Metal Cutting and Machine Tools
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Lecture - 10
Numerical problems and MCQ

Welcome viewers to the 10th lecture of the course Metal Cutting and Machine Tools. In this particular lecture we will be discussing some of the numerical problems which cover the subjects of the second week; that means, starting from mechanism of chip formation and then you know cutting forces calculation etcetera, etcetera. So, all these things as far as possible we will be covering and if required I will also upload a few question, questions or answers in text form. So, that you can watch it offline that is whenever you are not watching the lectures you can still open them up and have a look. So, let us move right away.

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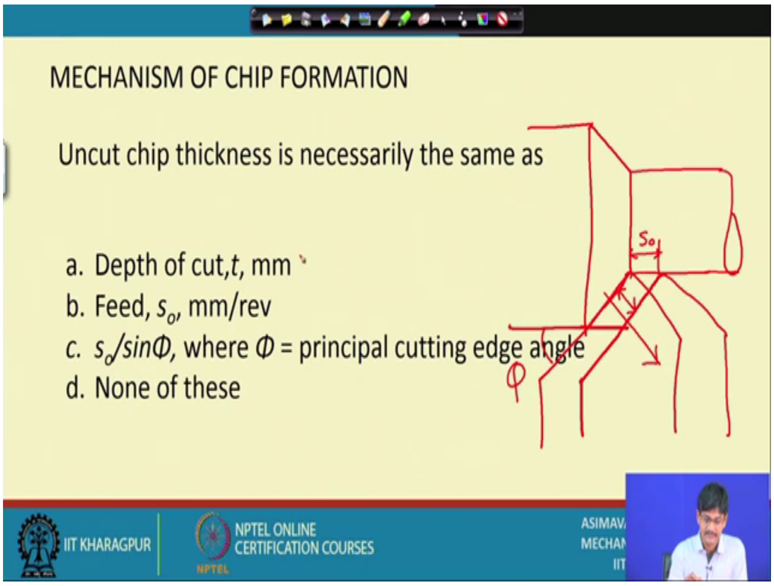

So, mechanism of chip formation, uncut chip thickness is necessarily the same as depth of cut t in millimetres, feed s o in millimetres per revolution, s o by sin phi where phi is the principle cutting edge angle and none of these.

So, if we quickly have a look at the figure just to remind you. This is one position of the tool there is a finished cylindrical part, this is another position of the tool and therefore, this is the feed s o, this angle is phi and therefore, the uncut chip thickness looking from the top this is our you know chip volume which is coming out it ultimately comes out this way. So, this is the uncut chip thickness and obviously, it is equal to s o sin phi. So, this is not correct and just a moment. This one is not neither this neither this one because this is s 0 s o by sin phi. So, the correct answer is none of these because uncut chip thickness is equal to s o sin phi.

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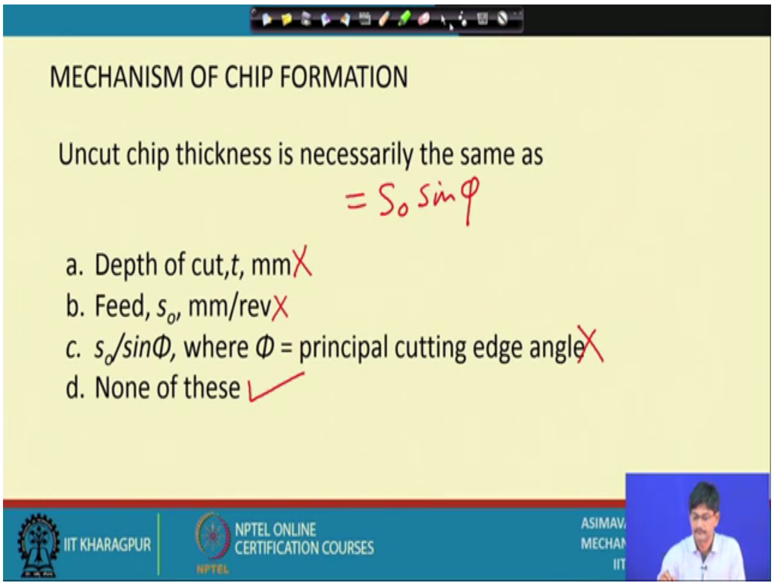

So, let us move on to the next one.

