CMM TUTORIAL MANUAL

GEOMETRIC DIMENSIONING AND TOLERANCING USING PC-DMIS

A step-by-step guide for ME 203 students

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INTRODUCTION

This tutorial teaches you to operate Coordinate Measuring Machines (CMMs) using PC-DMIS software. Whether you're new to CMMs or not, you'll learn basic machine operation through advanced geometric dimensioning and tolerancing (GD&T) measurements.

By the end of this tutorial, you will be able to:

- Set up and configure PC-DMIS software
- Operate the CMM hand controller safely
- Take accurate measurements on physical parts
- Perform dimensioning and tolerance analysis
- Generate measurement reports

This manual assumes you understand basic engineering drawings and geometric tolerancing concepts.

COORDINATE MEASURING MACHINE (CMM)

A coordinate measuring machine (CMM) measures component geometry by capturing discrete points on surfaces with a probe. CMMs use touch-trigger, scanning, and vision probes with mechanical, optical, laser, or white-light technologies. Operators control the probe manually or automatically via Direct Computer Control (DCC).

CMMs measure a probe's position relative to a reference position. The typical 3D bridge CMM moves the probe along three orthogonal axes (X, Y, and Z) in a Cartesian coordinate system. Each axis has a sensor that monitors the probe's position with micrometer precision. In addition, the probe can be angled to measure surfaces that would otherwise be unreachable.

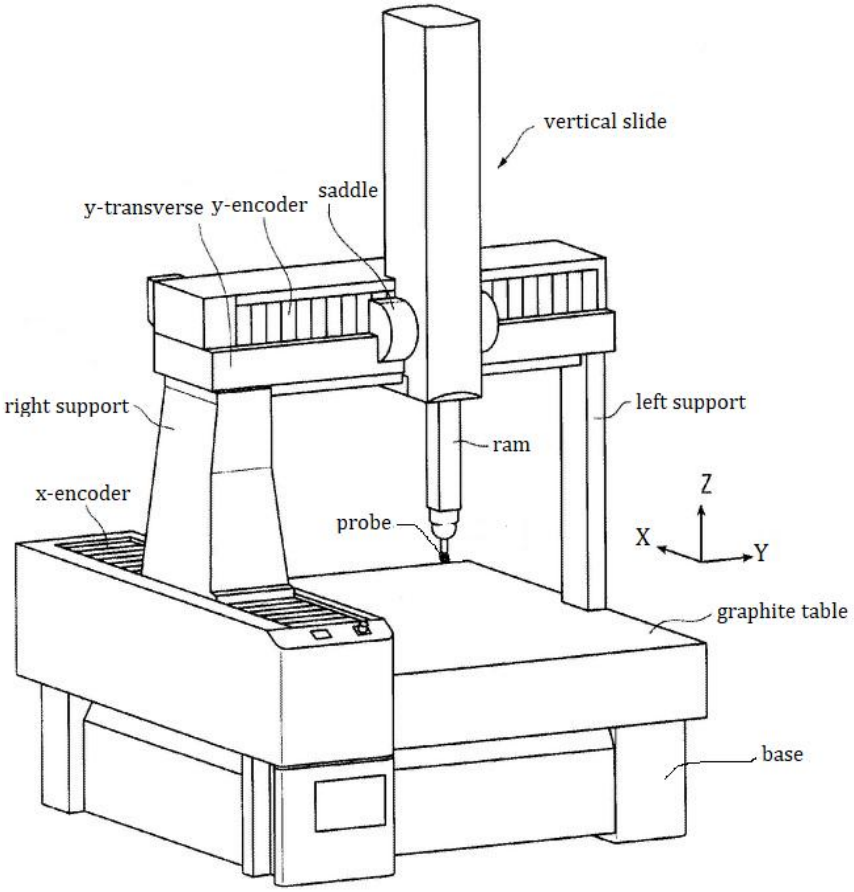
When the probe contacts the surface, the machine samples all three position sensors to record the point location. Repeat this process at multiple surface points to create a point cloud that describes the areas of interest.

CMMs commonly test parts or assemblies against design intent during manufacturing and assembly. Regression algorithms analyze these point clouds to construct and verify features.

