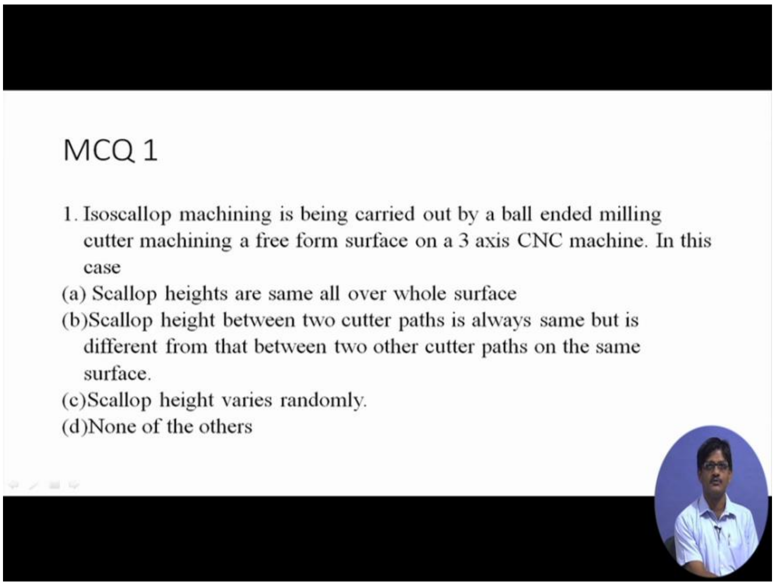
Computer Numerical Control of Machine Tools and Processes
Professor A Roy Choudhury
Department of Mechanical Engineering
Indian Institute of Technology Kharagpur
Lecture 20
Introduction to Computer Control- Role of Computers in Automation

Welcome viewers to the 20th and last lecture in the open online course "Computer numerical control of machine tools and processes". So let us move right away to some discussion and multiple-choice questions on the last 4 topics that we have covered.

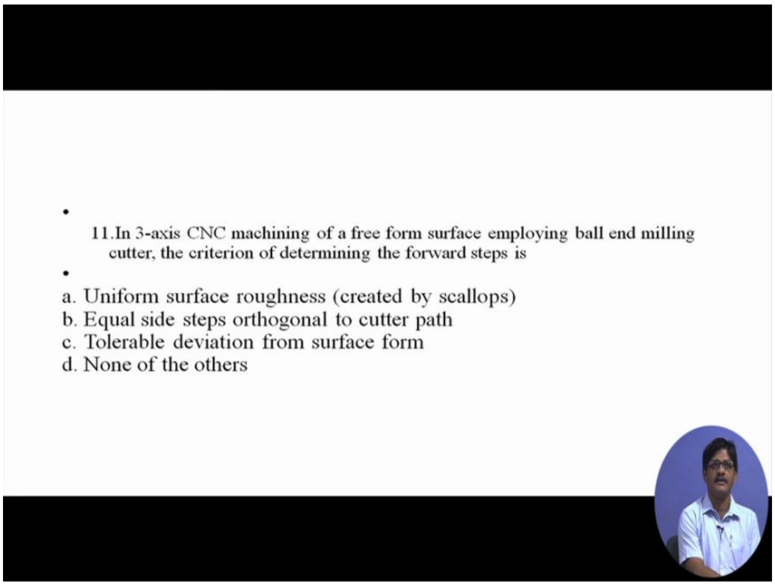
(Refer Slide Time: 00:41)



To start with the 1st question, the Isoscallop machining is being carried out by a ball ended milling cutter machining a free form surface on a 3 axis CNC machine okay, so Isoscallop machining, ball ended milling cutter, 3 axis machine, free-form surface. In this case… scallop heights are same all over the surface. 2nd option, scallop height between 2 cutter paths is always same, but it is different from that between 2 other cutter paths on the same surface.

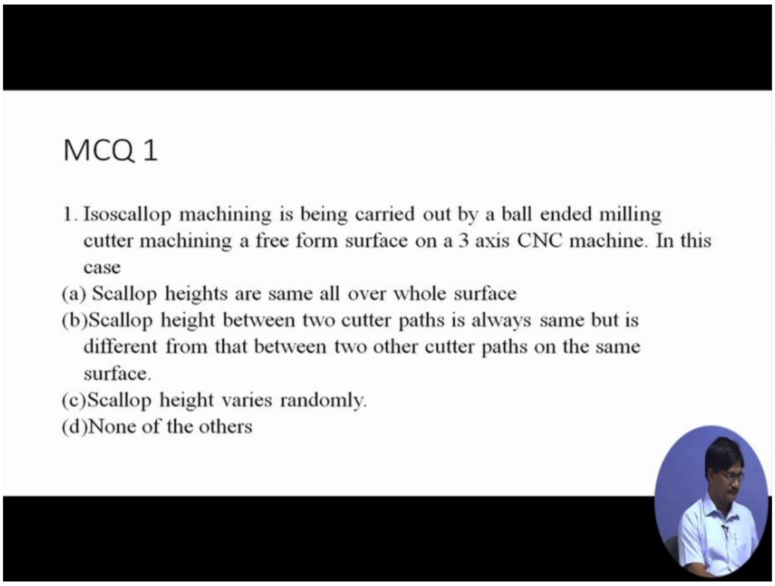
3rd, scallop height varies randomly and D, none of the others. 1st of all we can eliminate C, yes it is not correct, scallop height has to be uniform. Second A and B, A is suggesting while A is suggesting that it is uniform over the whole surface, B is suggesting scallop height is is uniform only for a particular cutter path. B is wrong, if Isoscallop machining is being talked about, scallop height has to be the same all over the surface, so option A is correct.

