Metrology
Prof. Dr Kanakuppi Sadashivappa
Bapuji Institute of Engineering and Technology Davangere

Lecture – 38
CMM Probes and CMM. Laser Vision

Now let us start the lecture number 2 in model 12 and the advance the metrology topic in this lecture we will be discussing about the different types of CMM probe, so we will discuss about the probe working and how the collision of probe with machine of work piece and what are the various probes like touch trigger, scanning type probe.

Then, we will also discuss about the calibration of probes and do we change stylus or probe depending upon the special required and then we will discuss about the vision probes and then we will move on CMM software wherein we will be discussing about the capabilities of software and then what are the various subroutine used in CMM software.

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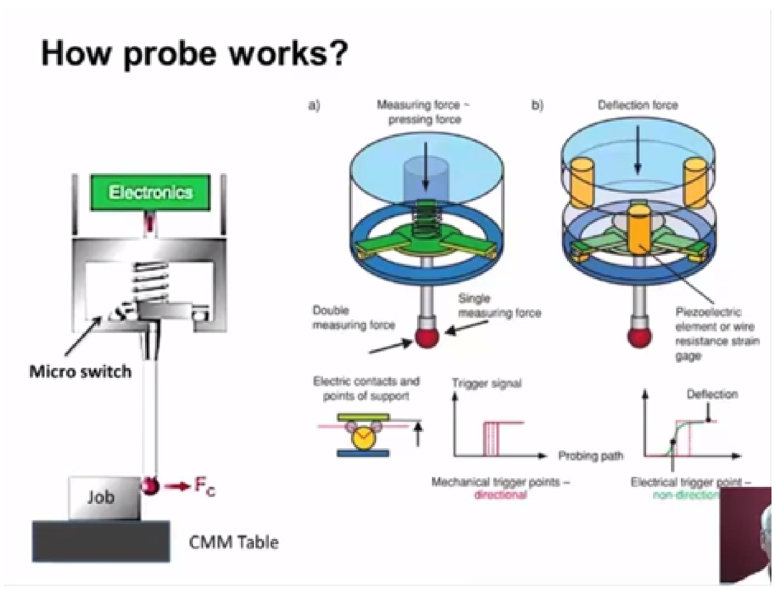

Now let us study how the CMM probe works in this picture are we can have the CMM table on which the work piece is placed and then this is the probe when the probe is moved in this direction this tip of the probe or the tip of the stylus will come in contact with the job and then it slightly probe will deflect like this and then the we can see 3 micro switches placed in the housing of the probe one is micro switch is available here.

Second one and one more behind the spring now when the probe when the stylus deflects the micro switch gets open and then a signal is set to be CMM software so this is mechanical probe wherein micro switches are used and then we have another type wherein piezoelectric element is used or wire strain gauges are used to send this contact of the stylus tip with the job.

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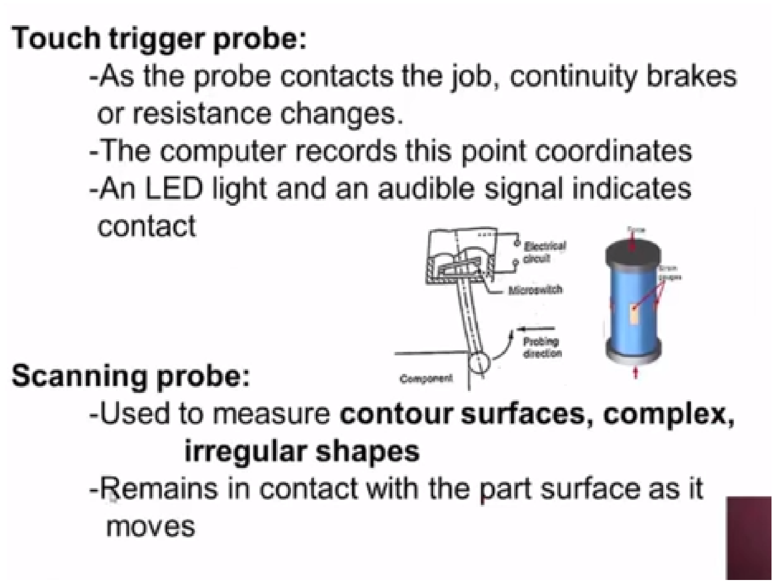

In the case of tough trigger probe as the probe contacts the job as shown here the continuity brakes or resistance changes if it is probe with micro switch type the micro switch will get open and the signal is sent to the CMM software if it is probe based on when the probe deflects the resistance of the changes and hence the signal is sent to the software.

The computer records this point coordinates that means whenever the probe comes in contact with the component the particular point coordinates or stored by the computer. An LED light and an audible signal indicates the contact in the case of scanning probe this is used to measure contour surfaces and very complex irregular shapes and this scanning type of probe remains in contact with the part surface as it move.

For example this is the probe this is the surface work part surface by the probe moves in this direction this tip it scans over the surface and then it will be sending the signals to the computer system and hence very complex 3D shapes can be assist using the scanning probe.

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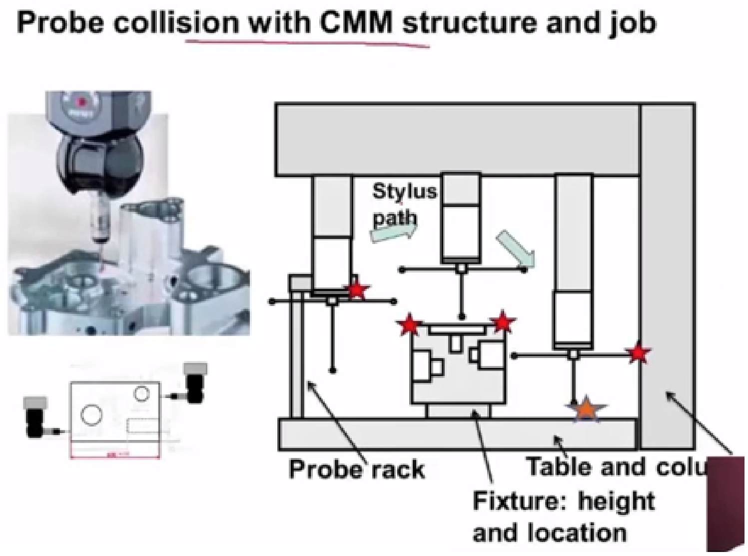

Now let us try to understand how the probe collision with CMM structure and job is avoided we can see here the table of the co-ordinate of welding machine the column of the co-ordinate of welding machine and this is over RM adventurer probe head is provided we have the pro fixed to the pro head and this is the probe rack.

Now the work piece this is the work piece to be inspected mounted on the fixture the height of the fixtures and the location of the picture is very major role now with the stylus is checking the inside whole features at the other stylus should not touch the table and the other 3rd stylus should not touch the column.

So in such a way we have to locate the fixture we select the fixture of proper height similarly when the probe moves it selects the appropriate probe from the rack and it will be moving in this direction for carrying the inspection so after carrying the inspection in this particular hole it will be retrieved and it should be moved up to a sufficient height.

So that this stylus will not touch the surface of the bore piece so like this the automatic path selection is done using the CMM software based upon the CAD details that is provided so you can see the probe based inspecting the complex part so after completing the inspection over here it has to move up to a sufficient right and then we should be bought to this collision for inspection.

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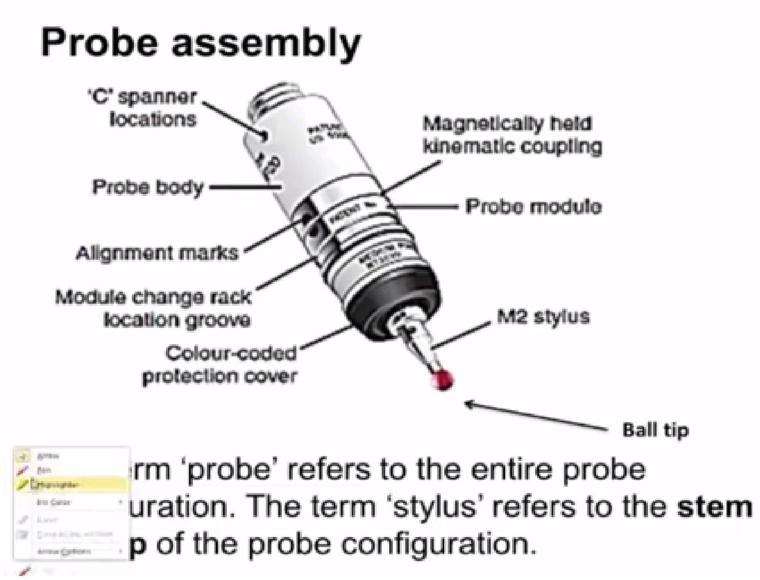

Now we can see the probe assembly this is the probe body which is fixed to the probe head using the spanners and then we have this, is the probe module which can be coupled with the probe body using the kinematic coupling we can see the alignment of the marks here to check whether the assembly of the probe module with the probe body which is correct or not and then you can select the appropriate stylus and it can be fixed to the probe module.

The term probe refers to the entire probe configuration and the term stylus refers to the stem and tip of the probe configuration so this is the stem of the a potion and this is the tip of the stylus.

