MATERIAL & TOOL CHARACTERIZATION

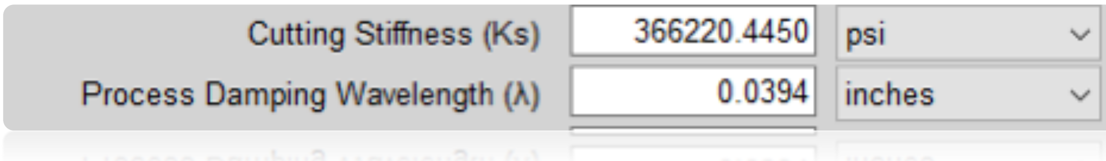
Using MSC MillMax & Harmonizer

ABSTRACT

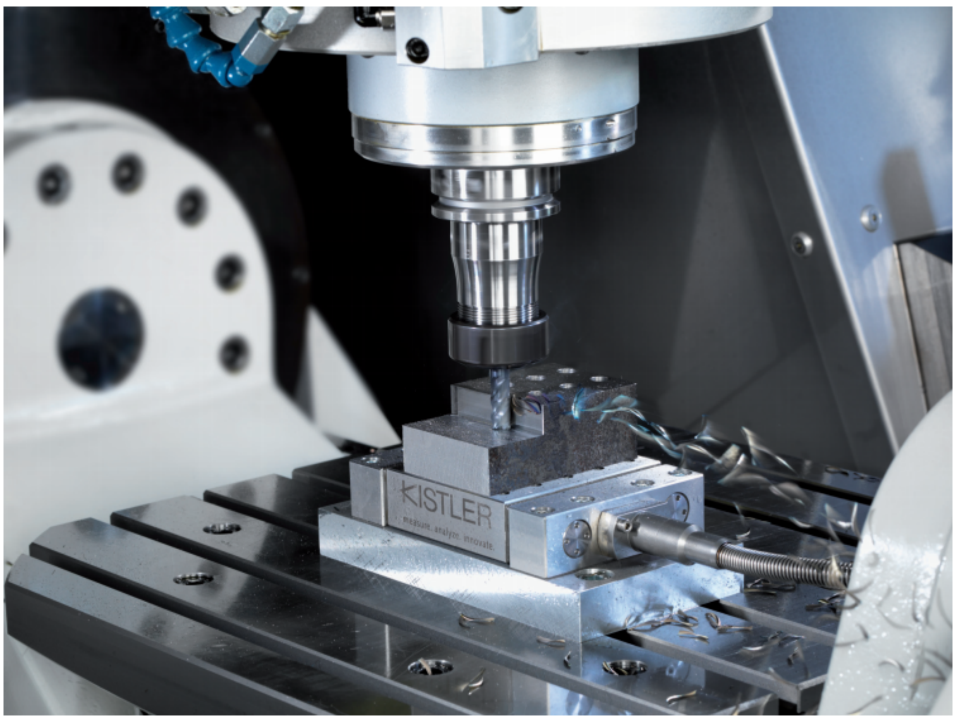
This paper describes using MSC MillMax and Harmonizer to test new cutting tool geometries and new material alloys in the field.

Material & Tool Characterization for HSM Endmills (High DOC/Low WOC)

Virtual Material and Tool Characterization



Generally, cutting force coefficients (K_s) and PD coefficients (λ) are determined experimentally using the tool and workpiece material in question and measuring the force during cutting using a dynamometer or by doing Finite Element Analysis (FEA) simulations with the proper constitutive material model. 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.*



Approximate values are often sufficient to get you the correct process predictions. These are included in the Dashboards. However, if you desire to determine a more precise value for the cutting force coefficients (K_s) and PD coefficients (λ) and measuring the cutting forces during the cut is not possible due to lack of the equipment, we provide a set of guided cutting tests using a Dashboard and Harmonizer to experimentally determine these values. Here are some examples of when these tests may be necessary:

- Additive Manufacturing affords the opportunity to create new high-performance alloys. The technique described herein enables the user to adjust the tabulated typical values in the MillMax database and capture the machinability of the new material in the field.
- New tool geometries and that are designed to increase process damping or change the direction of the cutting forces. This process enables the user to calculate the process damping and cutting stiffness for a new cutter in different materials.