(Refer Slide Time: 02:09)



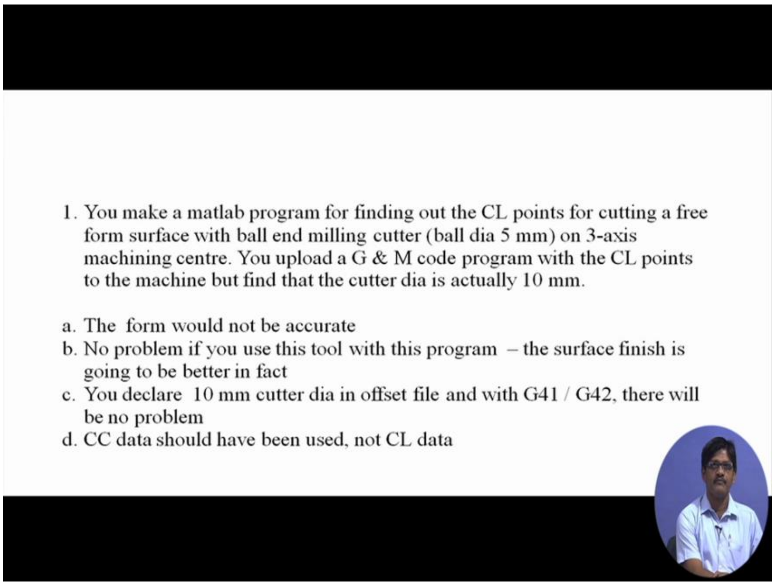
In a 3 axis machining of a free-form surface employing ball end milling cutter, the criterion of determining the forward steps is… So we have not up till now mentioned whether it is Isoscallop, iso-planar, iso-parametric, so it is the general case. So the criterion is, uniform surface roughness (created by scallops), equal sidesteps orthogonal to cutter path, tolerable deviation from surface form, none of the others. Here, first of all we are talking about forward steps and uniform surface roughness created by scallops does not come into the picture, so first one is not relevant. 2nd one also is talking about sidesteps and so it is not relevant, so A and B are gone.

(Refer Slide Time: 03:32)



C reads tolerable deviation from surface form and this is correct, we are tolerating a from tolerance of E from the design surface and that way C is the correct one. Sorry. If there are 18 control points okay 18 control points on a Bezier curve, the highest power of the parameter in the expression of the Bezier curve would be 19, 18, 17, 3, none of the other. Here we have already studied that if there is a Bezier with N number of control points, its highest power would be N minus 1, so C is the correct answer.

(Refer Slide Time: 04:11)



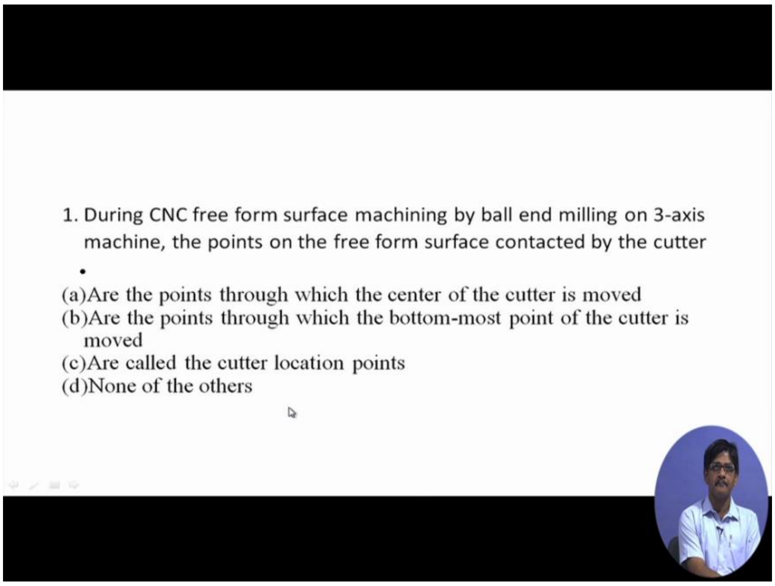
You make a Matlab program of finding out the CL points, so finding out the cutter location points, it might be one fix point on the cutter which may be the centre of the ball end of the round nose tool, so for finding out the CL points for cutting a free form surface with ball end milling cutter, ball diameter is also given 5 millimetres on 3 axis machining centre. You upload a G and M code program with the CL points to the machine, but find that the cutter diameter is actually 10 millimetres that means there is an actual cutter mounted on the on the spindle or available with you, which you have to use and that is having a diameter of 10 millimetres, while your program has been made with consideration of a ball diameter of 5 millimeters.

So as a consequence the options are, the form would not be accurate. And 2nd problem is you use this tool with this program - the surface finish is going to be better in fact. 3rd option, you declare 10 millimetre cutter diameter in offset file with G41 and G42 that means you are taking the help of cutter radius compensation or cutter diameter compensation and there you declare that the diameter this 10 millimetres and there will be no problem. And the 4th option is, CC data should have been used not CL data, so let us investigate what could be correct. 1st of all, CC data should have been used, not CL data, this is not correct we have had quite a good amount of discussion on this; CL data is required so D is gone.

Next, the form would not be accurate, this seems to be correct but 1st of all let us find out about others. No problem if you use this tool with this program - the surface finish is going to be better in fact. See if you are finding out the cutter location for 5 millimetre diameter and using 10 millimetre diameter instead, naturally the surface which is going to be produced it is going to be different. We are not bothered about the surface finish at this moment, we are bothered about the form and the form will definitely be different and therefore B is not correct. Next is you declare 10 millimetre cutter diameter in offset file and G41 and G42 as the case may be, this is also not correct

Why? Because G41/G42 cutter diameter compensation or radius compensation is only applicable in planar machining that means two-dimensional machining, but here we are moving in 3 dimensions to cutter would not be able to make use of this and a properly offset the tool in that case, so C is also not correct therefore, A is the correct answer.

