HEXAGON

CMS 106 / 108 Laser Line Scanners
White Paper

HI-TECH METROLOGY

1 Introduction

This paper explains the evolution of stationary and portable metrology probing systems starting from traditional single point tactile probes and concluding with the most advanced scanning laser probe, the CMS106/108 sensors, which are capable of reliable, high speed metrology of a wide range of materials in the most demanding of environmental conditions.

2 CMMs and portable CMMs

The aim of metrology is quite simple: to ensure that the items manufactured match the original intent of the designer. Metrology is accomplished by gathering as much mathematical information about the physical dimensional characteristics of the “as built” parts and comparing them against the designer’s specifications. Over time, the ability to do this has become increasingly sophisticated.

Initially, metrology was limited to measuring in just one dimension at a time—height, length, or depth. It was not until the late 1960’s when the first true three-dimensional coordinate measuring machines debuted in the market. At this juncture, metrology began to realize its true potential, where the physical characteristics of a part began to be able to be compared three-dimensionally to the design intent.

A coordinate measuring machine (CMM) is also a device used in manufacturing and assembly processes to test a part or assembly against the design intent. By precisely recording the X, Y and Z coordinates of the target, points are generated which can then be analyzed via regression algorithms for the construction of features.

Figure 1 Coordinate Measuring Machines

The typical "bridge" CMM is composed of three axes, an X, Y and Z. These axes are orthogonal to each other in a typical three dimensional coordinate system. Each axis has a scale system that indicates the location of that axis. The machine will read the input from the touch probe, as directed by the operator or programmer. As the probe touches the surface of the component the stylus deflects and simultaneously sends the X,Y, Z coordinate information to the computer.

These points are collected by using a probe that is positioned manually by an operator or automatically via Direct Computer Control (DCC). DCC CMMs can be programmed to repeatedly measure identical parts.

More recent innovations are touch probes that drag along the surface of the part taking points at specified intervals, known as scanning probes. This method of CMM inspection is often more accurate than the conventional touch-probe method and can be many times faster as well.

Figure 2 Contact Scanning Probe

Portable CMMs are different from "traditional" CMMs in that they most commonly take the form of an articulated arm. These arms have six or seven rotary axes with rotary encoders, instead of linear axes. Portable arms are lightweight - typically less than 10 kg (22 pounds) - and can be carried and used nearly anywhere. The inherent trade-offs of a portable CMM are manual operation (always requires a human to use it), and overall accuracy is in general less accurate than a bridge type CMM.

Figure 3 Portable Measuring Arm

Non-repetitive applications such as reverse engineering and large-scale inspection of low volume parts are ideally suited for portable CMMs. In addition, if parts are too large or heavy or if they have to be inspected whilst still in the fixture, a portable CMM that can be brought to the part is often the only solution.

3 The importance of the next generation of probing; optical scanning probes

The next generation of scanning probes, known as non-contact scanning, is advancing very quickly. This category includes both point and line scanning probes. Optical probes - particularly line scanners – work many times faster than the most advanced touch scanning probes to create very large data sets which, due to their large size, are called 'point clouds'.

These point clouds can be used to not only check size and position, but, due to the high density of point information compared to contact probes, to create a full 3D image of the part as well.

Optical scanners are most suited to complex freeform parts where the shape is not easily represented by simple prismatic entities, examples being car, aerospace, motorcycle bodies, trim and seats; many consumer products, medical components and blade shapes such as used for power generation. They have created a whole new range of solutions to common customer problems. Typical applications include:

1. Target Inspection / Validation

In this application, measurement of specific features contained within the point cloud can be made for the purpose of dimensional inspection or GD&T and the results compared against nominal values. This latter step could of course be performed using conventional tactile measurement but for larger parts where tolerances can be up to 0.5mm or more, an optical scanner is often faster since non-contact measurement is more tolerant to large deviations of the part from nominal.

In addition, due to the high density of information contained in the point cloud, the whole cloud can be compared against the full CAD surface model to give a 'colour map' of the deviations across the whole part. Such a tool is extremely powerful for first article inspection and production line tuning processes.

Typically a customer will just measure parts but in many cases the tool that produced the part will also be inspected.