The following test procedure is useful for determining the proper material (cutting tool) parameters to be used when creating a Dashboard. These values include:

- Cutting Stiffness (K_s)
- Process damping wavelength (λ)

NOTE: These tests do not have to be performed on the customer's machine or in the same toolholder. You can use the same cutting tool and sample material on another machine, update the material database and then tap test the customer's tool assembly in their machine to generate a Dashboard with the new material profile.

To begin, Tap-test the tool.

Use the SFM Calculator on the accompanying spreadsheet to multiply the cutting tool manufacturer's maximum SFM recommendation for the material you are testing by the value based on the radial engagement or width of cut (Ae) in the following table (if less than 25%):

Manufacturer's Maximum SFM		300
WOC (Ae)	**SFM Multiplier**	**Calculated SFM**
25%	1.25	375
24%	1.26	378
23%	1.27	381
22%	1.28	384
21%	1.29	387
20%	1.3	390
19%	1.31	393
18%	1.32	396
17%	1.33	399
16%	1.34	402
15%	1.35	405
14%	1.36	408
13%	1.37	411
12%	1.38	414
11%	1.39	417
10%	1.4	420
9%	1.72	516
8%	1.94	582
7%	2.16	648
6%	2.38	714
5%	2.5	750
4%	3	900
3%	3.5	1050
2%	4	1200
1%	4	1200

Go to Machine Details in MillMax, change the unit of measure from maximum RPM to SFM. Change the maximum surface speed If the result from the above chart is less the current maximum SFM. Generate the Dashboard (DCC).

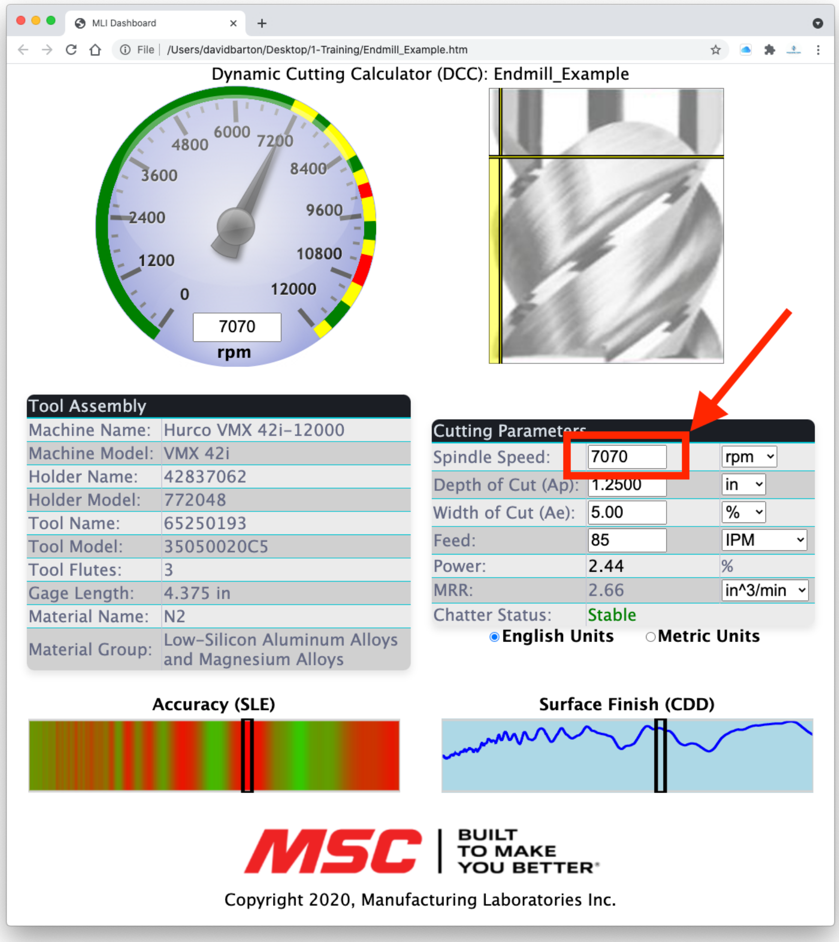


Figure 1a - Determine the Process Damping SS transition, PD_{SS}

Determine the process damping transition speed, PD_{SS}, and the process damping depth of cut, PD_{DOC}.

As shown in Figure 1a, set the Dashboard to the tool's maximum depth (Ap) of cut adjust the width (Ae) of cut so that there are clear stable (green) and unstable (red) regions of speed. If only green and yellow (conditionally stable) zones show, keep reducing the width of cut until red zones appear. Dial the Spindle Speed (SS) to the lowest stable zone, and determine the SS where the Vibration Indicator bar transitions from Stable (green) to Conditionally Stable (yellow) or Chatter (red), 7070rpm in this example.