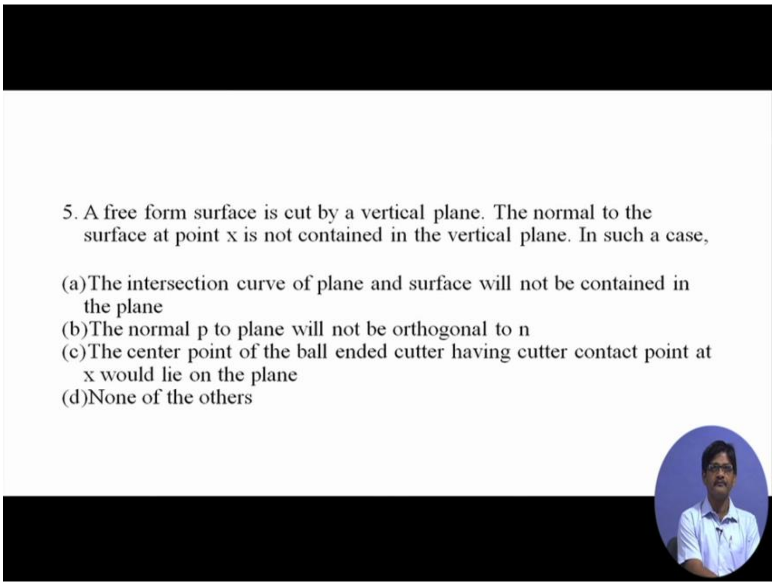
(Refer Slide Time: 07:37)



During CNC free-form machining by ball end milling on a 3 axis machine, the points on the free-form surface contacted by the cutter… are the points through which the centre of the cutter is moved, are the points through which the bottommost point of the cutter is moved, are called the cutter location points, none of the others. 1st one, are the point through which the centre of the cutter is moved, certainly not because these are lines on the free-form surface and therefore, if you move the centre of the cutter through these, part of the work piece will also be machined which is definitely not what you want.

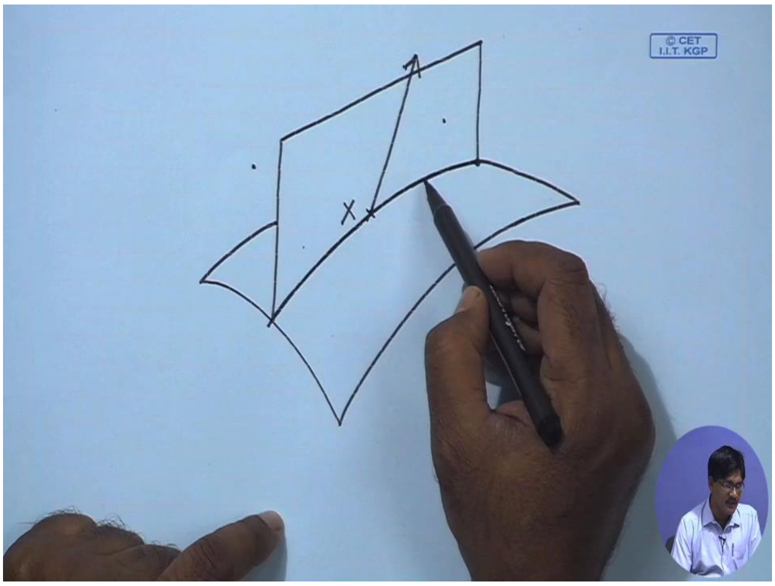
2nd option, are the points through which the bottommost point of cutter is moved, this is also not correct because the points on the free-form surface when contacted by the cutter should have the free-form surface and the cutter touching each other, tangential to each other. And if the bottommost point is just randomly put through these, it cannot produce the proper cutter path okay. Bottommost point might well not be tangential to these points on the free form surface in all the cases, so this is also not correct. These points are called the cutter location points, not correct obviously they are the cutter contact points, so the answer is none of the others.

(Refer Slide Time: 09:25)



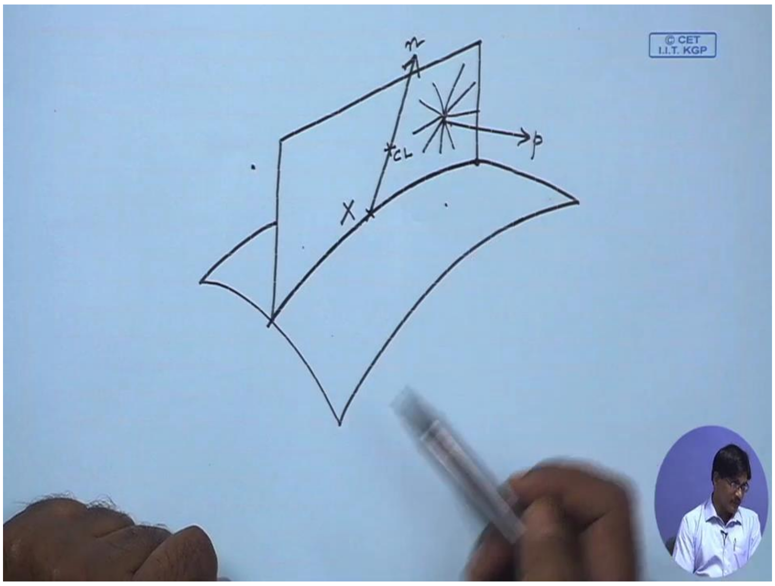
A free form surface is cut by a vertical plane. The normal to the surface at point X is not contained in the vertical plane, so point X is, let me draw a figure.

(Refer Slide Time: 09:43)



This is the surface and this is the vertical plane and this point is point X okay this is the point X. And we are saying that the free-form surface is having a normal at this point which is not contained in the vertical plane, so it is away from the vertical plane. In such a case, the intersection curve of plane interface will not be contained in the plain. So this means this means what we are saying is that this is the intersection curve, this will not be contained in the plane the 1st option, this is absolutely wrong because the intersection curve is definitely belonging fully to the plane and it is belonging fully to the surface is contained by both.

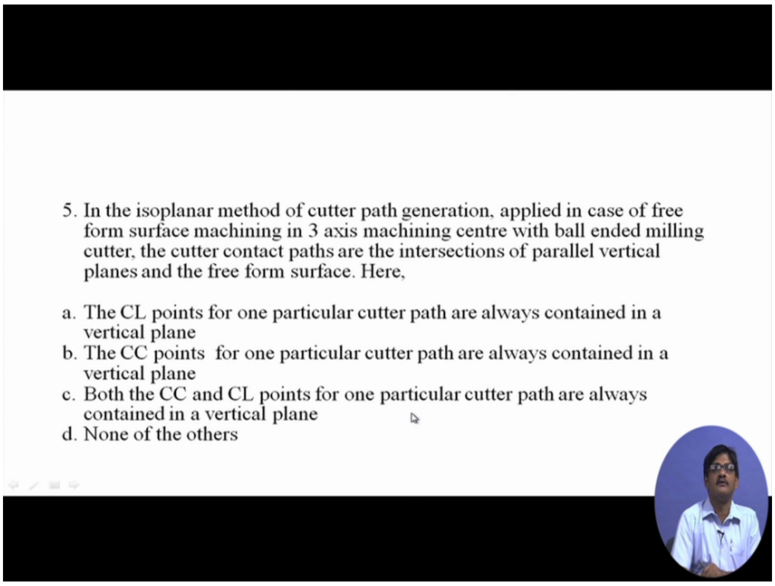
(Refer Slide Time: 11:49)



