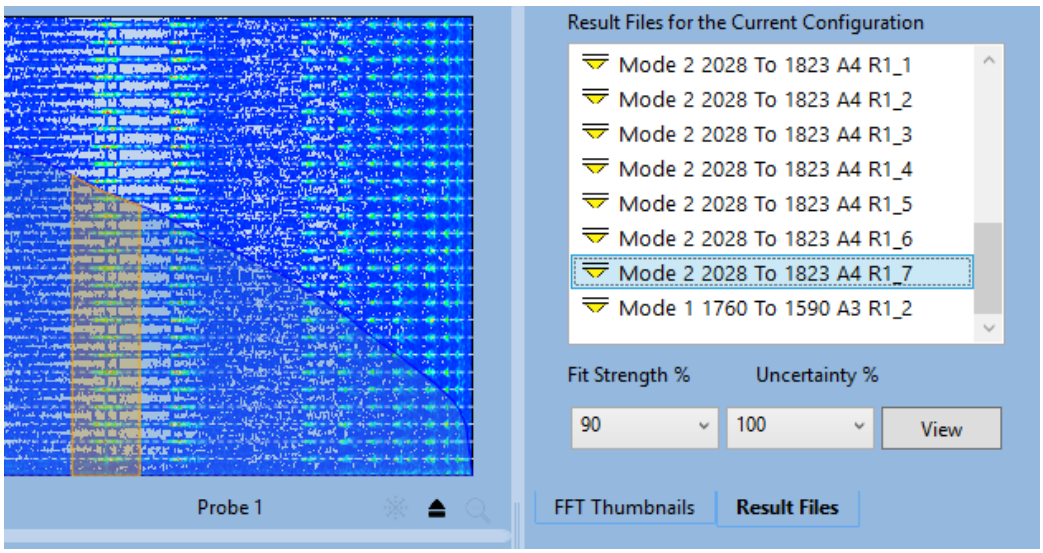


Figure 10 - Analysis Editing Display

Hovering the mouse over an entry in the list will display the summary information for the file as shown above. Pressing the *View button* will display the summary information for each blade in the 13. This chart is also used for displaying results from the Analysis Result Quick look (D) method.

Clicking on an entry will highlight the speed range of the analysis on the speed overlay on the FFT display in Orange. It will display the highlight regardless of whether or not *Show Speed Data* is selected in the FFT options.



Fit Strength is how we define how confident we are in the result. This can vary depending on the number of probes, noise, data quality and number of simultaneous modes. If a blades analysis result does not meet this threshold then the blade will not be shown in the Individual Blade Response chart. The blade result can still be viewed by shift clicking on the empty bar as normal.

Uncertainty is the calculated uncertainty from the analysis. Toi disable this setting select 100%.

Once the blades are displayed in the Individual Blade Response chart please refer to the Analysis Result Quick look (D) section for further instructions and information on how to view individual blade responses.

1.3.4. Analysis Editing Display (C)

This is where the various analysis areas are displayed and configured. The display has three main editors. Mode Line editor, Analysis Resultant Editor and Analysis Area Editor. Only one of these editors can be active at a given time. For more detail see the relevant sections.

 The display can be configured by pressing this button which brings up the configuration dialog. From here you can set various parameters for the display and choose which engine order lines are displayed. The engine order lines in the right hand panel will be displayed. They can be selected individually or in groups and added\removed to suit.

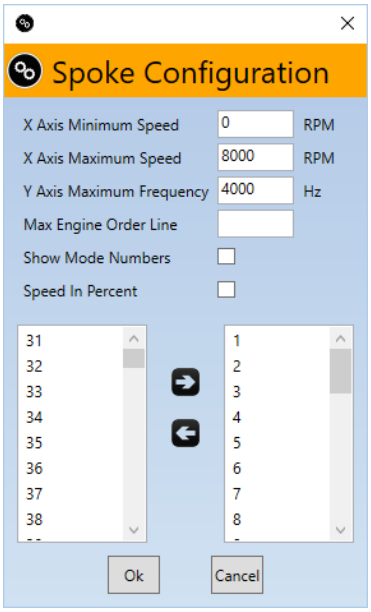


Figure 11 - Analysis Editor Configuration Dialog

 The display can be detached in order to make it easier to view. Pressing this button will pop out the display into a new container. To put it back again close the new display.

1.3.5. Analysis Result Quick look (D)

As part of the process to generate mode lines for the Mode Line editor based on real data this can display the results of the quick analysis. To enable quick analysis hold down the shift key while clicking on a response. See 1.6.1.

