Adding a DRO to a Rong Fu Mill/Drill

By

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Why a DRO?

• Trying to achieve a precision of 0.001 inches.
• Experience has shown that my Rong Fu Mill/Drill is potentially capable of 0.001 inch precision.
• DRO is cheaper than a new mill and a CNC system.
• DRO is faster and easier to use than a micrometer.
DRO

- From DRO Pros
- Model EL 400
- 3 Axis DRO
- Magnetic scales and read heads (no glass rods).
- $1200
- Problem: Mounting equipment designed for a Bridgeport style machine.
DRO

• A close up of one of the DRO magnetic read heads.
DRO

• Close up of Scale
• End shown bolted in place.
• All scales had to be trimmed to fit the mill.

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DRO

- Scale shown in cross section.
The Rong Fu Mill/Drill

- The Rong Fu Mill/Drill does not have the same large wide open areas for mounting a DRO that a Bridgeport style mill has.
- The EL 400 mounting brackets will not fit and cannot be used on a Rong Fu mill/drill.
- This creates an engineering opportunity.
Design of new mountings

- 2 man-months spent measuring and designing a series of new mounts.
- Detailed drawings were made.
- Materials
  - 1018 cold rolled steel
  - 6061 and 7075 aluminum
  - 360 brass
  - Stainless steel bolts (mostly)
- Imperial system threads selected for general purposes.
- Some metric screws kept from EL 400 mounts to avoid modifying scale bars and read heads. This would have invalidated the warranty. *

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Design continued

• New design heavily over-engineered.
• Extra set screws added to facilitate adjustment of read heads vis-à-vis the magnetic scales.
• Attempt made to keep iron or steel surfaces from contacting magnetic scales.
• Everything put together with socket head cap screws, button head cap screws and set screws. No welding.
X-Axis Components

• 5 parts
  – Swarf shield (Al)
  – Swarf shield mounts (2)
  – (Al)
  – Base rail (steel key stock)
  – Read head platform (Al)
X Axis Assembly

- Magnetic scale trimmed to length.
- Magnetic scale installed on back side of mill work table.
- Work table drilled and tapped for metric screws.
- Magnetic scale leveled with dial indicator.
X Axis Assembly

- Base rail attached to mill table with SHCS.
- Pre-existing holes used.
- Formerly holes held end of swarf shield.
- Old swarf shield removed from mill.
X Axis Assembly

• Read head platform attached to base rail with SHCS.
X-Axis Assembly

- Read head attached to read head platform.
- White plastic behind read head is a gauge used to set space between scale and read head.
X Axis Assembly

• Gauge removal proves read head is not too close to scale.

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X Axis Assembly

- Swarf shield mounts installed.
X Axis Assembly

• Swarf shield installed.
• X axis installation complete.
X Axis Space Consumption

- DRO X axis has consumed about ¼ inch of the space available between the vise and the mill column.
Y-Axis Components

• 7 parts
  – Mount for Y scale and swarf shield.
  – Swarf shield.
  – Read head base plate (Al)
  – Read head horizontal extensions (Al)
  – Read head vertical extension (Al)
  – Read head mounting plate (Al)
Y Axis Assembly

• Y scale / swarf shield mount attached to mill.
• Y axis scale cut to length and mounted on Y scale base.
• Note set screws in near end of swarf shield mount. These are used to make sure the scale is held vertically.
Y Axis Assembly

- Y axis swarf shield installed.
Y Axis Assembly

- Read head base plate installed on mill.
Y Axis Assembly

- Read head horizontal extensions installed.
Y Axis Assembly

• Read head vertical extension installed.
Y Axis Assembly

- Read head mounting plate installed.
Y Axis Assembly

• Read head installed.
Y Axis Assembly

- Another view of the completed Y axis assembly.
- Note how the Y axis assembly reaches around the swarf shield. This awkward reach is one of the reasons for the heavy over-engineering.
Z-Axis Components