PARTS OF A CMM

CMMs include three main components:

- The main bridge structure, which includes the base, graphite table, right and left supports, saddle, and three axes of motion.
- Probing system
- Data collection and reduction system — typically includes a machine controller, desktop computer, and application software (in this case, PC-DMIS).



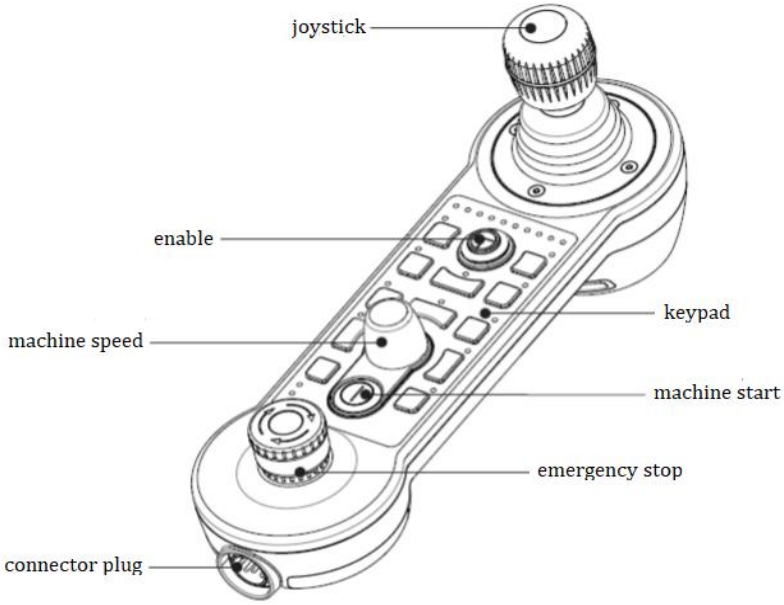
COORDINATE MEASURING MACHINE: main structure and probing sytem

THE DATA COLLECTION AND REDUCTION SYSTEM

HAND CONTROLLER

Use the hand controller to:

- Respond to prompts from the computer
- Move and position the probe
- Control the speed of the probe
- Turn servo power on.

