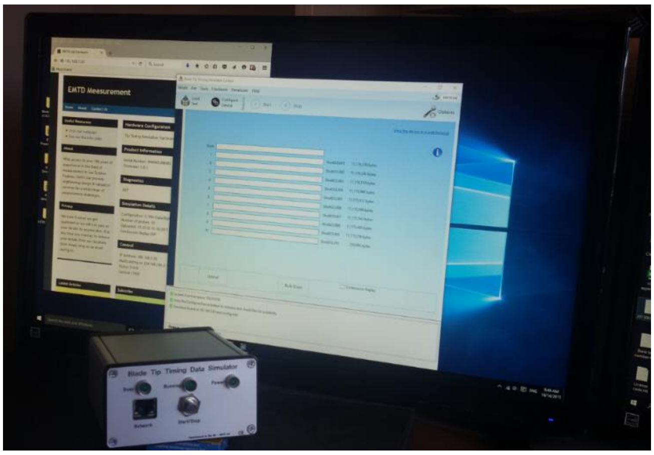
MultiTool Blade Tip Timing Acquisition, Analysis and Data Simulation Software

Editor Manual



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2. MultiTool Editor Mode

The Editor mode of MultiTool allows the user to create, edit and save a configuration file. A configuration file holds information about the test configuration used to acquire the data and this file is needed for all modes of MultiTool except Simulator.

Some MultiTool features are licensed separately. If the editor 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 the editor then please email support@emtd-measurement.com

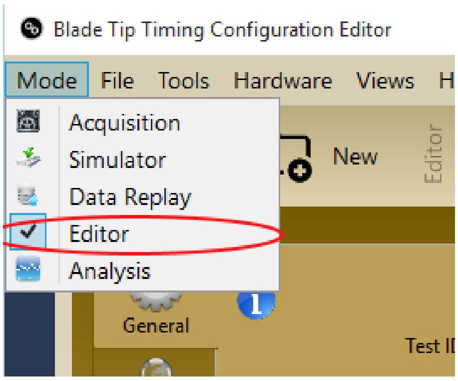


Figure 1 - Switching to Editor mode

2.1. Loading a configuration file

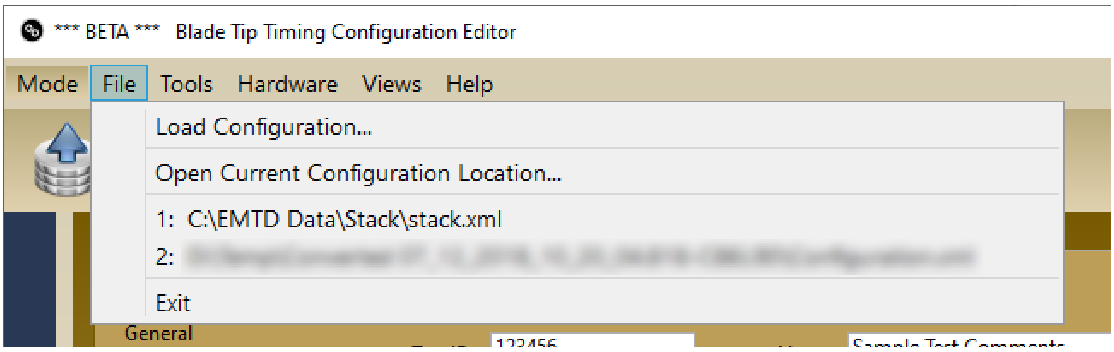


Figure 2 - Loading a configuration file

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 operating mode of the application so if you have loaded the file in the editor it will appear in the recent list but won't appear in any other operating mode's list until it has been loaded into that particular mode at least once.

If the configuration file has not been loaded before then select *Load Configuration* from the menu or press the Load Test toolbar button.

2.2. Editor Window

The editor mode of MultiTool has separate functions spread over multiple tabs. Some of these functions are licensed separately and may be greyed out. The Tool Buttons which only appear for the editor are black. When MultiTool switches to the editor the default window is a new configuration ready for editing.

