HARMONIZER® Users Manual 2011

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1.0 Introduction

1.1 Cover Page

The HARMONIZER® is designed specifically for use with uniform pitch metal removal type applications such as milling, boring, and turning. The HARMONIZER® is strictly a speed selection application tool. There is no warranty, implied or otherwise, to cure chatter problems due to the program lacking the capability to predict the depth-of-cut. For depth-of-cut predictions and more comprehensive stability analysis tools, please refer to MLI's complete MetalMAX™ product line.

Manufacturing Laboratories, Inc.
url: www.mfg-labs.com

1.2 Using this manual

This manual has been written to accompany the Harmonizer® Version 11 software.

The manual has been organized into specific chapters that contain background information, system requirements and steps for using the software.

Throughout the manual you will find words that are either underlined and/or appear in blue ink. The key to these words are as follows:

Blue is a topic or figure link. Clicking on this word will automatically take the user to that specific section within the manual or to the referenced figure.

Underlined and Blue is an Internet link. Clicking on this word will automatically open an Internet window and link the user to the specified website.

1.3 About Chatter

Definition of Chatter:

"Chatter is a self-excited vibration that occurs in metal cutting if the chip width is too large with respect to the dynamic stiffness of the system."

Recognizing Chatter:

Chatter is easily identified from both an audible and a visual perspective. There is a distinct sound associated with chatter and is a resultant from the vibrations occurring during the metal cutting process. The resulting surface finish is marred and unacceptable when chatter is present during the machining process. See Figure 1 below for an example of the resulting surface finish when chatter occurs and does not occur.

The Occurrence of Chatter:

Due to either normal wear conditions or by selecting a non-optimal combination of spindle speed and depth of cut all machine tools will experience chatter at some point during their useful life.

It should be noted that the feed rate is not a dependent variable of chatter. Therefore, adjusting the feed rate will neither help to eliminate chatter nor will it induce chatter.

Understanding and Analyzing Chatter:

Given that chatter is a sound wave phenomenon, it lends itself to being modeled using a mathematical approach. This mathematical approach provides a means to which the chatter sound wave can be analyzed, interpreted and useful information returned to the operator. The information returned by the HARMONIZER® can be used to select cutting conditions for a given machine tool that will avoid the occurrence of chatter.

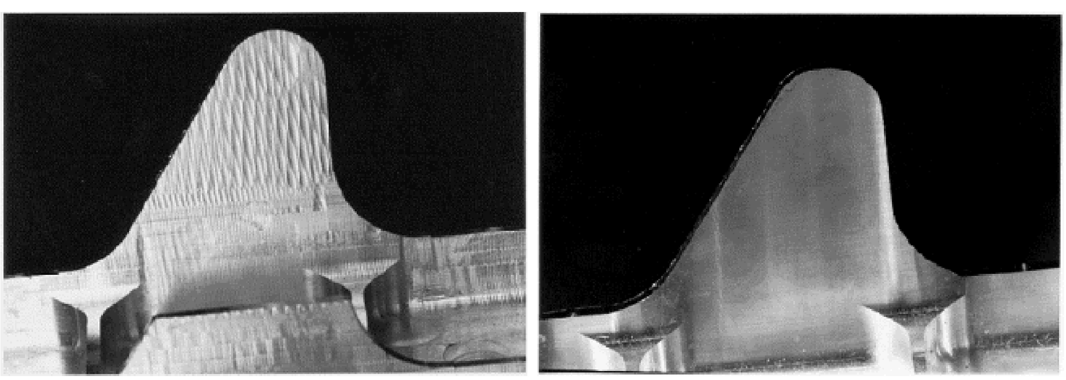


Figure 1: (left) Chatter or Unstable (right) No Chatter or Stable

1.4 About Harmonizer

What is the HARMONIZER®?

HARMONIZER® is a machining vibration monitoring package that can detect differences between stable and unstable machining. When unstable cutting conditions occur HARMONIZER® suggests alternative spindle speeds and/or reduction in depth of cut to eliminate the chatter. For more complete details on this process see the section entitled Technical Principals.

Background of the HARMONIZER®

The HARMONIZER® utilizes well developed signal processing strategies and machining vibration technology developed over 50 years including patented and patentable technology. In conjunction with MLI's other products this technology provides a complete solution to optimizing your machining capabilities while avoiding chatter completely.

What's New for Version 11.0

Version 11.0 of the HARMONIZER® software has been redesigned with a new look to be more user friendly and to provide better performance and reliability. The enhancements included in this version of HARMONIZER® are a direct result of feedback from users. These enhancements include:

2.0 Installation

2.1 Requirements

The HARMONIZER® software requires a laptop computer and a unidirectional microphone (or other recording device) for operation. HARMONIZER® is best used with an MLI tested and supplied microphone. However, any microphone is usually sufficient to achieve satisfactory results. The package can also run on virtually any audio card equipped computer and is supported for Win2k, WinXP, and Windows 7.

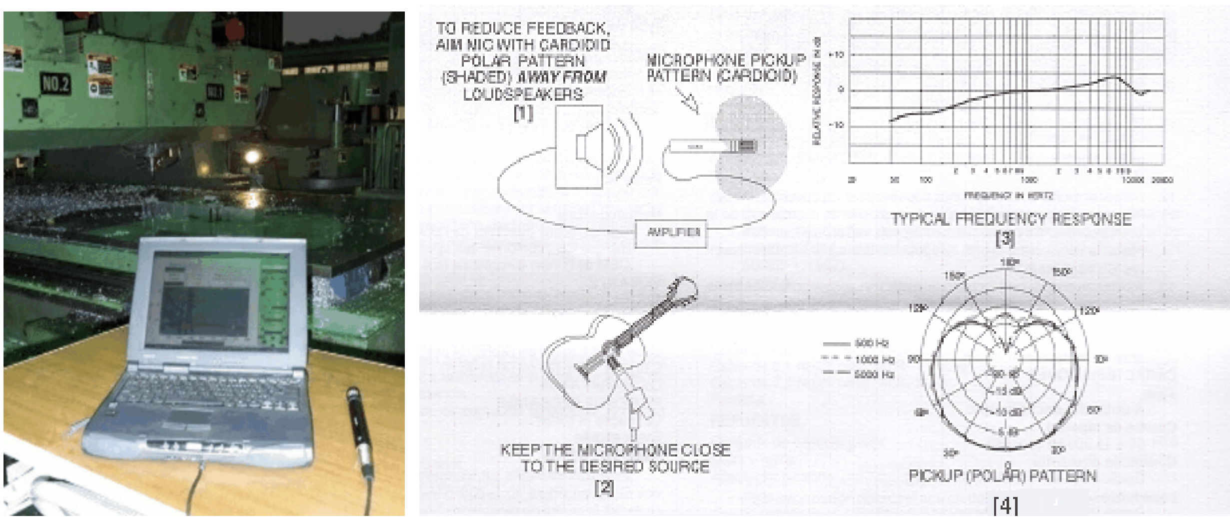


Figure 2: (left) HARMONIZER® Installed on Laptop (right) Microphone Characteristics

Microphone

HARMONIZER® requires a unidirectional microphone for best performance. A unidirectional microphone records sound from only one direction, eliminating problems resulting from recording other ambient sounds (not related to the desired cutting test) from a noisy manufacturing environment. MLI has an available recommended microphone for use with HARMONIZER®, as well as an iMic. This microphone has been characterized for performance over the frequency range of 100-15,000 Hz. The provided microphone has been mapped and a compensation curve provided in the software to insure the flattest possible response. However, any high grade instrument microphone with a relatively flat response is acceptable. Calibrated microphones are not required as the principal of operation only requires frequency information and not absolute sound level, power, or intensity.

Figure 3: iMic provided with HARMONIZER®

Figure 2: [1] demonstrates the concept of microphone feedback, [2] suggests where to place the microphone relative to the sound source, [3] show the typical frequency response of an acceptable microphone, and [4] shows the corresponding polar plot of the frequency response.

Computer

HARMONIZER® works best if run on a computer with the following minimum requirements:

Pentium class processor

Audio capabilities

- Audio amplifier and drivers or external USB audio driver

Memory

- 1GB RAM
- 60MB available hard disk space

Operating system

- Windows 2k or higher
- Directx9c
- .Net 2.0

Ports

- 1 USB for Hardware Lock

Monitor

- Minimum 1024 x 768 screen resolution

Lower performing computers and microphones (e.g. imbedded microphones) may be used but performance of the HARMONIZER® will suffer.

Operating System

** IMPORTANT **

PLEASE READ COMPLETELY BEFORE RUNNING HARMONIZER® OR METALMAX

All MLI software requires "Dot".NET 2.0 and DirectX9C upgrades to Windows 2k and higher.

MetalMAX and HARMONIZER® are written in the C.Net language. Most Windows OS's will need certain extensions for the HARMONIZER® to work. These extensions are available on the Microsoft Windows or MLI website. MLI software utilizes the latest capabilities of Windows Operating Systems.

- "Dot".NET 2.0
- DirectX9C End-User Runtimes

If your computer's Windows OS has not been updated recently, please download the Net Framework 2.0 update and load the DirectX9 End-User Runtimes software using the procedures outlined below.

Notes:
Depending on Internet connection speed, this download may take up to 45 minutes. This is a one time download that will also be useful for other leading edge software products.

If you are not sure if you have "Dot".NET 2.0 and DirectX9C End-User Runtimes:

To verify if you have "Dot".NET 2.0 access the Add or Remove Programs from the Windows Control Panel. If "Dot".NET 2.0 is installed on your computer you will see it listed as Microsoft .NET Framework 2.0, see Figure 4. If Microsoft .NET Framework 2.0 is not present in the currently installed programs, follow the instructions on how too download .Net Framework 2.0.

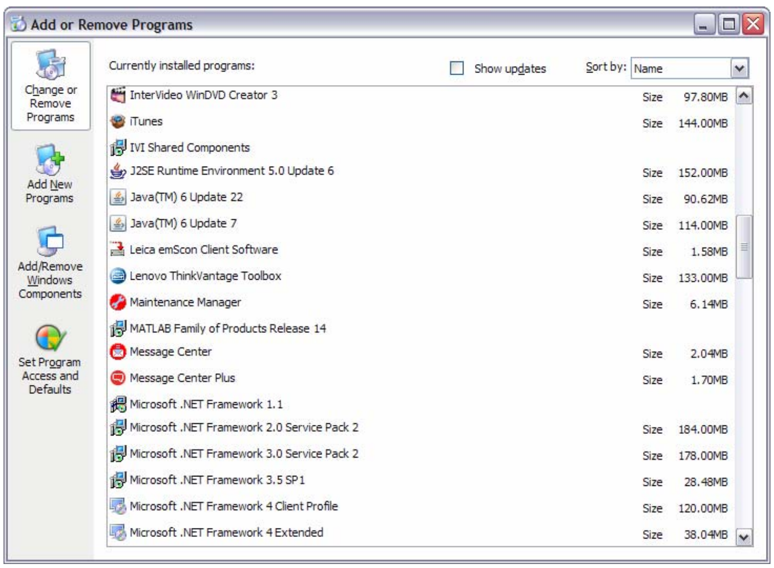


Figure 4: Add Remove Programs

To verify if you have DirectX9C End-User Runtimes installed on your computer. Access the Run dialog box from the Windows Start Menu. In the Open box type dxdiag, Figure 5. If DirectX is installed on your computer this command will open the DirectX Diagnostic Tool. If this the DirectX Diagnostic Tool does not open, the follow the instructions on how too download DirectX9 End-User Runtimes

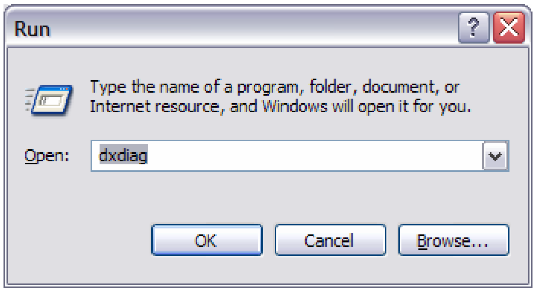


Figure 5: Run dxdiag

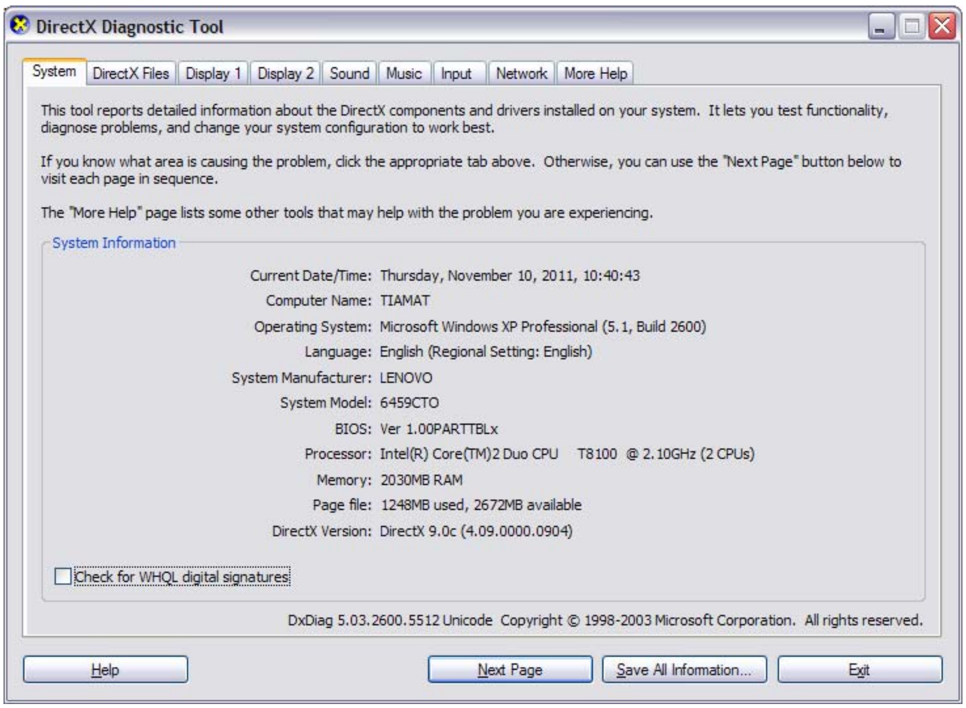


Figure 6: DirectX Diagnostic Tool

.Net Framework 2.0

To download or update .Net Framework 2.0 execute the following steps:

1. Go to the Microsoft Windows update website
2. Click on the Custom option button under Keep your computer up to date
3. Find the update labeled Microsoft .Net Framework version 2.0 and make sure it is selected to be installed
4. Click on Review and install updates
5. Check that Microsoft .Net Framework version 2.0 is listed in the updates to install
6. Remove any other updates listed by clicking the Remove button under the description of each update. (The Microsoft .Net Framework version 2.0 update may take up to 45 min to load. Therefore we suggest you do not download any other updates at this time.)
7. Click on the Install Updates button and follow the other instructions given. You may be asked to reboot the computer. Please follow all instructions.

DirectX9 End-User Runtimes

To download DirectX9, execute the following steps:

1. Go to the Microsoft Download Center
2. Search the download center for DirectX End-User Runtimes
3. Download the most up-to-date installation for DirectX End-User Runtimes

Installing HARMONIZER® on Computer

DO NOT install the HARMONIZER® software until you have completed the steps listed in the Operating System section FIRST.

HARMONIZER® can be installed on your computer from one of two sources, the Harmonizer.zip file downloaded from the MLI website or a CD-ROM available from MLI when the software has been purchased. The following instructions should work for either source.

NOTE: If you have Windows 7 as your operating system, the install has to be 'Run as Administrator' regardless of whether you are logged on as Administrator.

File download from website:

1. Download the Harmonizer.zip file and the HarmonizerInstall.exe file, available under the Support Tab on http://www.mfg-labs.com, and put it in a temporary directory
   a. For Windows 2k and XP use the following suggested folder location C:/Documents and Setting/All Users/Shared Documents/MetalMax
   b. For windows Vista and 7 use the following suggested folder location C:/User/Public/Documents/MetalMax
2. DO NOT insert A/D card or hardware lock dongle.
3. Run the HarmonizerInstall.exe file, and follow the instruction from Harmonizer Installer section below.

CD-ROM:

1. Insert the CD-ROM. Do not insert A/D card or hardware lock dongle.
2. Allow the CD-ROM to auto-start (may take 90 seconds or more). If it does not start after 2 minutes open Windows Explorer and run the HarmonizerInstall.exe program from the CD ROM root directory.
3. Follow the instruction from Harmonizer Installer section below.

Harmonizer Installer

When installing HARMONIZER® the following dialog box will appear, see Figure 7.

1. Choose the location where HARMONIZER® should be installed.
2. Choose the units (this can be changed in the [F12] Preferences after installation if needed).
3. Indicate the data acquisition hardware type that will be used. The default is a standard PC microphone.
4. Indicate which dongle type was provided with your purchase. Choose None if the hardware lock provided with your purchase is white with a blue stripe. If the

hardware lock provided with your purchase is a parallel port lock or a green USB port lock, you will need to install drivers for your hardware lock. To do this select the appropriate type of lock in the Legacy dongle drivers box on the installer window.
5. Click Install Harmonizer
6. Read the MLI License Agreement, then Click I Accept. Next, read the MLI Software Disclaimer, then Click I Accept. You will see text in the Installation Log box, as HARMONIZER® is installed.
7. Upon complete installation, a confirmation will be displayed stating ‘Harmonizer has been installed.’

If you will be using HARMONIZER® with a PC Microphone. You are now ready to run HARMONIZER®!

If you will be using HARMONIZER® with one of the supported data acquisition systems, you will need to install the appropriate drivers. To complete this process refer to individual data acquisition systems installation instructions provided by MLI with your purchase.

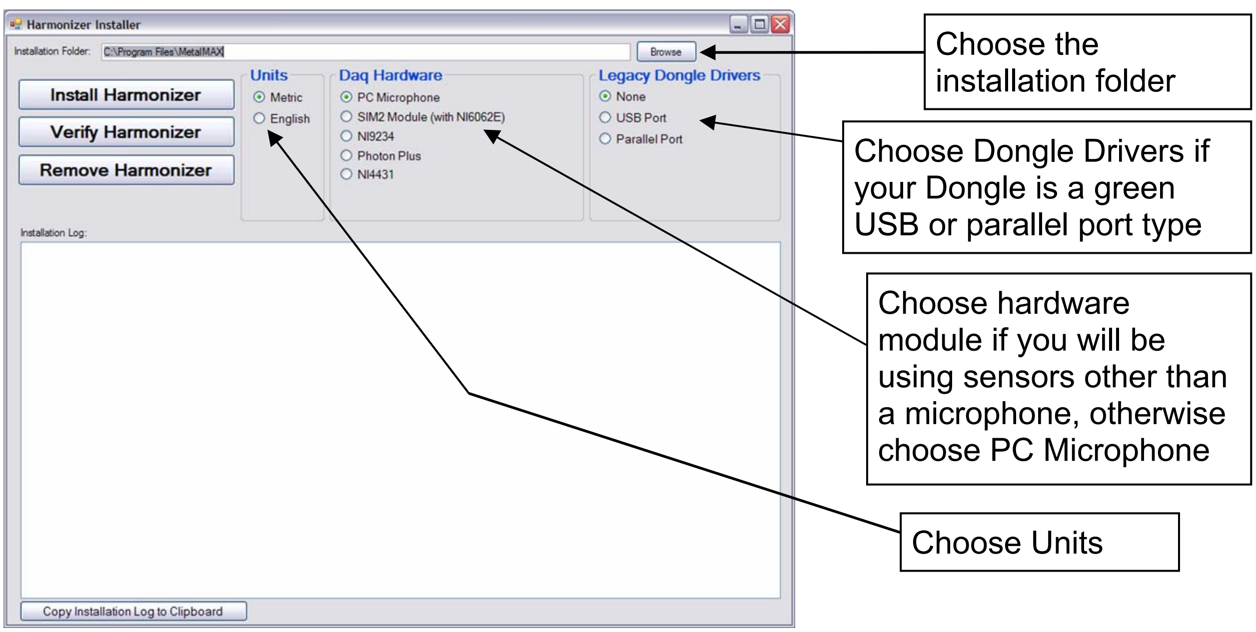


Figure 7: HARMONIZER® Installer

Verify Harmonizer: This button is a diagnostic tool to help troubleshoot Installation problems.

