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## Faceting Machine Alignment

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## Faceting Machine Alignment by Paul A. Head, Old Pueblo Lapidary Club Faceting Guild

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maintenance schedule using this procedure takes only about 15 minutes unless serious problems are encountered. Although a generic mast style machine is discussed the basic ideas will generally apply to other types as well. The essential elements of such a machine are depicted on Figures 1 and 2, or

The following outlines a procedure to check the alignment of a faceting machine using very simple tools and the machine itself. Key to the idea is NOT to cut anything. A periodic

defined in the following list. These basic machine elements have been capitalized for the rest of this text. **DEFINITIONS:** 

Q

O comments

ANGLE STOP: this can be either a hard or soft stop. It's purpose is to indicate and or limit cutting depth using metal to metal, audio, electronic, visual, or tactile methods. Not shown on the diagrams.

CHUCK: a device to lock the ROD into the QUILL. Not shown on the diagrams. <u>Faceting head</u>: this is the assembly of the YOKE, BODY, QUILL, ROD, INDEX, and also includes the PROTRACTOR, ANGLE STOP, and cheater, not shown on the diagrams.

<u>Height</u>: is defined to be the height of the TRUNNION AXIS above the LAP.

LAP: a perfectly flat disk with parallel faces.

Machine Coordinates: for this discussion LEFT and RIGHT are defined when the MAST is to your right side. The FRONT of the machine is toward you and the BACK is the far side. UP and DOWN are defined as the SPINDLE AXIS orientation.

and repeatability is assumed to be 0.1 degrees. Not shown on the diagrams.

Master lap: this is a LAP used to carry cutting and polishing laps that are not rigid enough to use directly on the PLATEN. Not shown on the diagrams.

Height micrometer: may be located on the MAST or as a part of the YOKE. It permits precision adjustment of the height. Not shown on the diagrams.

kit.

PIVOT AXIS: the vertical axis of rotation on which the faceting head turns. It must be parallel to the SPINDLE AXIS. Some machines use the MAST for this axis; some make it an element of the YOKE. It moves LEFT or RIGHT in line with the SPINDLE.

PROTRACTOR: any of several distinct mechanical or electronic devices used to measure the angle between the QUILL AXIS and the PIVOT AXIS. The PROTRACTOR ANGLE resolution

PROTRACTOR ANGLE: the angle between the QUILL AXIS and the SPINDLE AXIS.

QUILL AXIS: this axis of rotation is collinear with the CHUCK, ROD, and index axes. ROD: this is a 3 or 4 inch long piece of precision steel or brass shaft with indexing key, i.e., flat, bevel, groove, etc that fits your CHUCK. This is a tool that should be a permanent part of your

TRUNNION AXIS: the axis of rotation passing through the YOKE and BODY perpendicular to the PIVOT AXIS and the QUILL AXIS. The center of the PROTRACTOR is located on this axis.