Record this speed as PD_{SS} in Table 1a.

PD_{SS} = 7070 rpm

Table 1a: Starting Process Parameters

Parameter	Value	Units
PD_{SS}	7070	RPM
PD_{DOC}	0.030	in
WOC_{SS}	10600	RPM
B_{lim}	0.0175	in
$3/4*PD_{SS}$	5303	RPM
$2*PD_{DOC}$	0.060	in
$1/2*B_{lim}$	0.009	in

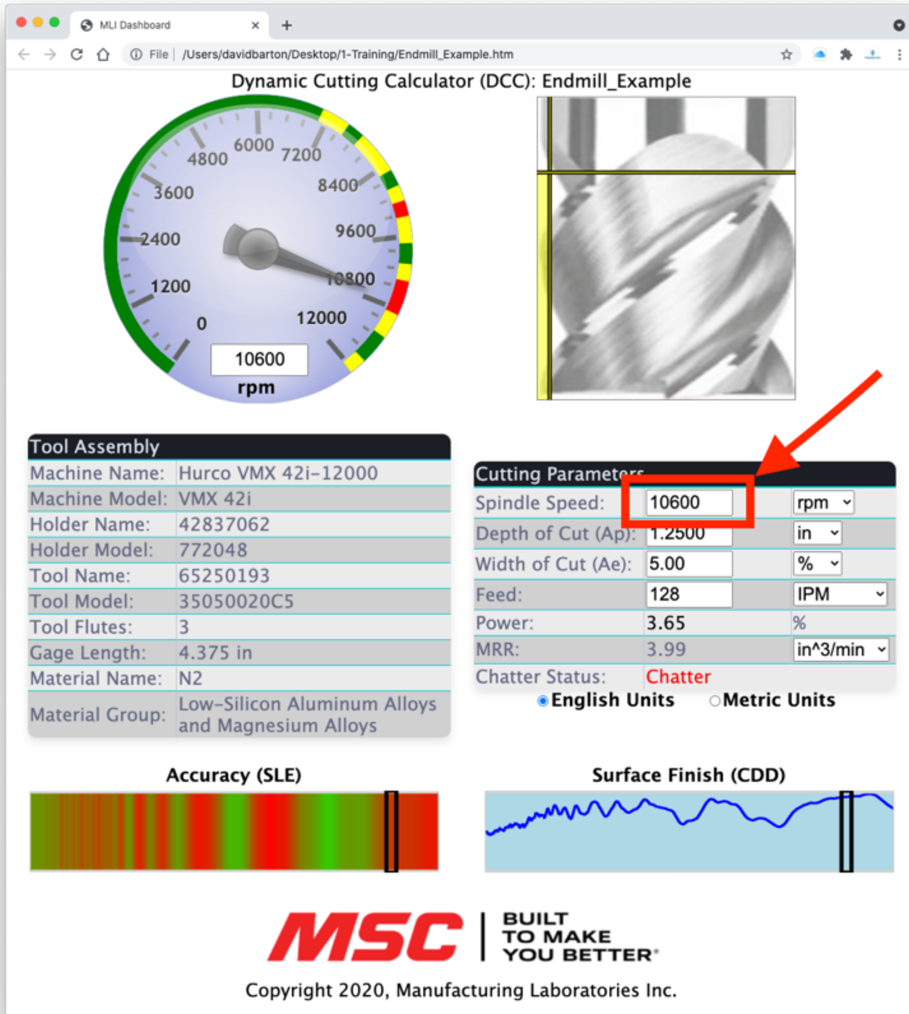


Figure 2a - Determine a SS for the DOC test, DOC_{SS}

As shown in Figure 2a, with the dashboard set as described in step 1, dial the SS to a speed which is in between two stable speeds in a red zone.

Record this speed as DOC_{SS} in Table 1a.