Copy Installation Log to Clipboard: This button will copy the text in the Installation Log window to the clipboard such that it can be pasted into a document, or email, or saved if needed.

<u>To Remove HARMONIZER®</u>

To remove HARMONIZER®, follow the steps below.

1. Run the HarmonizerInstall.exe file from the CD ROM or from the location on your hard drive where the file was initially stored. If necessary you can download the Harmonizer.zip file and the HarmonizerInstall.exe file as described above in the section Installing HARMONIZER® on Computer
2. Choose the location where HARMONIZER® was installed. Most likely this is the following folder: C:\Program Files\MetalMAX
3. Click Remove Harmonizer
4. You will be asked 'Do you want to remove common MetalMax files? Only indicate yes for this question if you no longer want to run any MetalMax Application. If this is the case you should consider running the MetalMaxInstall.exe and removing all MetalMax program. Otherwise, click NO.
5. You will see text in the Installation Log box, as HARMONIZER® is removed. When the program has been removed a confirmation will be displayed stating 'Harmonizer has been removed'

3.0 Technical Principals

- Operation of the HARMONIZER® is a convergent technique.
- The system drives the user to determine the optimum highest stable spindle speed (within the supplied range).
- The HARMONIZER® will also report if no stable speed exists.
- Due to the nature of sound fields and the highly focused frequency behavior of machining and chatter, the HARMONIZER® can detect very low levels of chatter when used properly.

3.1 What makes the HARMONIZER® work

The following information explains the general spindle speed selection technique for avoiding chatter. This selection technique is the basis of the HARMONIZER® package. Fundamental Concepts: Several fundamental concepts that exist in combating chatter using spindle speed selection are the following:

- Axial and radial depth-of-cut have a direct and proportional affect on the stability of machining.
- Spindle speed has a large deterministic affect on stability.
- Chatter frequency is related to the dominant natural frequency and spindle speed.
- Chip loads above a small minimal level do not strongly affect stability, only tool displacement.

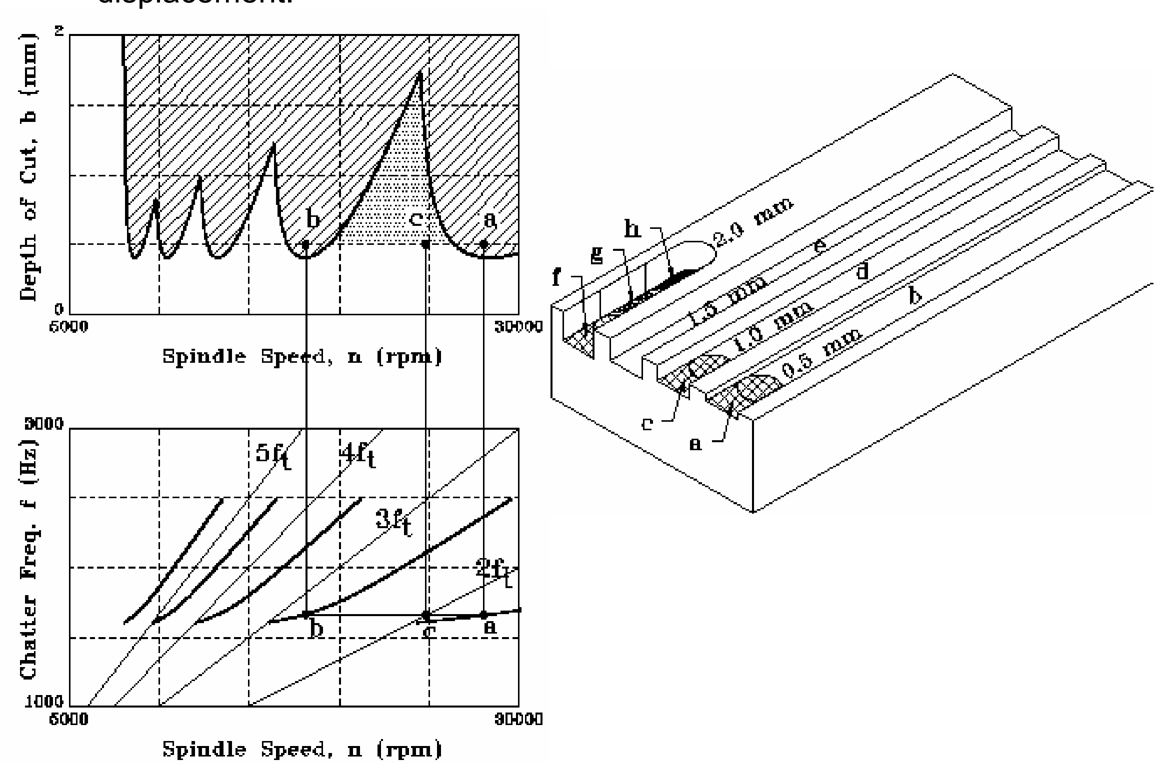


Figure 8: (top left) Stability Lobe Diagram and (bottom right) Tooth Frequency (Hz) Multiples (right) Cutting Test to Determine Chatter

Stability Plots: The top plot of Figure 8 displays a stability plot (hatch area indicates chatter) for a 2-tooth cutter in terms of axial depth-of-cut as a function spindle speed. The bottom plot displays (bold non-linear lines) chatter frequency (Hz) as a function of spindle speed. Also on this plot are lines of tooth frequency (Hz) multiples (straight lines marked 2ft, 3ft,…) as a function of spindle speed.

These two plots completely describe the spindle speed-chatter frequency relationship typical for most tools. The location and height of the curves may change depending on the tooling used but the form and shape of the curves remains very similar. The indisputable concept is that "spindle speed and chatter frequency are related"

From this relationship, as shown in Figure 8, a convergent technique can be applied to find the best spindle speed with minimal effort.

Speed Selection Techniques:

The basic technique is:

"select the spindle speed so that the tooth frequency or some multiple of the tooth frequency is equal to the chatter frequency"

Referring to Figure 8, assume that a cut is made at point "a" at a 0.5-mm depth. The upper stability plot indicates that this cut is chattering. The chatter frequency can be determined in the lower plot by finding the frequency for the same spindle speed point on the lowest chatter curve (bold non-linear line). It is about 1,650 Hz. Graphically the technique directs the spindle speed change to the spindle speed curve for the two times multiple of tooth frequency (marked 2ft) which corresponds to a spindle speed of just under 25,000 rpm (1650 Hz*60 cpm/Hz÷2 teeth cpm/rpm÷2nd multiple). The upper plot indicates that the new speed is in a chatter free area at point "c". Starting at another spindle speed, point "b", results in a similar outcome demonstrating the convergence of the technique.

Figure 9 more clearly demonstrates the convergence method and the benefit in being able to optimize a cutter's performance. A cut is attempted at the maximum speed of the spindle, in this case 30,000 rpm, denoted as ***"a"***. The technique selects a spindle speed at **"*b*"** which is stable. The depth-of-cut is then increased to 1.0-mm, point ***"c"***, which chatters. The technique is then applied again and a new spindle speed at point ***"d"***, further into the stable zone, is selected. Depth-of-cut is again increased to point ***"e"***, and this time it remains stable. A further increase results in a chattering cut at point ***"f"*** but since the depth-of-cut is above any stable pockets, no new spindle speeds, points ***"g"*** and ***"h"***, can be selected that are stable.

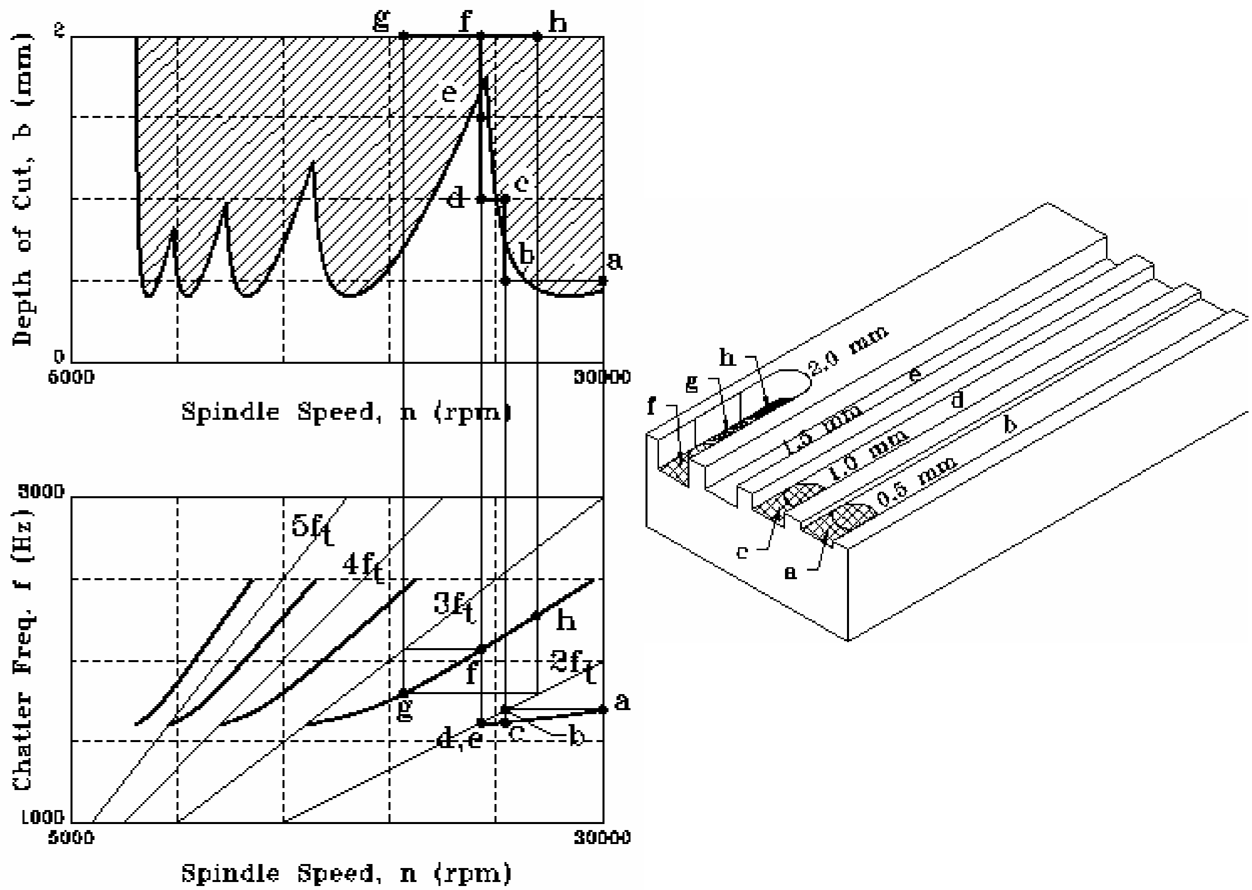


Figure 9: (left) Stability Lobe Diagram Demonstrating the Convergence Technique
(right) Cutting Test to Determine Chatter

This example clearly demonstrates that the technique converges to the optimal spindle speed where the highest depth-of-cut can be achieved. Obviously, it has practical application for testing tooling on a test block as show in Figure 9 where the optimal depth of cut can be quickly determined with a simple cutting test.

No Resonant Vibration: The most common misconception is that this technique drives the system into resonance. This is not the case because machining is not a "classic" forced vibration problem where the periodic force is applied regardless of system displacement. The cutting force being applied to the tool is a function of chip thickness. The chip-thickness is dependent upon cutter displacement, which is dependent upon cutting force. Therefore, this is very similar to a feedback-type system in which stability dictates rather than resonates vibration. Figure 10 illustrates the effect of the force. By synchronizing (aligning the phase of) the tool vibration so that it coincides with a tooth frequency (or multiple), the chip thickness, which is proportional to cutting force, is made constant. As a result, the force variation is minimized. The spindle speed, as long as it is in phase, only affects the number of vibration cycles between tooth passes.

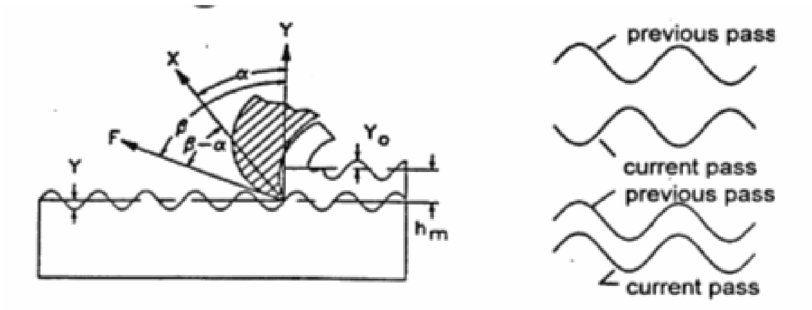


Figure 10: Chip Thickness Variation (Regeneration of Waviness)

Resonant vibration is not a factor because the force is independent of the process and therefore is not magnified in the "classical-resonant" sense when operating near a natural frequency. This is well-documented in literature and references can be supplied on request

3.2 Noisy Environments

The HARMONIZER® can operate even in noisy shop environments due to three following guiding principles:

Proximity

Machining noise is very closely approximated as a "point source". Therefore, its pressure logarithmically decays as distance from the source increases. Provided the user stands closer to the machine of interest, the HARMONIZER® will readily detect the desired machine's cutting noise. Inmost cases, the user can place the microphone outside the machine's enclosure and still acquire the required sound readings (if the user can hear the machining operation, then the microphone will detect the noise as well). In some cases, placement of the microphone inside the machine's safety enclosure may improve results. A microphone suction cup mount can be purchased from MLI for this use.

Unidirectionality

Use of a directional microphone can reduce the influence of off-axis noise from other sources when pointed at the cutting tool. The popular cardioid characteristic of most unidirectional microphones is more than adequate. The HARMONIZER® is provided with such a microphone.

Frequency Range

The vast majority of shop floor noise and extraneous machine sounds falls within the broadband frequency range. That is to say, the noise is of a high sound pressure level and it is spread over a very wide frequency range or band (broadband). The spreading characteristic results in no specific frequency having a very large magnitude. On the other hand, machining and chatter occur with their noise pressure focused at a very limited number of frequencies. These frequencies are easily recognizable compared to the background noise frequencies. Additionally, machining related frequencies, i.e. bearing noise, can be easily filtered due to their narrow bandwidth.

4.0 *Program Operation*

4.1 Main Screen

Upon starting HARMONIZER® software, the Plots Screen, shown in Figure 11, will be displayed. This is the main screen that displays the most important operating parameters in three sections. On the left is the Data Display Window which shows two plots, the Sound Magnitude vs. Frequency (top) and the Sound Wave vs. Time (bottom). The right-hand side of the screen is divided into two sections, the Control Window at the top and the Parameter Window at the bottom.

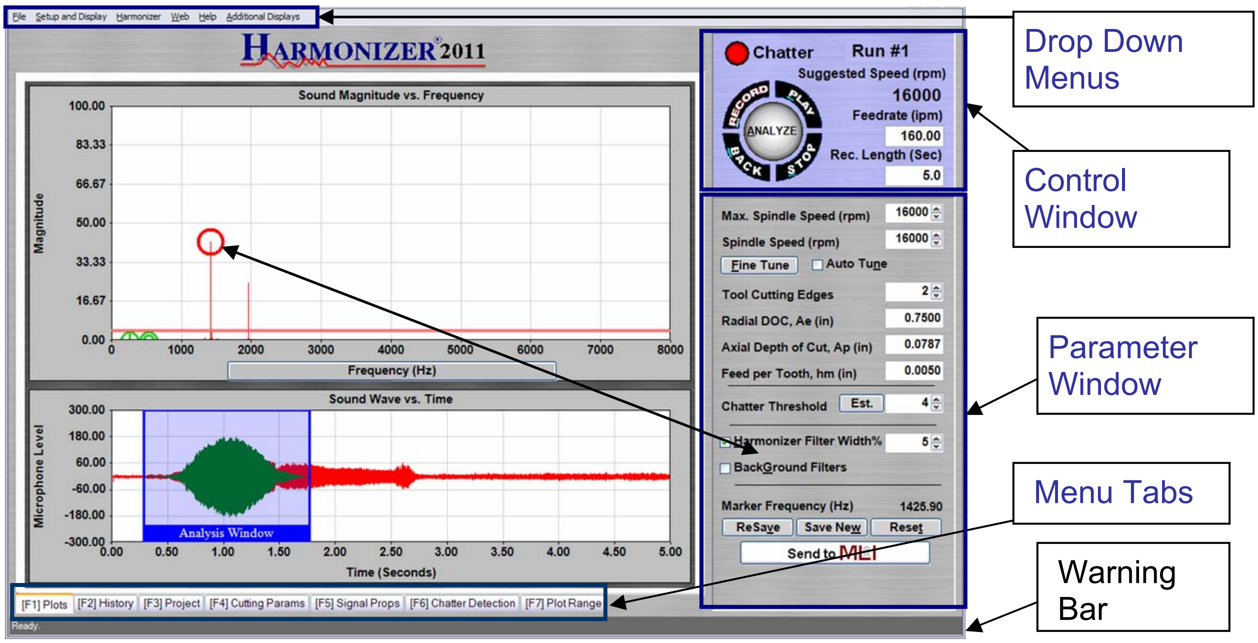


Figure 11: The plots screen as seen when first opening HARMONIZER®

Sound Magnitude vs. Frequency

The Sound Magnitude vs. Frequency (top plot in Figure 11) displays the Fast Fourier Transform (FFT) of the sound data displayed in the Sound Wave vs. Time plot (bottom plot in Figure 11).

Sound Wave vs. Time

The Sound Wave vs. Time displays the recorded sound level versus time. The blue Analysis Window is the FFT window. The settings for this window are found on the [F5] Signal Properties Tab. This window can be move to encompass different segments of the data, see Figure 29. The green signal overlay inside the Analysis Window is the time domain signal with the Filters applied as set on the [F6] Chatter Detection Tab. The green signal overlay inside the Analysis Window by default is turned off. This setting can be adjusted in the Advanced Settings. Contact your MLI representative for details on this setting.

Menu Tabs

All of the menus in HARMONIZER® can be accessed in 3 ways:

- The Drop Down Menus at the top left of the screen (Figure 11)
- The Menu Tabs at the bottom of the screen (Figure 11), or
- The hot key designations shown in square brackets [F1] through [F8].

Full details for each Menu Tabs selection are available in the section titled Setup and Display Menu.

- [F1] Plots
- [F2] History
- [F3] Project Settings
- [F4] Cutting Parameters
- [F5] Signal Properties
- [F6] Chatter Detection
- [F7] Plot Range

Control Window

The Control Window at the top right of the on the Main Screen [F1] is one of two ways to access the data recording and analysis features. These same features can be accessed using the Harmonizer Drop Down Menu at the top of the screen.

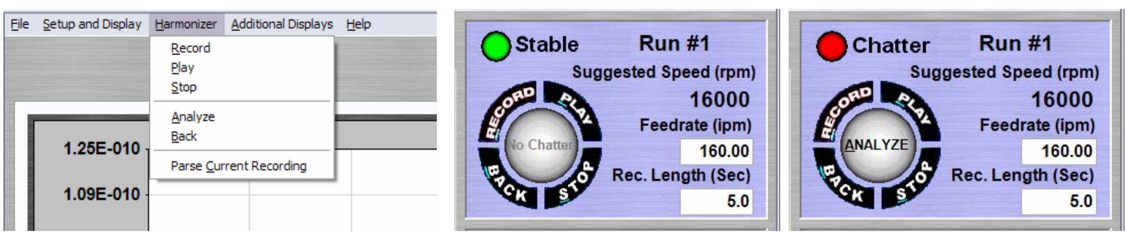


Figure 12: Harmonizer Drop Down Menus and Control Window showing Stable and Chatter

Record: This button triggers the software to record for 5.0 seconds (depending on the setting in [F5] Signal Properties)

Play: This button will play back the sound file just recorded.

Back: This button will revert back to the previous sound file. The current sound file will be deleted when using the Back button.

