**Metrology**
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**Lecture – 39**
**Feature Measurement Using CMM, Laser Vision**

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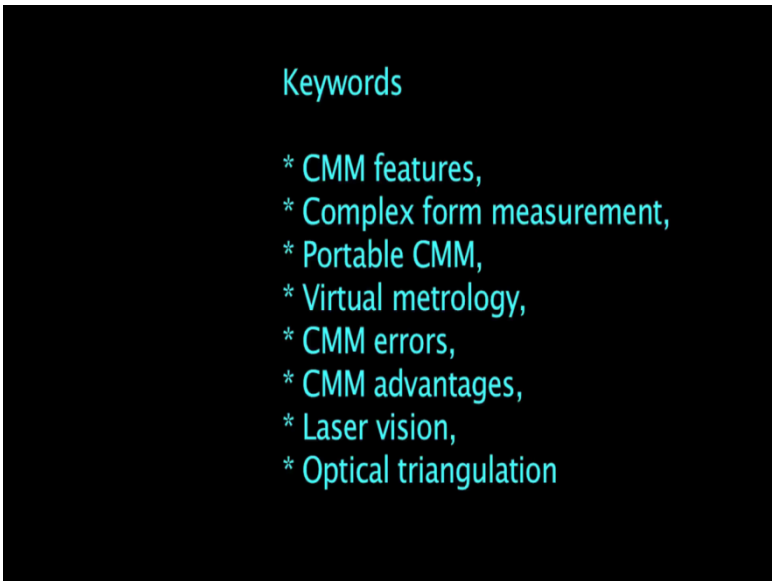


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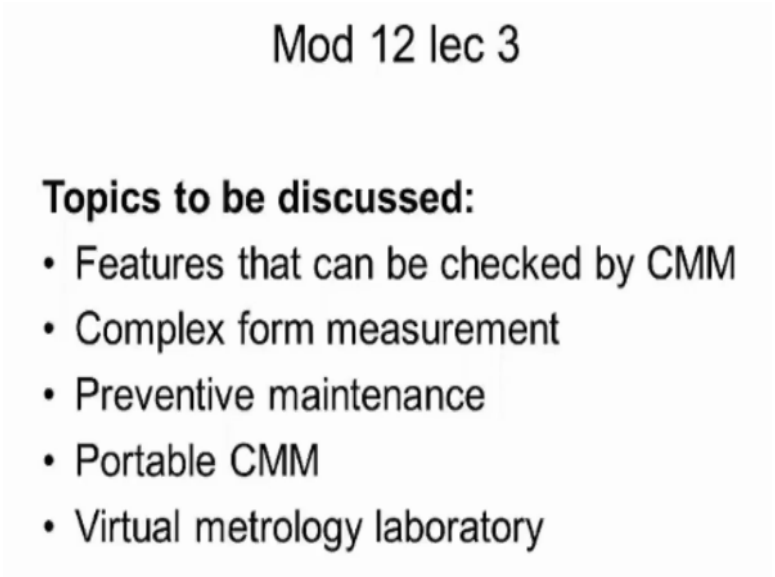


I welcome you all for the series of lecture on metrology, now let us taught lecture 3 in module number 12. In this lecture, the following topics will be discussed, what are the features that can be checked by CMM, complex form measurement using co-ordinate measuring machine, preventive maintenance of coordinate measuring machine and some details about portable

coordinate measuring machine, which can be moved to the shaft loads for measurement purpose and then finally we will discuss about virtual metrology laboratory.

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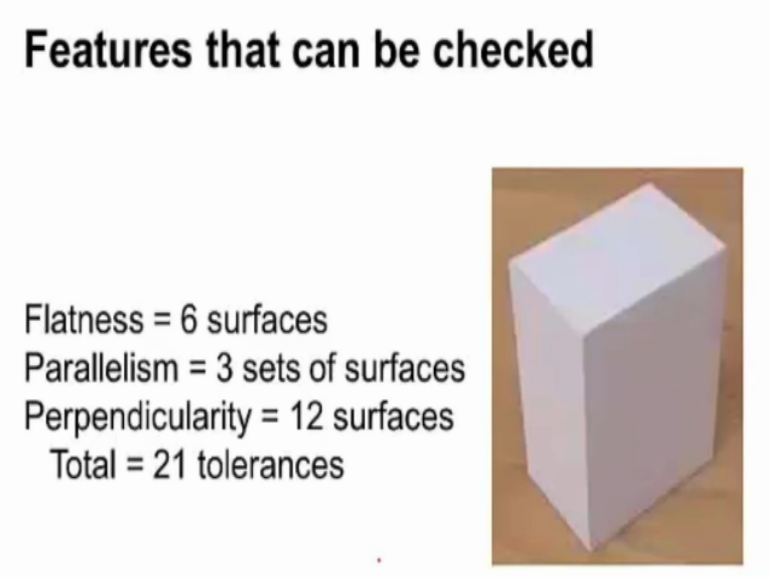


Now let us discuss what are the features that can be checked by using coordinate measuring machine. We can measure the flatness of 6 surfaces, we can see we have a prismatic work is here, which has 6 surfaces, flatness of 6 surfaces can be checked and parallelism of 3 sets of surfaces can be checked and perpendicularity also can be checked, perpendicularity between the 12 surfaces can be checked by CMM.

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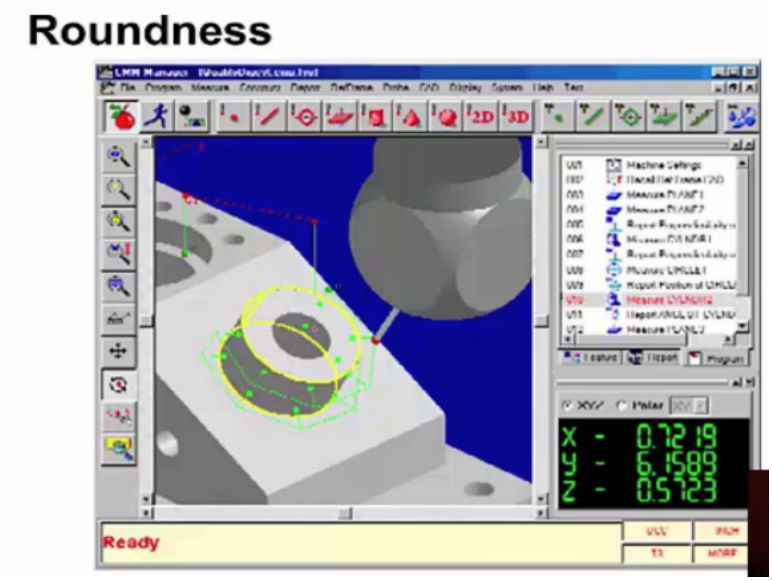


Roundness can be checked, for example see if we have a hole here and we want to measure the diameter of the hole, also the roundness of the hole, so by selecting the data points on the surface of the hole, we can find what is the roundness of that particular hole and then

straightness of a surface can be checked. We can say this is the work piece surface by selecting some data points on the surface of the work piece.

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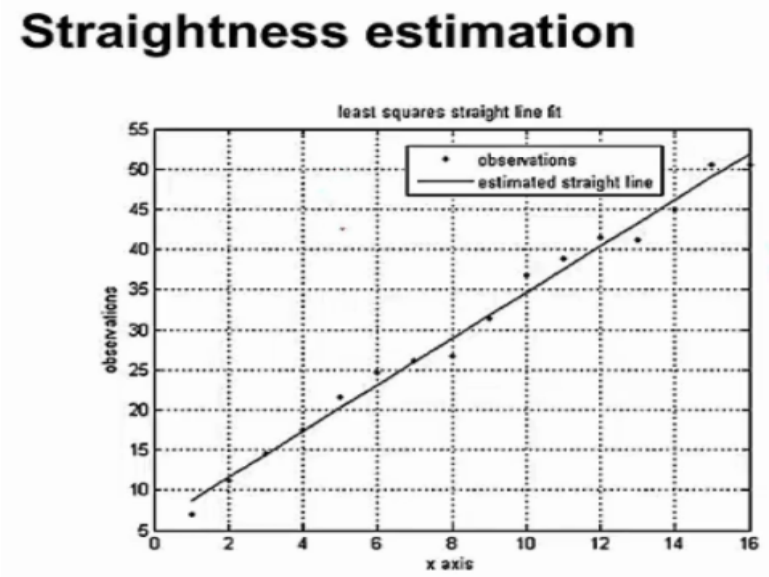


CMM can estimate what are the straightness of that particular surface. You can see here these points are data points obtained by the CMM and using the software, the straightness is estimated that means best fit line is fitted using the data points. Now in one setting, 5 faces can be inspected, all the 5 surfaces, features available in 5 surfaces can be checked.

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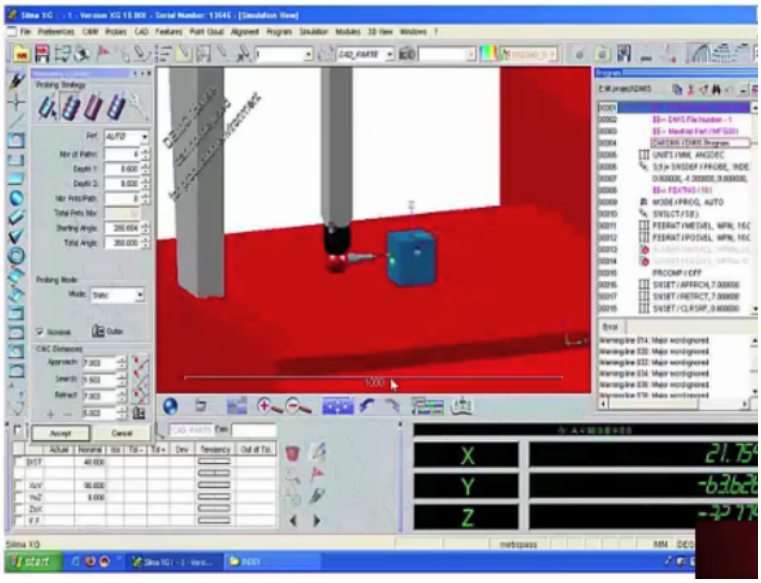


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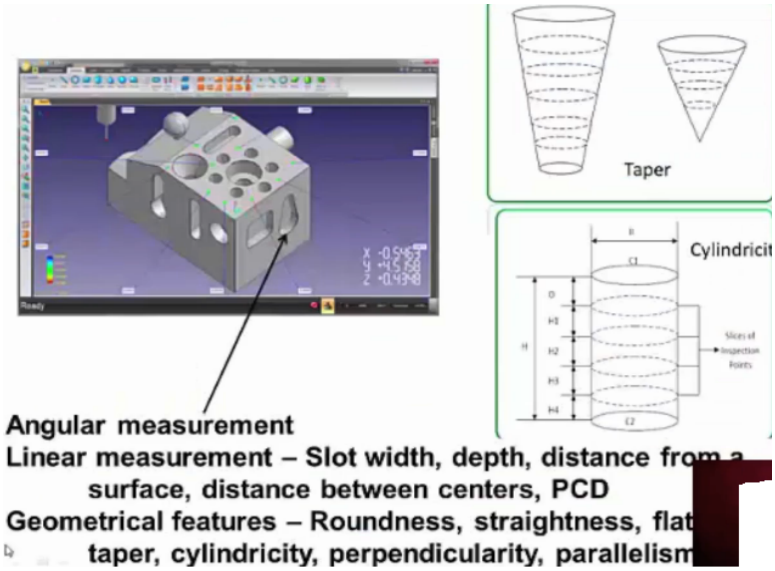


We can see here, we have a very complex work piece and the probe contact type probe, this work piece has many features, so it has angles, so angles can be measured and linear measurement is possible that is what is the slot width and what is the diameter of the hole, what is the distance between 2 surfaces, and what is the distance between 2 slots, distance between centres.

