Interim Tests

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Purpose

Interim tests are performance checks of a CMM that are done regularly between calibrations. Interim checks are important as they can proactively indicate that a problem exists with a machine and can also provide confidence in the equipment.

This article is written to describe different methods for CMM interim checks.

Items Affecting CMM Accuracy

There are several reasons the accuracy of a CMM may change. In some cases the changes are gradual while in other cases the changes are abrupt and happen as a result of some specific event or change to the system. The most common reasons for changes in the CMM are listed in the following sections.

Software Upgrades

When upgrading the CMM software a common mistake is not checking all compensation related settings. Some settings are minor while others are extreme (such as having the compensation map disabled completely). Even when experienced people upgrade software there is still a chance one or more critical settings are overlooked.

Based on past observations **any** software upgrade should be followed up by a machine test to verify that the CMM is still measuring properly.

Machine Repairs

Depending on the type of machine repair it is possible there are inadvertent changes which can affect accuracy. This covers both electronic and mechanical repairs and it depends on the purpose of what is repaired.

Most new controllers have as few discrete parts as possible so changing a logic card, for example, would likely represent the bulk of the controller. If this contains machine parameters, compensation data, or other machine specific data this kind of repair can affect machine accuracy if these settings are not duplicated precisely on the new system. In the event it is not possible to access the existing settings the potential for a mistake increases significantly.

Changing the machine scales or air bearings will have an obvious effect on the machine accuracy so no additional comments are needed about this. Changing motor gear boxes, limit switch positions, or even the placement of the machines stands under the machine table could affect the accuracy of the machine. There are many mechanical changes that can be done to a machine which have a questionable affect on the machine itself. The safest thing to do in this case is run a test of the machine to be sure it still measures properly.

Environmental Changes

The machine environment is usually the biggest concern for an accurate CMM. More significantly is when there are changes to the environment that have unexpected influence on the machine. If a machine is setup in an established environment, good or bad, it will work best under those conditions as it was adjusted in those conditions. A machine in a bad thermal environment (with large temperature gradients for example) that is suddenly subjected to a very good environment with very small thermal gradients will change significantly. The reverse is true as well but when improving the environment the expectation is the machine accuracy will automatically improve where in reality the machine accuracy has changed.

Contaminating Effects

Most CMM machines use air bearings for all moving parts of the machine. The air bearing gaps vary based on the type and size of bearing but generally in the area of 0.010 mm for a medium sized bearing. Air bearings are sensitive to dirt and oil and any build up between the bearing surface and guide way can easily change the machine dynamics.

Shop floor models of CMM's tend to use hard bearings instead of air bearings primarily due to dirt and other particulates that can settle on a machine. Machines installed in a shop floor environment that use air bearings require extra attention to keep all critical bearing surfaces clean and oil free.

If dirt is allowed to build up between the air bearings and the bearing surface ways the machine characteristics can be changed. A dragging bearing on certain parts of machines will appear as a hysteresis error which could manifest itself in a variety of ways (noticeably wrong diameter measurements with larger form errors is one possible outcome of a hysteresis error). The machine servo drives will work a little harder to keep the machine moving at the expected speed. If the contaminating material is abrasive then this can scratch both the bearing and bearing guide ways resulting is a smaller bearing surface area and a smaller air gap.

Changes from a build up of dirt or other contaminants can affect the machine over a period of time. Dirt or other contaminants that initially find their way into sensitive areas of the machine will have an immediate affect on accuracy.

Crashes

All equipment is subject to unwanted events such as collisions. CMM's that are faster are more likely to crash and, due to the faster speed, are more likely to damage something. Machines that are used by 'new' operators are prone to unintentional collisions.

Damage from collisions could be limited to just the probe or may extend into the structure of the machine. In some extreme cases air bearings have been dislodged and major CMM structures have cracked requiring extensive and expensive repairs. The big problem is when a collision occurs that affects the machine somewhere between minor and obvious.