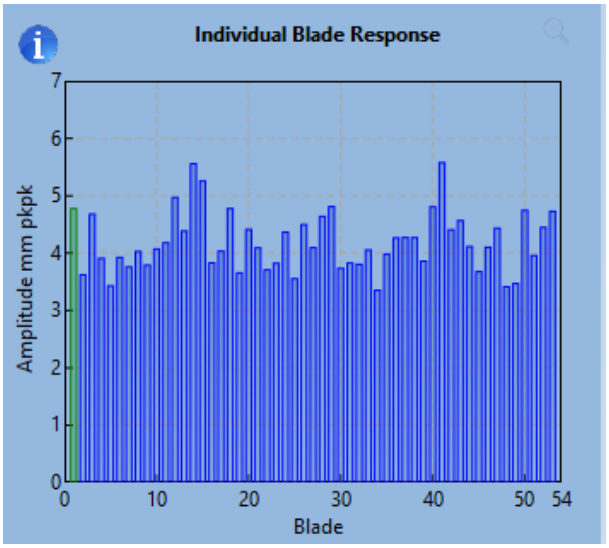


Figure 12 - All Blade Analysis Results display

The Analysis Quick Look Display shows the results of an analysis for each blade. For cases where there are large numbers of blades this display can be zoomed with the left mouse key. If the mouse is moved over the bars while holding the shift key then a summary box will be shown providing more detail on each blade.

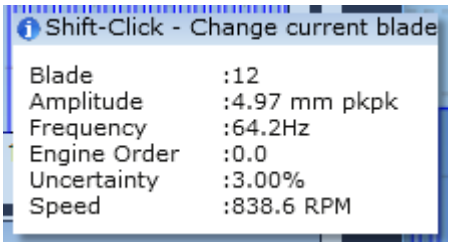


Figure 13 - All Blade Summary Display

Click the right mouse button on the Results display to bring up a context menu. This menu will allow you to export the data to disk or display the data in more detail in Figure 14 Individual Blade Data Result Viewer. The displayed data is a decimated subset of the data.

1.3.6. Blade Data Viewer

The Blade Data Viewer shown in Figure 14 displays the result of an analysis for an individual blade. It is used by both the Analysis Result Quick look (D) and the Analysis Area Editor methods.

The results can be plotted against revolution number or speed by ticking the plot against speed box. The info box shown is not available when plotting against speed.

For the full analysis method both the quality of fit and uncertainty of the measurement is calculated. The quality of fit is always shown but the uncertainty can be plotted by ticking the option. Note low values of uncertainty are good.

The purpose of the Red Cross is to indicate where the maximum value in the data is. If the display is zoomed around this point then eventually the peak data will sit on the cross. To change the current blade number click on the corresponding blade bar while holding the shift key down shown in Figure 12 - All Blade Analysis Results display.

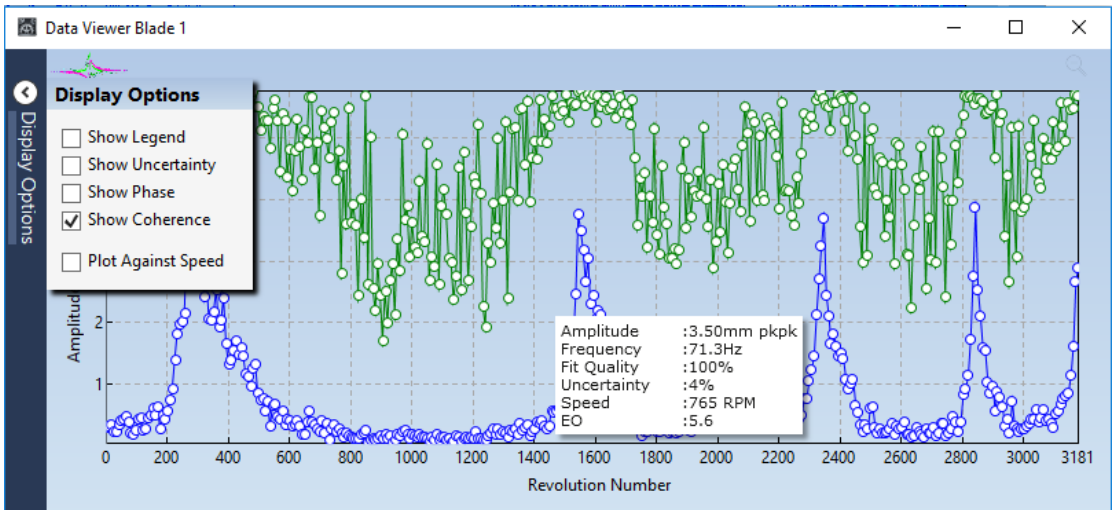


Figure 14 Individual Blade Data Result Viewer

1.4. Disabling Probes for Analysis

Using the - Individual Probe FFT display. to view probe quality some probes may need to be disabled. If the application has automatically disabled a probe it can also be turned back on again unless the file is empty or so poor that the application will not allow this. To enable or disable a probe use the Probe Enables Expander.

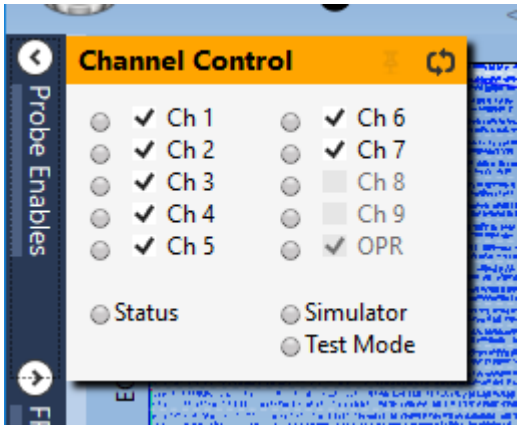


Figure 15 - Disabling Probes for Analysis

Probes that were not enabled in the configuration (because they don't exist) are greyed out. Probes can then be enabled or disabled by checking or unchecking the probe in the display.