Say this is the centre of 1 hole and this is the centre of another hole, what is the center distance, which circle diameters, those things can be checked by CMM, also geometrical features like roundness, straightness, flatness, taper cylindricity, perpendicularity and parallelism can be checked using appropriate subroutines. We can see here by selecting the measurement points on the surface of external surface or internal taper surface, the CMM can estimate what is the taper and then cylindricity also can be measured.

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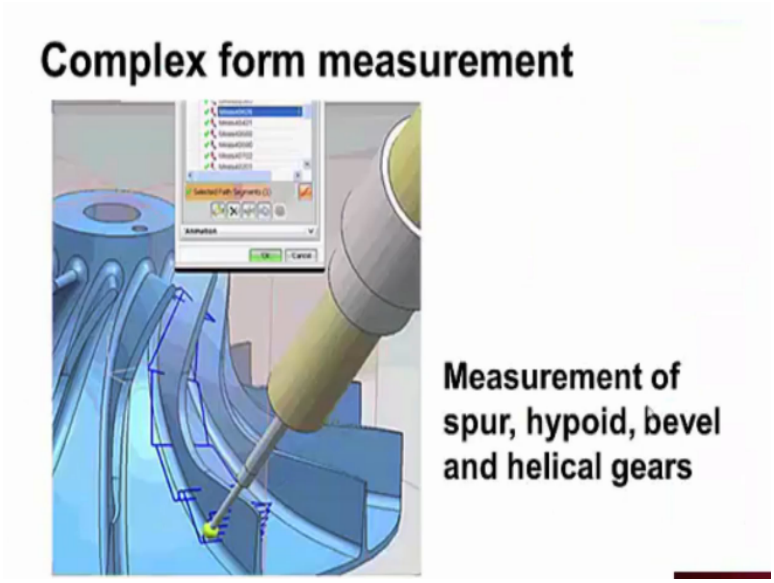


A complex profiles can be measured using coordinate measure machine, you can see here very complex tooth profile, so by selecting appropriate probe, the form of the profile can be estimated, so measurement of spur gear, haploid gear, bevel gear and helical gears is possible using coordinate measuring machine.

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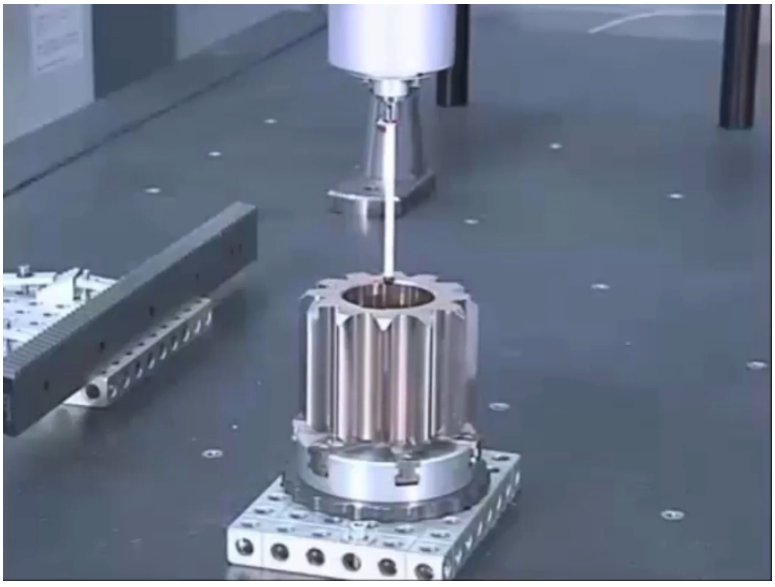

Now you can see the co-ordinate machine is inspecting the spur gear, the stylus is scanning the bore surface, now the stylus is moved, now it is scanning the tooth profile, it is scanning the tooth profile on the other side, now the ruby tip is scanning the tooth along the vertical direction, now it scans the other flank of the same tooth along vertical direction, now the inspection is over.

Probe is moving to the home position, now you can see the inspection of spiral bevel gear mounted horizontally using a fixture, now you can observe the automatic stylus changing, probar is selecting another stylus from the rack, now the stylus is moved towards work piece to be inspected, now one stylus is inspecting the flank surface because of the very complex nature, now the inspection of the same flank surface is continued by another stylus.

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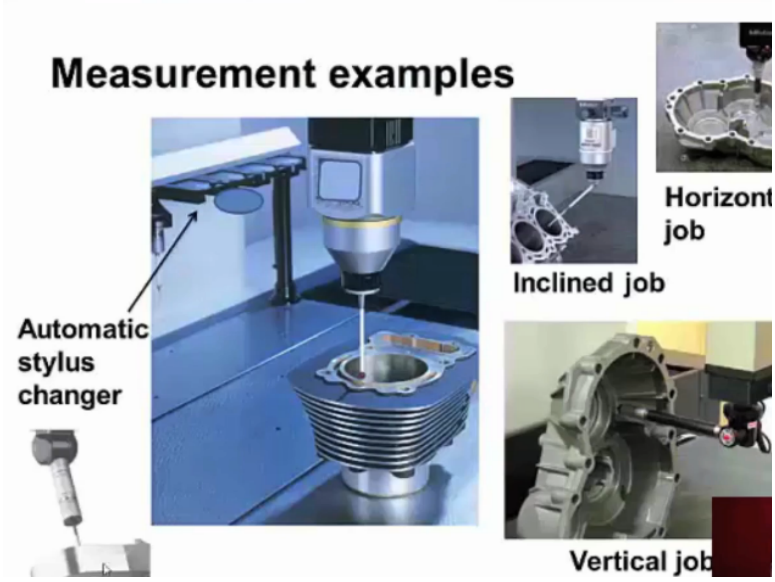


Now some measurement examples are shown here, we have a engine block wherein we have to measure the internal surface of the board and the details of the features and here other example is the diesel engine body, this inclined surface is there in which have bores and bores are to be checked, we can see the orientation of the probe is adjusted automatically and here the gear box cover is placed horizontally and then using this motorised probe.

We can measure the features like diameter of the hole, distance of the center distance and then the depth of the hole, etc. can checked and here where the job is placed vertically and we can see motorized probe is oriented and it can measure the depth surface details, center distance etc. depending upon the measurement requirement, the probes are selected automatically.

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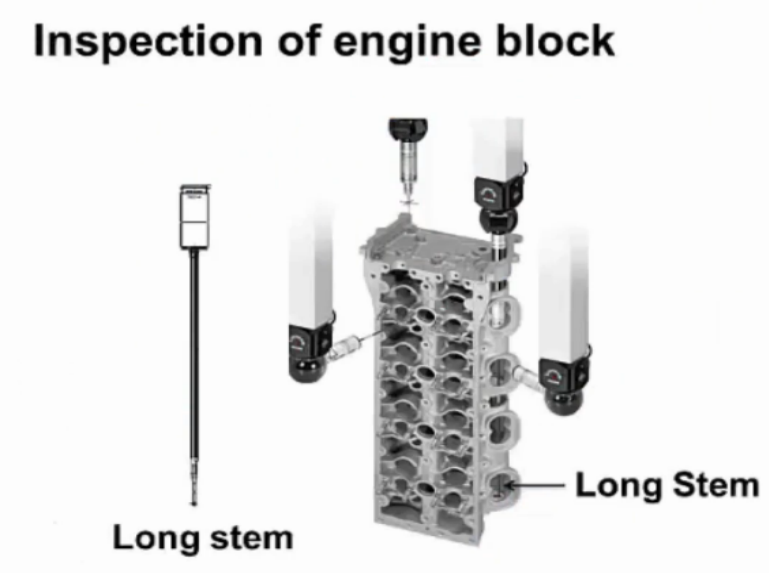


We can see here inspection of engine block by using long stems, we can see the probes has entered into the hole to check the features available at deep surface and using motorised probes, we can orient probe to check the various features and see the use of a star type probe and here using an extension bar and the probe style of the end, we can check the inner details it has entered into the hole to check the details available here.

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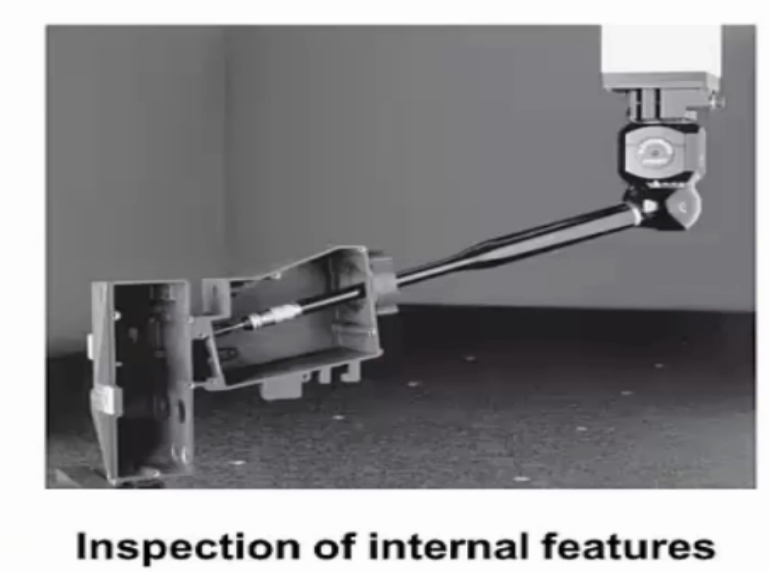


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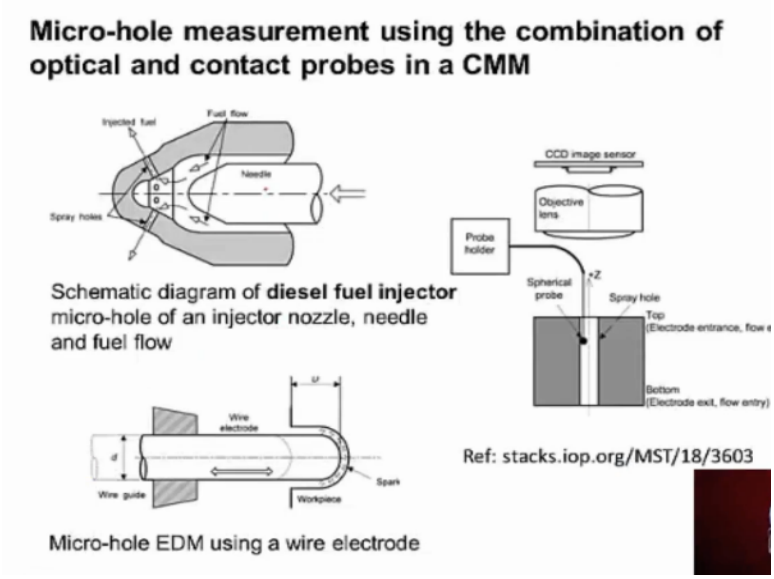


Here the micro hole measurement using the combination of optical and contact probes in a CMM, we can see the work piece placed in a fixture, which has a micro hole, this is the spray hole, and this is the optical probe, using a image sensor and this is the objective lens, so this is optical probe and then there is a contact probe also and there is a holder probe holder and this the work piece with micro hole, there is a top surface and this is the bottom surface of the component and the details of the work piece, which has the micro hole are given here.

So this is the schematic diagram of diesel fuel injector, which has micro holes, diesel micro holes of injector nozzle and this is the needle and here the fuel diesel will flow and it will come out of the nozzles, so these are the spray holes and how these micro holes are made, the details are available here using micro hole EDM, using wire electrode and this is the work piece wherein which the micro hole is to be made, so using this EDM process, micro holes are fabricated.