Stop: This button will stop the process of recording.

Analyze: The center of the control buttons will read No Chatter as shown in Figure 12 when the cut is stable. When the cut chatters the button will change to ANALYZE. Upon clicking ANALYZE a Chatter selection window will pop up. This window shown in Figure 13 will inform the user of the Chatter frequency or frequencies and suggest a new spindle speed. Upon clicking OK HARMONIZER® will update the Speed and Feedrate selections in the Control Window. At this point HARMONIZER® is ready for the user to make a new sound recording at the specified conditions.

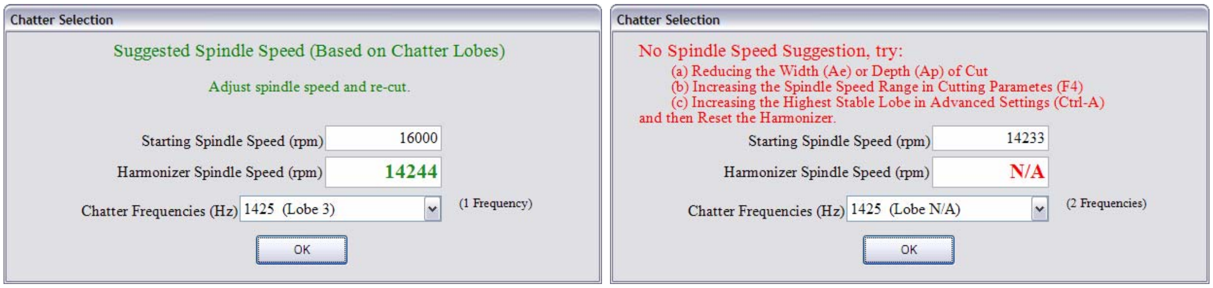


Figure 13: Chatter Selection Window (left) regulating to a new spindle speed (Right)

Parameter Window

The Parameter Window at the bottom right on the Main Screen [F1] displays the most important parameters in the chatter identification and regulation process. These are the parameters that directly affect the calculation or that the user will need to change during the regulation process.

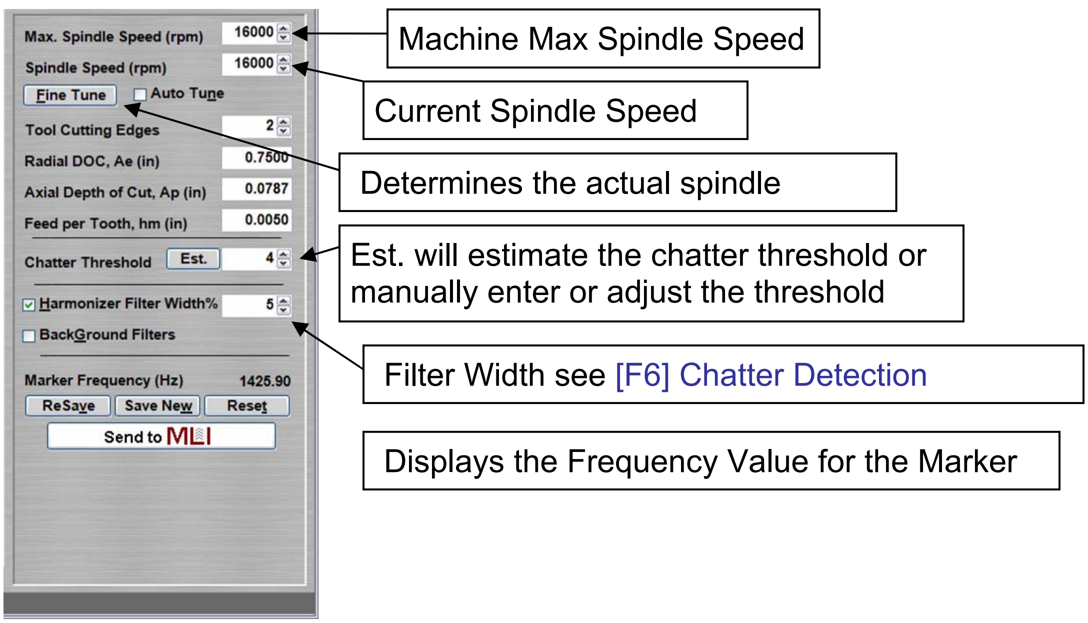


Figure 14: Parameter Window

Max Spindle Speed: The maximum spindle speed for the machine indicated on the [F3] Project Settings Tab

Spindle Speed: The current spindle speed or the suggested spindle speed.

Fine Tune and Auto Tune: Click Fine Tune to determine the actual spindle speed. If the Auto Tune option is active as indicated by a green check, then this step will occur automatically, see [F6] Chatter Detection, Filters. NOTE: If Auto Tune is selected and the spindle speed is changed in parameters or incremented from Analyze the spindle speed on the Parameter Window may not update until a new signal is recorded.

Chatter Threshold: Allows the use to manually indicate the magnitude of the sound that will be considered chatter by typing the desired value into the appropriate cell or by using the arrow keys to increment the value up or down, Figure 14. The default value is 100. Alternatively, after recording the sound wave, the user can choose Est. from the Parameter Window, and HARMONIZER® will estimate the chatter threshold based on the recorded signal. Finally, the user can indicate Cutting on the [F6] Chatter Detection Tab to automatically set the Chatter Threshold based on each recorded cut. If the user activates Cutting the display in the Parameter Window will indicate this by changing the Est. button to Cut, see Figure 32.

Harmonizer Filter Width: This selection turns on (green check mark) or off the spindle filters. If the spindle harmonic filters are not enabled HARMONIZER® will not estimate a chatter threshold. A warning will be displayed in the Warning Bar, Figure 11 ESTIMATE ERROR: The harmonic filters must be enabled in order to estimate a new chatter threshold. It also allows the user to change the recommended width of the harmonic filter. 5% is the nominal value. A more through explanation can be found in the [F6] Chatter Detection Filters section.

Background Filters: If this box is check then the background filters set in the [F6] Chatter Detection Filters Menu will be active.

Marker Frequency (Hz): Displays the Frequency value for the Marker, see Figure 11.

<u>Re-Save Data</u>

The Re-Save Data option saves the data with the existing file name and writes over the old file.

<u>Save New Data</u>

The save new data option will open a new file dialog box and allow the user to name a new file to save the data.

<u>Reset</u>

The Reset will delete all sound recordings from HARMONIZER®. Before doing so HARMONIZER® will warn the user that all unsaved data will be lost, as shown in Figure 15. This resets the sound recordings only, all information input into the [F3] Project Settings, databases, and/or edits to other parameters will be retained.

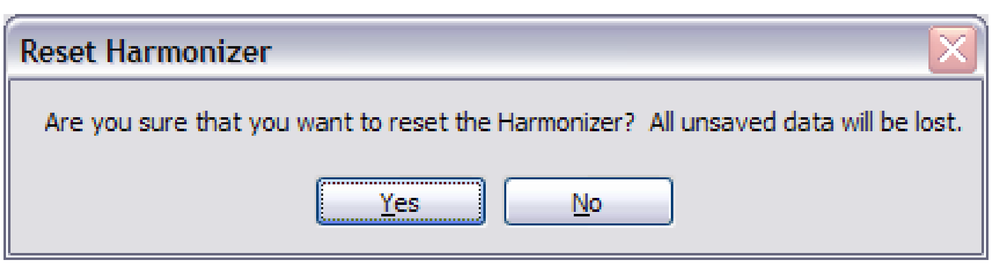


Figure 15: Reset Harmonizer

Send to MLI

The Send to MLI button provides the user a way to send a measurement or set of measurements directly to MLI. The MLI site and MLI Folder are options that must be specified when using the Send to MLI button on the main screen. Please refer to the Preferences section for description of these settings. 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.

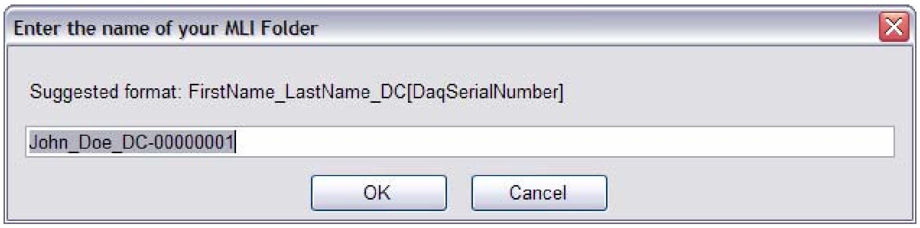


Figure 16: Send to MLI

4.2 Drop Down Menus

HARMONIZER® has six main menus located at the top of the screen. These menus operate in a customary windows format with a drop down list of options. All of the menus in HARMONIZER® can be accessed in 3 ways:

- The Drop Down Menus at the top left of the screen (Figure 11)
- The Menu Tabs at the bottom of the screen (Figure 11), or
- The hot key designations shown in square brackets [F1] through [F8].

File Menu

The File Menu utilizes the customary Window's program interface. It allows the usual function such as opening a new file, opening an existing file, saving a file, and printing a file.

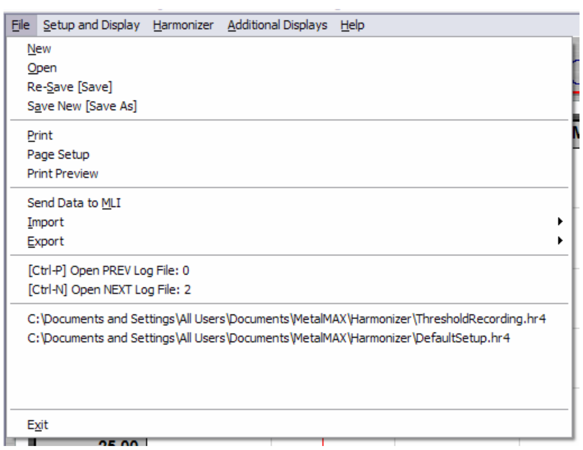


Figure 17: The File Menu and Export Menu

New: opens new file

Open: opens an existing file

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

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

Print: Allows the user to print the file

Page Setup: Allows the user to change the page setup parameters before printing.

Print Preview: Gives the user a preview of the page(s) to be printed

Send Data 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 16 and the corresponding explanation.

Import: The **Import** menu imports prior versions and .wav files that are recorded in the 16-bit mono (recommended), 16-bit stereo, or 8-bit mono. Other audio file formats cannot be imported as they usually employ compression schemes that distort the audio signal. Each must be in the appropriate format for correct import. Contact MLI for specific format information if needed.

Export: The **Export** menu provides the option to export the recorded data in one of two formats, ASCII or a Wave file. The ASCII files can be saved as either frequency data or as time data. These exported files can be used in a variety of other programs, depending on the users' preference. There are 5 formats that can be exported from TXF. Contact MLI for specific format information if needed.

- ASCII History Data
- ASCII Frequency Data
- ASCII Time Data
- ASCII Time Data (Compressed Format)
- Wave File

[Ctrl +P] Open Previous Log file: 0
[Ctrl +N] Open Next Log file: 1

File Names: Shows most recent files

Exit: To Exit HARMONIZER®, click the Exit option under the File Menu. This will close the program. If you have not saved your changes before closing the program, HARMONIZER® will warn you that the current file has been modified since it was last saved and prompt you if you want to save your changes.

Setup and Display Menu

The Setup and Display Menu includes several sub menus and is a very important premeasurement process.

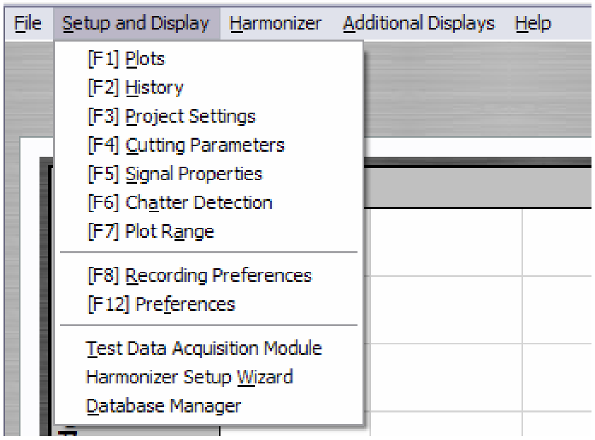


Figure 18: The Setup and Display Menu

[F1] Plots

The [F1] Plots returns the user to the main screen which displays the Sound Magnitude vs. Frequency (top plot in Figure 11) and the Sound Wave vs. Time plot (bottom plot in Figure 11). The Sound Magnitude vs. Frequency displays the Fast Fourier Transform (FFT) of the sound data displayed in the Sound Wave vs. Time. The Sound Wave vs. Time displays the recorded sound level versus time.

[F2] History

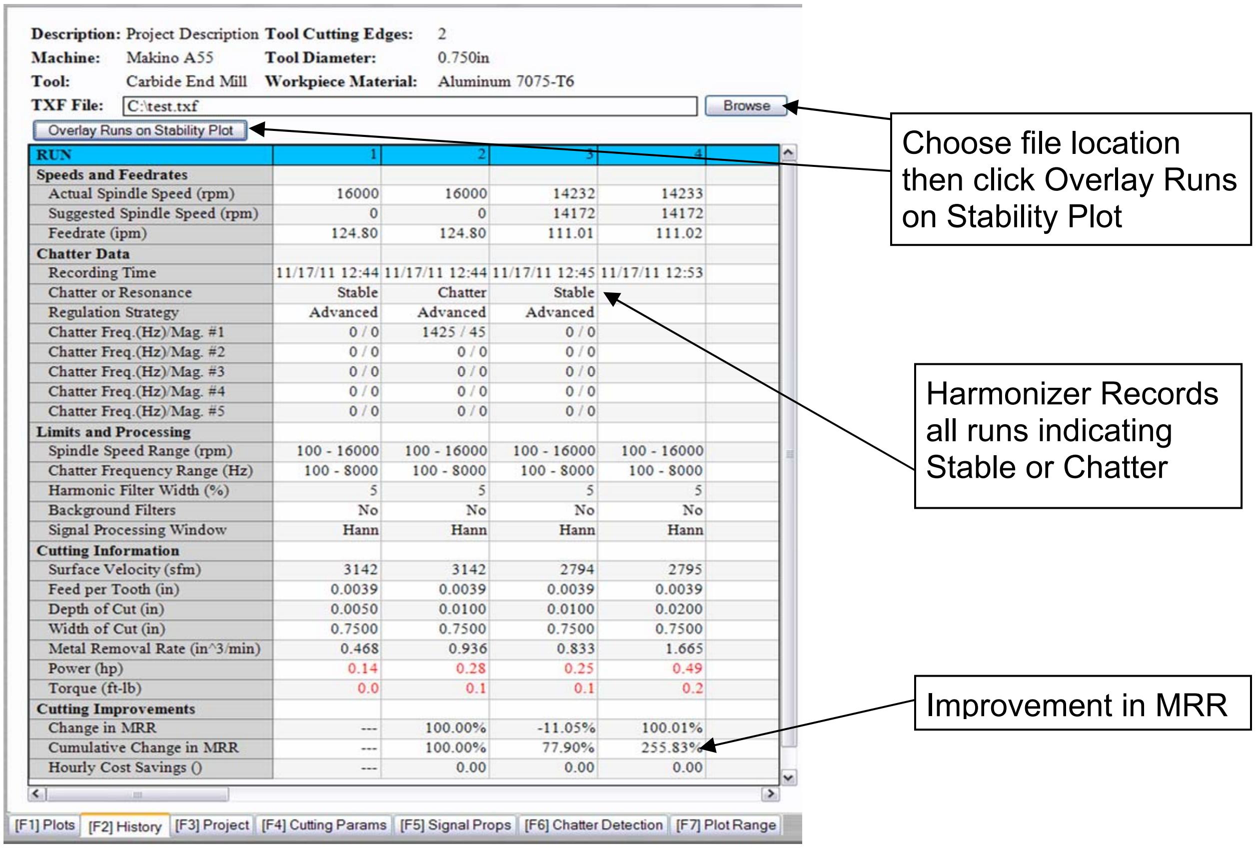
The [F2] History Tab keeps a record of all cuts that have been recorded. HARMONIZER® will increment the run number and save the data into the [F2] History Tab any parameter on the Parameter Window is incremented or if Analyze is selected on the Control Window. If the user wants to change a parameter without incrementing the run number this must be done from the [F4] Cutting Parameters Tab.

Change in MRR: Is the change in MRR from the previous run, not considering the stability of the cut, i.e. chatter or stable.

Cumulative Change in MRR: Is the improvement in the MRR compared with Run 1, not considering the stability of the cut, i.e. chatter or stable.

Overlay Runs on Stability Plot

If the TXF frequency response measurement is available for the cutting system (tool-holder-machine combination) for which the cutting tests are being performed, then the user can choose to have the stability plot generated with the runs overlaid. Stable cuts will be indicated with a green bull's-eye, while chatter cuts will be indicated with a red bull's-eye, as show in Figure 20. The runs recorded on the History Tab, Figure 19, correlate with the diagram in Figure 20.



Description: Project Description Tool Cutting Edges: 2
Machine: Makino A55 Tool Diameter: 0.750in
Tool: Carbide End Mill Workpiece Material: Aluminum 7075-T6
TXF File: C:\test.txf Browse
Overlay Runs on Stability Plot

RUN	1	2	3	4
Speeds and Feedrates				
Actual Spindle Speed (rpm)	16000	16000	14232	14233
Suggested Spindle Speed (rpm)	0	0	14172	14172
Feedrate (ipm)	124.80	124.80	111.01	111.02
Chatter Data				
Recording Time	11/17/11 12:44	11/17/11 12:44	11/17/11 12:45	11/17/11 12:53
Chatter or Resonance	Stable	Chatter	Stable	
Regulation Strategy	Advanced	Advanced	Advanced	
Chatter Freq.(Hz)/Mag. #1	0 / 0	1425 / 45	0 / 0	
Chatter Freq.(Hz)/Mag. #2	0 / 0	0 / 0	0 / 0	
Chatter Freq.(Hz)/Mag. #3	0 / 0	0 / 0	0 / 0	
Chatter Freq.(Hz)/Mag. #4	0 / 0	0 / 0	0 / 0	
Chatter Freq.(Hz)/Mag. #5	0 / 0	0 / 0	0 / 0	
Limits and Processing				
Spindle Speed Range (rpm)	100 - 16000	100 - 16000	100 - 16000	100 - 16000
Chatter Frequency Range (Hz)	100 - 8000	100 - 8000	100 - 8000	100 - 8000
Harmonic Filter Width (%)	5	5	5	5
Background Filters	No	No	No	No
Signal Processing Window	Hann	Hann	Hann	Hann
Cutting Information				
Surface Velocity (sfm)	3142	3142	2794	2795
Feed per Tooth (in)	0.0039	0.0039	0.0039	0.0039
Depth of Cut (in)	0.0050	0.0100	0.0100	0.0200
Width of Cut (in)	0.7500	0.7500	0.7500	0.7500
Metal Removal Rate (in^3/min)	0.468	0.936	0.833	1.665
Power (hp)	0.14	0.28	0.25	0.49
Torque (ft-lb)	0.0	0.1	0.1	0.2
Cutting Improvements				
Change in MRR	---	100.00%	-11.05%	100.01%
Cumulative Change in MRR	---	100.00%	77.90%	255.83%
Hourly Cost Savings ()	---	0.00	0.00	0.00

Figure 19: History Tab

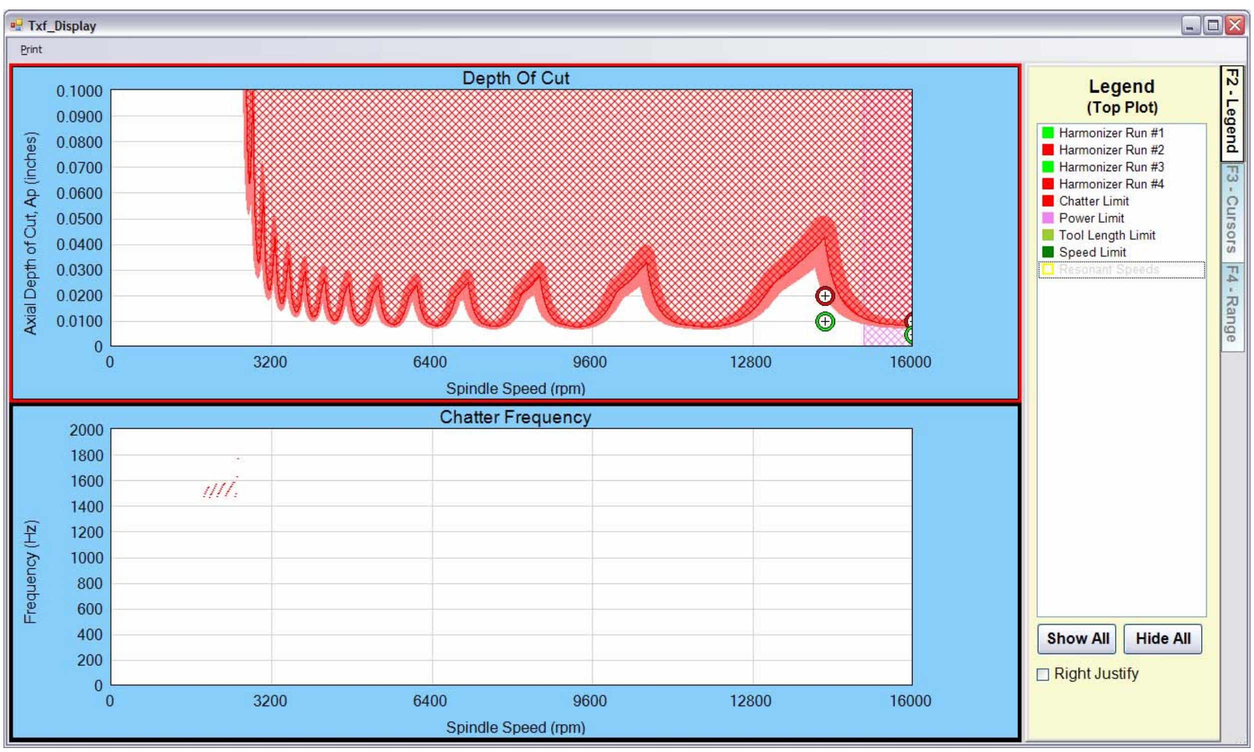


Figure 20: Overlay Runs on Stability Plot

[F3] Project Settings

The [F3] Project Settings Menu offers the ability to document specifics of the current measurement. It is recommended to include as much detail as possible in three areas, General Description, Machine, and Tool.