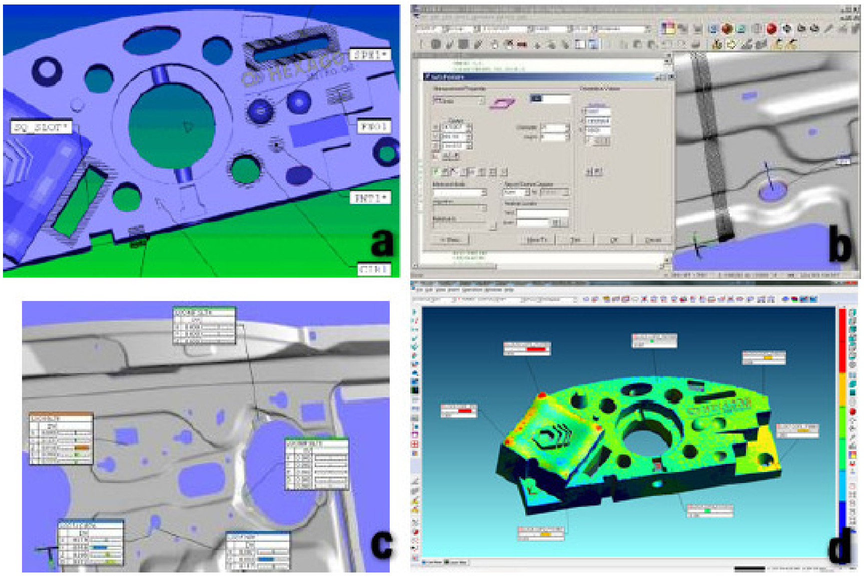

Figure 4 a) Scanned feature in PC-DMIS b) Feature inspection c) GD&T Analysis d) Part to CAD comparison

2. Reverse Engineering

Reverse Engineering is the process of taking a physical part, measuring it to determine its size and creating a CAD design from these measurements. This is most often used in cases where the product design process has significant manual operation, such automotive design. Despite the advances in CAD, many designs still start life as a physical model which then needs to be turned into electronic form.

In other applications legacy parts, for which engineering drawings no longer exist, are unavailable or out of date may need to be scanned in order to generate a CAD model to make tooling for replacements.

In both these cases, point clouds can either be processed by special software packages to create 3D CAD models or transferred directly to CAD software where a full working 3D model is created.

Creation of CAD model from the scanned point cloud

Figure 5 Reverse engineering - clay design

3. Replication (copying / scaling)

For applications where a one-off replica of a part is needed it may not be necessary to create a full CAD model. In this case the point cloud may be turned directly into a polygonal mesh which is a basic form of a 3D model. This mesh can be edited, for example, scaled or a half model can be mirrored to create the desired electronic part.

From this final mesh a physical replica can be created using standard manufacturing techniques like milling or Rapid Prototyping.

Typical copying applications include cultural heritage, for example, buildings where a façade has eroded over time and needs restoration or replication of sculptures in different scales.

Figure 6 Replication - Restoration

The applications described above cover a very wide range of objects with different materials (metal, plastic, clay). Thus the key customer requirements for an optical probe are:

- Repeatability – for series measurement, the results must be highly repeatable
- Reproducibility – independent of the operator programming or running the system, the results should be the same
- Flexibility – the probe should be able to measure a wide range of materials (for example, machined, semi-finished, stamped, forged, casted and painted metals, sand cores, wax, carbon fibre, plastics, clay, rubber, wood, ceramics) and be used easily on a range of different part sizes
- Reliable – must work under a wide range of environmental conditions
- Ease to use – minimal operator training is desirable
- And, last but not least, the accuracy must meet the needs of the application

4 The technology behind optical scanning - single point laser triangulation

The triangulation 3D laser point probe is a device that uses laser light to measure distance. The laser beam is projected on the subject and uses a 1D linear sensor (CCD or PSD) to detect the location of the laser spot. Depending on how far away the laser beam strikes the surface, the laser dot appears at different places in the camera's field of view. This technique is called triangulation because the laser spot, the camera and the laser emitter form a triangle. The location of the image of the laser spot on the optical sensor is measured from which the distance location of the laser spot on the object is computed.