- 9 parts
  - Swarf shield (Al)
  - Base plate (1018)
  - Scale plate (Al)
  - Sliding rail and tracks (360 brass)
  - Top side cover (Al)
  - Read head mounting block (Al)
  - Quill connecting plates.
Z Axis Assembly

- Z-axis scale trimmed and installed on scale plate.
- Brass outer rails installed on scale plate.
Z Axis Assembly

- Read head mounting block bolted to sliding rail.
Z Axis Assembly

• Sliding rail and read head mount installed on scale mounting plate.
Z Axis Assembly

- Base plate attached to scale plate.
Z Axis Assembly

- Top side cover installed on scale plate.
Z Axis Assembly

• First quill connecting plate attached to sliding rail.
Z Axis Assembly

- Second quill connecting plate attached to first quill connecting plate.
Z Axis Assembly

- Z axis assembly attached to mill.
Z Axis Assembly

• Quill attachment plate bolted to quill and vertical brass slide.
Z Axis Assembly

• Read head attached to read head mount.
• Note clearance gauge behind read head.
Z Axis Assembly

- Swarf plate installed.
Z Axis Assembly

• Final view of the Z axis assembly.
• Note the congestion and lack of space on this side of the mill.
Control Panel Installation

• Base of extension arm bolted to mill.

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Control Panel Extension

• Looking at back of DRO control panel.
• Kit came with only one extension arm. Put control panel in collision range of vertical axis control arm.
• DRO Pros sent free second extension arm.
Protecting the Y axis lead screw

- Removal of old swarf shield has left Y axis lead screw exposed.
Protecting the Y axis lead screw

• Made new swarf shield from poster board, denim, and rubber cement.

• DRO installation complete.
Testing the DRO

• Standard gage blocks used to test DRO.
Footnote on Edge Finders

• First tried carbide rod and feeler gage. Worst accuracy
• Next tried standard 0.500 edge finder. Better.
• Next tried standard 0.125 edge finder. Better.
• Finally tried laser edge finder. Best accuracy.
OK, but does X axis work?

- Positioned edge finder against vise jaw.
- Note that edge of laser beam barely touches vise jaw.
- Set X coordinate to 0.0000 on DRO.
Does X Axis Work?

• Positioned 1 inch gage block against front vise jaw.

• Positioned edge finder against gage block.
Does X Axis Work?

- 1.0000 inch gage block measures 1.0000
- DRO has an apparent resolution of 0.0002 inches. Cannot measure less than this.
Does X Axis Work?

- 2.0000 inch gage block measures 2.0006 long.
- 0.0006 inch too long.
Does X Axis Work?

• 3.0000 inch gage block measures 3.0000 long.
Does X Axis Work?

- 4.0000 inch gage block measures 3.9990 long.
- 0.0010 inch too short.
X test summary.

<table>
<thead>
<tr>
<th>Gage block length</th>
<th>DRO results</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0000</td>
<td>1.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>2.0000</td>
<td>2.0006</td>
<td>+0.0006</td>
</tr>
<tr>
<td>3.0000</td>
<td>3.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>4.0000</td>
<td>3.9990</td>
<td>-0.0010</td>
</tr>
</tbody>
</table>
Does Y axis work?

• Positioned 1 inch gage block against square held in vise.
• Positioned edge finder against gage block.
Does Y axis work?

• 1 inch gage block measures 0.9890 inches.
• This is 0.011 too short.
Does Y axis work?

- 2 inch gage block measures 1.9886 inches.
- This is 0.0114 too short.
Does Y axis work?

• 3 inch gage block measures 2.9954 inches long.
• This is 0.0046 too short.
## Y Test Summary

<table>
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</thead>
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<tr>
<td>1.0000</td>
<td>0.9890</td>
<td>-0.0110</td>
</tr>
<tr>
<td>2.0000</td>
<td>1.9886</td>
<td>-0.0114</td>
</tr>
<tr>
<td>3.0000</td>
<td>2.9954</td>
<td>-0.0046</td>
</tr>
</tbody>
</table>
Does Z axis work?

- Positioned 1 inch gage block against square and against front jaw of vise.
- Positioned edge finder on top of gage block.
Does Z axis work?