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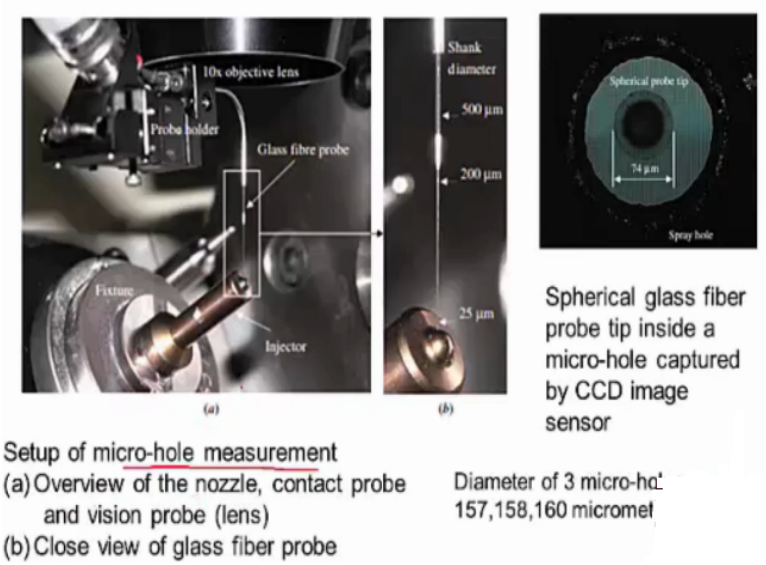


Now here we can see the arrangement, set of micro hole measurement, so in this first picture a, we an see the overview of nozzle, this is the nozzle of diesel engine injector nozzle and this is contact probe made of glass fibre probe and this is probe holder and this is the optical vision sensor, optical lens vision probe and in this picture, we can see the close view of glass fibre probe, we can see the diameter at this point is 200 micrometer.

At this point, diameter of the probe or the stem is 500 micrometer and this is the tip of the probe and this is work piece and here we have nozzle, micro hole and this picture shows spherical glass fiber probe tip, this is the probe tip, spherical probe tip with 74 micrometer diameter and this image is captured by the CCD image sensor, so the measurement results are diameters of 3 micro holes are measured. The diameter is 157 micrometer, 158 micrometer and160 micrometer, so using CMM very small holes, micro holes also can be measured.

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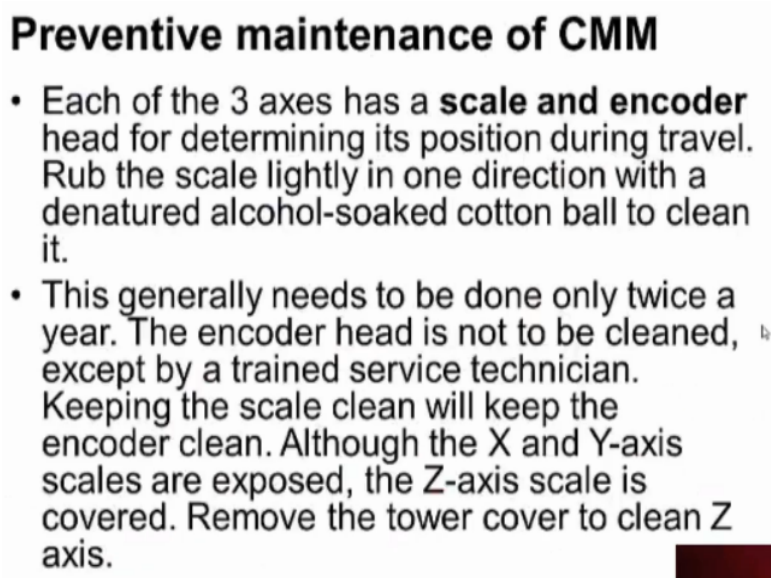


Now let us discuss how we can carry out preventive maintenance of CMM of each of the 3 axis as a scale and encoder head for determining which position during travel you should rub the scale this generally needs to be done only twice in a year then encoder. Head is not to be cleaned except by a trained service technician keeping their scale clean will keep the encoder clean although the x and y axis scale or exposed the Z axis scale is covered you should remove the tower cover to clean Z axis.

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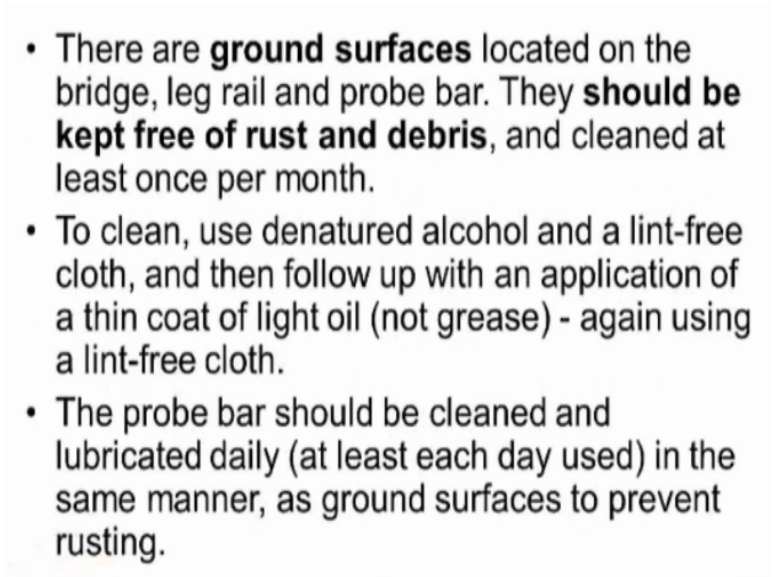


There are ground surfaces located on the bridge leg rail and prove that they should be kept free of rust and debris and cleaned at least once per month use denatured alcohol and a lint free cloth and then follow up with the application of a thin coat of light oil not grease again using a lint free cloth the probe bar should be cleaned and lubricated daily at least each day used in the same manner ground surfaces to prevent rusting.

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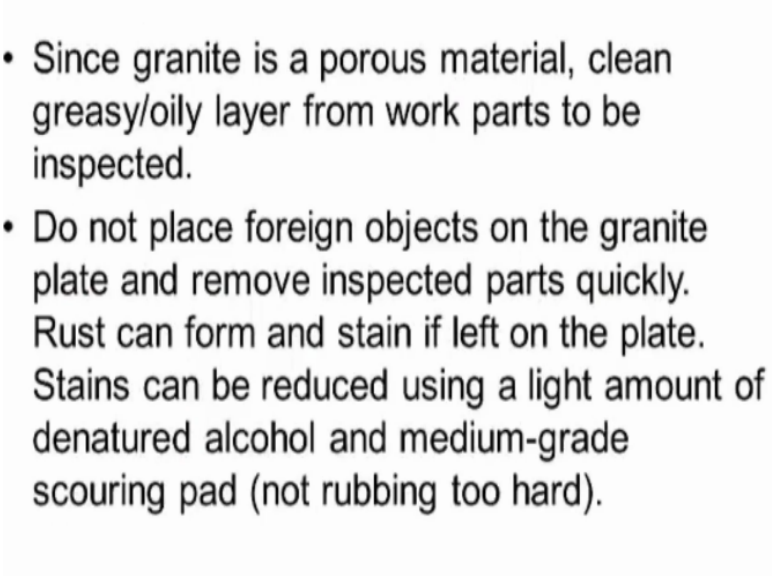


Since the granite table is porous material we should clean greasy layer oily layer from work parts to be inspected otherwise oil will enter in to the pores of granite so we should not place foreign object on the granite plate and remove inspected parts rust can form and stain if left on the plate stains can be reduced using a light amount of denatured alcohol and medium grade scouring .

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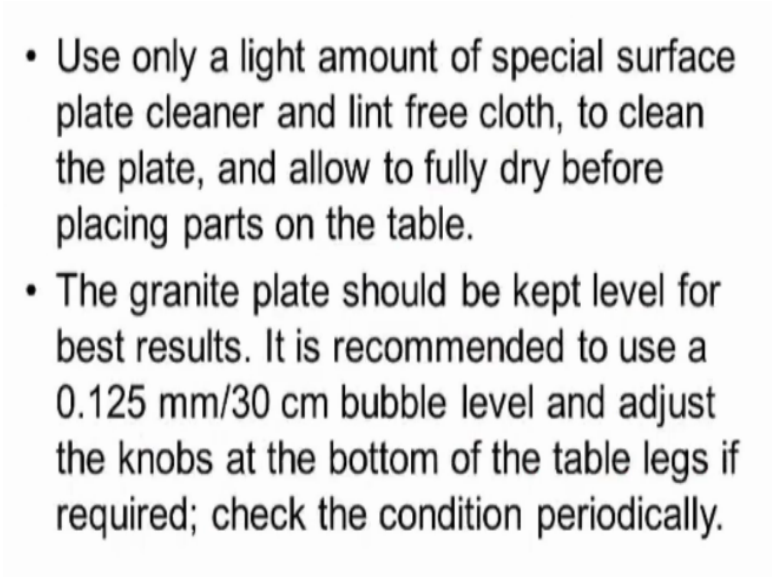


We should use only a light amount of special surface plate cleaner and lint free cloth to clean the place and allow to fully dry before placing parts on the table the granite plate should be kept level for best results it is recommended to use a 0.125mm per 30cm bubble level and adjust the knobs at the bottom of the table legs if required check the condition periodically.

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- **Gram gauge** enables the adjustment, reset and checking of probe trigger force settings on touch-trigger probes.
- Setting the optimum trigger force using the **gram gauge maximises a probe's performance.**
- The gram gauge can be used to set trigger force settings over a range from 4 to 35 grams.

We can always use a gram gauge enables the adjustment reset and checking of probe trigger probes setting the optimum trigger force using the gram gauge maximizes a probes performance the gram gauge can be used to set trigger force settings over a range from 4 to 35 grams.

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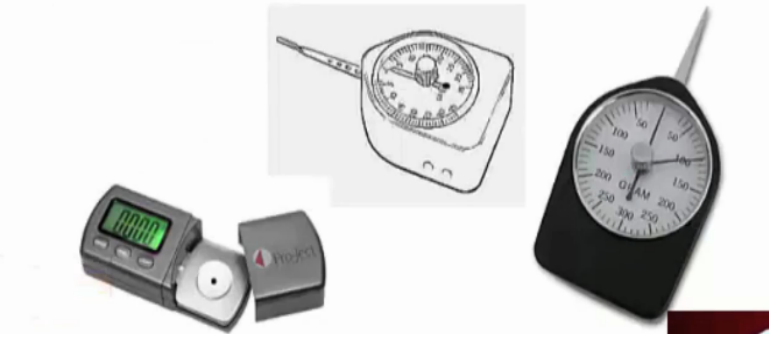
- The scale graduations are set at **1 gram** intervals which is sufficient for all probe trigger force measurements on CMMs.
- The conversion factor is 1 gf = 0.01 N.



The scale graduations are set at 1 gram intervals which is sufficient for all probe trigger force measurements on CMMs, here we can see the gram gauges these are analog gram gauges the least count of a gram gauge is 1 gm. in this case it is 10 grams and digital gram gauges is also available using these gram gauge we can set the force, trigger force the conversion factor is 1gram force equals 0.01 Newtons.