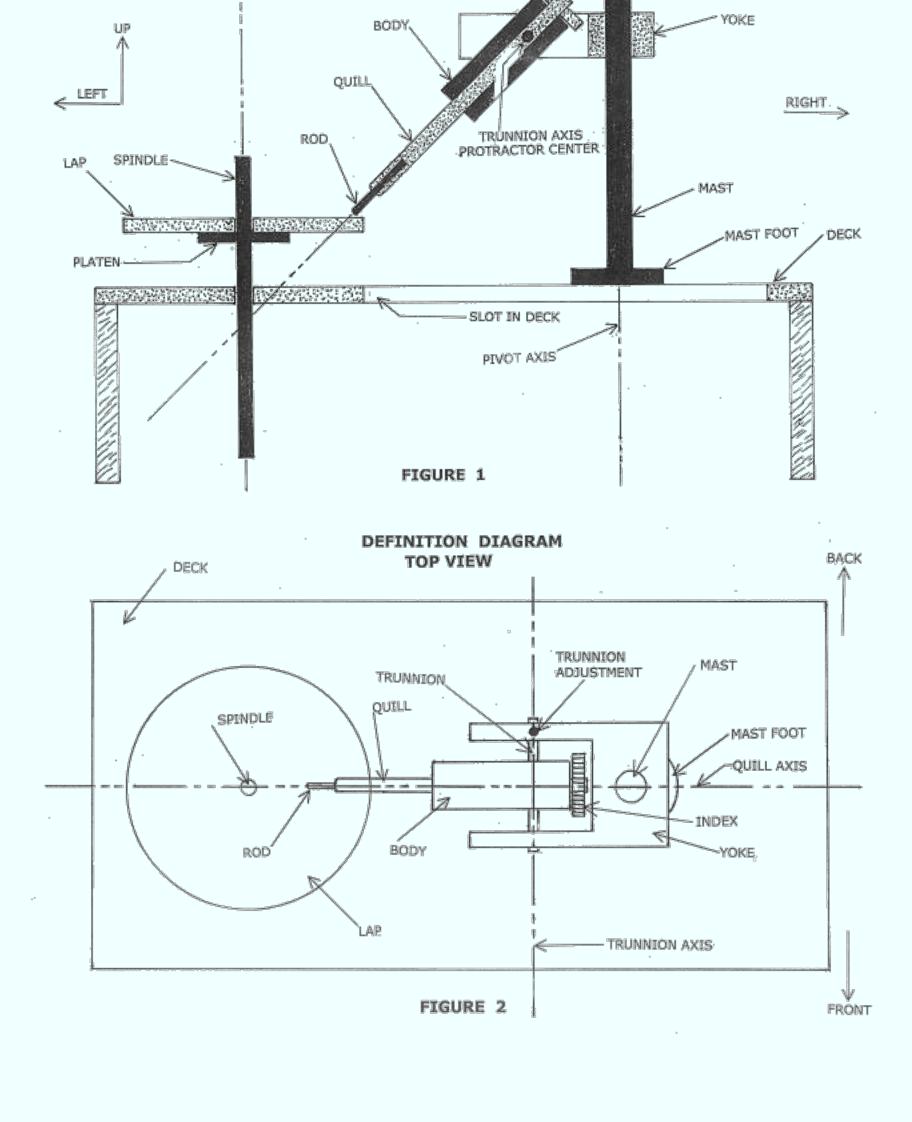
INDEX

PROTRACTOR ANGLE

SPINDLE AXIS: this axis of rotation is assumed to be vertical and is the **basic reference element** for all definitions and tests in this discussion.

QUILL AXIS SPINDLE AXIS

**DEFINITION DIAGRAM** FRONT VIEW



## Pencil.THE PROCEDURE: The procedure tests for these conditions.

**TOOLS REQUIRED:** 

Your faceting machine.

String or rubber bands.

1. The PLATEN is perpendicular to the SPINDLE AXIS. 2. The PIVOT AXIS is parallel to the SPINDLE AXIS.

• The appropriate wrenches and screwdrivers.

• Your eyes, ears, and a moveable light source.

• A two-inch precision machinist's square or block.

The LAP, a new ceramic lap is best. Do not use a cutting lap.

3. The TRUNNION AXIS is perpendicular to the SPINDLE AXIS. 4. The QUILL AXIS is perpendicular to the TRUNNION AXIS. That is, it swings in a plane parallel to or in the plane of the PIVOT AXIS.

• The ROD. See **DEFINITIONS**.

- 5. The QUILL, CHUCK, and ROD axes are co-linear. 6. The DECK is perpendicular to the SPINDLE AXIS and the PIVOT AXIS.
  - When rationalizing these tests, mentally construct a skeleton machine made up of these ideal axes of rotation and planes. As you go through each step grossly misalign the element being tested and analyze how cutting is affected. Mentally do the tests out of order and see if that will change the outcome of other steps.
  - The first six steps can be done in any order.
  - Step 1: thoroughly clean all moving parts and lubricate as recommended by the manufacturer. Also clean the QUILL, both faces of the LAP, master lap (if present), and the PLATEN. Use a cotton swab to clean out the CHUCK. Don't forget to clean the DECK and under the MAST FOOT.
  - **Step 4**: check the index gear and the index detent for burrs and dirt that would cause inaccurate settings.