Customer: Enter the customer name and facility location

Number: Enter the SAP number

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

Choose your machine, holder, and tool information from the drop down lists. If the item you desire is not in the list use the appropriate database button to create your machine, holder, or tool and save it to the database.

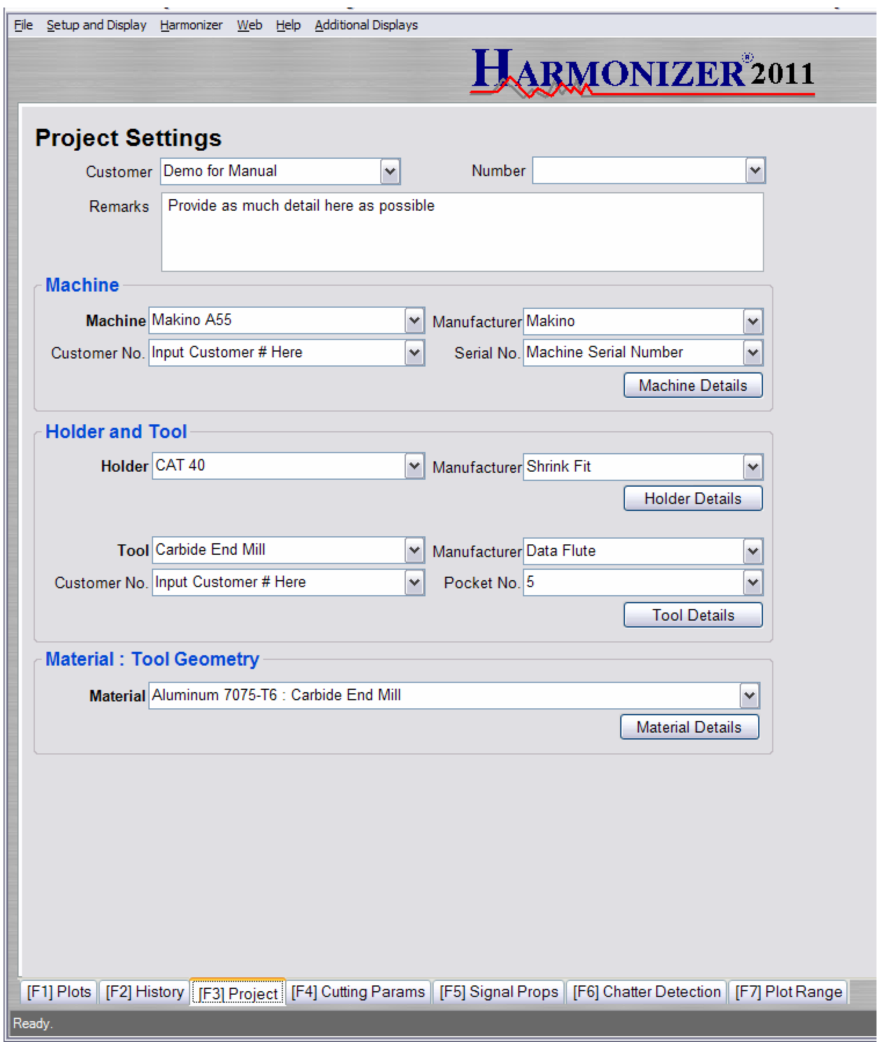


Figure 21: [F3] Project Settings

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 22. You must click ADD to save your machine to the database. If you click OK before click ADD TXF 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 machine definition has already been saved to a 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.

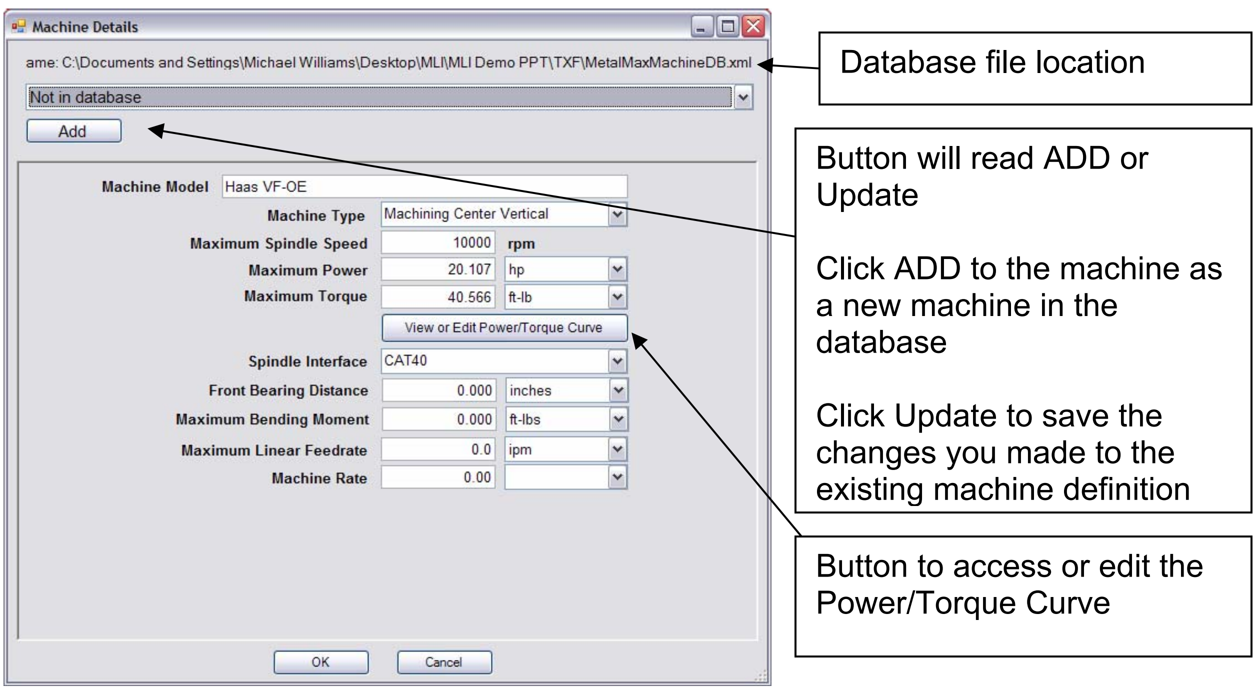


Figure 22: Update Machine Database from the Machine Details

__Edit Torque/Power Curve__

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.

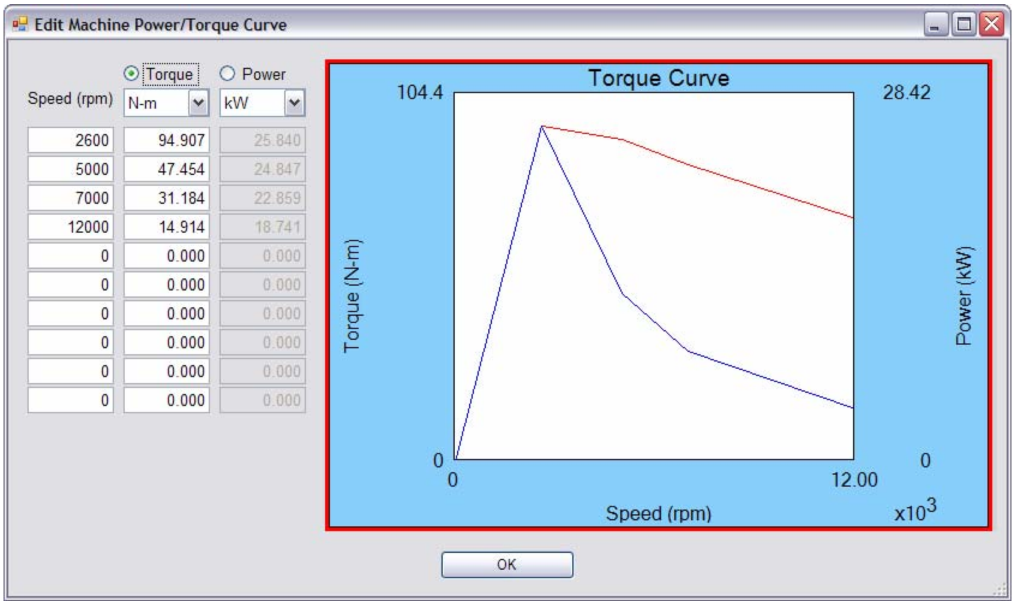


Figure 23: Edit Machine Torque/Power Curve

Holder Details

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 in to the cells of the dialog box shown in Figure 24.

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.

You must click ADD to save your holder to the database. If you click OK before click ADD TXF 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.

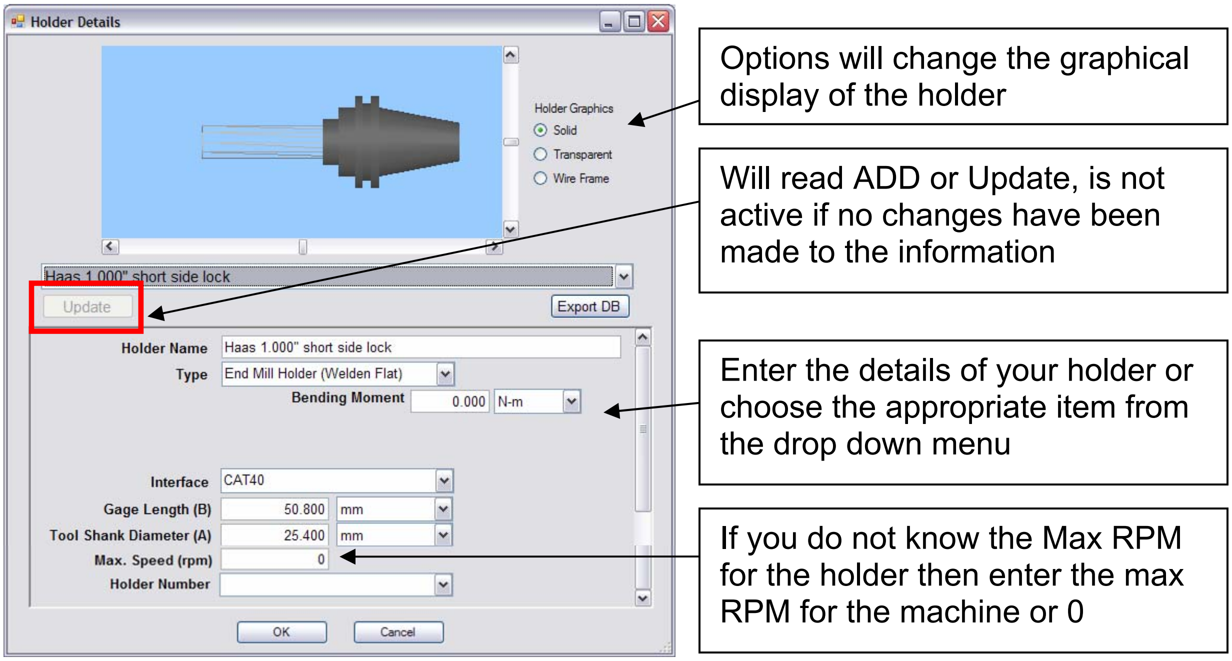


Figure 24: Edit Holder Details

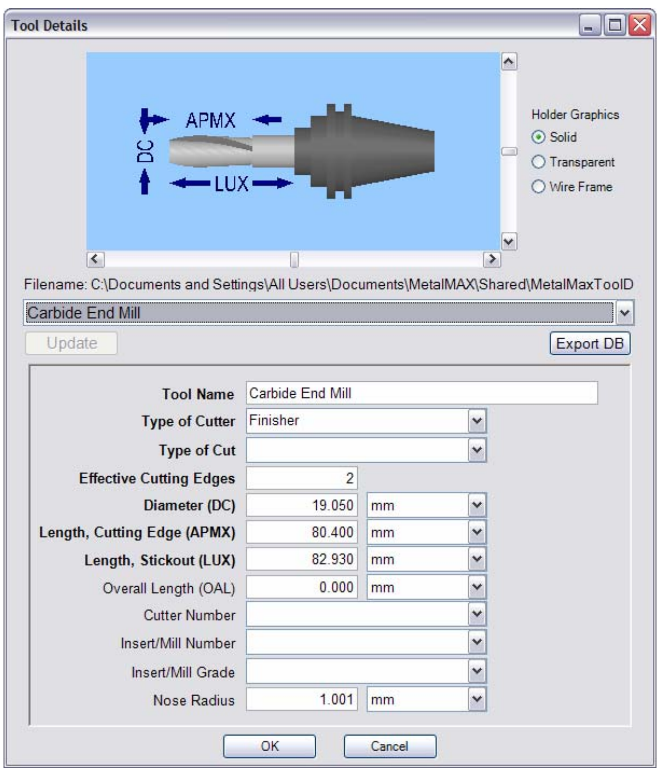


Figure 25: Edit Tool Details

Tool Details

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 in to the cells of the dialog box shown in Figure 25.

You must click ADD to save your tool to the database. If you click OK before click ADD TXF 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.

Material Details

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 in to the cells of the dialog box shown in Figure 26.

You must click ADD to save your material to the database. If you click OK before click ADD TXF 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.

The parameters in the Material Details are critical for correct calculation of the stability lobe diagram. The database includes approximate values for the cutting force coefficient (Cutting Stiffness) and Process damping wavelength for a wide variety of common cutting materials.

These values are often sufficient to get you "in the ballpark" for process predictions. While it is possible to determine more precise parameters for a particular set up, it is often not necessary. These coefficients are like other material properties such as Young's modulus or fatigue life which can have substantial variability. If you are a practitioner, you want to stay away from the edges of stability, because at the edges you are sensitive to all of the variables, many of which are not in your robust control. The user should choose the material that best represents the material they will be cutting. If the user wants or needs more precise values for the cutting stiffness and process damping refer to the Procedure for Obtaining Material/Tooling Parameters

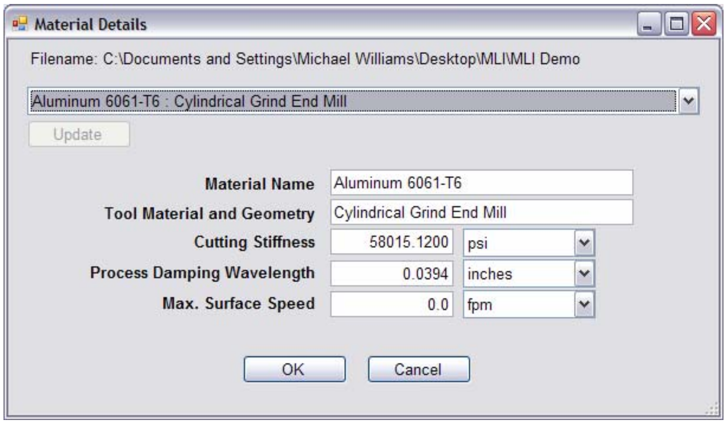


Figure 26: Material Details

[F4] Cutting Parameters

The [F4] Cutting Parameters menu provides a place for the user to document the specific cutting parameter for a cutting test. Several of these parameters are used directly in the software's calculations and therefore must be entered correctly for the software to function properly (these parameters are in red). If the user wishes to change the units of the parameter from Metric to English see [F12] Preference.

- Spindle Speed (in Revolutions per minute, RPM): This is the current spindle speed.
- Cut Type: Choose on of the three options:
  - Slotting
  - Conventional (Up) milling
  - Climb (Down) milling
- Radial Depth of Cut (in millimeters or inches): This is the width of cut. This parameter will not be accessible if Slot Milling is selected.
- Axial Depth of Cut (in millimeters or inches): Enter the starting axial depth of cut.
- Feed per Tooth (in millimeters per tooth or inches per tooth): Also refereed to as advance per tooth or chip load. If the feedrate is edited the feed per tooth will update appropriately.
- Feedrate (mm per minute or inches per minute): Enter the feedrate. If the feed per tooth is edited the feedrate will update appropriately.
- Cut Direction (in degrees): The X direction is defined as 0 degrees.

Workpiece Material

Select the material being cut from the drop down menu. To edit a material in the database or add a new material to the database click on the Add to DB.

- Maximum Surface Velocity: enter the maximum permissible surface velocity in surface feet per minute (sfm) or meters per minute (m/min) for the chosen material.

Tool Parameters

Select the Tool from the drop down menu. To edit a tool in the database or add a new tool to the database click on the Add to DB.

- Tool Cutting Edges: Number of teeth (flutes) on the cutter.
- Tool Diameter (in millimeters or inches): The diameter of the cutter.

Machine Parameters

Select the Machine from the drop down menu. To edit a machine in the database or add a new machine to the database click on the Add to DB.

- Maximum Spindle Speed: enter the maximum machine spindle speed in rpm
- Minimum Spindle Speed: enter the minimum machine spindle speed in rpm

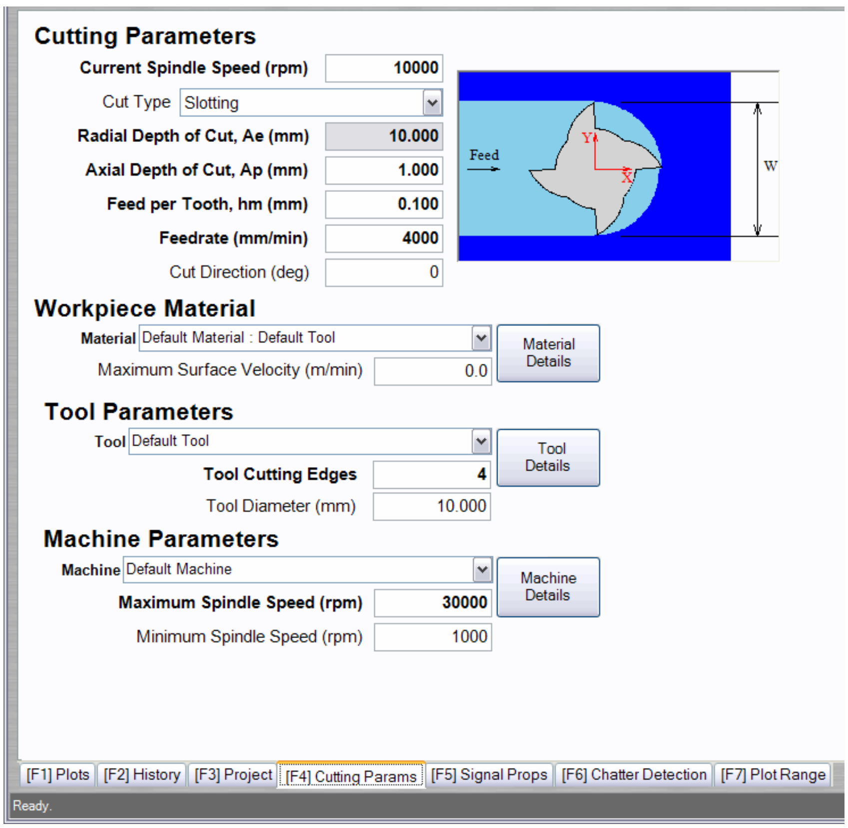


Figure 27: Cutting Parameters Tab

[F5] Signal Properties

The [F5] Signal Properties menu provides a place for the use to set parameters for the Recording, Data Logging, and Scaling and FFT Processing.

