High Performance Machining Specialists

Manufacturing Laboratories Incorporated

MSC MillMaxTM User's Manual 2020

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Version 0.1

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Variable Definitions and Abbreviations

Accelerometer: An instrument for measuring acceleration involved in the vibration of a machine.

Artifact: This is the version or style of artifact. This geometry must be stored or provided for obtaining the machine receptance.

Artifact Measurement: This is the two-point FRF measurement of the machine using the artifact.

Auto Spectrum Option: Setting allowing software to adjust the visible range on the graph automatically.

Calibration: The action of verifying proper operation and connectivity of the connection scheme.

Coherence: The data quality assessment which identifies how much of the system response is related to the input force.

Coupler: The MLI product name for the stand-a-lone Parameter Optimization Engine (POE).

Dashboard: Software window displaying useful information that the user can act upon, as well as making a visual representation of what is otherwise complicated data, easy to understand.

Data Acquisition Module (DAQ): Hardware interface between the hammer/accelerometer and the computer.

Direct Tool-Tip Measurement: The direct measurement that can be used to generate recommended cutting parameters.

Dongle/Hardware Lock: A small device to be connected to and used with a computer, required for creating or publishing a Dashboard.

Dynamic Cutting Calculator (DCC): Generates the MSC MillMaxTM Dashboard.

Frequency Response Function (FRF): The relationship between vibration and displacement of a tested machining system.

Hammer: An instrument for generating a vibration to be measured.

Machining System: Machine, tool assembly, and workpiece material combination.

Process Damping: The phenomenon where there is a very strong stabilizing effect at low spindle speeds that leads to a significant increase in the depth of cut.

Tool Assembly: Holder and Tool combination where the tool has a specified stickout or the overall assembly gauge length is provided.

Stickout: The length of the cutting tool that protrudes outside of the tool holder. ISO 13399 call this the Protruding Length (LPR).

Stimulus Location: The area where impact should occur.

Time Domain: The period during which measurement occurs.

Trap Double Hits: Signals the user if two impacts are detected during measurement.

Trap Overloads: Signals the user if the impact force level or the response of the accelerometer is above the voltage in set in the Signal Range box.

Trap Underloads: Signals the user if the impact force level or the response of the accelerometer is below the voltage in set in the Signal Range box.

Trigger Threshold: Level at which the software records a measurement.

1.0 Introduction

MSC MillMax™ is MSC's specialized frequency analyzer package that is tailored for FAST measurement of machine tool dynamics. This program primarily collects data from two types of sensors - an accelerometer and an impact hammer - to record the frequency response function of the machine-holder-tool combination being measured. The frequency response function of the structure can be experimentally determined using an impact test. The relationship between the vibration and displacement, X, and the excitation force, F is defined as the frequency response function (FRF), X/F. The results from the measurement are displayed graphically as the flexibility of the FRF.

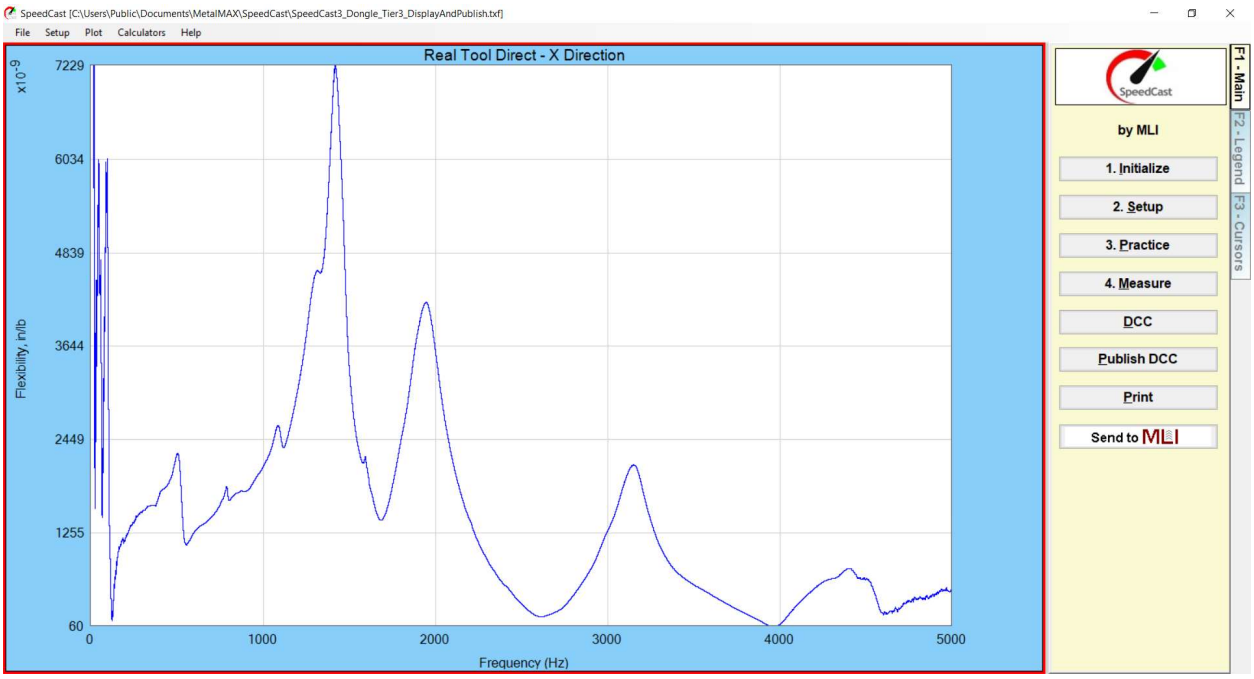

Figure 1: Impact Test to determine the FRF and Resulting Flexibility

1.1 Starting MSC MillMax™

To start MSC MillMaxTM, both the data acquisition card and the dongle must be on the computer before booting up the computer and accessing the software. Figure 2 and Figure 3 shows the measurement hardware connection scheme.

Figure 2: MSC MillMaxTM Kit, Dongle & DAQ Cable Attachment

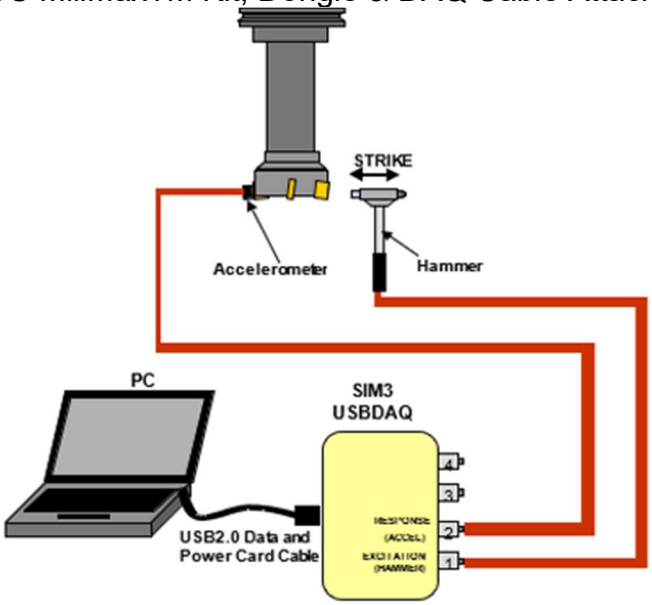

Figure 3: Connection Scheme for Measurement Setup

Data Acquisition Modules

Data acquisitions (DAQ) modules include

- MetalMax SIM5 (MS485B39) USB
- MetalMax SIM4 (DT9837B) USB
- MetalMax SIM3 (Photon Plus) USB
- MetalMax SIM2 (NI6062E) USB
- Data Physics Quattro
- Kistler 5165A4
- NI9234 USB
- NI9233 USB
- NI4431 USB

Other DAQ systems are compatible. Contact MLI for specific installation instructions for alternate DAQ systems.

Startup Instructions to Review or Analyze Existing Data and Resave Files

The DAQ module **does not** need to be attached to review, analyze, and resave data files. The USB dongle can be inserted with the computer already on and the software not yet opened.

Startup Instructions for Reviewing Data Only

No Dongle is necessary to review or manipulate the data. Simply start the computer and open MSC MillMaxTM. However, if you desire to save edits to the data or setting and then resave the file, you will need the Dongle (see above).

1.2 Data Acquisition

This section describes the series of steps necessary to use MSC MillMaxTM and prepare for data acquisition for a direct measurement or for an artifact measurement, Figure 4.

MSC MillMaxTM has 3 levels of User functionality and licensing as shown in Table 1 below. Level 1 does not require a hardware lock and allows the user to make a measurement but not create or publish a dashboard. Level 2 and allows the user to make a measurement and create a dashboard for viewing only, but not publish the dashboard. Level 3 allows all functionality.

Table 1: MSC MillMaxTM Licensing

MSC MillMaxTM Function	Hardware Lock		
	Level 1 (No Display or Publish) – No Hardware lock needed	Level 2 (Display Only)	Level 3 (Display and publish)
Make Measurements	✓	✓	✓
View Dashboard		✓	✓
Publish Dashboard			✓

To begin:

- Attach the USB dongle to the computer (see Table 1)
- Insert the DAQ Cable into a second USB port
- Attach the accelerometer cable into the port marked “Accel.” on the interface
- Attach the hammer cable to the second port marked “Ham.” and connect the other end of the cable to the hammer
- Scrape wax and roll it into a ball with your fingers
- Stick the wax ball to the unmarked side of the accelerometer (DO NOT put on the side with markings).
- Make sure the cutter is clean and dry
- Use the magnetic clasp to hold the accelerometer in place
- Attach the accelerometer to the end of the cutter
- The objective is to have the accelerometer as close to perpendicular and straight across the hammer strike as possible
- For an even number of flutes, mount the accelerometer on the edge of the tooth; for an odd number of teeth, mount the accelerometer inside one of the flutes
- To keep the accelerometer parallel, align the cable with the helix angle of the cutter
- Start MSC MillMax™

Once you have started MSC MillMaxTM, select the type of tool. Click on the appropriate button.

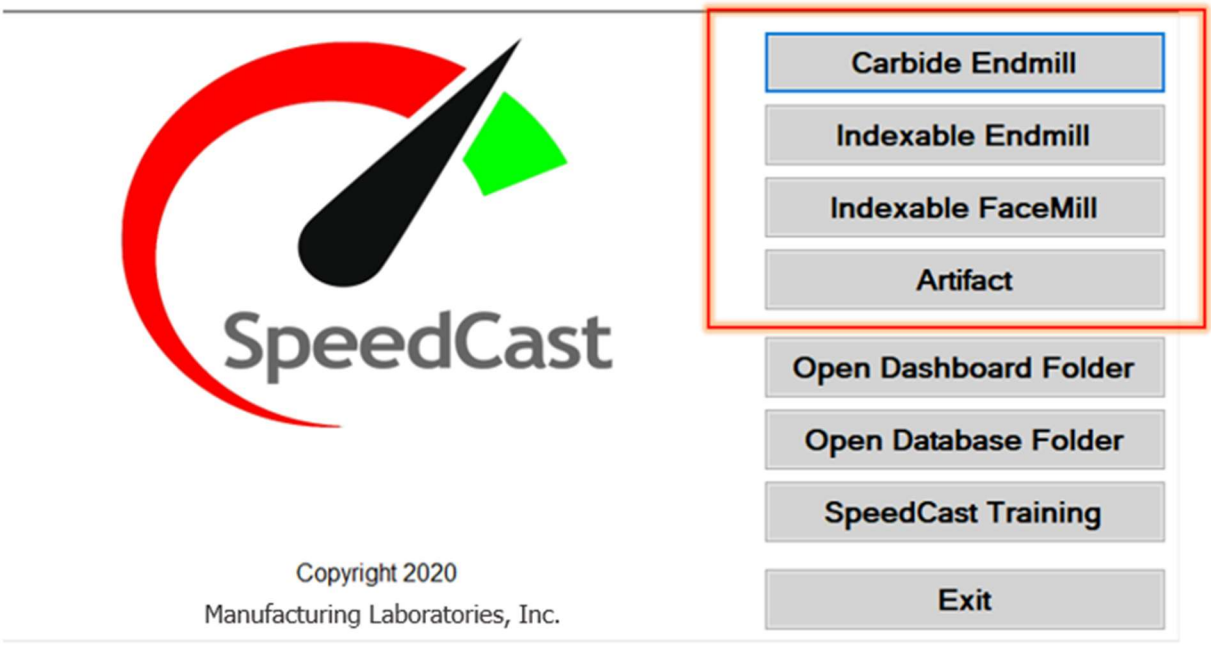

Figure 4: MSC MillMaxTM Startup Menu

Immediately after selecting a tool type, the screen in Figure 5 appears, and the software will automatically initialize (a red flashing “please wait”) to indicate the initial calibration of the system and hardware.

Calibration takes approximately 30 seconds. It resets the internal electronics and makes sure the sensors have settled close to 0. The purpose is to verify proper operation and connectivity and check that the channels have settled and to allow the user to review Voltage levels before collecting data.

The user can also manually calibrate by clicking the Initialize button.

When beginning to use the software, the user should follow the menus at the right of the screen in the order they are displayed from top to bottom.

Next, the user should access the Setup Menu using the Setup button. This is the most important tab.