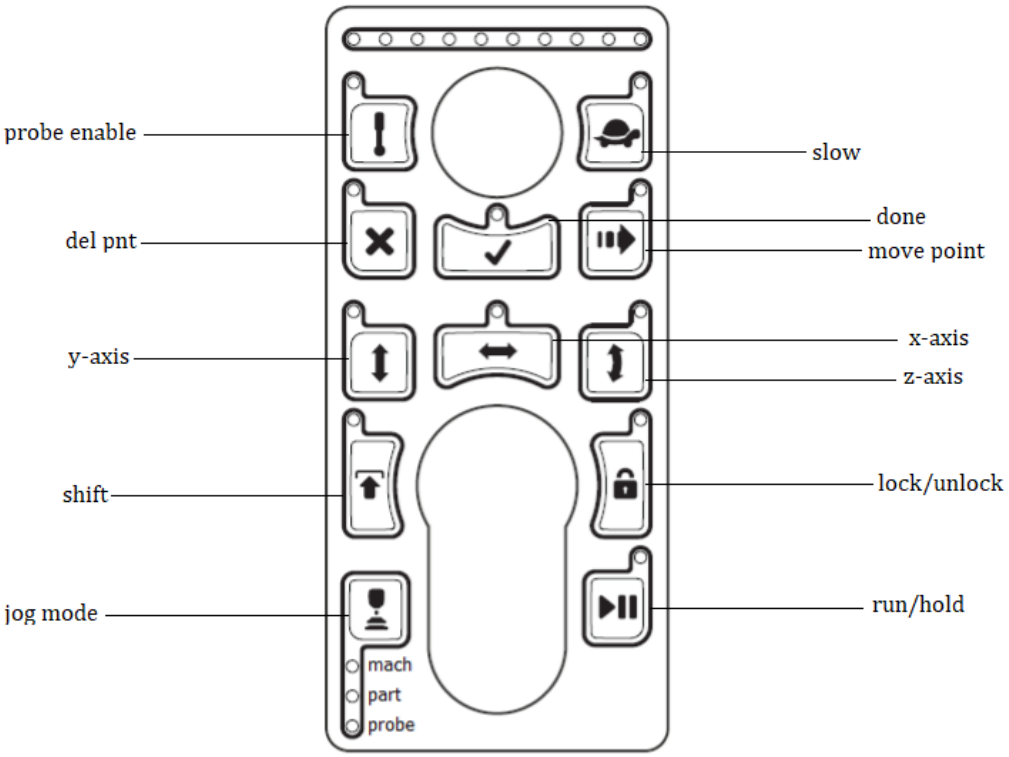


HAND CONTROLLER

PARTS OF A CONTROLLER

1. **Joystick** - This controls probe direction and position. Tilt the joystick to move the probe along the machine's axes (as indicated on the portable station); rotate it to move the probe up or down.
2. **Enable** - This enables movement; it prevents unwanted movement by default. Press and hold this button while steering the joystick to move the probe. In DCC mode, the CMM controls movement automatically, so this button is disabled.
3. **Machine speed** - This controls the probe speed. Rotate the knob to increase or decrease the speed of movement.
4. **Connector plug** - This hub connects the cable to the controller.

5. **Emergency stop** - This triggers an **ESTOP** condition. Press this latching button to interrupt power to the motor drive circuits by de-energizing a control relay. The joystick won't work in this condition. To re-enable the system, unlatch the **ESTOP** button (rotate it clockwise a quarter turn). After resolving the emergency, hold **MACH START** for about 2 seconds. The program may need to be reloaded.
6. **Machine start** - This starts the homing procedure. Press and hold for about one second to power the servo drive system.
7. **Keypad** - This contains controls for operating the machine. The following list explores the other buttons on the controller's keypad:



KEYPAD

- **probe enable**: This indicates one of three conditions:
  - *Not Illuminated* - The probe is enabled, but the controller will not report points.

SAFETY PRECAUTION
The controller ignores all probe signals, so the machine won't stop after a point is registered. Never take points in this condition; you may damage the probe.

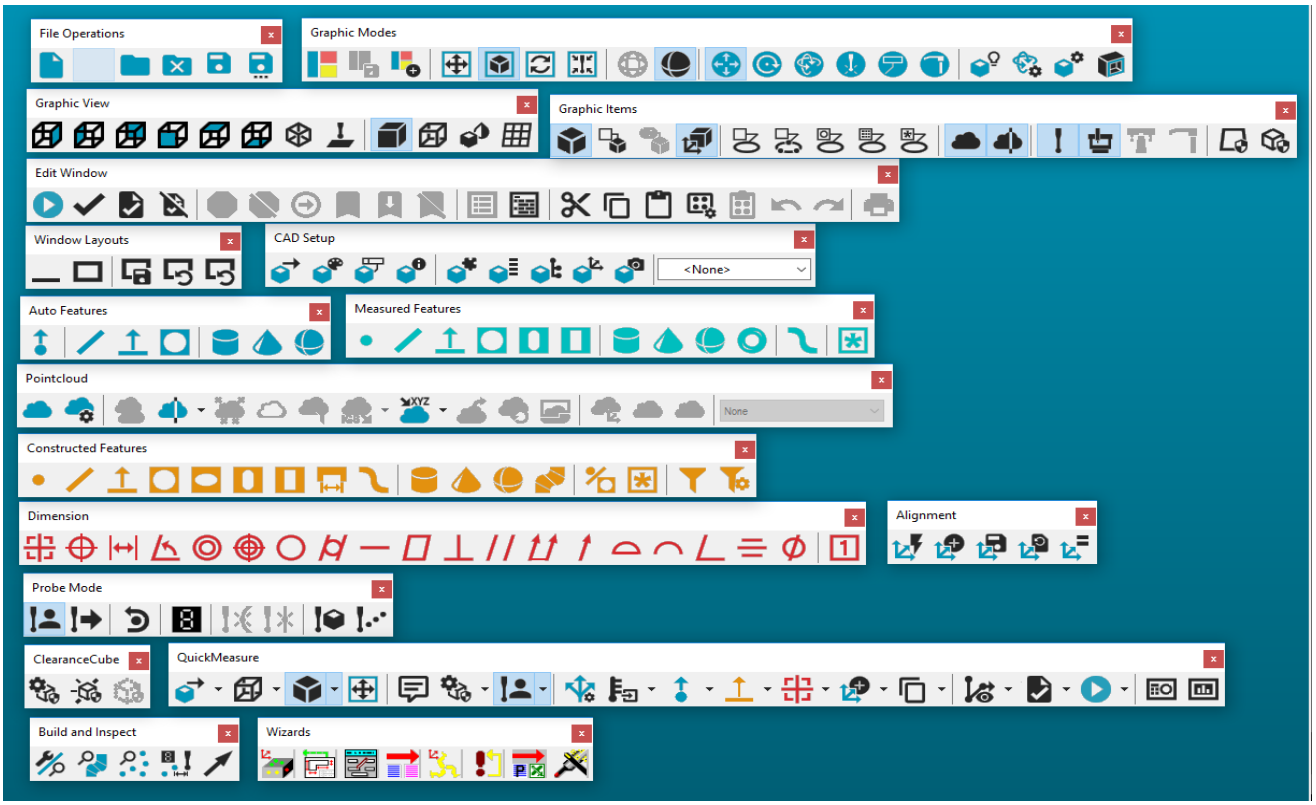
- *Illuminated* - The probe is enabled, and the host computer is ready to accept points.
- *Flashing* - The probe is temporarily disabled. Use this when manually aligning parts or cleaning the probe tip. The system won't record hits. Re-enable the probe to change the light from flashing to solid.