DOC_{SS} = 10600 rpm

Table 1a: Starting Process Parameters

Parameter	Value	Units
PD_{SS}	7070	RPM
PD_{DOC}	0.030	in
WOC_{SS}	10600	RPM
B_{lim}	0.0175	in
$3/4*PD_{SS}$	5303	RPM
$2*PD_{DOC}$	0.060	in
$1/2*B_{lim}$	0.009	in

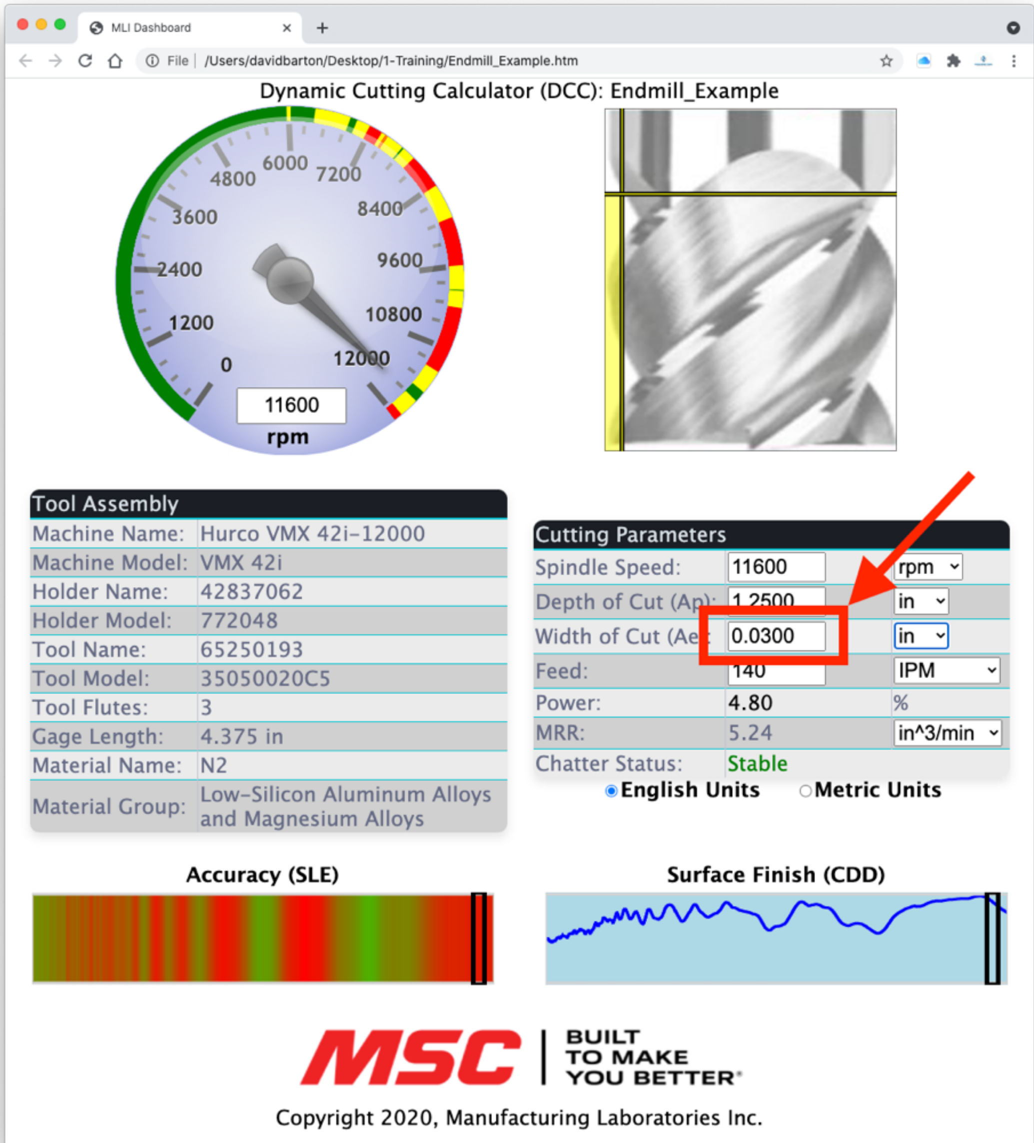


Figure 3a - Determine the Process Damping Depth of cut, PD_{DOC}

As shown in Figure 3a, Dial the SS to the largest stable pocket as close to maximum spindle speed of the machine. Keep the Depth of Cut (Ap) at its maximum. Increase the Radial Width of Cut (Ae) until the stable pocket becomes very narrow. This is the transition depth of cut from stable to chatter.

Record this value as PD_{DOC} in Table 1a.