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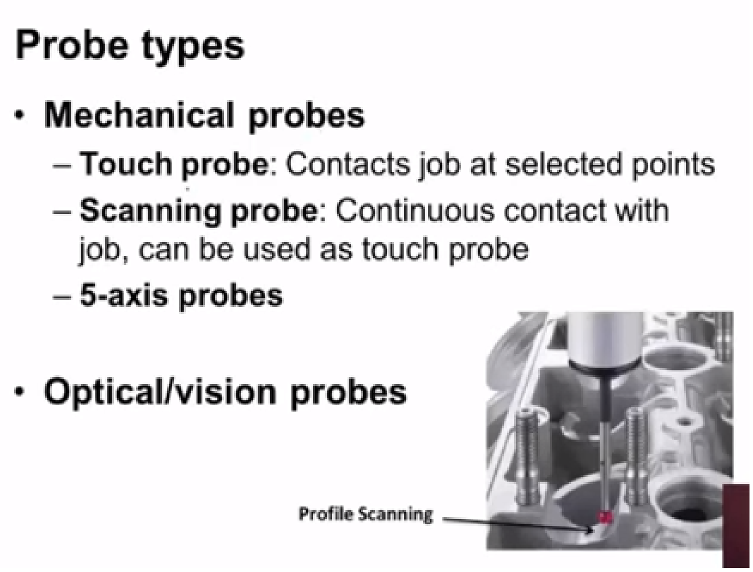

Now let us study the different probe types under mechanical probe we have touch trigger probe scanning probe and 5 axis probes this touch trigger probe it contacts the job at the selected points which are decided by the operator or by the inspection program the operator operates the joystick and he will move the probe and then probe will move and it makes contact with the work piece.

Then the like this measurement is carried out if it is with the CMM with the dedicated computer system these selected points are decided by the software or the inspection program. Now the scanning probe there is a continuous contact of the probe with the job and this can be also used as touch type probe and then we have 5 axis probes, where details of which we will be discussing shortly.

Other type of probe optical probe or vision probe so we can see here profile which is to be measured so the probe we have to select the scanning probe continuously it moves over the profile and then it will be sending the data points to the computer.

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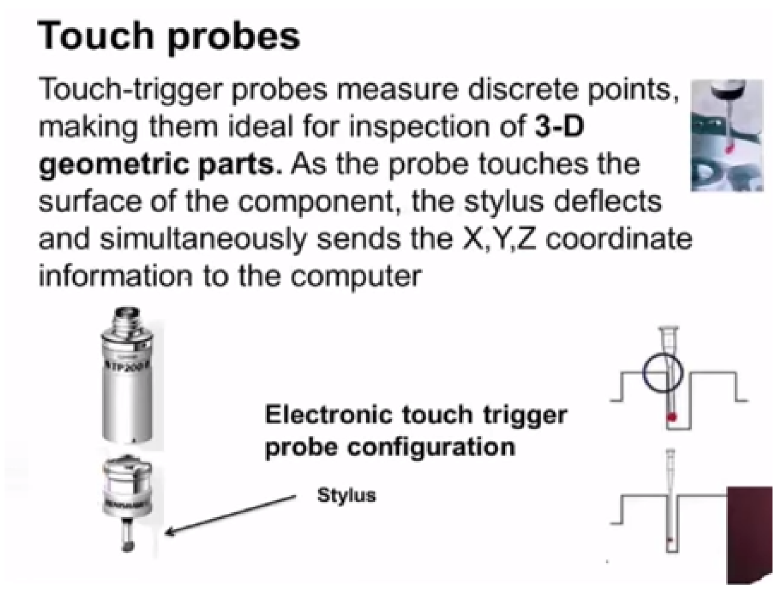

Now touch trigger probes the measure discrete points decided by the operator or by the software making them ideal for inspection of 3D geometric parts as the probe touches the surface of the component. We can see here the probe will move and it makes contact with the work piece surface as the probe touches the surface of the component the stylus deflects ,and simultaneously sends the X,Y,Z co-ordinate information to the computer.

Now we can see here the stylus and this is the probe module and the probe body so depending upon the inspection we have to select the appropriate stylus and appropriate module which can be assembled into the probe body and care must be taken to see that proper stylus with proper tips and the same length is selected we can see in this particular diagram the stem is in contacting the work piece surface which is incorrect.

So where is here only the tip of the stylus is in contacting the surface that means we have to select the appropriate stem and tip for the achieving the proper measurement.

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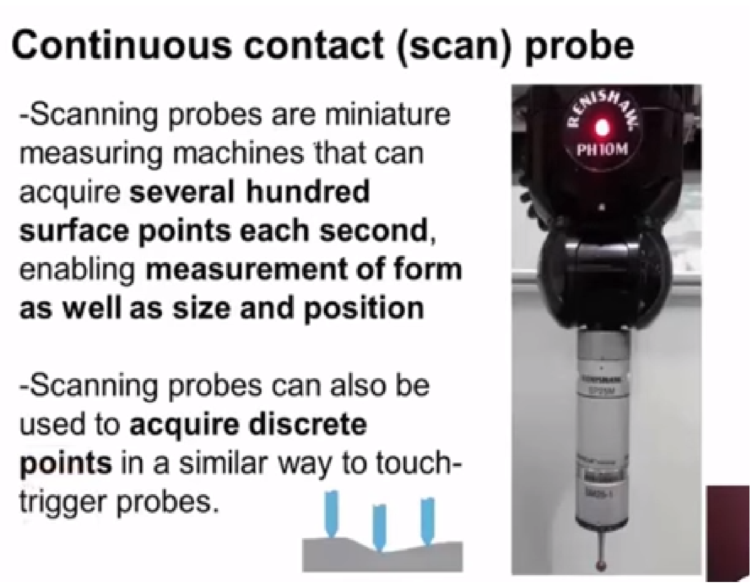

Now in the case of continuous contact probe these scanning probes are miniature measuring machines that can acquire several hundred surface points per second such as the speed of the acquiring the data points several hundred surface points are sensed by each second enabling measurement of form as well as size and position scanning probes can also be used to acquire discrete points similar to touch trigger type.

Now you can see here the probe when it moves like this it is scanning the surface and hence you can get the profile information.

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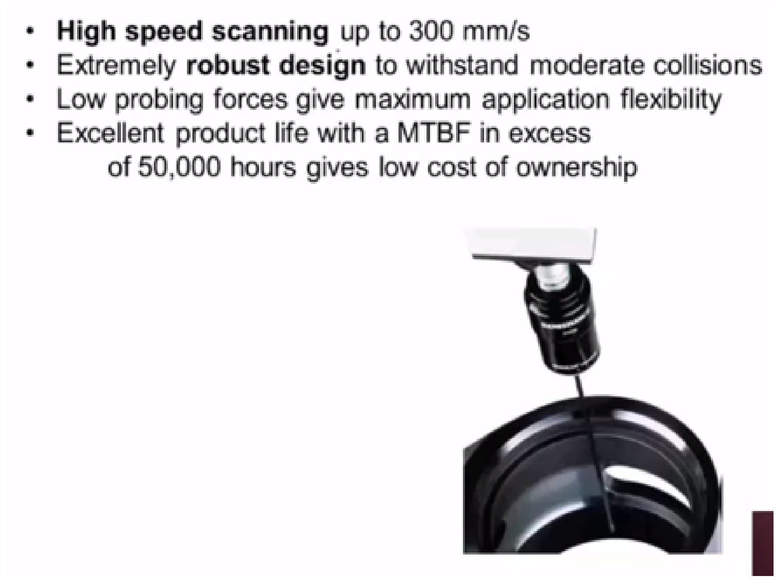

Very high speed scanning is possible with advanced scanning probe which can sense at the rate of 300 millimeter per second and extremely robust design to which stand moderate collisions low probing forces give maximum application flexibility because of this low forces rear stylus is also very less and excellent product life with a mean time before failure in excess of 50000 hours so this gives low cost of ownership.

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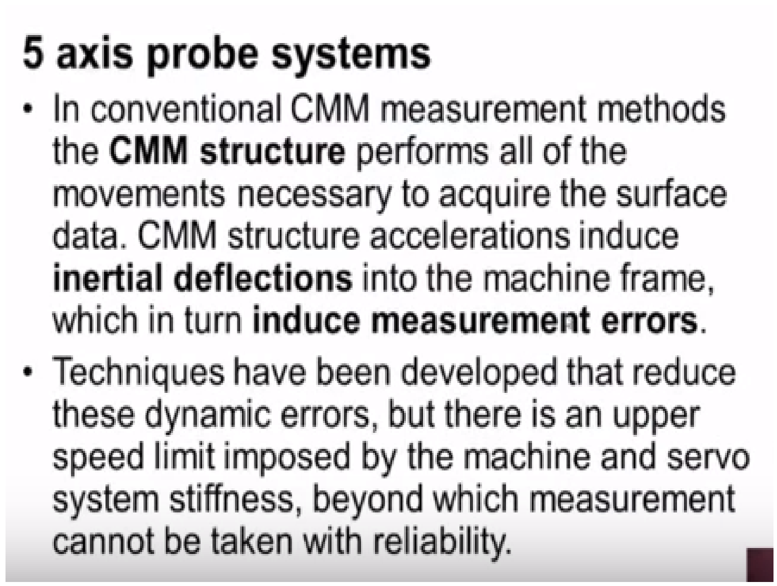

Now let us discuss the five axis probe system in conventional co-ordinate measurement methods the structure performs all the moments that is X/Z movements necessary to acquire the surface data CMM structure acceleration induced inertial deflection into the mission frame ,which in turn induce measurement errors.

Many techniques have been developed that reduce these dynamic errors but there is an upper speed limit imposed by the mission and servo system stiffness beyond which measurement cannot be taken with the reliability.