Requirements For Interim Tests

Testing the machine is good but in practice this is an unwanted use of the equipment. When machines are purchased the goal is to use them productively and not to spend time testing them. With this in mind the ideal interim test for a CMM would have the following characteristics:

- Fast. The less time it takes to run any kind of test on a machine is ideal. Time spent on testing can subtract from the time available for the primary use of the equipment.
- Simple. Tests that are simple to run are always better than complicated methods. There is a tradeoff somewhere between the two extremes since the more complex methods tend to reveal more.
- Minimal operator intervention. A test that is completely automated is preferred over one

that requires constant attention by an operator. This may become a training issue if the test is complicated.

- Comparable results. Machine specifications are often used as a basis for deciding if the CMM is performing properly. Running a test produces results that cannot be related to a measurement standard can pose a problem as it can be difficult to ascertain if the results are acceptable or not.
- Sufficiently reliable. The test must be able to detect when the machine is not measuring properly. If the test cannot detect obvious machine errors then it is not even worth running.

Tests that produce results that cannot be related to a measurement standard can be useful. If the test is performed immediately following a calibration all future measurement results can be compared to the first measurement. The first measurement becomes a base line for all future results.

Interim Test Methods

Several methods can be used for interim tests of a CMM; a few of the methods are listed in the following sections. As with all testing it is important to keep records so that measurements can be compared to past results.

Master Part

If a machine is dedicated to measuring one particular type of part then the best method to perform an interim test is to have a part with known results and measure this regularly. Each time this master part is run the measured results can be compared to the expected results.

If the master part is a high precision gauge quality (i.e. a perfect part) then this can also be used to validate that the part programs are correct. If the master part is calibrated then this may also be used to defer the machine calibration in favor of the master part calibration as it is only necessary to demonstrate capability.

One disadvantage of this method is that it can only reliably demonstrate that the machine is capable of measuring this particular part. A good measurement of the master part does not necessarily mean the machine is without problem that may appear when measuring a different type of part.

Another disadvantage is that it is nearly impossible to set measurement tolerances based on machine specifications since these results cannot be directly compared to the specifications of the machine.

The master part can be checked in different orientations of the machine, if possible. This can help identify machine problems by using the master as a kind of test artifact.

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Advantages	*Disadvantages*
• Easy to perform test. • Can be used to evaluate part program changes if the master part is gauge quality. • May be able to defer calibration of the CMM to the master part in some cases. • No special training required.	• Measurement results are unique. May be impossible to relate to machine specifications. • Results will show only machine errors relevant to the master part. • Each new part requires a corresponding master part.

Ball Bar

Ball bar testing of the machine is an effective way to do interim tests of a CMM. The scope of measurements can be adjusted from a minimal test to an extensive test if needed. The ball bar can be purchased or even manufactured using off the shelf precision spheres at both ends of a suitable length bar.

A minimum measurement pattern would consist of the four diagonals of a machine as shown in illustration 1. This pattern would show direct errors from squareness and indirect errors from changes in the geometry of the machine such as pitch, roll, and yaw.

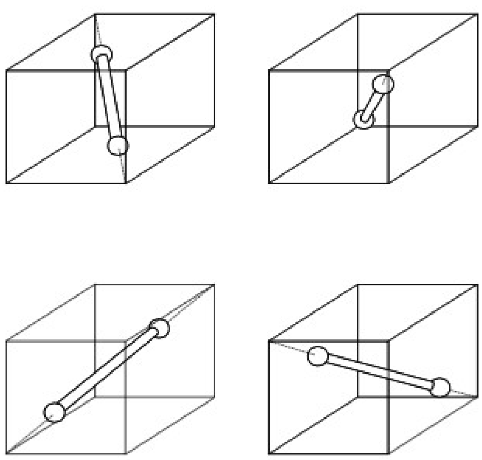

Illustration 1: Minimum measurement pattern with a ball bar.

Measurements with a ball bar are relatively fast and easy to perform with only the setup for each position requiring the operator.

The advantages of a ball bar is that the length of the bar can be purchase or manufactured suitable to the machine. If problems are found from the minimum tests additional measurement positions can be performed to identify the changes in the machine.

