10 DAMN GOOD X2 MINI MILL IMPROVEMENTS GUARANTEED TO GIVE YOUR MACHINE A PERFORMANCE BOOST!

(with video links to help you get started)

by Sergio Lares

cnc-minimill.com

1st Edition

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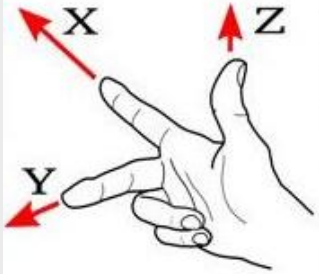
(Last Update: 7/8/2017)



column, lb	head, lb	rpm	ωw [Hz]	ω, opt [Hz]	
20	40	2500	42	104	
Xp ↔	Yp ↕	Zp ◉	Position [inch]	Coordinates	
6	2.5	8			
X ↔	Y ↕	Z ◉	P [lbf]	Applied Forces	
50	1	1			
850	6	6	M, lbf-in	Moments	
17			L1, in, Column	Column	
2.5			Ixx, in⁴		
7.5			Iyy, in⁴	L1	
10			Ip, in⁴		
6.125			L2, in, Head	Head	
14			Ixx, in⁴		
20			Iyy, in⁴	L2	
34			Ip, in⁴		
5.5			L3, in, Over hang	Overhang	
4			Ixx, in⁴		
6			Iyy, in⁴	L3	
10			Ip, in⁴		
Ecast, psi	12.0E+6	Esteel, psi	30E+6	Modulus	
Gcast, psi	7.0E+6	Gsteel, psi	13E+6	Shear	

δh	δv	δz	Linear [inch]	Static Machine Errors
2.81E-03	5.46E-05	4.56E-07		
θx*L	θy*L	θz*L	Rotation [inch]	
9.45E-04	1.66E-05	2.13E-05		
θx	θy	θz	Rotation [rad]	
1.40E-04	2.87E-06	1.25E-06		
↔	↕	◉	Machine √δ [in]	
δx,t	δy,t	δz,t		
3.75E-03	3.80E-05	2.17E-05	**3.75E-03**	
↔	↕	◉	Position √Ep [in]	Position Errors
Ex,p	Ey,p	Ez,p		
3.77E-03	-1.08E-03	3.55E-04	**3.94E-03**	

About the X2 Mini Mill

> The mini mill is an economical entry-level milling machine that has found homes in several muggy garages across the US and worldwide.

> The mini mill has evolved thru the years; e.g., to stay competitive, mini mill vendors offer subtle features such as machine color, spindle power, and spindle taper—R8 or 3MT.

> For the price package, the mini mill deserves a shutout for the value it provides: machine weight, garage friendly, and an R8 spindle. In fact, tooling for an R8 spindle is ubiquitous in the US—and that is very convenient—and that is probably the best feature of the machine.

How to Use This Guide

> This PDF is meant to be a digestible, compact solutions guide that exposes and gives you solutions to the top 10 mini mills design flaws of the X2 Mini Mill.

> Just as the mini mill is a great entry level milling machine—this guide is a great entry level reference guide to the Chinese Mini Mill (the X2 Mini Mill machine).

> Read the guide from top to bottom. Print the guide and highlight your own scribbles, sketches and notes. **Things change rapidly, so I expect to update this reference guide as needed**. Be wise and make sure to sign-up, or check CNC-MINIMILL.COM for the most current updates – things are about to change!

Feel Free to Send this Reference Guide to Your Mini Machinist Friends!

This reference guide suggest disassembly of the Mini Mill; use this guide at your own discretion.