Next option is the normal P, so this is the normal P to the plane, this is normal P to the plane and this is N, will not be orthogonal to N, this is correct. See if it is if it is perpendicular to P if N is perpendicular to P, all lines which are perpendicular to P, they will lie on this particular surface, so if it is away from this plane, it definitely cannot be orthogonal to N, so 2nd one is correct. Let us see the third one, the centre point of the ball ended milling cutter having contact point at X, so the Centre point of the ball end milling cutter would lie on the plane, no it will not lie because it will lie on this regular line so maybe this is the cutter location okay. The Centre point of the ball ended milling cutter having cutter contact point at X would lie on the plane, no it will not.

It will lie on N and N has been stated to be away from the vertical plane, let us quickly go back once to this line. For this we have investigated the intersection curve of plane and surface, will it not be contained in the plane this is absolutely wrong, the normal P to the plane will be will not be orthogonal to N, this is we have found is out to be correct and the Centre point of the ball ended milling cutter having cutter contact point at X would lie on the plane, definitely not; it will lie on the normal which is away from the plane and none of the others. None of the others obviously wrong, so we have B option B to be correct.

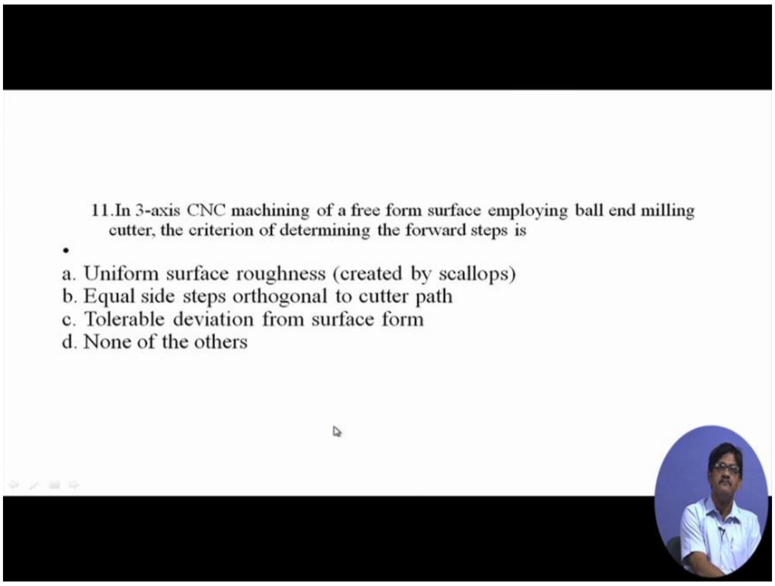
(Refer Slide Time: 12:49)



In the iso-planar method of cutter path generation applied in case of free-form surface machining in 3-axis machining centre with ball ended milling cutter, the cutter contact points are the intersection of parallel vertical planes and the free-form surface. Okay this we already know, in that case it is stated first the CL points for one particular cutter path are always contained in the vertical plane, not necessarily. They will be at the tips of the tangents sorry at the tips of the normal vectors at those very cutter contact points and the cutter contact points are lying on a vertical plane because they are found out by the intersection of vertical planes and the free-form surface.

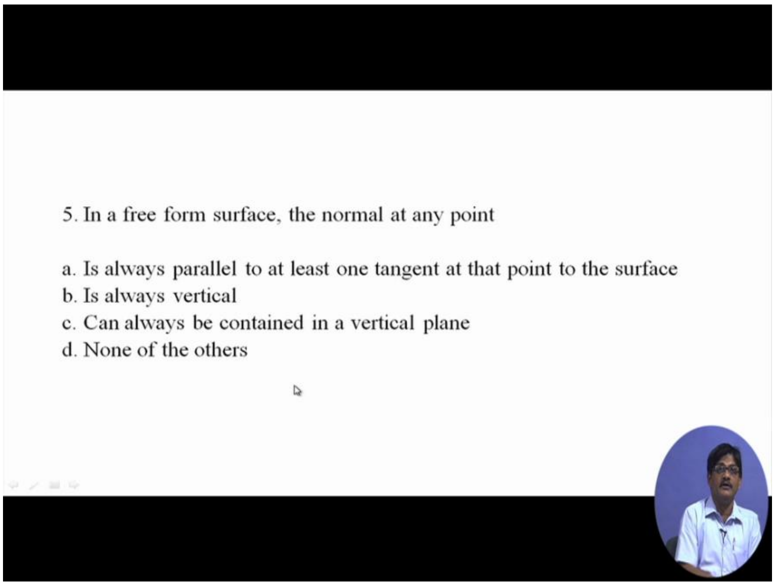
But these normal might will deviate from the vertical plane, so this is not necessarily correct A. The CC points for one particular cutter path are always contained in a vertical plane this is correct because they are formed by the intersection of a vertical plane and the free-form surface. Both the CC and CL points for one particular cutter path are always contained in the vertical plane, no it follows from A that this cannot be correct, none of the others, so the correct option is B.