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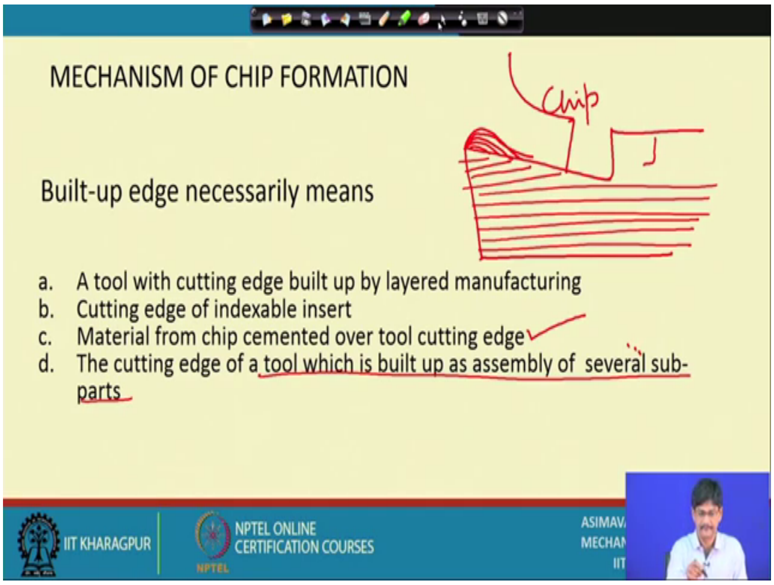

Built up edge, built up edge necessarily means a tool with cutting edge built up by layered manufacturing. Cutting edge of index able insert material from chips cemented over the tool cutting edge and the cutting edge of a tool which is built up as assembly of several sub parts. Actually built up edge sorry, actually if you have a look at the built up edge, if you have the tool this way and if you have the chip going this way built up edge is you know cementing of layers of chip material which suffers stagnation and it gets almost welded with the tool rake surface and thus it covers the cutting edge it deteriorates the cutting action. So, this one is correct.

A tool with cutting edge let us just check whether any of these fit by chance a tool with cutting edge built up by layered manufacturing it means that if you build the tool by you know layered manufacturing in that case the cutting edge is called the built up edge. No, this is not correct even. If you build up tools with layered manufacturing technology some work has been done in this direction definitely especially hollow tools in which you can preferentially leave hollow spaces inside for you know either for lubrication or for some other purpose maybe for damping. So, those are not being bent here. Cutting edge with index able insert no its not called a built up edge or a tool which is built with sub assemblies the cutting edge of that particular tool, no. So, C is correct.

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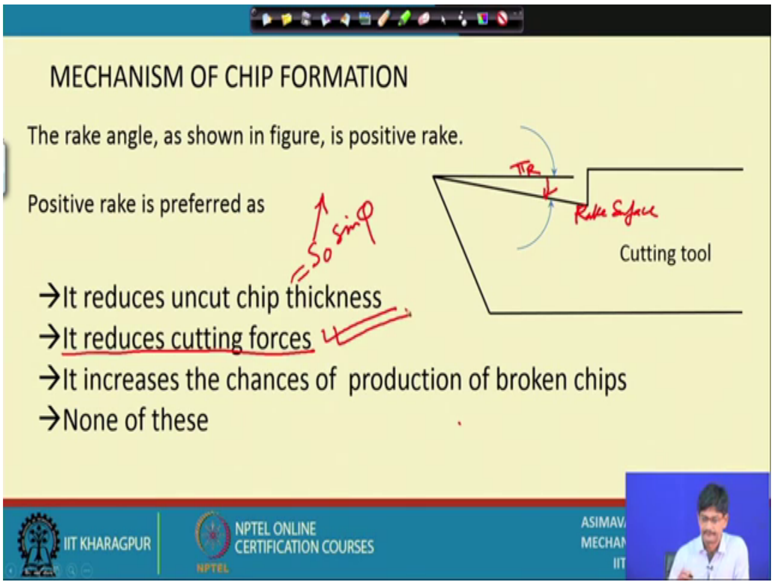

So, the rake angle as shown in the figure is positive rake. If this is the trace of the reference plane if we go clockwise from the reference plane we reach and if we reach the rake surface, rake surface is the trace of the rake surface then we are calling this rake angle positive. So, a positive rake is preferred as it reduces uncut chip thickness, no, uncut chip thickness is you know is equal to s 0 sin phi and it has simply no relation with rake angle s 0 is something we are setting completely independent of rake angle. It reduces cutting forces, it reduces cutting forces this is correct. Let us see whether there are other correct answers.