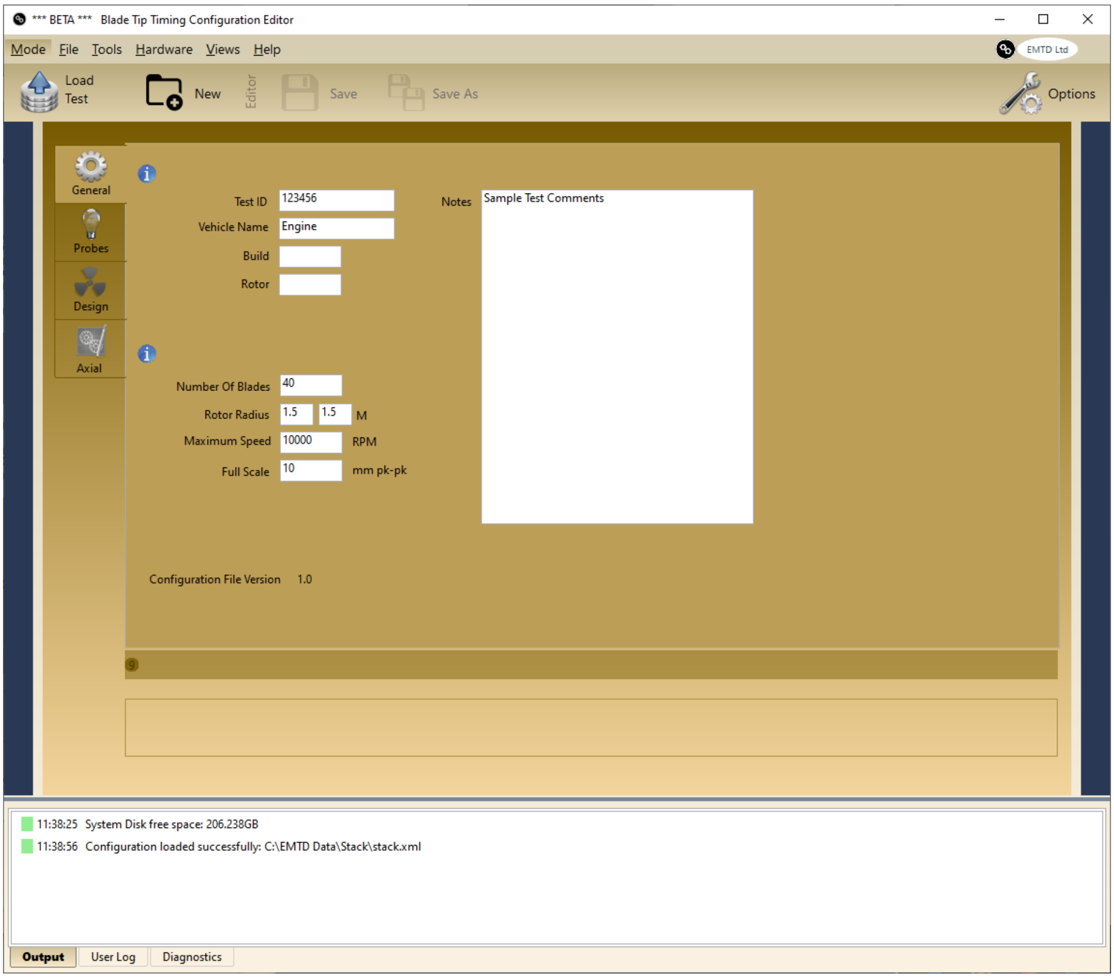


Figure 3 – Editor Main Display

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

2.3. Test Information

This screen contains information to help identify the test and describe some of the hardware geometry.

These parameters are not used in MultiTool internally and are for information only to help uniquely identify the test.

- **Test ID** - If your organisation assigns unique test identifiers for each test or part test then enter the number here.

- **Vehicle Name** - If your organisation assigns vehicle names for tests then enter the name here.

- **Build** – The build number can be used to differentiate when the same vehicle is tested multiple times but in different configurations.

- **Rotor** – Where the vehicle may have multiple stages of BTT fitted this helps differentiate the different stages.

- **Notes** - For any general comments relating to the test.

These parameters **are** required for correct operation of the system.

- **Number of Blades** – The number of blades on the stage being tested.