- **slow**: This button toggles between slow movement (LED on) and fast movement (LED off).
- **del pnt**: This will delete the last manual point.
- **done**: This is used to accept and register software commands. Function varies by software.
- **move point**: This learns positional moves, enters points, or continues program execution when prompted. Press to record coordinates at the current probe location. Function varies by software.
- **axes buttons:** These constrain the movement to the selected axes. Axes with illuminated LEDs are active. When **SHIFT** is active, the upper register X, Y, and Z axes cannot be activated, but the lower register A and B axes can be activated if available. X, Y, and Z represent machine axes. A and B represent motorized wrist axes. Press the x/y/z axis button to unlock the joystick and enable movement. Move the machine axially by pressing the appropriate axis button and steering the joystick.
- **shift**: This accesses lower registers of dual-function buttons - **X/A**, **Y/B**, **Z/W**, **LOCK/UNLOCK**, **RUN/HOLD**. When active, the lower registers can be accessed. W is for other machines with optional rotary tables.
- **lock/unlock**: To lock and unlock the probe head.
- **jog mode**: LEDs indicate the current motion mode (**PROBE/PART/MACH**). Toggle these settings to adjust how you manually steer the probe. This promotes perpendicular probe contact, improving accuracy and repeatability.
  - **MACH**: probe moves in the machine's coordinates (default).
  - **PART**: probe moves in part coordinates.
  - **PROBE**: probe moves along its center axis.
- **run/hold**: This is a two-function button. Press **HOLD** to stop program execution, press **RUN** to resume.

PC-DMIS

PC-DMIS is the key software for CMM data collection and reduction. Use it to create and execute measurement routines and collaborate on results. PC-DMIS provides a comprehensive GD&T toolset, discussed later in this manual.

Familiarize yourself with the Edit Window, QuickMeasure, and Dimension toolbars. These will be used frequently throughout this manual.



SETTING UP PC-DMIS

1. **Launch PC-DMIS**
    a. Double-click the PC-DMIS icon on the desktop.
    b. From the menu bar, click **File → New**.
    c. In the dialog box:
        a. Enter a filename in the *Filename* field.
        b. Set *Units* to your preferred choice (inches or millimeters).
        c. Click **OK**.
    d. When the "Temperature Compensation" dialog appears, click **Cancel** unless your work involves temperature changes.

2. Set the probe

The Probe Utilities dialog opens.

1. Select the type of probe you are using from the dropdown menu.
2. In the *Angle* field, select **`T1A0B0`** to set the angle to 30° (pointing down). This sets the probe normal to the surface of the graphite table.
3. Click **OK**.

3. Check the angle

In the Editor window, locate **`LOADPROBE`** and verify the angle changed.