Recording

The Recording properties allow the user to choose options on how the data is recorded including recording frequency, recording length, and the type of sampling.

Recording Device: shows the active recording device as set in the [F8] Recording Preferences

Recording Frequency: this parameter is the sample rate (in Hz) for the microphone or data acquisition system. The sample rate must be at least double the maximum frequency that the user desires to see. However, best practice is to have at least 5-10x the maximum frequency that the user desires to see. Note: if using NI PCMCIA card with SIM 2 module, it is not recommended to sample less than 25000 Hz due to potential aliasing.

Recording Length: sets the time duration for each sample recording

Continuous Loop: When Continuous Loop is chosen, HARMONIZER® will continuously record sound until the user stops the recording using the STOP button on the Control Window. If the selection 'Stop if Chatter is Detected' is selected HARMONIZER® will continuously record sound until chatter or resonance is detected.

Single Sample: When the option Single Sample is chosen, sound will be recorded for the value indicated in the Recording Length (5.0 second) when Record is activated on the main screen, Figure 11. The length of time can be changed by editing recording length.

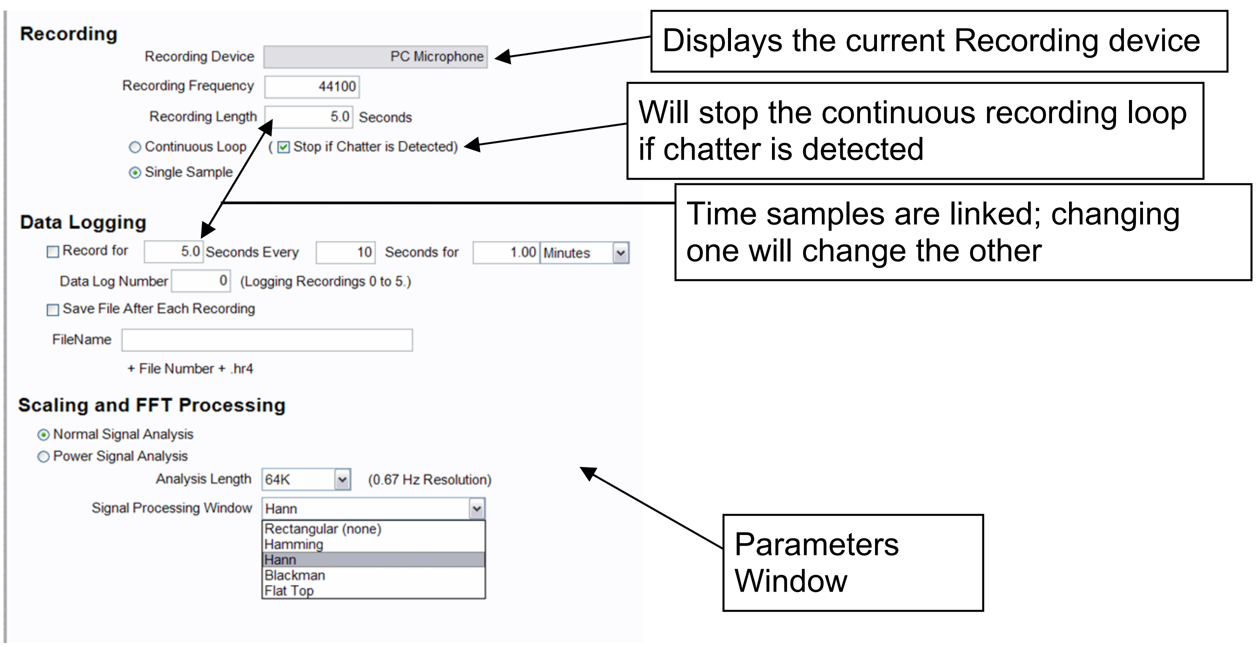


Figure 28: [F5] Signal Properties

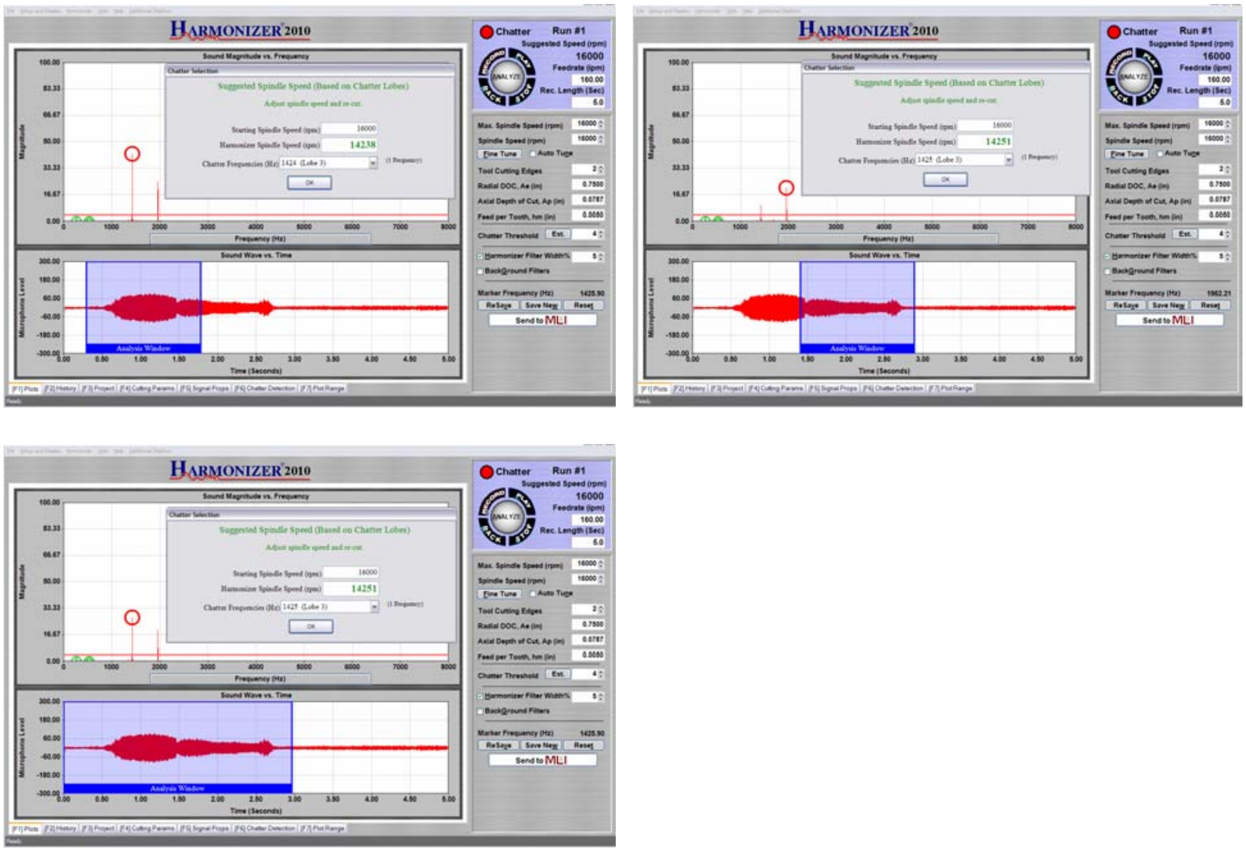


Figure 29: Example analysis with different FFT windows

Data Logging

The Data Logging Option allows multiple data acquisition files to be saved for one set of recorded data.

Example 1: to save data continuously over 6 minutes (360 seconds) resulting in 18 files each 20 seconds long. To achieve this, the user should enter:

Record 20 second blocks every 20 seconds for a total of 360 seconds.

To save the data the Save File after Each Recording box must be checked, a file name must be entered, and a file path must be specified.

Example 2: Record 5 second blocks every 10 seconds for a total of 60 seconds (which is the default setting for data logging, as shown in Figure 30)

This will result in a total of 6 files saved each 5 seconds long with a 5 second gap in the data recorded. So in continuous time you will get 0-5 seconds, 10-15 seconds, 20-25 seconds, 30-35 seconds, 40-45 seconds, and 50-55 seconds.

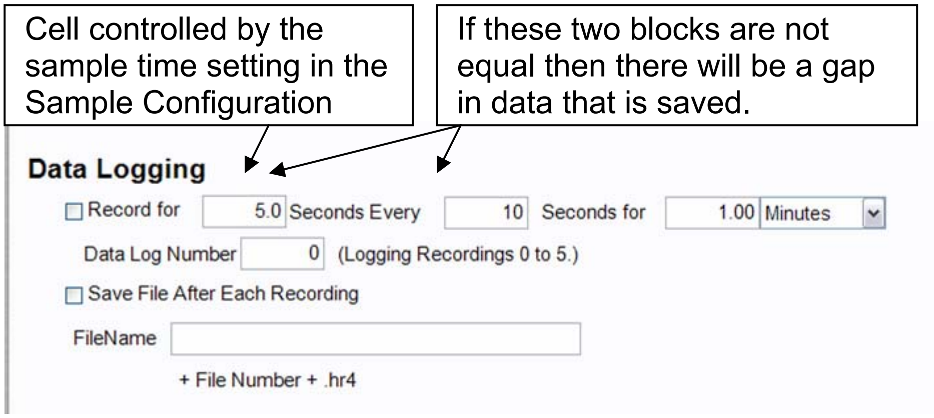


Figure 30: Data Logging

Scaling and FFT Processing

The Scaling and FFT Processing section on the [F5] Signal Properties Tab provided user adjustable setting related to the type of analysis, analysis FFT length, and the windowing options.

Normal Signal Analysis: Will display the Sound Magnitude vs. Frequency as the Fast Fourier Transform (FFT) of the sound data displayed in the Sound Wave vs. Time plot. This is the default. FFTs produce the average frequency content of a signal over the entire time that the signal was acquired.

Power Signal Analysis: The square of the FFT is considered the power of the signal. The Option for Power Signal Analysis will display the Sound Magnitude vs. Frequency plot as power instead of the FFT.

Analysis Length: The Analysis Length drop down box allows the user to choose the size of the FFT which will control the blue Analysis Window on the Sound Wave vs. Time plot. The higher the FFT size the better the resolution for the frequency in the frequency domain plot.

Signal Processing Window: For each channel and therefore each sensor, choose from the following filter options.

Rectangular (None): The rectangular window is the simplest window, taking a chunk of the signal without any other modification at all, which leads to discontinuities at the endpoints (unless the signal happens to be an exact fit for the window length). A rectangular window gives maximum sharpness but large side-lobes (ripples) or leakage. Leakage has the effect of hiding low-level signals. This choice is best for measurement with transients.

The Hann and Hamming window are quite similar; they only differ in the choice of one parameter.

Hamming: The hamming window is a two-term generalized cosine window with coefficients A=0.54 and B=0.46. With this window the frequency will not be as sharp as with the rectangular window but it will have much less leakage (i.e. side ripples).

Hann: The Hann window is also a two-term generalized cosine window, given by A = 0.5, B = 0.5. This choice maximizes the middle of window and makes the signal go to zero at edge of the window to minimize leakage. This window choice is the most common for typical machine monitoring measurements, and is the default.

Blackman: The Blackman window is a three-term window, given by A = 0.42, B = 0.5, and C = 0.08. This choice has slightly wider central lobes and less sideband leakage than an equivalent length Hamming and Hann window.

Flat Top: The Flat Top window is a low-resolution (high-dynamic-range) window with five terms, given by A = 1, B = 1.93, C = 1.29, D=0.388, and E=0.032. The flattop window gives excellent amplitude accuracy but gives up some frequency resolution.

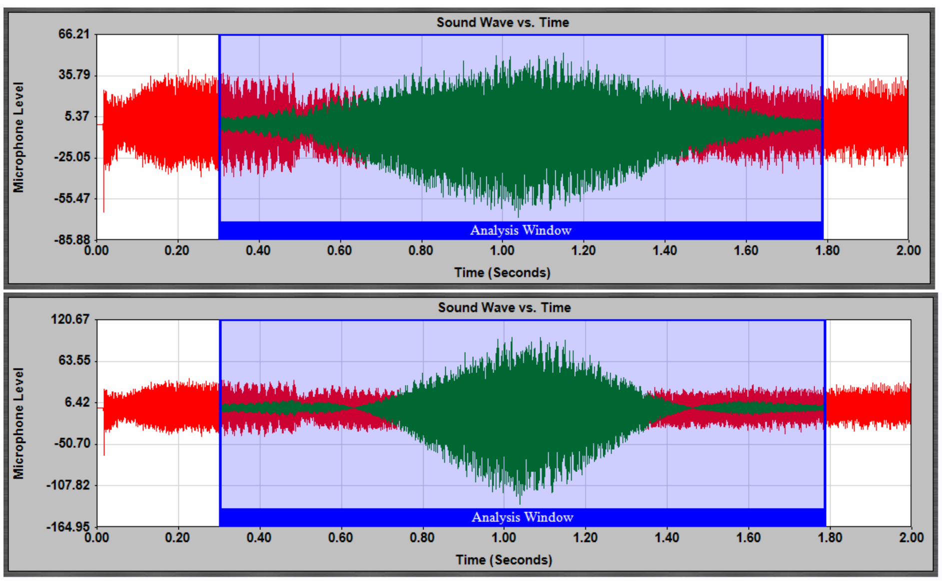


Figure 31: Example chatter signal with different filters (top) Hann (bottom) Flat Top

[F6] Chatter Detection

The [F6] Chatter Detection Tab allows the user setup and change Filters and Chatter Detection and Regulation. Many of these parameters can be changed in two places, on the [F6] Chatter Detection Tab or in the Parameter Window.

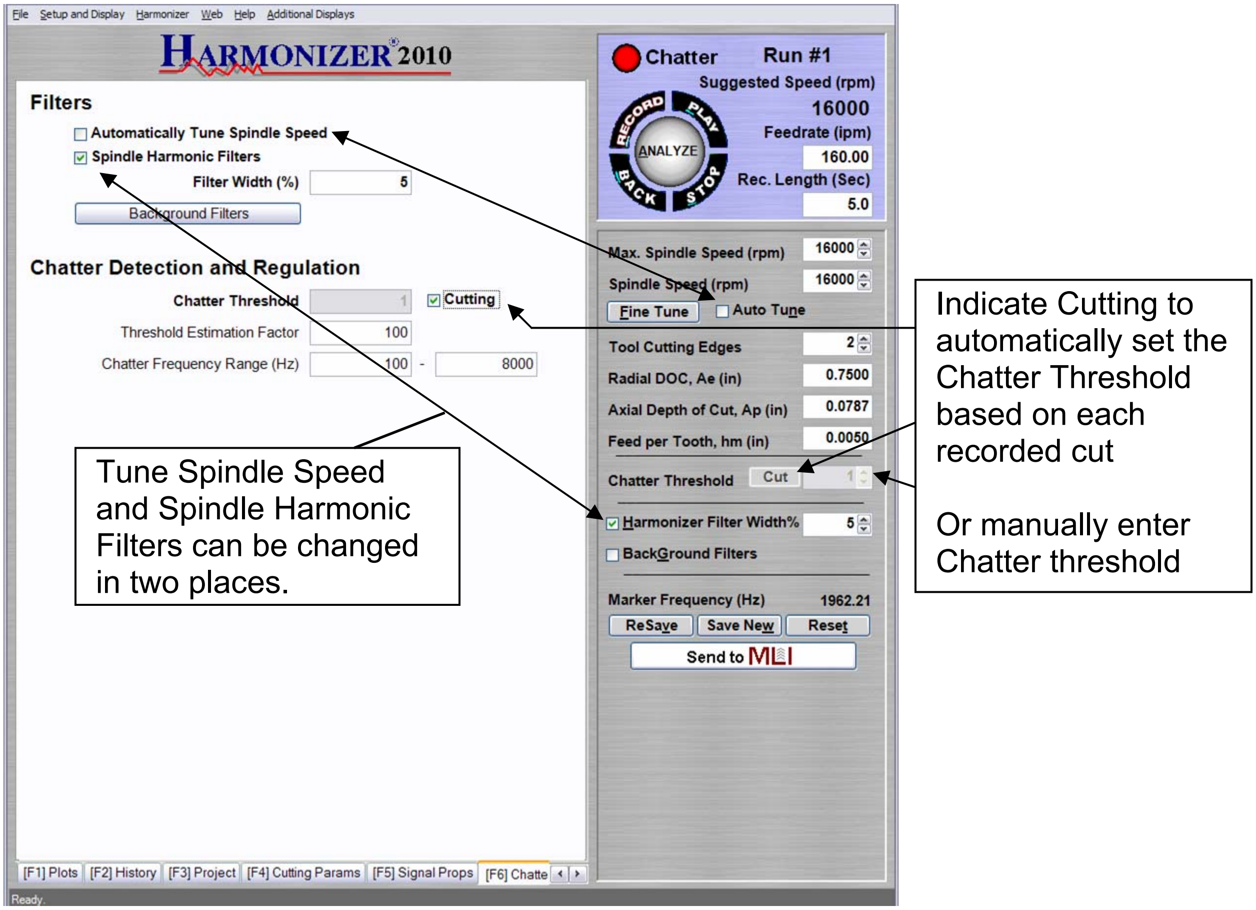


Figure 32: Chatter Detection Tab

Filters

Tune Spindle Speed, Spindle Harmonic Filters, and the Spindle Harmonic Filter Width are accessible from the [F6] Chatter Detection Tab or in the Parameter Window.

Automatically Tune Spindle Speed: If the Auto Tune option is active HARMONIZER® will automatically determine the actual spindle speed without the need to Click Fine Tune. NOTE: If Auto Tune is selected and the spindle speed is changed in parameters or incremented from Analyze the spindle speed on the Parameter Window may not update until a new signal is recorded.

Spindle Harmonic Filters: This selection turns on (green check mark) or off the spindle filters. If the spindle harmonic filters are not enabled HARMONIZER® will not estimate a chatter threshold. A warning will be displayed in the Warning Bar, Figure 11 ESTIMATE ERROR: The harmonic filters must be enabled in order to estimate a new chatter threshold.

Filter Width: This is the recommended width of the harmonic filter. It is defaulted to 5% and can be increased if the spindle speed varies due to a flexible spindle drive, or reduced if the spindle speed variation is very small. Spindle speed fluctuations occur with varying cutter load so you will want to increase this when the spindle load varies or if you are entering or exiting a cut during recording. Low spindle speeds typically have high torque capacity and do not fluctuate a lot. Generally speeds below 3,000 rpm can use a smaller filter width and speeds above 20,000 rpm a larger filter width. 5% is the nominal value.

Background Filters

Begin by recording the ambient noise level, which is all of the sounds in the shop except for the sound of the cut, including the sound of the cutter spinning in air. When making this recording the spindle should be rotating at the same speed that you will use to make the cut, however you should not be cutting with the target machine while setting the background filters. Then lower the red threshold line to below those frequencies that are to be filtered out. Once this is done, click the Background Filters button on the [F6] Chatter Detection Tab.