Depending on which analysis algorithms are being used a minimum number of probes will be enforced by the application. It will not let you disable a probe if it breaks this rule. In this case you may need to re-enable a disabled probe first in order to disable a different probe.

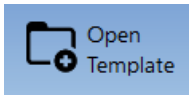
1.5. Analysis Areas and Analysis Templates

Each analysis in MultiTool is defined by an Analysis Area. Each area encapsulates an individual analysis. No distinction is made between asynchronous or synchronous analysis types and multiple areas can be defined. Currently this is limited to areas where there is only a single response active at a given speed.

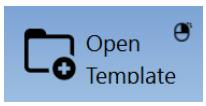
An Analysis Template describes all of the analysis areas to the analysis engine defining the analysis to be done on the dataset.

1.5.1. Opening and Saving an Analysis Template

An analysis template is a stand-alone file that is applied to but not linked to the dataset. This means that it can be copied and used on multiple datasets.



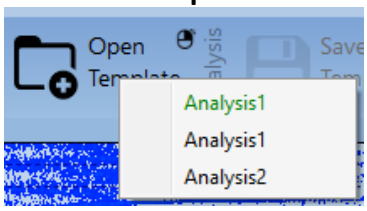
If an analysis template already exists it can be loaded into the editor using the Open Template button. Template files have the .xml extension and should not be edited manually. Simple typos or capitalisation errors will break the file and it will not load.



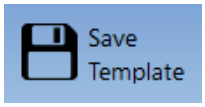
If an analysis template is located in the same directory as the dataset then a quick load is available when you see the mouse image on the Open Template button.

 Pressing the right mouse button on the Open Template button will display a list of valid templates. Select the one you want from the list.

Common Templates



If a folder exists underneath the configuration Directory called 'Common Templates' then any templates located in it will be appended to the list of available templates. These templates will be at the top of the list and shown in Green. Note the common templates can be named the same as an existing template. An example location would be C:\EMTD Data\Eng004\Common Templates



Once a template has been defined using the editor it can then be saved to disk using the save template button.

1.5.2. Mode Line Editor

We can create modes that match the model of the blade created during the FE modelling process. The Mode Line Editor is used to do this and can be enabled by pressing the button. If this button is greyed then you may have one of the other editors active. Close that first.

 The display can be detached in order to make it easier to view. Pressing this button will pop out the display into a new container. To put it back again close the new display.

Once the editor is active mode lines can be created by holding the control key and clicking on the appropriate part of the chart. Each click creates a point on the mode line allowing complex responses to be entered. For example starting at the left edge of the plot hold the control key down and click. Keeping the control key down move to the right and click again and a line will be shown. Add more sections as required and when finished release the control key and click once more on the display to create the mode line. A sample line is shown in Figure 16

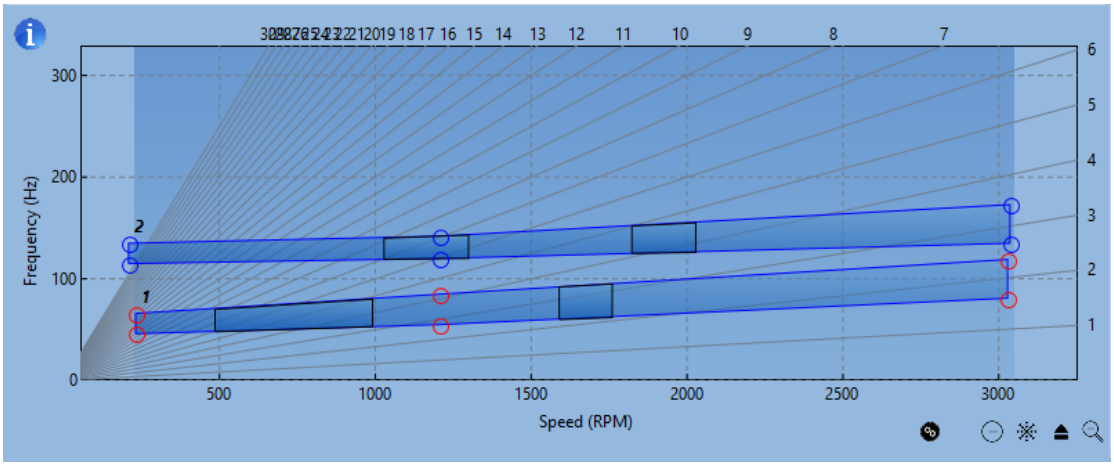


Figure 16 Editing a mode line

The red handles indicate that this mode is the currently selected mode in the editor window. When more than on mode has been defined the inactive mode lines will have blue handles. To select a different mode line click on it. The selected (red) mode lines data points are shown in the Mode Line Editor pop up window which is present whenever the Mode Line Editor is active. If it is accidentally closed disable and enable the mode line editor to bring it back. No data will be lost.