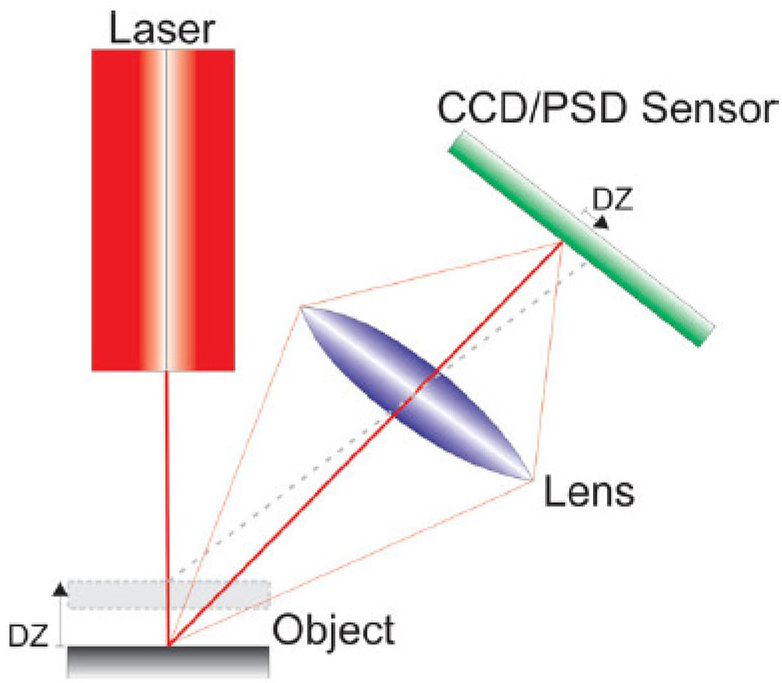

Figure 7 Principle of a laser triangulation sensor

Whilst laser point scanners can generally measure a wide range of surfaces quickly, in many cases, the speed difference to a tactile solution is not very large and they tend to be restricted to a number of niche applications where the surface is delicate or the features are too small for contact probes.

5 Laser line triangulation

To achieve a significant speed increase, the single spot scanner can be extended to a laser line system by extending the above system ‘into the plane of the paper’ of figure 4, namely by changing the sensor from a linear (1D) sensor to an area (2D) sensor and the spot laser to a line laser. This immediately increases the raw measurement speed by a factor of 1,000.

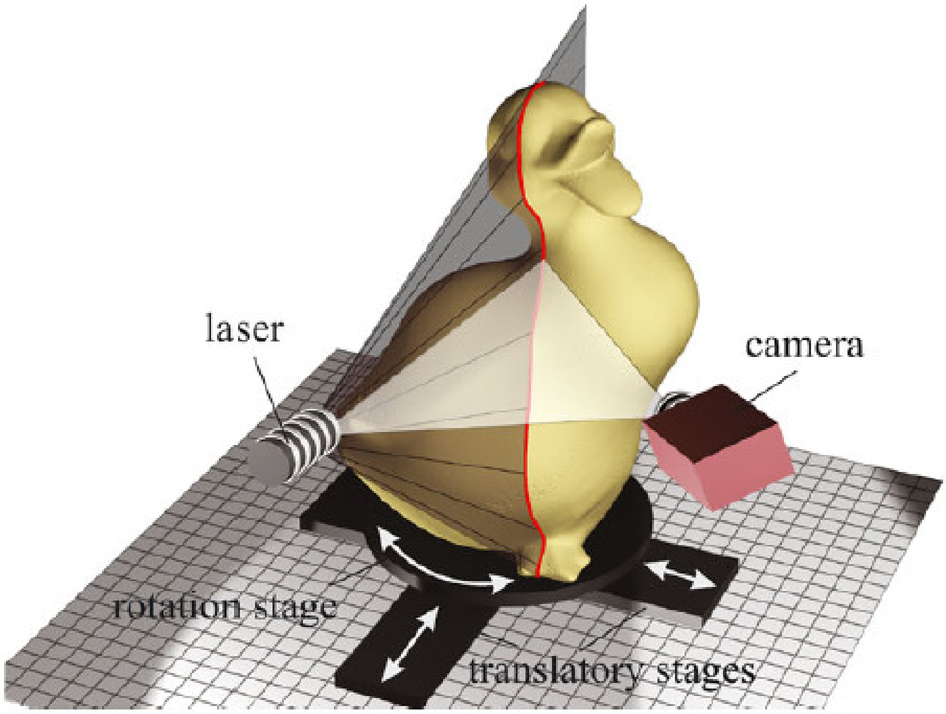

Figure 8 Principle of a laser line triangulation system

Although easy to implement, these simple 2D laser line systems have significant drawbacks:

- As the whole scene is always in view, secondary reflections on the surface of the object, for example, on highly reflective objects such as machined parts, can be falsely interpreted by the 2D image sensor as true data points and stored in the point cloud