Step 7: check that the PLATEN is perpendicular to the SPINDLE. This is called a flutter test. Flutter is independent of any misalignments of the MAST or faceting head and condition of

1. Insert the ROD into the CHUCK and lock in place. Set the INDEX to zero. Set the PROTRACTOR to 45.0 degrees and secure the BODY against a hard stop with string or rubber

**Step 3**: check for ratcheting height adjustment, i.e., the faceting head moves up and down as it is rotated about the PIVOT AXIS. Check for a non-slipping lock to the MAST.

The following steps must be done in sequence! If they are not, some alignment errors will be masked or could even accumulate. It is assumed that alignment errors are either corrected or minimized at each step.

**Step 6**: be sure that the ROD seats correctly in the CHUCK and can be locked securely in place.

band. If you don't have a hard stop rig up a temporary one. Take care not to strain the MAST.

1. Orient the LAP high and low marks FRONT to BACK. The LAP must not be moved during this test.

**Step 5**: check that the cheater (index micrometer or index splitter) is not loose.

**Step 2**: check for worn bearings in the PIVOT, TRUNNION, SPINDLE, BODY, and QUILL.

Follow these steps to determine the amount of flutter present.

the DECK. The most serious causes for misalignment are a damaged PLATEN or SPINDLE bearings, or a poorly machined PLATEN/SPINDLE assembly.

Of course these ideals can exist only with a perfect faceting machine but the more closely we approach the ideal the easier it is to cut a perfect stone.

2. Install the LAP and do not loosen for the remainder of the tests. The LAP is used because flutter is more easily measured as distance from the SPINDLE increases. 3. Move the MAST and faceting head so that the ROD will just clear the spindle nut, then set the ROD near the outer edge of the LAP towards the FRONT of the machine, just barely touching the LAP. Be sure the MAST is locked to the DECK.

4. Start the motor at very slow speed. Without moving the QUILL, adjust the height so that the ROD just audibly ticks the lap. Shut off the motor, turn the SPINDLE by hand to

5. Rotate the SPINDLE 180 degrees to the LAP'S low point and mark. These high/low marks will be used to minimize minor PLATEN flutter in subsequent tests by orienting them

relocate the high side accurately. Mark it with a pencil. If no high side can be detected, skip to Step 8 and ignore instructions to orient the high/low marks.

6. Reset the PROTRACTOR so the ROD just contacts the LAP at the low point. If you can measure the angle change you have a very serious problem. See Footnote [1]. Even if the PROTRACTOR does not change enough to measure but flutter is perceptible, you may still want to correct the problem. 7. Correcting flutter is not a casual process. The best cure is to have the PLATEN re-machined. See **Footnote [2]**. Other corrective procedures are possible such as three leveling screws between the PLATEN and a master lap.

no major cutting problems.

8. If flutter is excessive the remaining tests are compromised.

toward the MAST or perpendicular to that direction.

- Step 8: The MAST slide area of the DECK should be perfectly flat and perpendicular to the SPINDLE AXIS. If it is not, the alignment of the PIVOT AXIS and height will change when the MAST is moved. The DECK and MAST FOOT are very susceptible to wear. To check the condition of the DECK slide area:
- 2. Set the PROTRACTOR ANGLE to about 45 degrees and secure the BODY to a hard stop with string or a rubber band. 3. Swing the faceting head so the ROD is positioned just to the RIGHT of the SPINDLE nut and adjust the height so there is a very, very small gap between the ROD and the LAP. 4. Slide the MAST to the RIGHT in six or eight steps to the outer edge of the LAP, locking it down at each step. Observe the gap at each position. 5. Place a light low and to the rear of the machine so that the clearance between LAP and ROD can be easily observed.