(Refer Slide Time: 14:13)



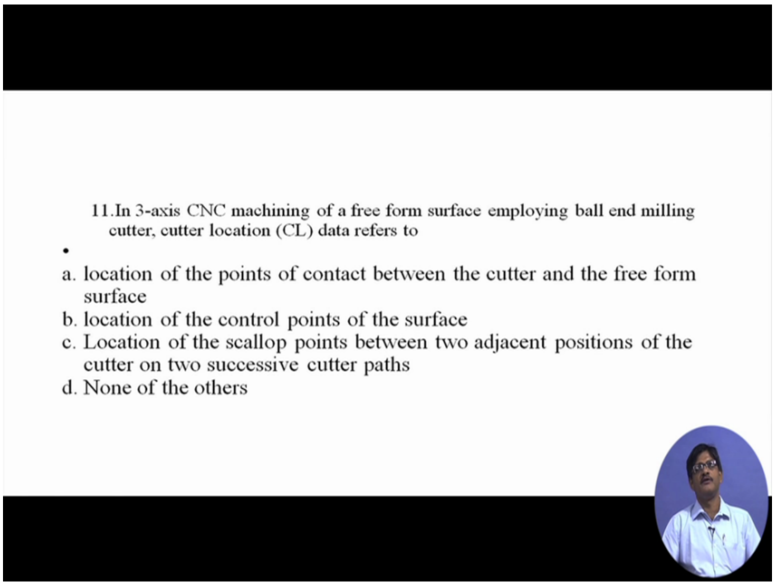
This I think we have already done, so let us quickly move on.

(Refer Slide Time: 14:22)



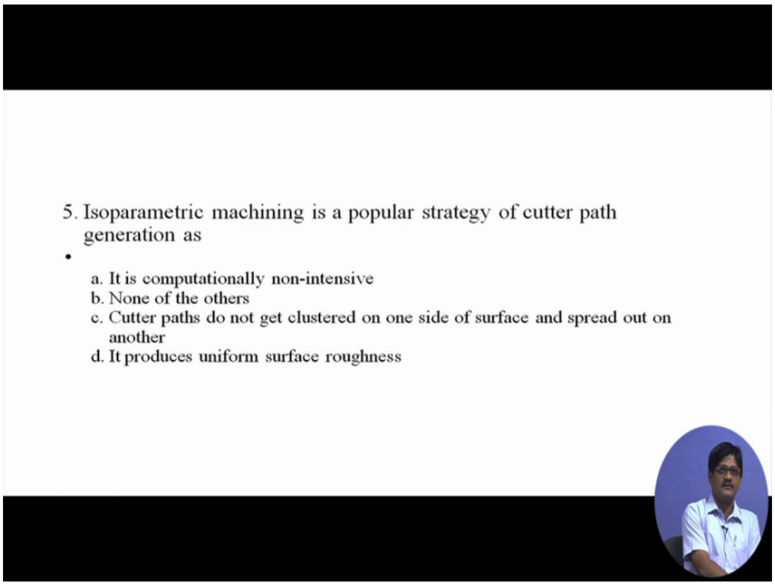
In a free form surface, the normal at any point… is always parallel to at least one tangent at that point to the surface, is always vertical, can always be contained in a vertical plane, none of the others. So the 1st one, the normal at any point on a free-form surface is always parallel to at least one tangent at that point to the surface, this is wrong because the normal is always perpendicular to any tangent at that point to the surface. The normal at any point is always vertical, no it can well be inclined. Can always be contained in a vertical plane, this is correct, any vector for that matter can be contained in a vertical plane you just have to rotate a bit rotate a vertical plane a bit and you will ultimately be able to contain that particular vector, so the correct answer is C, can always be contained in a vertical plane.

(Refer Slide Time: 15:37)



In a 3 axis machining of a free-form surface employing ball ended milling cutter, cutter location data refers to… Location of the points of contact between cutter and the free-form surface, no this is CC point so A is not correct. B: location of control points on the surface, control points have nothing to do with cutter location points. Location of the scallop point between 2 adjacent positions of the cutter and the successive cutter paths, scallop points have nothing to do with cutter location data, none of the others, so answer is none of the others.

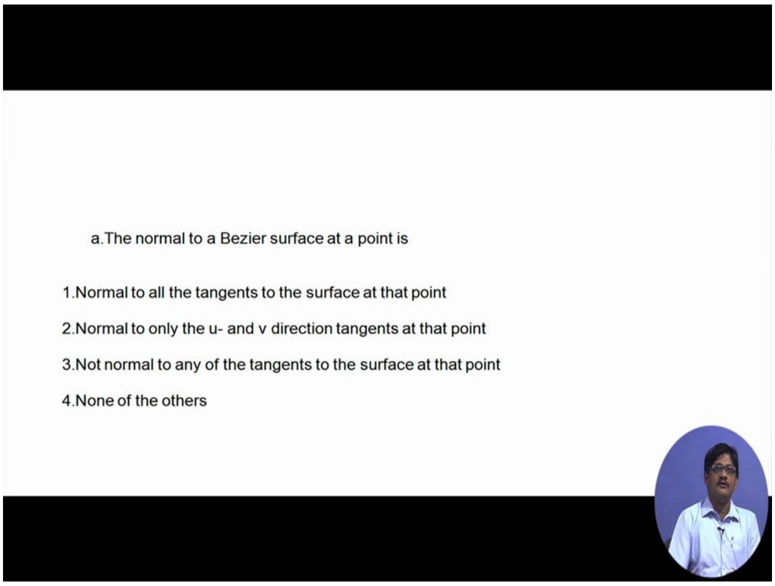
(Refer Slide Time: 16:24)



Iso-parameter is machining is a popular strategy of cutter path generation as… It is computationally non-intensive, none of the others, cutter path do not get clustered on one side of the surface and spread on the other, it produces uniform surface roughness. So let us see, it produces uniform surface roughness certainly not that is the business of Isoscallop machining, so D is out.

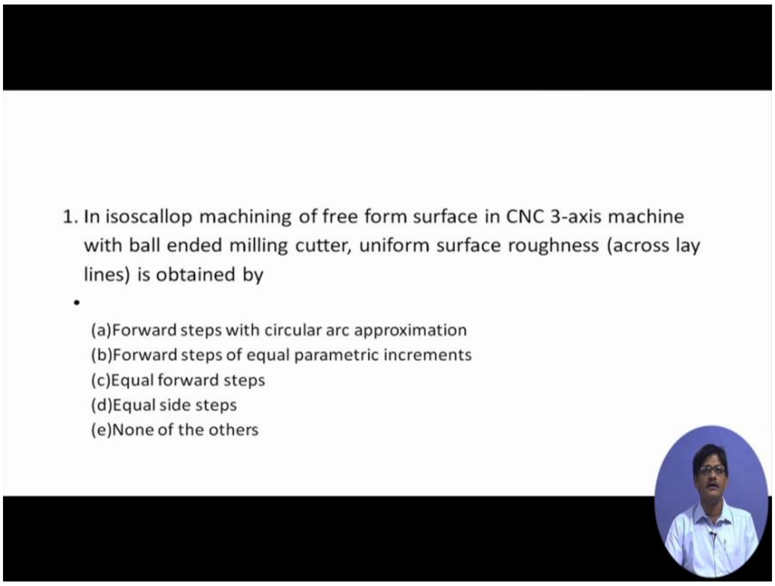
C: cutter paths do not get clustered on one side of the surface and spread out on the other, this is actually just the opposite is true for iso-parameter is machining, cutter paths to get clustered on one side or may get clustered on one side and they may spread out on another side, so C is not correct. So what remains is D and A, let us see A, it is computationally non-intensive this is correct. Finding out cutter paths in case of Iso-parametric machining is extremely simple, so correct answer is A.