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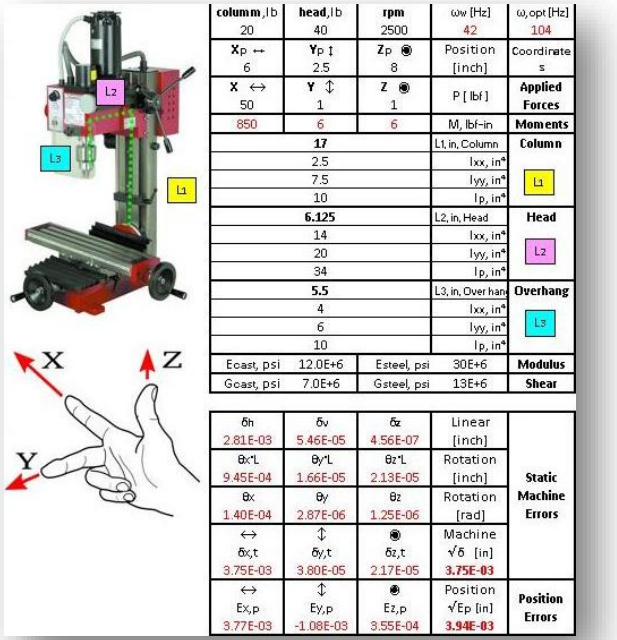
1. Backlash—X, Y and Z axis	6. Z-axis Head Drop
2. Dovetail and Gibs	7. Spindle Runout
3. Spindle Bearings	8. Spindle Head Assembly (tramming needed)
4. Spindle Motor Can Run Hot	9. Circuit Board – Spindle Controller
5. Plastic Gears—Transmission Box	10. Flimsy, Rubbery Column Flex

X2 Mini Mill



column, lb 20	head, lb 40	rpm 2500	ωw [Hz] 42	ω,opt [Hz] 104
Xp ↔ 6	Yp ↕ 2.5	Zp ◉ 8	Position [inch]	Coordinates
X ↔ 50	Y ↕ 1	Z ◉ 1	P [lbf]	Applied Forces
850	6	6	M, lbf-in	Moments
	17		L1, in, Column	Column
	2.5		Ixx, in⁴	L1
	7.5		Iyy, in⁴	
	10		Ip, in⁴	
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	14		Ixx, in⁴	L2
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Ecast, psi 12.0E+6		Esteel, psi 30E+6		Modulus
Gcast, psi 7.0E+6		Gsteel, psi 13E+6		Shear

δh 2.81E-03	δv 5.46E-05	δz 4.56E-07	Linear [inch]	Static Machine Errors
θx*L 9.45E-04	θy*L 1.66E-05	θz*L 2.13E-05	Rotation [inch]	
θx 1.40E-04	θy 2.87E-06	θz 1.25E-06	Rotation [rad]	
↔ δx,t 3.75E-03	↕ δy,t 3.80E-05	◉ δz,t 2.17E-05	Machine √δ [in] **3.75E-03**	
↔ Ex,p 3.77E-03	↕ Ey,p -1.08E-03	◉ Ez,p 3.55E-04	Position √Ep [in] **3.94E-03**	Position Errors

Mathematical Modeling

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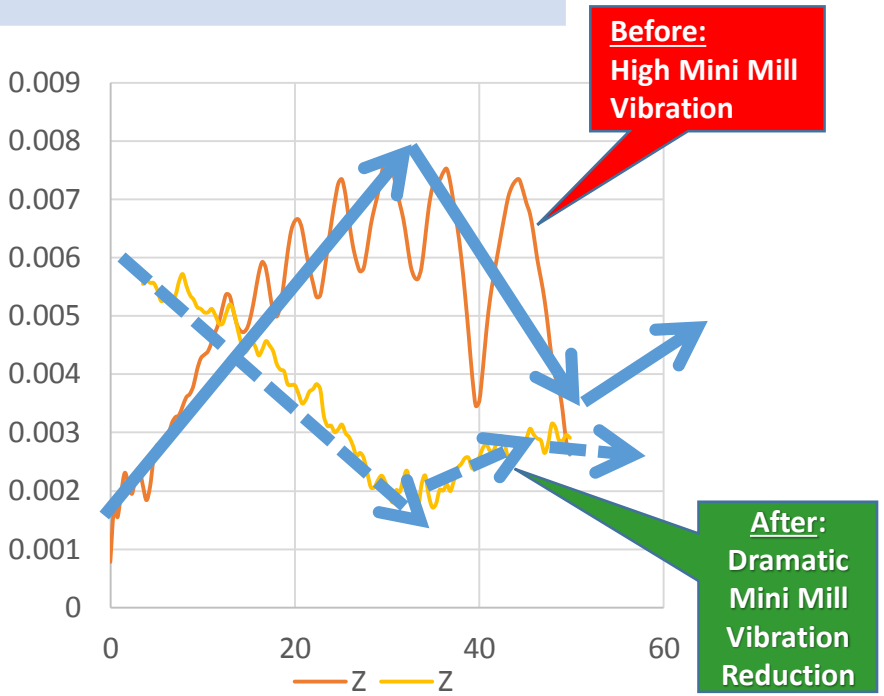


