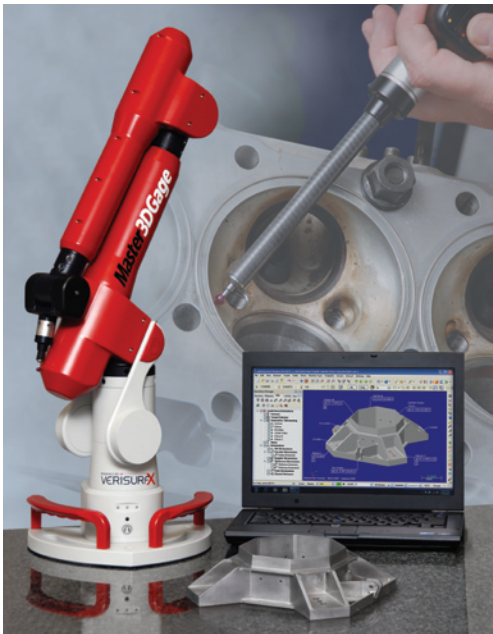


What Your Shop Needs to Know About Portable CMMs



Written by:
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Discover how rapid shop floor inspection makes quick work of quality.

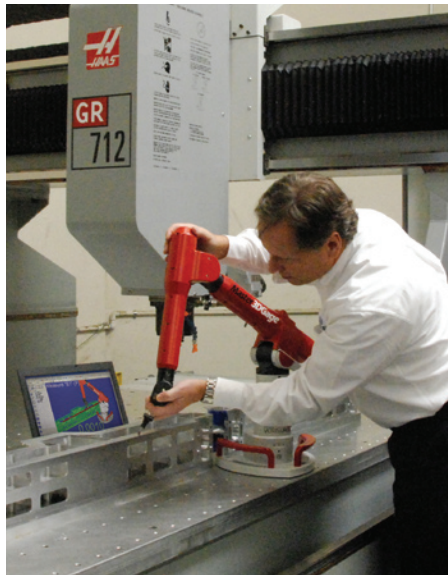
For the machine shop that supplies the aerospace industry, PCMM (portable coordinate measurement machine) and MBD (model based definition) are everyday terms that are integral parts of its daily inspection routines. In the effort to drive quality and control processes, aerospace OEM's have altered the inspection methodology and the tools of their entire supply chain. Many of these suppliers are small or mid-sized machine shops that have invested in inspection hardware, software and processes to satisfy strict quality standards. With the success of these supply chain efforts, Portable CMM's and the Model Based Definition Inspection technology are expected to spread to all industrial segments.

Now, it would appear that these new inspection tools and processes would place a big burden on the machine shop while benefitting only the aerospace manufacturer. It is true that this approach to quality control and inspection does demand more than what the usual assortment of hand tools and gages can deliver. It places much more emphasis on CMM-based inspections, which could mean a big investment in quality control. However, the new quality practices actually benefit the machine shop, fabricator or tool maker and it costs a lot less than they might expect.

By deploying PCMMs to the shop floor, these small businesses are realizing great gains without staffing up in the quality control department. These companies are performing thorough and accurate measurements much quicker than previously possible. They have adopted a convenient and efficient measurement process that covers everything from incoming inspection through final part inspection. And they have gained greater control over their processes.

So, how do these small shops respond to the demands of aerospace manufacturers and realize all of these advantages? They have adopted a rapid shop floor inspection approach: taking 3D measurements on the floor at the source for immediate feedback and reporting against the Engineering quality specifications.

This approach is a growing trend outside of the aerospace industry and a strategy that many non-aerospace machining and fabrication shops are using today.



Rapid Shop Floor Inspection

The Tools

There are three items needed to implement rapid shop floor inspection: hardware, software and Engineering data.

To conduct inspections on the shop floor, a PCMM is needed. Although there are several options, the common PCMM choice for the small machine shop is typically an articulated arm with a positive contact probe.

Temporarily mounted on any rigid surface, these lightweight devices are easily transported anywhere in the shop. Arms have joints that let the machinist extend and rotate the measurement probe into every channel, bore or pocket. With a reach of 2 to 12 feet, the arms do not have physical size limits common with stationary CMMs. These features make them versatile inspection tools.