PD_{DOC} = 0.030"

Table 1a: Starting Process Parameters

Parameter	Value	Units
PD_{SS}	7070	RPM
PD_{DOC}	0.030	in
WOC_{SS}	10600	RPM
B_{lim}	0.0175	in
$3/4*PD_{SS}$	5303	RPM
$2*PD_{DOC}$	0.060	in
$1/2*B_{lim}$	0.009	in

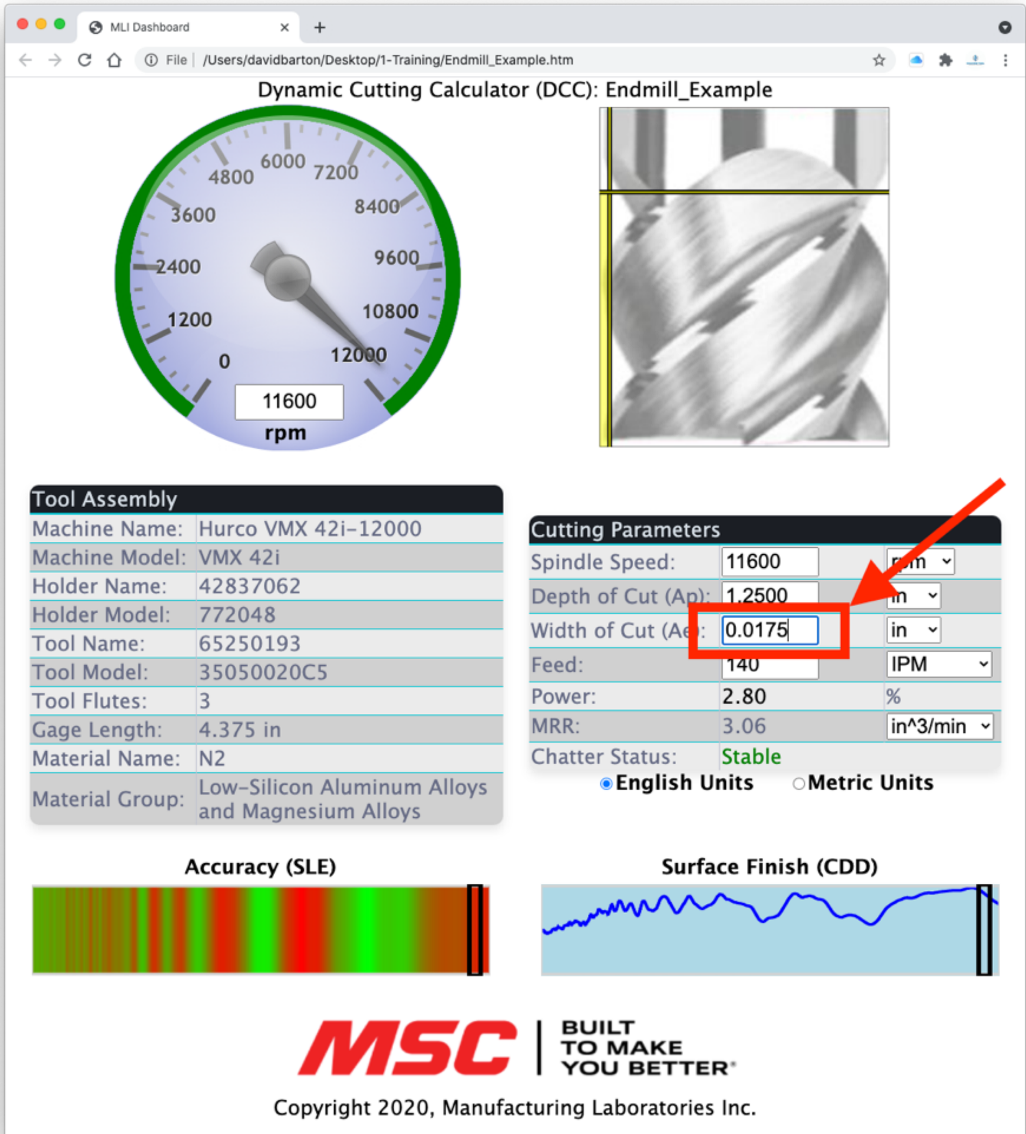


Figure 4a - Determine B_{lim} the depth of cut where all speeds are stable

Determine the Width (Ap) of cut value where the entire SS dial goes green (i.e. all speeds are stable). Keep the Depth of Cut (Ap) at the maximum. As shown in Figure 4, reduce the width of cut (Ae) and determine the depth of cut where all speeds are stable.