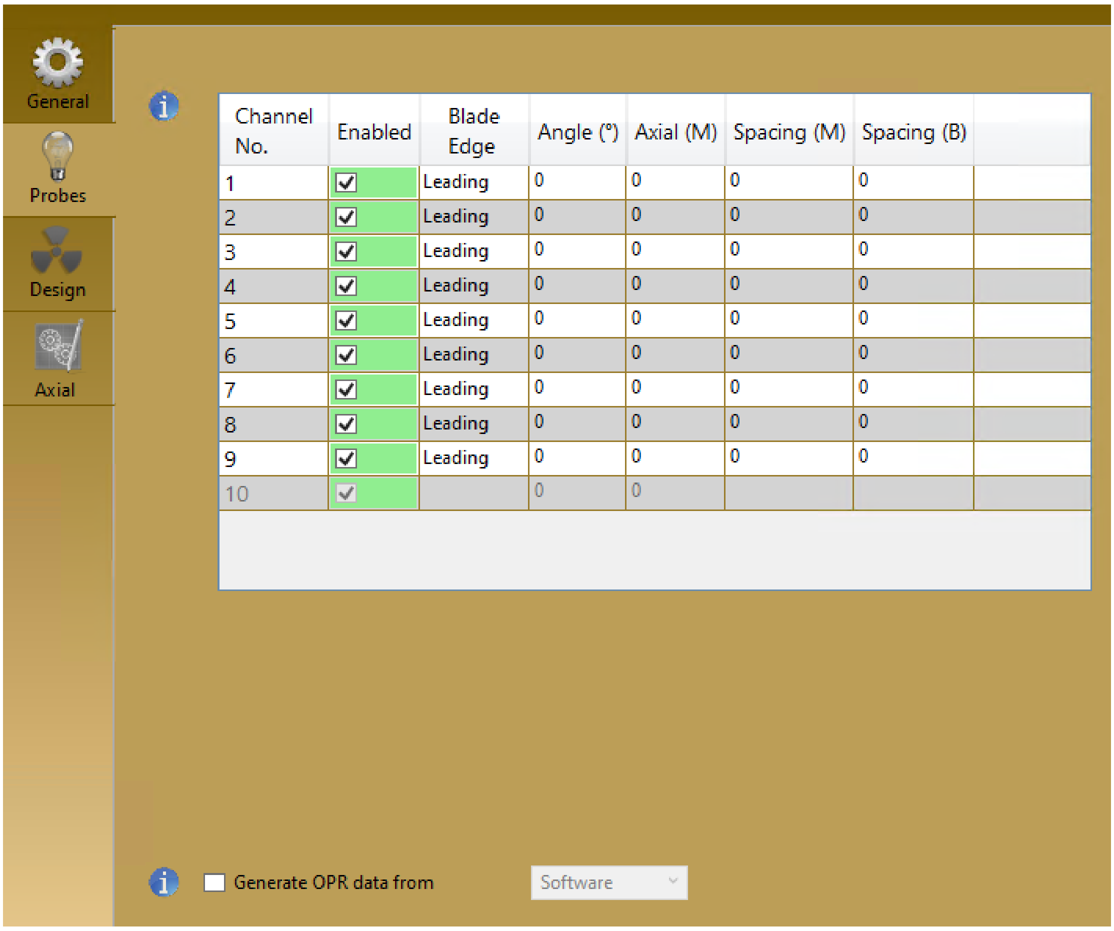
- **Rotor Radius** – The distance in meters from the centre line to the tip of the blade. For applications where the probes may be at multiple axial positions and the blade tip is not square then enter a value for the font of the blade and one for the rear of the blade. For flat blades use the same value twice.

- **Maximum Speed** - The maximum speed of the tested stage under normal operating conditions. This is important so that the acquisition system can be correctly configured and is also used by the replay and analysis modes as part of the data quality checks. This value should be within +/- 200 RPM.

- **Full Scale** – This value is used to set the initial full scale of the displays that use mm pk-pk. This value should be an integer value.

2.4. Probe Information

The probe information tab holds information on individual probes. This information is critical in ensuring a quality result and great care must be taken to make sure that this is accurate. Both the Replay and analysis modes will perform checks on the raw data and will throw out any dataset that has incorrect values.



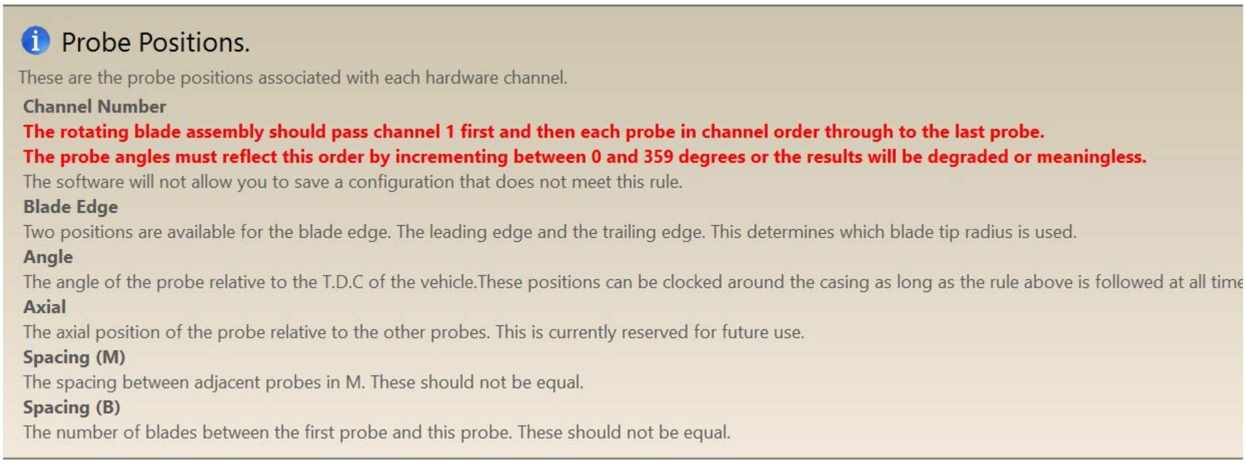
Channel No.	Enabled	Blade Edge	Angle (°)	Axial (M)	Spacing (M)	Spacing (B)
1	☑	Leading	0	0	0	0
2	☑	Leading	0	0	0	0
3	☑	Leading	0	0	0	0
4	☑	Leading	0	0	0	0
5	☑	Leading	0	0	0	0
6	☑	Leading	0	0	0	0
7	☑	Leading	0	0	0	0
8	☑	Leading	0	0	0	0
9	☑	Leading	0	0	0	0
10	☑		0	0		

