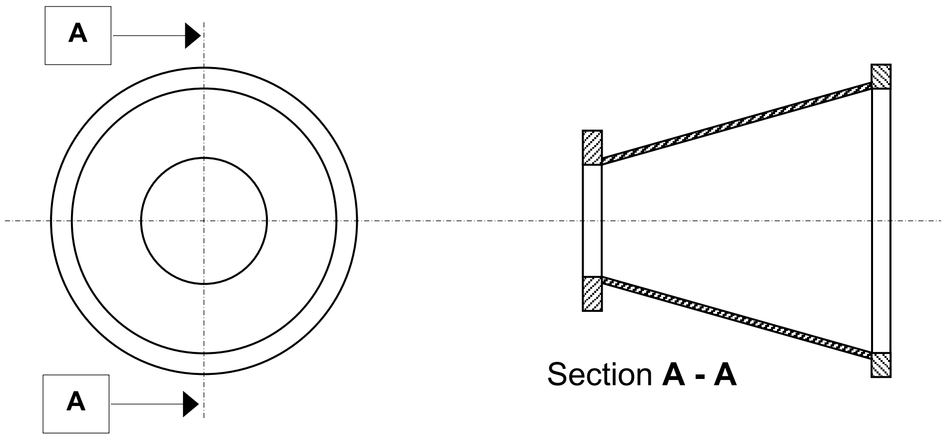
Educational Articles: **Article nr. 4**

Computer Tomography applied to 3 Dimensional Metrology

Primarily based on human intellect, the evolution of 3 Dimensional Metrology is also and largely based on the evolution of auxiliary technologies such as: materials, electronics, software, sensors, etc.
The availability of concepts and materials originally developed for other than measuring allowed new revolutionary techniques to be integrated with measuring devices of varying complexity; this is the case of Computer Tomography. Developed for medical use this technique has been rather recently applied to 3 Dimensional Metrology with surprisingly positive results.
But what is "*Tomography*"? Tomography is the image of a section or "*tomogram*" of a given object. Since we have to focus on the industrial use of tomography we may say that the simplest example of a tomogram is the section of a part represented on the drawing of the part itself.



Section **A – A** is one tomogram of the very simple part represented in the sketch above. Now, the image of the before mentioned section has been obtained with a drawing; in Computer Tomography the same image would be a 2 Dimensional X-ray image.
In Computer Tomography the basic concept is to use penetrating radiation to obtain a number of 2 Dimensional X-ray[(1)] sections of a given object; Digital Geometry Processing will be then utilised in order to obtain a 3D image, both internal and external, of the object itself.
The Tomography originated at the beginning of the 1900 when the Italian radiologist Alessandro Vallebona presented a method to represent a section of a human body on the radiographic film.

The modern Computer Tomography based system represents a non contacting measuring method particularly suitable for the following applications:

- *Gauging.*
- *Defect checks.*
- *Porosity analyses.*

[(1)] X-ray, also known as Röntgen radiations after the name of the inventor, are a form of electromagnetic radiation, characterised by wavelength, frequency and energy.

- *Assembly inspection.*
- *Damage analysis.*
- *Inspection of materials.*
- *Reverse engineering.*
- *Comparison of geometries.*
- *Archaeology.*
- *Geology.*

It is rather intuitive that advantage of this technique is that it allows "*seeing*" inside a part and this is extremely important.
In the manufacturing industry it happens that, in order to completely verify the correspondence of a part to its theoretical specifications, the object itself must be cut, namely destroyed; this goes under the definition of "*Destructive Testing*". Computer Tomography may evidently allow the part test without the need for destroying it thus permitting remarkable savings. In destructive testing the part to inspect has first to be sectioned and then machined to properly expose the layer, or layers, to be measured; operations which are obviously not necessary with Computer Tomography. Not to mention the fact that the component under inspection can then be utilised if within specifications.
Furthermore the technique in question allows also to detect material defects such as porosity, imperfections etc. that would not be possible with conventional methods.

