9.3 Advanced Maintenance

9.3.1 Overview

Each PCNC is tuned at the factory to meet or exceed certain precision metrics. These metrics are indicated on the *Certificate of Inspection* that is included with each mill, along with the actual values measured for each metric as part of Tormach's Quality Assurance program. The following advanced maintenance procedures may become necessary over the ownership lifetime to maintain the original factory precision:

- Gib adjustment
- Angular contact bearing preload adjustment
- Geometry adjustment (tram)

These adjustments are generally used to address component wear-in over time, but may also be needed to correct misalignment resulting from misuse, a hard crash of the system, or when some components are removed or replaced due to damage. The frequency of these procedures depends on both how the mill is used and how often.

The adjustments in this section should not be considered lightly as a wrong adjustment can adversely affect mill precision. Before making any of the adjustments in this section ask:

- Why am I making this adjustment?
- How will I measure the effect of this adjustment?
- What unintended consequences may result from this adjustment?

If you do decide to make an adjustment, do not assume where the error is from. The error could be attributed to a specific problem, or from the combined effect of several problems. Mistakenly making the wrong adjustment can make matters worse. As a practical example, if the Z-axis gib is too loose, it will cause the spindle head to tilt slightly downwards, toward the column. It would be fairly easy to incorrectly assume that the issue is with the column and base connection (often referred to as tram), and make an adjustment by inserting shims between the column and base. Instead of correcting the real issue, this adjustment causes the column to slant back to correct for the head leaning down. Now, the mill is running in a slight parallelogram in addition to a loose head.

9.3.2 Definitions

The following definitions are important to the advanced maintenance discussion.

Lost motion: the difference between commanded motion and observed motion. This is sometimes referred to as apparent backlash. There are a number of components of lost motion, including conventional backlash, bearing compressibility, sliding friction, and thermal expansion.

Backlash: the major component of lost motion in a machine tool axis. It results from the clearance between moving mechanisms. This is sometimes referred to as play. There are two sources of conventional backlash that can be adjusted on the PCNC:

- Space between gib and way needed to support an oil film. This is tuned by tightening the gib.
- The space between the ball bearings and races in the angular contact bearing pair that supports the ball screw. This is tuned by increasing the angular contact bearing pair preload.

9.3.2.1 How to Measure Lost Motion

Correctly measuring lost motion is critical to successfully undertaking any of advanced maintenance procedures detailed in the following sections. Mill setup and tuning is done under no-load conditions. The precision measurements recorded in the Tormach *Certificate of Inspection* are taken under no-load conditions. The accuracy of a machined feature is not an indicator of machine precision. Tool flex, workpiece flex, fixture flex, thermal expansion, and other factors contribute to the overall machined-part accuracy.

The following tools are essential:

- Dial indicator
- Dial test indicator
- Magnetic dial stand

The following method describes the proper procedure to measure X-axis backlash. An analogous procedure is used to measure Y- and Z-axis backlash.

1. Mount a dial indicator to the mill table along the X-axis to the left of the spindle, with the tip pointing at the spindle.

***NOTE:** If your indicator only reads in increments of .001", then the best you can hope for a reading is +/- .0005". For best results, use an indicator that has increments less than .001".*

2. Jog the Y- and Z-axis to position the spindle head so the indictor tip contacts the outer diameter of the spindle cartridge (see **Figure 9.1**).
3. Carefully jog the X-axis in the positive direction until the indictor contacts the spindle. After initial contact, continue to jog the X-axis in the positive direction so that the dial makes at least one complete revolution; stop when dial reads 0.
4. Zero the *X DRO* field in PathPilot®.

Figure 9.1

5. In MDI field, program a positive X move of .01” at a feed rate of 5 IPM: G01 X.01 F5. The spindle head moves slightly in +X direction. When finished, indictor should read .010”.
6. Program an X move back to 0: G01 X0 F5. The spindle head moves slightly in the -X direction. The X DRO should say 0; however, the dial indicator should read a number very close to 0. This value is the measured lost motion.

