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Modern Trends in Metrology

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1. Introduction:

Metrology is the science of measurement. Use of computers in the field of metrology has revolutionaries the way measurements are taken and the inspection data is processed. Traditional measuring instruments can provide excellent solutions for the measurement of features such as length, height, width, inside and outside diameters, flatness, roundness, angles, and so on. The problem with traditional measurement techniques is that each measured feature may require individual inspection instruments and individual setups as well as analysis of data by manually. By using computers, it is easy to store large amounts of data and to analyze it.

Integration of hardware capabilities and appropriate software made the measuring systems very powerful and efficient. Automated inspection methods have enabled large number of measurements to be performed quickly and simultaneously without physical intervention from the operators. Due to these capabilities “on-line”, “in process” and “100% inspection” techniques have become a reality. Non contact and vision system based measurements were developed to meet the demands of good flexibility and high speed. In this article, the recent developments in the field of metrology have been described.

2. Coordinate Measuring Machines

With the advent of computer controlled machine tools, the demand has grown for a means to support this equipment with faster inspection and in many cases 100% dimensional inspection. In order to meet this need, Coordinate Measuring Machines (CMMs) have been developed. The CMM plays a vital role in automated inspection process. CMM has now become a mandatory piece of equipment for manufacturing industry due to the pressing need for an accurate measuring instrument and detailed documentation of the components being produced.

The advantages of using CMMs over conventional gauging techniques are flexibility, reliability, reduced set-up time, least measurement uncertainty, reduced operator influence and improved productivity. The CMM can also be fully automated and linked to a Computer Aide Design (CAD) system as well as used to measure and verify Geometric Dimensioning and Tolerancing (GD&T) call outs.

A variety of CMM configurations are available and each configuration has advantages that make it suitable for a particular application. The primary configurations are cantilever, bridge, column, gantry and horizontal arm. The CMM uses three orthogonal coordinate system and give the data in terms of Cartesian coordinates in millimeter/inch.
In contact CMMs the probe of CMM is made to touch the component at a desired measurement point and the CMM gives the coordinates of the measured point in terms of X, Y and Z coordinates with reference to the machine datum.

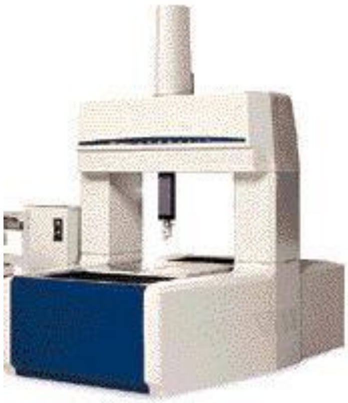

Fig. 1: Contact CMM

Fig.2: Touch trigger probes used in contact CMM

In non contact CMMs the video and laser sensors that does not contact the part are used for carrying out the inspection. The non contact CMMs make it possible to measure complex, precisely fabricated items and materials such as automotive and aerospace components, printed circuit boards, microelectronic circuits and features that cannot be accessed by conventional contact type machines and gauges. Measurements can be obtained from thin or soft workpieces; and brittle, elastic or moving parts can be measured accurately and quickly, as the measurement technique is neither invasive nor destructive. This is advantageous in a production environment, allowing quality control and real time feedback to be readily integrated into the manufacturing process. These systems are used in many diverse industries, with typical users including pharmaceuticals, food production, engineering, electronics and aerospace.

Fig.3: Non Contact CMM

3. Vision Systems

Vision systems are gaining popularity in the modern automated inspection process due to their inherent capability of accurate measurement. A plethora of industrial activities are benefited from application of machine vision technology on manufacturing process. Industrial vision systems are used extensively in industry for inspection of dimensional quality, surface quality and structural quality. The vision systems are accurate, fast, clear, rugged & portable, high resolution and lightweight optics. Most vision systems are equipped with one or more video cameras linked to a vision processor. The vision processor digitizes the camera image and analyze it to define the object.

