THREE-DIMENSIONAL MEASUREMENT WITH LASER

Abstract – This paper presents some laser measurement methods and equipment and also proposes complex equipment for a rapid recognizing of the small part types.

Key words – three-dimension, laser measurement methods.

1. Introduction

In industry in general, the main need is to reduce the manufacture and inspection’s time cycle. This results in a constant goal to optimise each stage of production, and to optimise the time of inline and final inspection. In order to ensure a more efficient quality control, SMEs producing small series precision mechanics complex components seek total solutions, integrated and adapted to their needs and current production tools.

Today, many companies carry inspection tasks in a conventional way (manual tools for inline control, CMM). The inspections are integrated into manufacture but the system is not computerised. Indeed, the manual methods such as palmer and caliper, lack rapidity and imply a manual treatment of the collected data. This leads to time consuming, inaccurate dimension measurement and inconsistency in quality control, and low efficiency of the whole production line. The inspection and measurement of precision machined parts is also difficult and slowed down because of the requirement to check their three-dimensional features. Most of all, the logistics and the slowness of the methods of traditional control with CMM make the quality control complicated and thus have a direct influence on competitiveness. To improve this productivity, SMEs would need a tool for inspection allowing to largely reduce the inspection time cycle, while keeping at least the same level of quality.

This paper presents some laser measurement methods and equipment and also proposes complex equipment for a rapid recognizing of the small part types. The following aspects have been taken into consideration:

- The adaptation of the existing sensors and inspection approaches in order to improve the measurement and repeatability accuracy, robustness of the measurement, and computerisation of the quality control and management: contact, non-contact as well as combined contact and non-contact techniques are used and reconfigured at a machining centre for inspection and adaptive control of machining operations.
- The improvement of the data acquisition and processing as well as inspection result visualisation: optimal methods for data alignment, noise reduction, 2D & 3D dimensioning, datum control and management, as well as expert systems for inspection and machining operation control.
- Optimisation of the general process of machining and measurement: SOFTWARE

2. State of the Art

2.1. Coordinate Measurement Machine – CMM

A coordinate measuring machine (CMM) is typically used to generate 3-D points from the surface of a part. It’s digitising a part in three dimensions. However, it is often used to make 2-D measurements such as measuring the center and radius of a circle in a plane, or even one-dimensional measurements such as determining the distance between two points. Typically, CMMs are configured to measure in Cartesian coordinates. There are also CMMs that measure in cylindrical or spherical coordinates. They can measure any part surface within their working volume.

CMMs typically generate points in two ways: point-to-point mode, where the CMM taps or touches the part and generates a single point per tap, or scanning, where the CMM moves over a part, generating data as it moves. Scanning generates significantly more data than tapping, but is typically not as accurate.

CMMs are manual or automatic. While the CMM hardware generates the coordinate data, the software bundled with the CMM (or in many
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instances sold separately) analyses the data and presents the results to the user in a form that permits an understanding of part quality, and conformance to specified geometry.

The most important advancement in CMM technology over the past several years is error mapping of the CMM. A machine is precisely measured and significant errors are corrected mathematically via software. As a result, looser tolerances can be used on the system hardware, and the resulting errors (as long as they are highly repeatable) are eliminated in software. This results in lower manufacturing costs, while retaining or even improving the capabilities of the CMM. Other major design innovations in the past were linear air bearings and linear scales for improved repeatability and accuracy.

New user-friendly software that allows the CMM and probe to be accurately, quickly, and easily calibrated have also made the CMM more accurate and easier to use.

Two types of probes dominate CMM operation: trigger probes and scanning probes. Both types can be contact or non-contact. Trigger probes send a signal to the CMM when contact has been made with a surface. These probes operate in a point-to-point modes, generating a single point of data every time contact with the part is made. Scanning probes follow the surface and generates “clouds of points”. We can distinguish between tactile scanning (like Renishaw REVO) and laser scanning.

2.2. Mobile articulated arm CMM

Articulated arms can do all functions as CMM’s. Since more Degree of Freedom (DOF) are introduced, articulated arms are very flexible for measurements of individual parts. The key difference between CMMs and articulated arms is that the accuracy of the articulated arms is much lower compared to stationary bridge-type CMM, and of course the repeatability accuracy is low as well. Accuracy ranges for Articulated arms are normally about 20 to 40 microns. But for many operations, the accuracy of articulated arm CMMs is sufficient for a variety of processes. The advantage of articulated-arm CMMs is that they generally have a larger work volume than bridge CMMs, and can reach areas that are not easy to access with typical CMMs. Although quoted accuracy for articulated arm CMMs is not sufficient, it should be seriously considered as an alternative. Also, articulated arm CMMs are more portable. Typically, they can be set up for in-line measurement quickly. On the downside, articulated-arm CMMs are manually driven while gantry-type CMMs are both manual and servo-driven.