Data Validation Analysis

1. Backlash—X, Y and Z

The three major backlash errors sources—the X, Y and Z axis; the largest backlash error being the Z-axis—the gear/pinion rack. Mathematically speaking, small errors amplify; e.g., the mill head length (6”) that tilts 1.5 degrees has an error of: Error=(6”)*(1.5°)*(2π)/(360°) = 0.026”

Axis	Specification	Backlash	Comments/Solutions/Notes
Z	• Gear rack • Gibs • Dovetail	0.010” to 0.050”+	• Shimming the gear rack may reduce backlash by 0.010” or better. • The flimsy column, dovetail mating, gib adjustment, X/Y ACME screws, gear rack and pinion on the Z axis contribute to overall machine error. • Carefully tighten brass screw nut on X and Y axis—but don’t expect to eliminate all the backlash—best backlash reduction is about ~0.003”. • Screw and brass nut wear will increase backlash errors. • Use anti-backlash spring loaded compensation mechanism. • Thermal and machine assembly contribute to overall machine errors.
X and Y	• Acme Screw • Pitch: 16 TPI	0.003” to 0.005”+ [Fwd/Bkwd]	

2. Dovetail

The dovetails are not a precision fit—you may experience a *tight-loose* fit on each axis.

Axis	Components	Error [thousands]	Comments/Solutions/Notes
X Y Z	• Dovetail • Gibs	Variable—error amplifies as travel increases; small errors amplify big. **Example**: 4” travel at 0.25° tilt has an error of: Error=(4”)*(0.25°)*(2 π)/(360°)= 0.004”	• Preferably surface grind the gibs; remove all the burrs on the gibs—and in the male and female dovetails. • Adjust gib screws carefully; too tight produces high friction in dovetails. • Hone mating dovetails (male & female) until a smooth fit is achieved. Use high-spot blue to actually see the high spots on the gibs and dovetails.

3. Spindle Bearings

The mini mill uses deep groove bearings—but for milling—angular contact or taper bearings are much better in combo loading (radial & axial).

Spindle Taper	Stock Deep Groove Bearings	Angular Bearing Upgrade	New Bearing Break-in (recommended process)
R8	• 6206-2RS; 30 mm X 62mm X 16 mm, Top Bearing. • 6007-2RS; 35mm X 62mm X 14 mm, Bottom Bearing.	• 7206 Angular; 30mm X 62mm X 16mm, Top. • 7007B Angular; 35mm X 62mm X 14mm, Bottom.	Watch for high temperature—shouldn't be hot to the touch! ***New Bearing Break-in Process:*** > 5-10 mins @ 500 rpm > 5-10 mins @ 1,000 rpm > 5-10 mins @ 1,500 rpm > 5-10 mins @ 2,000 rpm > 5-10 mins @ 2,500 rpm > 20-30 mins at *top speed. *top speed depends on belt pulley or plastic gear mini mill. After break-in period—you should be ready to mill.
MT3	• 6007-2RS (or ZZ), Top Bearing. • 6206-2RS (or ZZ), Bottom Bearing. • Bearing Seals: 2RS, rubber; ZZ, metal.	• Angular Contact • Quantity: 2 • Type: 7206B-2RS • Preload by nut—but not too tight!	

4. Spindle Motor Can Run Hot

The mini mill spindle motor can run hot—this seems to be more of a luck of the draw.