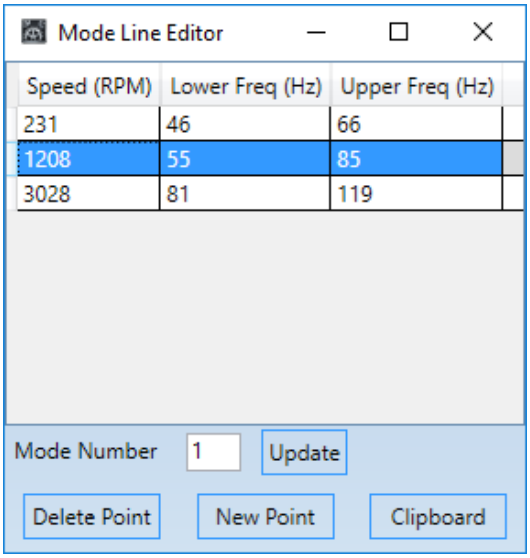


Figure 17 Single Mode line Editor

As can be seen from the example the mode line has three points represented by three sets of red handles. The currently selected handle is filled with red and highlighted in the table with a blue background. The current point can be edited or deleted using the buttons in the editor. The mode line is given a unique number when created and this can also be changed in the editor. Whether or not the mode number is displayed is a configuration option. See Figure 11 - Analysis Editor Configuration Dialog

The whole mode line can be moved with the mouse by dragging it with the mouse ensuring it is not on any handles. The individual mode line points can be added to,

changed or deleted either by editing the value directly or dragging the corresponding red handle with the mouse. Drags can be undone to a limited extent using Ctrl Z.

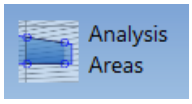
A minimum of two points is required to define a line and the points are always ordered by speed with the lowest speed being the first point. The mode lines are restricted to a maximum of 500Hz frequency band. The bigger this band is the longer the analysis process will take so it is advisable to make the bands only as big as required. They can always be adjusted at any time.

 To delete the selected mode line press this button. If no mode lines are selected then it will be greyed out. Pressing the delete key will perform the same function.

 To delete all mode lines then press this button. The use will be asked to confirm this action because any defined analysis areas attached to the mode line will also be removed. This cannot be undone.

1.5.3. Analysis Area Editor

We can create analysis areas which attach to a mode line and define a single analysis for the dataset. The Analysis Area Editor is used to do this and can be enabled by pressing the button. If this button is greyed then you may have one of the other editors active or no mode lines defined.



 The display can be detached in order to make it easier to view. Pressing this button will pop out the display into a new container. To put it back again close the new display.

Once the editor is active an analysis area can be created by clicking inside a mode line while holding the Ctrl key down. This creates a new analysis attached to the mode line. If you subsequently delete the mode line then you will also delete the analysis area. The areas cannot be moved outside of the mode lines. If a wider frequency or speed band is required then edit the mode line instead. As mode lines are edited or moved then so are any analysis areas attached to them.

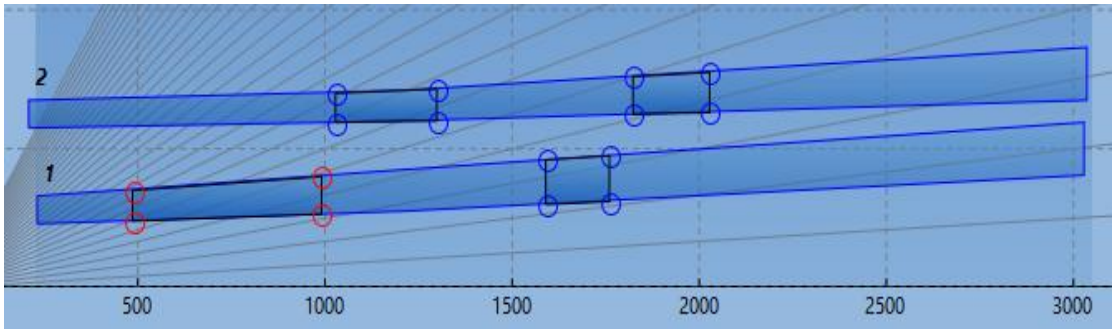


Figure 18 Analysis Area Selected

The selected analysis area is shown with red handles and unselected areas are shown in blue. To select an analysis area click on it. If the analysis areas do not have handles then the Analysis Area Editor is not active or you are looking at a mode line. The areas can be moved and resized in the same way that the mode lines can.

All analysis areas are displayed in the Analysis Control Panel. The selected area is highlighted with a blue background. If an area is selected in the control panel it will also be selected on the display and either method can be used to select an area.

The analysis areas must lie inside the speed range of the dataset. They are allowed a small overlap of around 10%. If the analysis are speed range exceeds this then the perform analysis button will be disabled.