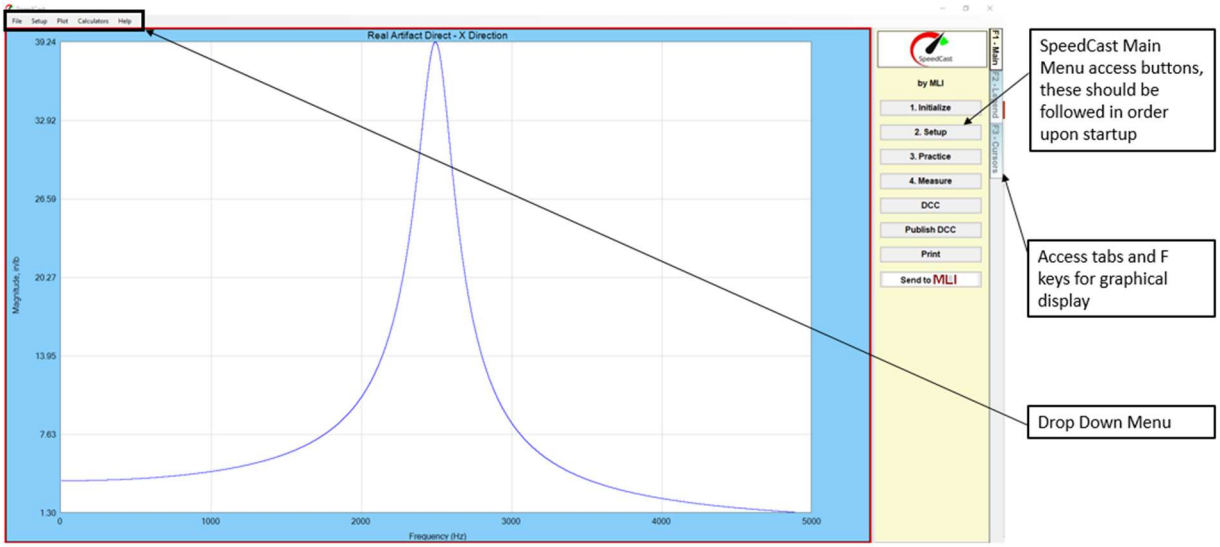

Figure 5: MSC MillMaxTM Main User Interface Screen

Setup Menu

The Setup Menu has 3 tabs: the Project Tab, the Measurement Tab, and the Sensors Tab. Again, the user should enter the necessary data or make the appropriate selection on each tab, following the tabs in order. The MSC MillMaxTM menus are very similar to those in the other MetalMax products.

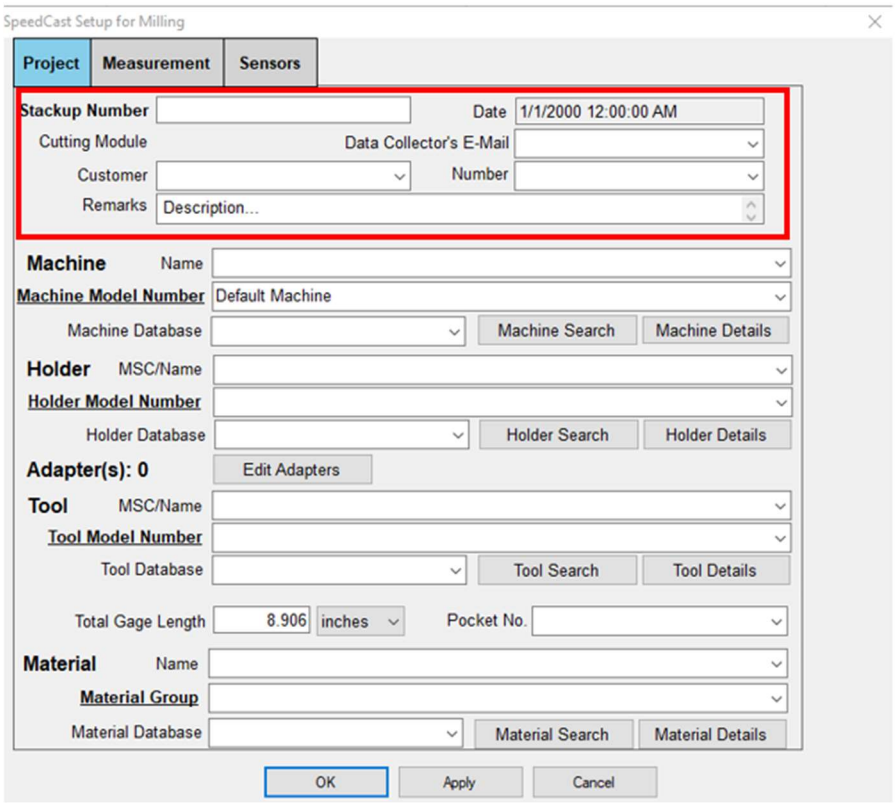

Figure 6: MSC MillMaxTM Setup Menu

Project Tab

Stackup Number and Date: these will populate automatically once the file is saved.
Data Collector's E-mail: enter the email address of the data collector. This person may be different from the person analyzing the data and will be helpful for communication if there are any questions regarding the measurement.

Customer: Enter the customer name.

Number: Enter the Tool Assembly Number if applicable.

Remarks: Enter an appropriate project description in the designated box. Always include as much detail as possible.

Project Tab Cutting Tools

Figure 7 shows the Project Tab for the selections of Carbide Endmills, Indexable Endmills, or Indexable Facemills from the MSC MillMaxTM Startup Menu, Figure 4. Follow the steps as indicated on the screen

1. Select Machine Make
2. Select Machine Model and RPM
3. For a generic tool holder style, Select Toolholder OR if the specific brand and type of toolholder is known
    a. Select the Holder Database
    b. Select the Holder Model
4. For a generic tool style, Select the Tool OR if the specific brand and type of tool is known
    a. Select the Tool Database
    b. Select the Tool Model
5. Select the Material Group

Project Tab Artifact

Figure 8 shows the Project Tab for an Artifact Measurement selected from the MSC MillMaxTM Startup Menu, Figure 4. In this case, no tool or material should be selected. Follow the steps as indicated on the screen

1. Select Machine Make
2. Select Machine Model and RPM
3. Select the Artifact

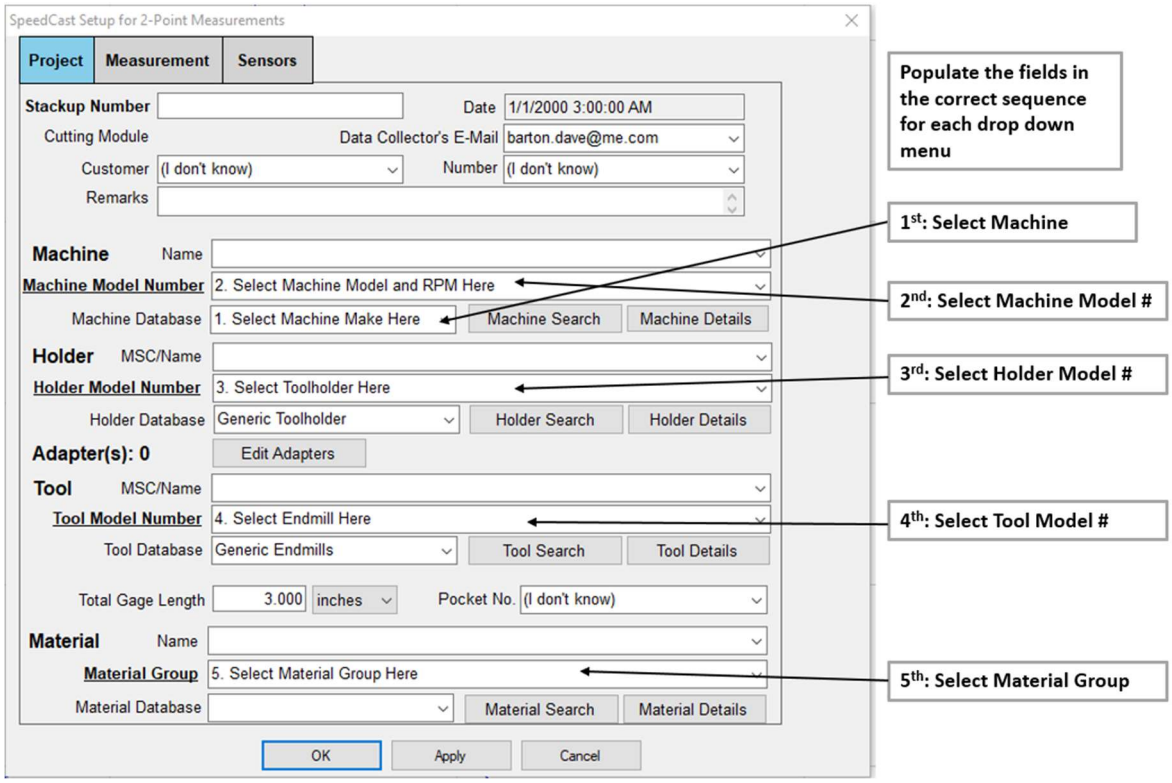

Figure 7: MSC MillMaxTM Project Tab for Direct Measurement

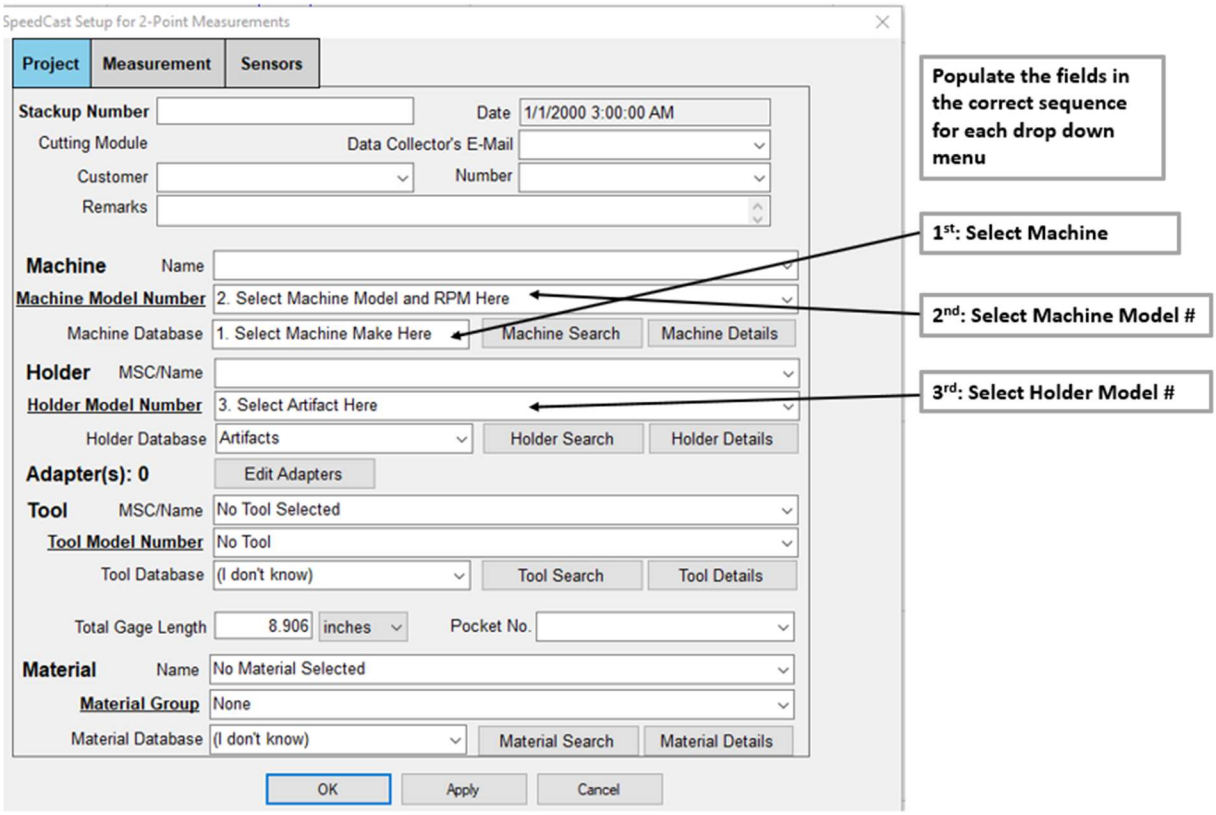

Figure 8: MSC MillMaxTM Project Tab for Artifact Measurement

Machine Details

The Machine Details button is used to create a new machine definition and to save this machine definition by adding it to the database. To achieve this, enter the appropriate information in to the cell of the dialog box shown in Figure 10. Items in bold are essential information needed to fully complete the calculations and should not be left blank. You must click ADD to save your machine to the database. If you click OK before clicking ADD, MSC MillMaxTM will ask 'Do you want to ADD it to the database now?' If you answer NO, the information will be local to this file only and will not be stored in the database.

If the machine definition has already been saved to the database, then the ADD button will change to UPDATE, allowing the user to update the existing machine definition in the database.

Cancel: At any time, you may click cancel to exit the dialog box without saving any of the changes.

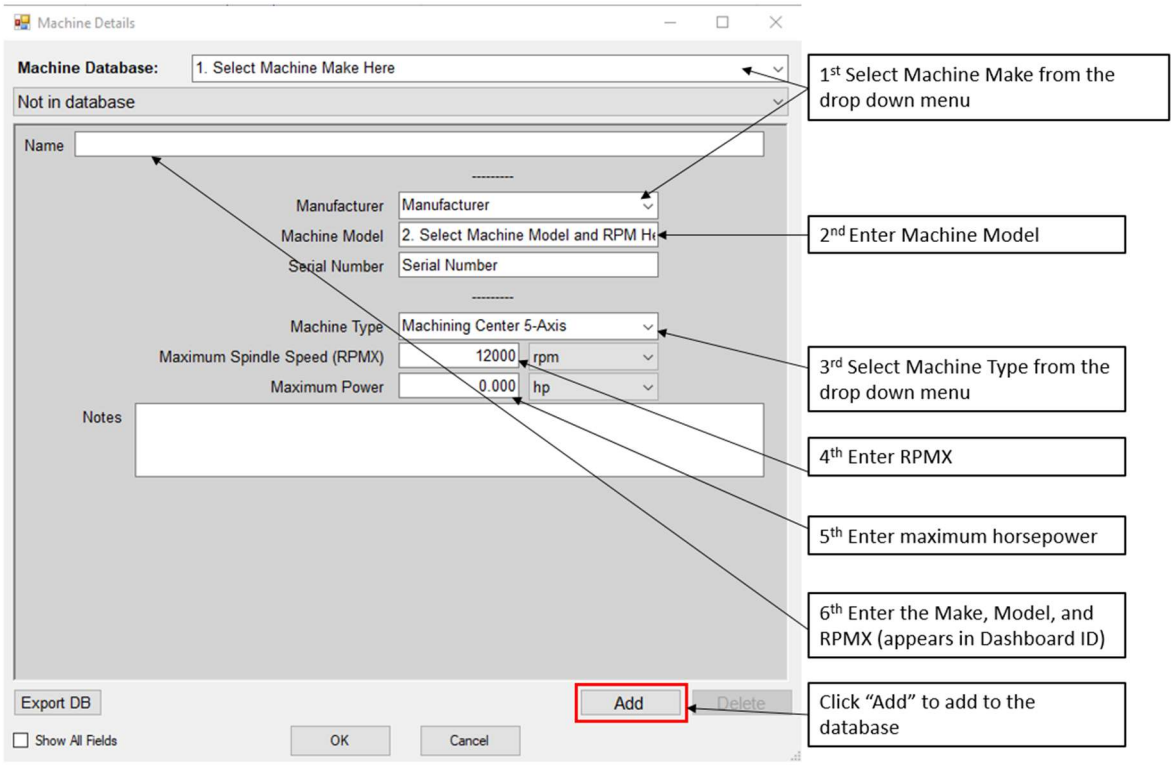

Figure 9: Update Machine Database from the Machine Details

View or Edit Power/Torque Curve

Be sure **Show All Fields** on the lower left is checked to view the window as shown in Figure 10. Every machine has a Power curve associated with its performance. This information will be provided by the machine manufacturer. If you have this information, enter it in the appropriate cells. The values entered into the cells are point pairs on the

graph of either spindle speed and torque or spindle speed and power. The graph on the right will show the Power in red and the Torque in blue. CAREFUL to select the correct units. Click OK when complete.