If the angle hasn't changed:

1. In the QuickMeasure toolbar, click **PROBE TIP → `T1A0B0`**.

SAFETY PRECAUTION
Before proceeding to do anything else, ensure the area surrounding the probe or CMM is free from anything that could cause damage.

2. When the confirmation dialog appears, click **Yes** to rotate the wrist.

4. Import the CAD file

1. From the menu bar, click **File → Import → IGES**.
2. Navigate to and select your part file (.igs extension).
3. Click **Import**.

NOTE
*The part file must have a **.igs** extension for PC-DMIS to be able to run it*

5. Fix the surface vectors

1. In the "IGES Import" dialog:
    a. Check the **Fix surface vectors** checkbox.
    b. Click **Process**.
2. When processing reaches 100%, click **OK**.
3. After importing, verify that all CAD vectors are normal to the part surface.

MANUAL DATUM SPECIFICATION

To specify a datum, at least 3 points must be marked on the block.

1. In the QuickMeasure toolbar:
    a. Click the dropdown arrow next to **Graphic Mode**.
    b. Select **Program Model**.
    c. A virtual probe appears on screen. Select four random points. Verify the CAD vectors are normal to the surface.
    d. Press the **End** key to register the surface as the first plane.
    e. Repeat this process for two more datums.
2. Check the Editor Window to verify points registered as expected features. For example, ensure that the editor registers the first surface as a plane rather than a line. If not, override the editor's guess.
3. Execute the code in the editor window.

SAFETY PRECAUTION
Before clicking execute, ensure the speed on the hand controller is set to zero (no steady green light), and slow mode is enabled.

The editor color-codes the code:

- **Green**: Already done
- **Blue**: currently working on
- **Yellow**: yet to be worked on

TAKING POINTS ON SURFACE

1. Secure the block properly on the graphite table before taking any measurements.
2. A dialog prompts you to take the first point.
3. Set the speed between the minimum and maximum using the **machine speed** knob. Press and hold the **enable** button and use the joystick to move the probe.

SAFETY PRECAUTION
When close to the surface, move slowly to avoid deflection and ensure accurate readings.

4. After the first point, the machine beeps and records the reading.
5. Repeat these three more times.

SAFETY PRECAUTION
When done, move the probe far away from the surface and set controller speed to zero

NOTE
To crosscheck number of readings taken, look at the bar at the bottom edge of the PC-DMIS screen where points taken are displayed

6. The dialog prompts you to end the plane after recording all points. Press Done to register the datum. Repeat for the remaining datums.

NOTE
If a surface is thin, just one point *can be taken. The only downside to this is that you cannot use this surface to check for parallelism or perpendicularity*

ALIGNMENT

A block can be aligned in six degrees of freedom: three translations and three rotations, each in the x, y, and z axes.

1. To align a part:
    a. Click at the end of the Edit Window to set the cursor there for new readings.
    b. In the QuickMeasure toolbar, click **Alignment**.
2. In the dialog:
    a. Select the top datum.
    b. Set *Level* to **z+**.
    c. Click **Level**. The origin moves up to align with the top surface.
    d. Select the front datum. To eliminate rotations around the z and y axes, rotate to **y- about z+** and click **Rotate**.
    e. Select the top datum once more to fix translation. Check the box next to z and click **Origin**.
    f. Select the front datum again and check the box next to y. Click **Origin**.
    g. Select the side datum and check the box next to x. Click **Origin**.
    h. Click **OK**.

DIMENSIONING

Measure individual surfaces to determine overall block size.

NOTE
More readings make for accurate measurements

CIRCLES

1. Fix z.
2. Take readings of your circle.
3. Rename the feature ID.
4. In the QuickMeasure toolbar, click **Dimension → Location Dimension**.
5. In the "Feature Location" dialog:
    a. Select the circular feature you want to dimension.
    b. In the axes section:
        - Uncheck **Auto**.
        - Check **R** (radius).
    c. Verify *Units* match your preference (inches or millimeters).
    d. Click **Create**, then **Close**.
6. To view the results, click **Report Window** in the QuickMeasure toolbar.
7. Click the **Report Window** again from the QuickMeasure toolbar to close it.