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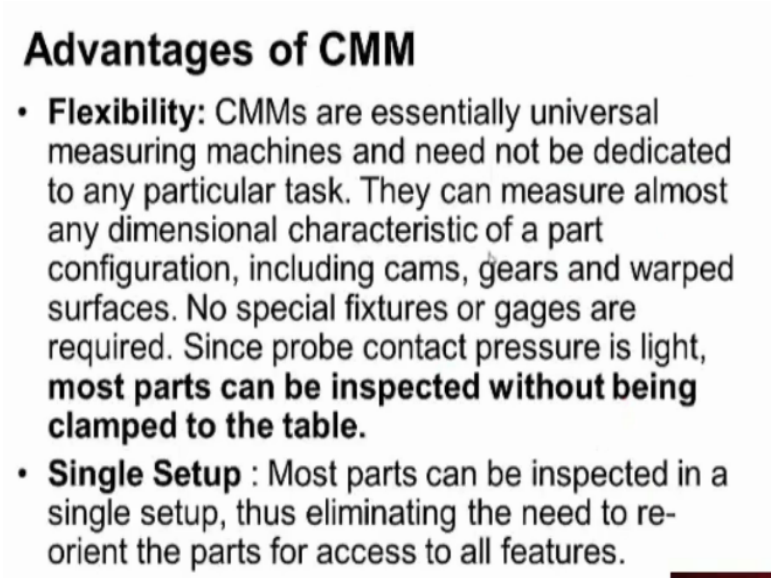


Now let us study the advantages of co-ordinate measuring machines the very first advantage is flexibility co-ordinate measuring machines are essentially universal measuring machines and need not be dedicated to any particular task. they can measure almost any dimensional characteristics of a part configuration including cams gears and warped surfaces.

No special fixtures or gages are required to use co ordinate machine. Since probe at the pressure is very light, most part can be inspected without being clamped to the table. So clamping devices is rarely used single setup measurement .most part can be inspected in a single setup thus eliminating the need to re orient the parts for access to all features.

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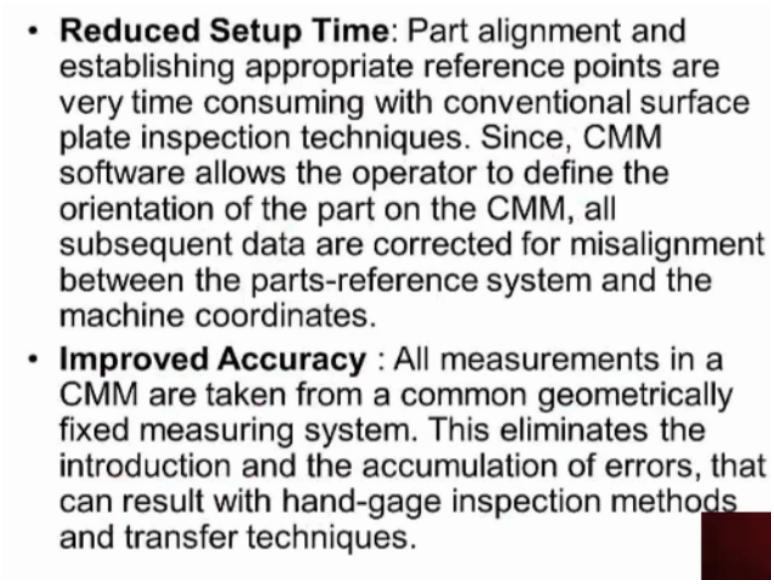


And we can achieve reduced set up time part alignment and establishing appropriate reference points are very time consuming with conventional surface plate inspection

techniques since CMM software allows the operator to define the orientation of the part on the CMM all subsequent data are corrected for misalignment between the parts reference system and the machine coordinates because of this the set up time is reduced very much.

And we achieve improved accuracy. All measurements in a CMM are taken from a common geometrically fixed measuring system. so, this eliminates the introduction and accumulation of errors that can result with hand gauge inspection methods and transfer techniques.

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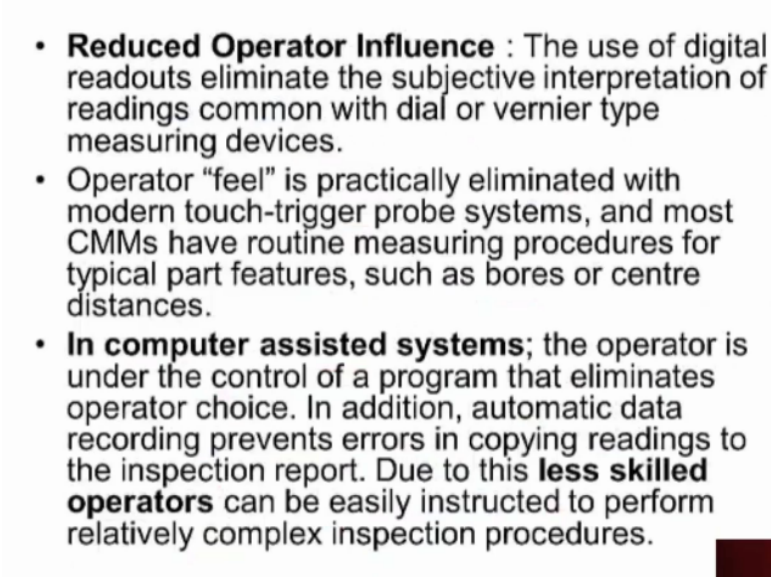


Reduced operator influence the use of digital readouts eliminates the subjective interpretation of readings common with dial or vernier type measuring devices since the measurement data is directly is transferred to the computer system the operator errors are minimum and operator feel is practically eliminated with modern touch trigger probe systems and most co ordinate measuring machines have routine measuring procedures for typical parts features such as bores or center distances.

In computer assisted systems, the operator is under their control of a program that eliminates operator's choice in addition automatic data recording prevents errors in copying readings to the inspection report. In conventional measuring systems, the operators reads the direct indicators or whatever the operator is using should copy the reading to the inspection report

That time you may make mistake in a computer assisted systems such error are completely eliminated due to computed assisted system less skilled operators can be easily instructed to perform relatively complex inspection procedures.

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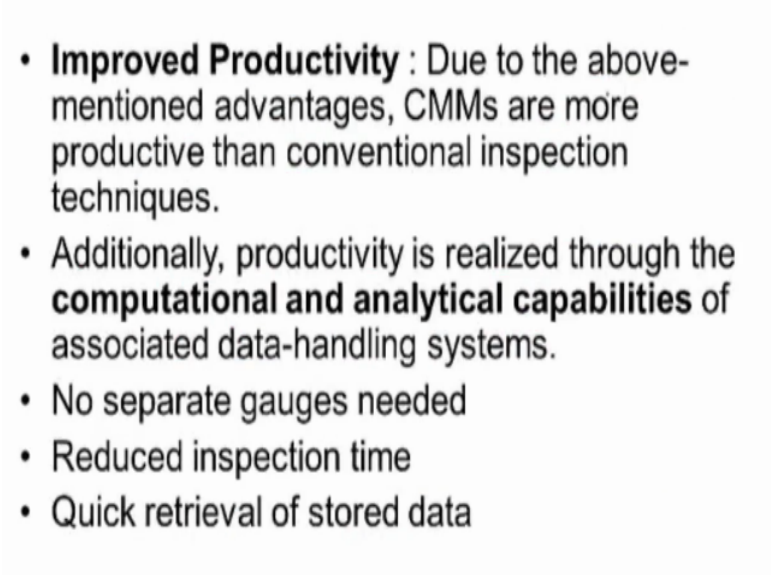


And this is improved productivity due to the above mentioned advantages co ordinate measuring machines or more productive than conventional inspection techniques additionally productivity is realized through the computational and analytical capabilities of associated data handling systems and no separate gauges needed all its features can be measured in one set up in CMM and reduced inspection time and quick retrieval of storage data.

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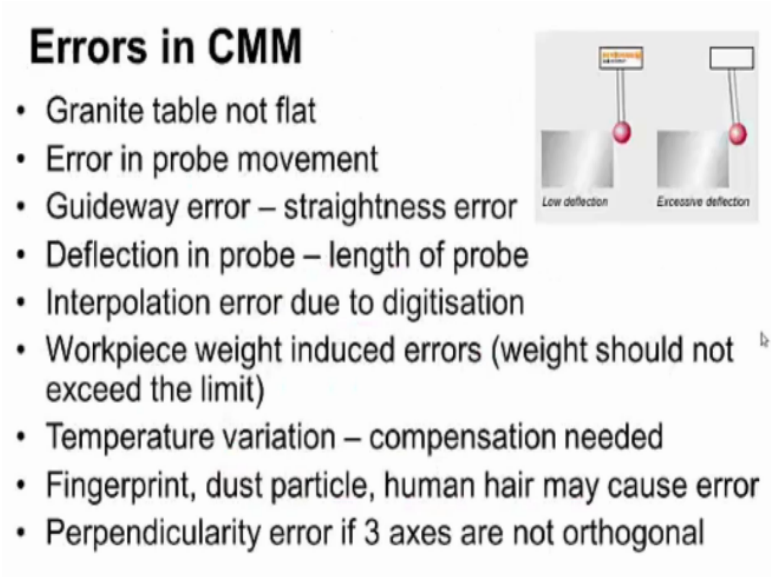


Now let us see the errors possible in co ordinate measuring machine. The granite table or cylinder table should be very much flat. If the table is not flat and is there is some error in the granite table surface then we keep the work piece in resting like this. So it will rest on the table with some inclination so because of this errors will be introduced. And error in probe, the probe when it moves in x and y and z direction, there is an error in the guide way.

The guide way is in this movement the guide way may not be straight or may not be moving in the straight path because of this there will be error in the measurement and deflection in the probe. If we use unnecessary long probe it will bend too much and because of this too much deflection error is introduced and Weight induced errors when we keep the work piece on the table work connected.

If the weight is too much then the granite table made deflect like this and because of this the measurement error will be introduced so we should take care to see that the way it should not of the work piece does not exceed the limit specified by the manufacturer then the temperature variation because of the expansion and contraction error will be introduced. So it is very essential that whenever we use the co-ordinate measuring machine, the temperature variations are minimized.

And proper compensations are given for the variation and the fingerprint dust particle human hair may cause error in the measurement we should clean the work piece surfaces and we should clean the probe surfaces with the clean gel and then we should conduct the measurement. Perpendicularity error, if 3 axis or not orthogonal because of this also measurement error will be introduced.

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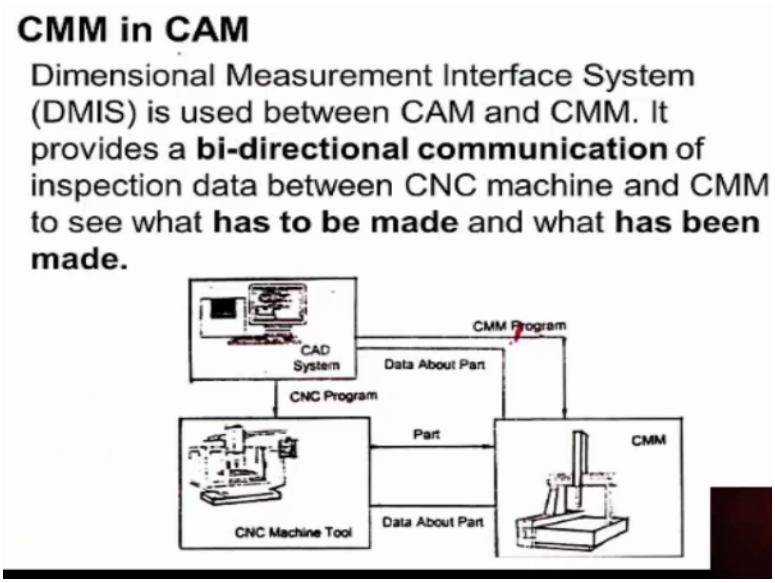


Then Coordinates measuring machine in computer aided manufacturing system dimensional measurement interface system (DMIS) is used between the computer aided manufacturing and CMM it provides a bidirectional communication of inspection data between CMC

machine and Coordinates measuring machine to see what has to be made and what has been made that is intended and what is made this difference can be assessed by the DMIS assistance.

We can see here this is the cad system which will provide the CAD data to the CMC machine and this generates program based on cad system to the CMC machine tool and this generates CAD program based on CMC machine.