It increases the chances of production of broken chips just the opposite if you have higher rake it increases the chances of getting a continuous chip. None of these, therefore, this one is the only correct answer.

Let us move on to the next problem.

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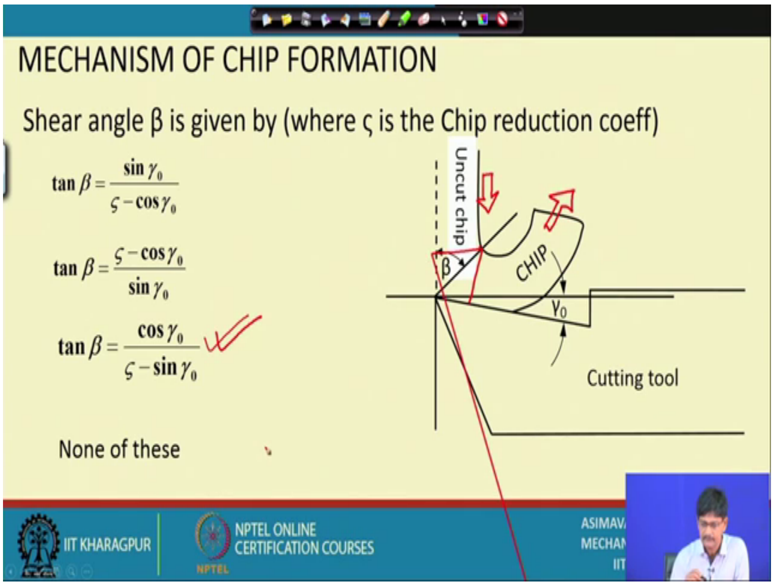

Shear angle beta is given by where zeta is the chip reduction coefficient and we are given several expressions for the tan and for the tangent of the angle beta. Let us see what is beta. Here comes down the you know uncut chip down with cutting velocity and it goes out as a chip with fear, with whatever velocity the chip is having, the chip velocity this is the place where we are considering in a single plane we are assuming in a single plane across a single plane the whole of the deformation of the you know chip is taking place some deformation of course, takes place in the secondary deformation zone, but here we are considering a cross a plane the primary deformation is taking place.

This is angle beta, and we have to find out the tangent of angle beta. This one if you remember we have already derived in the class and this happens to be the correct answer. What do you do if you do not remember the expression? It is very frequently happening that whatever we do by heart in the exam hall we do not recall it. In that case the derivation is very simple I will just give you the basics drop two perpendiculars here sorry for that, new drop two perpendiculars here one here and one there. So, in these two perpendicular I mean right angle triangles the hypotenuse is shared and therefore, the hypotenuse can be expressed in terms of two angles one is this beta and this one happens to be gamma o and therefore, this one will be 90 degree minus beta plus gamma o and from there we can get a relation that is hypotenuse is equal to you know uncut chip thickness divided by sin beta and it is also equal to chip thickness divided by the sin of this angle.

So, this way we can easily establish the relationship I am not going into the derivation because it is already done in previous lectures. So, we just move on with this particular statement that only this one is correct the others are all wrong.

So, let us go on to the next problem.

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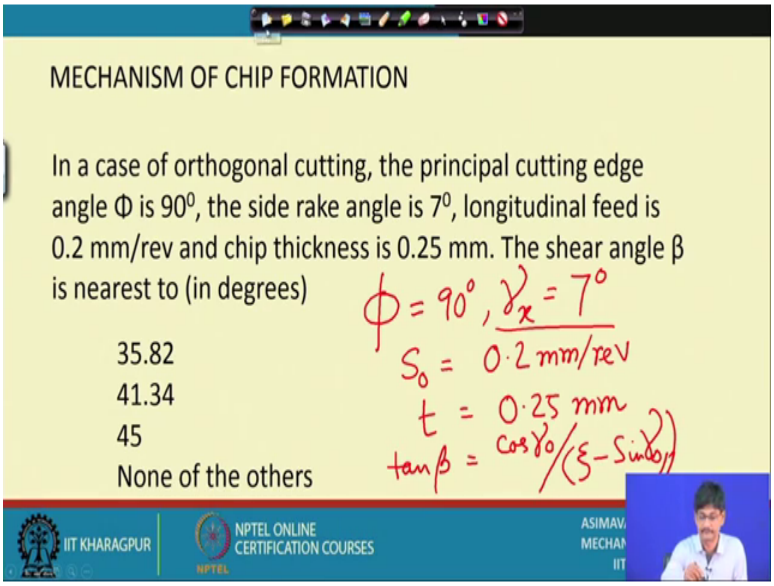