Figure 4 - Probe Information

2.4.1. Channel Number

Note – The way the probes are connected to the acquisition system is vital to the correct operation of the whole system. Experience has shown that this is a major cause of errors in testing with BTT. The following information is available by placing the mouse over the info point on this tab.

Note in particular the text in red.



The problem with describing the probe configuration arises because:

- Different vehicles rotate in different directions.
- Different manufacturers assign angles in different rotational directions.
- Different manufacturers assign blade numbers in different rotational directions.

To avoid worrying about the above EMTD has implemented a simple scheme in MultiTool.

> The system expects that a rotating blade will travel under probe one first then under probe two and then on through the remaining probes in order until it passes under the last probe.

Note - MultiTool will not allow you to save a configuration that breaks this rule.

2.4.2. Probe angles

We are dealing with probe angles out of order as they are impacted by the above policy.

The probe angle entry records the angular position of the probe around the casing. As stated above the vehicle scheme may well define the angular position around the casing (0-359) in the opposite direction to rotation.

> MultiTool expects the probe angles to increment from 0-359 in the same rotational direction as rotation.

Note - MultiTool will not allow you to save a configuration that breaks this rule.

If the above is not true then new values for angles need to be calculated that ensures that the above two rules are not broken. Note that absolute angle values are not important. It is the angular distance between probes that is required for calculation so the following examples are identical but the second one is in the correct form.

1. P1-5 : 200, 250, 300, 350, 40
2. P1-5: 0, 50, 100, 150, 200

2.4.3. Enabled

Ideally all probes will be enabled but if a probe is broken of particularly noisy it can be turned off in the configuration.

No data will be recorded from disabled probes. EMTD recommends that all probes are left enabled as they may work intermittently over certain speed ranges or temperature bands and the software will be able to use this data for an analysis.

2.4.4. Blade Edge

Two positions are available for the blade edge, leading edge and trailing edge. These labels may only make sense in some vehicles but they are only used to determine which rotor tip radius is used for calculations. Assign leading edge to use the first rotor tip radius and trailing edge to use the second.

2.4.5. Axial position

This is the axial position of the probe over the blade. The reference for this measurement depends entirely on the data provided to the Axial Position Calculator. For example if the data provided is measured with respect to the front edge of the blade then this axial position is with respect to that. The same goes for the trailing edge of the bale or and other reference point.

2.4.6. Spacing (M)

This column is read only and displays the spacing between each adjacent probe in Meters around the casing.

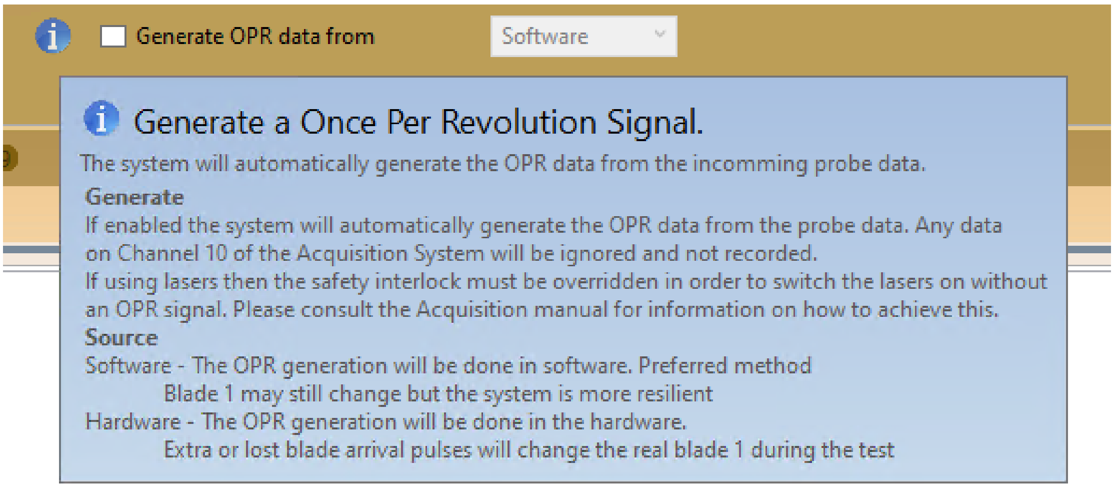
2.4.7. Spacing (B)

This column is read only and displays the spacing between each probe and probe 1 in blade pitches around the casing. A blade pitch is the distance between two blades.