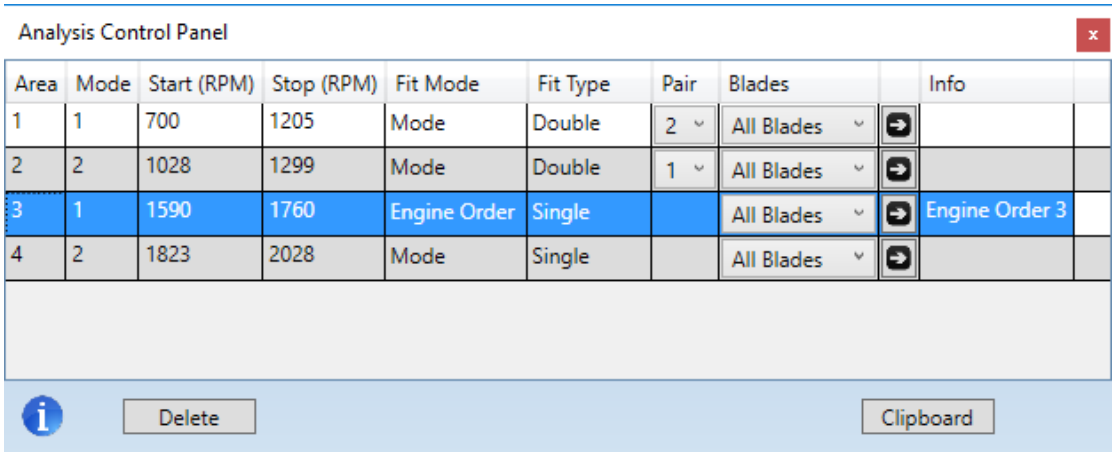
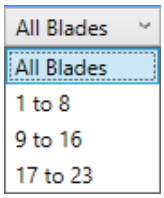


Figure 19 Analysis Control Panel

Each analysis area is given a unique number from 1 to n. **Mode** is the mode number of the mode line that it is attached to. **Start** and **Stop** speeds are in RPM and can be edited in the table directly or by dragging one of the handles.

The **Fit Type** of analysis can be a single or double analysis. A double analysis is where two responses are active at the same time. The **Fit Mode** selects the fit algorithm used in the analysis. This can be either the default 'Mode' or a tracked 'Engine Order' fit which ignores any asynchronous contribution.



For a large dataset it may be desirable to only analyse a few blades to have a quick look at the results. The default is to process all blades. The options may look different on your computer as the number of blades that can be analysed simultaneously is equal to the number of cores in the computers processor.

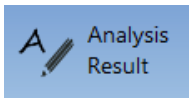
Any extra information will be displayed under **Info**.

Perform Analysis

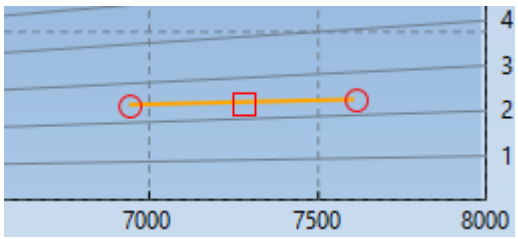
To perform an analysis click on its corresponding button. If this button is greyed then one or more of the analysis rules have not been met. A dataset must have been loaded and the dataset must contain the speed range defined in the analysis area.

1.5.4. Quick Analysis Result Editor

When a quick analysis has been performed on a dataset to aid in positioning mode lines the results may not be in the desired place. The quick Analysis Result Editor can be enabled to move or change the result. The editor can be enabled by pressing the button. If this button is greyed then you may have one of the other editors active or no quick analysis has been performed.



The results of a quick analysis are automatically added to the display and are represented by a yellow line. The selected line has red handles.



To move the whole line drag using the Square handle. To extend or move an end point drag the relevant circular handle.

To delete the selected line press this button. If no result lines are selected then it will be greyed out.

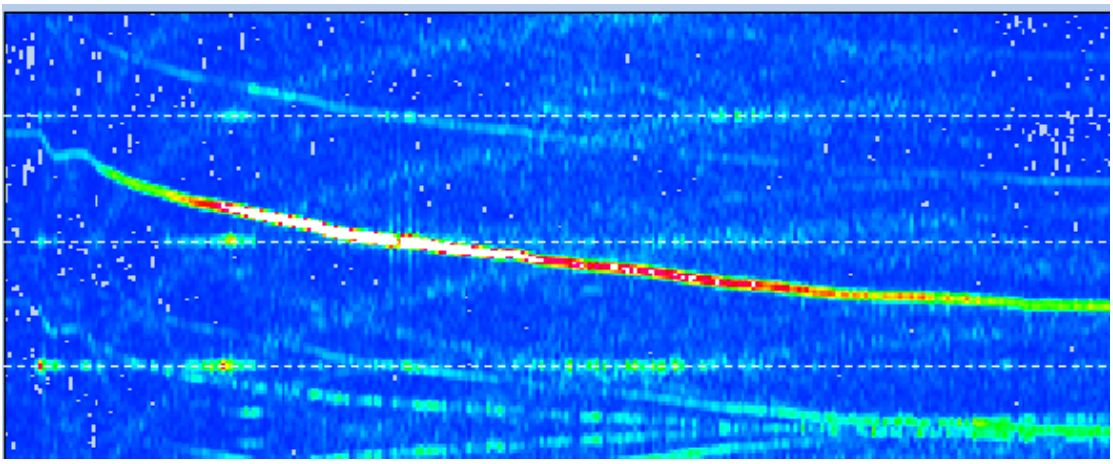
To delete all quick result lines then press this button. The use will be asked to confirm this action as this cannot be undone.