The second component of a rapid shop floor inspection system is the software that receives all of the information from the arm. In the most basic mode, the software will log and report measurements taken with the arm. However, the big gains in time and efficiency happen when the software's full functionality is leveraged. For example, the software will create prompted inspection plans as datums and features are selected while in teach mode. It will also provide real-time inspection data with visual, on-screen references. To really expedite the inspection process, it can import a CAD reference model for direct comparison of the manufactured part to its design intent.

Since the arm will be used in a variety of applications, the software will allow the user several modes of operation.

- Direct measurements for on-the-fly spot checking as an alternative to a hand tool.
- Measurement to drawings in accordance with datums, dimensions and GD&T callouts.
- Direct comparison to a CAD model that contains the dimensional requirements.

The final piece of the rapid shop floor inspection solution is the quality specification and inspection plan. As just stated, the inspection work can be performed by referencing a part's engineering drawings. This approach works fine, but the inspection process becomes much quicker when that data is assigned to a digital reference within the PCMM's software. Start by importing the 3D CAD model and then assign the quality specifications from the drawings to the digital model. This allows the software to prompt where measurements are to be taken and immediately report a pass/fail condition.



Portable Coordinate Measurement Machine (PCMM)

PCMMs add portability to the capabilities of the traditional, stationary coordinate measurement machine (CMM). Like the stationary devices, PCMMs capture 3D measurements that are used to inspect and qualify parts, products or objects. Using six degrees of freedom probing technology, the PCMM returns X, Y, and Z coordinates of points on the surface of an object from any angle. However, to gain portability, the touch probe is mounted on the end of a lightweight, articulated arm.

Articulated arms have joints that provide six or seven rotary axes versus the three linear axes of motion commonly used on CMMs. Spanning 4 to 12 feet, these arms allow an operator to position the touch probe in any orientation to capture most, if not all, measurements in a single set-up. Like CMMs, PCMMs can also be outfitted with laser scanners to capture dense point clouds of measurement data.

The Freedom of Probing

Articulated arms have six degrees of freedom (DOF) and positive contact probing that allows for real-time inspection without triggering points. When compared to stationary CMMs, this simple statement has a lot of impact on operators and operations.

To achieve precise measurements, the touch triggering probes on stationary CMMs require controlled speeds when coming in contact with the part surface. Slowing the approach to the feature increases inspection time. And if the approach is not along the X, Y or Z axis, some time will be added to the front end of the process for probe angle calibration. To establish accurate probe compensation and spatial orientation when adding the fourth or fifth DOF, every probe angle that will be used to measure a part must be calibrated to a master sphere.

Probe angles on stationary CMMs pose a challenge beyond the time to calibrate. Since additional DOFs are gained with an indexing head, the probe angle is adjustable in 7.5 degree increments up to 105 degrees from vertical. This limit on probing limits access to features. As a result, CMMs often need custom holding fixtures to position a part to give the probe direct access to a feature of interest. For many parts, multiple fixtures are needed.

With an articulated arm, the probe approaches the part at any angle without slowing down as it nears the surface. This eliminates probe angle calibration and custom holding fixtures.

For large items and structures, PCMMs take on other forms. Using lasers and infrared light, long-range PCMMs can capture measurements to distances of several hundred feet. In industrial applications, laser trackers are the most common form of long-range PCMMs.

Model Based Definition (MBD)

With model based definition (MBD), a 3D CAD model is the sole reference object for all details and specifications regarding a part, sub-assembly, product or tool. In its purest form, no other documentation is referenced when describing the characteristics and qualities of an object. So, MBD is an approach where the CAD file provides much more than a description of the design intent.

In the realm of inspection-related activities, MBDs supply all of the dimensional and tolerance information. There are no drawings. The CAD model contains all of the specifications, including the GD&T callouts. The dimensional specifications may be either annotations within the model file or digital specifications linked to a feature. With the latter approach, inspections are completed simply by referencing the CAD model and picking the appropriate points on the object. This eliminates all manual documentation and data entry and expedites the inspection process.

An advanced concept linked to MBD is minimum dimensioning. With this approach, a global profile tolerance is applied to the CAD model and only those features that are critical to function are explicitly defined through GD&T callouts.

For the fortunate shops whose clients have adopted MBD, the process becomes even faster. Since the model contains all the quality specifications, it is simply imported, and a few moments later inspections can be performed. This eliminates all the manual effort to interpret drawings, document measurements and report against the prints.