In case of orthogonal cutting the principle cutting edge angle is 90 degrees, phi is 90 degrees the rake the side rake angle is 7 degrees. So, phi the most important thing to be you know for this year what are the, what is the data. It is given phi is equal to 90 degrees gamma x is equal to 7 degrees, longitude feed s o is equal to 0.2 millimetres per revolution of work piece and the chip thickness happens to be chip thickness t happens to be 0.25 millimetres. The shear angle beta is nearest to in degrees. So, we have to find out the value of the shear angle how do we do that.

If you remember we can use the previous expression. So, these options among them let us use this data, but here in comes the catch. I mean the problem, what is the problem like? Side rake angle is given while in the expression for the shear angle which we have as tan beta equal to cos gamma o divided by zeta minus sin gamma o this refers to the orthogonal rake. Now do we have to painstakingly find out sorry find out the expression of the orthogonal rake from the side rake angle certainly not why let us see. What is this? Just a moment. In this case what we can do is that let us draw the cutting tool and immediately something will become very clear to us. Phi is equal to 90 degrees.

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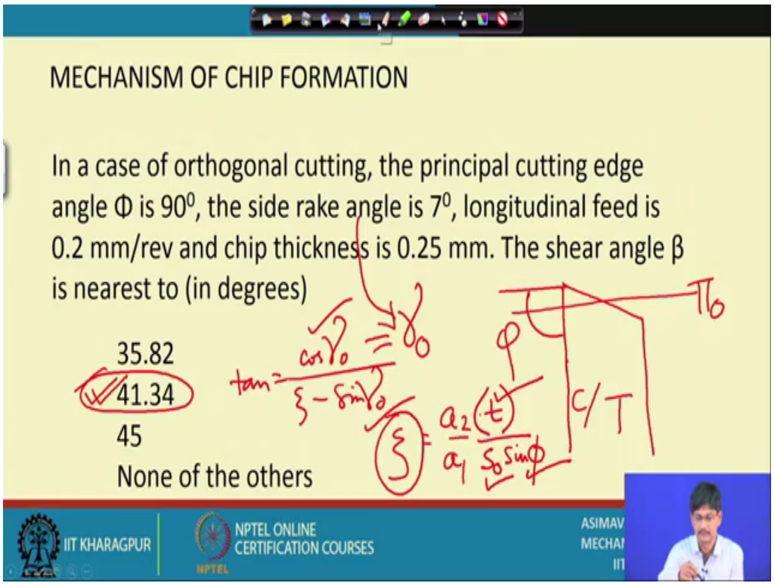

That is it this is the cutting tool I am writing in short cutting tool. This happens to be the angle phi and therefore, we can say that the orthogonal plane is here. This is the trace of the orthogonal plane seen from the top and therefore, side rake and the orthogonal rake they become the same angle. Therefore, we can use this value as the value of the orthogonal rake, side rake is equal to orthogonal rake. So, our principle problem is solved.

Now, can we find out the value of zeta because as we wrote down tan beta is equal to cos gamma o, now this is taken care of divided by zeta minus sin gamma o. This is taken care of we can easily find it out cos 7 degrees sin 7 degrees zeta. Zeta is equal to if you remember it is equal to a 2 by a 1, where a 2 stands for chip thickness which is t and a 1 stands for uncut chip thickness which is s 0 or s o sin phi, phi is given, s o is given therefore, everything is given chip thickness is given, s o is given, phi is given we can find out zeta completely. I have carried out my calculations I am sure you can do it now because it is simply algebra if you have a calculator handy with you, you can do it within seconds I have got this one to be correct. Please check your respective calculations.

This one happens to be the correct answer the shear angle you will get the tangent of the angle and then you have to find out arc tan or you to find out inverse tan whatever software or whatever calculator you are using. So, please check up.