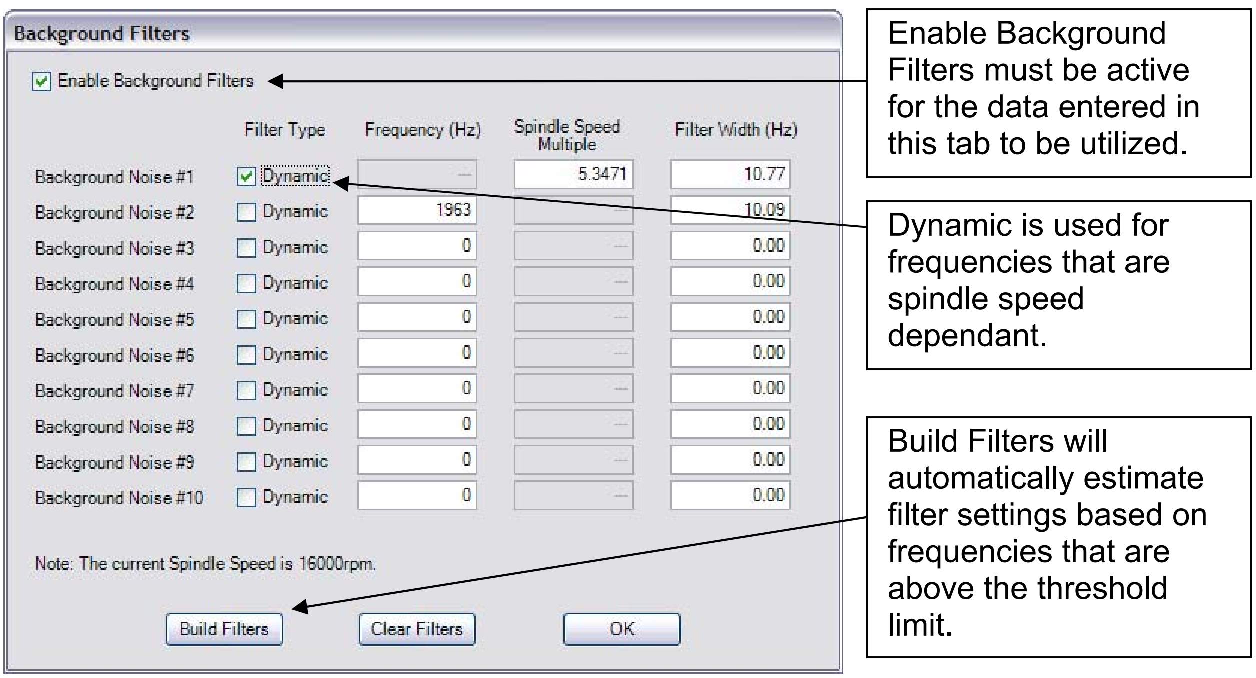


Figure 33: Background Filters

Filter Type Dynamic: The user should indicate a filter type of dynamic if the frequency that is being filtered will change with spindle speed.

Build Filters: This button will automatically estimate filter settings based on frequencies that are above the threshold limit.

Clear Filters: Will clear all Background filters, resetting all values to 0.

Chatter Detection and Regulation

The Chatter Detection and Regulation section on the [F6] Chatter Detection Tab provide the user adjustable setting related to regulating or analyzing the signal for Chatter.

Chatter Threshold: Allows the use to manually indicate the magnitude of the sound that will be considered chatter by typing the desired value into the appropriate cell, Figure 32. The default value is 100. Alternatively, after recording the sound wave, the user can choose Est. from the Parameter Window, and HARMONIZER® will estimate the chatter threshold based on the recorded signal.

Cutting: The user can indicate Cutting to automatically set the Chatter Threshold based on each recorded cut. If the user activates Cutting the display in the Parameter Window will indicate this by changing the Est button to Cut.

Threshold Estimation Factor: This is the default value for the chatter threshold estimation. The user can change this setting such that the chatter threshold is different than default value of 100.

Chatter Frequency Range: These values indicate the range of frequencies that Harmonizer will look for chatter. The default ranges are generally valid. The user may wish to adjust these to avoid some known prevalent frequencies in the shop that are not chatter. However, the user must also be sure that chatter will not occur outside the set range.

[F7] Plot Range

The [F7] Plot Range menu lets the user choose to allow the computer to automatically AutoScale or set the maximum and minimum value for each plot.

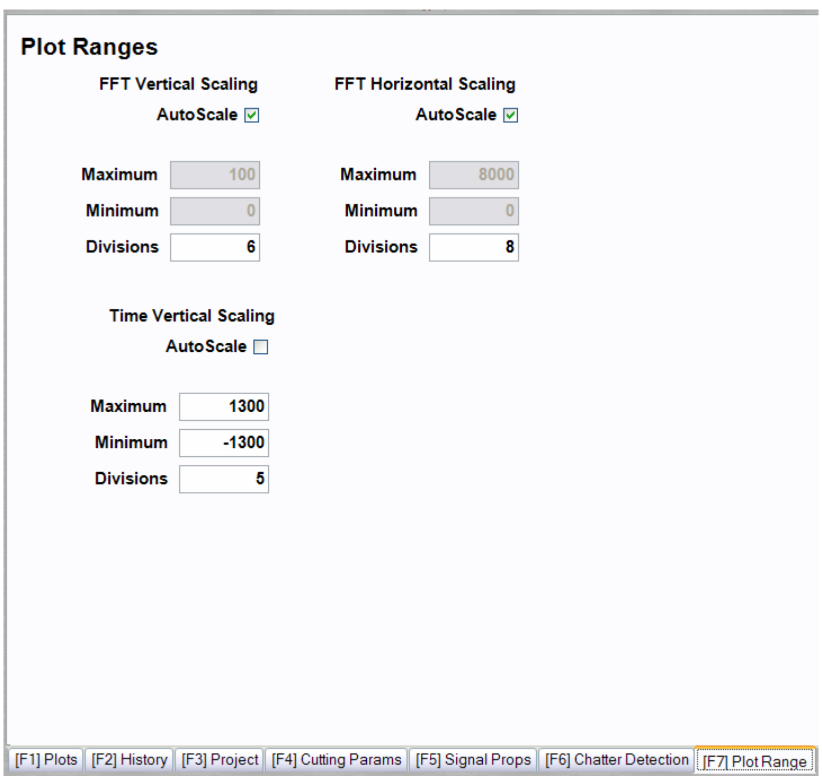


Figure 34: Plot Ranges

FFT Plot Vertical Scaling gives the user the option to allow the computer to automatically AutoScale the Y data (the Magnitude) as it is recorded. Alternatively the user can set the maximum and minimum value for the range of the Y axis (Magnitude).

FFT Plot Horizontal Scaling gives the user the option to allow the computer to automatically AutoScale the X data (the Frequency) as it is recorded. Alternatively the user can set the maximum and minimum value for the range of the X axis (Frequency)

Time Plot Vertical Scaling gives the user the option to allow the computer to automatically AutoScale the data (the Sound Level v/s Time plot) as it is recorded or alternatively set the maximum and minimum value for the range of the y axis (Sound Level).

[F8] Recording Preferences

Recording Preferences is found under the Setup and Display menu or can be activated using [F8]. This option allows setup of the recording device and its properties.

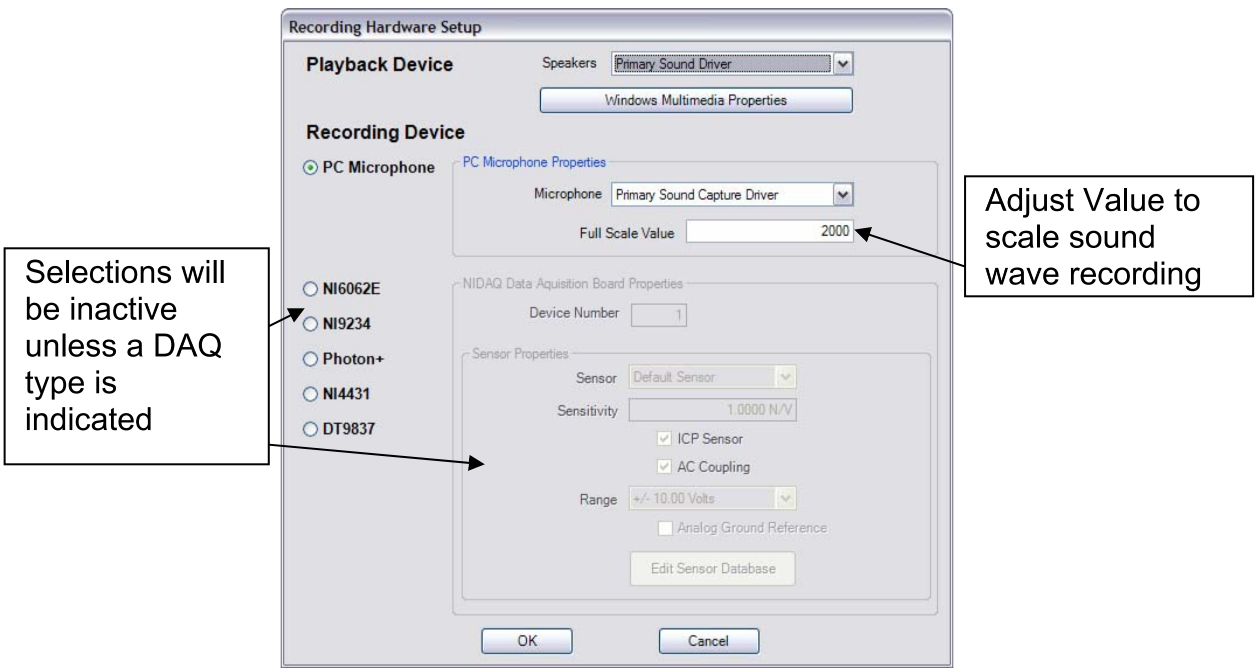


Figure 35: Recording Hardware Setup

Playback Device

This menu allows the user to select the speakers for playing back the sound recording using the Play button in the Control Window.

Sometimes HARMONIZER® will display a warning Sound Recording warning in the Warning Bar along the bottom of the Main Screen. The Windows Multimedia Properties button will open the Sounds and Audio Device Properties so that the user can adjust the sound recording levels.

Recording Device

HARMONIZER® allows for two types of recording devices, a PC Microphone or one of 5 types of NiDAQ Data Acquisition Boards. The Properties for each of these devices (depending on which one is active) can be adjusted using this Menu, Figure 35.

If the user will be using a sensor where the sound will be recorded through a data acquisition system and not the PC microphone jack, then the user should indicate which data acquisition system was provided when they purchased the HARMONIZER® or MetalMax hardware and software. Choices are as follows.

- NI-6062E Card (Standard MetalMax SIM2 from 2000-2008)
- NI-9234 Card (New USB 50kHz base option for 2009)
- Photon Plus (New USB 100kHz High End option for 2009)
- NI4431
- DT9837

The NI device number should also be specified.

Next, a sensor type, sensitivity, and ranges should be selected.

Sensor Name: For each channel the user must choose a sensor from the database or supply the appropriate information and add their sensor to the database

Signal Range: This setting is not linked to the database. The Signal Range must be indicated by choosing the desired value from the drop down menu. For the best signal to noise ratio the range should be set just above the peak signal. If the user is unsure what values to use, it is recommended to set the range high. Once the user is able to determine what range the sensor is detecting, this value can be reduced and the measurement repeated.

Analog Ground Reference: This setting ties the ground reference in the measurement to the computer's power supply. This could be the battery or the wall outlet AC power supply. It is recommended that data is collected with the laptop unplugged to eliminate any grounding issues with the AC power. Ungrounded AC power supplies can cause major DC shifts.

If grounding problems persist, uncheck this option to float the ground which will allow the ground of the target to be the ground reference in the measurement. This sometimes is necessary when the object being measured (e.g. the cutting tool or machine) is poorly grounded.

Sensor Database

To edit a sensor in the database or add a sensor to the database click on the Edit Sensor Database button, the menu in Figure 36 will appear.

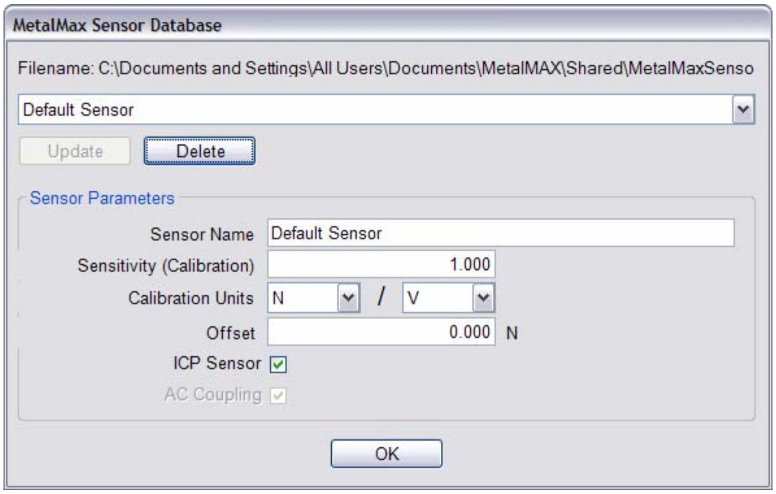


Figure 36: MetalMax Sensor Database

Enter the sensor name, sensitivity with the correct units, and indicate if it is an ICP Sensor and if it requires AC Coupling. Careful to indicate the correct Calibration Units. Then click Add to add the sensor to the database. You will know the sensor is added to the database because the drop down menu will now display your new sensor name.

ICP Sensor: ICP is a type of sensor that requires a power amplifier. The PCB sensors in MetalMax kit are all ICP sensors. An ICP sensor should always be AC coupled. As a result if ICP is indicated, then the option for AC Coupling will automatically be indicated and will not be a setting the user can change.

AC Coupling: Eliminates DC shifts away from ground reference, so data decays to 0 for the mean signal. This setting will become active when the ICP option is NOT indicated.

[F12] Preferences

HARMONIZER® preferences can be accessed by the [F12] hot key or from the Setup and Display Menu at the top of the screen. This window allows the user to set the paths for the Data Directory, the Setup File, and the Database Locations. The Data Directory, the Setup File, and the Database Locations can be edited by typing in a new directory path or by clicking on the Browse button and choosing the directory from the pop up window.

The MLI site and MLI Folder are options that must be specified when using the Send to MLI button on the main 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.

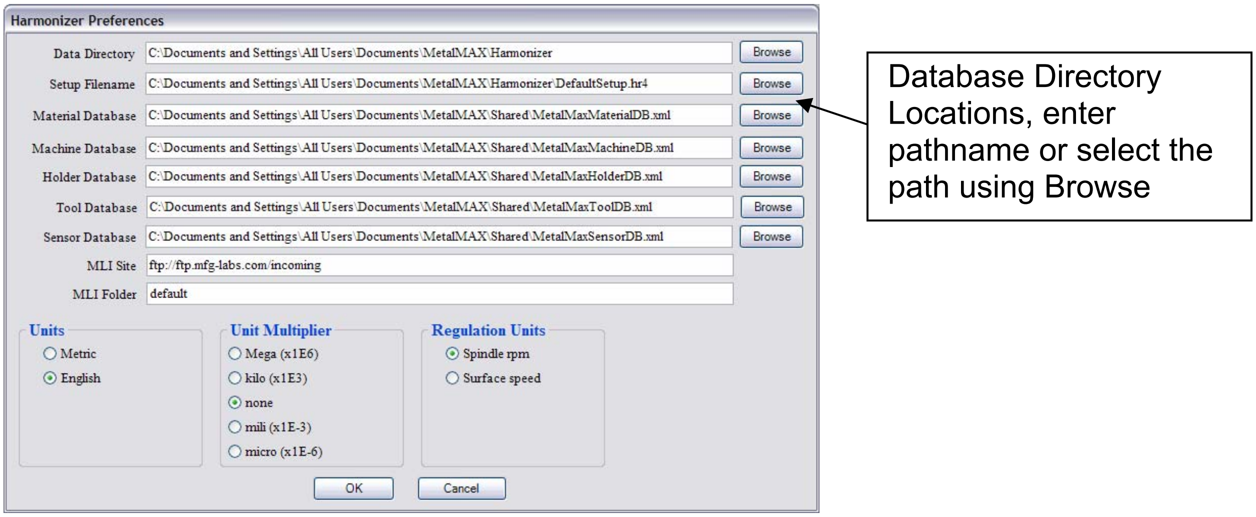


Figure 37: [F12] Preference

Units

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

Unit Multiplier

The Unit Multiplier selection allows the user to select scientific notation for the Y axis. So if the Y axis scale on the Sound Magnitude Plot is 0-150, then

- Mega would rescale the axis to 0 to150xe6
- Kilo would rescale the axis to 0 to 150xe3
- None would be 0 to150
- Mili would rescale the axis to 0 to150xe-3
- Micro would rescale the axis to 0 to 150xe-6

This setting scales both the Magnitude plot as well as the Sound Wave Plot.

Regulation Units

The Regulation Units selection allows the user to change the units for the Chatter Selection, Suggested new speed. The choices are

- Spindle Speed in rpm (revolutions per minute)
- Surface Speed

Test Data Acquisition Module

The test data acquisition module is only for when DAQ units are utilized. A similar test screen will appears as in SpinScope and TXF indicating a good connection to the DAQ unit and displaying test signals to confirm adequate readings on the connected sensor (channel 1 only).

HARMONIZER® Setup Wizard

The Setup Wizard will direct you through a sequence of dialog boxes that will guide you in setting up the HARMONIZER® hardware and initial software settings.

Database Manager

The Database Manger is accessed from the Setup and Display Menu. The Database Manager allows the user to manage the databases by adding, editing, or deleting definitions from each database. The database information is very similar to the information located under the Details Button. However, the Details Button show the minimum required information whereas the Database allows the user to record additional information not included in the Details Button.

NOTE: If edits have been made in under the Details Button, but have not been added to the database by clicking ADD, the information located in the database may be different than the information local to the TXF file.

The default database location will correspond to the databases indicated in the preference menu.

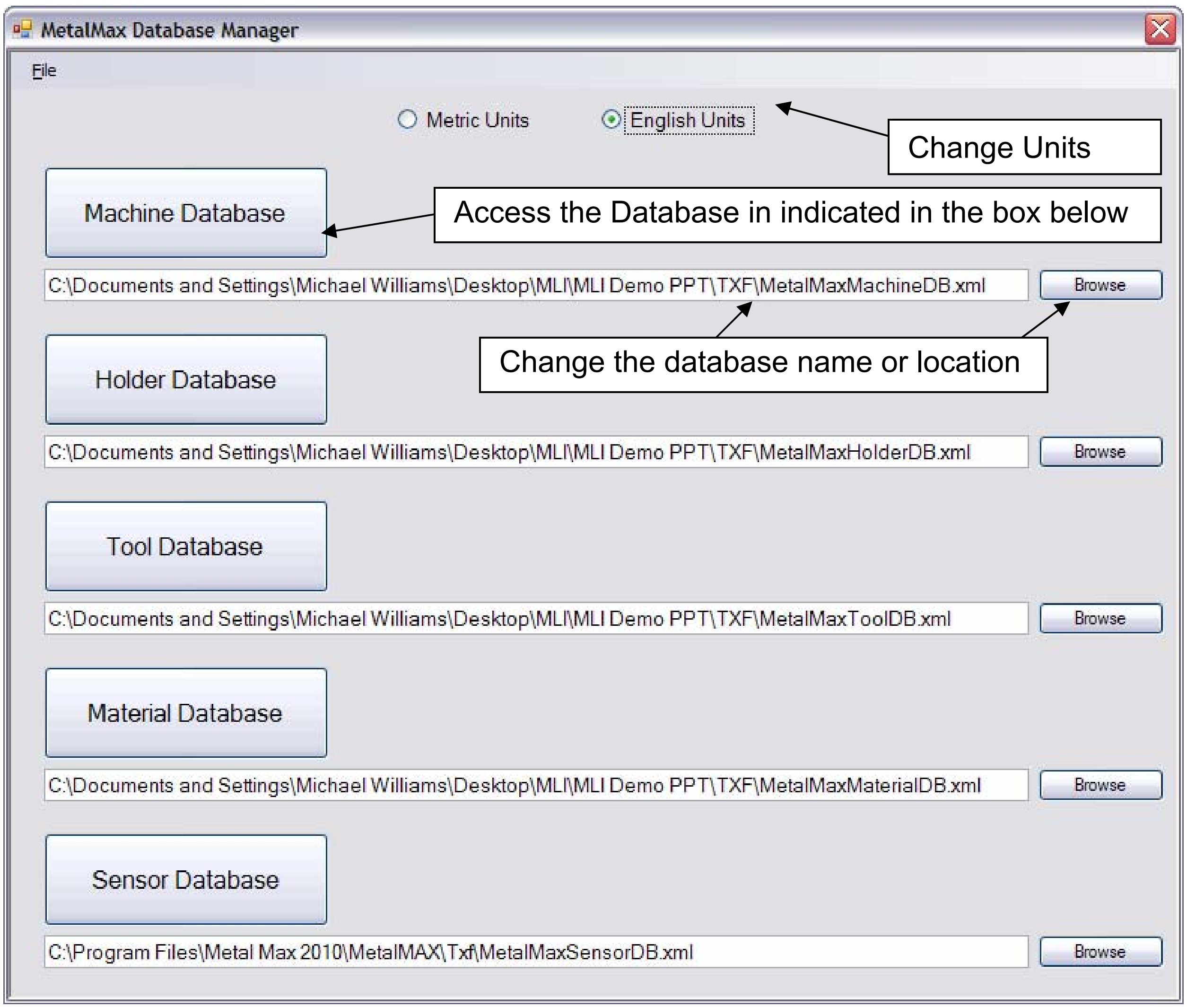


Figure 38: Database Manager

File: The File menu allows the user to export each individual database or all the databases.