(Refer Slide Time: 17:43)



The normal 2 Biezer surface at a point is… Normal to all tangent to the surface at that point, this is correct. Normal to only the u and v direction tangents at that point; wrong. Not normal to any of the tangents to the surface at that point; wrong, none of the others, so the 1st option is correct normal to all tangents to the surface at that point. Here I should mention that I will mainly restrict the question on free-form surface to conceptual questions and maybe questions based on simple calculations, but not generally numerical problems. Maybe questions of this type and may be say derivations that small derivations that we have done Delta t is equal to root over etc for finding out forward steps, based on those I might be giving small derivational problems in MCQ form.

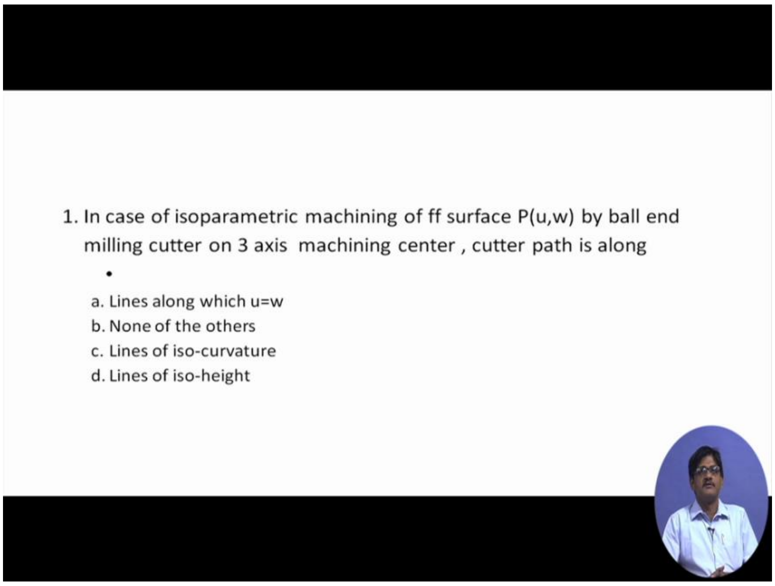
(Refer Slide Time: 18:58)



In Isoscallop machining of free-form surfaces in CNC 3 axis machine with ball ended milling cutter, uniform surface roughness is obtained by, uniform surface roughness across lay lines that means perpendicular to the lines of cut, so uniform surface roughness is formed by… Forward steps with circular arc approximation, forward steps of equal parametric increments, equal forward steps, equal side steps, none of the others. In this case, forward steps with circular arc approximation it is not relevant, forward steps and side steps cannot be they are not connected with each other so A is not correct, B is also with the same logic not correct, C is also not correct with the same logic.

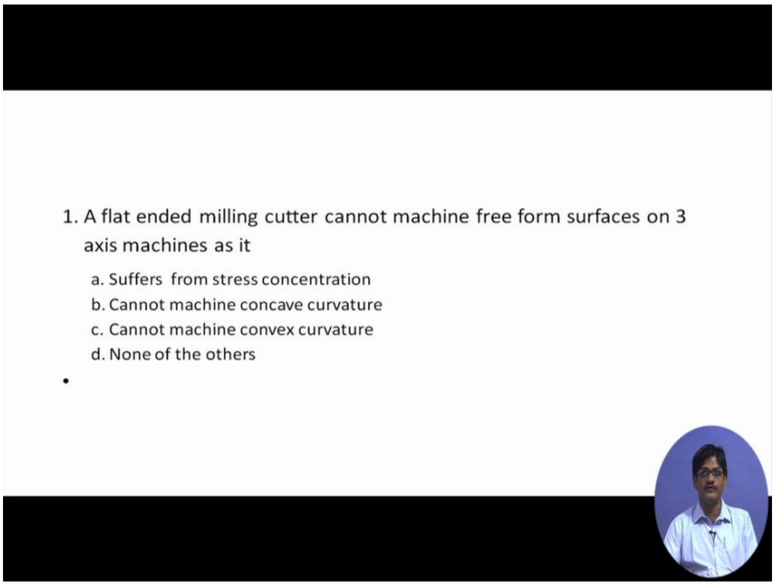
D says, “equal side steps” does it mean that I mean it suggests that D states that you will get uniform surface roughness if you give equal side steps, this is incorrect we have done we have gone through a quite a lot of calculations to understand how side steps can be found out in order to give uniform scallop height, so equal side steps will not necessarily give us uniform surface roughness, none of the others must be correct here.