The disadvantage of a ball bar is that the operator is required to setup for each measurement position that is tested. With a proper stand this is not so difficult to switch between different positions but it is practically impossible to automate. Also, without a calibrated ball bar, it is not possible to verify that the measurement length is correct (only repeatability of the length is checked with a ball bar).

Advantages	*Disadvantages*
• Somewhat easy to test machine. • Test results, if measured as defined by a supported standard, can be compared to manufacturer specifications. • Equipment used for the test is relatively inexpensive and can be manufactured in-house.	• Measurements cannot be automated. • Training is required for testing and interpretation of the data. • Only length repeatability is checked unless ball bar is calibrated. • Only scale and angular data can be checked; straightness errors have little influence in the measurements.

Renishaw Machine Checking Gauge

The Renishaw MCG is similar in approach to a ball bar measurement except this uses a fixed reference point for all measurements. The one end of the measurement bar pivots on a fixed point and the CMM carries the other end of the measurement bar on the end of the CMM probe.

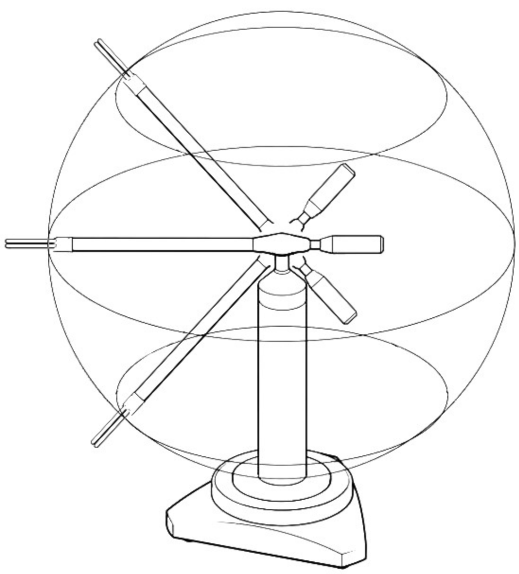

Illustration 2: Renishaw Machine Checking Gauge

The big advantage of this gauge is that the measurement process is automatic and requires only minimal operator intervention. The amount of time required to measure the gauge depends on how many measurements are required.

The disadvantage of this gauge is that it rides on a custom stylus connected to the CMM probe and is therefore sensitive to false probe triggers. This gauge cannot be used with analogue probes or high sensitivity probes. Although the pattern of measurements is good, unlike a ball bar, additional measurement positions are not possible.

Advantages	*Disadvantages*
• Easy to perform test. • Measurement is automatic once setup. • Measurements cover common sources of machine errors.	• Some training is required. • Part programs to drive the gauge tend to be complicated. • Gauge is carried by CMM probe and is sensitive to false probe triggers. • Cannot be used with high end CMM probes. • Only scale, squareness, and partial angular data can be checked; straightness errors have little influence in the measurements. • Some machine errors cannot be tested using this gauge.

Sphere or Hole Plates

These are plates with a pattern of spheres or holes. Two examples of the different kinds of plates are shown in illustration 3 and 4. These artifacts are typically calibrated where the relative location of each feature is known to every other feature on the plate.

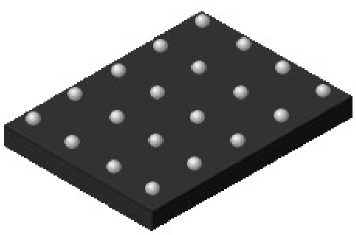

Illustration 3: Ball plate example

Illustration 4: Hole plate example

These types of artifacts are relatively easy to measure on any CMM and require little operator involvement once setup on the machine. These types of artifacts are also commonly used performance testing artifacts.

The disadvantage for this type of artifact is that these are 2D measurements. A more complete test of the machine would involve measuring the grid plate in all three working planes (XY, YZ, and ZX).

This type of artifact would need to be periodically calibrated in order to be effective.

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Illustration 5: Variation of a hole plate which is more like a ball bar. This is a 1D version of the 2D hole plate artifacts.