7. If the gap changes width smoothly, the PIVOT AXIS alignment relative to the SPINDLE AXIS does not change. However, the height does change. That is annoying but will cause

8. Erratic variation of the gap is caused by a wavy or lumpy condition between the MAST FOOT and DECK. This causes the PIVOT AXIS to tilt erratically. The height will also

change erratically. 9. This condition is corrected by having the slide area of the DECK and MAST FOOT refinished. A competent local machine shop can do this. Step 9: ROD runout is caused by misalignment of the CHUCK and QUILL and/or of the ROD and CHUCK. It can be checked as follows:

6. If no adjustments were needed there is no runout. Skip to Step 10.

AXIS and ROD AXIS are parallel but not collinear.

the QUILL AXIS, BODY, and TRUNNION AXIS combined.

6. Only if the gap tapers is factory repair needed.

width, there is no problem.

error position. Reset the ANGLE STOP to define this as our 90-degree angle reference.

To check that the PIVOT AXIS is perpendicular to the LAP (parallel to the SPINDLE AXIS):

2. The LAP high and low marks should be oriented FRONT to BACK. The LAP must not be moved during this test. 3. Position the MAST and faceting head so that two or three inches of the ROD nearly touches the LAP. The Quill should be pointing toward the SPINDLE throughout this test. Place a light source low and to the BACK of the machine so the gap between the LAP and ROD can be easily observed. 4. Adjust the height and if necessary adjust the PROTRACTOR angle so that the gap between the ROD and the LAP is barely visible and of uniform width.

5. Rotate the QUILL through index settings of 12-24- ...-84-96, keeping the gap the same by adjusting the PROTRACTOR and height as needed. Record the index at the minimum

7. If only the PROTRACTOR was changed the runout is angular; the QUILL AXIS and ROD AXIS are not parallel or collinear. If only the height micrometer was changed the QUILL

8. The fault could lie with the CHUCK, QUILL, or bearings. This is a factory repair job. Step 10: A LEFT or RIGHT tilt of the PIVOT AXIS has the effect of changing the PROTRACTOR ANGLE or the height as the ROD is swept across the lap. A FRONT to BACK tilt decreases the angular range of the PROTRACTOR and the height. (See the **thought problem** in Step 12 and especially note the QUILL AXIS rotation.)

2. Rotate the LAP 90 degrees so that the high and low marks are oriented FRONT to BACK, minimizing minor lap flutter for the second part of this test.

3. Sweep the ROD across the LAP. If the ROD touches the outer edges of the LAP equally but not at the center, the PIVOT AXIS is leaning to the RIGHT.

6. Does the ROD maintain a uniform gap with the LAP? Does the gap change uniformly from maximum to minimum or change erratically?

1. Set the index to zero. Set the PROTRACTOR to 90.0 degrees and secure the BODY against a hard stop. Take care not to strain the MAST.

- 1. Turn the LAP so that the high and low point marks are oriented LEFT to RIGHT toward the MAST. Set the index to the minimum error setting determined in Step 9. The effects of ROD runout and flutter are now minimized for the first part of this test. 2. Set the PROTRACTOR to 45.0 degrees and secure the BODY to a hard stop. Move the MAST so that the ROD will swing past the SPINDLE nut. 3. Set the ROD to just barely touch an outer edge of the LAP. Then sweep the ROD across the lap to the other edge. If the ROD does not maintain uniform contact, the PIVOT AXIS
- 4. Many machines provide some means to correct the problem by adjusting the LAP to the MAST or by adjusting the MAST to the LAP. The adjustment will generally involve three adjusting screws located at the SPINDLE, MAST, or on the faceting head. Shims can also be used between the DECK and SPINDLE bearing housing. The adjustment should be stable unless the machine is dropped or otherwise shocked. The next two steps require that the TRUNNION AXIS be adjustable. If the TRUNNION AXIS is not adjustable, skip to STEP 12 and you can at least determine if there is a problem with

4. If the ROD touches only at the center, the PIVOT AXIS is leaning to the LEFT.

is not perpendicular to the LAP. Both LEFT/RIGHT and FRONT/BACK misalignments are likely to be present.