2.4.8. Once per Revolution Derivation (OPR)

> **Caution**
> EMTD strongly suggests that when planning a test that provision is made for a physical OPR system.

The EMTD BTT system is able to derive an OPR signal in the case where the main OPR has failed or one is not available. EMTD strongly suggests that when planning a test that provision is made for an OPR signal to the system. In challenging environments where some data loss is inevitable an OPR signal can make analysis much easier for some of the more complex analysis methods. Where an OPR is not available there is the choice to derive an OPR from the probe signals either in the hardware or in the software.



The help popup above can be shown by holding the mouse over the info icon in the probes tab.

The Hardware OPR generation consists of selecting every n^{th} blade passing signal where n is set by the MultiTool to the number of blades and routing this signal to channel 10. This operation is performed in the hardware acquisition unit.
This method can create problems common in other OPR derivation techniques. This being that the start up is random meaning that 'blade 1' changes from run to run. Secondly the order may change during data collection so that 'blade 1' shuffles due to lost and surplus signals. For real time acquisition and this is not usually a problem for the monitoring of displacements, however during analysis the blade order may change invalidating any analysis performed.

For this reason we recommend that a second software derived OPR is generated after the test and used for the analysis of data. These tools are available in MultiTool replay software where other automated validation checks are also made

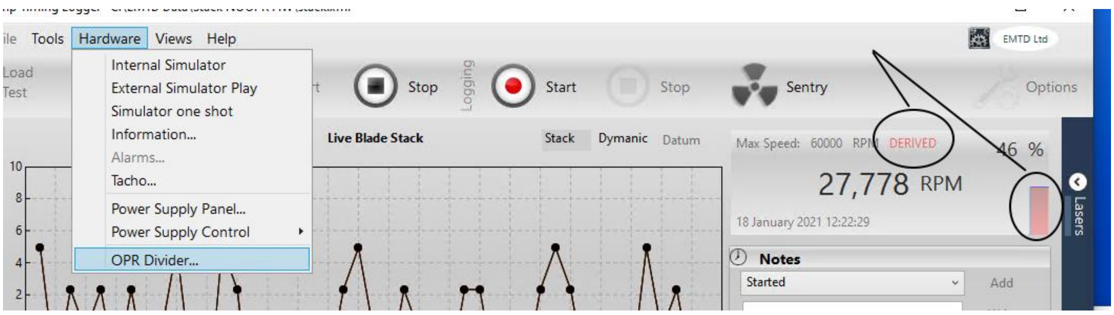
Creating a software OPR after all of the data has been collected allows MultiTool to correct for errors as it has access to all the data. Multitool will also maintain the position of blade 1 across all manoeuvres for analysis purposes.

Please note it is not possible to identify the physical blade 1 from the rotor assembly using a derived OPR. This is only possible with a physical OPR.

To enable the OPR generation, load a configuration into the Configuration Editor and switch to the probes tab. At the bottom select the 'Generate data from' checkbox. Now select hardware or software (preferred).

The current preferred method is software and with this method there is no choosing the source probe for derivation. To derive the signal in hardware then a single probe will have its blade arrival pulses divided by the number of blades to generate an OPR signal. This hardware algorithm may be developed further with more learning capability in the future. Note that for perfect probe signals, no lost or surplus, the end result will be the same. However, the software method has more resilience.

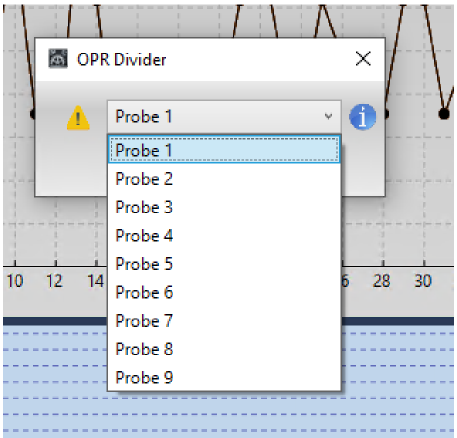
Save the configuration and load it into the Acquisition Mode of MultiTool. When running the system will have an enabled menu under the hardware Menu Item.



Selecting this will bring up the source probe selection dialog. Note that when the OPR is derived the word DERIVED is displayed in red in the Speed trace display and the fill colour of the speed envelope is now also red. This is a visual aid for the operator that the OPR is derived.

In the OPR source probe dialog select the probe providing the best data in the list and press okay. The system will now use this as the source probe for dividing down into an OPR pulse.

Note – For recreating the OPR after the test please refer to the Replay manual where this process is described.



2.5. Test Design

If the probe design component of MultiTool has been licensed then the tab will be selectable as shown in Figure 5 - Probe Positioning Design Figure 1. If this option is greyed and you believe that you have a valid license for probe spacing design then please email
support@emtd-measurement.com

Note - The probe spacing's used are critical for the design of the test.