Advantages	*Disadvantages*
• Easy to perform test. • Test results, if measured as defined by a supported standard, can be compared to manufacturer specifications. • Measurement is automatic for each setup of the gauge. • Measurements cover common sources of machine errors. • Can be used to test for straightness errors if three of more positions exist along any direction.	• Measurements are only performed in two axis of the machine. A minimum, complete measurement requires the gauge is oriented in the three working planes of the CMM. • Gauges can be expensive if purchased. • Larger plates tend to be heavy especially if made from material such as steel.

Validation Specific Artifacts

Some companies have produced artifacts that are specifically designed for the rapid testing of coordinate measuring machines. An example of one artifact is shown in illustration 6. This artifact is similar to a ball bar test except it doesn't require the operator to reposition the ball bar between each measurement position.

This type of artifact would need to be calibrated periodically. Unlike a ball bar you are not checking pure length repeatability through the volume so this would need to be taken into account when analyzing the results.

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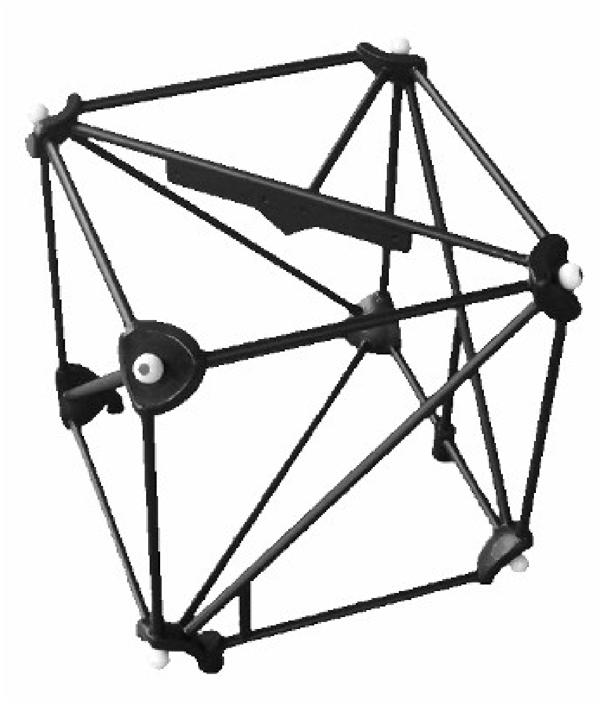

Illustration 6: Artifact used for volumetric testing

Advantages	*Disadvantages*
• Easy to test machine. • Solves the problem of having an automated ball bar test. • Fast and covers a large part of the CMM volume.	• Gauge will require calibration. • Direct sphere to sphere distances will need to be adjusted to account for the nominal distance if ball bar type evaluations are required. • Only scale and angular data can be checked; straightness errors have little influence in the measurements. • Sphere measurements performed using different probes so results are a mix of machine and probe calibration errors.

Manufacturer Recommended Calibration Artifacts

Interim checks on a machine can be done using the same artifacts that are used when the machine is calibrated. The big advantage is that the machine specifications can be used directly which may not be possible using other methods.

The cost of test equipment such as step gauges or Koba bars are high but it is in the realm of something that could be purchased if deemed necessary. Some companies are able to purchase laser interferometers to test the machine although this equipment tends to be quite expensive. For companies that have many machines it can become cost effective to have a dedicated department to inspection and calibration of all internal CMM machines.

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Reference standards would need to be calibrated periodically in order to be effective. Use of equipment, particularly a laser, requires extensive training to be used properly. The exclusive use of a laser for testing is generally frowned upon as it is easy to have situations where the laser could be misleading (a situation that is less likely when physical gauges are used).

In some cases having and maintaining internal calibration equipment is still less expensive than using external calibration providers. For companies that are large enough to have a dedicated calibration department periodic checks on all machines can be done more regularly replacing the need to have operators perform interim checks.

Advantages	*Disadvantages*
• Capability to completely test the machine. • Test results, if measured as defined by a supported standard, can be compared to manufacturer specifications.	• Requires extensive training, particularly when lasers are used. • Testing can take a considerable amount of time. • Standards used require periodic calibration.

Revision History

Revision	*Date*	*Reason*
1	Feb 12, 2016	Initial Release