1. If the ROD touches only at one outer edge, the PIVOT AXIS is leaning to the FRONT, or to the BACK of the machine.

**Step 11**: Check that the QUILL AXIS is perpendicular to the TRUNNION AXIS. Misalignment will cause spiraling, see Step 12.

5. On some machines the TRUNNION AXIS and the QUILL AXIS are not coplanar, requiring height adjustment to compensate.

ANGLES of 45 degrees and 0 degrees. See the spiral? Did the height change? Is the PROTRACTOR ANGLE range affected?

2. Set the PROTRACTOR to zero degrees. Keep in mind that the ANGLE STOP has been reset to define a 90-degree reference.

4. Reorient the high low marks LEFT to RIGHT, then check that the ROD is perpendicular to the LAP along the FRONT to BACK direction.

- 1. Locate the TRUNNION AXIS adjustment. If present, it will be on the YOKE or the BODY. Tilt the axis as far as possible, either up or down. 2. Set the MAST and faceting head as in Step 9. 3. Tilt the TRUNNION AXIS as far as possible the other way. 4. If the gap between the ROD and LAP remained uniform in width (not tapered), the QUILL AXIS is perpendicular to the TRUNNION AXIS. If the gap width varies but is of uniform
- Step 12: If the TRUNNION AXIS is not perpendicular to the SPINDLE AXIS, the machine will cut stair step girdles. The problem is often called spiraling. User variable TRUNNION alignment is used to emulate a true cheater on some machines. If Step 11 was completed the adjustment will likely need to be reset. Thought problem.

Assume the TRUNNION AXIS is grossly miss-aligned so it is parallel to the SPINDLE AXIS; mentally cut a girdle facet. Now align the TRUNNION AXIS properly, perpendicular to the

SPINDLE AXIS. Do not change the index setting and cut another girdle facet; the QUILL AXIS rotated 90 degrees relative to the LAP. Work through the effect with PROTRACTOR

3. With the machinist's square or square block, check that the ROD is perpendicular to the LAP along the LEFT to RIGHT direction. Reset the PROTRACTOR if it is off.

5. If it is off, look for an adjusting mechanism on the YOKE or BODY that moves one end of the TRUNNION UP or DOWN. If there is none, a factory repair is needed. If Step 11 was

Step 13: Check the 90-degree measurement range of the PROTRACTOR. If the PROTRACTOR radius is 3 inches and the center is displaced 0.01 inches from the TRUNNION AXIS

there is a distributed error of about 0.2 degrees. This will probably cause no serious cutting problems. But an error 0.2 degrees occurring all at one place will almost certainly create a

Checking that the TRUNNION AXIS is perpendicular to the SPINDLE AXIS requires the index be set 90 degrees off the position of the minimum angular ROD runout error (as determined in Step 9); this minimizes ROD runout error. For example, if the minimum angular error is on index 96, the index should be set to 24 or 72. 1. Set the index as described above. Orient the high/ low marks FRONT to Back.

3. Raise the faceting head and reset the PROTRACTOR to 0.0 degrees. Move the MAST so the ROD is positioned about midway between the SPINDLE nut and the outer edge of the LAP. 4. Place the precision square or block against the ROD in line with SPINDLE nut. If necessary reset the PROTRACTOR ANGLE to make the ROD perpendicular to the LAP. 5. Record the PROTRACTOR ANGLE.

2. Orient the high/low LAP marks FRONT to BACK.

adapter body.

FOOTNOTES:

skipped the error detected will combine both alignment problems.

cutting problem sooner or latter. For example, the scale reads 41.5, 41.6, 41.9, 42.0.

1. Set the PROTRACTOR to 45 degrees (or 90 degrees) and the index to 0.

2. Install the adapter in the CHUCK, and lock in place.

sides the transfer block is likely OK.