Record this WOC as B_{lim} in Table 1a.

B_{lim} = 0.0175"

Table 1a: Starting Process Parameters

Parameter	Value	Units
PD_{SS}	7070	RPM
PD_{DOC}	0.030	in
WOC_{SS}	10600	RPM
B_{lim}	0.0175	in
$3/4*PD_{SS}$	5303	RPM
$2*PD_{DOC}$	0.060	in
$1/2*B_{lim}$	0.009	in

Table 1a: Starting Process Parameters		
Parameter	**Value**	**Units**
PD_{SS}	7070	RPM
PD_{DOC}	0.030	in
WOC_{SS}	10600	RPM
B_{lim}	0.0175	in
$3/4{*}PD_{SS}$	5303	RPM
$2{*}PD_{DOC}$	0.060	in
$1/2{*}B_{lim}$	0.009	in

Cutting Tests

Two cutting tests will be performed:

1. The Depth-of-cut test: At a WOC_{SS}, the first set of tests will increment the width of cut from below B_{lim}, to higher until chatter is detected using Harmonizer.
2. The Spindle Speed Test: At a pre-selected depth or width of cut, greater than B_{lim} the second set of tests will increment spindle speed using a constant depth or width of cut starting at some low spindle speed and increasing speed until chatter is detected with Harmonizer.

In both tests utilize the Harmonizer to determine when chatter is present

Depth-of-cut test:

- At the spindle speed WOC_{SS} and a depth of cut that is 1⁄2 b_{lim}
- Program successively deeper cuts in an increment equal to 10% of b_{lim}
- Using the Harmonizer detect at what depth of cut chatter starts. You may have to go beyond 8 test cuts to reach chatter. When chatter occurs use the prior non-chatter cut as the test value ($b_{lim\text{-}test}$).

Table 2a: Depth of Cut Test			
	SS	WOC	Stable or Chatter
Cut 1	10600	0.0088	Stable
Cut 2	10600	0.0118	Stable
Cut 3	10600	0.0148	Stable
Cut 4	10600	0.0178	Stable
Cut 5	10600	0.0208	Stable
Cut 6	10600	0.0238	Stable
Cut 7	10600	0.0268	Stable
Cut 8	10600	0.0298	Chatter
	$b_{lim\text{-}test}$	0.0268	

Spindle speed test:

- Use 3⁄4 the PD_{SS} of this speed as the starting speed.
- For WOC use a value two times the PD_{DOC}.
- Increase spindle speed in 10% increments of PD_{SS} until chatter occurs. You may have to go beyond 8 test cuts to reach chatter. When chatter occurs record prior stable speed test as the test limit speed ($PD_{lim\text{-}test}$).

Table 3a: Spindle Test Example			
	SS	WOC	Stable or Chatter
Cut 1	5303	0.060	Stable
Cut 2	5833	0.060	Stable
Cut 3	6416	0.060	Stable
Cut 4	7058	0.060	Stable
Cut 5	7763	0.060	Stable
Cut 6	8540	0.060	Chatter
Cut 7	9394	0.060	Chatter
Cut 8	9863	0.060	Chatter
$PD_{lim\text{-}test}$	7763		

Go to the Materials Tab and select the closest material to the one you are testing. Enter the Cutting Stiffness (K_s) in the $K_{s\text{-}new}$ Calculator for that closest material and select the unit of measure (PSI or N/mm^2).

$K_{s\text{-}new}$ **Calculator**	
Closest Material Group	**M1**
K_s	304579.38
b_{lim}	0.0175
$b_{lim\text{-}test}$	0.0268
$K_{s\text{-}new}$	**198885.79**

Enter the Process Damping Wavelength (λ) in the Process Damping Calculator and select the unit of measure (mm or inch).

Process Damping Calculator	
Closest Material Group	**N1**
λ	0.0236
$PD_{lim\text{-}test}$	7106
PD_{ss}	7070
λ_{new}	**0.0237**

Enter the new Cutting Stiffness (K_s) and Process Damping Wavelength (λ) values into the Material Details and save as new a material profile for the specific tool and material tested. Generate new Dashboard with the new material profile.

New Material		
Material Description		
Material Name/Number		
Maximum Surface Speed	400	SFM
Cutting Stiffness	0.0257	PSI
Process Damping	1.005	inch
Cutting Tool Brand		
Cutting Tool Number		

Send copy of completed spreadsheet and to barton.dave@me.com for addition to master database.