To create a new definition in the database

To create a new machine in the database start with the default setup by choosing not in database from the drop down menu. Enter all the known information, paying specific attention to items in bold. When all the relevant information is entered, click ADD to add the machine definition to the database. Follow the same sequence to create new definitions for other databases.

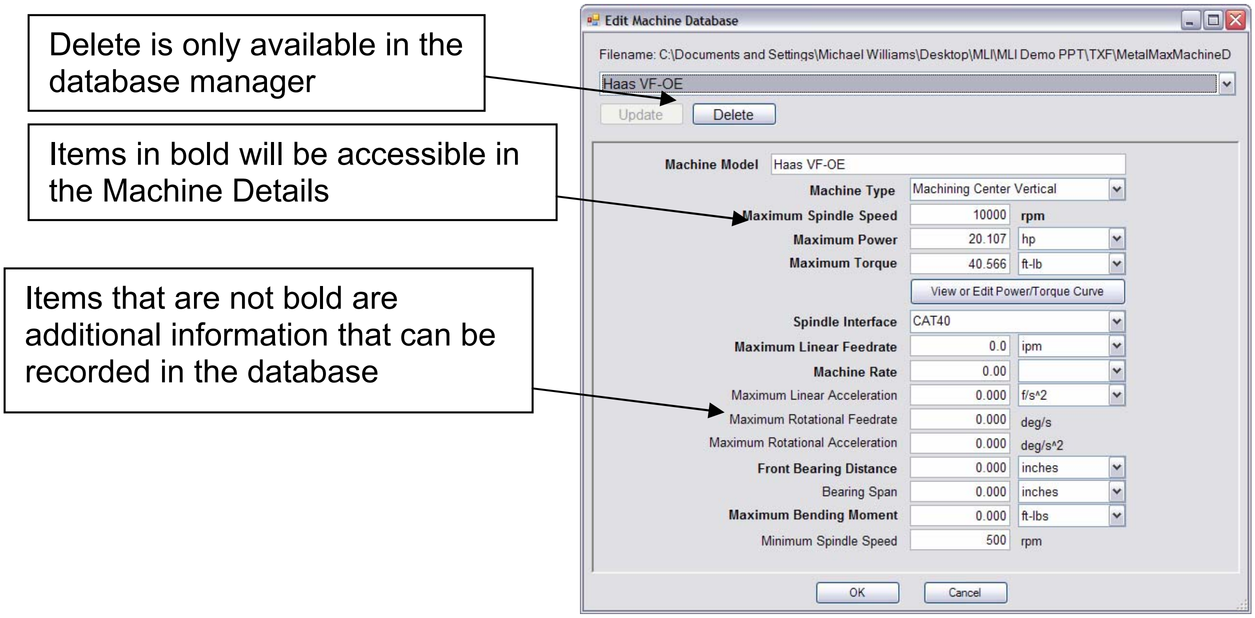


Figure 39: Edit Machine Database

Harmonizer

The Harmonizer Drop Down Menu on the menu bar at the top of the screen is one of two ways to access the data recording and analysis features. These same features can be accessed in the Control Window at the top right of the on the Main Screen [F1]

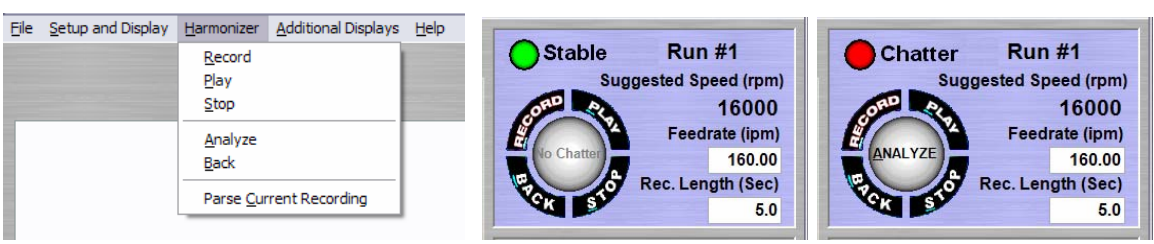


Figure 40: Harmonizer Drop Down Menu and Control Window showing Stable and Chatter

Help

The Help Menu provides three options, About, MLI website, and Help Manual.

About provides patent and copyright information for the HARMONIZER®.

Help Manual accesses the help files for HARMONIZER®.

Additional Display

The Additional Display Menu provides advanced plotting and analysis of the recorded signal.

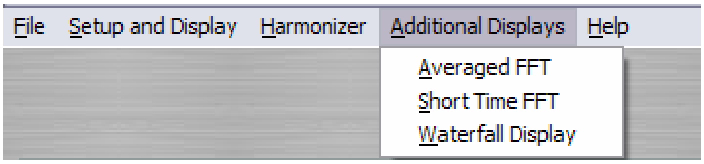


Figure 41: Additional Displays

Average FFT is a standard FFT as shown in the Main Screen, Figure 44 (top right).

Short time FFT: Standard FFTs do not clearly indicate how the frequency content of a signal changes over time. The Short FFT displays this information by cutting the signal into blocks and computes the spectrum of each block. To improve the results create a short FFT with overlap between the FFT blocks as shown in Figure 43 and Figure 44.

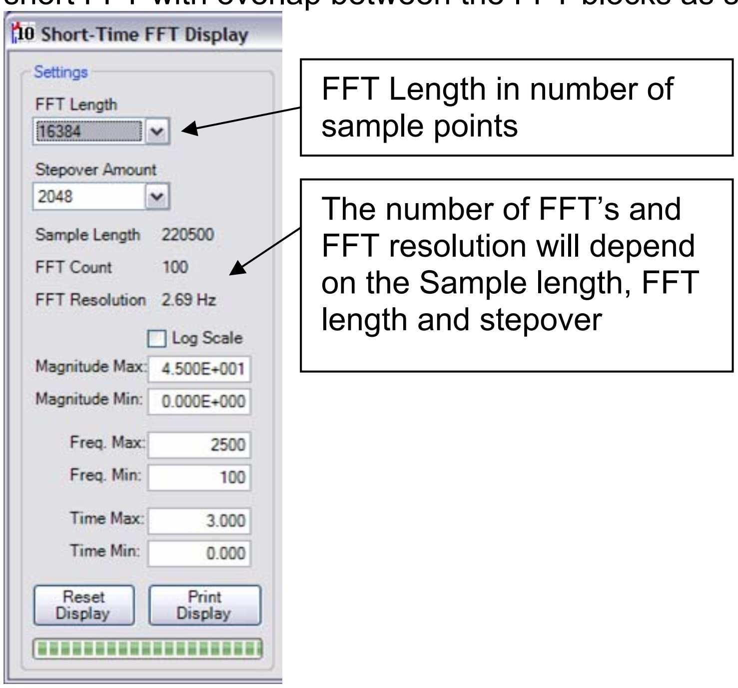


Figure 42: Short Time FFT Inputs

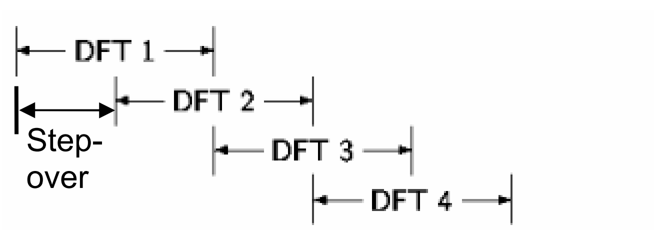


Figure 43: Short Time FFT Stepover

The top left plot in Figure 44 shows a sound recording which was chattering. The two chatter frequencies are 1425 and 1962 Hz. Depending on the size and position of the FFT window, either chatter frequency can be dominant. To see how the FFT changes with time a short time FFT is plotted, Figure 44 bottom left is a Short Time FFTs with no overlap and the bottom right is a Short Time FFTs with overlap. Both plots show that the 1425 Hz frequency is mainly occurring between 0.5 and 1.5 seconds and then it dies out, while the 1962 Hz occurs equally over the entire sound recording. This same information can be seen in a 3D format using the Waterfall FFT, Figure 45.

Waterfall FFT: A waterfall is a presentation of both frequency domain and time domain data on a single graph.

Both Figure 44 and Figure 45 tell us that while the cutter is first engaging the workpiece chatter occurs at 1425 Hz, but once the cutter is fully engaged the dominant chatter frequency is at 1962 Hz. This knowledge can aid the user in what length FFT and where to place the FFT window.

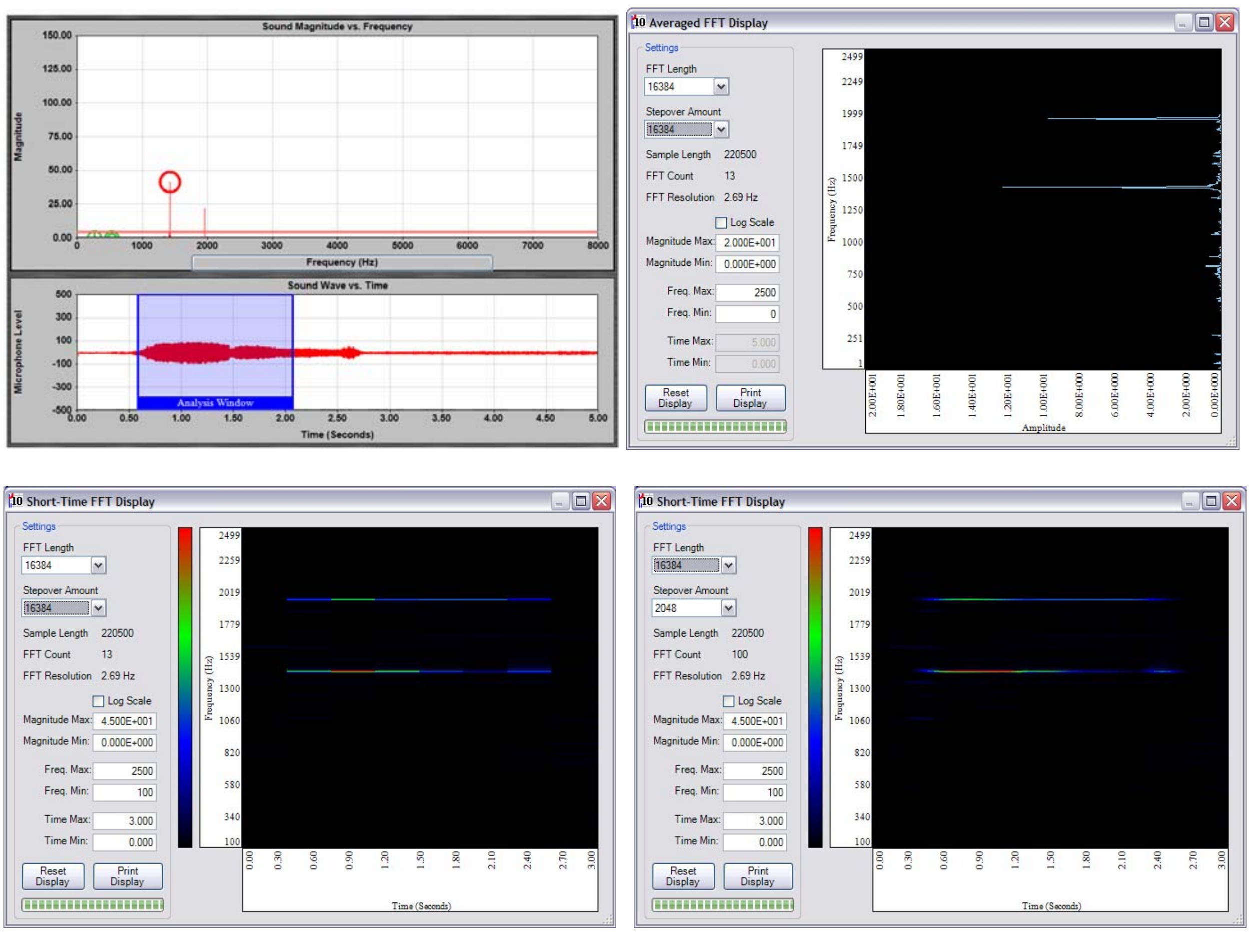


Figure 44: (Top left) Harmonizer Main Screen showing a Chatter recording (Top right) example spectrum with Averaged FFT (bottom left) Example Short Time FFTs with no overlap (bottom right) Example Short Time FFTs with overlap

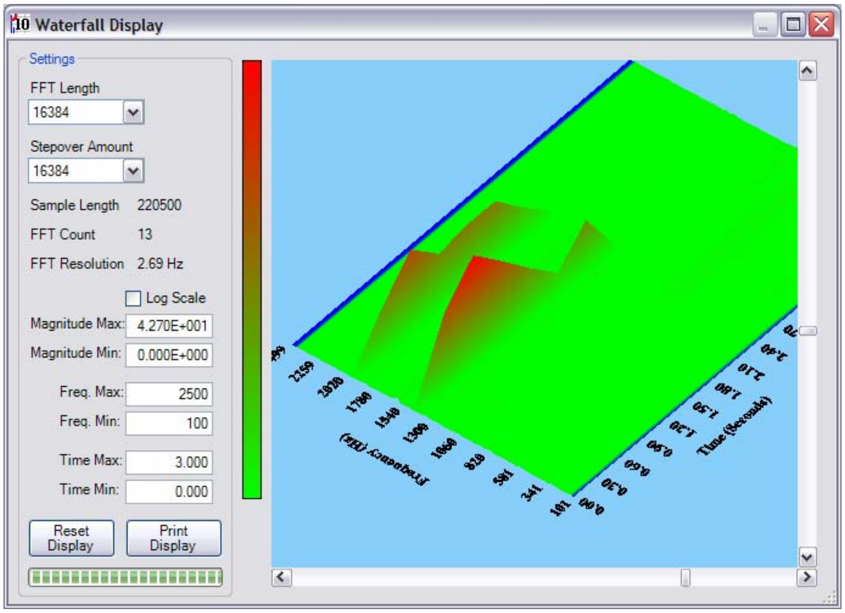


Figure 45: Waterfall FFT

5.0 Basic Steps and Quick Reference

The HARMONIZER® is designed specifically for use with uniform pitch metal removal type applications such as milling, boring, and turning. The HARMONIZER® is strictly a speed selection application tool. There is no warranty, implied or otherwise, to cure chatter problems due to the program lacking the capability to predict the depth-of-cut. For depth-of-cut predictions and more comprehensive stability analysis tools, please refer to MLI's complete MetalMAX™ product line.

Hardware Setup

After installing HARMONIZER® as described in Installing HARMONIZER® on Computer, attach the hardware key (printer port or USB key) to your PC. If using the printer port, the hardware key can be used in series with the printer cable.

Either the PC's internal audio system and driver can be used or the supplied iMic. It is suggested that the PC internal system be used and the iMic is provided as a standardized back-up, Figure 3.

Plug in the MLI supplied unidirectional microphone or any good commercial recording microphone into the microphone jack on your PC. You have the option of either holding or mounting the microphone on the outside or inside of the machine. Locate the microphone at a point that provides good sound detection of the cutting being performed. Check the microphone's battery to ensure an ample power source is available. Point the microphone towards cut and turn the microphone **ON**.

Start HARMONIZER® by double clicking on the icon provided on the desktop.

Press the [F8] Recording Preferences key. Under Recording Device select the appropriate microphone from the pull down menu, Figure 46.

Next at the top of the window is the Windows Multi-media Properties button. Click on this button and select the Audio Tab, Figure 47.

Under Sound Recording make sure the correct device is selected and press the Volume button and adjust the microphone or volume setting to at ¾ to full scale. Exit and close.

Make a test recording in a normal environment or for some test sound. The recording should display an audio trace in the lower plot of the Harmonizer. A warning or error may appear after the recording.

If it is Yellow and states the recording volume is too low then raise the microphone level or switch sources, e.g. to the iMic (using the Line setting on the iMic). If a Red bar appears then go back and lower the microphone setting in the recording control volume.

NOTE: *The yellow too low warning does not generally indicate a bad measurement. Data is still useful*. However the Red indication means the measurement has saturated the audio amplifier and is not useable.