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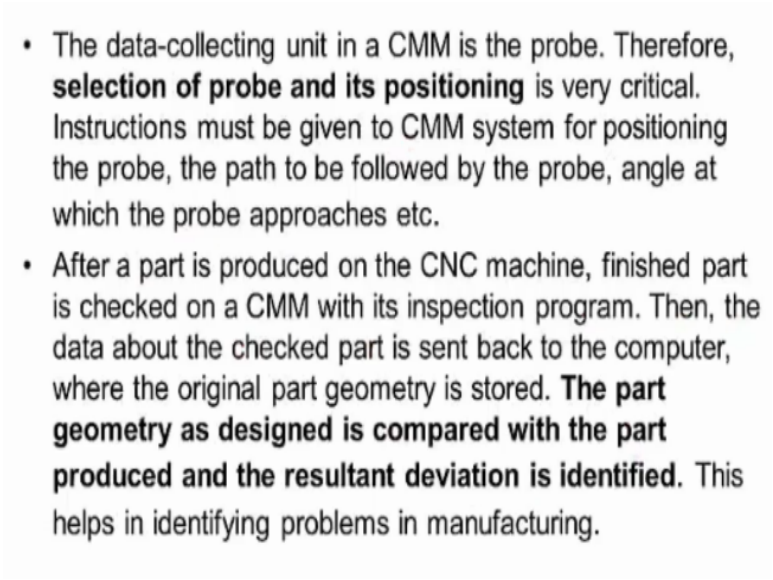


We have understood that the data collecting unit in a CMM is a probe therefore selection of probe and its positioning is very critical instruction must be given to CMM for positioning the probe the path to be forward by the probe angle at which the probe approaches etc all the instructions to be given to the software after a part is produced in a CNC machine. After part is checked on a CMM with its inspection program generate CMC program based on the CAD system program.

And CNC program or the part program is supplied to the CNC machine tool for machine the work piece. This CAD system also generates inspection program based upon the cad data and that is applied to the co-ordinate machine now we have understood that the data collecting unit in co-ordinate measuring machine is the pro inspection pro, therefore the selection of probe and its positioning is in the CMM machine is very critical proper instructions must be given to the CMM system for positioning the probe properly.

And the path what is the path to be followed by the probe and what angle the probe should approach the work piece in section should be properly given by the software and what is produced on the CNC machine the finished part is moved to CMM with his inspection program in its work piece with the inspection program then the data about the check the path you sent back to the computer.

In this diagram we can observe that the inspection program generated by the cad system is given to the CMM and the path what is produced using this CNC program is supplied is more to the CMM measuring machine inspect the work piece using the CMM program and the data on the inspected work piece is sent back to the cad systems for making necessary corrections if there is any deviation in the work piece in the desired size that data is reversed to alter the CMC program so that the error is minimized or the error is nullified.

The data about the checked part is sent back to the computer where the original part geometry is told the path geometry as designed as compared using the park produced and the resultant deviation is that is error data is identified this helps in identifying the problems in manufacturing and relating programs in co-ordinate manufacturing machine.

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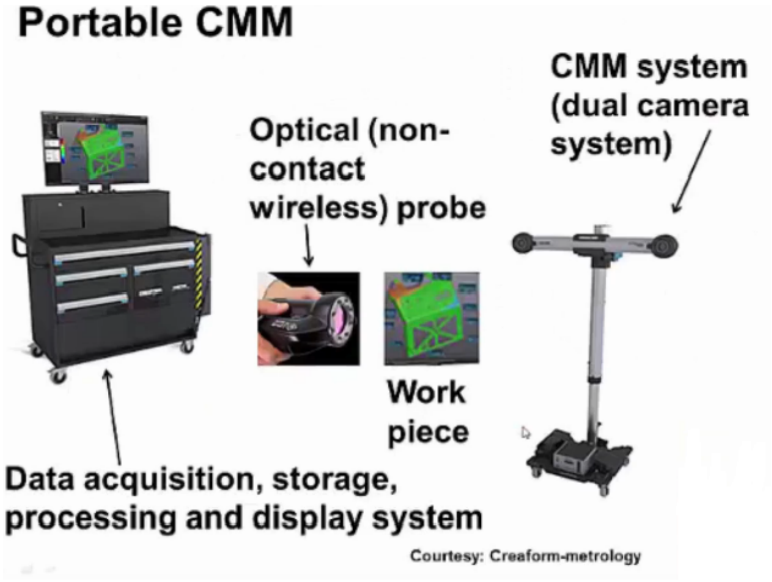


Now let us move to a topic very interesting topic. portable CMM in the previous discussion we studied about the various configurations of coordinates measuring machine how the measurement data is obtained what are all the different types of probes and then we also learned about the software the CMM software and we learnt that the coordinate measuring

machine set up in the metrology lab or if it is shop floor CMM it is moved to the shop floor and it is placed in the production line.

The work pieces stepping are inspected or moved to the table of CMM and then the inspection is carried out sometime if the work piece cannot be moved to the table of that means they have a very huge work piece very huge asking which cannot be placed on the to the table of the CMM in that case is the CMM itself is moved to the path called portable CMM. In this illustration we can see various elements of portable CMM we have CMM system.

This is dual camera system we can observe of the two cameras here and this is mobile unit we can see the wheels it can be moved to the place where the huge work piece is placed and then this is installed or place near the work piece and then we have an optical pro which is non contact wireless probe this probe we have to move around the work piece.

The CMM system the dual camera system will be monitoring the work piece as well as the probe movement as well as the work piece movement will be continuously monitored by the dual camera system. And then it establishes the dynamic referencing using optical triangulation technique and this optical prob take the images from the work piece and then the data is sent to the data acquisition storage processing and display system.

This is a dedicated computer system with a software all the data obtained by this optical prob is transferred wirelessly to this data acquisition system this system after acquiring process the data and the results are displayed on the monitor.

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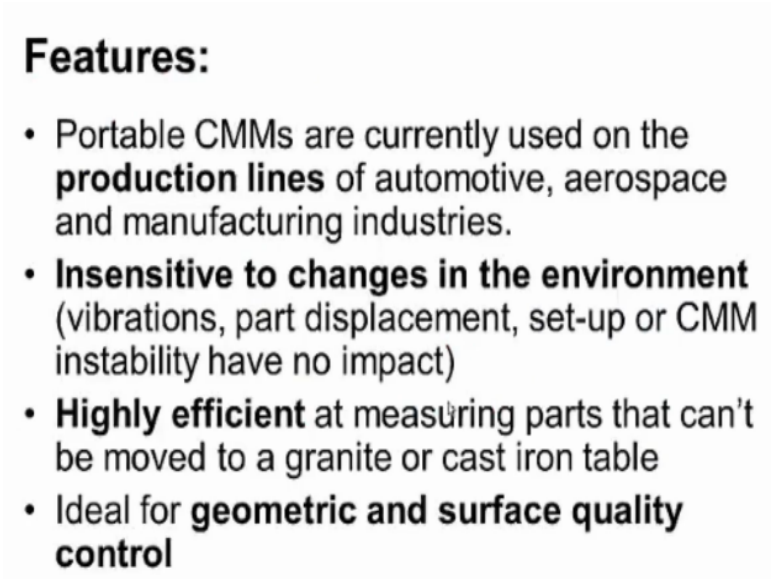


now what are the features of portable CMMs these portable CMM used on the production line of automotive aerospace and manufacturing industries they are insensitive to changes in the environment that means the vibration of the work piece because of the nearby vibrations are part displacement and then set up or CMM instability have no impact on the measurement the portable CMM are highly efficient at measuring parts that can't be moved to a granite or cast iron table they are very much ideal for geometric and surface quality control.

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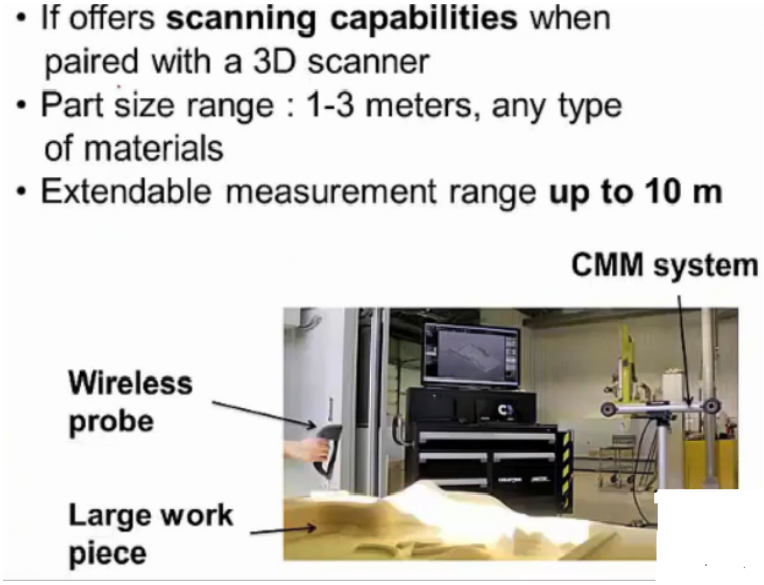


These portable CMM of scanning capabilities when paired with 3d scanner the font size the work piece size ranges from 1 to 3 m and any type of materials can be is inspected that is hard material very soft materials can be inspected since it is non contact type of measurement very soft materials can be inspected without any difficulty. The measurement range can be extended up to 10 m.

In this picture we can see this CMM system we can see this mobile CMM system and this is the huge work piece which is to be inspected and then we have wireless probe both probe and the work pieces are monitored are continuously viewed by the dual camera system and then the image captured by the wireless vision probe is sent to the computer system for processing.

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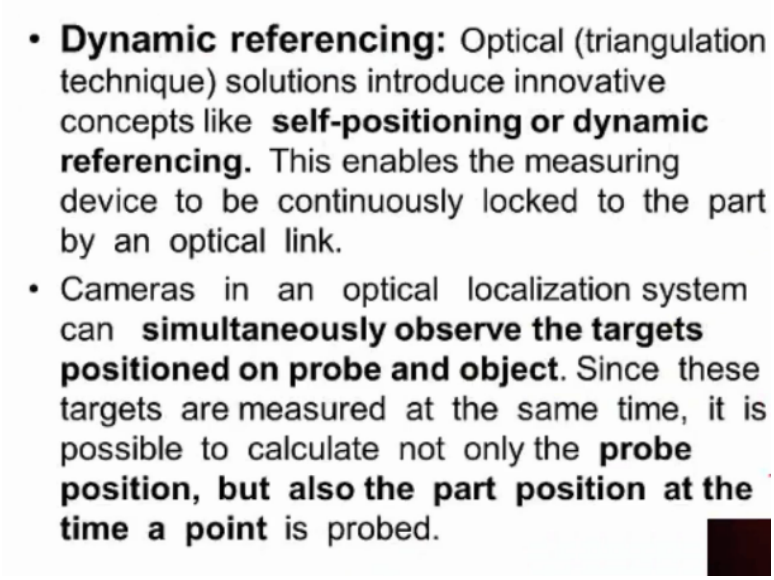


Now optical triangulation techniques are used for dynamic referencing this is required for self-positioning or dynamic referencing of the work piece or the probe system. This dynamic referencing enables the measuring device to be continuously locked to the part by an optical link. cameras in optical localization system can simultaneously observe the targets positioned on probe and object.

That means that targets are in other words the reflectors are placed on the work piece to be inspected and also they are placed on the probe these targets on the reflective surfaces continuously observe the cameras since the targets are measured at the same time the targets are placed on the object and on the probe system measured at the same time it is possible to calculate not only the proposition but also the path position at the same time.