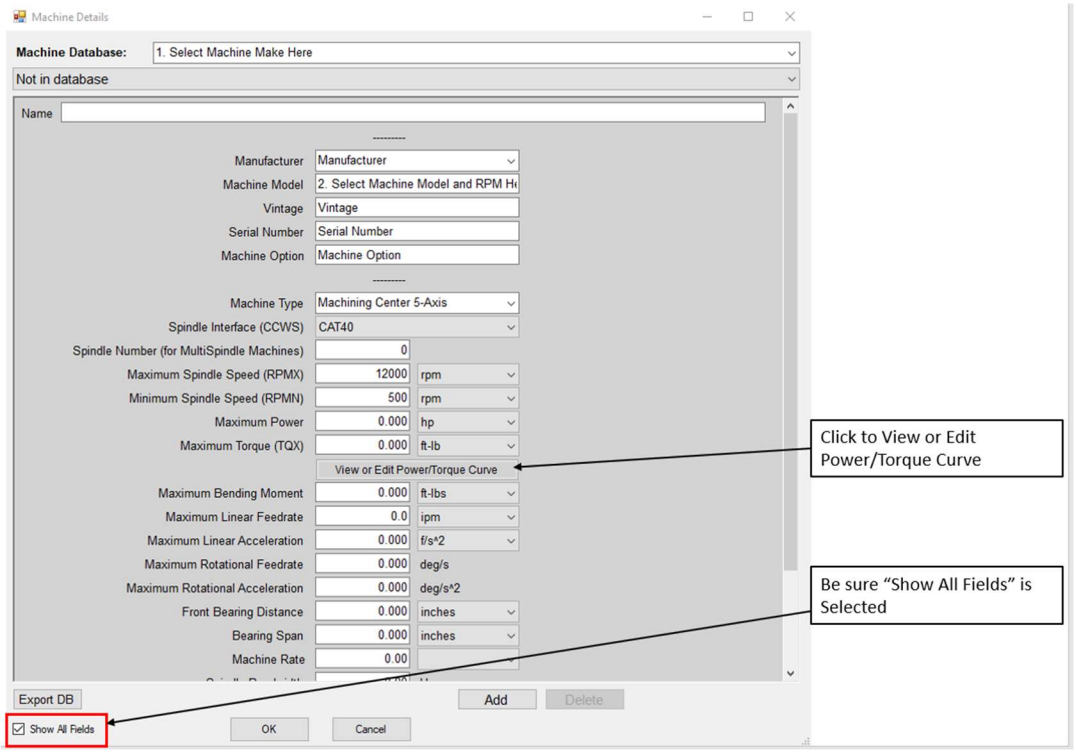

Figure 10: View or Edit Power/Torque

Holder Details (Applies to Direct or Artifact Measurements)

The Holder Details button is used to edit or create a new holder definition and to save this holder definition to by adding it to the database. To achieve this, enter the appropriate information into the cells of the dialog box shown in Figure 11.

Items in bold are essential information needed to fully complete the calculations and should not be left blank. All items in this dialog box are essential, except for the holder number. If you do not know the Max RPM for the holder then enter the max RPM for the machine. Be sure the **Show All Fields** box on the lower left is checked.

You must click ADD to save your holder to the database. If you click OK before clicking ADD, MSC MillMaxTM will ask 'Do you want to ADD it to the database now?' If you answer NO, the information will be local to this file only but will not be stored in a database.

If the holder definition has already been saved to a database, then the ADD button will change to UPDATE, allowing the user to update the existing holder definition in the database.

Holder Graphics: When the user chooses different holder types from the drop-down menu, the display for the holder graphics will change. The display of the holder graphics can also be changed using the options to the right of the display window.

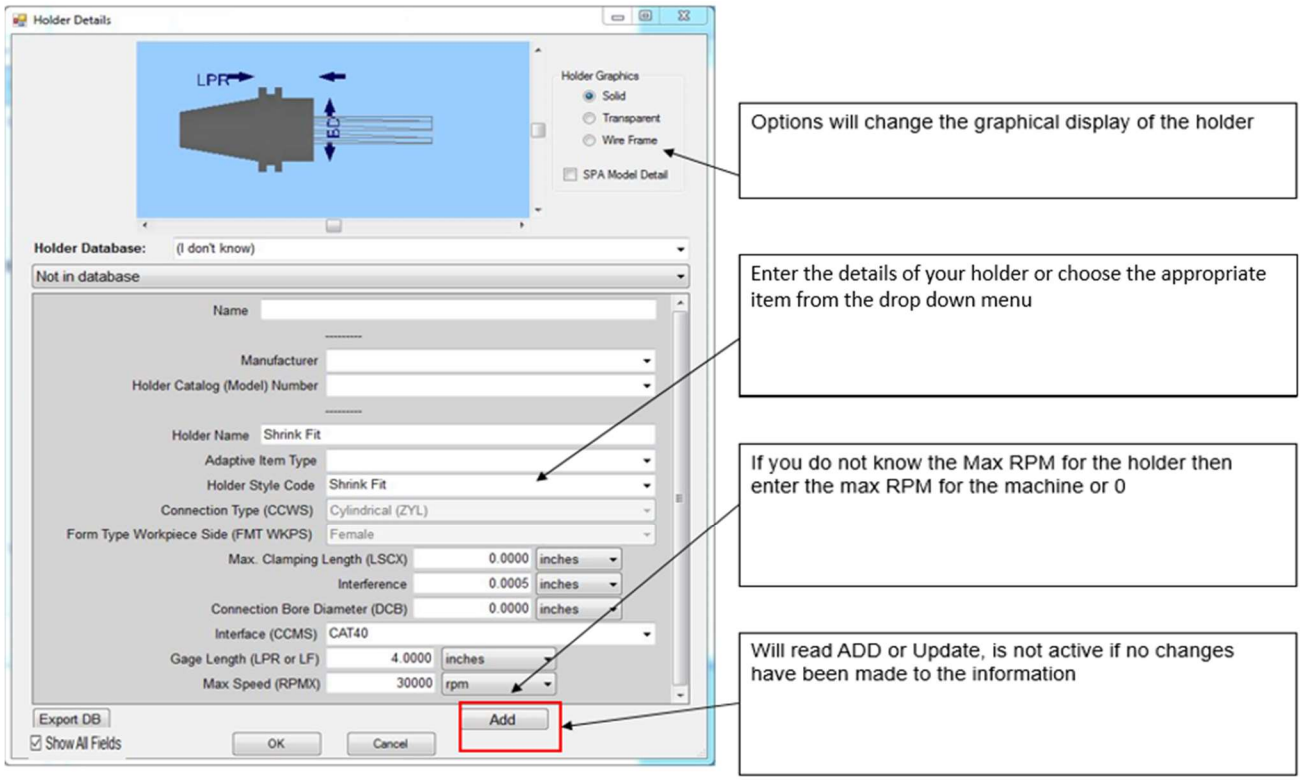

Figure 11: Holder Details

Tool Details (Applies to Direct Measurements only)

The Tool Details button is used to create a new tool definition and to save this tool definition to by adding it to the database. To achieve this, enter the appropriate information into the cells of the dialog box shown in Figure 12.

Items in bold are essential information needed to fully complete the calculations and should not be left blank. Be sure the **Show All Fields** box on the lower left is checked.

You must click ADD to save your tool to the database. If you click OK before clicking ADD, MSC MillMaxTM will ask 'Do you want to ADD it to the database now?' If you answer NO, the information will be local to this file only but will not be stored in a database.

If the tool definition has already been saved to a database, then the ADD button will change to UPDATE, allowing the user to update the existing tool definition in the database.

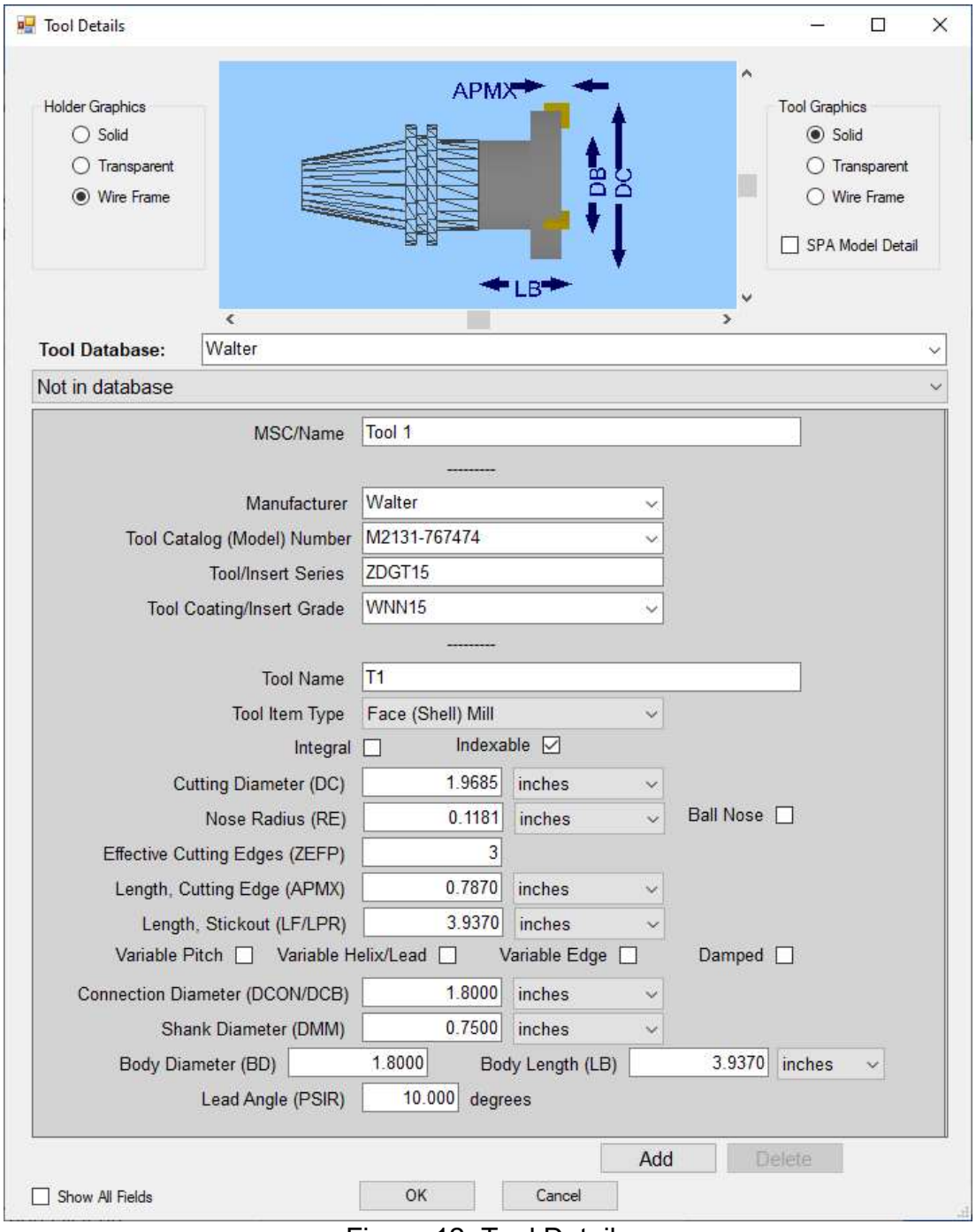

Figure 12: Tool Details

Adapter Details

If you are using extensions or adapters, click on the Edit Adaptors button. Then click on Adapter Details button to enter data.

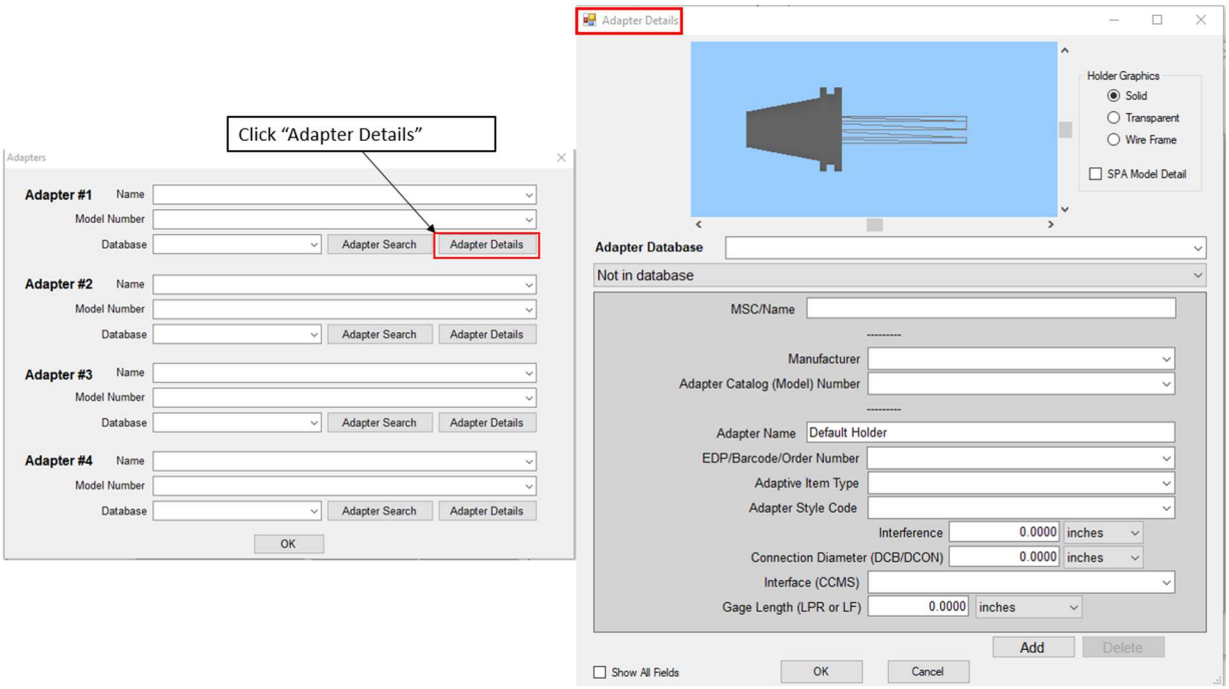

Figure 13: Adapter Details

Material Details (Applies to Direct Measurements only)

The Material Details button is used to create a new material definition or to edit and existing material definition. To achieve this, enter the appropriate information into the cells of the dialog box shown in Figure 15. Be sure the **Show All Fields** box on the lower left is checked.

