Educational Articles: Article nr. 1

Premise

***ia.cmm**, the **I**nternational **A**ssociation of **C**o-ordinate **M**easuring **M**achine Manufacturers will shortly be three years old and counts among its members the majority of CMM manufacturers. Founded to support and promote the world-wide diffusion of CMM technology, **ia.cmm** has been serving as a competent and active partner to international organizations and scientific communities involved in the area of 3D Dimensional Metrology. **ia.cmm** working groups are active in the area of machine specifications, software and service to ensure users, all over the world, that the best practices in terms of verification, standardisation and maintenance are followed by our Member Companies.*
*Under the auspices of **ia.cmm**, important initiatives like OSIS (**O**ptical **S**ensor **I**nterface **S**tandard) have grouped experts from all continents to make the integration of non contacting measuring system with CMM easy and reliable, with evident advantages for end users and machine and sensor makers. Other significant developments like DME / I++ were fully supported by our Association.*
*Besides continuing the beforehand mentioned programs **ia.cmm** activities, in the very next future, will be oriented to educational programs and to make of the **ia.cmm** label a warranty of quality and reliability for world-wide CMM users.*

*The article that follows is the first of a series of documents aimed to explain the very basics of Co-ordinate Measuring Machines; a kind of literature which may be useful to those who are approaching the CMM world for the first time and to those who wish to refresh their basic knowledge. These few pages represent the first step of the educational program that **ia.cmm** is now starting.*

Maurizio ERCOLE
ia.cmm
Chairman of the Board

Use and scopes of the Co-ordinate Measuring Machine

The Co-ordinate Measuring Machine (CMM) is a relatively young operating unit, if compared with other kind of equipment such as Machine Tools; as a matter of fact the CMM was invented in the early sixties, since then it has become an indispensable part of any manufacturing process.
The CMM is obviously utilised to "*measure*" in the sense that it is capable of detecting the position of points in the space with very low uncertainty.
The meaning of the verb "*to measure*" is so important that borders with philosophy and would deserve an article on its own; but, for the objectives of this document let us just consider that the measurements taken by the CMM can be used for different goals and, surprisingly, the CMM can be utilised for technological activities other than measuring.

The CMM, on the bases of its hardware and software configuration and of the operating context of which is part, may be utilised for different activities that are named "*Applications*".
The main applications carried out with the machines in question are as follows:

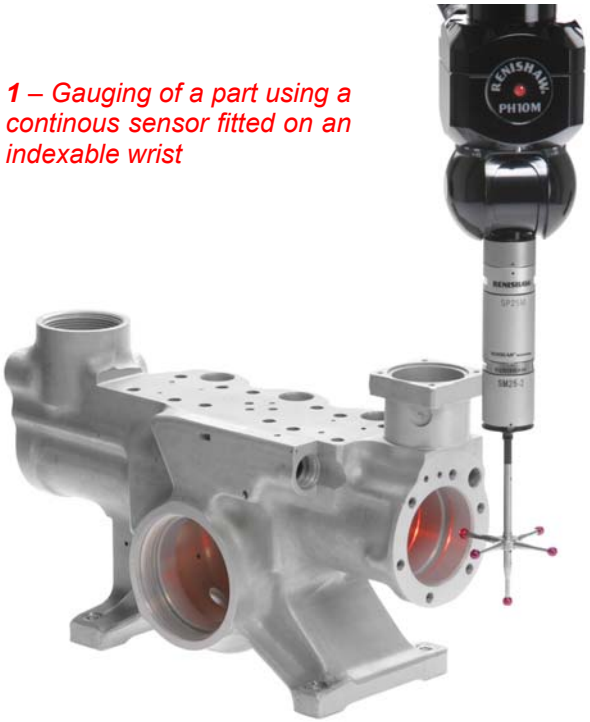
- *Gauging*
- *Digitising*
- *Scribing and light drilling*
- *Light milling*

Among the four above mentioned application the first two are certainly the more common and, between these two, the first is undoubtedly the more diffused.

Gauging

This activity is carried out to verify the status of a physical object with respect to its theoretical definition, the latter expressed either by means of a drawing or a mathematical model.

The parameters taken into consideration to compare the object feature to its nominal description are "*Dimension, Form, Orientation and Position*".
It has to be noticed that the CMM is the only instrument that may verify the previously mentioned feature characteristics simultaneously by means of a single measuring operation. The determination of the Geometrical characteristics of an object (dimension, form, orientation and position) by means of conventional equipment other than a co-ordinate measuring machine, requires the use of a number of different instruments and a sequential series of measurements.