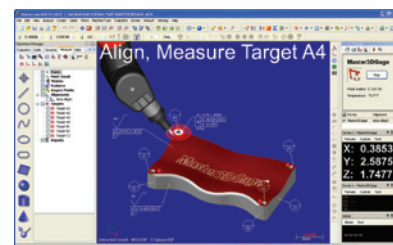
With these three components—PCMM, software and quality specifications—machine shops have a portable inspection tool that is the equivalent of a cart full of hand tools and gauges and a roll of engineering drawings. Everything that is needed to determine go/no go is bundled in a rapid shop floor inspection tool that travels to the work piece.

The Process

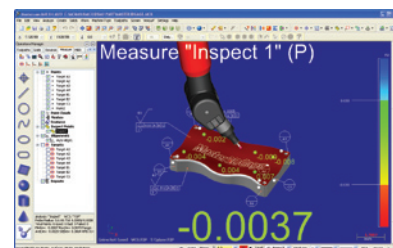
The PCMM goes to the source of the inspection, which can be on the loading dock, manufacturing floor, machine shop or tool room. All that is needed is a little space and a stable work surface to mount the arm and place the part. With battery operations and optional wireless communications, the truly portable systems do not even require a wall outlet or a cabled connection. After a quick calibration routine, the system is ready for operation.

The inspection process is much simpler than that for a conventional CMM. In three simple steps—align, inspect and report—the process is complete. Start by placing the part within range of the arm. No fixturing is needed as long as the part does not move while measurements are taken. Next, probe the reference surfaces (E.G., datums) that align the physical part to the digital CAD model. Now, the part is ready for inspection.

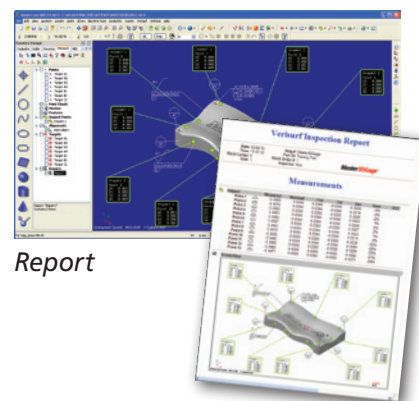
Take the desired measurements by touching the probe to the part and click the record button. Just touch and go on to the next measurement. Alternatively, drag the probe along a surface to pick up a continuous stream of measurements. With each measurement that is made, the system gives immediate, on-screen feedback. The dimensions and deviations are annotated in green when within the specified tolerance band and in red when the dimension fails.



Align



Inspect



Report



When the inspection is complete, output the results in an inspection report that presents the information in the traditional tabular format augmented with any desired reference images. When describing his rapid shop floor inspection process, one tooling inspector stated, "The beauty is that we simply align the model and start checking it. We get immediate reporting and feedback." This is in stark contrast to the time, effort and talents needed when using traditional measurement tools.

The Advantages

As can be seen through the description of rapid shop floor inspection, it provides all of the capabilities of a stationary, programmable CMM while offering the convenience and flexibility of hand tools and hard gages. It is a multi-functional, go-anywhere, use-anytime inspection tool that does not have the overhead of time-consuming programming and does not need the skills of a highly trained metrology professional. In short, it is a simple yet powerful tool that is easy and convenient to use.

It is also easy and convenient. Measurement results are produced quickly with little effort, which is what the small to mid-sized shop needs. But how quick is it? One aerospace supplier stated that when inspecting with a measurement arm against a CAD reference model, the process took just 10 minutes. Without a PCMM and the CAD reference model, the same part took 12 hours to inspect. That company also offered an example comparing an arm to a CMM. Inspecting to prints, the arm was 75 percent faster than a manually operated CMM.

When asked how it chooses its inspection tools, another user stated, "We always look to do things the quickest way possible with the least amount of effort." So with this common sense approach, when a process is painless and "pleasurable," it will be used and implemented more often. This is in line with what quality professionals have long realized: difficult and tedious processes can lead to short cuts that can result in quality problems.

The bottom line is that rapid shop floor inspection makes it quick, easy and painless to measure parts and assemblies often and thoroughly. This lessens the likelihood of running "at-risk;" minimizes scrap and production delays; and maximizes product quality.

So, what are some of the other aspects that make rapid shop floor inspection so quick, easy and convenient? Following are a few of the most notable.