• 1 inch gage block measures 1.0002 inches.
• This is 0.0002 too tall.
Does Z axis work?

- 2 inch gage block measures 1.9722 inches.
- This is 0.0278 too tall.
Does Z axis work?

• 3 inch gage block measures 3.0098 inches.
• This is 0.0098 too tall.
# Z Test Summary

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<td>1.0002</td>
<td>+0.0002</td>
</tr>
<tr>
<td>2.0000</td>
<td>1.9722</td>
<td>-0.0278</td>
</tr>
<tr>
<td>3.0000</td>
<td>3.0098</td>
<td>+0.0098</td>
</tr>
</tbody>
</table>
## Conclusions

| **X Axis** | 1. Errors on order of $0.001$ or less.  
2. Seems to work tolerably well. |
|------------|------------------------------------------------------------------------|
| **Y Axis** | 1. Errors average $0.009$  
2. Significant problems.  
3. Perhaps DRO error correction features will improve or cure this. |
| **Z Axis** | 1. Errors average $0.0126$  
2. Severe problems. |
The real problem with Z axis measurements is the rack and pinion drive used for quill movement.
There is a lot of play in it.
Formerly I used a height gauge to reset the quill.
Note that the height gauge pointer is upside down.
It fits under the bottom edge of the quill and can be used to make minute adjustments.
The technique is to flip the height gauge in and out while slowly lowering the quill with the fine adjustment wheel.
Have to check work piece after every cut.
Metal working techniques

- Metal removal with end mills is more time consuming and costly than other methods.
- Whenever possible I remove larger masses of metal with drills and saws.
- The vertical slot was cut with an end mill. The slot makes room to get a saw into the middle of the work piece.
Metal working techniques

- Reciprocating saws will cut 1018 steel but not tool steel.
Metal Working Techniques

- Diablo makes metal cutting blades of stainless steel with carbide teeth.
- They will cut mild steel... aluminum and brass.
- Blade will cut ½ inch thick mild steel at rate of about 16 inches/hour.

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Metal Working Techniques

• End mill used to finish the cut.
• Finished part is the base of the Y axis mount.
Metal Working Techniques

• Installation guide recommended a table saw blade to trim scale components to length.
• Carbide teeth make cutting aluminum easy.
Metal Working Techniques

• By setting the table saw at an angle it was possible to cut the Y axis base so that it fit against the sloped side of the mill.

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Metal Working Techniques

• A slitting saw mounted in the mill made it possible to evenly cut long pieces of aluminum.
• Cuts limited to 0.030 inches per pass.
• Multiple passes needed to complete a cut.

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Metal Working Techniques

- Y axis swarf shield cut with mill slotting saw.
Metal Working Techniques

• Encountered several problems with counter bores.
  1. Pilot cutter too large
  2. Head slot cutter too large
  3. Counter bore went dull quickly
Substituted drill bits for counter bores.

- Used smaller drill just barely larger than threaded section of the SHCS.
- Used larger drill just barely larger than head of SHCS.
- Resulted in very tight fitting counter bores.
Z Error Analysis and Resolution

- The real problem with Z axis measurements is the rack and pinion drive used for quill movement.
- There is a lot of play in it.
- Formerly I used a height gauge to reset the quill.
- Note that the height gauge pointer is upside down.
- It fits under the bottom edge of the quill and can be used to make minute adjustments.
- The technique is to flip the height gauge in and out while slowly lowering the quill with the fine adjustment wheel.
- Have to check work piece after every cut.
Questions

• Does this installation seem reasonable?
• Any suggestions for fixing the problems?
Future Problems

• Mill stand is a weak and flimsy affair made of angle iron and sheet metal.
• One leg is slowly giving way.
• Mill looses level after 2 weeks of use.
• Mill looses tram after 1 hour of use.
• Need new much heavier duty mill stand.
• New stand to have:
  – table top of 2 sheets of ½ inch steel plate.
  – legs of 4 inch square mild steel ¼ inch thick.
  – heavy duty pivoting feet that have leveling screw.
The End