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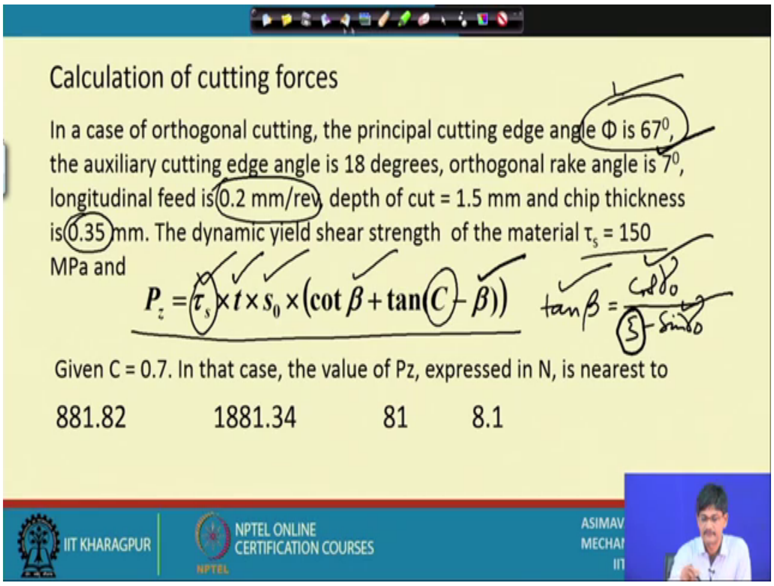

Calculation of cutting forces. In a case of orthogonal cutting the principle cutting edge angle phi is 67 degrees, the auxiliary cutting edge angle is 18 degrees, orthogonal rake angle is 7 degrees, launching feed is 0.2 millimetres per revolution, depth of cut is 1.5 millimetres and chip thickness is 0.35 millimetres

The dynamic yield shear strength of the material tau s is equal to 150 mega Pascals and P Z is to be taken as you know within in you know in agreement with merchants second proposed model. P Z is to be taken as tau s into t into s o into cot beta plus tan C minus beta this we have derived the last day given C is equal to 0.7 radians, 0.7 radians in that case the value of P Z expressed in Newtons is nearest to 881.82 Newtons, 1881.34 Newtons, 81 Newtons and 8.1 Newtons. Now, how do we proceed to solve this sort of problems first of all let us check whether all the data which is you know required here it is provided or not.

So, first of all if we have to find out P z, we need tau s we need tau s is tau s provided yes. So, I put a tick here. I need the chip thickness is chip thickness provided, yes chip thickness is provided. I need the feed is the feed provided yes feed is provided. I need beta, is beta provided - no, but I can find out beta. What sort of equation am I going to use? We have solved it just now. So, I just write it and I understand that we can solve it cos gamma o divided by zeta minus sin gamma o, but this raises a question are. All these things provided we definitely need you know orthogonal rake orthogonal rake is given. So, this is all right.

And what else, zeta, zeta is once again a 2 by a 1. So, do we have depth of cut yes do we have feed, yes and do we have principle cutting edge angle, yes. So, we can find out tan beta. So, this part is solved, this part is solved. Last of all what is C, C is given. So, it is completely you know we can find out this expression completely. And you know what are the answers let us see, I think I might have solved it myself in subsequent pages sorry.

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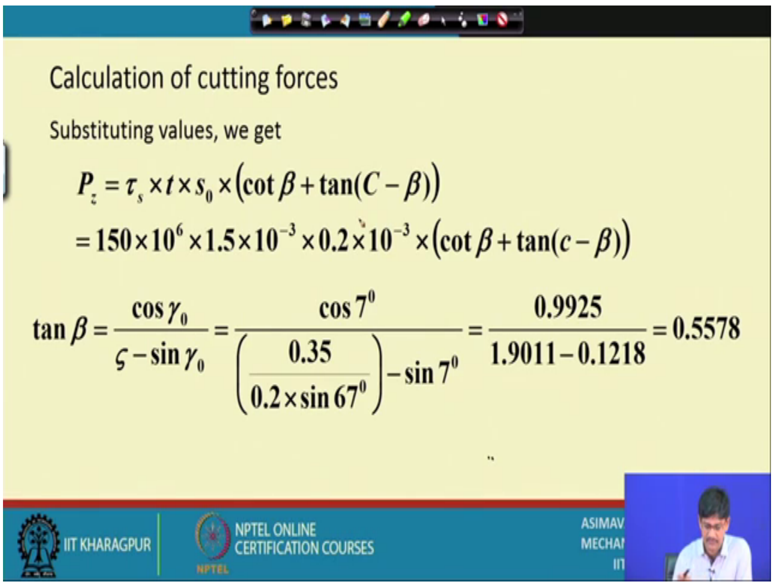