Computer Tomography Metrology Systems

These systems consist of a high precision mechanical structure (CMM technology) on which both X-ray source and detectors are located. The part to be examined is fitted on a high precision rotary table which allows a number of radiographies to be taken at different angles.
As any precision metrology system also the machines in question must be subject to the proper conditions in terms of environment in order to be able to supply their full performance.

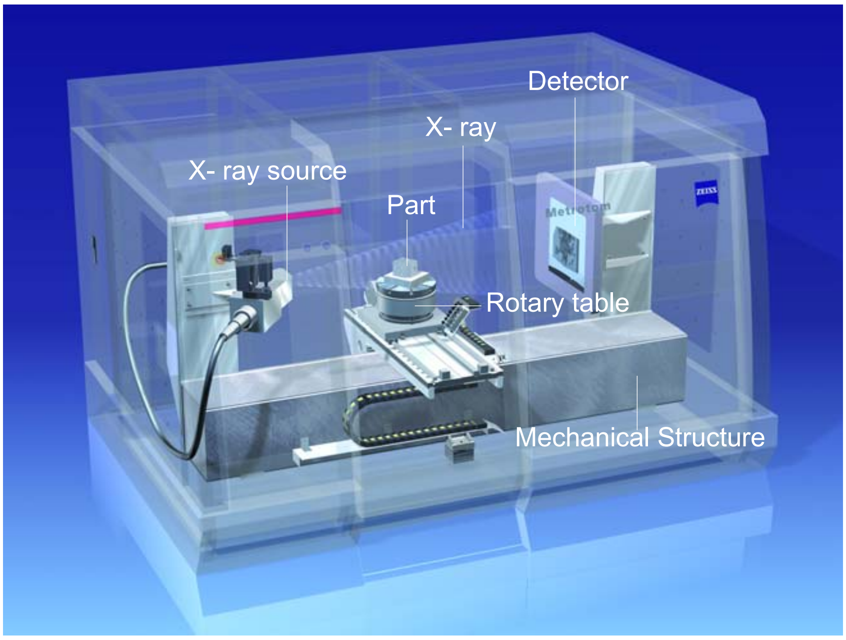


Fig. 1 – Functional scheme of a Computer Tomography based Dimensional Metrology System

A key factor for image resolution[(2)] in Computer Tomography scanning is determined by the number of detector elements which are comparable to the number of pixels on a digital camera. Consequently, the resolution of the scan may be increased by increasing the resolution of the detector.

It has to be noticed that most of these systems require that the entire shape of the part under analysis is framed

[(2)] *In Dimensional Metrology "Resolution" is the minimum measuring unit that the concerned instrument is able to read; in the case in question we may simplify as the level of detail of the image which, as said, is function of the resolution of the detector.*

within the detector surface. In the case of large components this condition may clearly represent a limitation in resolution.
Unassisted exposure to X-ray may be dangerous for human beings, therefore Computer Tomography Metrology System are built to be safely utilised without risk of contamination. Depending on the specific country a number of rules have however to be observed to comply with the local laws on Radiation Protection.