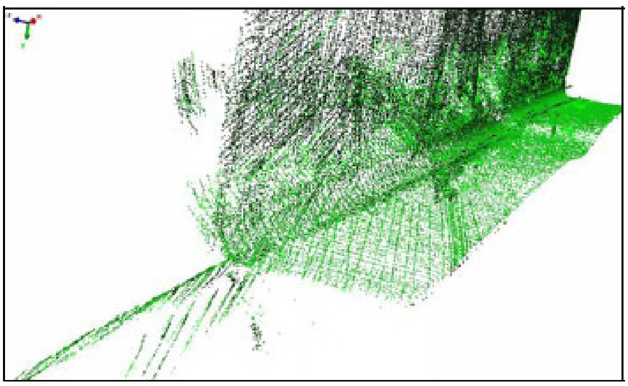

Figure 9 Example of poor quality point cloud from a laser line scanner caused by spurious reflections from a concave machined surface

- Light from the whole scene enters the camera lens, making the system sensitive to ambient light
- A complete camera image has to be analysed before you can feedback any changes to the laser power to keep it at an optimal level. This restricts the laser adjustment frequency to around 50Hz or 20ms with a typical camera speed. If you are scanning a part at a speed of 100mm/s, there could be 2mm of movement between the time the laser needs to change and actually changing, resulting in inaccurate or missing data
- The laser power is dissipated over the whole line, meaning you need a more powerful and less safe laser
- If the laser line covers a surface area with different reflective characteristics it is very difficult to get high quality data on both surface types.
- The laser generation method and increase laser power, produces stronger laser speckle interference, which is seen as noise in the range measurements

Typically these systems need to have several parameters adjusted depending on the part you are measuring. And if the part changes, you have to retune the settings, making setup quite time consuming.

6 A better solution - scanned spot laser line triangulation

The CMS106 (for stationary CMMs) and CMS108 (for portable arms) are more sophisticated laser scanners of the scanning spot type - the measurement is performed by sweeping the triangulation plane of the single point sensor shown in Figure 4 over an angle using a mirror fixed to a oscillating motor. Scanning spot scanners are also often called laser line scanners, like the system in Figure 5, since their final output is also a line, even if the points contained in the line are captured sequentially, rather than simultaneously.

Figure 10 CMS Laser Scanner

The CMS106/108 also have a unique laser power control provided by an independent optical detector running at a much higher speed than the linear CCD sensor. This allows the laser power to be optimised during the measurement process itself.