9.3.3 Gib Adjustment

9.3.3.1 Overview

PCNC mills use dovetail-gibbed ways to guide the X-, Y-, and Z-axis motion.

Over time, the dovetail ways and gibs wear from sliding friction and it may be necessary to tighten the gib to reduce axis backlash. To compensate for wear, the design of a dovetail-gibbed way allows for the position of the gib to be adjusted to maintain an appropriate sliding clearance.

A properly adjusted gib minimizes lost motion by balancing conventional backlash and sliding friction. A gib that is too loose results in excessive conventional backlash; a gib that is too tight cannot adequately support an oil film resulting in excessive sliding friction.

The position of the tapered gib plate is controlled by two screws on either end of the gib that capture the position of the gib with respect to the saddle. These screws can be adjusted (as a pair) to tune the tightness and sliding friction of the dovetail way for each axis. **Figure 9.2** shows the Y-axis gib mechanical detail; the X- and Z-axis have similar detail.

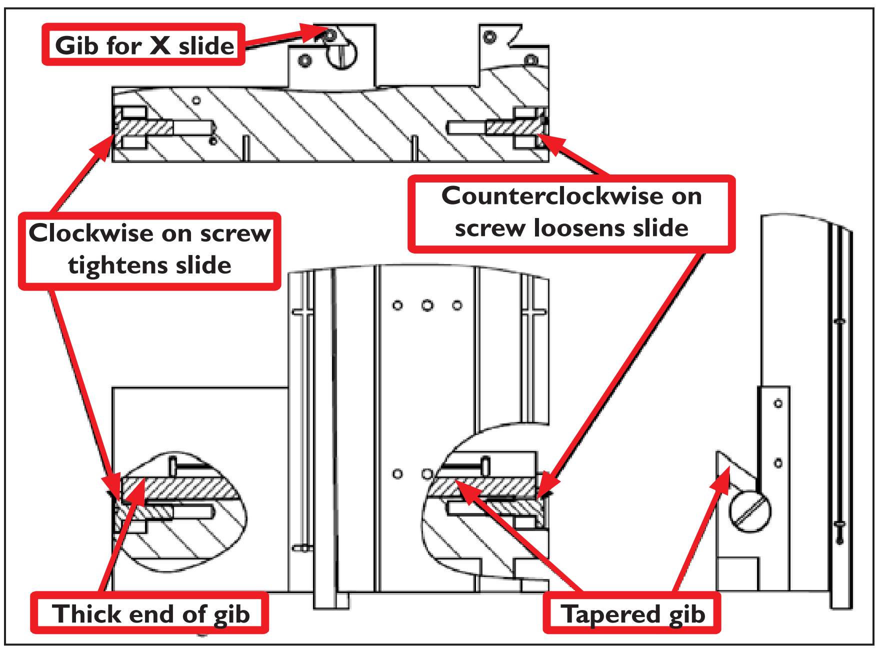

Figure 9.2

9.3.3.2 Adjustment Procedure

The gib tightening adjustment procedure for each linear axis is detailed in the table below.

Gib Plate	Tighten[1]	Notes
X-axis (PCNC 1100)	Left screw clockwise/right screw counterclockwise	No cover removal required
X-axis (PCNC 770)	Left screw counterclockwise/right screw clockwise	No cover removal required
Y-axis	Front screw clockwise/rear screw counterclockwise	Remove front and rear way covers to access gib screws
Z-axis	Upper screw clockwise/lower screw counterclockwise	Support spindle head with wooden block on table

[1]To loosen, reverse rotation direction indicated in table.

NOTE: *It is difficult to assess the correct clearance for the gib, as a very small adjustment can create a dramatic change in sliding fiction.*

The recommended method for gib adjustment is to measure axis lost motion while incrementally tightening the gibs to arrive at the correct setting. The following procedure describes this method for the Z-axis. A similar procure can be used to adjust the X-axis and Y-axis gibs; however, it should be noted that the X- and Y-axis gib adjustments cannot be considered in isolation. Tightening or loosening a gib on either axis also has an effect on the opposing axis.