The principal parts of laser based measuring equipment are a laser scanner head and the measuring arm. Technical specifications proposed for the measuring head:

- Resolution: 0.1 um
- Linearity: 1 um
- Repeatability: 1 um
- Accuracy: ±1 um

Technical specifications proposed for the measuring arm:

- Measuring volume: 500x500x500 mm
- Positioning accuracy: ±1 um

Below are some proposals for the measuring components, included firms and characteristics.

2.3. Measuring arm

As specified above, the measuring arm can be actuated manually or automated.

2.3.1. Manually

2.3.1.1 METRIS - Interleuvenlaan 86 -3001 Leuven –Belgium

The Metris MCA, Manual Coordinate measuring Arm, is a precise, reliable and comfortable portable measuring system available in a 6 or 7 axis version. It feels perfectly at home in the metrology lab as well as on the shop floor.

![Fig. 2.3.1.1](image)

The MCA can be equipped with a wide range of probing systems for touch trigger measurements, continuous scanning and laser scanning. Its flexibility makes the measurement arm the perfect...
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partner for a wide range of measurement tasks.

The MCA comes in a 6 axis and a 7 axis version with two variants. The I6 and I7 variants are ideally suited for those applications where a quick verification of dimensions are needed. The M6 and M7 variants provide higher accuracy required for true metrology applications. Both variants come standard with the electromagnetic brake for optimal handling comfort, while the quick mount probe adapter facilitates the easy exchange of measurement probes.

2.3.1.2. Steinbichler optotechnik GmbH - Am Bauhof 4 -D-83115 Neubeuern

ABIS Serie

Fig. 2.3.1.2.a  Fig. 2.3.1.2.b  Fig. 2.3.1.2.c

ABIS II Highest Standard for Surface Inspection sets standards - Independently of offline or inline operation, the measuring system is able to identify all relevant types of defect: dents, bumps, sink marks, pits, waviness, constrictions and cracks are quickly and reliably detected at a high resolution and then evaluated. Regardless of the ambient lighting conditions, the sensor supplies high-precision measurement results without a need for additional dimming.

The system’s expandability offers a great advantage to the user: ABIS II can be extended individually from the ABIS II Interactive offline configuration through to the full system integration into the production area, thereby providing extremely flexible application possibilities. If the evaluation time is to be reduced, the system can be scaled, i.e. supplemented by additional computers without any problems.

The ABIS II software enables users to enter individual defect characteristics and severity levels based on the auditor’s experiences. This allows including the experience of the quality assurance staff directly into the system’s classification and tolerance criteria, which in turn can be customized to the individual state of production. ABIS II thus takes the lead among the currently available surface inspection systems.

2.3.2. Automated (Robot Like)

2.3.2.1. Perceptron GmbH | Stahlgruberring 7 | Germany  D - 81829 München

Powered by Perception’s industry-leading sensor technology, the AutoScan Flexible Ring Gauge is a revolutionary new gauging concept that can improve your overall quality and deliver dramatic cost savings. Traditional ring gauging is a manual, time-consuming process that relies on a small sampling of points on a small sampling of parts. With AutoScan, a robot mounted sensor sweeps across the entire surface of the part to provide a more complete picture – faster and with highly accurate results.

- AutoScan’s robot mounted sensor is programmed to move continuously over a part or sub-assembly, greatly reducing the time required to inspect each part. Part changeover is also greatly reduced with the introduction of a four-station rotary table.
- Accurate, repeatable results

Fig. 2.3.2.1

2.3.2.2 METRIS - Interleuvenlaan 86 -3001 Leuven –Belgium
Robot scanners: K-ROBOT

Inline robotic scanning and inspection
K-Robot upgrades any industrial robot or actuator into a flexible, productive and accurate metrology solution. The K-robot metrology chain features proven Metris metrology components. K-Robot is perfectly suited for applications that require productivity and flexibility while offering metrology accuracy.