Minimal set-up

Like all hand tools, there is no pre-programming needed to start the measurement process. Simply pick the features to be measured to get the required inspection data. Another time saver is that there is no fixturing



needed, which is not the case for CMM inspections and many manual measurement methods. Since the physical object is aligned to the CAD model, it can be in a random orientation. Just place the part on a table and measure a few datum points to automatically align the arm to the CAD model and begin real-time inspection.

Another advantage is that most inspections can be completed with only one or two part orientations. With a basic CMM, there are only three axes of motion, so features on sidewalls and the bottom of the part cannot be measured without another set-up. With six degrees of freedom (DOF), the arm can measure everything but the bottom surface. So, in most cases two orientations expose all features of the part that are to be measured.

Portability

Although it has already been stated, portability is an advantage that is worth mentioning a second time. Lightweight and ruggedized for shop floor operations, the arm travels to the part or tool that needs to be inspected. Since the arm comes to the object, there is no wasted time or effort in transporting the work piece to a CMM and back to its original location. The arm intercepts the part or tool in its work flow to minimize process disruptions.

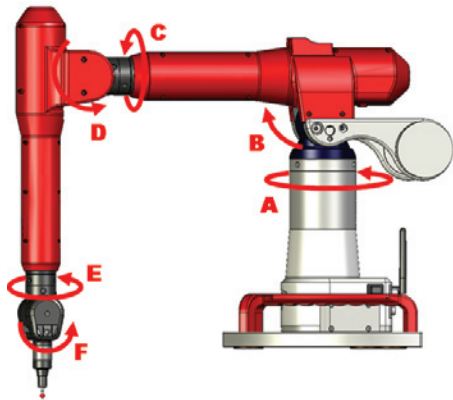
In some cases, parts will remain on a CNC mill or in a welding fixture while measurements are made. This avoids breaking down the setup, which saves time and eliminates any possibility for repositioning error when the part is returned to its original setup.

Portability is especially crucial for oversized objects that are too big or too heavy to be transported to a CMM. With an arm, the item stays in place yet gets the thorough inspection of a 3D measurement device. Without the PCMM, the only option is to make do with gages and single dimension measurement devices.

On occasion, a machine shop may want to inspect its suppliers' parts at their facilities to avoid any surprises at the time of incoming inspection. The portability of the arm makes this possible. There is no difference in transporting the rapid shop floor inspection system 100 feet or 100 miles.

No Size Limits

The stroke of a dial indicator, Z-axis travel of a CMM or throat of a micrometer limits the size of the part that may be measured. Gages, hand tools and CMMs have fixed working envelopes or maximum linear dimensions. Although an articulated arm does have a maximum reach, its working envelope far exceeds that of the measurement tools common to a machine shop. Even a small arm with a two-foot span has a working envelope of nearly four feet. And if that is not enough, it can be repositioned to capture the balance of the dimensions that were previously out of reach.



Automated Collection, Calculation & Reporting

With any manual inspection, using either hand tools or CMMs, someone has to note the measurements, do the math and log the data to be able to report if a part is acceptable. This manual process is not only tedious and time consuming, it is also prone to error.

With rapid shop floor inspection, there are no hand calculations and no manually entered data. As each measurement is taken, the software logs the data, performs background calculations and compares the result to the quality spec. When the inspection is complete, it then outputs the inspection report. This saves time, reduces labor and eliminates the possibility of clerical errors.

Flexibility

Rapid shop floor inspection is a versatile tool that is multi-function and multi-purpose. It offers a great deal of flexibility in how, when and where it is used.

It can be used for one-time measurements like a hand tool, or it can be an alternative to a CMM for thorough evaluations to a carefully planned inspection. It can be used by the skilled tradesman, or it can be leveraged by a QA professional. It measures IDs, ODs, depths and distances like basic gages, and it calculates parallelism, true position and concentricity like an advanced CMM.

While machine shops retain the traditional measurement tools, many find that they use them much less frequently after acquiring a rapid shop floor inspection system. The height gages, gage blocks, calipers and CMMs still have their uses but just not as frequently.

When to Use

The flexibility of the tool and the quickness of the process make rapid shop floor inspection a viable tool for everything from incoming inspection to final part inspection approval. Virtually anywhere that hand tools are used or nearly any inspection that relied on a CMM is a candidate for this alternative method of inspection. When a machine shop's staff becomes comfortable with its new tool, it will also find new applications that were not considered in the past because the traditional tools were not up to the task.