 $F = A - a\cos[\cos(A) + D/L]$ 

A = 45 degrees F = 0.016 degrees

A = 30 degrees F = 0.023 degrees

A = 10 degrees F = 0.066 degrees

A = 5 degrees F = 0.133 degrees

1. Set protractor to 90 degrees; be sure that the ROD AXIS is parallel to the LAP as described in Step 9.

2. If the angle is less than zero degrees, i.e., the range is greater than 90 degrees the error CAN NOT be residual error in the PIVOT AXIS or TRUNNION AXIS adjustments. The geometric center of the protractor can be at fault, or the protractor is miss-marked in some way. 6. Usually no adjustments are available except on electronic PROTRACTORS. This will be a factory fix and once corrected should be permanent. **Step 14**: While not a part of the faceting machine, the 45-degree (or 90 degree) dop adapter can be a source of error and frustration. The adapter shank should have the same

diameter tolerance as the dops and lock into the CHUCK properly. Check that the shank is tight in the adapter body. The ROD should be a snug fit and positively locked into the

geometric center of the PROTRACTOR is not coincident with the TRUNNION AXIS. The PROTRACTOR scale could also be incorrectly divided.

1. If the angle is greater than zero degrees, i.e., the range is less than 90 degrees, and the error could be residual error in the FRONT to BACK PIVOT AXIS adjustment, or the

3. Install the ROD into the adapter. Locate the faceting head and set the height so the ROD is positioned between the edge of the LAP and the SPINDLE nut. The ROD should not touch the LAP. 4. Using the precision square or block, check that the ROD is perpendicular to the LAP on all sides. If there is residual PROTRACTOR error you will see it here. 5. This misalignment has three possible remedies, replacement, repair, or cheating. Unless the error is very large, just cheat, it's much cheaper.

**Step 15**: The transfer block is also a possible source of trouble. Apart from the mechanism that holds dops in the block, checking the alignment of the V grooves is easy. Simply place

the ROD in one of the V grooves of the transfer block, then slowly slide it into the other. If it slides in easily, place the ROD in the other V groove. If the ROD slides smoothly from both

[Footnote 1] PLATEN flutter is generally expressed as a vertical measurement (D), taken at some fixed distance from the SPINDLE AXIS. Since the PROTRACTOR ANGLE (A) changes as the ROD follows the turning LAP, another useful means of expressing flutter is the angle variation (F). The following formula expresses this angle as function of (L), (A), and

A = 90 degrees F = 0.012 degrees A = 60 degrees F = 0.013 degrees

(L) is defined as the length from the TRUNNION AXIS to the end of the ROD.

Assume L = 5 inches and D = 0.001 inches; then for

that about 0.001 inch flutter is the most that can be tolerated. This nonlinear formula shows why flutter is noticeable when cutting low angle facets and is imperceptible when cutting a girdle facet.

[Footnote 2] Machining the PLATEN should be done turning the SPINDLE on its own bearings. Turning the SPINDLE/PLATEN assembly on a lathe may not be good enough to insure the necessary precision. A small machinist's compound table and tool post should be clamped to the DECK of the faceting machine. This table will need to be very carefully set up so that the cutting tool will move along a radial path perpendicular to the SPINDLE AXIS. The faceting machine's motor is used to turn the SPINDLE. Blue the PLATEN surface and

LAP Flutter can be caused by debris between the PLATEN and LAP, a LAP with non-parallel faces, or a LAP with undulating surfaces. During the cutting process flutter is often caused

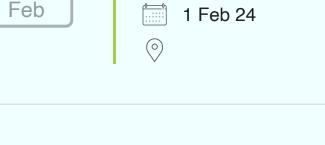
proceed to make very fine cuts until the blue is removed.

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by coarse grit laps, nearly worn out laps and by a loose SPINDLE nut.

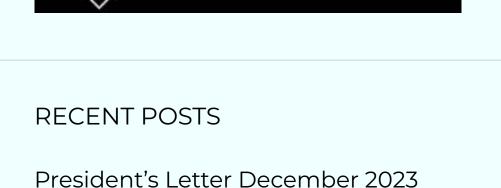
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