Key benefits and features:
- Independent metrology chain
  - Requires no external metrology, reference part or CMM
  - Independent of robot accuracy: Robust for robot drift, warm-up, backlash
  - No need for cyclic robot calibration
- Increase product quality by introducing metrology accuracy
  - Focus on the product quality by measuring part against CAD
  - Global absolute accuracy: better than 100 μm in working volume
- Process integration by using industrial robots
  - Fast and lean manipulator for laser scanner
  - Flexible adaptation for different parts and models
- Robust and flexible integration
  - Scans almost all materials due to enhanced sensor performance
  - Robust against ambient light conditions
  - Dynamic reference auto-alignment on rotating tables
  - Inspection results in MS Excel and SPC compatible formats (Q-Stat, QC-Calc)
  - Standard Ethernet interface to robot controller

Robot CMM Arm

Metris RCA is a robotized CMM arm that introduces patented technology to accelerate repetitive 3D inspection jobs. The Robot CMM Arm combines a highly accurate internal 7-axis articulated arm with an external skeleton driven by electric motors. This unique concept creates a measuring robot that drives a Metris MMD laser scanner along the programmed motion path. Thanks to premium encoder technology and stiff carbon fiber axes, RCA intrinsically offers truly absolute measurement accuracy within an inspection volume of 4.2 meter diameter today, and with larger models to come later

The RCA is equipped with the Metris MMD laser scanner. Digital Metris laser scanners feature excellent material scanning capabilities and offer fast data acquisition for both feature and surface inspection

2.3.3. Comparison between manually and automated measuring arms:
- manually measuring arm have a lower cost, the software (for measuring and driving) is also lower but measuring time is longer than an automated arm.
- automated measuring arms are more expensive, the software is more complex (needs modules for measuring but also for driving ) and more expensive but the measuring time is shorter

2.4. Software:
The programs must provide automatic measurement routines, and perform a detailed, dedicated graphic analysis of the dimensional quality of the part under evaluation. They must implement algorithms for error compensations (e.g. consider changes in shape
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of the measuring device due to temperature variation in case of in-line measurements)
Regarding the software needs, some good examples are:
- CAMIO – from METRIS, Belgium
- GeoMagic Software from GEOMAGIC, Inc USA

3. Equipment proposal

3.1 Measuring equipment in cylindrical coordinates having an articulate arm system with Laser Touch Probe

In order to integrate a complex equipment for quality control we present a proposal (see Fig. 3.1) for a complex measuring system.

This proposed solution consists of:
- Cylindrical coordinates measuring system including
  - linear movement subsystem
  - 2D Laser measuring subsystem
  - positioning and rotating parts subsystem
- Measuring arm
- Measuring head
- Frame of machine

Technical data:
- linear measuring travel:
  - 500 mm
- linear displacement resolutions:
  - 0.0001 mm
- 2D diametrical resolution:
  - 0.0001 mm
- measuring laser head resolution:
  - 0.0001 mm
- measuring and positioning arm accuracy:
  - 0.010 mm

4. Conclusions

Fig. 3.1
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4.1. Technical proposes for rising positioning accuracy:
- Arm length diminution to necessary
- Number of joints diminution to necessary
- Use high accuracy positioning transducers

4.2. Technical proposes for rising the measuring accuracy of the head:
- using a measuring head with a proper accuracy (ex: optoNCDT 2200 of the Micro-Epsilon laser family made by MICRO-EPSILON MESSTECHNIK GmbH & Co. KG, Germany)

4.3. The requirements had to be well defined to choose a proper scanner to handles parts of different materials and surface finish types.
The environment – industrial, in line processing - is an important factor.
The system must be very robust, with temperature compensations and (electromagnetic) noise immunity.
To achieve superior performance in 3D Scanning some improvements must be made by:
- choosing appropriate scanning methods for different parts, taking into account the resolution and accuracy needed.
- Algorithms for compensation of systematic measurements errors
- mechanical improvements of the scan device, especially if fast scanning is required.

Features:
- preferably with no moving parts
- the scanner head for in-line applications should be easily integrated with 3-7-Axis arms as well as with any traditional CMM

For measuring bore diameters is preferably a solution like CimCore, Mitutoyo, Kreon’s scanners which combine traditional metrology and non-contact measurement technology for increased precision.
The proposed system will finally allow to increase the productivity by reducing considerably times of in-line measurement and the various application software packages to applications, make it possible to the users to treat and have their results of measurement nearly instantaneously and more effectively.
The equipment will bring on reducing cycles and costs, improving quality which will offer above average profitability leading to attractive return on investment for SMEs in the precision mechanics sector. That will foster the employment growth in this specifically area, and will have an economic impact: making their non-contact devices more suitable to the needs of small SMEs, the RTD performers developing and producing integrated solution for inline dimensional control will have access to the huge market of precision mechanics SMEs.

The equipment will have an impact on different sectors, enabling a wider use of non-contact measurement techniques for small series of precision mechanics parts, in aeronautical industry, automotive applications, supplying of high precision parts biomechanics, optics or rail transport applications.