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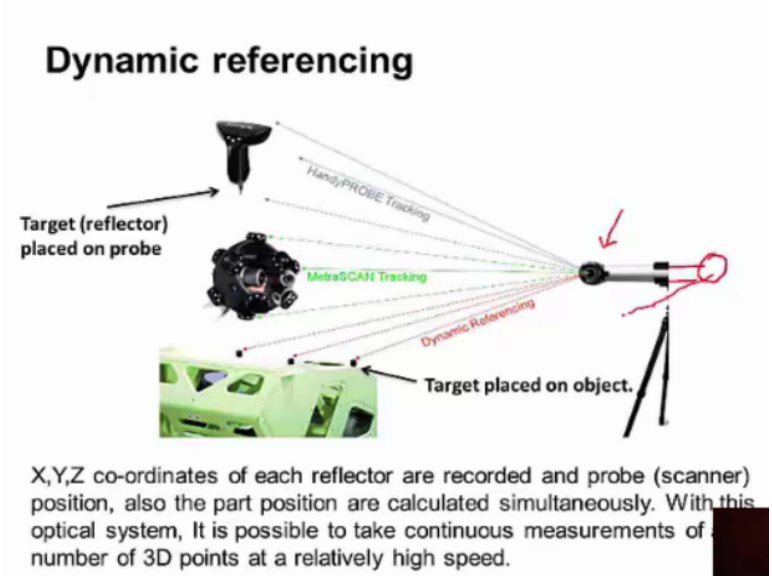


Now the illustration shows the dynamics referencing we have this dual camera system which continuously monitoring the probe system, the work piece as well as the scanner system Now this is the work piece to be inspected we can observe that the target or the reflectors are placed at specified locations on the work piece to be inspected and also on the scanners reflectors are placed and then the reflectors are placed on the probe system.

Also the xyz coordinates of each reflector or recorded the dual camera system will be recording xyz coordinates of the reflectors placed on the work please and xyz coordinates of the reflector placed on the probe or the scanner system. And also the bar position after monitoring the reflectors the proposition and the path position are calculated simultaneously that is means the proposition is locked with the work piece with this optical system.

It is possible to take continuous measurements of the number of 3d points at a relatively high speed as the probe is moved around the work piece for the measurement there is a dynamic locking between the probe and the work piece because the dynamic referencing and when the probe moves, the distance is calculated and hence the measurement is made.

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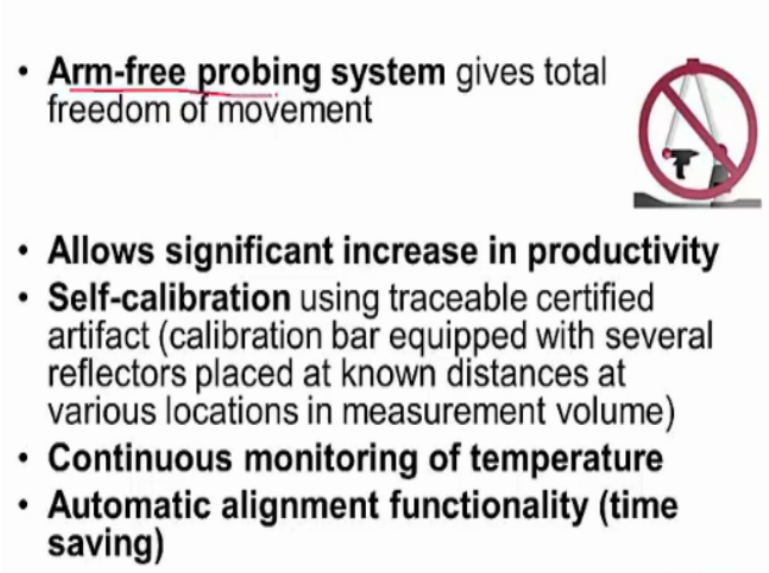


Since the probe is wireless it is arm free probing system so it is total freedom of movement and the operator can move the probe system easily around the work piece for measurement and this wireless system allows significant increase connectivity self-calibration using traceable certified artifact is possible that means.

The artifact calibration bar equipped with several reflectors placed at known distances at various locations is used for the calibration of the system and there is a continuous monitoring of temperature and the temperature compensation is possible and automatic alignment functionality is also present which is saves a lot of time.

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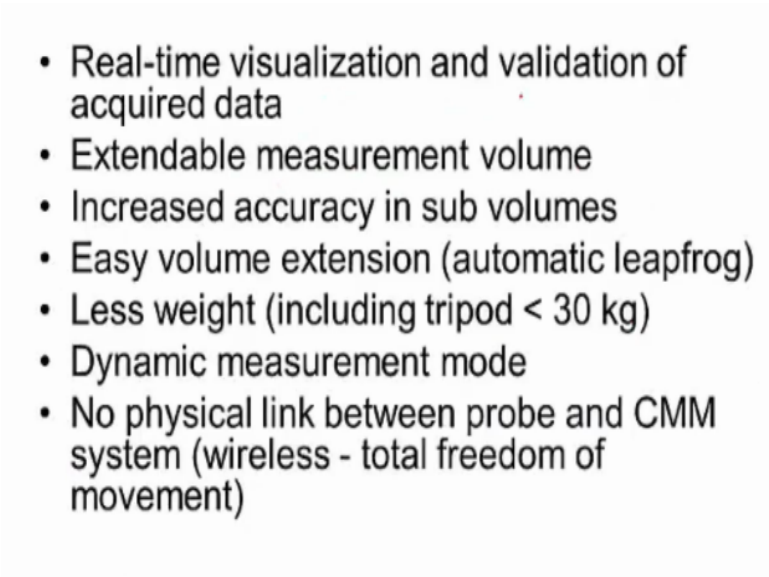


And there is a real time visualization and validation of acquired data, the measurement volume can be extended on the requirement, increased accuracy in sub volumes is possible,

easy volume extensions by automatic leapfrog system. And the total weight of the system is very less including tripod it is less than 30kg and dynamic measurement mode is possible. There is no physical link between probe and CMM system and hence there is total freedom of movement for the operator.

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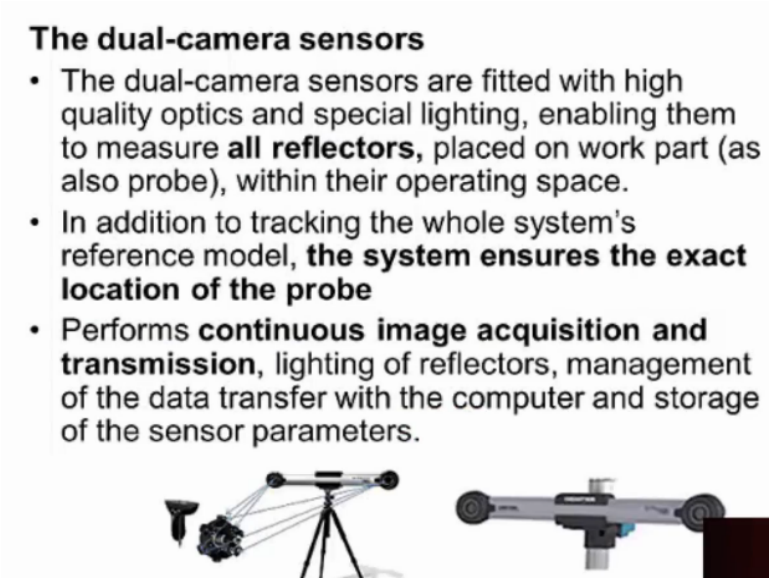


Now let us discuss about very important element in the portable CMM that is dual camera sensors. The dual camera sensors are fitted with high quality optics and special lighting systems enabling them to measure all reflectors so these cameras they will be sensing all the reflectors provided on the work piece as well as the scanner and the probing system. In addition to tracking the whole systems reference model.

The system ensures the exact location of the probe because of the triangulation technique used in the portable CMM system ensures the exact location of the probe with respect to the work part it performs continuous images acquisition and transmission. You see the probe and scanner will be sending the images to the computer system and also the dual camera sensor will also be sending the images to the computer system for processing.

This dual camera system performs continuous performs continuous image acquisition and transmission, lighting of reflective management of data transfer with the computer and the storage of the sensor parameters acquisition and transmission.

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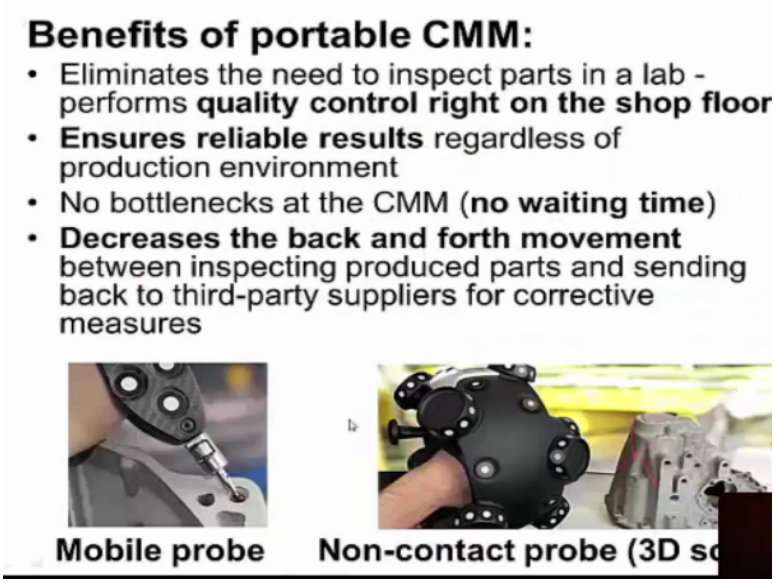


Now what are the benefits of the portable CMM so this portable CMM eliminate the need to inspect parts in a lab that means we need not have to move the parts to the inspection lab or metrology lab. Since the portable CMM itself is movable to the shop floor where the user casting or the huge part is present and it performs quality control right on the shop floor and this portable CMM ensures the reliable resources regardless of the production environment.

That means even if the vibration is present or destiny parameter is present for irrespective of that regardless of that it gives good results. No bottlenecks at the CMM, so no waiting time at the co-ordinate measuring machine this decreases the back and forth movement between the inspecting produced parts and sending back to the third party suppliers for corrective measures, so this picture shows the mobile probe and non contact probe.

So the probe can be contact type varying any mechanical probe is present or it can be non contact type in which is using this is non contact 3D is produced. This picture shows that time optical probe and this is non contact probe, 3d scanner so without any physical contact. This system will be scanning the work part and it will be sending the images to the computer system.

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Now the portable CMM improves the efficiency of quality control process right up to the product delivery it ensures 100% compliance with standards and regulations and it guarantees top quality finished products volumetric accuracy of up to 0.085 mm in real life shop floor conditions regardless of instabilities vibrations thermal variations, etc.

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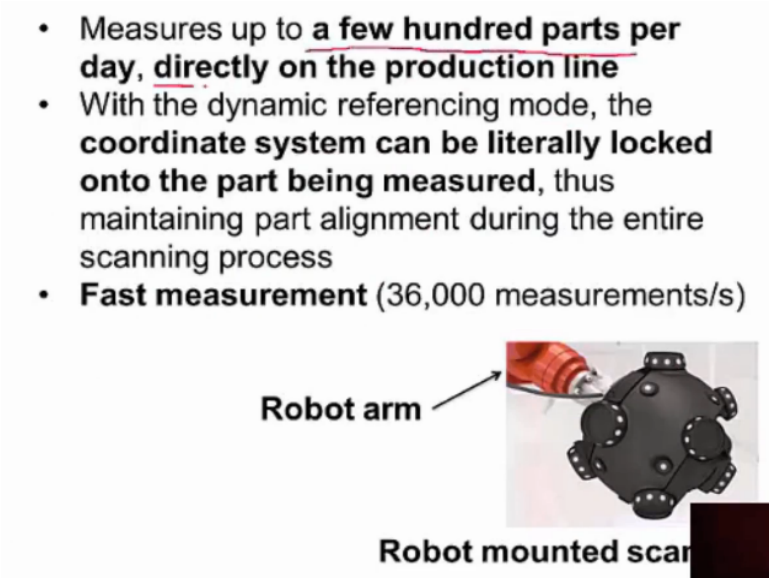


It measures up to a few 100 parts per day, directly on the production line so such is the speed of portable CMM with the dynamic referencing mode the coordinate system can be literally locked onto the part being measured thus maintaining the alignment during the entire scanning process and very fast measurement is possible 36,000 measurement/second is possible.