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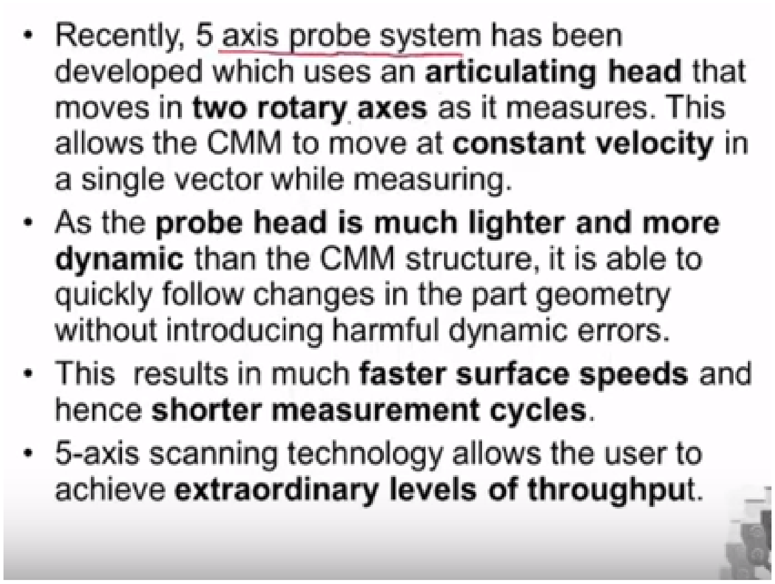

Recently, 5 axis probe system has been developed which uses and articulating head that moves in to rotary axis as it measures that means 5 axis probe system has additional to rotary axis that is A axis and B axis along with the X basic motion given by the same structure. This allows the CMM to move at a constant velocity in a single vector while measuring as the probe head is much lighter and more dynamic when compared to the CMM structure.

It is possible to quickly follow changes in the part geometry without introducing harmful dynamic errors. This results in much fastest surface speed and health shorter measurement cycles 5 axis scanning technology allows the user to achieve extraordinary levels of throughput.

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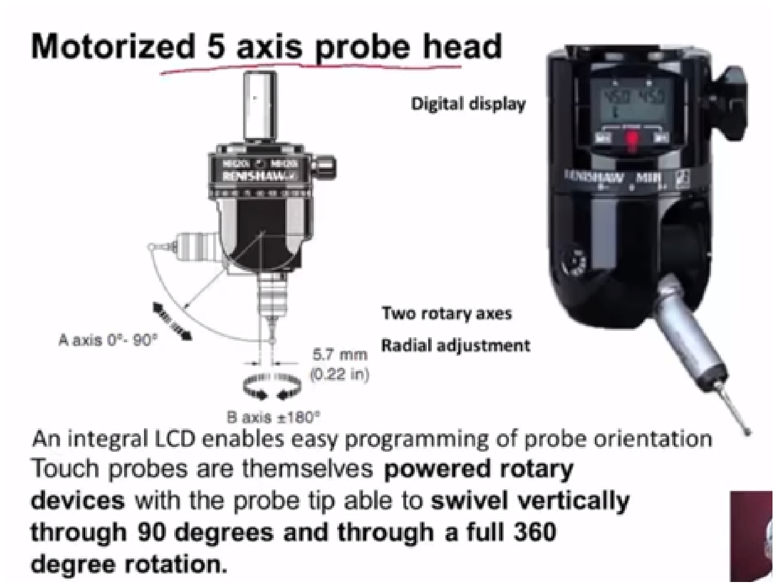

Now you can observe a motorized 5 axis prepared here this is the probe head and appropriate styluses can be incorporate inserted into the probate we can observe here that apart from X,Y,Z motion given by same structure these motorized probe heads have their own A access moment as well as the B axis movement so that stylus can be swiveled here and the stylus can rotate in + 180 degree or - 180 degree.

Apart from that the radial adjustment is also possible there is an integral LCD enables easy programming of probe orientation Show the depending upon the inspection requirement the probe orientation can be adjusted and this is the digital display built internally probe head.

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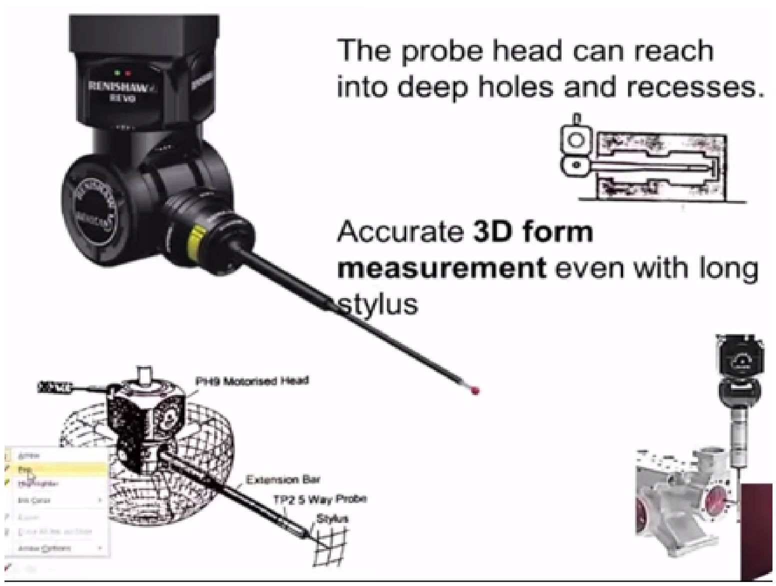

Now I can see here the use of extended bars probe head can reach the deep holes and recesses and the internal details deep hole details can be measured and accurate 3D form measurement even with a long stylus is possible. We can see here extension bar the measurement volume can be selected.

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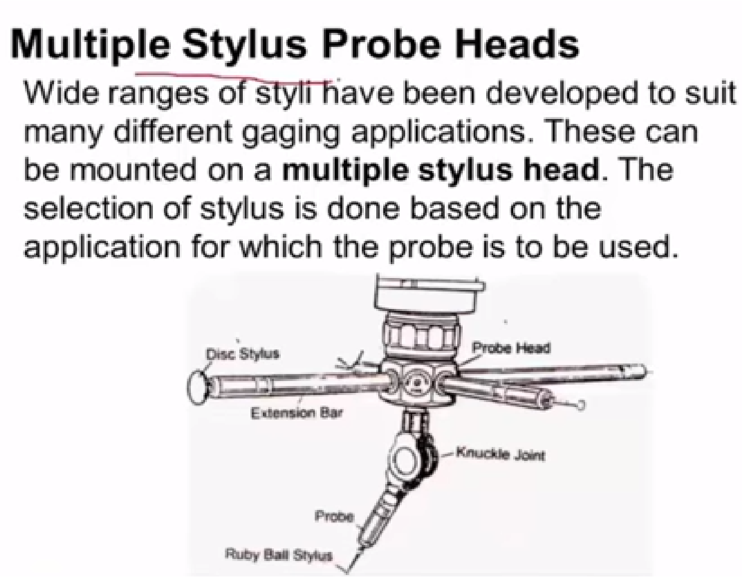

Now apart from single stylus probe heads multiple stylus probe heads or also possible you can see here we have probe head with multiple stylus is disc stylus with an extension bar ruby ball stylus with knuckle joint similarly we can insert appropriate stylus here depending upon the inspection requirement wide range of styli have been developed to suit many different gaging applications.

These can be mounted on multiple stylus head the selection of stylish is done based on the application for which the probe is to be used.

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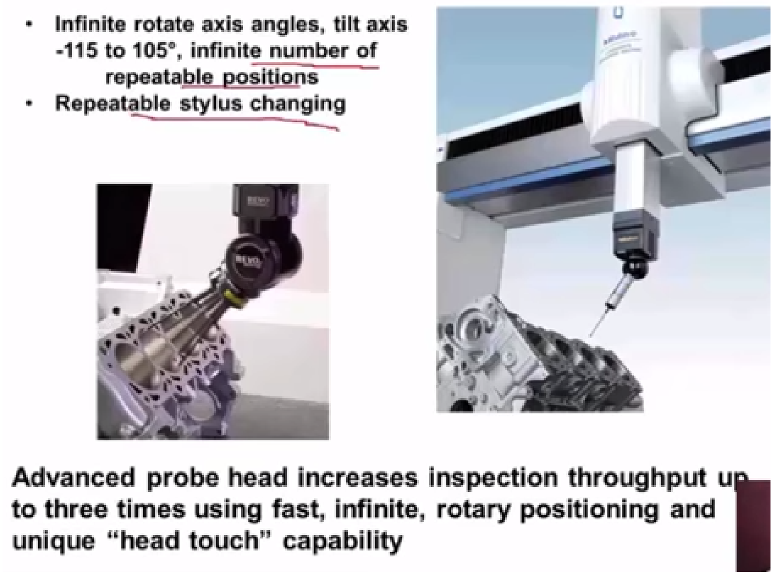

Now you can see here with the help of motorized probe head infinite number of repeatable positions and repeatable stylus changing is possible you can see the motorized high axis probe head is fixed to the Z axis. It can orient its angle can be adjusted depending upon the work piece inclination work is angle here also we can see the incline surface and bow is to be checked.

So the five axis heads will help in inspection of these holes which are at some inclination advanced pro head increases inspection throughput up to 3 times using past infinite rotary positioning and unique head touch capability.