Calculation of cutting forces, first of all we are substituting values 150 into 10 to the power 6, t is to be expressed everything to be expressed in meters, when everything is expressed in meters 150 into 10 to the power of 6 Pascals. Next, t is 1.5 millimetres into 10 to the power minus 3 meters 0.2 s is 0.2 into 10 to the power minus 3 cot beta tan beta has been founded as by the method that we had talked about. So, this is coming to be tan beta is coming to be 0.5578 and that corresponds to an angle roughly 30 degrees. So, we will put the value of 30 degree here and we will put the value of beta here as well in radians and then convert the whole thing to degrees if your calculator is degree compatible.

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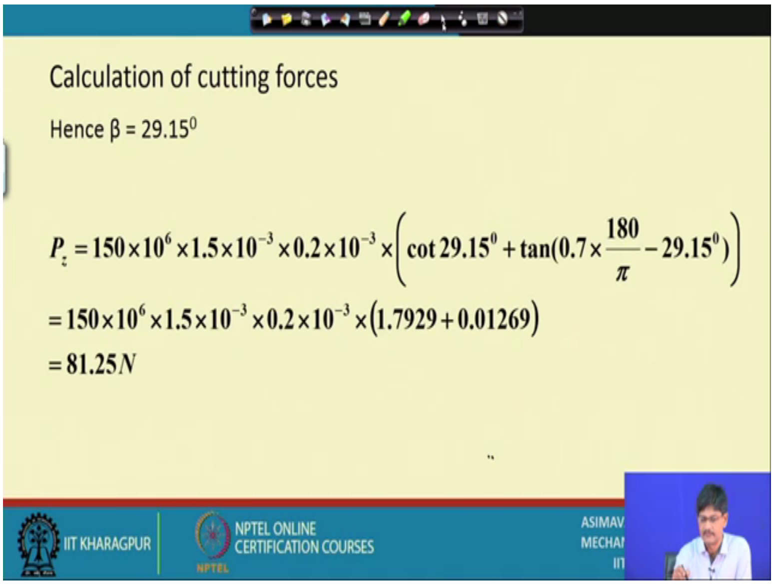

Now, let us see what we found. Yeah, hence we found out the value of beta and after that we have put here cot beta plus tan C yeah we have converted this to degrees and therefore, we can retain the degrees here and therefore, by the multiplication I have found the answer to be 81.25 Newtons. So, if we go back just a moment, this is the correct answer it is nearest to this value, this is the correct value 81 Newtons.

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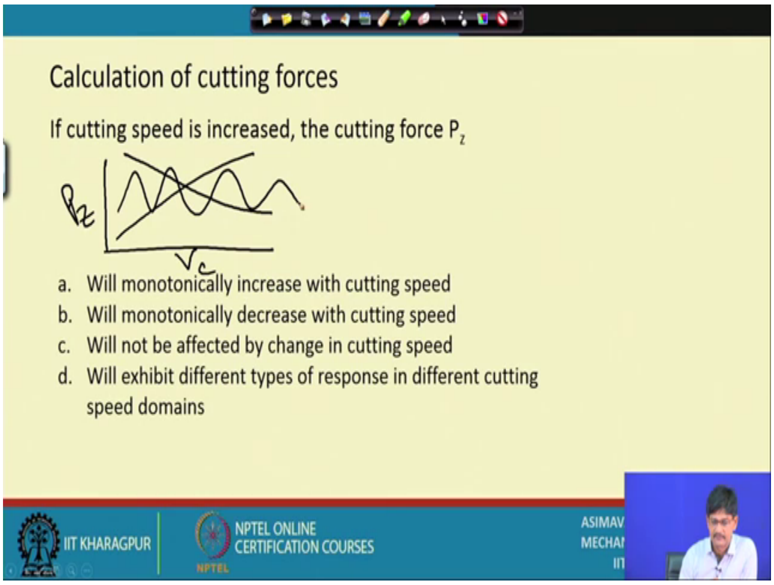

Next, if cutting speed is increased the cutting force P Z will monotonically rise with cutting speed; that means, what we are suggesting here is this that if we plot say P Z for the time being and this is V C in that case we will find that if cutting speed is increasing P Z will in monotonically increase with it. And the second option says no it will be monotonically decreasing. Third it will not be affected by change in cutting speed. Fourth it will exhibit different types of response in different cutting speed domains maybe it means this which one is correct. That is quite interesting let us see.