The design tab should be used to determine the optimal probe spacing's to use. EMTD is able to provide detailed training on this subject but some general rules of thumb for doing this are.

- Equal spaced probes are not recommended as it impacts on some algorithms.
- Multiple passes can be made using the calculate button. No two answers will be the same and some may be better than others.
- The more probes that are used, the better the uncertainty associated with the measurement.

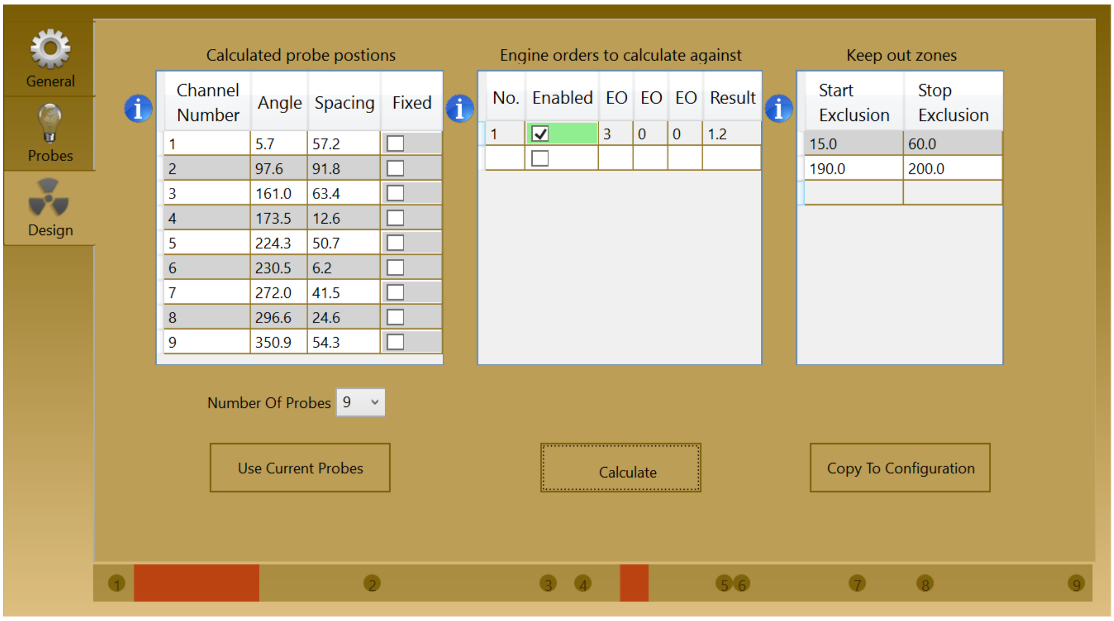


Figure 5 - Probe Positioning Design

The display is split into three parts. The probe positions, the expected engine order responses and the keep-out zones.

For a new design select the number of probes, enter the expected responses and press Calculate.

For an existing design load the configuration and press *Use Current Probes*. This allows the results to be calculated using fixed probe positions. This is valuable where an unexpected response is found and the quality value needs to be calculated for it using the existing probe positions.

The first section will be populated when the calculations are complete. Once a satisfactory set of spacing are provided they can be moved to the Probe tab by pressing *Copy to Configuration*.

If small adjustments ned to be made then each probes angle or spacing can be altered. Note that pressing calculate will overwrite the angles unless they are fixed. To fix a probe angle and protect it from being changed in the calculation tick the fixed box next to the probe.