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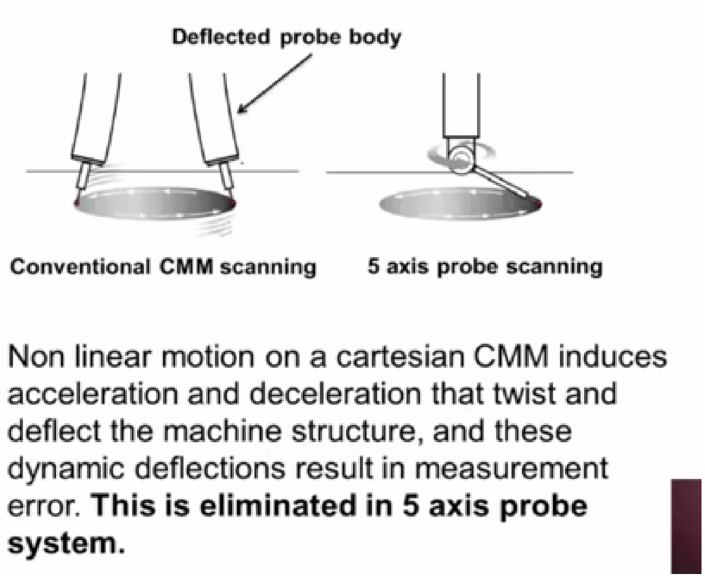

Now you can see here this is deflected probe body when we use conventional probes and here we are using the five axis scanning type probe so non linear motion on cartesian CMM induces accelerate and deceleration the twist and deflect the machine structure and these dynamic deflections result in measurement error this is eliminated by using 5 axis probe system.

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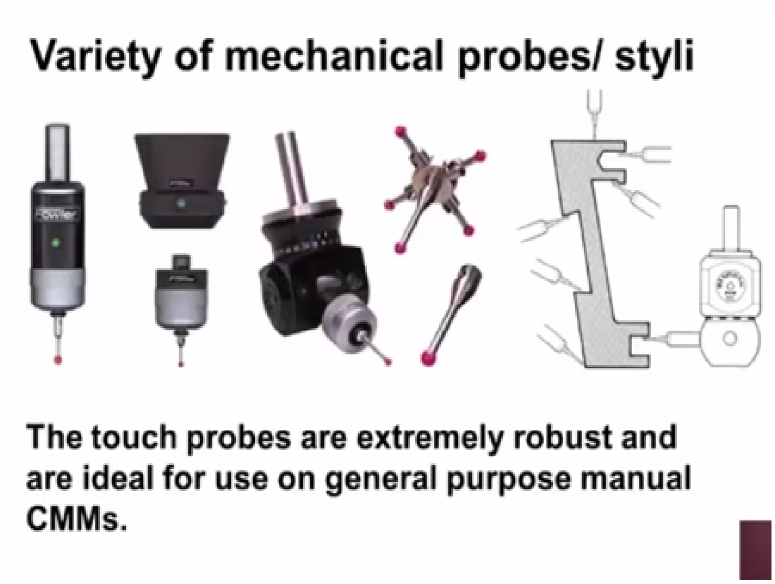

Now you can see this pictures show variety of mechanical probes the motorized probes where in the angle can be changed star type probe heads are possible motorized probe head where in the angle can be adjusted depending upon the work piece type these touch probes are extremely robust and are ideal for use on general purpose manual co-ordinate measure machines.

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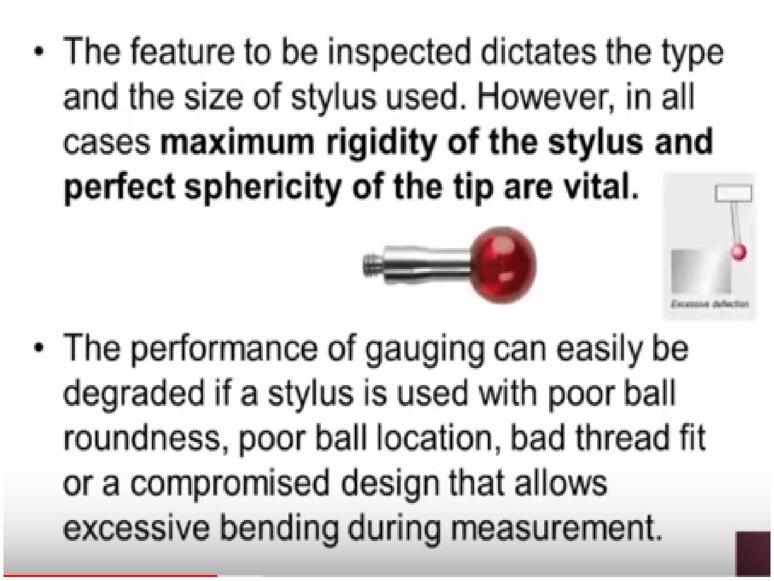

The feature to be inspected dictates the type and the size of stylus used however in all cases maximum rigidity of the stylish and perfect sphericity of the tip or vital. In order to have accurate measurement you can see here there is a excessive deflection of the probe which means selection of stem of proper thickness and proper length is very important in order to avoid excessive deflection and perfect sphericity is also vital.

So that we get the accurate measurements the performance of gazing can easily be degraded if a stylus is used with poor ball roundness, poor ball location, bad thread fit or a compromised design that allows excessive bending during measurement.

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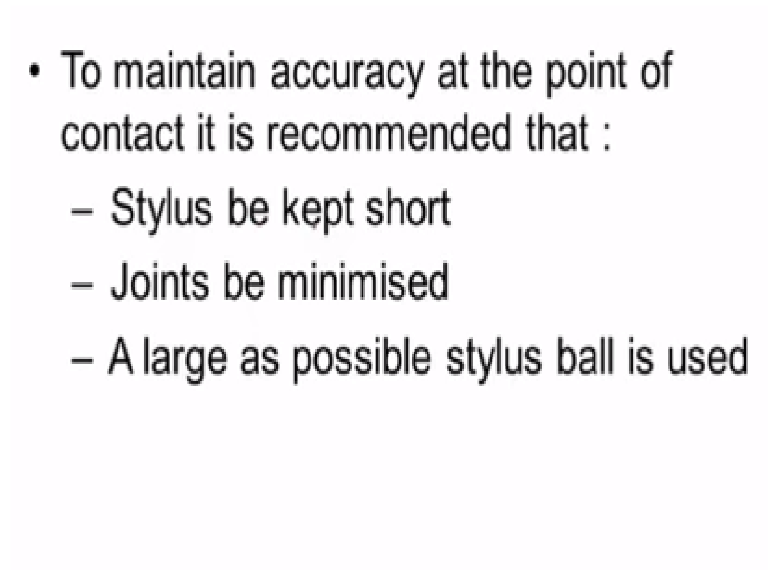

To maintain accuracy at the point of contact it is recommended that stylus be kept short so unnecessary stylus should not be used which causes the large amount of deflection which will lead to incorrect measurement. Joints be minimized between probe and stylus minimum joints should be there as large as possible stylus ball should be used.

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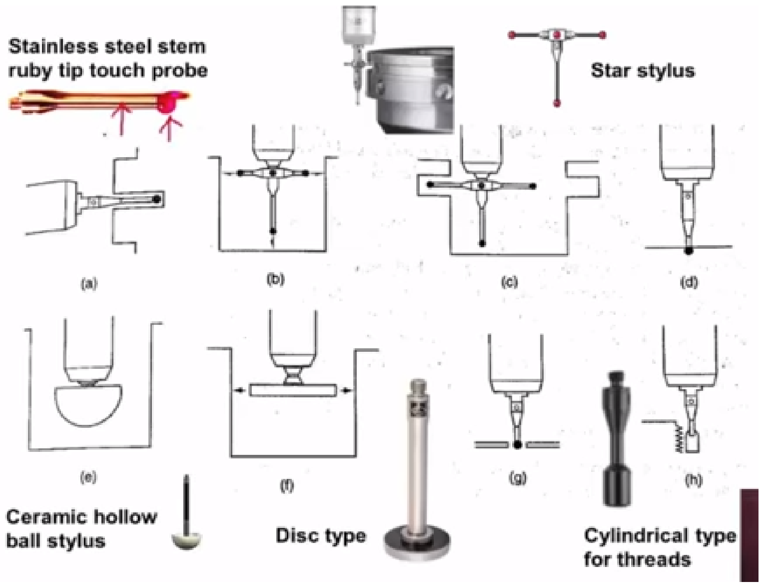

Now you can see a variety of probes here this is stainless steel stem ruby tip and this stem is made of stainless steel which is used to measure the recesses as well as the surface height width etc now you can see here star stylish and here we are observing. How we can use star stylus to measure the external grooves.

So similarly here the measurement of group using the stars stylus and here we have ceramic hollow balls stylus for measurement of diameter of holes a disc type stylus and a cylindrical type for threads.

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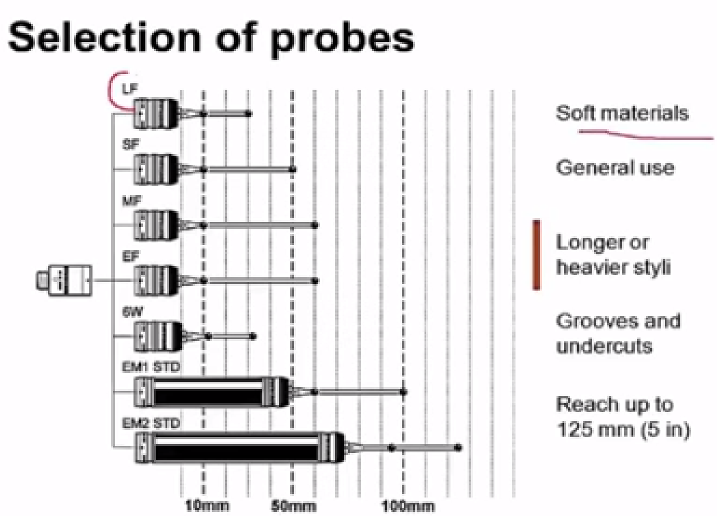

Now how do we select the probes depending upon the material if you have a soft material the probes with low force requirement so for general we can select the SF type rear and longer and heavier styli. We should use the medium force requirement and similarly grooves and undercuts depending upon the type of the inspection we should select the probes of appropriate length with appropriate force requirement.