The picture shows the scanner mounted on the Robot Arm and give the inspection program for the robot arm and the robot arm will move as per the program and scans work part.

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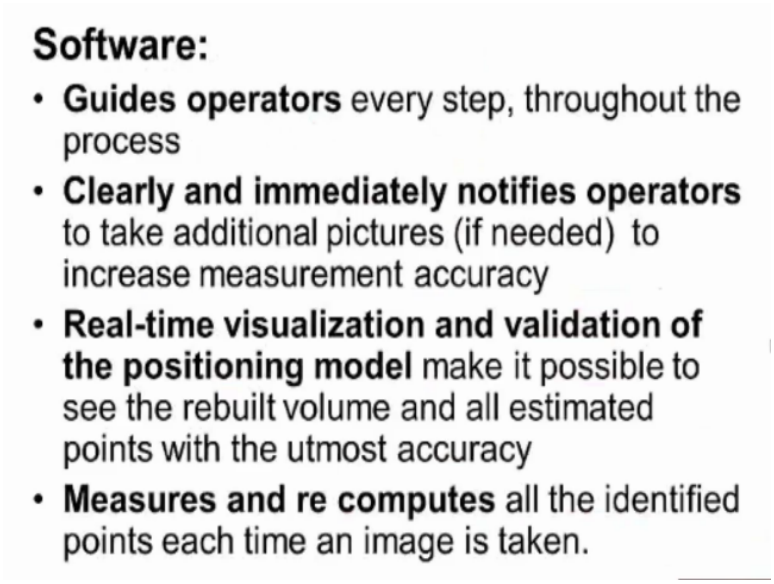


Now let us discuss about portable CMM Software. This software guides operators every step throughout the process it clearly and immediately notifies operators to take additional pictures whenever needed to increase measurement accuracy. Real-time visualization and validation of the positioning model make it possible to see the rebuilt volume and all estimated points with the utmost accuracy. The software measures and re computes all the identified points each time an image is taken.

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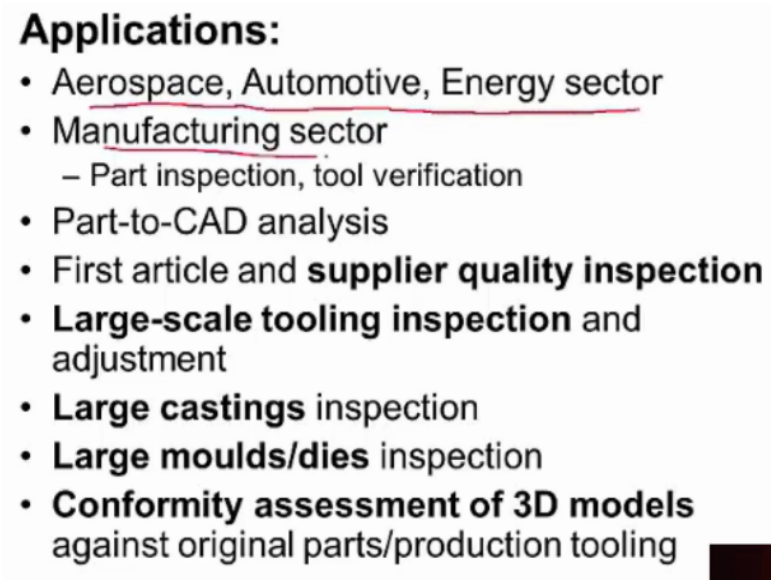


Now what are all the applications of Portable CMM. These portable CMMS are used in Aerospace, automotive energy sector, and in the manufacturing sector Part inspection and

tool verification is possible. Portable CMM is used to part to CAD analysis and then first article and supplier quality inspection is possible and then for large scale tooling inspection and adjustment used for large castings can be inspected using portable CMMs.

Large moulds and dies can also be inspected and then conformity assessment of 3D models against original parts and production tooling is possible.

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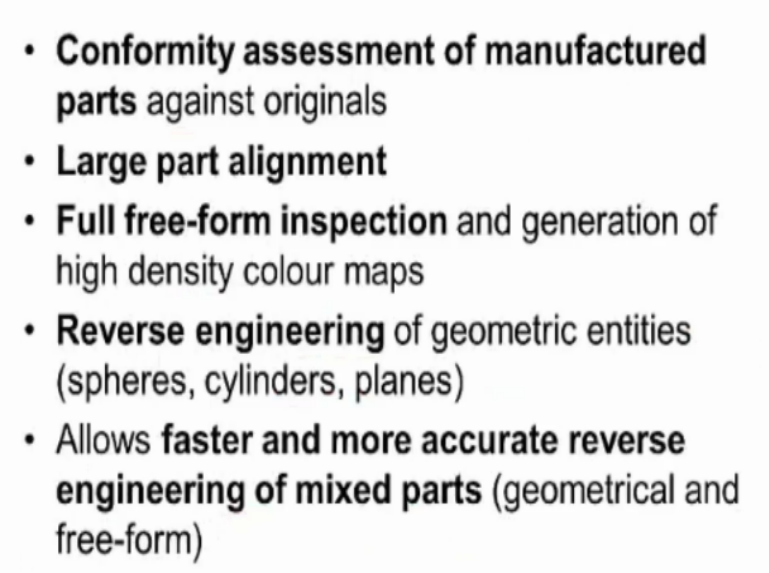


Conformity assessment of manufactured parts against originals and then large part alignment can be achieved. Full free form inspection and generation of high density colour maps can be generated and the reverse engineering of geometric entities spheres, cylinders and planes is possible. The portable CMM allow faster and more accurate reverse engineering of mixed parts geometrical and free form parts are there.

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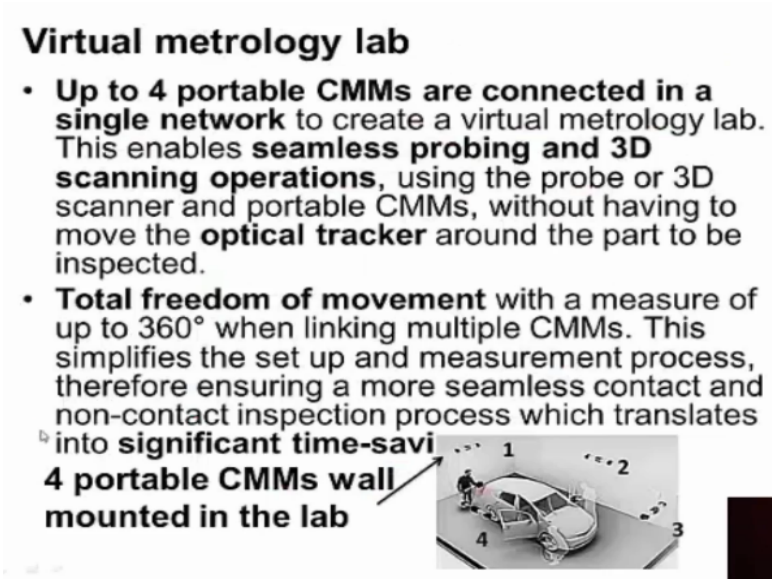


Now let us discuss about another topic known as virtual methodology lab in the previous portable CMM only one dual camera that is used and measurement is made. Now let us assume the work piece is very large. For example, in this picture we have shown a car body show in such very large work pieces if we use only one set of dual camera then the measurement is possible only in this region, when we want to measure the front side of the car body then we have to move this dual camera to this place.

And then we have to carry out the inspection that means the inspection is not seamless we have to break the inspection process then finally we have to assemble them in order to avoid such things virtual metrology labs can be developed wearing up to 4 portable CMM are connected in a single network. We can observe here this is the work piece to be inspected we have one dual camera system here second dual camera system here, third dual camera system here.

And forth dual camera system mounted on the walls in the lab. And then the operator holds the probe or scanner and moves around the work piece around the car body for making the measurements without any was continuously he will be moving around and he takes the readings that is up to 4 portable CMM are connected in a single network to create a virtual metrology lab.

This enables seamless probing and 3d scanning operation using the probe or 3d scanner or portable CMM without having to move the optical tracker that is the dual camera system around the path to be inspected if we use only one optical tracker or dual camera system we

have to move around the work please so that it is avoided networking 4 trackers in the system.

Total freedom of movement with a measure of up to 360 degree when linking multiple co-ordinate measuring machine. This simplifies the setup and measurement process there for ensuring a more seamless contact and non contact inspection process which translates into significant time saving.

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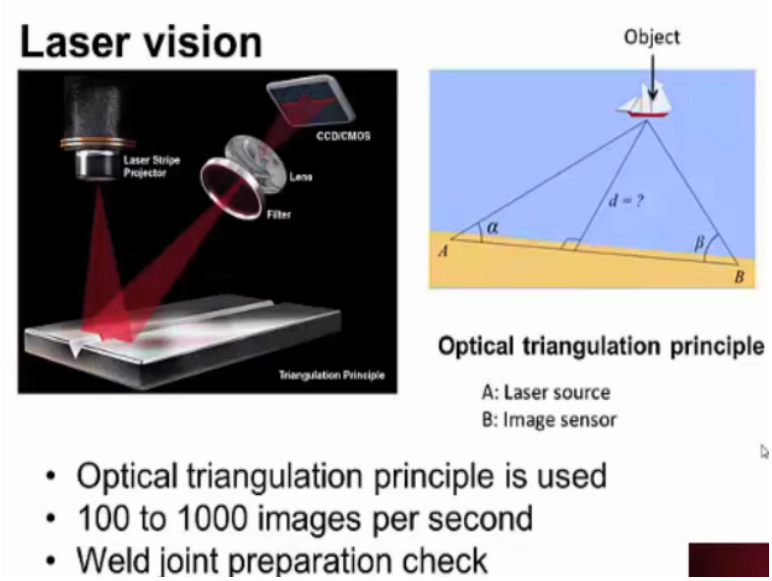


Now let us discuss about Laser Vision. Lasers are used for measurement of work Pieces for Single dimension 2D measurement as well as the 3 dimensional measurement is possible using Laser vision The Laser vision setup is schematically shown which has Work Piece to be inspected they have a laser source and then the filter lens and then this the image sensor CMOS is used to sense the image..

Now in a laser vision, optical triangulation principle is used principle is like this A is Laser Source and B is the image Sensor and this is the object which is to be inspected and we have to find out what is the distance between the object from the line joining the A and B and these 2 angles alpha and beta it is possible to get this D this principle is used for the measurement 100 to 1000 images per seconds can be captured in this system.

Normally it is used in weld joint preparation to check whether the joint weld joint preparation is ok or not. what is the lead distance? What is the angle? Whether there is any mismatch is there such things can be inspected using laser vision.