1.6. Walkthrough – Performing an analysis

This is a step by step guide to how to set up and execute an analysis.

1.6.1. Tracking a Response

Load a dataset into MultiTool and find an area where a response occurs such as that shown below.



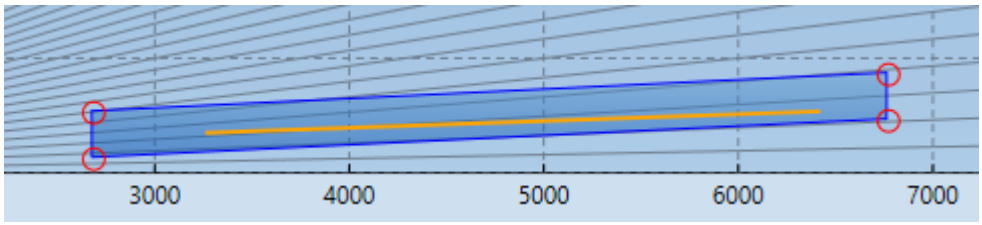
Select the desired tracking mode in 1.7.3. In order to track the response we click on it at the left most part that meets the initial tracking conditions and it tracks to the right. If the display is zoomed then the system will not track outside of the display. This is useful where you need to limit the tracking due to noisy data or away from an area that contains a second response.
When the tracking has completed it will display the tracked points on top of the FFT display. If here were not enough points in the tracked data nothing will be displayed. With enough track points the system will calculate:

1) The Nodal Diameter (ND) of the response for each tracked value along with the percentage of the tracked values that had the same result. 100% being the best possible indication.
2) The number of tracked samples.
3) The average frequency of the tracked data.

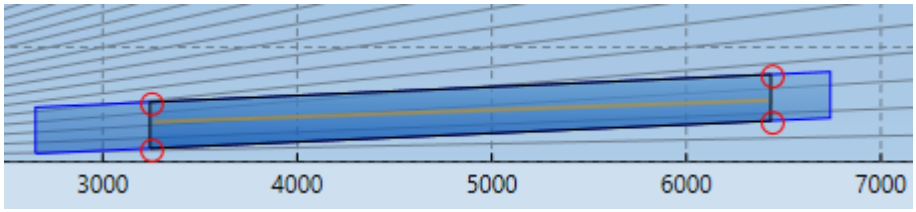
If the Shift key was pressed during the track then a quick all blade analysis will be performed and the results added to the 1.3.5.

A Yellow 1.5.4 will be added to the Editor window. If this result is not in the correct place it can be moved or extended using the editor. This result can be deleted once the mode line and analysis area but leaving at least one as a visual que is recommended.

Using the 1.5.2 a mode can then be created over the analysis result as shown below.



Using the 1.5.3 an analysis area can then be attached to the mode line. Hold the control key and click inside the mode line.



We have now created a single area analysis. However this analysis will be performed on all areas of the dataset that match the speed criteria. When an area is highlighted in the Analysis Control Panel the FFT display will highlight the parts of the dataset that match the speed range. In the case below there are two regions that match and each will be analysed separately.

Each analysis will have its own output file. The output files will be saved to the same location as the data and named with the speed ranges and number of the analysis area.