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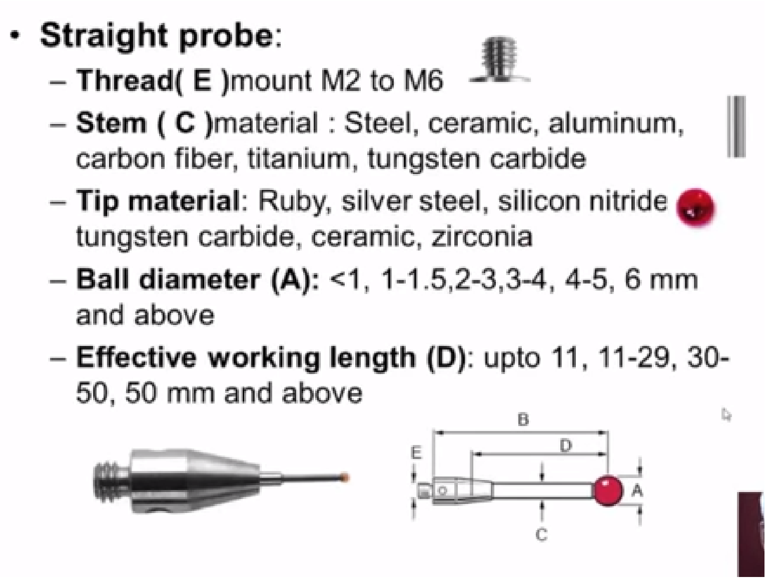

Now let us see the details of the straight probes now this diagram shows straight probe stylus. Now this is the third portion which will go into the probe body different threads are possible to m2 to m6 threads are possible and then this is the stem portion stems are available with different materials like steel, ceramic, aluminium, copper, fibre, titanium, tungsten carbide.

And available with different diameters also and at the end we have tipped this is the property problems are available at different tip material like a ruby, silver, steel, silicon nitride, tungsten carbide, ceramic and zirconia, and tips are available with different shapes also so this shows ball type tip and balls.

And balls of different diameters up to 6 mm and above available depending upon the section requirement so effective working length of the probe is be so probes of different working length are available up to 11 millimeter 11 to 29 mm 32 to50 mm and 50 mm and above and depending upon the application we can select probes of different length.

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Straight styli are designed to inspect simple features where direct unobstructed contact with a measured surface is possible. A tungsten carbide stem provides exceptional rigidity particularly for styli with small wall and stem diameters. Ruby is regarded as the industry standard for stylus tips it is one of the hardest material available and suitable for most applications. Due to adhesive nature, ruby tips are not recommended for scanning aluminium parts.

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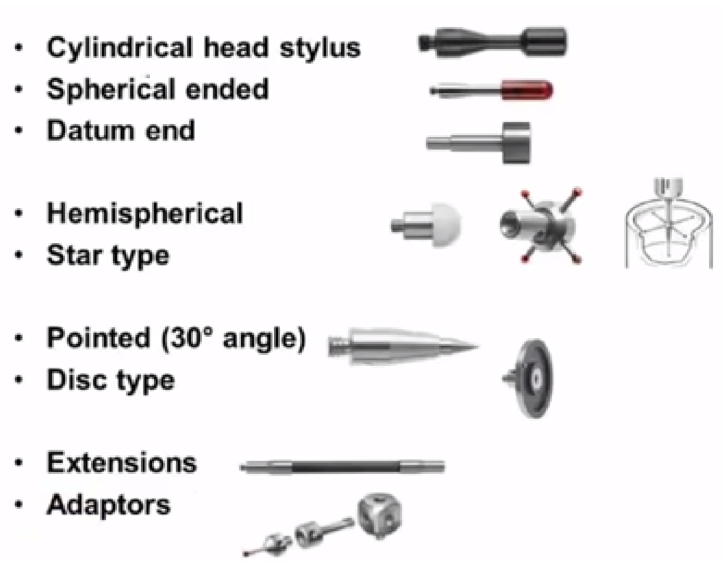

Now this picture shows cylindrical head stylus you can see the tip a cylindrical type which can be used to measure threads and is spherical ended stylish and then we have datum end and hemispherical tips are also available for measurement of holes of larger diameter and then we have star type wherein different types can be mounted on this head to head then we have pointed tips for measurement of threading.

Then extension roads are possible to measure deep hole details, so extension rods can be used at the end we can have the stylus and adaptors are also possible between the probe head and the stylus tip.

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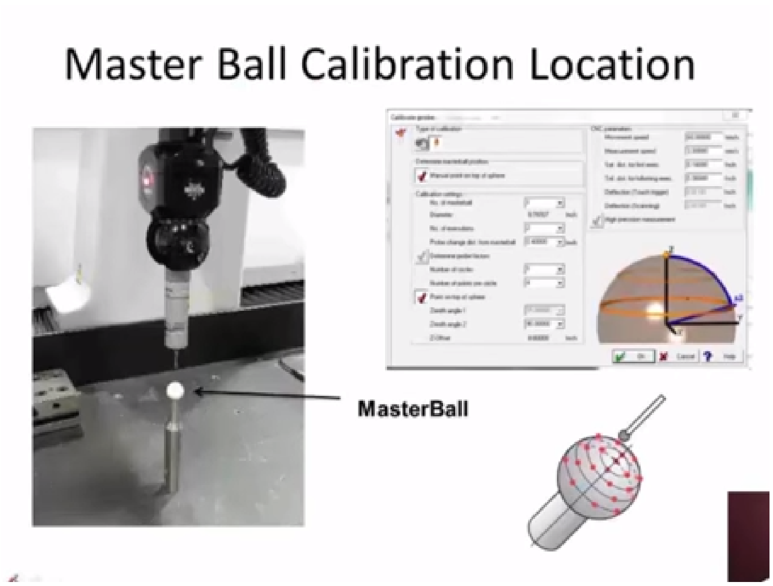

Now before we use CMM with the selected stylus we should calibrate whether the probes are capable of giving proper readings or not. For that master ball is used the master ball is placed on the specified location. Normally on the centre of the table and the probe is selected the probe is fixed into the stylus is fixed into the probe body.

Then the stylus is made to scan the surface of the master ball and the readings are analyzed to check whether the probes are giving proper readings or not.

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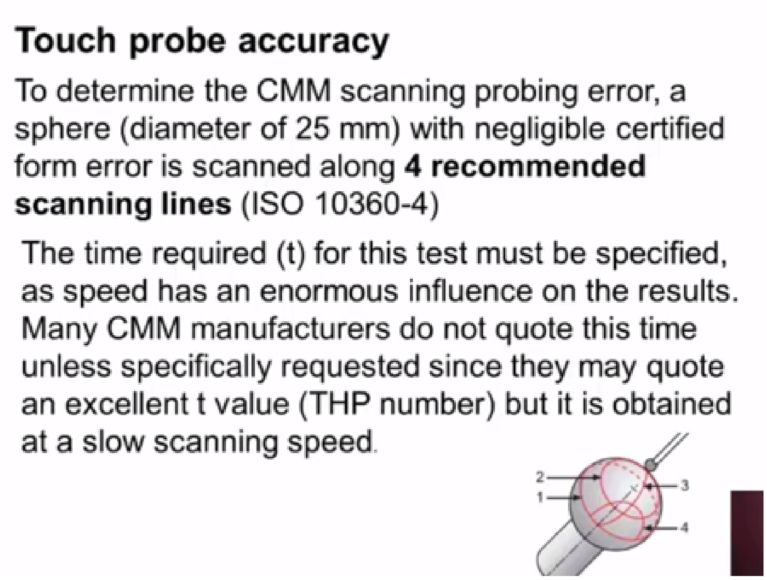

Whenever we select a nib probe find whether the probe is capable of giving correct readings or not, so we should calibrate the touch probe to determine the CMM scanning probing error a sphere of diameter of 25 mm with negligible certified form error a scanned along for recommended scanning lines.

So in this picture you can see this is the master ball which is used to calibrate the probes selected so this is the probe selected which is to be calibrated so the master ball is placed at the specified location of the same table and the probe selected is made to scan the surface of the master ball along the 4 lines.

This is the line number one line number to line number 3 and we have line number 4 so the probe selected scans the surface of the master ball these 4 lines as per the ISO10360-4 the time required t for this test must be specified as speed has an enormous influence on the results many cm of manufacturers do not quote this file unless specifically requested since they may quote an excellent t value but it is obtained at a slow scanning speed.

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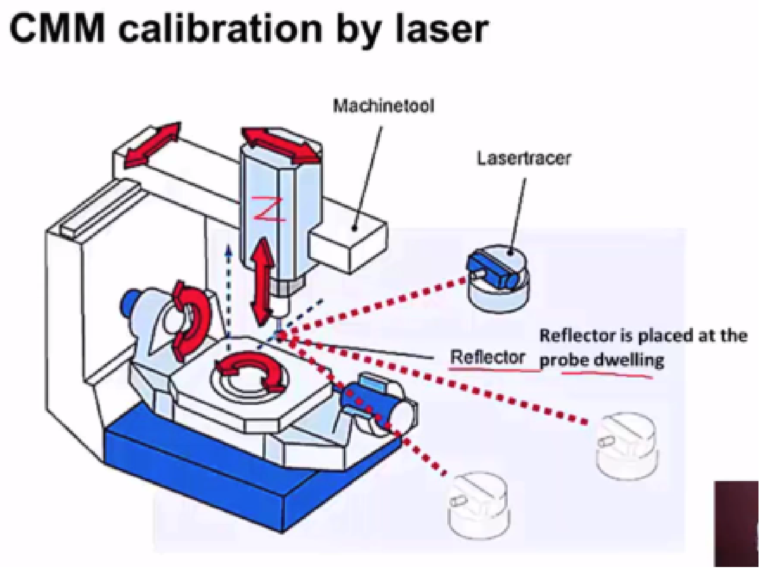

Now how do we celebrate the CMM now it the reflector is placed at the probe doing to this is the z axis the z-axis of CMM and the place where the stylus is inserted, so this place is a reflected is placed and the program inspection program is run the reflector will move as per the inspection program.