Monotonically rise increase with cutting speed this does not happen. Monotonically decrease this also does not happen, then what does happen. Is it not affected by cutting speed? No, it is affected let us see.

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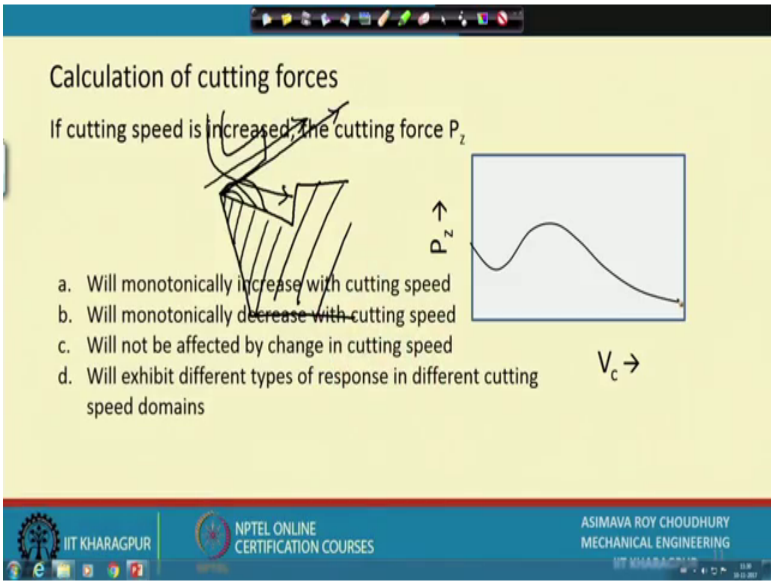

This is the typical response of P Z with respect to V C cutting speed and the main cutting force. When the velocity is very less as the speed increases with that we find from a high, higher value at static friction as gradually the speed increases the cutting force goes down because the effect of change of static friction with dynamic friction. However, after that the onset of the phenomenon of built up edge sets in at very low speeds built up which is not there, after that when built up edge forms it gives you know it sort of changes the behaviour of the cutting tool in such a way that as if the pole a positive rake is changed to a negative value of rake. Let us have a quick look what actually happens.

If this be the tool, if this be the built up edge, this is the resultant direction in which the chip has to move when a built up edge has formed and therefore, instead of flowing this way instead of sensing the actual rake which is there on the surface of the tool, it senses a much higher negative value of rake which means that forces are going to be high. So, as the built up edge goes on getting you know established in the medium level speed the cutting force rises, the cutting force rises and reaches a maximum, but after that with the onset of higher speeds the built up edge becomes unstable and it gradually collapses. So, that we again have a reduction of the forces.

Finally the effect of suffering of the material with higher temperatures attained at higher velocities that sets in and we have a reduction monotonic reduction of the cutting speed. So, ultimately when you are free of any other you know special effects then the front phenomenon is like this that cutting speed will reduce with higher sorry cutting force will reduce with higher speeds, in the high speed domain.

So, I should mention here one thing that is in the high speed domain this is one phenomenon, that is the cutting speed is going to you know the energy of cutting that is going to manifest it itself by higher temperatures, attainment of higher temperatures with soften the material. But at high speed cutting takes place at high with the accompaniment of higher strain rates, at higher strain rates we will find that there is an expression which predicts that the shear strength of the material is going to rise. If that happens if the shear strength rises there will be an opposing effect that there will be higher forces experienced.

So, these two are contradictory, from the point of view of high strain rates will have higher forces existing and from the point of view of higher temperatures attained we will have softening of them a work material leading to lower forces and ultimately we can see here that the softening of the material is dominating. So, the answer is will exhibit different types of response and different cutting domains, this one is correct.

Now, let us move on to other questions.

