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Sceptre Application Notes
Multi-Function CMM
CMM with Sceptre capabilities replaces many different Gage Laboratory Instruments

A **Gage Laboratory** is a costly expensive proposition for any company. Not only do the separate instruments in them cost a significant sum each but also they must each be serviced, maintained and calibrated on regular basis. In many cases each instrument requires a **separate operator** because they each have their **own software** which in turn requires **specialized training and operation techniques.** In many cases these secondary costs add up to be more significant than the original purchase price over a very short time span.

To the Metrologist, the words “Coordinate Measuring Machine”, bring to mind a certain capability. Namely the three dimensional determination of hole locations and planes. It replaces what use to be done on surface plates. Most CMM’s move around with a touch trigger probe and touch the surface in several spots and evaluate the location of features. These touch probes must impact the surface to record a point because only the moment where it triggers (or the switch opens) do we know where the tip is. Before impact the tip is not on the surface and after the whole probe assembly has been displaced out of its null position.

A Sceptre based CMM is not only a good CMM in the classic understanding of what a CMM does but its advanced data collection capabilities can yield results as good or better than the conventional specialized instrumentation found in the gage lab. Equipped with a three dimensional analog probe the system can take continuous data without having to leave the surface. Because it works continuously, data can be acquired during the whole probe cycle and thus vibrations and transients can be filtered out increasing accuracy and repeatability of single point touches. It also enables Sceptre to scan or sweep a part and acquire a continuous stream of data on known or unknown surfaces.

I will limit this discussion to universal/general purpose instruments as opposed to specialized instruments such as gear checkers and special gages. A Sceptre based CMM can replace several different types of instruments – Contour Tracer or Profilometer, Surface Finish Instrument, Roundness Checker, and Optical Comparators or Vision Systems.

Contour Tracers or Profilometers are a class of instruments that usually consist of a primary motorized linear slide and a secondary indictor axis which is biased toward the part and may contain a scale or analogue transducer. The motorized axis in most cases moves at a constant velocity and the stylus, which is attached to the secondary axis, follows the part. These devices are very useful for gradually sloped contours. Errors occur when this device is used on sharply sloped contours.

On sharply sloped contours, the contact force vectors begin transfer from the secondary axis, which floats at a constant force, to the primary axis, which is has no such compliance. What then occurs, are undetectable deflections in the stylus, probe assembly, and mechanical instrument members in the direction of the primary axis. **Higher net contact forces** also result due to this lack of compliance in the primary axis. In the extreme case where you begin to have a vertical slope or even a negative slope, the secondary can not react appropriately and the **stylus** will **even break off**. This is one reason why **ball type** styli are usually never used on this type of instrument while the **pointed type** will **shank off.**

Another error that will occur is in the **analysis** of the **theoretical part** to the **acquired data**. The stylus tips are not of infinite small radius and must be account for when you mathematically try to analyze the shape against the raw primary and secondary signals. The builders of these instruments try to minimize this by reducing the size of the tip and only specifying accuracy on gradually sloped contours.

Sceptre is not limited in these ways since it is completely omni-directional and actually servos to the work piece at a constant contact force, regardless of the shape being inspected. Sceptre in addition uses a ball tip and is equipped with probe tangency compensation routines that properly correct the data from center of ball to point of surface contact.

Surface Finish Instrumentation – There is a diverse class of instruments used for measuring surface finish. The most common and accurate are similar in concept to contour tracers except that they are designed for very **high resolution** and **high response speeds**. These devices usually have much smaller working range than contour tracers and generally sample very short segments of data on the part but at a high accuracy and data density.

Nonlinear surfaces contours or geometric shaped surfaces are difficult for most surface finish instruments because they acquire data in straight lines only and their sensors work uni-directionally. When measuring curved or contoured surfaces they attempt to take data in the non-curved direction or take very short samples so as to not see the shape change within in the data. This limits sampling flexibility.