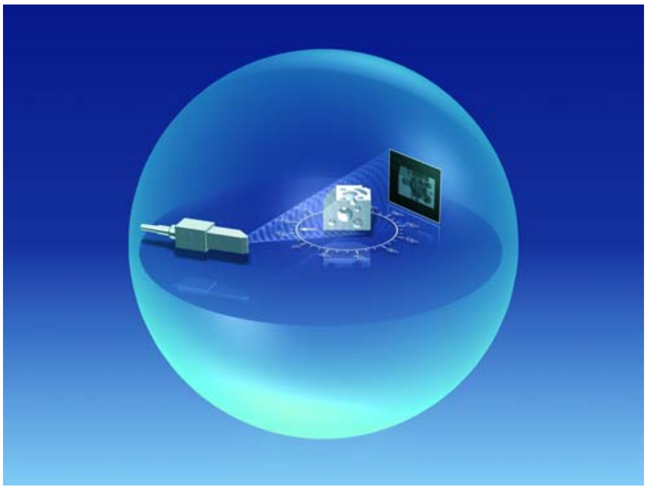
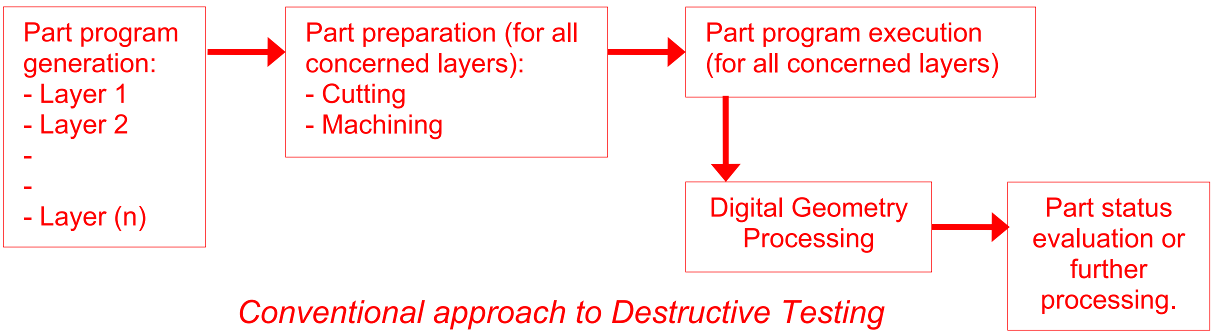


Fig. 2 - Computer Tomography Metrology System are built to be safely utilised without risk of contamination.

Of course independently of the fact that these systems are based on the use of rather sophisticated sensors and detectors, the overall reliability of the readings depends on the whole technology chain of the system, like any modern CMM. Therefore structure geometry, dynamic stress, control, software, calibration, environmental control, etc. are all the parameters that ultimately determine the quality of the output.
Summarising, a Computer Tomography Measuring systems is based on the use of X-ray technology that allows capturing a substantial number of 2D radiological images of a given object which is sequentially rotated around one single axis. The images are then digitally processed to obtain the part geometry (internal and external) to be compared with theoretical specs.

Computer Tomography approach to Destructive Testing

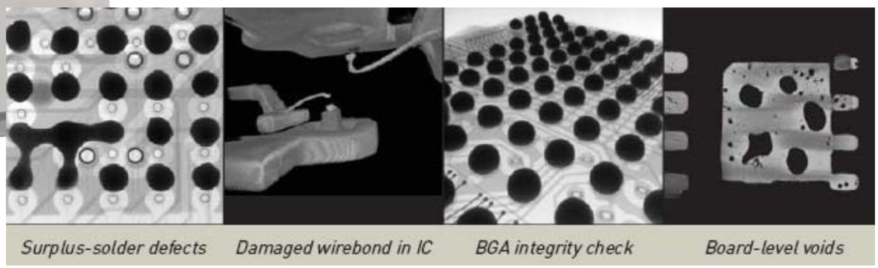


Conventional approach to Destructive Testing

Of course the technology in question does not represent the "*ideal solution*" for all the manufacturing Dimensional Inspection cases but <u>does</u> represent the ideal solution for a number of cases, such as:

1. Part inner inspection and gauging that would demand destructive testing.
2. Inspection and gauging of part of very small dimensions.
3. Inspection and gauging of part where both Tactile and other Non Contacting methods present limitations.

Fig. 3 – A typical application example: Computer Tomography for electronic inspection.



The X-ray based Metrology System has widened the application of 3D Metrology; electronics and industrial are two of the major application domains.
Typical electronics X-ray and CT application examples include quality verification, troubleshooting and repair:

- *Analyze interconnection failures on devices and (assembled) printed circuit boards (wire bonds, solder joint problems, vias, etc.).*
- *Verification of rework, repair (and re-ball) of BGA and other devices (de-solder and solder reflow, etc.).*
- *Detection of material defects (inclusions, voids, cracks, etc.).*
- *Detection of counterfeit parts.*