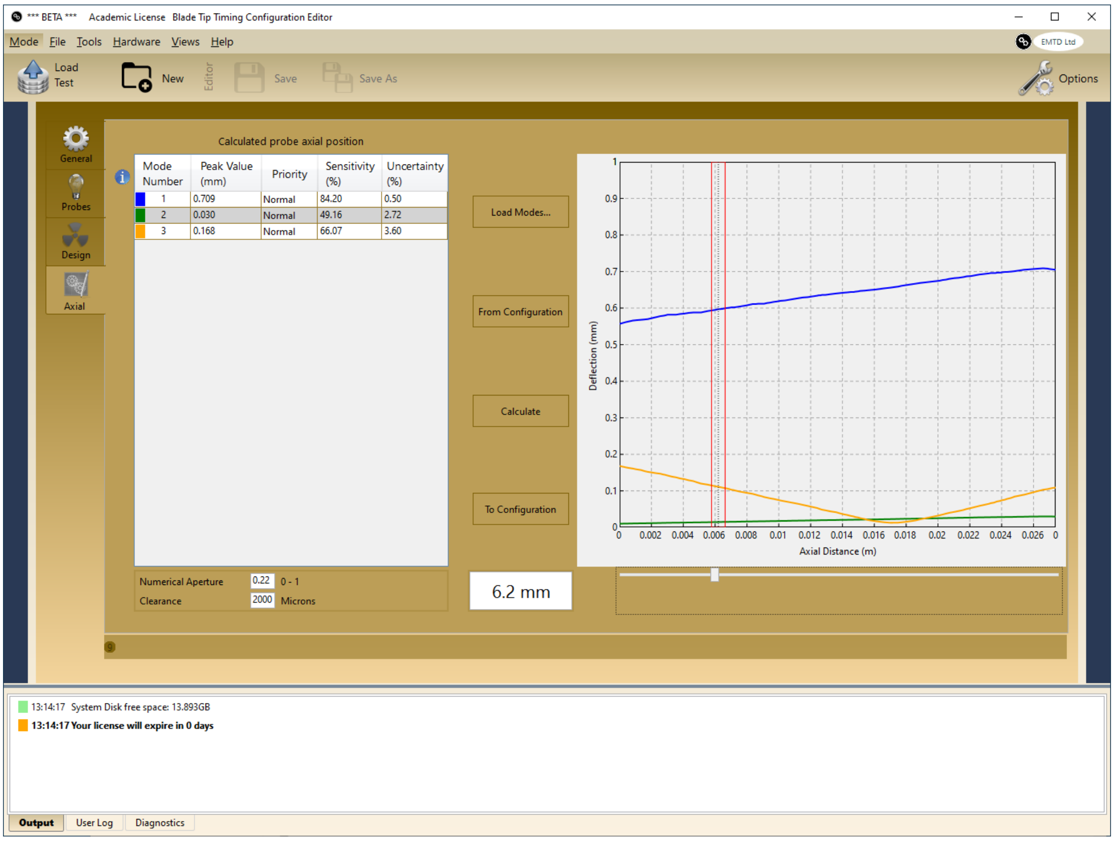
The second section allows expected engine order crossings to be input into the calculation. Each line represents an expected response. For a single response only enter one value per line. For two simultaneous responses enter both values on the line and for a treble use all three. Note that even though the calculator can use up to three simultaneous crossings on each line the analysis system currently only supports one. Putting two or three in will assist in calculating the best probe spacing sans these lines take precedence over a single response line in the calculation.

The third section allows keep out zones to be defined. Keep out zones are areas on the casing where a probe cannot be physically placed due to other engine hardware being in the way. Enter these as angles in degrees, again in the direction of rotation.

The display at the bottom of the page shows the flattened casing with probes 1-n (left to right) and the keep out zones in red.

2.6. Axial Probe Position

If the probe design component of MultiTool has been licensed then the axial position tab will be selectable as shown



Mode Number	Peak Value (mm)	Priority	Sensitivity (%)	Uncertainty (%)
1	0.709	Normal	84.20	0.50
2	0.030	Normal	49.16	2.72
3	0.168	Normal	66.07	3.60

Figure 6 - Axial Probe Position Calculator

All mode information is w.r.t. the first value in the data file. If the data is trailing edge to leading edge then all measurements will be w.r.t the trailing edge. Etc.

2.6.1. Mode Data File Format

The *Load Modes* button will open a file dialog window. The default initial folder will be the currently loaded configuration. If no configuration is loaded then it will look for a temporary folder.

The axial position file type must be a csv. If the data is provided in a Microsoft Excel xlsx file format then save the data as a csv file. An example file can be downloaded from emtd-measurement.com downloads section.

The data must be in the format shown in the table below.

- The key column heading 'Node #' must be present exactly as shown.
- All deflections must be in meters and positive.
- Mode numbers will be taken from any number present in the header column. See the table below for an example of modes 1, 2 and 3.
- No gaps are allowed between rows and columns in the data or between the header and the data. It must be as shown.

		Deflection (m)		
Node #	Axial position	Mode (1)	Mode (2)	Mode (3)
1	0	0.000557	1.01E-05	0.000168
2	0.000408	0.000562	1.05E-05	0.000164
3	0.000827	0.000566	1.09E-05	0.000161
4	0.00104	0.000567	1.1E-05	0.000159
5	0.00134	0.000568	1.12E-05	0.000157
6	0.00156	0.000569	1.13E-05	0.000154
7	0.00177	0.00057	1.15E-05	0.000152
8	0.00206	0.000573	1.17E-05	0.00015
9	0.00235	0.000576	1.2E-05	0.000148
10	0.00255	0.000578	1.21E-05	0.000147
11	0.00272	0.000579	1.23E-05	0.000145

Figure 7 - Blade Mode Information

2.6.2. Mode Information Table

Once the blade mode data has been successfully loaded then the table will populate with the data and update the graph of deflection vs axial position.

Calculated probe axial position

Mode Number	Peak Value (mm)	Priority	Sensitivity (%)
1	0.709	Normal	100.00
2	0.030	Normal	100.00
3	0.168	Normal	61.31

Each mode will have a colour coded row with the following information. This colour is the same used on the chart to draw the data for each mode.