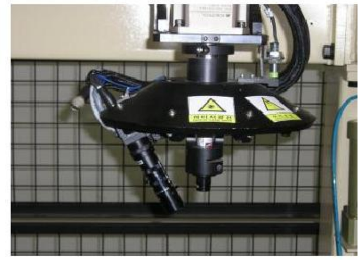

Fig 4: Laser Vision System

Most vision systems consist of a video camera interfaced with the vision computer through a video buffer called the frame grabber. The digitized image is stored in the memory of the vision computer and subsequently processed. Vision systems are being used, in a variety of inspection tasks. Product inspection is a major area in manufacturing where a significant increase in productivity is assured when using automated visual inspection systems. In addition, these systems provide better quality control, since human inspectors find it difficult to concentrate throughout the work shift and errors in their judgment become more likely. By using vision systems measurements can be carried out at any angle along all the three reference axes X, Y and Z without contacting the part. The measured values of the component parameters are then compared with the specified tolerances which are stored in the memory of the computer.

4. 3D Scanners

Traditionally the inspection of parts is done coordinate measuring machines (CMMs) are used for the inspection of parts. But that process is slow and expensive. In order to overcome these disadvantages, industries are moving toward 3-D inspection methods. 3-D scanners make it possible to capture the shape of an endless variety of objects at high speed and with high-quality scans. This system consists of scanning unit, motion subsystem, and related software - in an integrated format, with the addition of a graphics workstation

Using 3D scanners the whole design, manufacture and inspection processes can be significantly speed and can cut down on development costs. Inspections on all of parts, which involves examining every feature and dimension for flaws or deviations from the original model can be carried out by using scanners. By using the scanners all the manufacturing process are digitized. By using these 3-D scanners, hundreds of thousands or millions of points far more than the most sophisticated CMMs. After obtaining the point clouds, the part CAD solid model can be registered to the point-cloud either by matching at critical datum's or using a best-fit algorithm. Color maps can then be created showing the differences between the solid model and the actual point-cloud. Tolerances can be adjusted for a more critical examination.

3-D scanners can captures highly detailed 3D models that can be analyzed, modified and physically reproduced using automated milling machines or rapid-prototyping systems. These systems are ideal for supporting tasks such as; product design, CAD/CAM, research, animation and special effects for film, medical applications and reverse engineering. The resultant 3D model is displayed instantly on a graphics workstation. The motion subsystem built into the system furnishes both cylindrical and linear scanning. The motion platform can rotate the object in front of the scanning unit, and the scanning unit can scan in a linear path across an object on the platform. These scanning patterns allow you to scan virtually any type of objects. In some cases larger objects can be scanned in parts and assembled using the software.

Fig.5: 3D scanner

5. Micro scopes

5.1 Scanning Tunneling Microscope (STM)

The scanning tunneling microscope (STM) is widely used in both industrial and fundamental research to obtain atomic-scale images of metal surfaces. It provides a three-dimensional profile of the surface which is very useful for characterizing surface roughness, observing surface defects, and determining the size and conformation of molecules and aggregates on the surface. Several other recently developed scanning microscopies also use the scanning technology developed for the STM. A precursor instrument, the topografiner, was invented by Russell Young and colleagues between 1965 and 1971 at the National Bureau of Standards (NBS) [currently the National Institute of Standards and Technology (NIST)]. The electron cloud associated with metal atoms at a surface extends a very small distance above the surface. When a very sharp tip, in practice, a needle which has been treated so that a single atom projects from its end, is brought sufficiently close to a surface. There will be a strong interaction between the electron cloud on the surface and that of the tip atom, and an electric tunneling current flow when a small voltage is applied. At a separation of a few atomic diameters, the tunneling current rapidly increases as the distance between the tip and change of tunneling current with distance results in atomic over the surface to produce an image.