Spindle Taper	DC Brush	Upgrade	Comments/Solutions/Notes
R8 MT3	• Advertised as 500 watt • Motor power varies by vendor and mini mill machine model	• Upgrade DC motor to brushless • Treadmill motor also an option • Replace stock DC motor ?	• If your motor is not running hot to the touch—ignore this section. • Motor temperature increases if the mill is used for hours, or if you are cutting heavy passes—this is normal and expected—but overheating is not! • Check motor brushes, fuses, switches potentiometer; they may need to be replaced.

5. Plastic Gears—Transmission Box

The mini mill spindle is driven by plastic gears that will easily break—this is not a maybe—this is a when will they will break flaw!

Spindle Taper	Part in Question	Solution	Comments/Solutions/Notes
R8 MT3	• Plastic gears that drive the spindle have the tendency to easily strip—this is only a matter of time until they strip—guaranteed to fail!	• Replace plastic gears with metal • You may have to custom make your own gears • Upgrade to a belt drive pulley system	The plastic gears create a lot of annoying noise!

6. Head Drop

The Z-axis (spindle head) will drop—and this is a very dangerous and annoying design flaw.

Spindle Taper	Part in Question	Solution	Comments/Solutions/Notes
R8 MT3	• The Z-axis head will drop on your work when you are milling/drilling.	• Lock the z-axis • Pneumatic (air) spring upgrade kit • Counterweight	• If you plan to upgrade your mini mill to CNC—locking the Z-axis is obviously not a good idea. • Some vendors sell the air spring vs the torsion spring mini mill design. • Counterweights and air spring kits help…but removing the torsion spring will make it harder to move the Z-axis.

7. Spindle Runout

A stock spindle runout of 0.001” (no load) or better can be expected; however, higher rpm may lead to higher runout.

Spindle Taper	Component	Solution	Comments/Solutions/Notes
R8 MT3	• Spindle taper .001, or better • Non-concentric bearing bores. • Spindle Bearing Housing bores can either be too tight, or too loose—this is not good!	• Grind/mill the bearing seats if they are not within bearing tolerance. • Clean spindle taper –watch for chips.	• Personally I’ve measured 0.0026” at 6,000 rpm—this doesn’t include other stack up errors such as the flimsy, rubbery column (0.016”)! • The spindle tapers are not hardened! • The spindles tapers are relatively soft and will nick easy, especially if chips get stuck to the spindle taper. **Bottom line**: Keep the spindle taper clean!

8. Spindle Head Assembly Alignment

When you mill or drill—the hole alignment and mill finish may be crappy as heck!

Spindle Taper	Component	Solution	Comments/Solutions/Notes
R8 MT3	• Z-axis – Spindle Head Aliment assembly.	• Tram the milling head—this is a must do! • Adjust the gibs and dovetail fit—but not too tight—aim for a smooth running fit.	• If you are not familiar with tramming the mill head, ask a professional machinist—anybody experienced at trimming a mill. **Tramming the Mini Mill Head** • *https://www.youtube.com/watch?v=a7egZi6znms*

9. Circuit Board – Spindle Motor

The cheap spindle circuit board
will crap-out on you for no reason!

Spindle Taper	Component	Solution	Comments/Solutions/Notes
R8 MT3	• Circuit board that controls the spindle motor.	• Replace it with a higher quality controller such as a treadmill controller	• Careful wiring the circuit board – you don't want to eliminate the E-stop—and you don't want to short your new circuit board! • USA (120 VAC) version

10. Flimsy, Rubbery Mini Mill Column

All Mini Mills Suffer From a Bad Back—a Crippled Back!

Spindle Taper	Component	Solution	Comments/Solutions/Notes
R8 MT3	• The Z-axis flimsy rubbery mini mill column	• Column Back Brace (quick fix)	• A back brace will help a little bit, but won't solve the flimsy, rubbery nasty problem. • A Bad Back (Bad Mini Mill Column) handicaps surface finish, tolerance, concentricity—too much vibration and flex.