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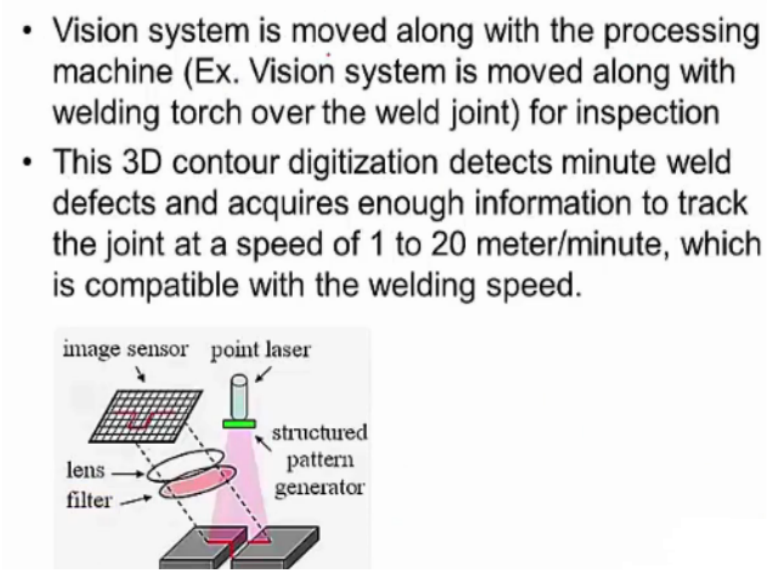


Now the Vision system can be moved along with the processing machine for example, if we are checking the Weld joint. This is the welded portion we have to check whether the weld is ok or not so. This is the welding unit going in this direction behind this it can have laser vision system which checks whether the welding is proper are not. So this vision system is used to check preparation of joint as well as inspection.

This 3D contour digitization detects minute weld defects and acquires enough information to track the joint at a speed of 1 to 20 meter per minute which is compatible with the welding speed apart from weld joints this system can be used to check the profiles here we can see 2 work pieces are placed and we need to check what is the depth and what is the width. See width information is required, as well as the depth information is required.

We can see the point laser source and structured pattern generator will generate required pattern of laser and optical lens are there so that the image the reflected light falls on the image sensor and here the image sensor will capture the picture and it can be analyzed to check depth and width measurement.

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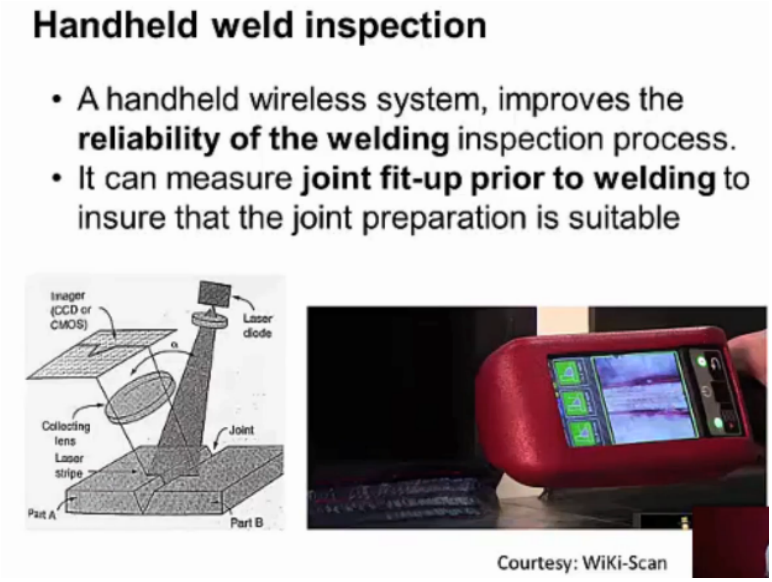


Now we can see a Handheld welding Inspection device. So this is weld to be inspected and we can move this inspection system and we can get we can see the image and also get the image captured and stored. It can measure joint fit-up prior to welding to insure that the joint preparation is suitable.

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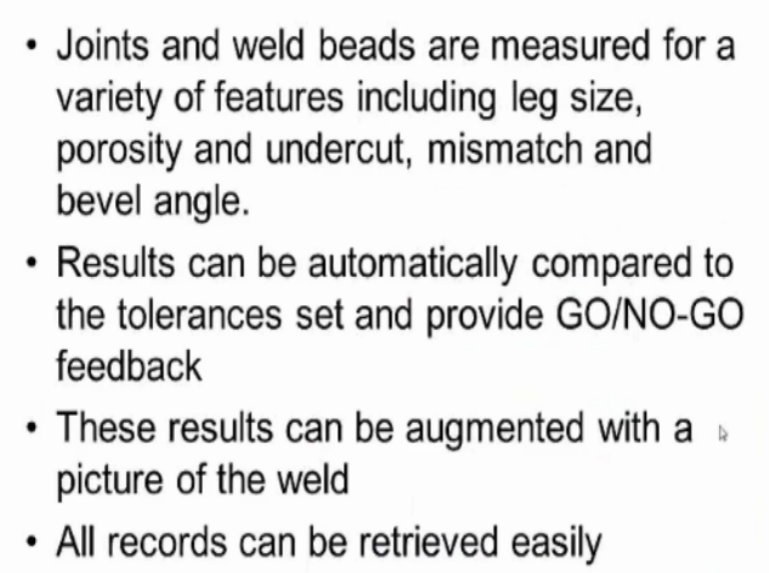


Joints and weld beads are measured for a variety of features including leg size, porosity and undercut mismatch and bevel angle. The measurement results can be automatically compared to the tolerances prescribed and comparison is made. The system provides Go or No Go feedback these results can be augmented with a picture of the Weld. All the measurement records can be retrieved easily.

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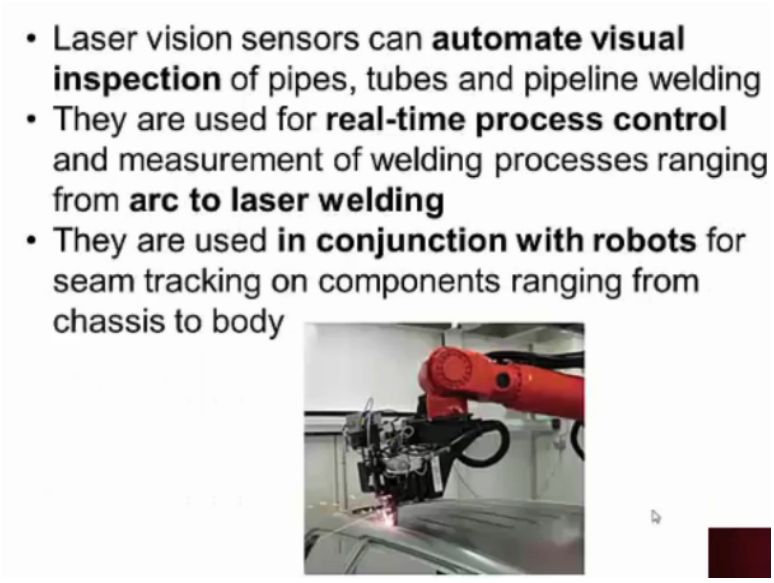


Now the Laser vision sensors can automate visual inspection of pipes tubes and pipeline welding they are used for real time process Control and measurement of welding processes ranging from arc to laser welding now.

We can see here the welding system as well as laser vision system together mounted on a Robot. So when the robot moves welding are carried out simultaneously the bead is inspected for quality so there is any defect in weld the feedback can be given to the system so that rectification can be carried out.

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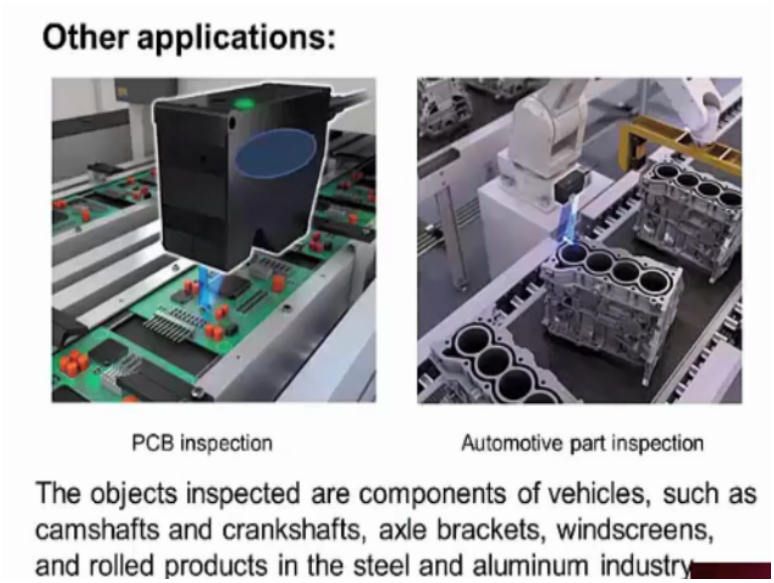


Apart from welding inspection there are many other applications of laser vision system the vision system can be used to check PCB and automotive parts can be inspected parts such as camshaft crankshafts axle brackets windscreens etc can be inspected using laser vision

system. The vision systems can also be used to check the profiles. You can see here we have a work piece profile like this.

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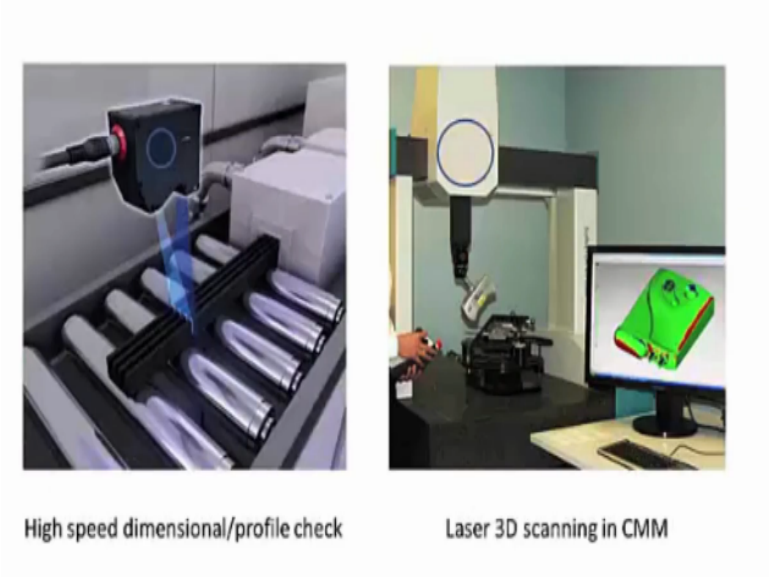


Now the vision systems can be used to check the profiles, we can see here we have work piece profile like this using laser system we can check the profile is ok or not using this optical triangulation technique the measurement of work piece is possible the measurement system is mounted in CMM and 3D inspection of work pieces can be carried out.

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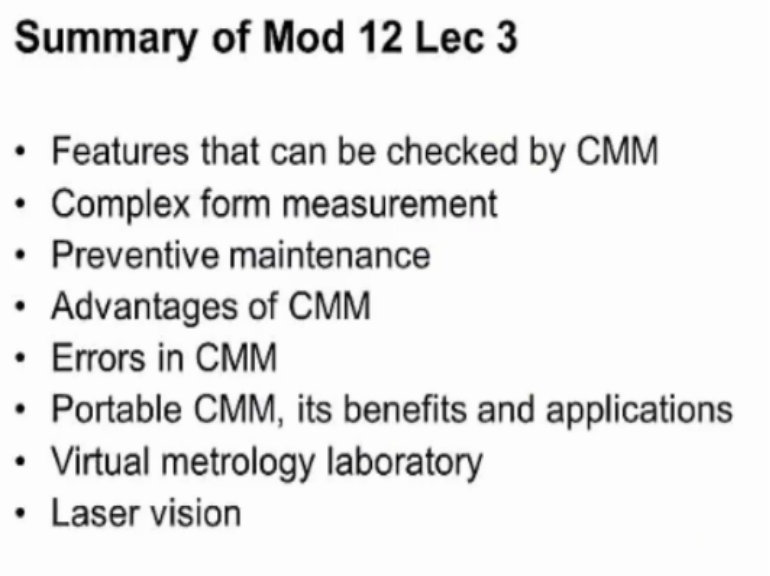


Now let us conclude lecture number 3, in this lecture we discussed about what are the features that can be checked by coordinate measuring machine complex form measurement of work pieces and how to maintain CMM, advantages of CMM, common errors in CMM

portable CMM its benefits and applications and then we studied about virtual metrology laboratory and laser vision we will conclude this session. Thank you.