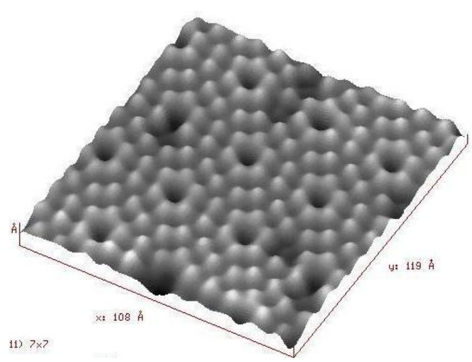

Fig.6: Image obtained from STM

Scanning probe microscopes are increasingly able to do more than report on one property of the specimen as a function of position (like the piezo-height at which current between STM tip and specimen is held at some set-point value). Thus modern "atomic force" microscopes can map lateral force and conductivity along with height, and image-pairs from an air-based STM scanning to and fro can be used to map friction coefficient along with height. As these instruments provide more robust ways for "getting small" and checking things out, visualization facilities are improving rapidly as well. Already, topographic maps may be colored using non-topographic information like data on coefficient of friction. This allows ray-tracing programs to seriously put our 3D pattern recognition abilities to work in the nano-world and allows software like that in virtual reality markup language (VRML) browsers to offer human-viewpoint exploration & travel between nano-locations, even for participants connected far and wide across the world-wide web.

5.2 Atomic Force Microscope (AFM)

The atomic force microscope is a scanned-proximity probe microscopes. Unlike traditional microscopes, AFM do not use lenses, so the size of the probe rather than diffraction effects generally limits their resolution. The Atomic Force Microscope is being used to solve processing and materials problems in a wide range of technologies affecting the electronics, telecommunications, biological, chemical, automotive, aerospace, and energy industries. The materials being investigating include thin and thick film coatings, ceramics, composites, glasses, synthetic and biological membranes, metals, polymers, and semiconductors. The AFM is being applied to studies of phenomena such as abrasion, adhesion, cleaning, corrosion, etching, friction, lubrication, plating, and polishing. By using AFM one can not only image the surface in atomic resolution but also measure the force at nano-newton scale. Generally, the force between tip and sample is measured by tracking the deflection of the cantilever. This was done by monitoring the tunneling current through a second tip positioned above the cantilever.

In fact, without the breakthrough in tip manufacture, the AFM probably would have remained a curiosity in many research groups. It was Albrecht, a fresh graduate student, who fabricated the first silicon microcantilever and measured the atomic structure of boron nitride. Today the tip-cantilever assembly typically is microfabricated from Si or
The era of AFM came finally when the Zurich group released the image of a silicon (111) 7X7 pattern. The world of surface science knew that a new tool for surface microscope was at hand. After several years the micro cantilevers have been perfected, and the instrument has been embraced by scientists and technologists. The force between the tip and the sample surface is very small, usually less than 10^{-9} N. The detection system does not measure force directly. It senses the deflection of the microcantilever.

Fig.7: AFM head

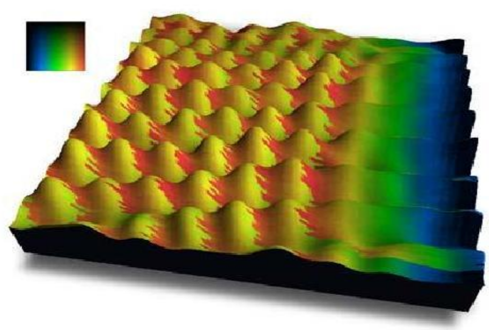

Fig.8: Image captured by AFM

6. Scope:

Nowadays, as requirements for short delivery time, product diversity and improved enterprise agility are continuously increasing, there is a growing need to have the right information in the right place at the right time and in the right form. In this context, computer aided metrology will have a growing role as an important provider of experience based information especially for the engineering and maintenance and measurement functions of the company. The present level of hardware and software already makes it possible to build a flexible Computer aided metrology system. In profile metrology STM and AFM are used as profile measuring instruments in nanometer resolution and in the Laser measurement techniques are widely used. However, we have no nano-resolution measuring instruments for three dimensional machine parts. Therefore, efforts are being made to develop a nano-CMM.

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