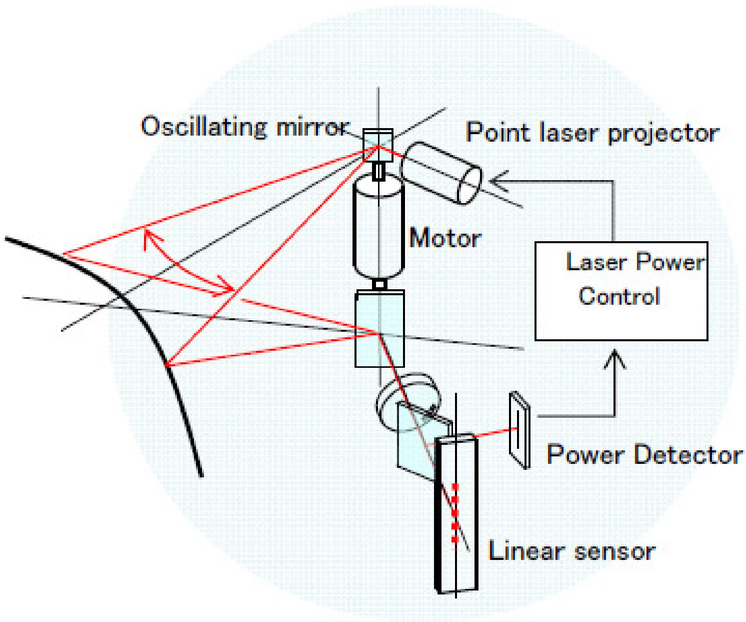

Figure 11 Scanned laser spot principle

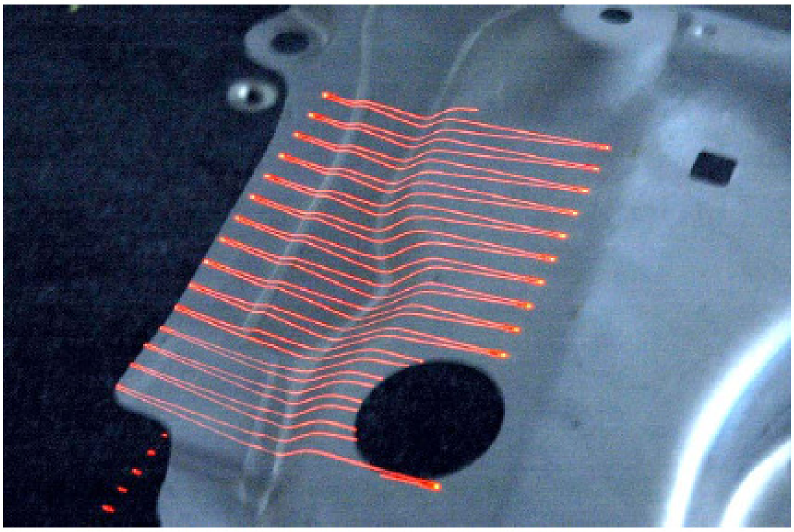

Figure 12 Scanned laser spot path viewed over time – note the back and forth nature of the beam

Scanning laser spot technology overcomes the problems of the basic laser line scanners mentioned previously:

- only one point in the whole scene is measured at a time, thus the chance of secondary reflections and false points is extremely low
- only a fraction (1/1000) of the whole scene is visible at any time, thus the system is extremely immune to ambient light

- the intensity of the laser light is continuously adapted for each point on the line in real time during the measurement process, this means the distance travelled by the spot before the power is changed is a fraction of the spacing between the points on the line, typically around 10 microns
- the laser beam power is the same as a single point sensor
- the process of scanning of the laser spot automatically reduces speckle noise

These benefits combine to give a considerably more accurate measuring system that tunes itself to the object being measured with no operator input.
A further advantage of a scanned spot is the ability to vary the scanning angle – producing a function similar to zoom lens on a camera. The CMS has 3 possible zoom settings.

7 Key Features of CMS Sensors

Below is a summary of the key benefits of the CMS106/108:

- **Automatic laser power control**
  – They scan an extremely wide range of materials and colours
  – They scan up to ±60 degrees even on machined surfaces
- **3x Zoom**
  – 24mm, 60mm or 124mm line length with up to 2000 points per line.

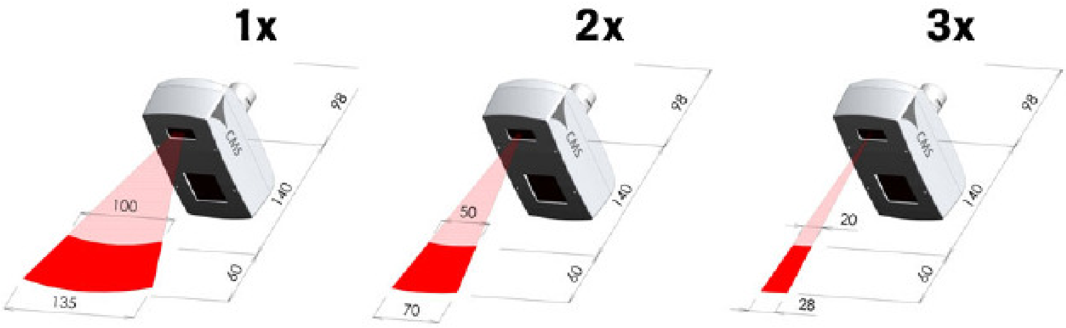

Figure 13 CMS 3x Zoom capability

- **Strong immunity to the environment**
  – Full temperature compensation
  – Extreme ambient light immunity
  – IP64 rating against dust and water
- **High accuracy**
  – 2D feature positional accuracy of ±20µm

8 Summary

This paper has explained how stationary and portable metrology probing systems have evolved over the years, and how the unique technology in the CMS106 and CMS108 produces an accurate, fast probe capable of measuring a wide range of materials in demanding environmental conditions whilst being repeatable, reproducible, flexible and easy to use.

9 About the author

Pete Champ is a product manager for Hexagon Metrology whose responsibilities include laser triangulation scanner development. He has been pioneering laser line scanning since 1991 and has led the development of several market-leading products.

References

Figure 7 Georg Wiora
Figure 8 Cteutsch

Hi-Tech Metrology

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