(Refer Slide Time: 20:38)



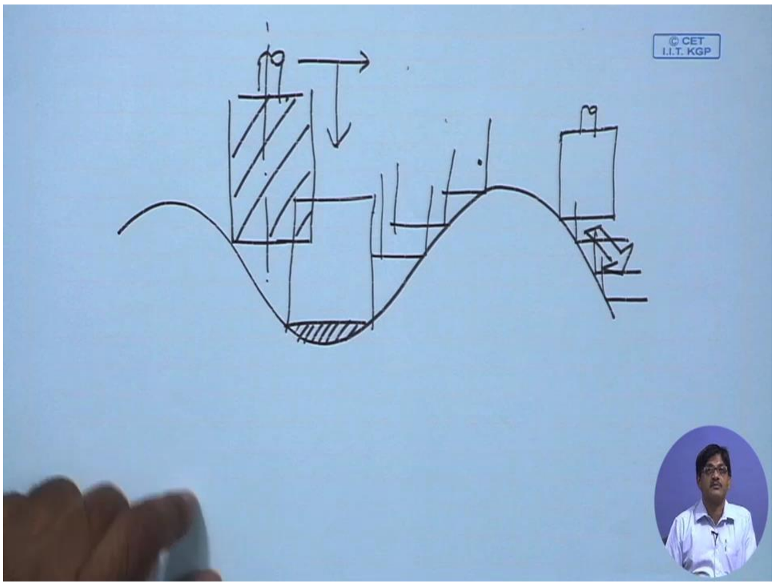
In case of isoparametric machining of free-form ff means free-form surface P (u, w) by ball end ball end milling cutter on a 3 axis machining center, so this is isoparametric machining. Cutter path is along lines along which u = w, none of the others, lines of iso-curvature and lines of iso-height, none of these are correct so none of the others, why? Because in case of isoparametric machining, the cutter paths coincide with the isoparametric line not iso-curvature neither iso-height, isoparametric lines mean along which one of the parametric values will be constant, we have has discussion on this in previous lecture.

(Refer Slide Time: 21:40)



A Flat ended milling cutter cannot machine free-form surfaces on 3 axis machining as it… Suffers from stress concentration, perhaps what is suggested is that the flat ended milling cutter has sharp edge at the at the very end of it so that there can be stress concentration due to that sudden I mean that that sharp edge. B is, cannot machine concave curvature that means if you have concave curvature on the body, the flat ended milling cutter cannot handle that. C: cannot machine convex curvature, none of the others. Here the correct answer is, cannot machine concave curvature. Due to very shape of it the flat ended milling cutter cannot go beyond a particular distance, let me draw quick figure so that I can share the idea with you.

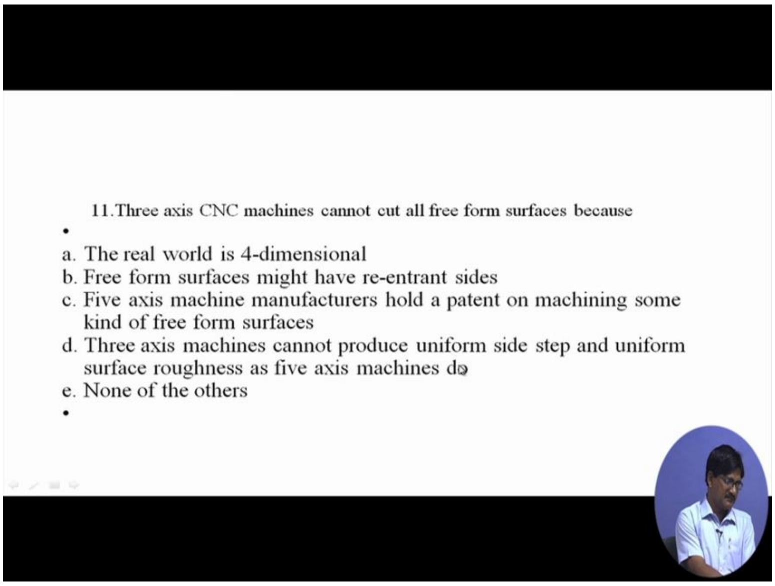
(Refer Slide Time: 22:45)



If you have a surface with a concave curvature okay and if you have this particular end milling cutter with teeth like this, it cannot go beyond this particular position and leaves behind this material uncut, this material is not removed by this cutter because it is a 3 axis machine, it can only move this way it can move that way and it can move in and out of the paper, so it has no way of machining removing this material. But what if it has convex curvature, does it have any issues with that, no because it can cut from this side, it can machine here it can go down this way in this particular plane and machine all those places, it has no problem with accessing any such places in the convex part. Concave it gets stuck here, it cannot go beyond.

So cannot machine concave curvature, let us come back to this cannot machine concave curvature is correct, B is correct. What about A, suffers from stress concentration? The answer to this is if it suffers from stress concentration then it it it would not have been applicable in other cases also, so this cannot be the reason for which it cannot machine free form surfaces. Had it been stated that it cannot machine anywhere okay, any machining application it is not applicable because it suffers from stress concentration, then we could have considered it but the problem is in that case that sort flat ended milling cutter will not have existed okay, if it cannot be used universally, it would not have existed in the 1st place, so correct answer is B.

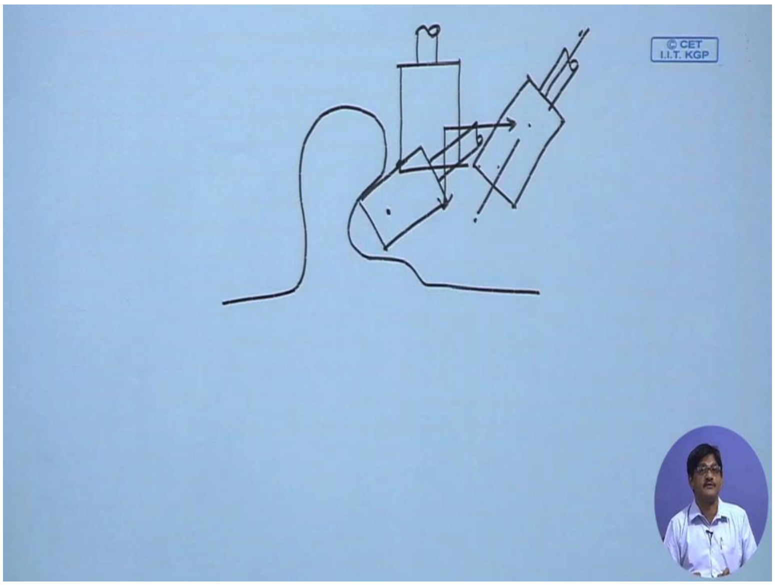
(Refer Slide Time: 24:59)



Three axis CNC machines cannot cut all free-form surfaces because… Real world is 4-dimensional, no is the real world 4 dimensional we will consider the real world to be three-dimensional now okay so the 1st one is not correct. B: free-form surfaces might have re-entrant sides. C: 5 axis machine manufacturers hold a patent on machining some kinds of free-form surfaces and three axis machines cannot produce uniform sidestep and uniform surface roughness as 5 axis machine do, and none of the others. Here, 3 axis machines cannot produce uniform surface roughness uniform sidestep and uniform surface roughness, et cetera, but still they can cut free-form surfaces okay.