So the motion of the reflector is trapped by the laser tracer and then the what is the moment of the reflector as per the reflector program and what is the actual movement as inspected by the tracer they are compared to check whether there is any error in the CMM movement, so like this CMM can be calibrated by laser tracer.

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Now we can also calibrate co-ordinate measuring machines using slip gauges that means this is the table of CMM on which the slip gauge of known length, the length =10 millimeter, so the slip gauge of known length is placed and then we should insert the stylus in the probe body and then it is moved the probe is moved in this direction and it makes contact at this place and reading 1 is a recorded.

Similarly the probe is more to this place and then it is made to touch the slip gauge at this place and reading R2 is taken now the difference between these reading R2-R1 minus the tip diameter should be equal to this slip gauge length then the CMM movement is okay like this co-ordinate measuring machines can be calibrated using the slip gauges.

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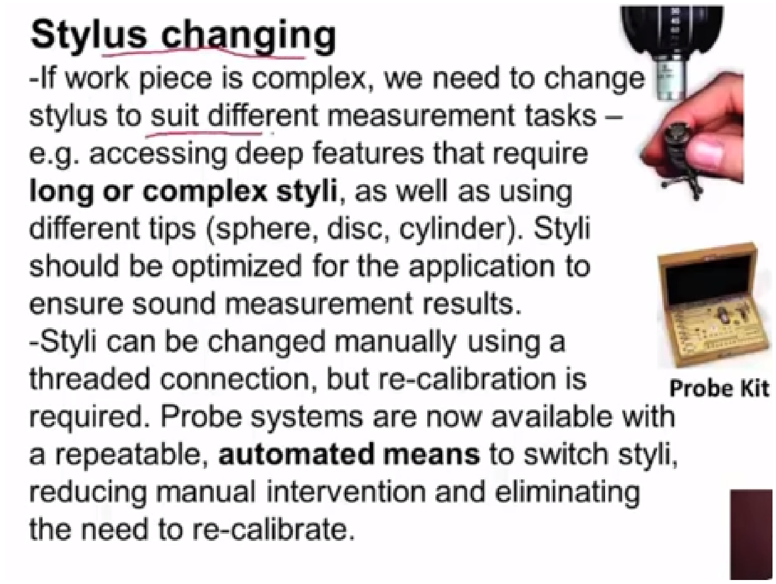

Now depending upon the inspection requirement we need sometimes to change stylus that is if the work piece is complex we need to change stylus to suit different measurement tasks for example as this thing deep features that require long or complex styli, as well as using different tips spherical, disc type and cylindrical type tips for measurement of threads.

So style I should be optimized for the application to ensure sound measurement results, so this style I can be changed manually using a threaded connection so whenever we change manually recalibration is essential probe system are available with repeatable automated means to switch styli reducing manual intervention and eliminating the need to recalibrate.

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Now in this demonstration we can see the movement of the probe now this moving in the access plus minus 180 degrees+/-180 degrees movement. Now it is a axis movement now we can see the calibration of probe using master ball before using probe we should calibrate.

Now the operator is operating the joystick is moving the stylus and he is and he is inspecting the incline surface of the work piece stylus is contacting at 4 different places in the incline surface when the probe touches the red light blinks. After this inclination is calculated the probe is adjusted for proper orientation and again the joystick is operated and the stylus is moved.

So that stylus touches the inner surface of the bow or the incline surface it is the contacting the inner surface of the board, so we can see the blinking of the red light. Now after getting the measurement point the software will calculate the diameter and the centre point coordinates**.**

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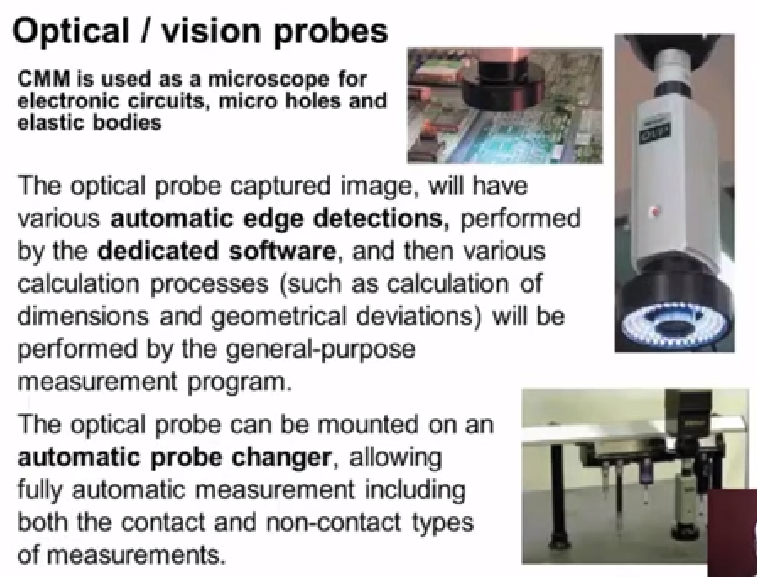

Now recently optical probes are known as vision probes are developed and by using these vision probes CMM can be used as a microscope for measurement of electronic circuits for measurement of micro holes or measuring very rubbery materials or elastic bodies. The optical pro captured can see in this diagram. we have an optical probe and this is the electronic circuit which is being inspected by the vision probe.

So this probe moves on the electronics so circuits and captures and captures the image and the captured image is analysed and measurement or readings are taken the optical probe capture image will have various automatic age did actions performed by the dedicated software and then various calculation processes such as calculation of dimensions like thickness, width, depth, length etc.

Geometrical deviations will be performed by general purpose measurement program. The optical probe can be mounted on an automatic probe changer we can see we have probe changer wearing various kinds of text type, and scanning type probes are mounted we can also see vision probe in the automatic probe changer.

Which allows fully automatic measurement including both the contact and noncontact types of measurement techniques depending upon the requirements sometimes the contact type probes are selected and inspection is carried out and whenever the non factor measurement is required this vision probe is selected inspection carried out.

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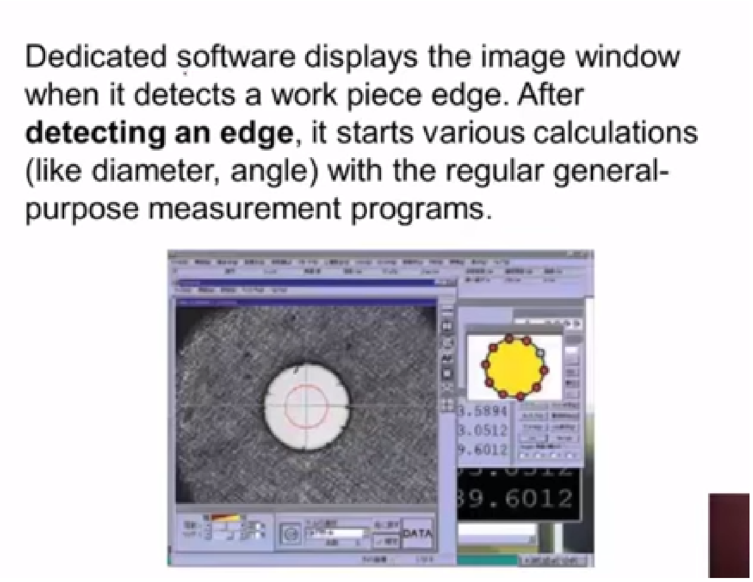

Dedicated software available in the computer system displays at the image window when it detects a work piece edge when vision type probe is used for inspection. After deducting an edge it starts various calculations like diameter, thickness angle etc with the regular general purpose measurement program here you can see and adjust deducted this is the hole available in the work piece.

So the dedicated software it detects the edge like this and then the various points are the coordinates of various points on the selected edge are obtained and then the software will calculate, what is the diameter of the hole what are the X,Y,Z co-ordinate points of this centre point. So like this software will calculate the required details, required features.

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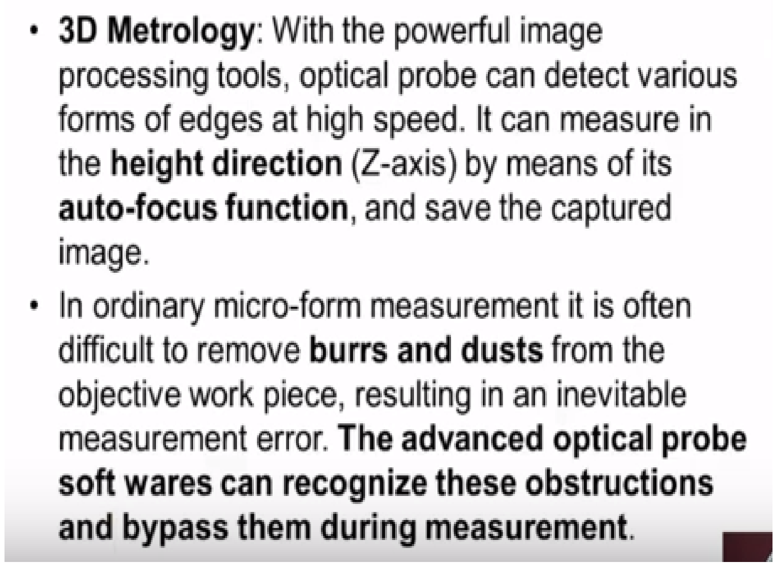

Now using the vision probes and with powerful image processing tools, which is possible to have 3D metrology that means it can measure the vision probe can measure in the height that is Z axis also by the means of it autofocus function by using auto-focus function. The height of the work pieces height of various features can be measured and hence the 3 dimension measurement is possible.