1. Loosen the upper gib screw eight rotations and tighten the lower gib screw eight rotations. This ensures that the gib clearance is quite loose.
2. Use a dial indicator to measure lost motion in the Z-axis (refer to *How to Measure Lost Axis Motion* earlier in this chapter). With a very loose gib, the majority of the measured lost motion is attributable to the backlash in the angular contact bearing pair. On a new mill, this value measured should be less than 0.0015” on the Z-axis and less than .0013” on X- and Y-axis.
3. Tighten the gib by one turn by loosening the lower screw first, then tightening the upper screw. Measure the backlash again.
4. Repeat this procedure until the measured backlash begins to increase. At this point, the gib setting is slightly too tight.

5. Back the adjustment off to the point just before you saw the increased backlash. That is the ideal setting for the axis (see **Figure 9.3**).

NOTE: *After any gib adjustment, ensure that both adjustment screws are tight or the gib may move out of adjustment.*

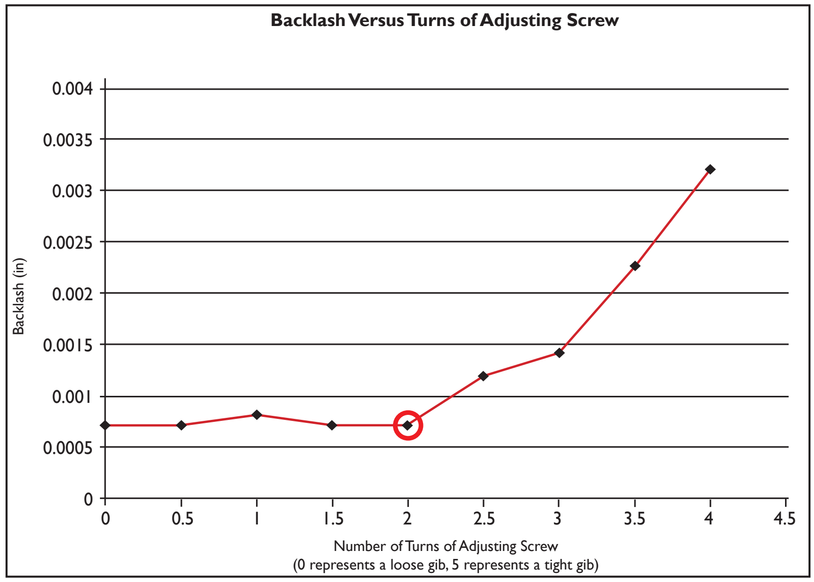

Figure 9.3

9.3.4 Angular Contact Bearing Preload Adjustment

9.3.4.1 Overview

Each axis utilizes a double-nut, pre-loaded ball screw. The pre-load in the ball nut is set at the factory by placing a precision ground spacer between the two ball nuts. Lost motion attributable to the ball screw assembly is less than 0.0004”. Ball nut preload is not operator-adjustable.

The ball screw mount bearings are located near the driven (motor) end of each ball screw. These are a pre-loaded angular contact bearing pair and are operator-adjustable. Under typical use, these bearings should be adjusted so that observable lost motion is between 0.0005” to 0.0013”.

Figure 9.4 and **Figure 9.5** show a cross section of a typical ball screw shaft mount. The ball screw shaft is in the center and the crosshatched section in **Figure 9.5** is the axis motor mount that houses the bearings. There are two angular contact ball bearings, forming a pre-loaded pair. The ball screw *Cover Plate* holds the two outer races together, along with the *Spacer* that is between them.

The inner races are held between the *Sleeve* (left side) and the shoulder cut into the ball screw shaft (right side). The *Sleeve* is held against the left inner bearing race by the *Adjustment Nut* and a *Lock Nut*. When the *Adjustment Nut* is screwed tighter toward the bearing pair, the preload increases.

Over time, it may become necessary to adjust the ball screw bearing preload to account for bearing wear. The bearing preload will also need to be adjusted if a bearing replacement becomes necessary.

Improper ball screw bearing preload will result in either excessive backlash in the mill if it is too loose, or rapid wear and excessive friction if it is too tight. It should be noted that if your ball screw, ball nut, or angular contact bearings are worn, or if your gibs are adjusted too tight, you will not achieve appropriate lost motion values.