Incoming Inspection

When the truck backs up to the dock, roll the arm over to meet the incoming parts. Instead of sending them to wait in the queue at the CMM, they can be thoroughly inspected as they arrive. With immediate, on-screen feedback, each is passed— or failed— before being carted into the plant. Also, the system will record all results for traceability and trend analysis.

In-Process Inspection

With the focus being shop floor inspection, the majority of the time the PCMM will be on the floor while the manufacturing operations are in process. Following are some typical examples.

1. Checking parts in/out of the process.

Before starting a new manufacturing operation or sending parts on to the next process, use the arm to confirm the quality of the part. As noted earlier, in/out inspection can even be performed while the work piece is fixtured in the CNC mill, router or lathe.

2. Verify tooling.

The quality of jigs, fixtures and dies is important to the quality of the parts that they make or align. So, use the arm to inspect them when put into service. For long-running tools, use it for routine measurements to check for wear, damage or distortion.

3. Align parts and tools during the build.

Rapid shop floor inspection is ideal for fine-tuning part alignments before assembling components. For example, use the arm to check the positioning of pieces held by a welding fixture. Adjust the parts as recommended by the inspection software before hitting them with the first tack weld.

4. Monitor process controls.

In the day-to-day operations of most machine shops, lot sizes are too small for statistical process control (SPC), PPAPs and CpKs. But this does not mean that machine shops do not have to worry about process control. Over time, process parameters shift and tools wear, so the machine shop needs to routinely check output quality to catch variance before it becomes a problem.

In this area, rapid shop floor inspection helps in two ways. First, it is an ideal tool to assist in identifying the process variables that must be controlled to produce good parts. Second, it is the perfect measurement tool for spot checking to confirm that those parameters are stable.



About the Author

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Ron has 20 years experience as a Machinist and over 15 years of CNC programming. During his career Ron has been a Shop Foreman, learned Lean Practices, Sigma Six, and Kaizen. He has studied Quality Management Systems and how to implement them in a Job shop environment and has supported in the set-up and implementation of AS9100:REV B quality system. Ron has set-up, run, and programmed many different types of CNC turning centers from simple 2-axis lathes to 7-axis Mill/Turns; he has designed fixtures, tooling, and completed extensive time and R.O.I studies for all types and ranges of operations and applications, including Solid Modeling (Solidworks, Catia V5 R18, PRO-E Wildfire 3, AutoCad, and Mastercam V7 to X4 MU3).

Ron Branch's Specialties:

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Problem Detection and Diagnosis

When problems occur, turn the arm into an investigation tool. Rather than inspecting parts or processes to a pre-defined plan, use it to query the part to determine where the problem lies and what its root cause is. The arm offers the flexibility to conduct "what-if" diagnosis to understand the cause and effect.

Customer Approval

Before investing in an exhaustive first article inspection, confirm the critical-to-function dimensions with the arm. Since the process is easy, quick and visual, many elect to inspect the parts in front of the client. These shops claim that they have better communication with the client that leads to faster approvals.

Since the inspection shows results on the CAD model, anyone on the client's review team will be able to see the true quality of the part. This gives them immediate qualification of the features that are important to function. It also lets the shop perform impromptu measurements to clarify an important point or investigate an area of concern.

Supplier Site Inspections

When the machine shop becomes the client, the portability of the inspection tool allows it to perform all of the inspections that have been discussed at its supplier's facility. They use the portable CMM to confirm first articles before they are loaded onto the truck. In these instances, the shop gets early detection of quality problems and a thorough set of data information that helps to diagnose a process that is no longer in control.

Conclusion

Rapid shop floor inspection is a versatile process that is used throughout manufacturing operations. Although sophisticated enough to satisfy the demands of the aerospace industry, it is perfect for the small or medium machine shop. Simple to learn, easy to operate and quick to report; this is an inspection system that companies of any size can easily incorporate into the manufacturing work flow.

While aerospace suppliers had little choice concerning adoption of model based definitions and PCMMs, these companies have become advocates of the tools. They see how efficiently they can gather data that confirms the quality of their parts, tools and processes or identifies the source of process variance. And from their experience, they predict that this aerospace-promoted inspection process will rapidly extend into all commercial industries.