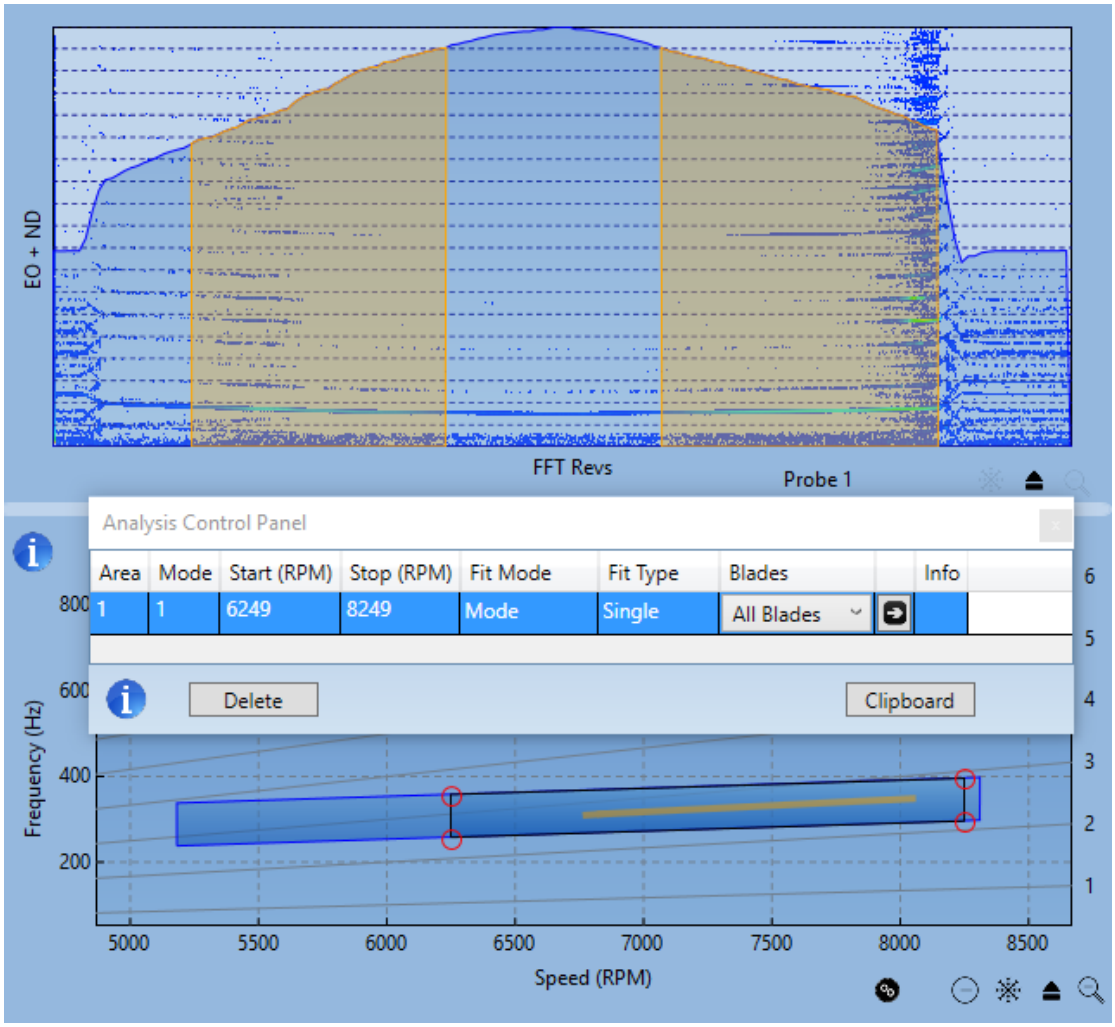


Figure 20 Analysis Area Highlighted Speed Ranges

 To perform an individual analysis, click on its corresponding button. If this button is greyed then one or more of the analysis rules have not been met. A dataset must have been loaded and the dataset must contain the speed range defined in the analysis area. There must also be enough revs to perform the analysis.

Minimum Analysis Revolutions

For some datasets an analysis area may highlight lots of unwanted smaller parts of the file caused by speed changes during the manoeuvre. To prevent these smaller areas appearing a minimum number of revolutions can be specified in the preferences dialog. See *Figure 21 Tracking Preferences* for the setting. A default value of 500 revolutions is used.

To perform a double analysis two analysis areas must first be paired. To do this use the **Pair** column as shown below. If the **Pair** column is not visible then there are not two areas with their **Fit Mode** set to double.

Area	Mode	Start (RPM)	Stop (RPM)	Fit Mode	Fit Type	Pair	Blades	
1	1	700	1205	Mode	Double	2	All Blades	
2	2	1028	1299	Mode	Double	1	All Blades	

For a double analysis the double fit will only be performed when the two areas overlap on the **Spoke Chart**. The non-overlapping areas will be analysed as singles. If no areas overlap then the analysis will be run as a single.

Once an analysis has completed the results can be viewed by switching to the Results tab and populating the results view. See the section Analysis Results Viewer (B) for help in doing this.

Analysis Results File Size limitations

Performing an analysis on a large dataset can result in very large analysis result files. There are two types of result file available to the user, the Comma Separated Values (CSV) and a binary file. A CSV file is always written but there is now an option in the Analysis Window to also write the binary file. If the written CSV file is larger than 200MB then a binary file is always written. When viewing results in the Analysis Results Viewer (B) the system will default to the CSV file unless the csv file is larger than 200MB, in which case it will use the binary file. Both files must exist so do not delete either one.

In cases where the CSV file is less than 200MB and an optional binary file has been written, the user has a choice. By default the viewer will use the CSV file. If the Control key is held while clicking on the *View* button then the system will use the binary file (if present). The Results Viewer displays the source of the data in the title bar, either ‘CSV’ or ‘Binary’.