Useful Mini Mill Videos

(videos links to help you get started)

Content	Video
How to tram the X2 Mini Mill Head	https://www.youtube.com/watch?v=a7egZi6znms
Introduction to the X2 Mini Mill	https://www.youtube.com/watch?v=8XWCHPO8kZ4&t=1s https://www.youtube.com/watch?v=YuqTzOpDCEA

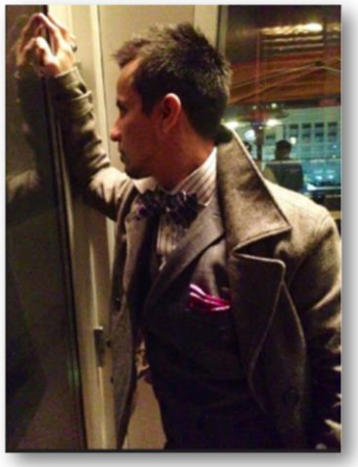
About MEngineer

> I'm a mechanical engineer with a mechanical passion for Mechanisms, Re:design and Re:innovation.

> I am Bi-literate in English and Spanish, which means that I'll be publishing information in both English and Spanish.

> By using ingenuity—you too can solve complex problems and arrive to elegant MacGyver type of hack solutions. Go hack your Mini Mill today!

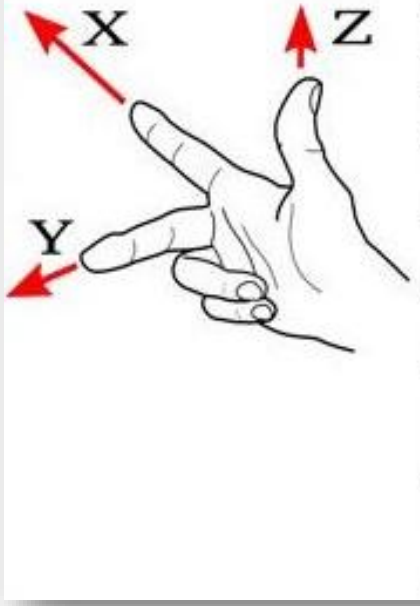
—**Sergio Lares**; know as "**Gadget Man**".



This is a mathematical modeling of the X2 Mini Mill Machine – this is what I use to design, predict and optimize a machine.

INPUTS: The math model account for forces, deflections (machine flex), natural frequencies and position of cutting (predicts how much error [by flex] the machine will have at a certain point.

FUTURE WORK: I will also be factoring temperature, which is usually the largest error source in machines; e.g., CNC machines and lathes.



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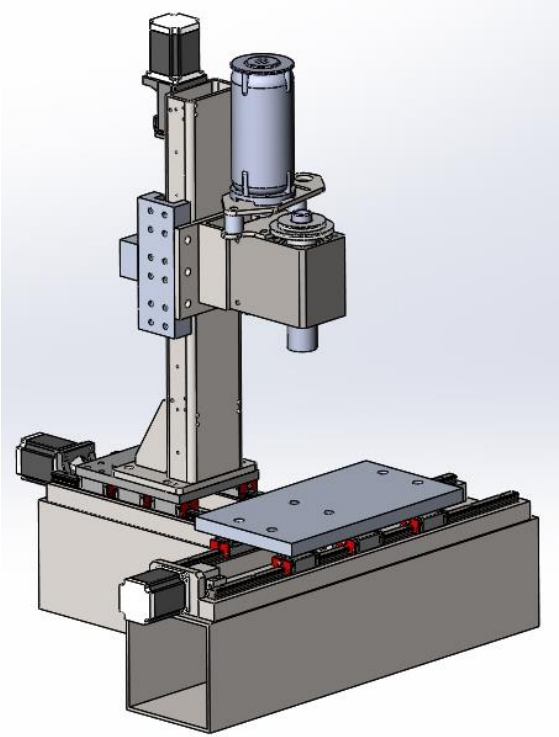
PLEASE TELL US WHAT YOU WOULD LIKE TO SEE IN FUTURE UPDATES



Ideas to consider:

1. Would you like to see more videos (on what) ?
2. Math analysis examples (deflection, forces and errors)?
3. How to convert your X2 CNC Mini Mill into CNC?
4. CNC (and/or manual) project to do over a weekend?
5. CNC X2 Mini Mill Conversion Kits?
6. 5-axis CNC Mini Milling?
7. Automatic Tool Changes – for Desktop CNC Mini Milling?

Please email suggestions at: **sircigars@yahoo.com**