For example, a surface finish instrument **cannot** measure the **surface finish** of a **hole or boss** along the **arc**; it can only measure **along the axis**. This is a reasonable compromise if the hole has been made using circular cutting action (i.e. drilled or milled). But if the hole has been made with axial cutting action (i.e. stamped, broached or contour milled) the surface finish grain is invisible.

Conventional surface finish instrumentation may have a bulky sensor that must be lined up normal to the surface. In small features, this limits access. On a Sceptre-based CMM a stylus can be bent or jointed to reach the desired surface.

To understand more precisely the differences and advantages of a **Sceptre CMM** over a classic surface finish instrument please ask for a copy of *EMD Application Notes Vol. 3 No. 8*. In this application note you will see a correlation study of a **Sceptre** CMM on a calibrated surface finish standard. In brief, surface finishes of up to **4 micro inch** or **0.1 ì m** can be reliably measured on a CMM. Except for a small fraction of very highly finished surfaces the CMM delivers correlatable data with more automation, sampling certainty and flexibility.

The ability to separate out geometric dimensioning variations, waviness/form, and surface finish from a single data set requires the use of geometric evaluations along with specific filters to isolate the desired variation. These tools are available within Sceptre.

Roundness Checker – Is an instrument designed with a high precision (usually pneumatic) rotary spindle on which round or circular work pieces are centered. The instrument may be equipped with another linear axis and an indicator / probe. The primary displacement motion is the spindle while the indicator monitors the part surface relative to the center of the spindle.

If the part is mounted eccentric to the spindle or the part is not round then the indicator absorbs the additional travel. At very high precision levels, this type of indicators may have some linearity errors as a result of relatively long travel strokes. At any point though these indictors exhibit very high repeatability (approximately 1 micro inch [0.02 um]). Combine that accuracy with the air spindles which also has a run-outs of 3-5 micro inches [.05 um] and this relatively simple instrument is extremely accurate for roundness. This device is usually mastered with a precision ring gage or calibration ball for absolute diameter evaluations.

A Sceptre equipped CMM is capable of achieving the equivalent function two different ways.

1. Equipped with a precision rotary table the CMM would use equivalent methodology and accuracy is equivalent to a conventional roundness tester. (Requires the circular surface to be centered on the rotary table)
2. XY&Z normal scanning mode frees up the system from the restriction of having the feature centered on a rotary table. For example It is important to note that the XY&Z scanning mode involves complex dynamic machine motions that may have axis reversal errors and such, while in the normal XY&Z scan mode ± 1.0 um is typical. Please ask for a copy of *EMD Application Notes Vol. 3 No 7* for more complete information.

Optical Comparators, Toolmaker Microscopes and Vision Systems are found in most gage laboratories. They consist of an optical imaging and mechanical staging system. The stage positions the feature of interest into the field of view of the optical system and then measurements are made by combining the scales on the stage and the optical system.

On classic, Toolmakers microscopes, the operator moves the stage so that the cross lines of the imaging system is superimposed on the imaged edge. Scale readings are taken when the operator feels he is in the right position. On Optical comparators, the part shadow is projected onto a screen and the operator compares the shadow with a template attached to the projection screen, this is field of view measurement. Vision systems combine image edge detection technology, computers and software analysis to automate the inspection procedure and take out some of the operator guesswork.

The evolutionary path these systems took minimized the importance of the stage. Comparators for example need the stage to only hold the part securely while field of view measurements are made on the projection screen. In most cases they are used and specified in 2D only. As a result most use hard or mechanical bearings that have not been used on CMM's in 20 years.

Today, we need to operate in 3D and staging has become a greater concern. The precision of CMM type mechanical platforms is needed even on vision systems. Sceptre has a vision probe and image processing features that enable it to replace these optical inspection instruments. The Sceptre Vision Probe is designed as an attachment to the CMM when optical inspection is needed.