SURFACE ANGLE

1. Create a datum for each of the inclined and straight sides.
2. Execute from cursor.
3. Take four points for each side of the surface.
4. Rename the feature IDs.
5. In the QuickMeasure toolbar, click **Dimension → Angle Dimension**.
6. In the "Angle" dialog:
    a. From the *Sort ID* list:
        - Select the straight side feature name. This becomes your reference.
        - Select the inclined feature name.
    b. Select **3D Dimension**.
    c. Click **Create**, then **Close**.
7. Take a look at the **Report Window**.

FILLET

1. Fix z.
2. Take at least three points. For this example, take six points on the curved edge.
3. Rename the feature.
4. Take readings of the circle it shares a center with.
5. Rename that feature as well.
6. In the QuickMeasure toolbar, click **Dimension → Location Dimension**.
7. Select the feature name of the concentric circle, then click **Create**.
8. Click the curved edge's feature name.
9. Click **Create**, then **Close**.
10. Take a look at the **Report Window**.

FORM TOLERANCES

Before anything else, ensure the cursor is at the end of the edit screen.

FLATNESS

1. Take 8-10 points on the top surface.
2. Rename the feature ID.
3. In the QuickMeasure toolbar, click **Dimension → Flatness**.
4. In the "XactMeasure GD&T" dialog:
    a. From the *Feature* list, select the flatness feature.
    b. Set the *Tolerance* to the nominal value.
    c. Click **Create**, then **Close**.
5. Take a look at the **Report Window**.

CYLINDRICITY

1. Fix z.
2. Take 3 points at the top of the inner cylinder.
3. Enable z and go down the inner cylinder.
4. Fix z once more.
5. Take 3 points at the bottom of the inner cylinder.
6. Press **done** on the controller.
7. In the QuickMeasure toolbar, click **Dimension → Cylindricity**.
8. In the "XactMeasure GD&T" dialog:
    a. From the *Feature* list, select the cylindricity feature.
    b. Set the *Tolerance* to the nominal value.
    c. Click **Create**, then **Close**.
9. Take a look at the **Report Window**.

ORIENTATION TOLERANCES

PARALLELISM

1. In the QuickMeasure toolbar, click **Dimension → Parallelism**.
2. In the Feature Control Frame tab:
    a. Set the *Geometric Tolerance* to the nominal value.
    b. Set the *Material Condition* to **RFS** (leave empty/blank).
    c. Click the **[+]** button next to the frame.
    d. In the "Datum Definition" dialog:
        - Select the front datum to make it your reference.
        - In the *Datum* field, the default name is A. This can be changed to any letter.
        - Click **Create**, then **Close**.
    e. Click **[+]** again to set A as the primary datum.
3. In the "XactMeasure GD&T" dialog:
    a. From the *Feature* list, select the parallel feature.
    b. Set the *Tolerance* to the nominal value.
    c. Click **Create**, then **Close**.
4. Take a look at the **Report Window**.

PERPENDICULARITY

SURFACE

1. In the QuickMeasure toolbar, **Dimension → Perpendicularity**.
2. In the Feature Control Frame tab:
    a. Set the *Geometric Tolerance* to the nominal value.
    b. Set the *Material Condition* to **RFS** (leave empty/blank).
    c. Click the **[+]** button next to the frame.
    d. In the "Datum Definition" dialog:
        - Select the front datum to make it your reference.
        - In the *Datum* field, the default name is A. This can be changed to any letter.
        - Click **Create**, then **Close**.
    e. Click **[+]** again to set A as the primary datum.
3. In the "XactMeasure GD&T" dialog:
    a. From the *Feature* list, select the flatness feature.
    b. Set the *Tolerance* to the nominal value.
    c. Click **Create**, then **Close**.
4. Take a look at the **Report Window**.

AXIS

1. In the QuickMeasure toolbar, **Dimension → Perpendicularity**.
2. From the *Feature* list, select **cylinder**.
3. In the tolerance input fields above the Feature Control Frame tab:
    a. Enter the plus tolerance value (before the **/** symbol)
    b. Enter the minus tolerance value (after the **/** symbol)
    c. Enter the diameter value
        • Note: Do not include +/− signs; the software adds them automatically
    d. Set the *Material Condition* to **RFS** and the *Primary Datum* to **Flatness**.
4. Click the dropdown arrow next to **Primary Datum A**. You'll see:
    [x] to delete datum definition, and **[+]** to add datum definition.
    Choose **[+]**.
5. In the "Datum Definition" dialog box, click **Flatness → Create → Close**.
6. Click the dropdown arrow next to **A** and choose **Datum Definition B** as your secondary datum.
7. Click **Close**.