You must click ADD to save your material to the database. If you click OK before clicking ADD, MSC MillMaxTM will ask ‘Do you want to ADD it to the database now?’ If you answer NO, the information will be local to this file only but will not be stored in a database.

If the material definition has already been saved to a database, then the ADD button will change to UPDATE, allowing the user to update the existing tool definition in the database.

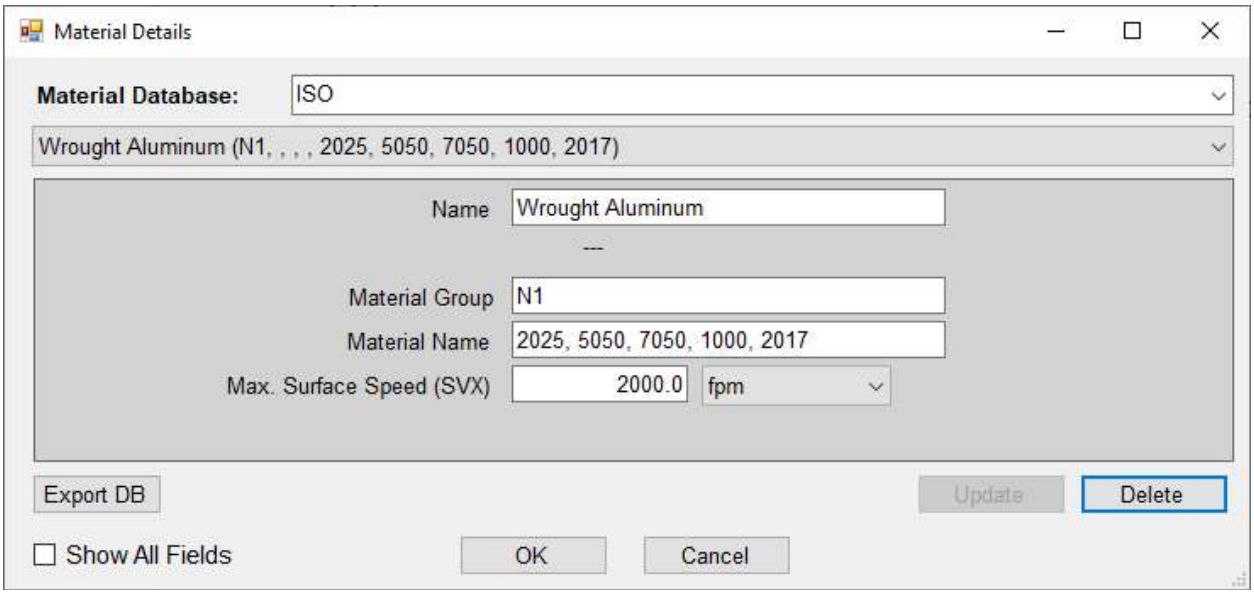

Figure 14: Material Details

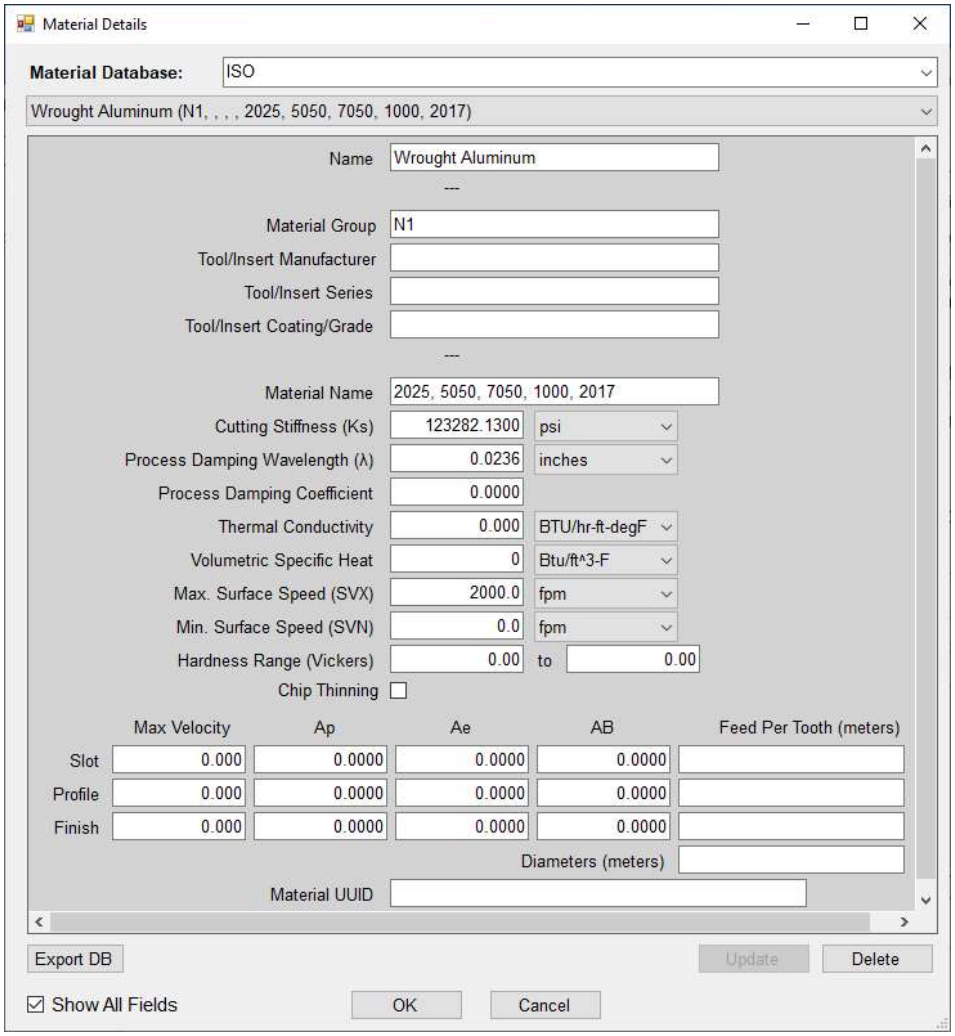

Figure 15: Material Details, All Fields

Measurement Tab

The Measurement Menu allows the user to set up the Measurement Configuration including the direction of the impact and the sensitive direction of the response accelerometer.

Measurement Bandwidth: Only one measurement bandwidth can be applied to a set of measurements. For artifact measurements, the bandwidth should be set to 10 KHz which is the default.

For tool direct measurements, the user should indicate the desired measurement bandwidth. If you are uncertain:

- set this parameter to a high value,
- make a measurement, and then
- reduce the measurement bandwidth down as low as possible to still capture the relevant frequencies, and then
- remake the measurement.

Next, indicate what measurements you will be making using the enable boxes. A green check mark represents that the measurement is enabled. Next, set the active measurement. This means the first measurement that you will be making.

The display shows the active measurement setup, including the accelerometer location and impact location. For each measurement that will be made, make the measurement active, and then use the + buttons to indicate the appropriate stimulus and response directions for the measurement setup.

The column labeled Stimulus Location will indicate where the impact should occur.

When making a measurement, it is best to always start with the X direction active and make a corresponding X direction measurement. In this case the software will automatically prompt the user to continue to the next measurement (i.e. the Y direction and then any other enabled measurements). Otherwise, the user will have to manually indicate the active measurement between each set of impacts.

Figure 16 shows the Measurement Tab for a tool direct FRF measurement. This type of measurement requires two impact, X-direction and Y-direction.

Figure 17 shows the Measurement Tab Tool for an artifact FRF measurement. This type of measurement requires four impacts, X-direction and Y-direction direct and X-direction and Y-direction cross.

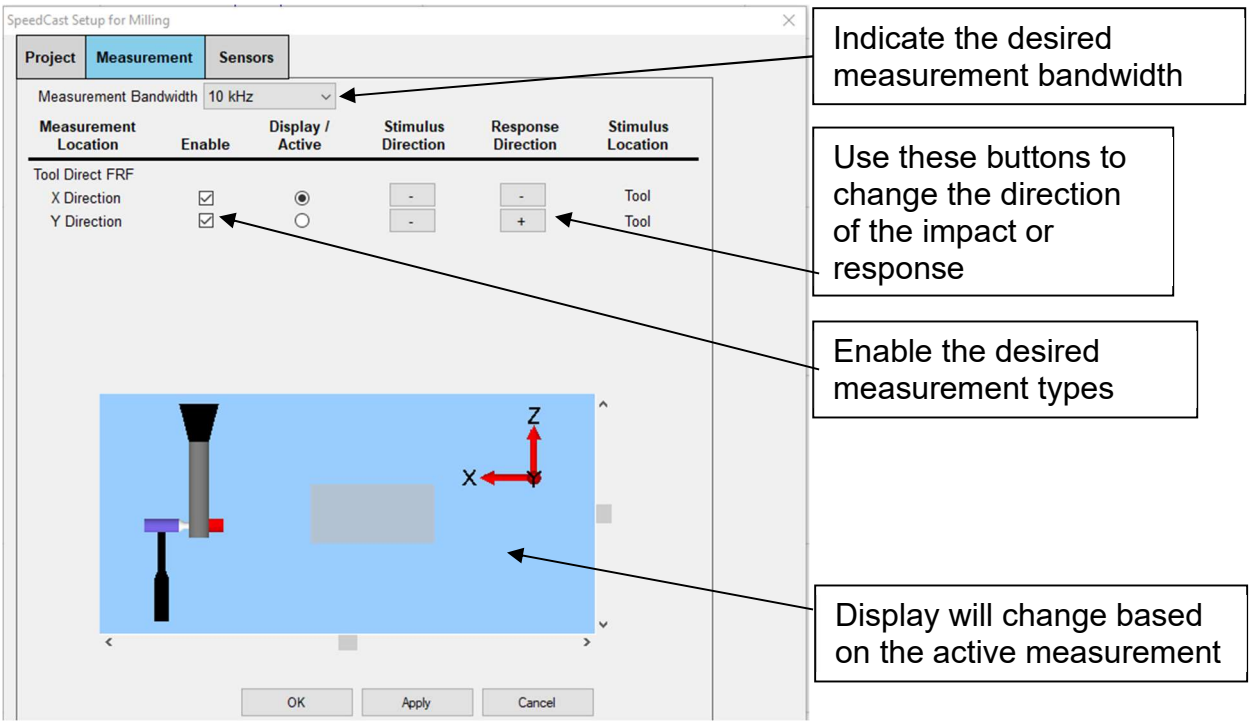

Figure 16: Measurement Tab Tool Direct FRF

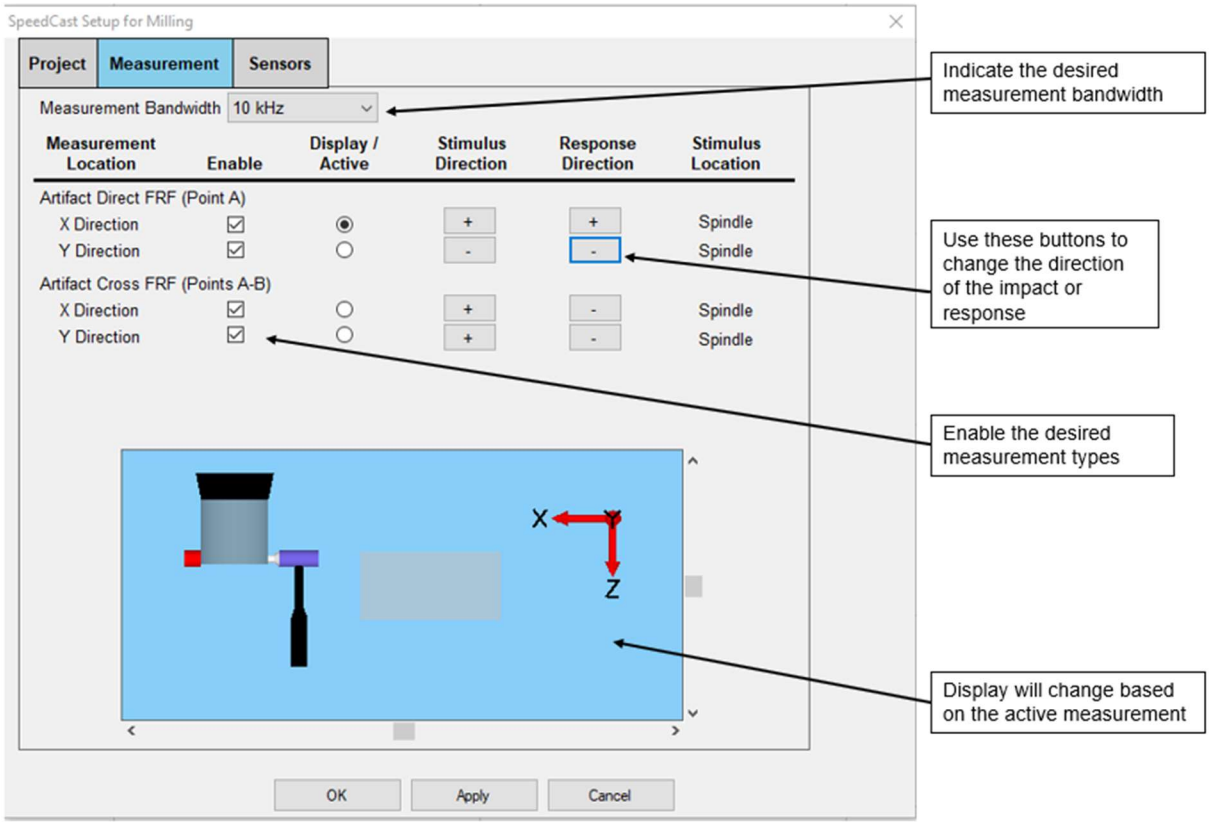

Figure 17: Measurement Tab Artifact Direct/Cross FRF

Sensors Tab

The Sensors Tab is where the user indicates what type of sensor is being used.