1.7. Tracking Preferences

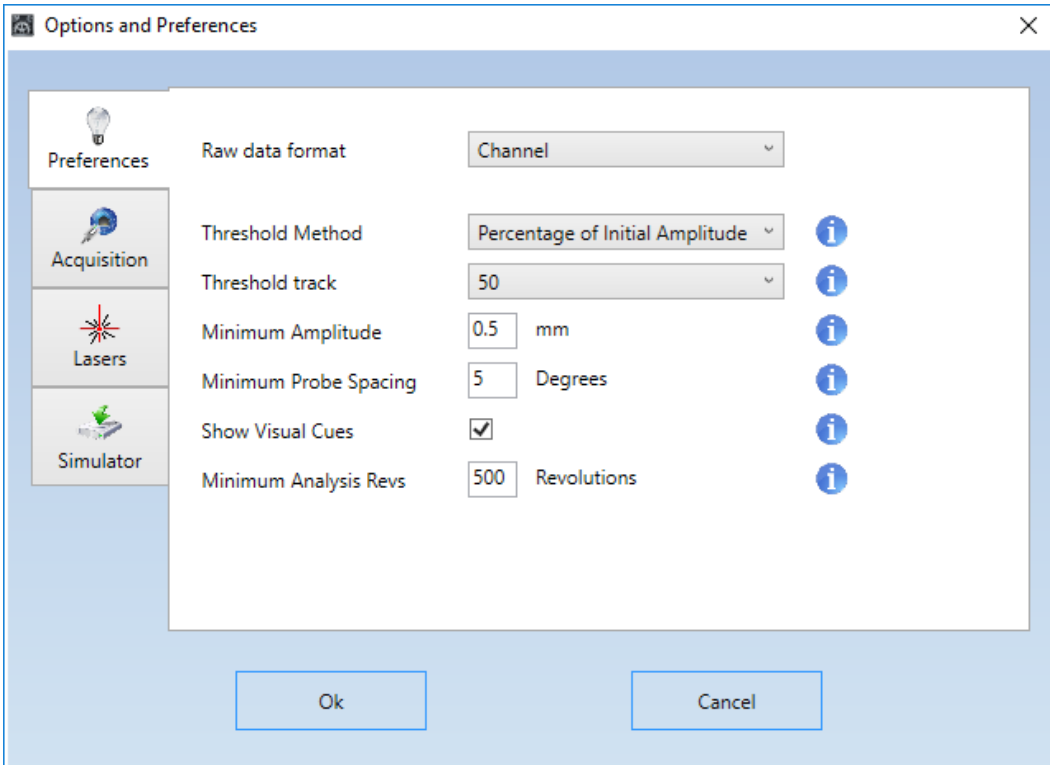


Figure 21 Tracking Preferences

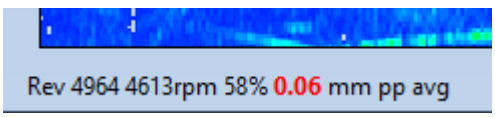
There are several ways to configure how the system tracks a response in the FFT display. The mode is set using the Threshold Method.

Extra help is available throughout MultiTool wherever there is an information icon. Hover the mouse over these icons to display useful information.

1.7.1. Fixed Min Value

When selected the tracking algorithm will continue to track the track the peak value of the response until the amplitude of the response falls below the value specified in the minimum Amplitude field. It will allow it to temporarily fall below this value for one FFT rev so that small gaps can be bridged.

In this mode the FFT live cursor display will show a red amplitude when the response under the mouse pointer is not sufficient to start tracking.



1.7.2. Percentage of Initial Amplitude

When selected the tracking algorithm will continue to track the track the peak value of the response until the amplitude of the response falls below the percentage of the initial clicked on value specified in the Threshold Track drop down list. It will allow it to temporarily fall below this value for one FFT rev so that small gaps can be bridged.

1.7.3. User Defined Track

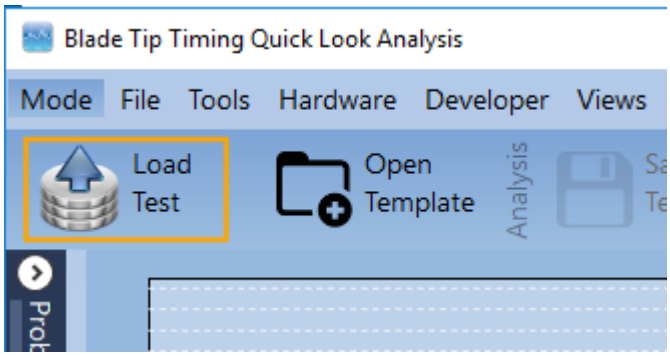
When the response is very small or irregular or has gaps in it the tracking algorithm can sometimes struggle to differentiate between the response and the background noise around it.

The user defined track method allows the user to click twice to define a tracking line. The line can be defined in either direction but the system will always track left to right along the line. The tracking system will track the maximum value from the data along the line within a +/- 5 bin range but with no minimum value.

The first click on the FFT that is not defining a zoom (dragging out a zoom rectangle) will register the first point. The cursor will then change to a pencil. If this click is in error press the escape key to reset the system. A second click will initiate the track and the tracked data will be shown over the data.

1.8. Visual Cues

A series of visual cues will be shown as flashing borders around buttons, images, tabs and other part of the application to highlight the next possible step in the workflow. It is also used to highlight parts of the application that the user may be unfamiliar with. These look like the following but flash several times before stopping.



Visual Cues can be turned off in the Preferences Dialog. See Figure 21 Tracking Preferences.