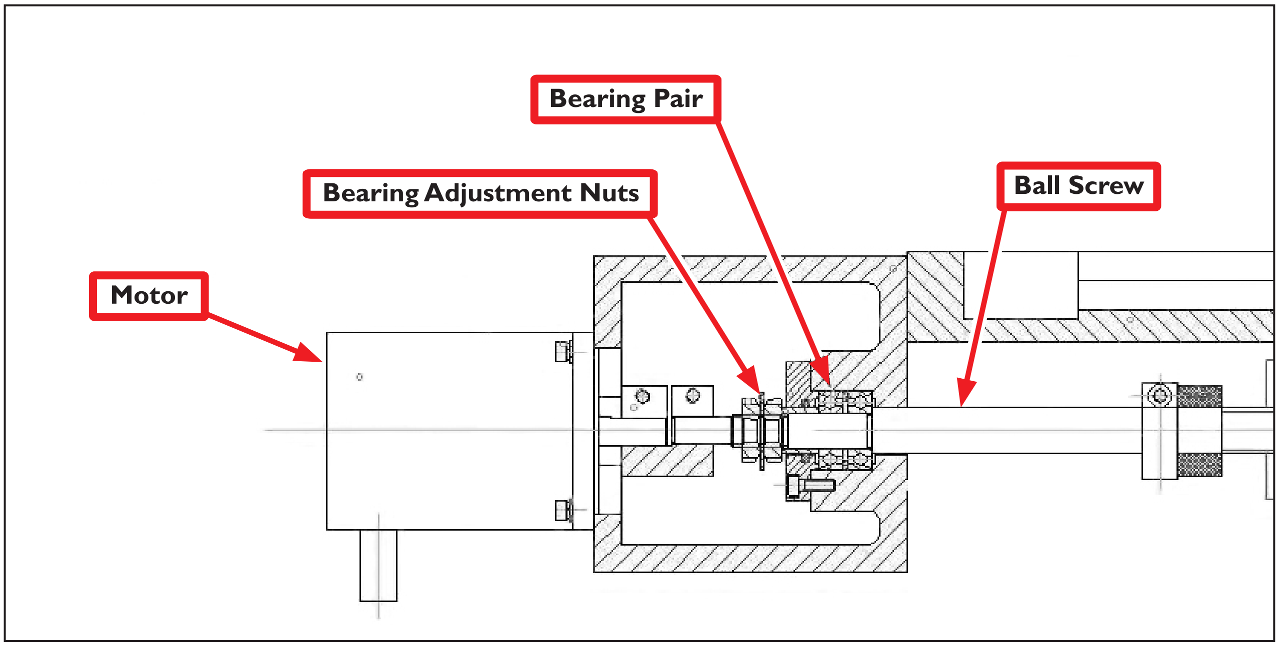

Figure 9.4

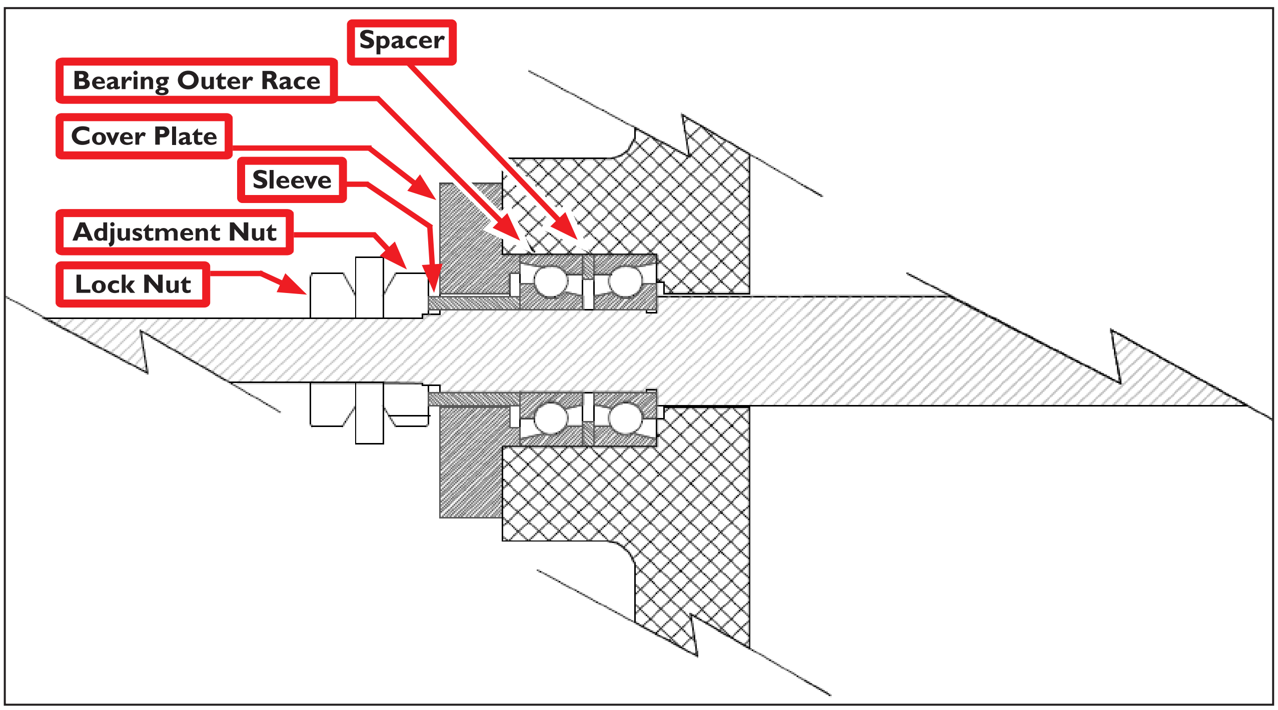

Figure 9.5

Figure 9.6 shows how the force of preload is transmitted through the bearings, from the inner race to the outer race. In a preload pair, this force is then transmitted back to the inner race by an opposed bearing. It should be apparent that the correct orientation of the angular contact bearing is critical to the operation.

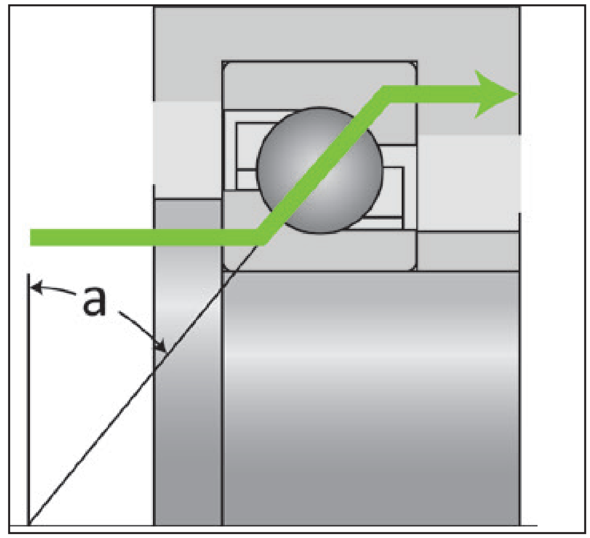

Figure 9.6

9.3.4.2 Adjustment Procedure

To adjust the angular contact bearing pair preload, the following kit is required (see **Figure 9.7**):

PN	Description
35355	AC Bearing Service Tool Kit

There are two nuts: the adjustment nut and the lock nut. The nut nearer the bearing housing is the adjustment nut, and the one nearer the axis motor is the lock nut (see **Figure 9.5**).

NOTE: *When working on the Z-axis, remove any tooling from the spindle and support the head by resting the spindle nose on a block of wood.*

1. Loosen the lock nut and back it off about two turns.
2. Hold the ball screw to prevent it from rotating with a pair of pliers on the coupling and tighten the adjustment nut until there is slightly more backlash than you ultimately want to achieve. Tightening the lock nut will slightly increase the bearing preload.