Measurement Configuration: Choose the measurement configuration for which you are setting the Sensor information.

Sensor Name: Select from the available list.

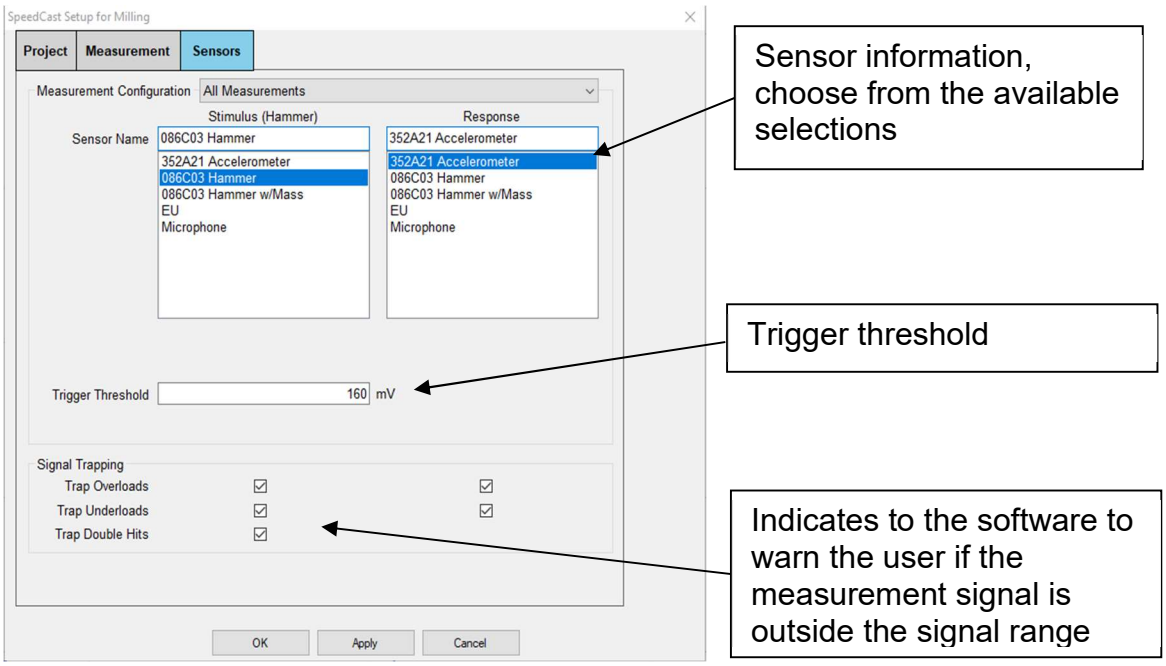

Figure 18: Sensors Tab

Trigger Threshold: This value indicates to the software what level signal is considered a measurement. It should be set high enough such that if the user moves the hammer around, or sets it down on a table to rest, the software does not trigger a measurement.

Signal Trapping:

While making a measurement, MSC MillMaxTM will warn the user if any signal levels exceed the range set in the Signal Range box. The default setting is for all these warnings to be active.

Trap Overloads: Will signal the user if the impact force level or the response of the accelerometer is above the voltage in set in the Signal Range box, see Figure 21.

Trap Underloads: Will signal the user if the impact force level or the response of the accelerometer is below the voltage in set in the Signal Range box, see Figure 21.

Trap Double Hits: Will signal the user if the software detects two impacts within the measurement window.

Tap-Testing:

Practice

The practice section allows the user to practice hitting and to get comfortable with the setup.

Required Machine Setup

- Machine should be warmed up to operating temperature – **never** tap-test a cold spindle
- Spindle should be **away** from the home position
- Spindle should be unlocked so it can be rotated by hand

Load the tool assembly into the spindle or practice fixture. Rotate the accelerometer to the x-axis. Click the Practice button. The Practice Screen opens and prompts the user to “Hit Now”. Tap the tool on the x-axis and continue tapping until the green “Practice Complete” alert appears, Figure 19. This may take as few as two or as many as seven taps to complete. Click “OK”.

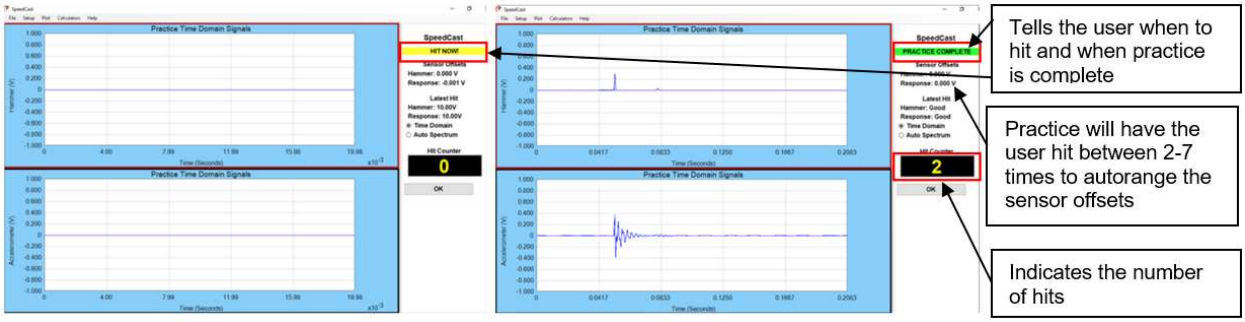

Figure 19: Practice Screen Prompts: Hit Now & Practice Complete

Auto Spectrum shows the frequency range and force magnitude that is created by the impact, as shown in Figure 20.

In Figure 20, the frequency range that was sufficiently excited by the impact was 0-1600 Hz. If frequencies greater than 1600 Hz appear in the flexibility plot, then they should be disregarded, or a different hammer and accelerometer combination should be used to sufficiently excite the desired frequency range. The user can also use this information to change the measurement bandwidth (see Figure 16).

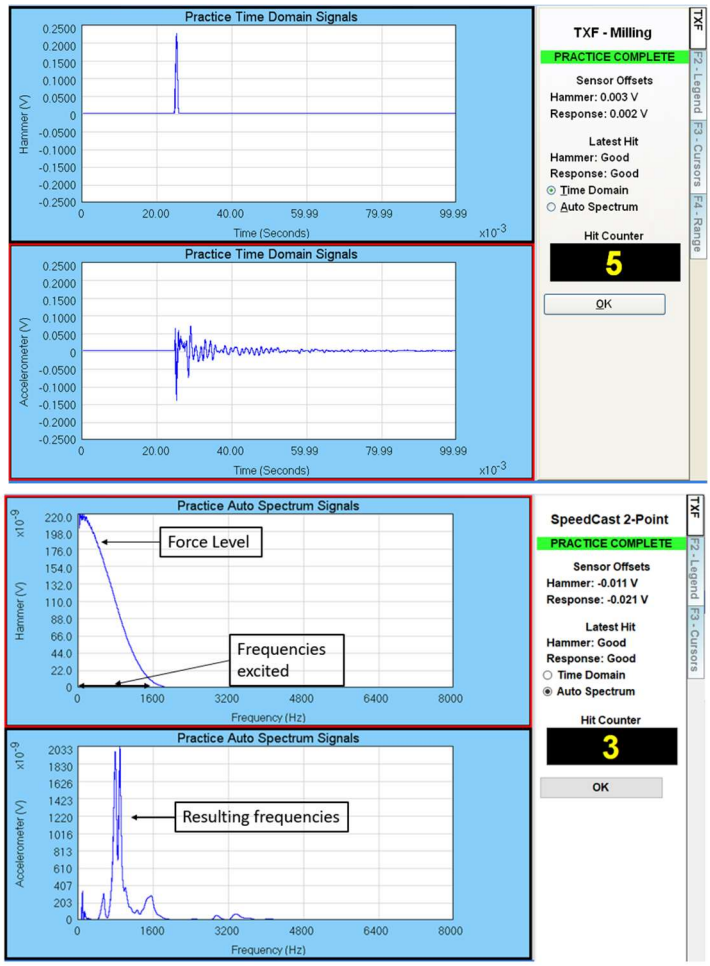

Figure 20: Time Domain and Auto Spectrum Options in Practice Section

Measure

The Measure button brings the user to the screen which will allow the user to record the FRF's.

Once you click Measure, you must confirm your machine, holder, and tool and click "OK".

Begin tapping the tool on the x-axis. If you hit too hard or soft, or perform a double-hit, you will get an alert on the screen which will go away when you hit again. A successful tap within range will be automatically accepted. Continue until you complete five successful tap-test measurements and click "OK".

Rotate the accelerometer to the y-axis and begin tapping in the Y direction. Continue tapping until you complete five successful measurements and click "OK". You will receive a message that all measurements are complete, and your file will automatically save.

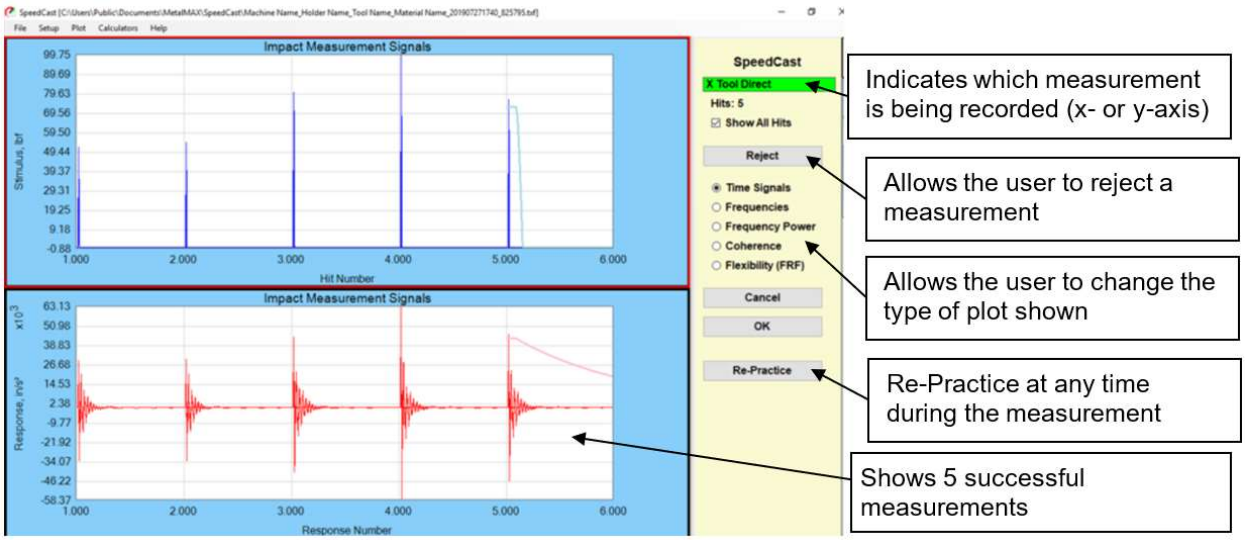

Figure 21: Measure

Re-Practice: If during the measurement process too many errors (Hit Harder or Hit Softer) are experienced, the user can go back to the Practice screen to practice hitting again and/or to reset the autorange values for the sensors.

Cancel: will cancel the measurement and NOT record any of the data.

Dynamic Cutting Calculator (DCC)

Click the DCC button to immediately generate the MSC MillMaxTM Dashboard from the measurements you have taken.

If you have publishing rights, you can click the Publish DCC button to generate a shareable Dashboard. It will take up to one minute to generate the Dashboard. It will be an .html file that can be shared on any device including tablets and smartphones.

Process Damping Region:
Process damping is a phenomenon where there is a very strong stabilizing effect at low spindle speeds that leads to a significant increase in the depth of cut. This effect is essentially added damping to the system which is based on the wavelength of the wavy surface a vibrating cutter will leave on the surface of the part and the tool geometry. The increase in the damping is larger for shorter wavelengths. The parameter in MSC MillMaxTM that effect the calculation and display of this region is the Process Damping Wavelength located on the Project Tab under Material Details.

This phenomenon is very important when machining materials, which, because of their properties, cannot be machined at high speeds. Often, although low cutting speeds must be used, large depths of cuts are possible without experiencing chatter. This can lead to productive metal removal rates, even for materials which are known to be difficult to machine.