Mode Number – The number taken from the column Header. Mode (1) = > 1

Peak Value – The largest displacement value found for the mode.

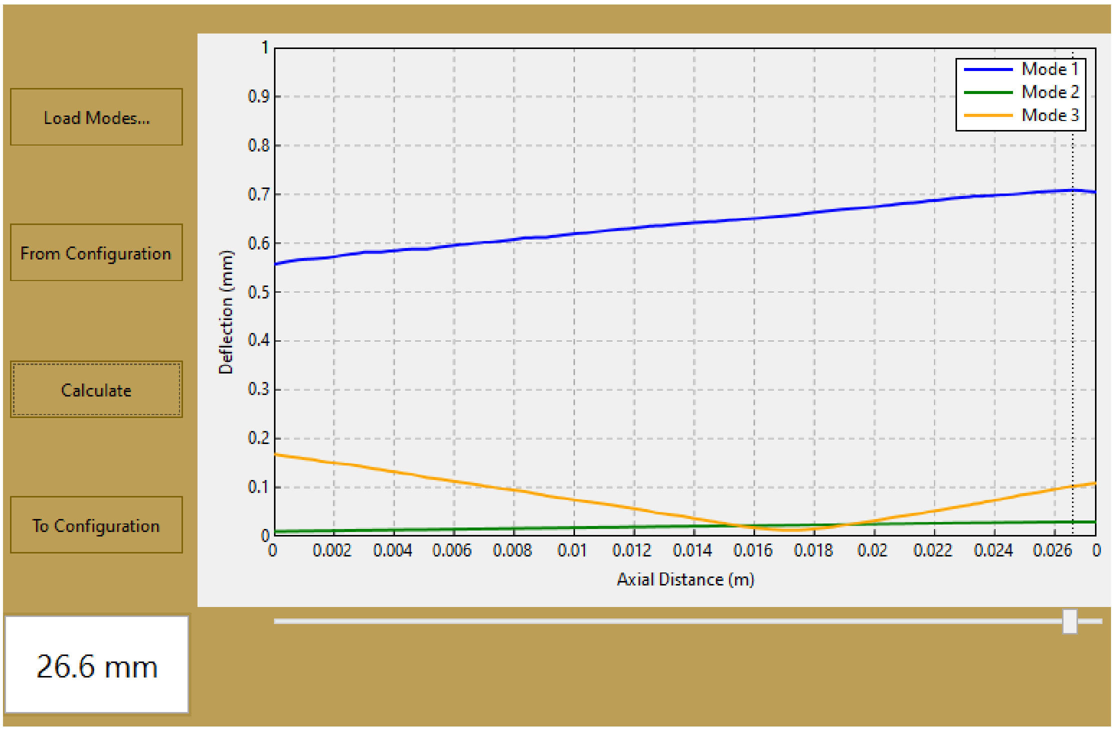
Priority – The importance associated with the mode. There are three choices, two of which are mutually exclusive.

Normal - Each mode is treated equally.
High - Only consider this mode.
Reject - Choose the least sensitive position for this mode.

If all modes are normal then the calculator will attempt to find the best compromise position for all modes.

Sensitivity – The value at the current position as a percentage of the peak value.

Uncertainty - The uncertainty due to spot size for each mode at the current axial position.



Calculate

The calculator will attempt to find the optimal position. However the more modes that are present can make it increasingly harder to find a solution that is good for all modes. The slider can be manually moved if the operator prefers to set the position manually.

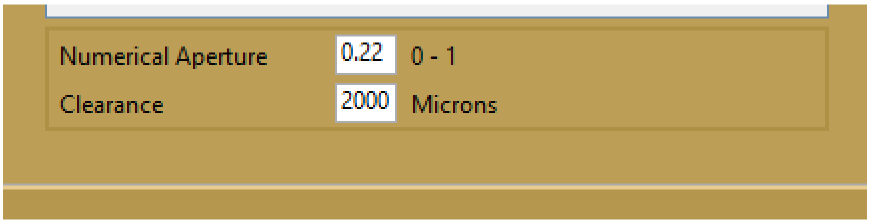
From Configuration

Copy the axial position from the currently loaded configuration file to the editor and set the slider to that position.

To Configuration

Copy the current axial position to the currently loaded configuration file to the editor overwriting the data in the configuration file. The mode data file will be copied over to the configuration folder to be used as part of the post processing analysis.

2.6.3. Affects due to clearance and Numerical Aperture



By specifying both the tip clearance and the Numerical Aperture we can calculate the spot size at the blade. This can be used to provide and uncertainty in the axial position at any position. This uncertainty band is shown on the mode data chart as two red lines. The uncertainty due to spot size for each mode at the current axial position is shown in the mode table.