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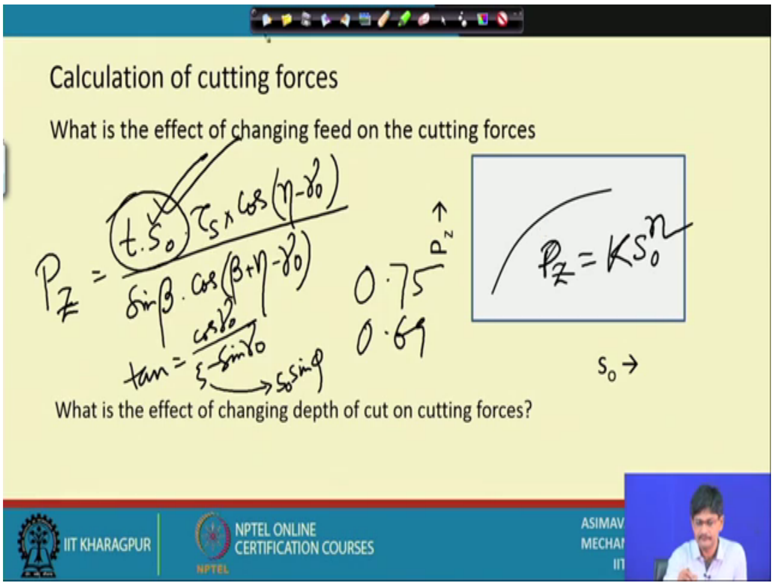

What is the effect of changing feed on the cutting forces? If the cutting forces are, I mean if the feed value is changed if we go from low feed from higher to high feed definitely by you know by pure even by pure guests a student can say that yes the cutting forces are going to increase. But let us see in what way.

The expression of P Z tells us P Z is equal to t into s o into tau s into course eta minus gamma o divided by sin beta into cos beta plus eta minus gamma o etcetera and if you take P xy or other expressions you will find that these things are there in cutting force expressions. Therefore, we can say yes it is going to be directly proportional, but now we find that the relation between P Z and s o has a relation of this type; that means, it suggests that P Z will be sorry, P Z will be equal to some constant multiplied by s o to the power some constant say let us call it n for the time being and n is obviously, less than 1 and by experiments it has been founded generally you know it is around 0.75 to 0.69 this range. Why does this happen? This happens because fear is not only present here, but it is obviously, present in beta because tan beta is containing cos gamma o by zeta minus sin gamma o and zeta contains s o sin phi in its denominator.

So, simply for this reason itself alone for this reason alone we can say that it is not going to be a proportional relationship and it comes out actually this way. So, this is the answer, this the effect of changing feed will have this sort of a response on the cutting forces.

Now, let us see the last part. What is the effect of changing depth of cut on cutting forces? If you change depth of cut it will be found that more or less the, if we express P Z as equal to K into depth of cut to the power n and will be roughly 1, maybe in some cases 1.02 or 0.99 etcetera for different forces. So, it is more or less proportional. If you double the depth of cut you can express more or less the cutting speed will be doubled.

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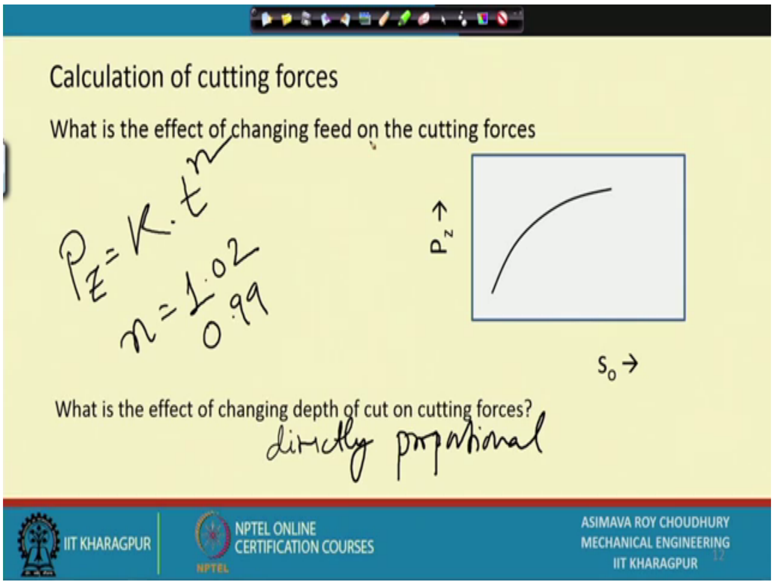

So, this one is directly proportional we can write for all practical purposes, directly proportional and this one to the power roughly 0.75 to 0.69.

So, with this we come to the end of the you know discussion of numerical problems and you know small thought provoking problems. I expect to give you some textual problems by uploading them and keeping them on the website so that you can open them up and enrich your knowledge and share our discussions later on.

Thank you very much.