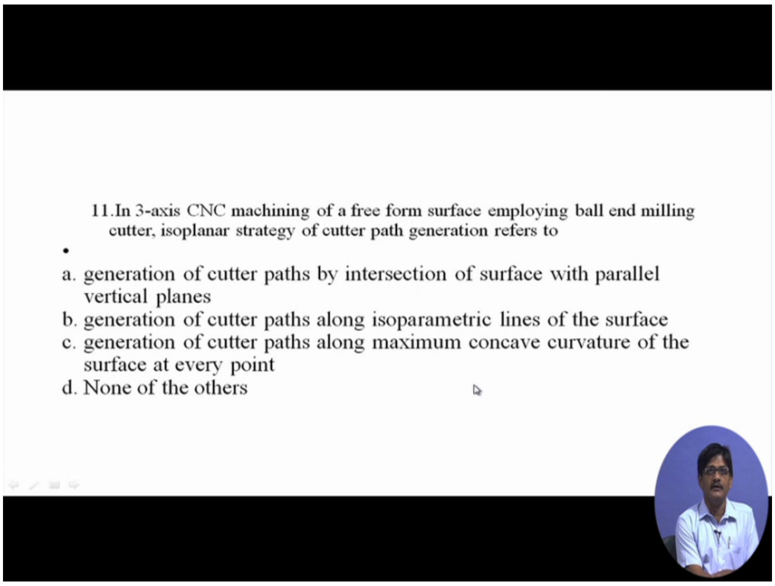
So we cannot say that it cannot cut of free-form surface because it cannot produce uniform surface roughness at the very beginning, their logic is wrong so this is not applicable okay, so 3 axis machines can definitely cut surfaces but it is not true that we cannot say that it cannot cut a surface because it is not producing uniform surface roughness, so this idea is wrong so we are not accepting D. 5 axis machine manufacturers hold a patent on machining some kind, frankly speaking I do not know of such patents and I would not be ready to accept this particular statement, so C is also considered to be wrong by us. Free-form surfaces might have re-entrant side, let us have a quick look what we are talking about.

(Refer Slide Time: 26:56)



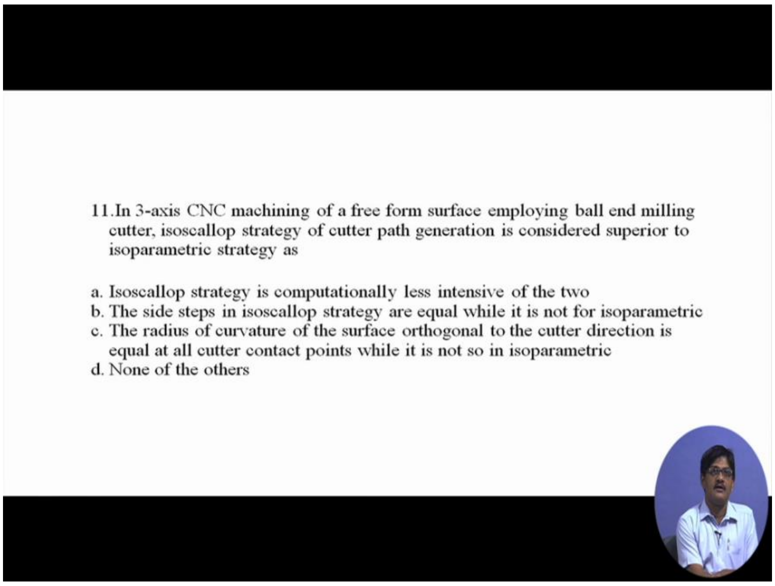
If there is a body like this we are saying this is the re-entrant side, it cannot be accessed by a tool which is coming from the top and it can only move down side and this side also, this cannot get inside but if you have a tool which can rotate, its axis can rotate and it can take up this configuration then you can get inside like this okay, 3 axis machines cannot do this and therefore, 3 axis machines cannot machine all types of surfaces because surfaces might be having this sort of a configuration which is called re-entrant side, so answer B is correct.

(Refer Slide Time: 27:54)



In 3 axis machining of free-form surface employing ball ended milling cutter, iso-planar strategy of cutter path generation refers to… Generation of cutter paths by intersection of surface with parallel vertical planes, so we are talking about iso-planar strategy and generation of cutter paths by parallel that seems to be correct A. Let us see, generation of cutter paths along isoparametric lines of the surface, wrong. Generation of cutter paths along maximum concave curvature of the surface at every point, no, none of the others so A is correct.

(Refer Slide Time: 28:41)



In 3 axis CNC machine of a free-form surface employing ball ended milling cutter, Isoscallop strategy is considered to be superior to Isoparametric as… Isoscallop strategy is computationally less intensive of the two, this is not correct Isoscallop strategy is in fact computationally more intensive. The side steps in Isoscallop strategy by the way computationally less intensive or more intensive means that you have to put more computational effort in case of more intensive case. Less intensive means you have to put less computational efforts. So the sides steps in Isoscallop strategy are equal while it is not so for Isoparametric. Mind you, iso-sidestep are not equal in Isoscallop, scallop height is equal but not side steps, B is also wrong.

The radius of curvature of the surface orthogonal to the cutter direction, so the radius of curvature of the surface orthogonal to the cutter direction is equal at all all the contact points for Isoscallop, this is not correct this cannot be correct because it depends on the surface, it cannot depend upon the Isoscallop strategy. Radius of curvature of the surface orthogonal to the cutter direction depends on the surface and not on the method, so none of the others, it is correct in this case. So with this let me see how many other questions we have okay that is that is that is the end, so we come to the end of the lecture series.

And I will review the lectures once again and if I feel that okay one or two lectures or notes if it can be shared I mean one more lecture or some extra notes if it can be shared with you and if some corrigendum is required that means if there are some errors or mistakes or typographical errors or some mistakes in delivery, I will add a note of corrigendum which will explain all those errors to all the viewers. So thank you very much for being with us and I am sure that it will be a very good experience both for you and for us, thank you.