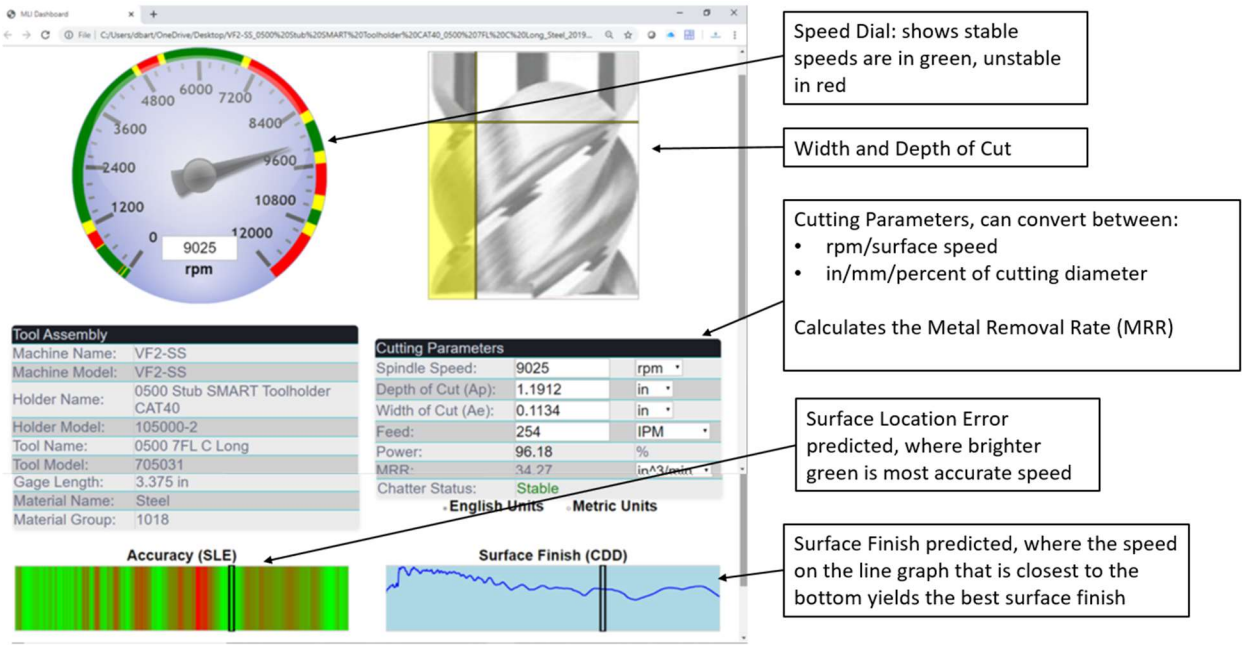

Figure 22: MSC MillMaxTM Dashboard

Save

The file will be named automatically and saved automatically when closing MSC MillMaxTM. The filename depends on the F12: Preferences. The save new data option will either:

1. Open a new file dialog box and allow the user to name a new file to save the data.
2. Automatically save and rename the file to the data directory set in the F12: Preferences.

Send to MLI

You can send data to MLI by clicking on the Send to MLI Button on the MSC MillMaxTM Main User Interface Screen or by navigating to **File** and selecting **Send Data to MLI**. The MLI site and MLI Folder are options that must be specified when using the Send to MLI Option. When using the Send to MLI Option, the correct MLI folder must be specified, or the data will not be sent. Contact you MLI representative to get the correct setup information.

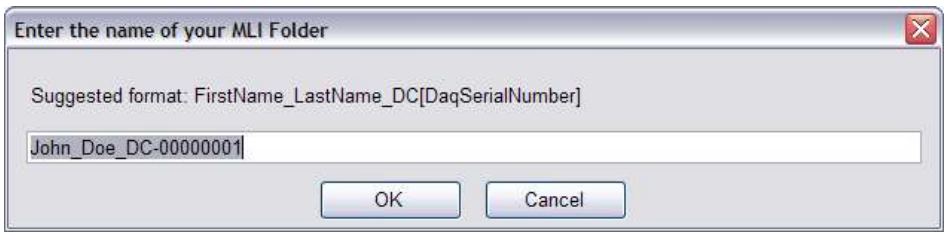

Figure 23: Send to MLI

1.3 Data Plotting and Analysis

This section describes the setting for changing the visual display of the data.

F Keys for Graphical Display Properties

Shortcut menus are available on the right side of the main screen, activated by using the F keys.

F1 or Esc: Main MSC MillMaxTM Screen
F2: Legend
F3: Cursors

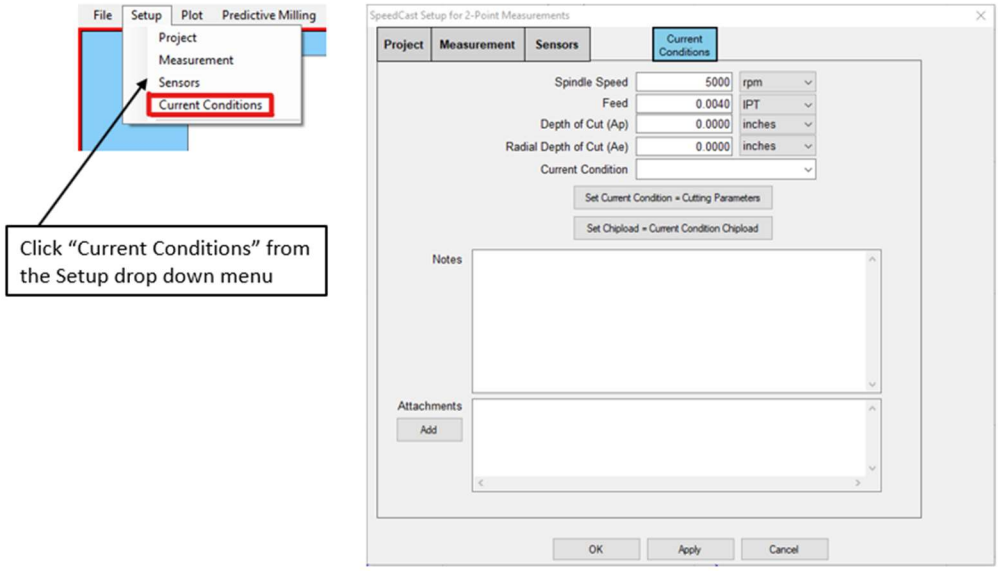

Figure 29: Current Conditions Window

F1 or Esc: Main MSC MillMaxTM Screen

This function, F1 or ESC, returns the user to the MSC MillMaxTM Main User Interface Screen.

F2: Legend

This tab allows the user to turn on and off the limits for each plot and to change the properties (color and line width) of each data set. To access the properties menu for each data series, point the cursor at the desired data series and right click.

F3: Cursors

This tab lets the user apply a cursor to a given data set and acquire the values of the data at the cursor location. The cursor will be relative to the data selected in the Data Series drop down box.

Figure 24 shows the data cursor (inside the red circle) and the relevant Frequency and Flexibility values associated with that data point.

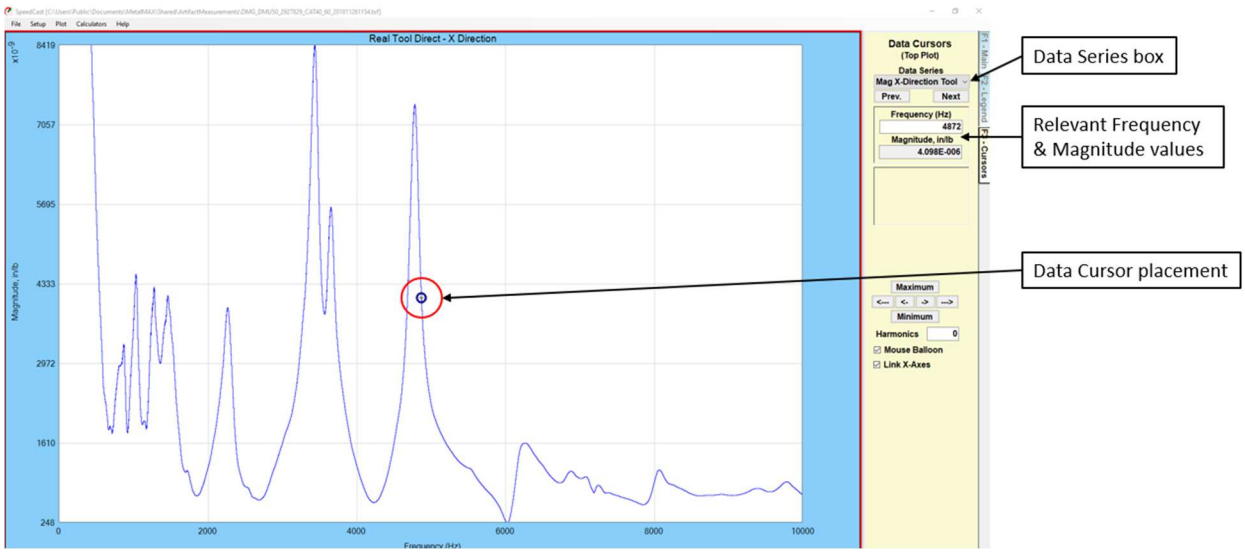

Figure 24: Data Cursors

Right Click and Zoom options

A menu is accessible by Right Clicking in any plot window. This menu provides zooming options as well as a fast way to change the plot being displayed, Figure 25.

To zoom into a specific region on the plot, hold the left mouse button down and drag a box around the region that you desire to zoom into.

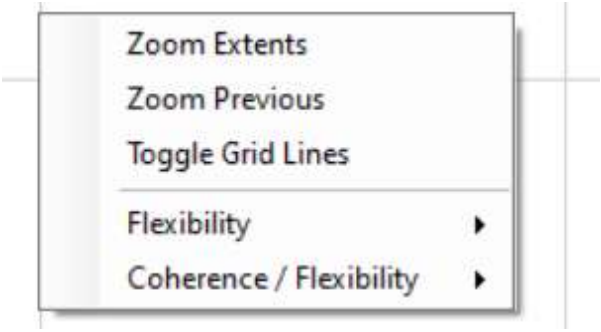

Figure 25: Right Click Menu

Zoom Extents: This option will reset the axes range to the maximum range.

Zoom Previous: This option will reset the axes range to the last plot selected using the zoom window.

Toggle Grid Lines: Will turn the grid lines on/off.

Flexibility: Allows the user to choose to display the Flexibility plots for each measurement made.

Coherence/Flexibility: Allows the user to choose to display the Coherence and Flexibility plots for each measurement made.

F12: Preferences

This is an important settings menu that allows the user to indicate a variety of preferences related to topics such as database locations, units, and the DAQ type.

Setup File: The setup file location allows the user to set the default location for the setup file.

Data Directory: The data directory location allows the user to set the default location for the databases.

Artifact Data Directory: The artifact data directory location allows the user to set the default location for the saving artifacts. If the user selects an artifact from the artifact database, the file will be saved into the artifact data directory.

Settings for Send To MLI: The MTGP User, MTGP Password, and MSC MillMaxTM Folder location are options that must be specified when using the Send to MLI button on the F1 or Esc: Main MSC MillMaxTM Screen. When using the Send to MLI option the correct MLI folder must be specified. Contact your MLI representative to get the correct setup information.

Reset all Database Locations to Defaults

The 'Reset all Database Locations to Defaults' will set the Database Locations to the default path names.

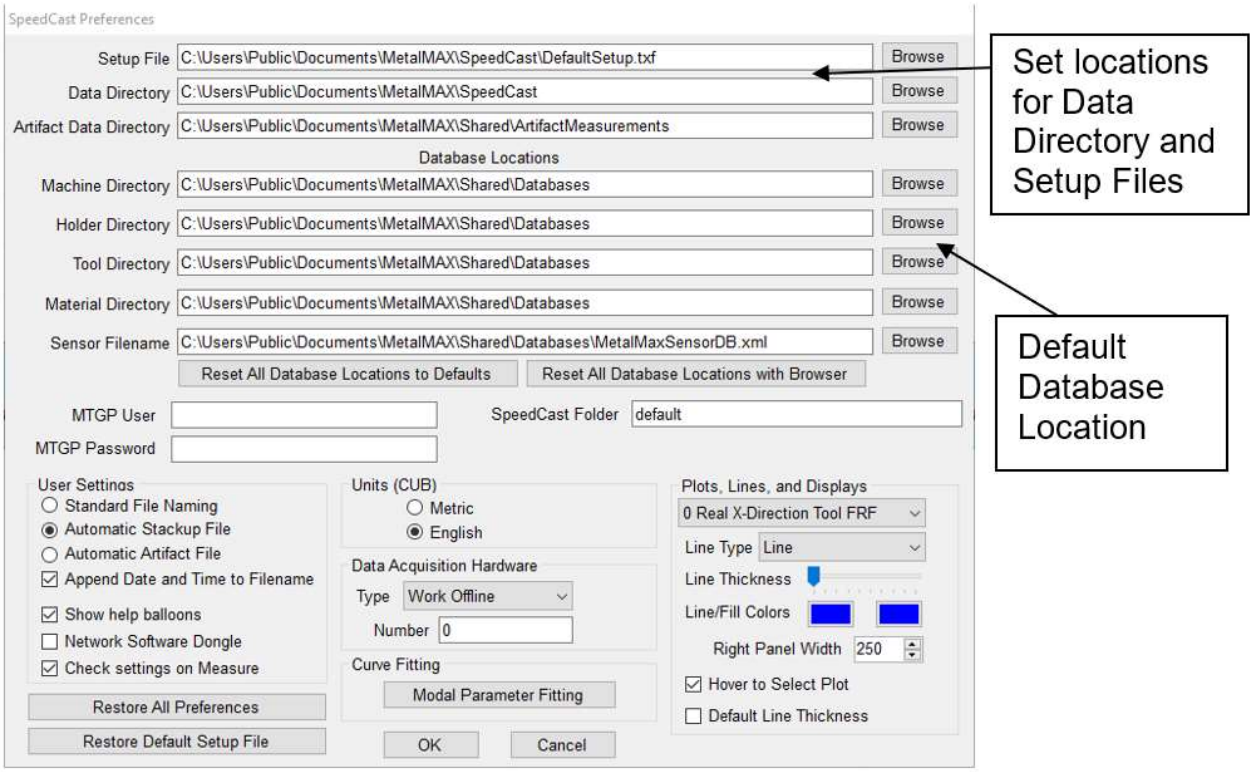

Figure 26: MSC MillMaxTM Preferences

Reset all Database Locations with Browser

When using the ‘Reset all Database Locations with Browser’, the data directory location will be the default. Additionally, the data directory location will be the location for files saved using the Save option.

User Settings

User File Naming – If User File Naming is selected the Random Number and Append Data and time to file name will not be accessible. For User File Naming, a dialog box will be displayed for the user to enter a filename.

Automatic Stackup File -- Used for Tool Direct Measurements. If Automatic Stackup File is selected, MSC MillMaxTM will save the data file to the directory indicated in Data Directory without asking the user what directory and with the following naming convention:

Machine Name_Holder MSC/Name_Tool MSC/Name_Material Name
Example: Haas VM-6-15000_43907716_01418169_P5
Example data and time: Haas VM-6-15000_43907716_01418169_P5_202006150940

Automatic Artifact File -- Used for Artifact measurements. If Automatic Artifact File is selected, MSC MillMaxTM will automatically force the Append Date and Time to Filename and the Random Number will be disabled. Then it will save the data file to the artifact directory indicated in data directory and with the following naming convention:

MachineManufacturer_MachineModel_MachineSN_HolderName_Year-month-day-time
Example: Haas_VM-6__BlueSwarf Artifact CAT40 Long_100_202006150940

Append Date and Time to Filename -- Append date and time to filename can be selected in addition to the Automatic Stackup File, will be forced on for the Automatic Artifact File, and will not be accessible for User File Naming.