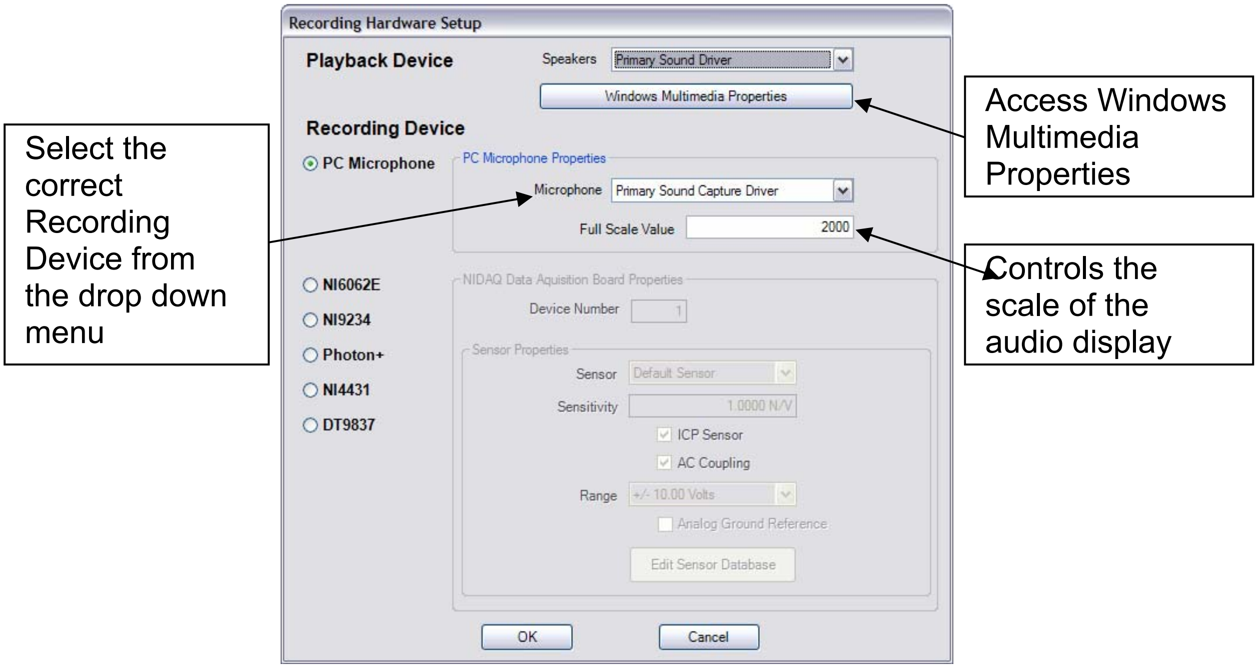


Figure 46: Recording Hardware Setup

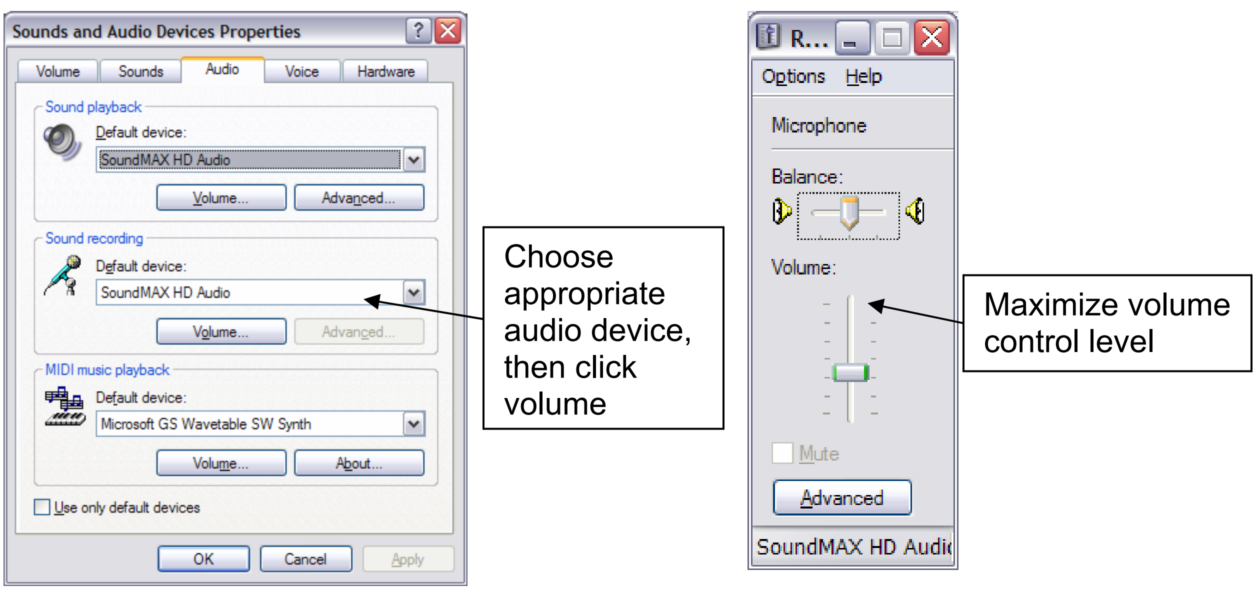


Figure 47: Sound and Audio Device Properties

Scaling the Display:

After taking some background noise test recordings the “Est” Threshold button can be used. If the estimate is 5 or less for the background noise recordings then go back to the [F8] Recording Preferences screen.

From the [F8] Recording Preferences screen adjust the “Full Scale Value”. It controls the scale of the audio display. It can be increased if the Threshold “Est” is too low (below 5). Generally increase it by a factor of 10.

The system is now initially configured and ready to use. Please follow the manual instructions for full operation. Also, there are instructive Presentations on the CD-ROM and test audio files for your practice.

Setup Harmonizer

Access the Project screen using [F3] or the tab at the bottom of the screen.
Enter the information describing your current process. It is recommended to include as much detail as possible here. See [F3] Project Settings for more detail.

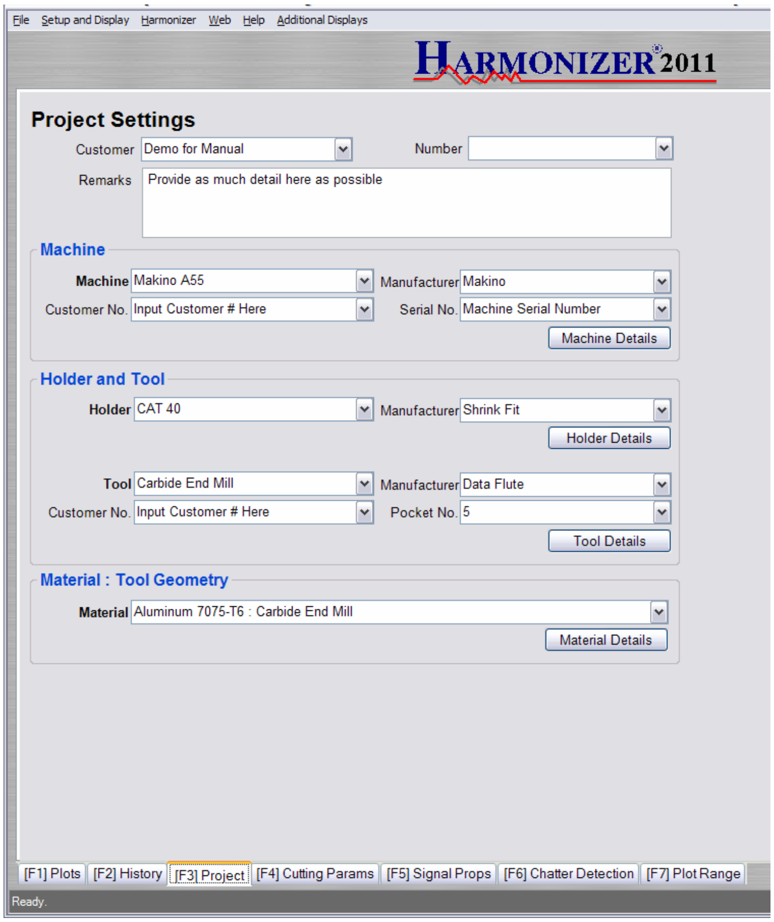


Figure 48: [F3] Project Settings

Next, access the [F4] Cutting Parameters screen using [F4] or the tab at the bottom of the screen.

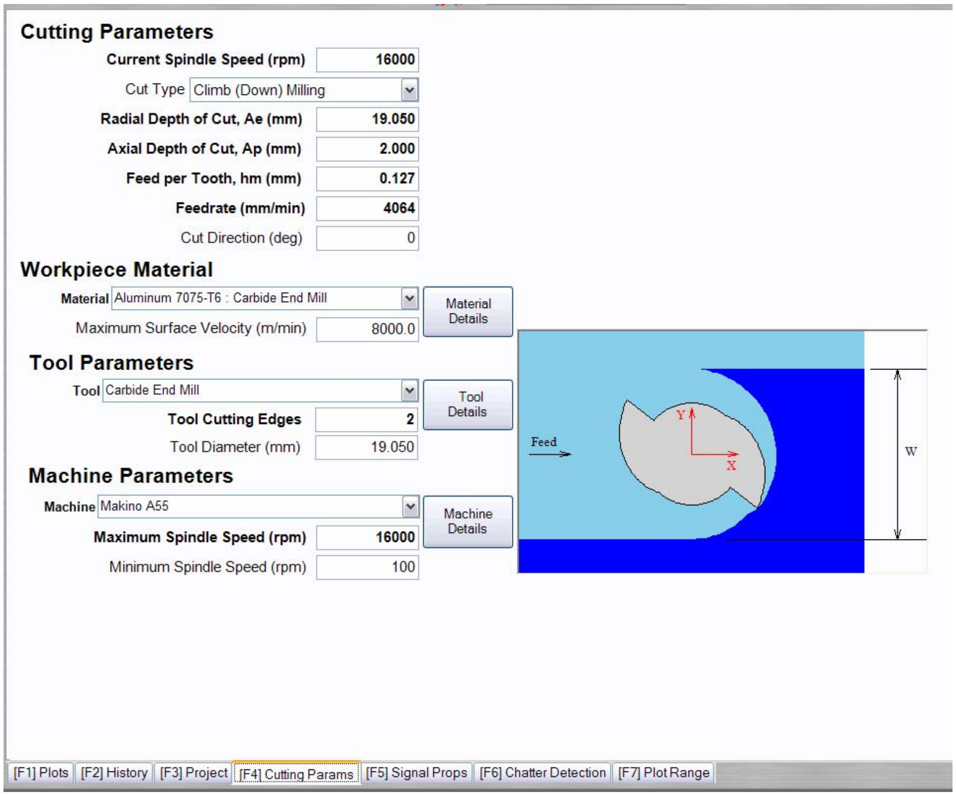


Figure 49: [F4] Cutting Parameters

5.1 Sound Recording

Problem (1): WARNING: The recording level is very low, you may need to increase your recording volume

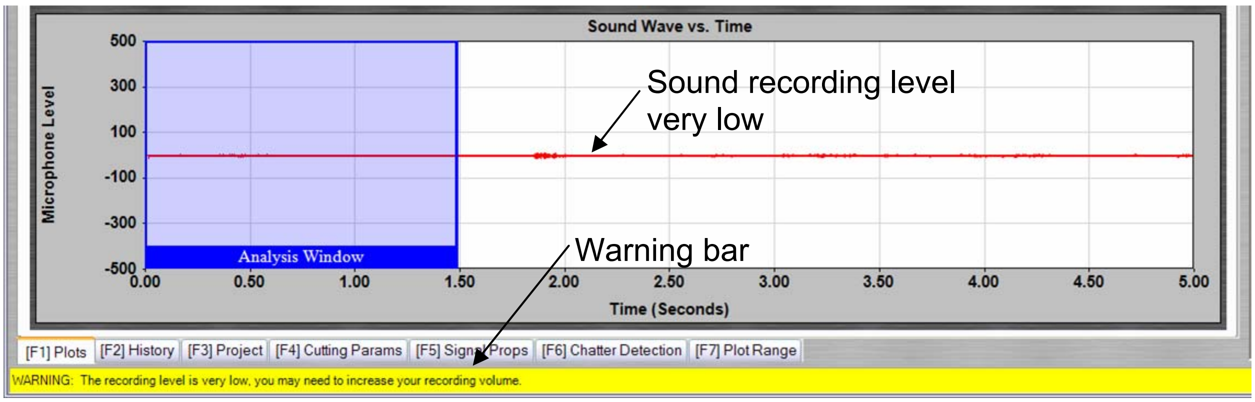


Figure 50: Recording Level Very Low Warning

To fix this issue, the user needs to Adjust the audio properties for the sound recording device. Sounds and Audio Devices window can be accessed by Clicking on the Windows Multimedia Properties button on the [F8] Recording Preferences Menu. The user can also access this option by right clicking on the sound icon on the windows tool bar and choosing Adjust Audio Properties, or by going to the Control Panel and clicking Sounds and Audio Devices.

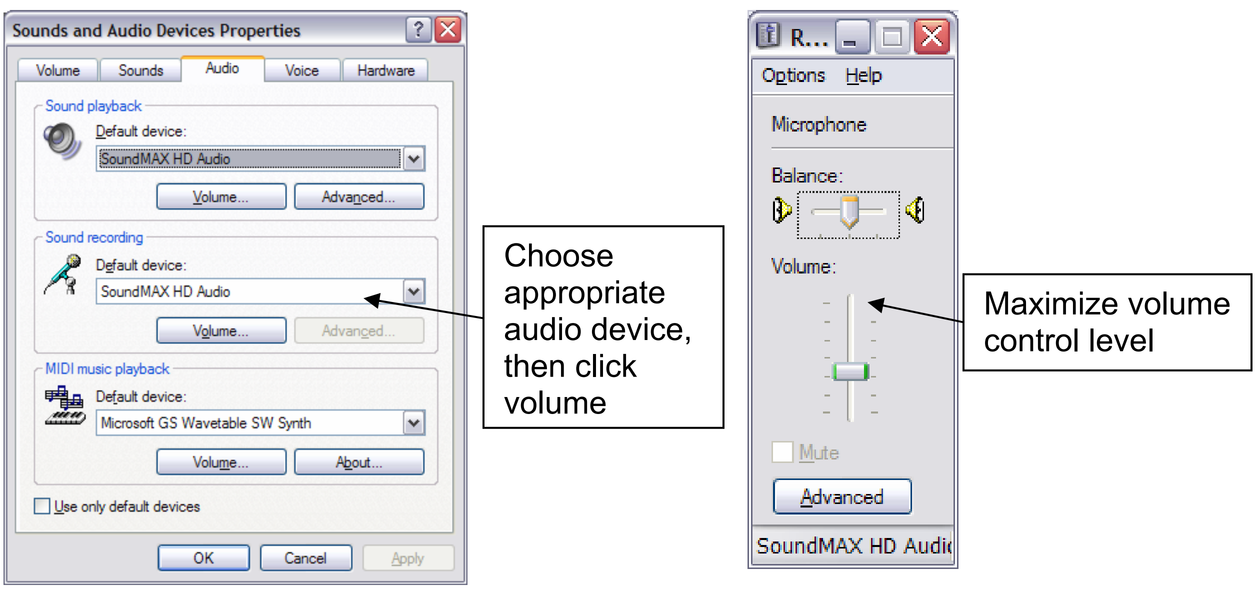


Figure 51: Sound and Audio Device Properties

To adjust the Sound properties

- Choose the Audio Tab
- Choose the appropriate sound recording device from the drop down list.
- Click Volume under the Sound recording device

- A window will open that controls the volume level for the recording device.
- Slide the volume slider bar to the maximum level

If this does not provide a high enough sound volume, then from the main screen in HARMONIZER® access the [F8] Recording Preferences Menu under the Setup and Display Menu, see Figure 35

- Choose the appropriate sound recording device from the microphone drop down list.
- Adjust the Full Scale Value until the recording level is acceptable. Generally increase it by a factor of 10.

6.0 *Procedure for Obtaining Material/Tooling Parameters*

The following test procedure is useful for determining the proper material (cutting tool) parameters to be input into the MetalMax™ "material" database. These values include:

- Cutting Stiffness (Ks), Metric units N/mm^2 and English Units psi
- Process damping wavelength (λ)

In the procedural description we will refer to the general stability graph in Figure 52.

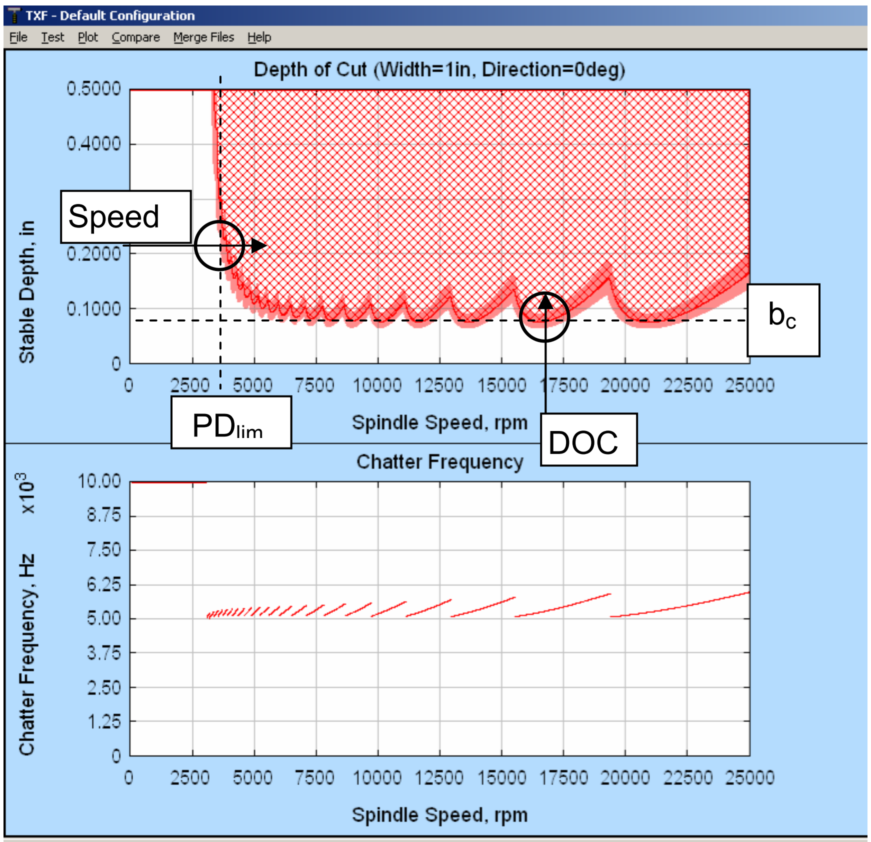


Figure 52: Stability Lobe Diagram

Obtain the FRF

Measure the cutting tool as generally prescribed.

Calculate the Stability Lobe Diagram

The computation should be for a slot-type cut and use a material definition that is closest to the one being cut (e.g. Aluminum 7075-T6 for an unknown grade and heat treat aluminum).

Cutting Tests and Initial Cutting Parameter Start Points

Two cutting tests will be performed:

1. At a pre-selected spindle speed, the first set of tests will increment depth of cut from a low depth of cut to higher until chatter is detected.
2. At a pre-selected depth of cut, the second set of tests will increment spindle speed using a constant depth cut starting at some low spindle speed and increasing speed until chatter is detected.

Depth-of-cut test:

- At some high speed select a "worst" case spindle speed (~16250 rpm in Figure 52). This spindle speed corresponds to the bottom of a lobe, (i.e. a depth of cut that produces a critical limit value (b_{cr}) from the stability chart).
- Start at a depth of cut that is ⅓ to ½ the b_{cr} and program successively deeper cuts in an increment equal to 10% of $b_{cr.}$
- Using the HARMONIZER® detect at what depth of cut chatter starts. When chatter occurs use the prior non-chatter cut as the test value ($b_{cr\text{-}test}$).

So for the example in Figure 52 you would start at a depth of cut of 0.04" or 0.06" and then increment in steps of 0.01".

Spindle speed test:

- Evaluate at what spindle speed the depth of cut asymptotically rises to a maximum, labeled PD_{lim} (on the left side of the graph in Figure 52). Use ¼ to ½ of this speed as the starting speed. For DOC use 2 times the limit value that was found in the DOC tests.
- Increase spindle speed in 10% increments of PDlim until chatter occurs. When chatter occurs record prior stable speed test as the test limit speed ($PD_{lim\text{-}test}$).

So for the example in Figure 52, PD_{lim} is at 3750 rpm so you would start at 1875 rpm. The depth of cut would be between 0.16" and 0.2". You would increment your spindle speed by 10 rpm for each cut, yielding 3750, 3790, 3830, 3870, etc until you get chatter.

In both cases utilize the HARMONIZER® to get a clear detection of chatter conditions.

Adjust the Database

Cutting Stiffness Value (K_s)

- Create and new material definition.
- Calculate the ratio between the predicted limit depth of cut b_{cr} and the test limit depth of cut $b_{cr\text{-}test}$.
- Using the original Ks to calculate the new cutting stiffness ($K_{s\text{-}new}$).

$$K_{s-new} = K_s \frac{b_{cr}}{b_{cr-test}}$$

Process Damping Wave Length (λ)

- Calculate the ratio between the predicted limit speed, PD_{lim} and the test limit speed PD_{lim}, test
- Using the original wave length, λ, use the ratio to calculate the new wavelength λ_{new}.

$$\lambda_{new} = \lambda \frac{PD_{\lim - test}}{PD_{\lim}}$$

Special Notes

Generally, Cutting force coefficients and Process Damping coefficients are determined experimentally. For a given work piece in a particular set up, it is possible to make a precise measurement, but there is substantial variability. In this sense, these coefficients are like other material properties such as Young's modulus or fatigue life. The usual procedure is to tabulate a typical value. If you need a more precise number, you have to measure your work piece in your set up.

However, you do not need a more precise number if you are not an academic. If you are a practitioner, you want to stay away from the edges of stability, because at the edges you are sensitive to all of the variables, many of which are not in your robust control. Hence, the warning track in TXF. Very precise evaluation of the cutting force coefficients for a particular specimen in a particular set up gives a false impression of precise control.

While it is possible to carry out finite element simulations of cutting with the proper constitutive material model to determine cutting coefficients, a more common technique is to use the tool and work piece in question and measure the force during cutting. This information can then be used to determine the corresponding cutting force coefficients. See Section 4.7 in the book Machining Dynamics by Schmitz and Smith. However, approximate values are often sufficient to get you "in the ballpark" for process predictions. These are included in MetalMax.