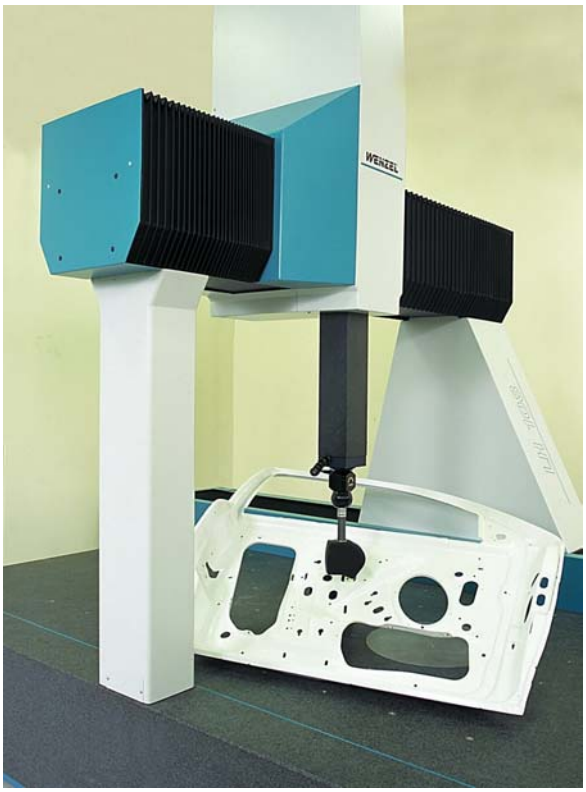
***1** – Gauging of a part using a continous sensor fitted on an indexable wrist*

Conventional Dimensional Metrology is essentially based on the use of manual instruments and more or less sophisticated, single purpose gauges; this approach results rather expensive and it is very dependent from the user skills.
As it will become clear in the next articles, the dimensional inspection by means of a CMM allows, not only the certification of the part but, if included in the right context, also the tuning of the manufacturing process, the determination of the quality output by the process itself and the verification of the reliability of the "*in-line*" inspection media.
Summarising the Gauging (or Dimensional Inspection) is an operation carried out when the theoretical definition of the object to measure is known.

Digitising

In the modern technology of manufacturing objects of daily use, two kind of design can be distinguished, the "*functional*" and the "*creative*" design.
Even though, from the technological point of view, in the creative design the functional aspect can not be ignored, the genesis of these kind of designs is of a very different matrix. While the functional design is essentially based on "*experience/knowledge*", the creative design is fundamentally based on the "*aesthetic*" aspect. Before proceeding it has to be made absolutely clear that even the objects designed following aesthetic criteria must result functional; there is not place in nature for non functional things.
The functional design, in almost all cases, is originated by the knowledge of the physical principles which are at the basis of the object or mechanism which has to be conceived; being the principle known also the morphology is known. Morphology intended as the geometries that will determine the physical presence of the object to be designed in the

space. It is rather clear that having to design a shank the designer will immediately think to a cylinder as the ideal shape even before thinking to the relevant dimensions (experience). The creative aspect in these cases is in the originality of the design in terms of costs and parts reduction, reliability, etc.
On the other hand in the creative design, if we want a form of art generally called "*style*", the morphology of the object to be generated is defined, time by time, by the inventive capacity of the stylists; the form of the object is therefore not defined in the canonical geometrical sense. The outcome of style project will consequently be an object, more or less aesthetically pleasant, but without any geometrical description that would allow the production on industrial scale.
It has however to be considered that in almost all cases it is necessary to mass produce the product of a style design (which is generally a physical style model); it is therefore extremely important to determine the mathematical definition which represents the surface of the object and that will allow the generation of all the parameters necessary to produce it.
The procedure, carried out with a CMM, in order to define the mathematical model of a part with theoretically unknown surface is called "*Digitising*".



By means of digitising sessions on a CMM it is possible to determine the value of the X, Y and Z co-ordinates of the points belonging to the surface of the style model. A further process of these co-ordinates allows the generation of the "*surface entity*" of the digitised model. Starting from the surface, and by means of computer assisted procedures, it is possible to obtain the machining parameters necessary to generate the dies used to produce the designed object on industrial scale.

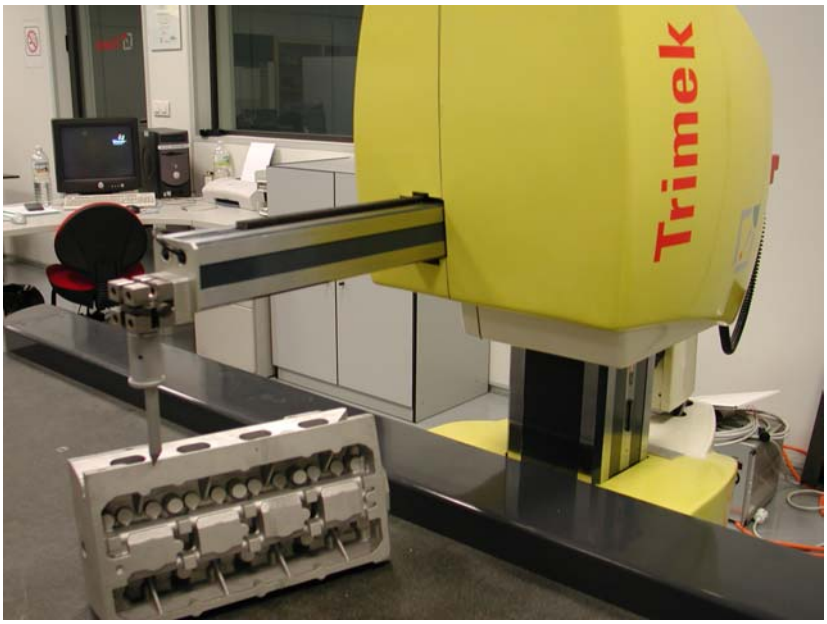
***2** – Part digitising on a Travelling Bridge CMM equipped with an Optical Sensor fitted on an indexable wrist*