In ordinary micro form measurement it is often difficult to remove burrs and dusts for example we have a work piece like this where in there is hole and here some burrs are there in the ordinary measurement, these burrs cannot be compensation. These burrs cannot be made were as the use vision type probes.

So this burrs and that can be removed automatically the advanced optical probe softwares can recognise. These obstructions and by burrs and dusts and by pass them during the measurement.

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3D Vision Measuring System

This vision system combined with the ability of a touch-trigger probe can reach undercuts and similar features not accessible to the camera.

Courtesy: mitutoyo.co.uk

Now 3D vision measuring systems are developed wherein vision probes are provided as well as touch trigger probes are also provided in the machine, so vision probes are used for measurement of the various features and then the touch trigger probe is provided to reach undercut and similar features which are not accessible by the vision probe or camera.

You can see here we have vision probe and then touch trigger probe using the combination of this the complex work pieces can be measured wherein the undercut are such things are there in work piece which are not accessible by the vision probe.

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- This advanced machine is extremely productive on most work pieces because of its **high-intensity-LED stroboscopic image capturing technique** that operates while the stage is moving. This eliminates the time needed to accelerate, decelerate and then hold the stage motionless while a measurement is made.
- **Programmable ring lighting** is also provided to give the **flexibility in lighting direction, angle and intensity**, that enables achievement of **maximum surface contrast** for best imaging resolution, and hence accuracy, on the more problematic workpiece.
- The fixed bridge, moving table design is used for the **ultimate in rigidity**. A **programmable power turret** provides **control of magnification** for optimal viewing.

This advanced machine is extremely productive on most work pieces because of its high intensity led stroboscopic image capturing technique that operates while the strange is moving that means when the stage is moving along with the work piece the measurement is possible that means we need not have to stop the table for the making measurement.

Programmable ring lighting is also provided to give the flexibility in lighting direction angle and intensity that enables achievements of maximum surface contrast for best imaging resolution and hence accuracy on the more problematic work piece.

The fixed bridge moving table design is used for the ultimate in rigidity a programmable power torrent provide control of magnification for optimal viewing that means whether the Required or 10X magnification or 20X magnification ,so that can be programmed, so the turret will rotate as per the program and then we can have the required magnification.

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In this demonstration we can observe the co-ordinate machine with vision probe and yeah touch trigger probe I can see the movement of the co-ordinate vision mission the vision probe of the co-ordinate vision mission now the touch trigger probe is inspecting spur gear inspecting the profile of spur gear. Now the vision progress inspecting the tooth profile gear tooth profile using the optical system. Finally the software will present the measurement results on the computer monitor.

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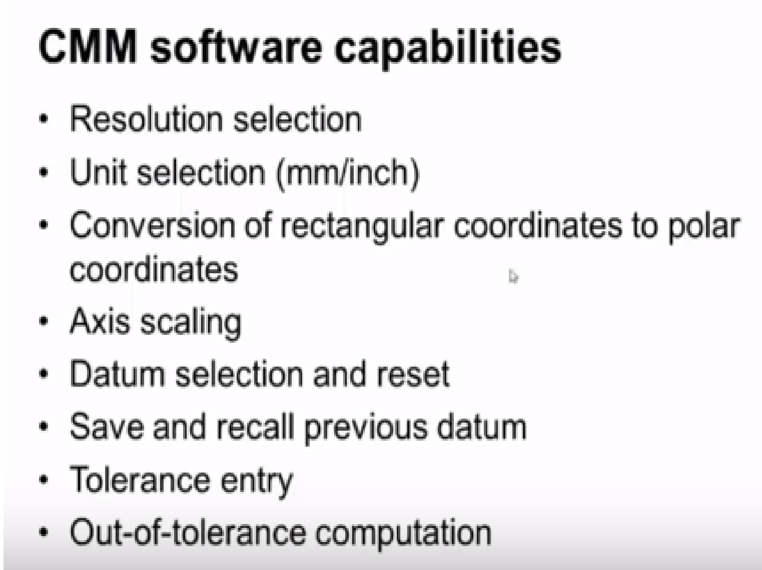

Now let us study what are the capabilities of CMM software in the advanced CMM software is possible to select the required resolution that is weather accuracy requirement is upto.01 millimeter or.001 millimeter or .0001 millimeter like that required accuracy resolutions can be selected.

Unit selection is also possible depending upon the requirement within the selecting in the system. Conversion of rectangular coordinates to polar coordinates is possible, axis scaling is possible, datum selection and reset is possible, save and recall previous datum is also possible. We can do the tolerance entry out of tolerance computation is possible.

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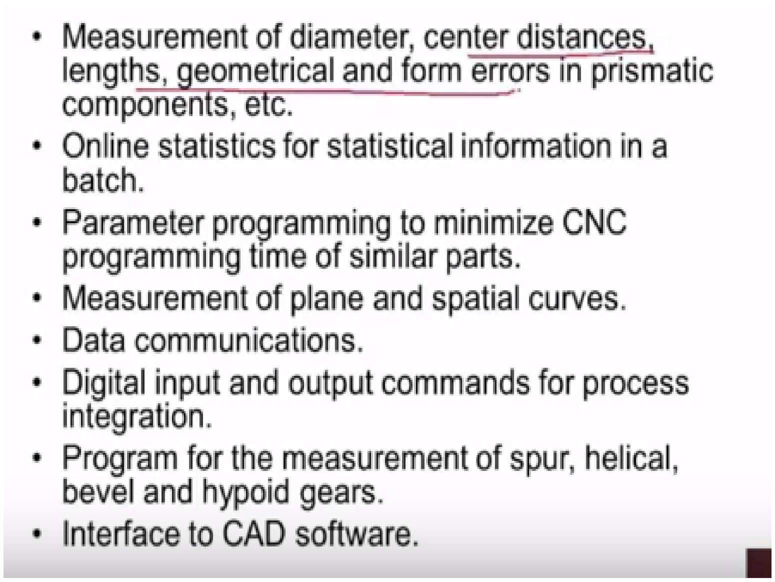

Measurement of diameter, centre distance, lengths, geometrical and form errors in prismatic components can be calculated. Online statistics for statistical information in batch is possible, Parametric programming to minimise CNC programming time for similar parts as possible measurement of plane and spatial curves are possible, data communications is possible, digital input and output commands for process integration are available.

Program for the measurement of spur gear, helical gear, bevel gear and hypoid gears is available and then interface to CAD software is also possible.

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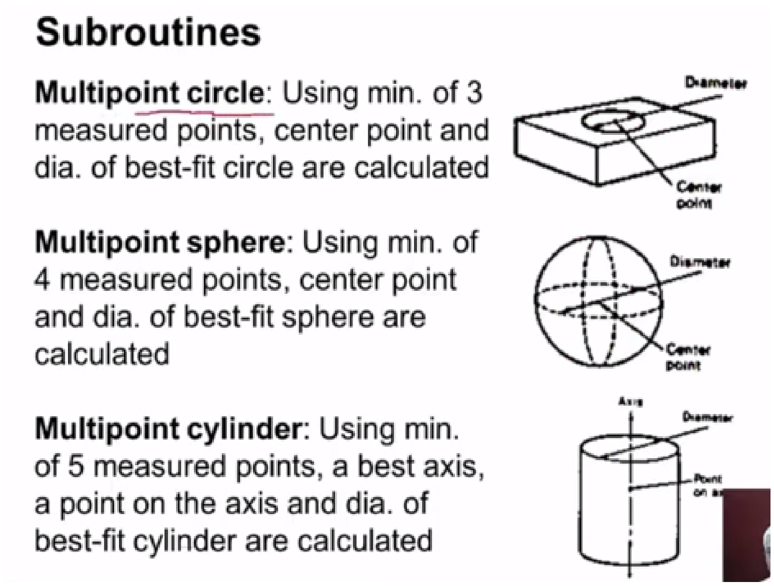

Now various subroutines are used for doing for making the competition, so on the subroutines are discussed here multipoint circle that means we have the work piece but hole here by selecting the minimum of 3 points for example first here and then second is at this place and third point at this place, so using the minimum of 3 measuring point centre point and diameter of best fit circle can be calculated.

Multipoint sphere using minimum of 4 measured points so 1point is here second at this place and third at this place and forth. at this place using the minimum of 4 measured centre point the software can calculate. What is the coordinates of the centre point and what is the diameter of the best fit spear can be calculated.

Multipoint cylinder using minimum of 5 measured points based axis point on the axis and diameter of best fit cylinder can be calculated that means on this cylinder we have to select the 5 measured points then the software is calculated a best access and. Point on the axis and diameter of best fit cylinder can be calculated.