TRUE POSITION TOLERANCES

Measure the cylinder's true position tolerance using both RFS and MMC.

Regardless of Feature Size (RFS)

1. In the QuickMeasure toolbar, click **Dimension → Position Dimension**.
2. In the dialog box, from the *Feature* list, click **cylinder**.
3. In the Feature Control Frame tab, set the *Feature Tolerance* value and *Material Condition* to RFS (the empty option).
4. In the Nominals tab, click **Nominal**.
5. Set the x, y, and df values, and df tolerance.
6. Close the dialog box.
7. Take a look at the **Report Window**.

Maximum Material Condition (MMC)

1. In the QuickMeasure toolbar, click **Dimension → Position Dimension**.
2. In the dialog box, from the *Feature* list, click **cylinder**.
3. In the Feature Control Frame tab, set the *Feature Tolerance* value and *Material Condition* to MMC (the M option).
4. In the Nominals tab, click **Nominal.**
5. Set the x, y, and df values, and df tolerance.
6. Close the dialog box.
7. Take a look at the **Report Window**.

CONCLUSION

This manual covered essential CMM operations with PC-DMIS, from basic setup through advanced tolerance analysis. With practice, these procedures will become second nature.

For additional support or questions not covered in this manual, consult your instructor or the PC-DMIS Help documentation.

Remember: Always prioritize safety when operating the CMM. Move slowly near surfaces, maintain awareness of the probe's position, and set the controller speed to zero when not measuring.

QUICK REFERENCE

NORMALIZING VECTORS TO SURFACE

1. From the menu bar, click **Edit → Graphic Display Window → CAD Vectors**.
2. In the dialog box, highlight the whole part on the display window.
3. Click **Fix surface vectors**, then **Close**.

OVERRIDING A FEATURE ID

1. Select the feature ID you wish to change.
2. From the menu bar, click **Edit → Override Guess → Plane.**
3. In the dialog box, confirm you want to change the feature ID.
4. In the Editor Window, double-click the feature name and rename it for easier tracking.

EXECUTING CODE IN EDITOR WINDOW

1. In the QuickMeasure toolbar, click the dropdown arrow next to **Mark**.
2. Select **Clear Marked**.
3. Click the **Mark** dropdown arrow again and select **Mark All**.
4. In the dialog box, confirm it’s okay to mark manual alignment.
5. In the QuickMeasure toolbar, click **Execute**.

JOYSTICK MOTION

When using the joystick, motioning:

- **Counterclockwise** moves the probe down.
- **Clockwise** moves the probe up.
- **Forward (away from you)** moves the probe in the positive y direction.
- **Backward (towards you)** moves the probe in the negative y direction.
- **Left** moves the probe in the negative x direction.
- **Right** moves the probe in the positive x direction.

FIXING Z

1. Press the z-axis button on the hand controller and ensure the green LED light is off. This disables motion in the z direction.
2. Simultaneously steer the joystick and check the z coordinate on the bar at the bottom edge of the PC-DMIS screen. If the coordinate remains unchanged, z is fixed.

EXECUTING FROM CURSOR

In the QuickMeasure toolbar, click the dropdown arrow next to **Execute**. Click **Execute from cursor**.

REPORT WINDOW

The **Report Window** displays measured and nominal values, tolerances, deviations, and out-of-tolerance values. Each feature is color-coded on the right. Colors indicate:

1. **No color/grey:** measured value is equal to the nominal value
2. **Black:** measured value is slightly off the nominal value
3. **Green:** measured value is within the tolerance range of the nominal value
4. **Yellow:** measured value is on the borderline of the nominal value
5. **Red:** measured value is out of tolerance range
6. **Purple:** measured value is between the upper tolerance range and the out-of-tolerance range. This occurs when measurements are too small for accurate CMM readings.