Scribing

Legacy of old times dimensional metrology, "*scribing*", is still very utilised in various application sectors.
This activity consists of scribing physical lines (or other 2D geometric elements) on the surface of the part to be analysed. To do this the part is generally painted with special colours (either blue or white) and by means of hard cutting mechanical devices, fitted on the probe holder of the CMM, lines representing characteristic elements of the part are engraved on the paint. The line scribing is made along two Cartesian axes with respect to a physical reference system (the CMM axes) to which the part has been physically

aligned; this allows, for instance, to determine the third dimension at the intersection point of two scribed lines; this may result very useful in so far as it supplies intuitive information on the surface status of the part. Another important use of scribing is to allow the determination of material allowance of a part prior to machining it. For this last scope the machining references are practically scribed on the raw part in order to evaluate, before beginning long and expensive operations, if the finished part may be obtained from the raw component.
Before the CMM came on the scene a number of tools were necessary to carry out scribing operations, such as:

- Reference plates
- High gauges
- Squares
- Compasses
- Scribing tools
- Etc.



The reference plate and the tools orthogonally located on it reproduced a physical Cartesian reference system indispensable to carry out scribing operations.
The CMM, utilised in manual mode, has made scribing easier, more accurate and practicable also on components of very large dimensions. When used for scribing the CMM is generally equipped with swivelling scribing tools and pneumatic light drilling devices.

3 – Scribing a part by means of an Horizontal Arm CMM

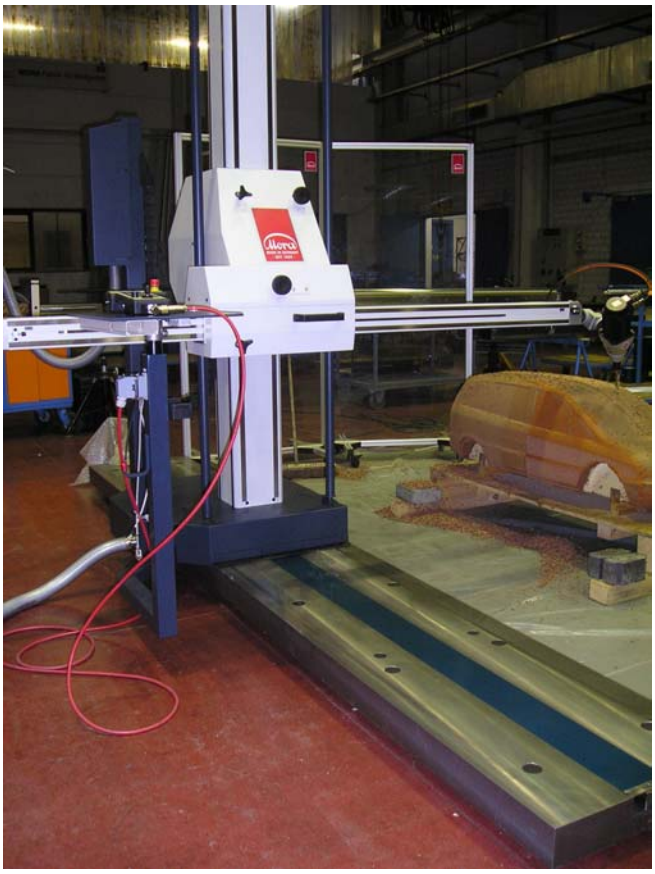
As said scribing on CMM is generally done in manual mode even though a numerically controlled measuring machines can be utilised for automatic scribing if properly configured.

Light milling

Even if mostly designed to support light mechanical stress, the CMM can be utilised where necessary, for light milling operations on relatively soft materials, such as:

- Clay
- Polystyrene
- Aluminium
- Etc.

Generally the milling on CMM is carried out in styling studios in order to reproduce scaled models or to modify the models themselves. Very often in these cases it is particularly rational and efficient to carry out both digitising and milling on the same machine.



It has however to be re-underlined that even if the structure of a CMM may be of very large dimensions, it can not support high mechanical stresses not to loose its geometric characteristics. Therefore the maximum power applicable on the spindle is of about 150÷200W. Higher powers may be obtained on very big machines handled by milling machine numerical controls; in these cases powers in the range of about 1,5KW may be obtained.

***4** – Light Milling of a part by means of an Horizontal Arm CMM*

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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 pictures 1÷4 is just example of one of the many applications that can be very efficiently carried out with the equipment there represented.