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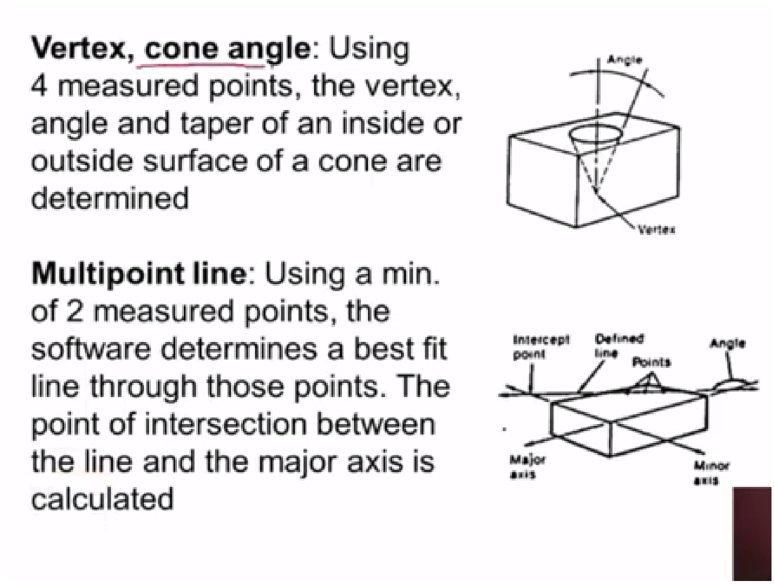

Vertex cone angle using 4 measured points so on this conical features 4 points should be selected using these 4 points software will calculate the vertex angle and taper of an inside or outside surface of a cone so if you have an extended outside cone 4 points for measuring points should be given and software will calculate what is the co-ordinate of this vertex and what is this angle and what is the paper that can be calculated.

Multipoint line using a minimum of 2 measured points the software determines best fit line through those points the point of intersection between the line and the major axis is can also be calculated we have this major axis here and we have the best fit line here. So these are the 2 measured points and this is the best fit line and what is the angle between the major axis and the best fit line that can be calculated using the software.

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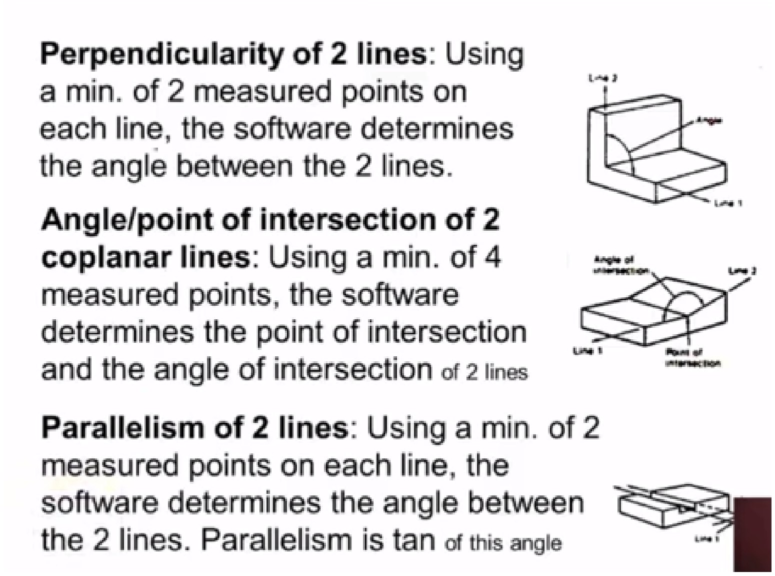

And perpendicularity of 2 lines you can see here we have one plane here and other plane here and this is the line in the first plane and this is the line in the second plane, so what is the perpendicularity of these 2 planes can be calculated by the software. That means we have to give the minimum of 2 measured points on each line to 2 points A and 2 points.

We should give then the software will calculate the perpendicularity between do these 2 lines or planes. Angle of intersection of 2 coplanar lines using a minimum of 4 measured points the software determine the point of intersection so here we should give 2 points and on the line 2 we should give 2 points and the software will determine the point of intersection.

So the coordination intersection can be calculated and the angle of intersection of to this angle can also be calculated. Parallelism of 2 lines can see here line 1 and line 2 and using the minimum of 2 major points on easy lines so we should give we should select the 2 points online one and 2 points on line to that means total 4 points we should give then the software determine the angle between these 2 lines then the parallelism is tan of this angle.

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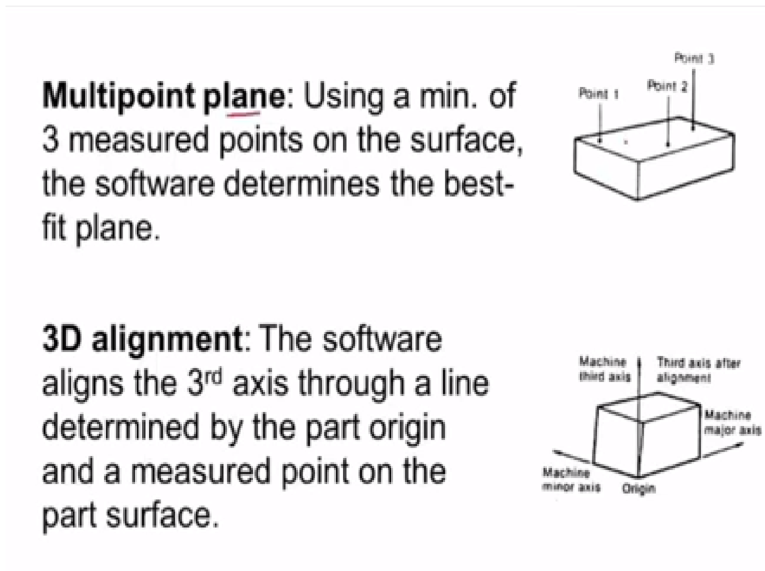

And then multipoint playing so we have a plane surface here we should give a minimum of 3 measured points we should select one and one contact point here, second contact here, third contact here that means we should move the probe and we should make the contact here and third point here then the software will establish the best fit plane passing through 3 given points.

Then 3D alignment, so software aligns the third axis, so this is the third axis the software aligns third axis through a line determined by the part origin this is a part origin and a measured point on the part surface.

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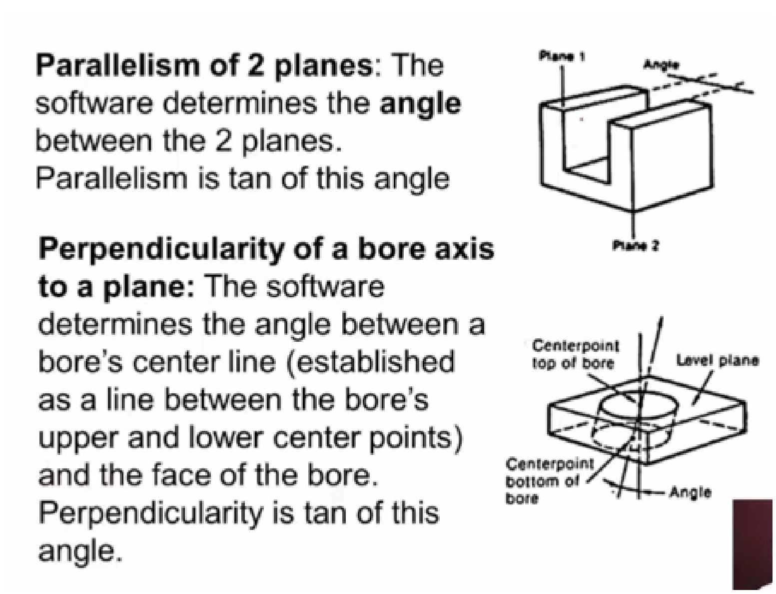

Parallelism of 2 planes now in this diagram you can see this is plane number 1 and this is plain number to we want to check whether these 2 planes are parallel to each other that means we have to select one point here and other point on this plane. Similarly 2 points on this second plane then software will determine best fit line passing through these 2 points.

Similarly best fit line passing through these 2 points and then it will calculate what is the angle between these 2 lines in other words angle between these 2 planes the software determine the angle between 2 planes parallelism is tan of this angle. Perpendicularity of bore axis to a plane I can see a work piece here with a bore and this is the bore surface the software determine the angle between a bores.

So this is the bore's centre line established as a line between the both upper and lower centre points, so this is the bore's upper. and this is the bore's lower centre point. It establishes an axis passing through these 2 centre points that will be the bore's axis and what is the perpendicularity between the bore axis and the bore face and that will be calculated by the software what is the angle between the boat surface the face of the boy and the centre line and perpendicularity is tan of this angle.

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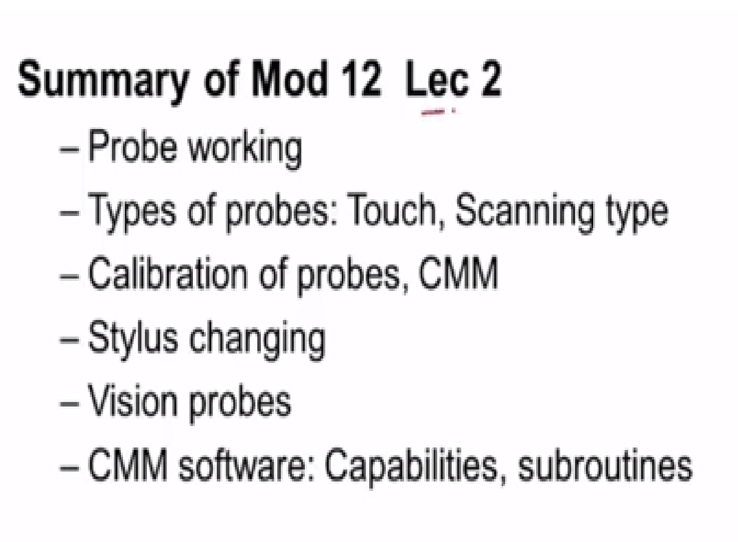

Now let us summarize the model 12 lecture number 2. In this lecture we have discussed about probe working how the probe works wherein we discussed about micro switch arrangement in the probe are video electric element, provision of straight gauges probe and what are the different types of mechanical probes touch type and scanning type probe.

How the calibration of probes and calibration of CMM is carried out we also discussed about the stylus changing depending upon the special requirement and we also discussed about the vision probes and finally we discussed about CMM software, where in we discussed about capabilities of software and what are the subroutine used in the software with this we will conclude this lecture. Thank you.