Help Balloon

If the user clicks on a field a help balloon will appear giving simple instructions regarding the type of data to be entered, see Figure 27. If the user does not want the help balloons to appear, uncheck Show Help Balloons on the lower left of the MSC MillMaxTM Preferences, Figure 26.

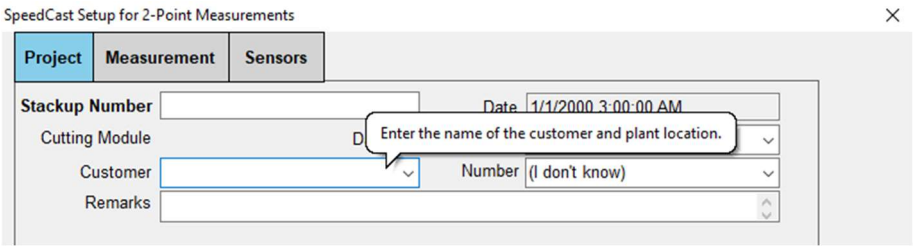

Figure 27: Help Balloon

Units

The user should specify if their measurements are in Metric or English Units.

DAQ type

The user should indicate which data acquisition system was provided when they purchased the MetalMax hardware and software. Choices are as follows:

- Work Offline
- SIM5 (MS 485B39)
- SIM4 (DT9837b)
- SIM3 (Photon+)
- SIM2 (NI6062E)
- Data Physics Quattro
- Kistler 5165A4
- Nat. Inst. NI9234
- Nat. Inst. NI9233
- Nat. Inst. NI4431
- Automated Artifact

The NI device number can also be specified.

1.4 Drop Down Menu

The Drop Down Menus are another way to access all the features described above. In addition, there are other menu options available in the Drop Down Menu that cannot be accessed any other way.

The File Menu

The file menu allows the user to create a new file, open and existing file, re-save the data, save the data with a new file name, import data and export data, and print options.

New: Opens a new file.

Clear Data: Will clear all measurement data from the file.

Open: Opens an existing file.

(Re)Save: saves file using the existing file name, this writes over the existing file and will save any changes made to the document.

Save (Save As): saves file with a new name

Send to MLI: The Send to MLI button provides the user a way to send a measurement or set of measurements directly to MLI, see Figure 23.

Batch File Operations: This selection allows the user to update files to the latest file format.

Publish: Generates a shareable Dashboard as an .html file that can be shared on any device including tablets and smartphones.

File Names: Shows most recent files

Exit: Exits program

Setup Drop Down Menu

The Setup Menu allows the user to access the same features as in the panel at the right of the main MSC MillMaxTM Screen.

The Project Tab, Measurement Tab, and Sensors Tab are explained in full detail under their respective sections in the manual.

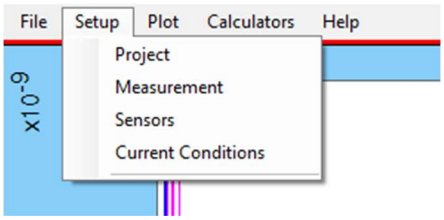

Figure 28: Setup Menu

Current Conditions

The primary purpose of this option is to provide a place to record the user's current cutting conditions and any notes regarding the stability or desires of the user. Current Conditions can be accessed from the drop down menu or as a Tab from the Setup interface (if it has been enabled using the MSC MillMaxTM Advanced Features Menu).

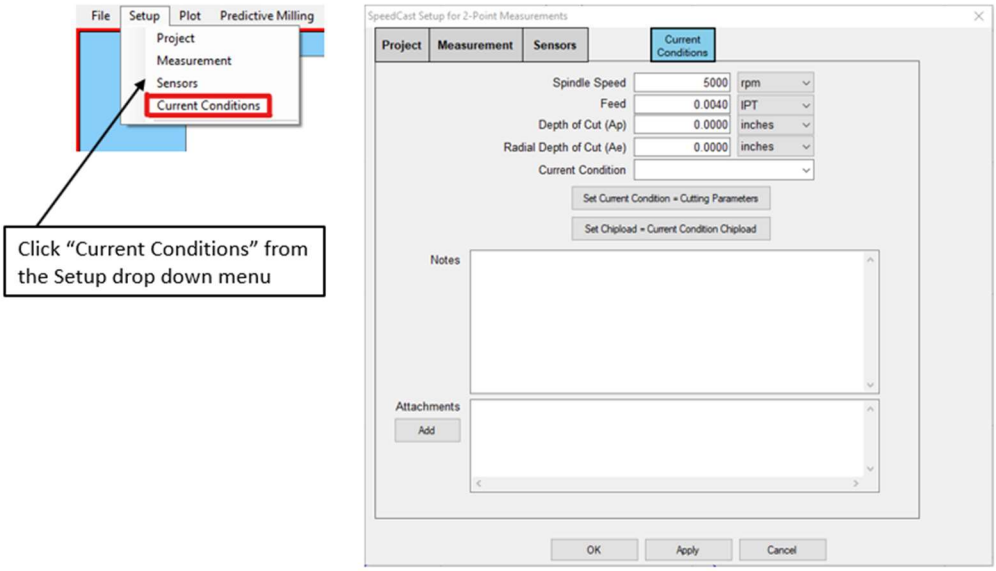

Figure 29: Current Conditions Window

Plots, Lines, and Displays

This setting allows the user to change the size of the right panel column where buttons Initialize, Setup, Practice, Measure, DCC, Publish DCC, Print, and Send to MLI are located.

The Plot Menu

The Plot Menu allow the user to access the same menus seen in the tabs along the right side of the MSC MillMaxTM Screen, F1 or Esc: Main MSC MillMaxTM Screen, F2: Legend, F3: Cursors, as well as the Flexibility and Coherence and Flexibility options, see Figure 30.

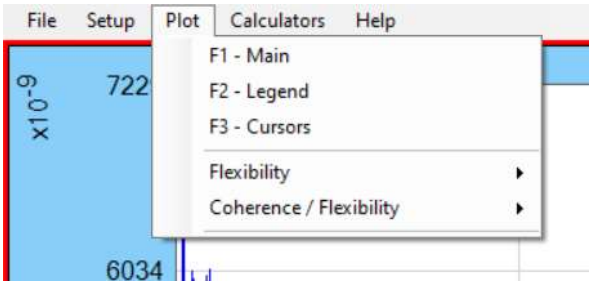

Figure 30: Plot Menu

Flexibility:

Allows the user to choose to display the Flexibility plots for each measurement made.

Coherence / Flexibility:

Allows the users to choose to display the Coherence and Flexibility plots for each measurement made, as shown in Figure 32. Coherence is a data quality assessment which identifies how much of the system response is related to the input force. The options available in this menu will change based on the active measurements set in the Measurement Tab.

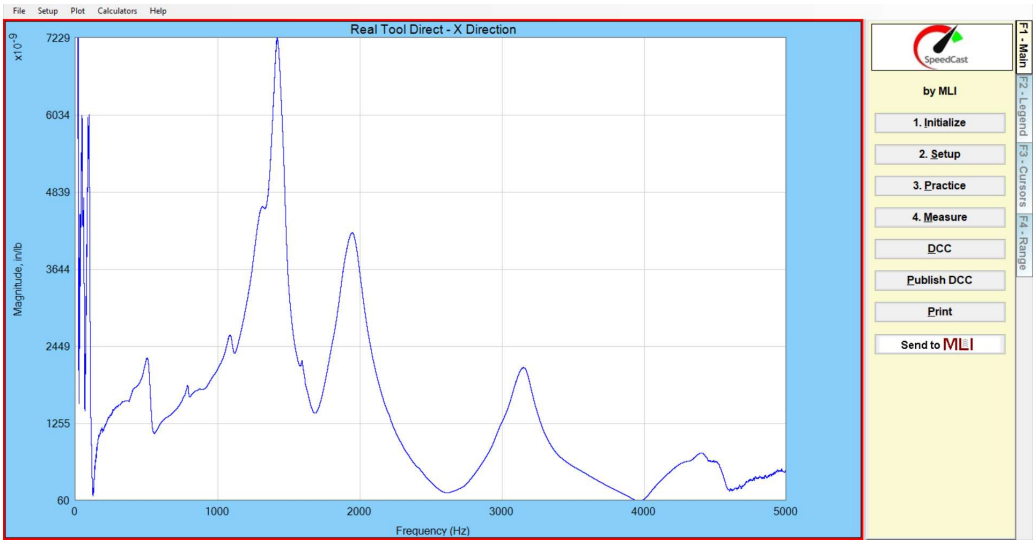

Figure 31: Flexibility

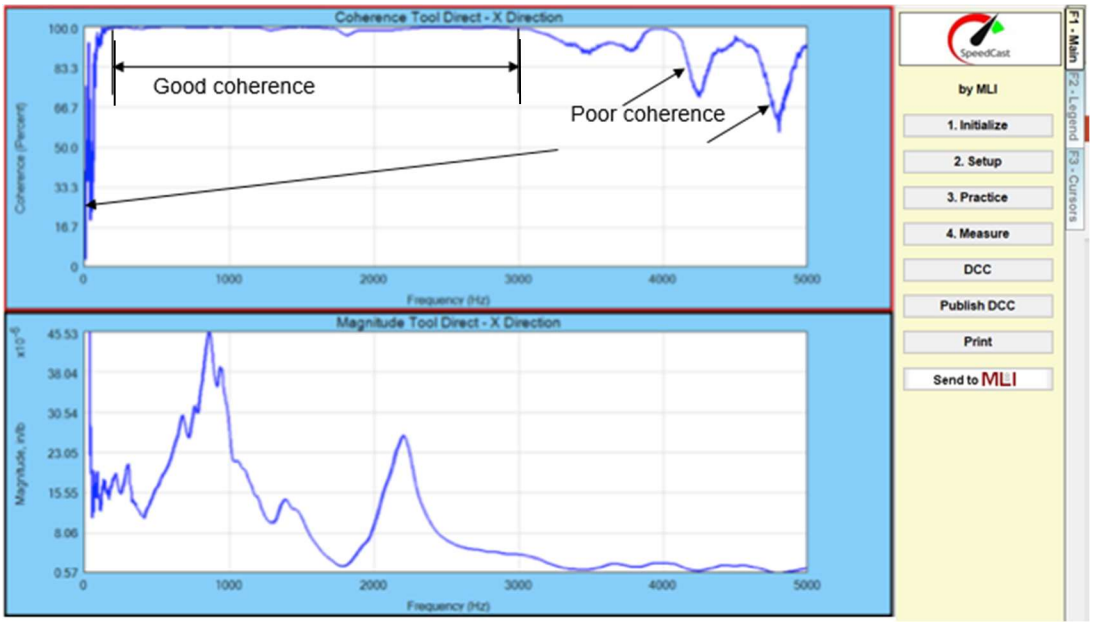

Figure 32: Coherence and Flexibility

Calculators:

There are two options on this down menu: Current Conditions Calculator and Dynamic Cutting Calculator (DCC), the latter of which can also be activated by clicking the DCC button on the MSC MillMaxTM Main Menu, Figure 5.

Current Conditions Calculator:

The current conditions calculator provides the Power and Metal Removal rate for the current conditions.

Dynamic Cutting Calculator (DCC):

This will generate the MSC MillMaxTM Dashboard. The same as using the DCC button.

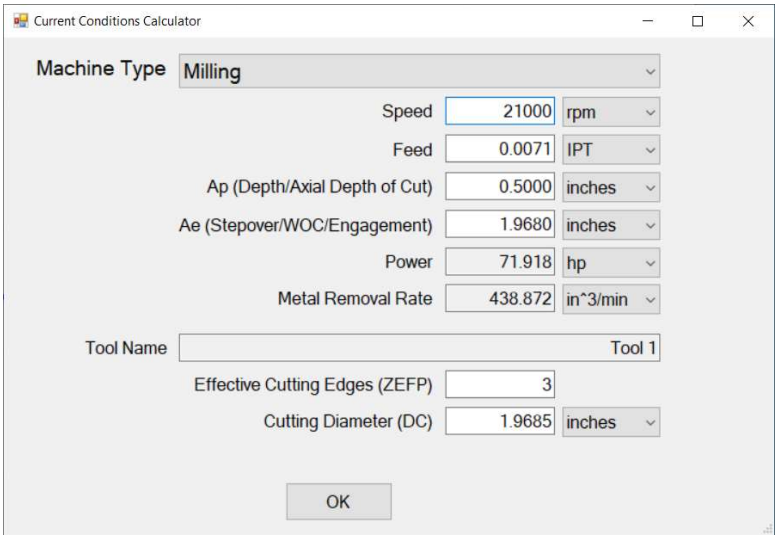

Figure 33: Current Conditions Calculator

Help Menu

Manual: Opens up MSC MillMaxTM user manual as a .pdf file.

MLI Website: Automatically connects the user to the MLI website if computer is connected to Internet.

MSC MillMaxTM Training: Sends the user to the website taptest.co, where the user is prompted to create (or enter an existing) login to be given access to training material.

Stackup Configuration: This option displays for the user the machine and tool stackup. It lists the Machine, Holder, Tool, Material, and File Type.

About: Provides the MSC MillMaxTM release that is currently installed, the copyright information, and information about the individuals that were involved in coding the relevant release.