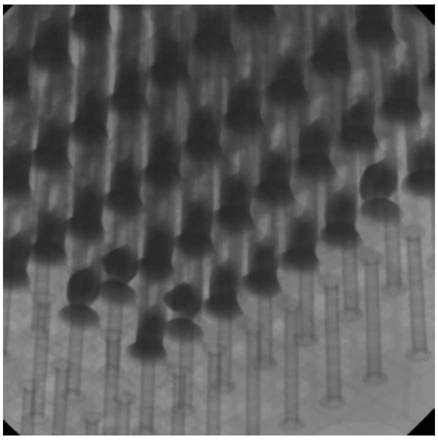
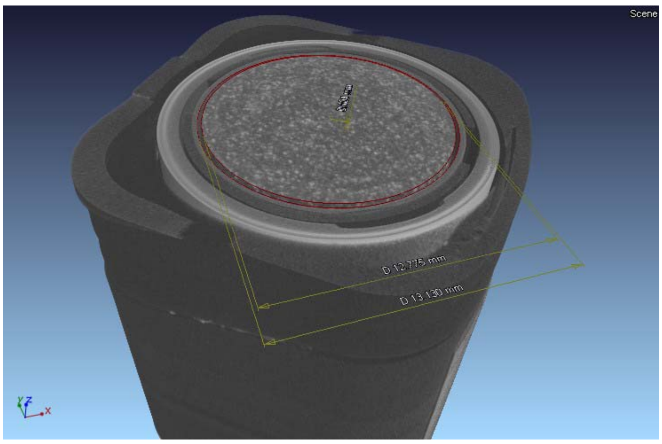


Fig. 4 – Open vias.

Fig. 5 – Lipstick tube verification.



While in industrial applications, CT scanning is applied for diverse purposes:

- *Verification of medical implants and animal bone in growth into implant.*
- *Inspection of soil and stone samples to prepare for large infrastructure construction.*
- *Inspection of cosmetics sprays cans, sticks, dispensers, etc. to verify production quality.*

Essentially the set of data generated by a Computer Tomography 3 Dimensional Measuring System may be utilised for a number of different goals, namely:

1. Material imperfection inspection.
2. Gauging.
3. Part to CAD comparison.
4. Reverse Engineering.

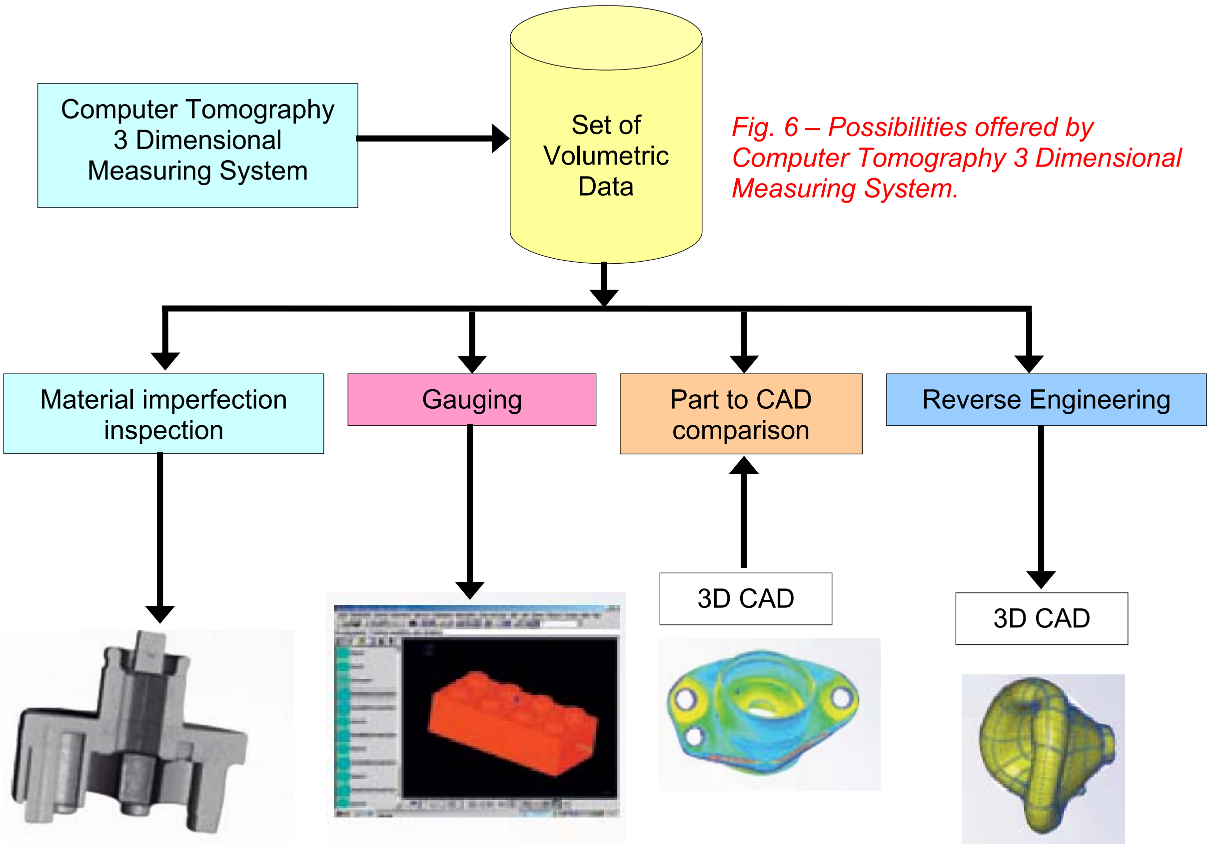


Fig. 6 – Possibilities offered by Computer Tomography 3 Dimensional Measuring System.

As it happens rather often with new, revolutionary systems, internationally recognised standards for the certification of Computer Tomography accuracy when applied to 3 Dimensional Metrology are not yet available.

This generates a situation where User and Supplier have to define and agree on procedures and artefacts for the specification and the verification of the metrology performance of the whole system.

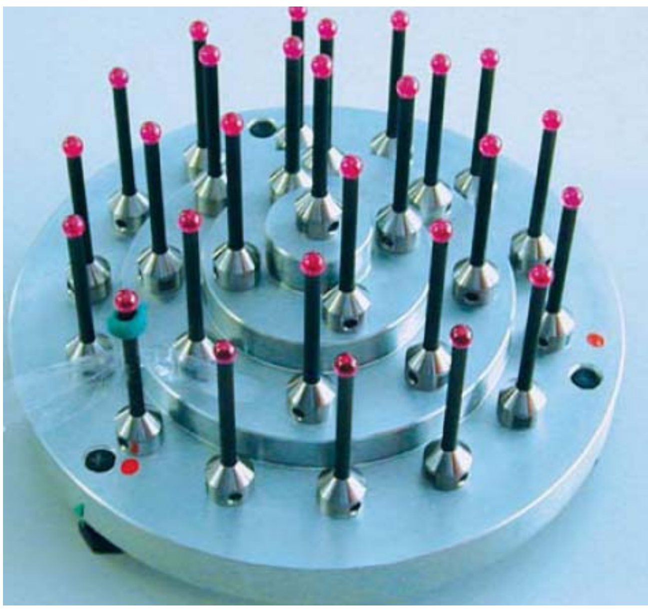


Fig. 7 – An interesting artefact for the determination of Measuring Uncertainty and Repeatability in Computer Tomography applied to 3 Dimensional Metrology.

Utilised in the same application environment of Co-ordinate Measuring Machines, Computer Tomography Metrology should be subject to the analogous criteria to certify the reliability of its output.
Already existing standards may represent an interesting reference point for the definition of specification in this innovative approach to 3 Dimensional Metrology.

*The Images for this article have been kindly supplied by the following **ia.cmm** Member Companies:*

- ***Carl Zeiss IMT** – (Germany)*
- ***METRIS** – (Belgium)*

NOTE FOR THE READER:
Please do not identify the Companies which supplied the images utilised in this article with the applications shown in the photo. Each of the shown pictures is just example of one of the many applications that can be very efficiently carried out with the equipment of the Companies in question.