Figure 9.7

9.3.4.3 Determining Proper Angular Contact Bearing Preload

To properly estimate the torque needed to overcome angular contact bearing friction, the bearings must be isolated from the stepper motor detent torque. Use the following procedure:

1. For adjusting the X-axis, position the table near the right hand end of its travel (i.e., X near to zero). This ensures that the bearing is near to the ball nut to minimize bending of the screw during tests.

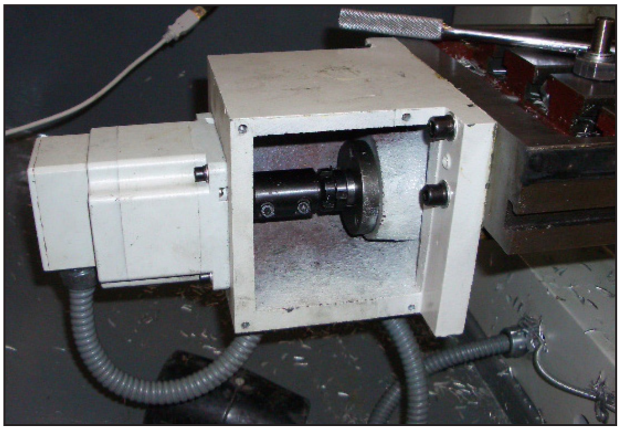

Figure 9.8

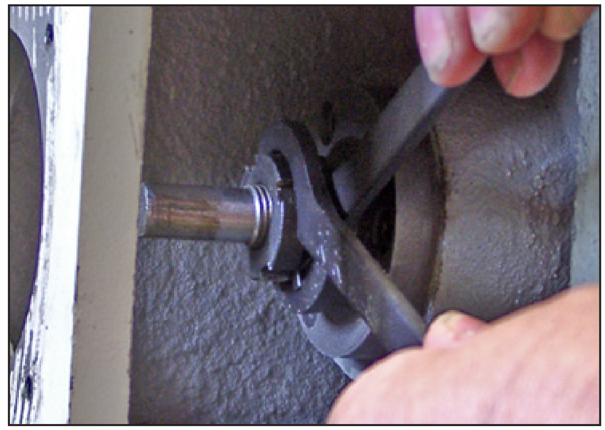

Figure 9.9

2. Remove X-axis motor mount cover plate (see **Figure 9.8**).
3. Loosen two screws clamping the coupling between the stepper motor shaft and ball screw end.
4. Remove four cap screws holding the axis motor to the motor mount and remove axis motor. Take care not to put any strain on the motor wires.
5. Insert a 1/2” diameter rod (included in AC Bearing Service Tool Kit, PN 35355) or drill blank into the coupling. This will effectively extend the ball screw shaft outside of the motor mount.
6. Clamp a handwheel or vise grip on the end of the rod; this allows sensitive feel for the torque caused by the preload on the bearings. Rotation should be smooth with a small perceptible drag; this corresponds to a medium preload of about 150 pounds. If the rotation feels tight, you have too much preload and will dramatically shorten the life of the bearings. If the rotation is free, you have little or no preload and backlash will be excessive. This test should be done with the lock nut tight.
7. Using kit’s spanner wrenches as shown **Figure 9.9**, adjust preload (refer to *Adjustment Procedure* section earlier in this chapter).
8. Re-mount box and motor; ensure that coupling is symmetrically fitted to the motor shaft and the screw end and is fully tightened (see **Figure 9.9)**.

9.3.5 Geometry Adjustment of Precision Mating Surfaces

All precision mating surfaces are pinned together with tapered dowels during assembly at the factory. The pinned connection ensures that factory alignment is maintained in the event of a tool crash. Each dowel pin has a small metric threaded hole in the center that can be used to extract the dowel should it be required for disassembly.

Under typical usage, no adjustment of pinned connections should be necessary. In the event of a hard crash, shims can be used to make minor alignment adjustments between pinned components. Small adjustments (less than .010”) will generally not require a full disassembly of the pinned connection. In these cases, the alignment dowels can be left in place, and the shims can be inserted into a small opening created by loosening the bolted connections.