Advanced Features

MSC MillMaxTM has an Advanced Features menu which the user can access by hitting "CTRL-A", Figure 34:

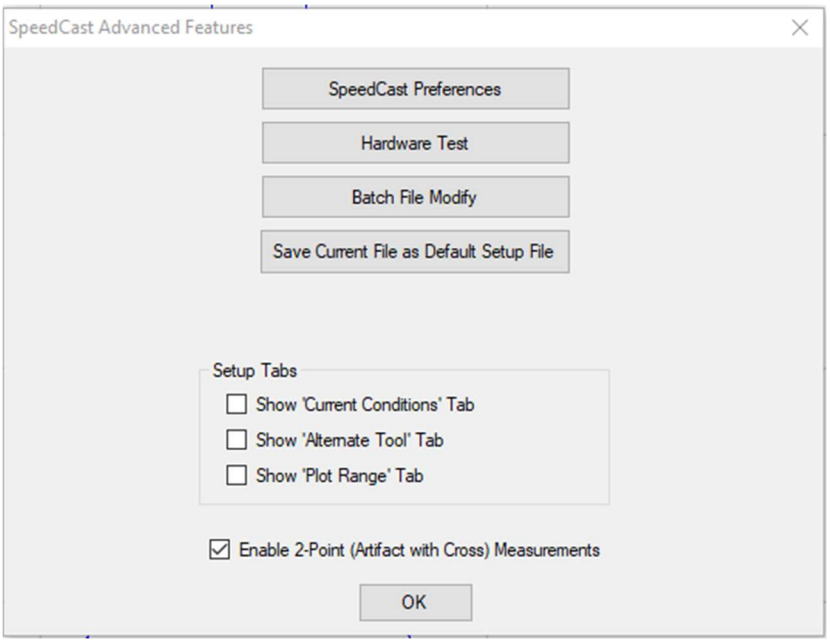

Figure 34: MSC MillMaxTM Advanced Features Menu

MSC MillMaxTM Preferences: This button brings you to the same Preferences Menu as hitting F12.

Hardware Test: This menu gives the user a graphical display of the calibrations process. It checks for approximately 30 seconds to see if the channels have settled and displays Calibration Successful at the top and shows which channels settled at the bottom of the screen. It also allows user to review Voltage levels before collecting data.

Batch File Modify: Allows the user to manually modify a configuration.

Save Current File as Default Setup File: Saves the file currently in use as the DefaultSetup.txf file in the MSC MillMaxTM program folder on the user's hard drive.

Setup Tabs: The user can check "Show 'Current Conditions' Tab", "Show 'Alternate Tool' Tab", or "Show 'Plot Range' Tab", which will enable them as options on the Setup drop down menu as well appearing as tabs inside the Setup window, Figure 36.

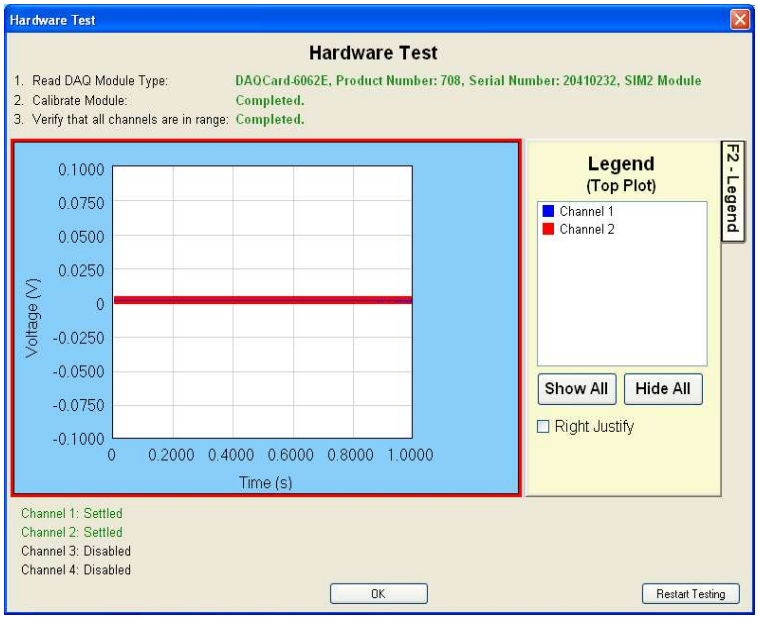

Figure 35: Hardware Test

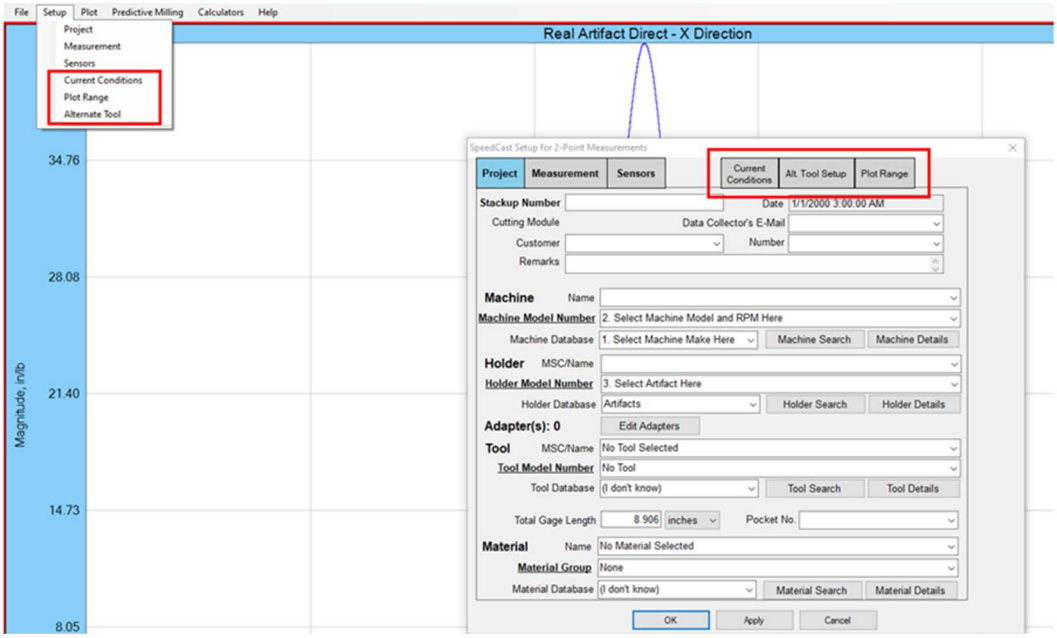

Figure 36: Advanced Features Setup Tabs

2.0 Best Practice Rules

This section will review some of the best practices to help the user correclty choose a hammer and acclerometer pair for a given measurement and to review techniques for making a good impact on a given structure or tool.

Most hammer and accelerometers of the ICP type, contained in MetalMAX, have a maximum “linear” range of 5 volts. Although they can be utilized and produce output higher than 5 volts the best results are achieved when signals do not significantly exceed 5 volts (a warning is given in the software when this occurs).

Selection of the hammer and accelerometer pair is fundamentally an intuitive decision with some trial and evaluation. Some basic rules in making the initial selection are as follows:

2.1 Selection of the appropriate hammer

A hammer will have multiple tips each having a different stiffness for altering the force level and the impact duration, as shown in Figure 37. The choice of hammer and tip is critical to correctly excite the desired structure.

The hammer tip hardness controls the frequency response and has little effect on force levels. Harder tips provide higher frequency response.

Added mass or weight/extender will increase force but not dramatically alter frequency response.

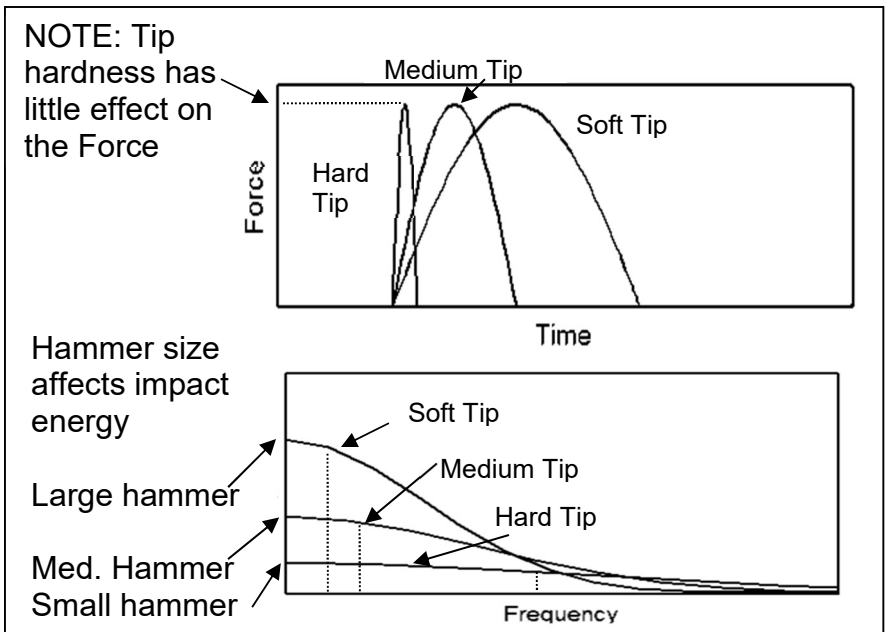

Figure 37: (top) Impact duration for soft, medium, and hard tip (bottom) Magnitude of impact energy versus frequency content of impact for different hammer mass and tip stiffness

A structure with a larger mass will require a larger impact force and therefore generally require added mass or a larger hammer size.

The flexibility of the impact, bottom plot Y axis, is determined by the mass of the hammer, while the frequency content of the impact is controlled by the stiffness of the tip, (X axis on the bottom plot of Figure 37).

2.2 Selection of the appropriate accelerometer

It is imperative to choose an accelerometer with suitable sensitivity for the desired frequency range of interest. First, it is desirable to have an accelerometer with as high a sensitivity as possible. However, the higher the sensitivity the higher the mass of the accelerometer. A high mass means a lower maximum working range because of the low natural frequency of the transducer. Additionally, it is feasible that the mass of the accelerometer can change the dynamics of the structure being measured. Second, mounting and orientation are critical. These considerations must be addressed when choosing which accelerometer is best for a given measurement.

The accelerometer mass and sensitivity are the main factors for accelerometer selection.

The accelerometer mass should not exceed 15% (ideally 10%) of the “modal/reflected” mass of the measurement location.

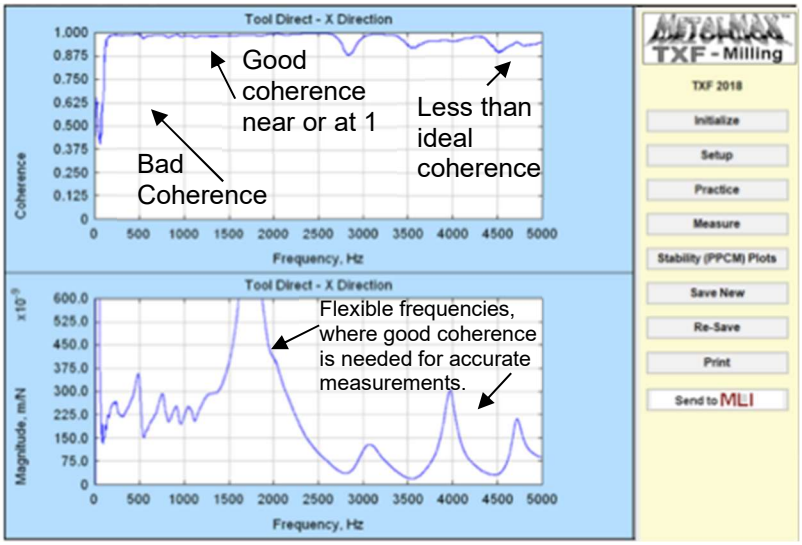

Figure 38: Coherence Flexibility Graph

The accelerometer and hammer voltage levels are observed during the “Autorange” process. A minimum signal strength of 10 millivolts is acceptable for most measurements. When making a measurement if the accelerometer signal strength is not at least 10 mV then an accelerometer with a different sensitivity should be used or the hammer mass and strike velocity should be altered accordingly.

Quantitative evaluation of the FRF measurement is ultimately made using the “Coherence” plot in MSC MillMaxTM. Values of at least 0.80 (80%) at the location of the flexible frequencies (modes) produce the best results, see Figure 38.

2.3 Targeting

Basic rules for targeting the hammer on the tool or work piece (or any structure).

Parallel alignment of the hammer tip with the measuement axis of the accelerometer at impact is most important. To achieve this it may be necessary to hit the structure off

axis from the accelerometer. This is of course needed when the accelerometer is mounted on the hammer impact side of the structure, as shown in Figure 39.

The machine should be place in an approximate cutting position, e.g. do not measure the home position of the machine (unless for maintenance monitoring purposes to achieve a consistent measurement location).

Avoid attaching the accel. or attaching the hammer to secondary structures, e.g. rings, seals, inserts, etc. It will insure that measurement does not contain extraneous vibration characteristics of the secondary structure or produce arbitrary loading conditions.

With any adhesive ensure that the minimum amount of adhesive (wax, loctite, etc.) is used between the accelerometer face or mount and the structure.

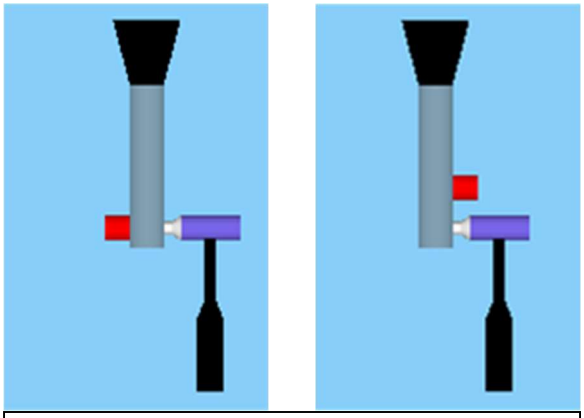

Figure 39: (left) Desired impact configuration, ensure hammer is aligned parallel to the accelerometer measurement axis (right) Impact off axis with the accelerometer to maintain axes alignment

Do not attempt to “hammer” the structure. Allow the hammer’s own weight to create the impact force. Additionally, allow the hammer to freely “bounce” off the structure. Grip the hammer only tightly enough to guide it to its target.

Table 2: Nominal Sensitivity (Calibration) Factors

Hammer/Accelerometer Serial No.	Sensitivity (Calibration)
SM Hammer 086D80	25 mv/lb
MD Hammer 086C04	5 mv/lb
LG Hammer 086C05	1 mv/lb
SM Accel 352C23	5 mv/g
MD Accel 352A21	10 mv/g
LG Accel 352C68	100 mv/g
Spin Accel 353B14	5 mv/g
XLG Accel 393A03	1000 mv/g

Note: Added mass/weight/extender will affect the sensitivity; refer to calibration sheets for the specifics.