Mechanics of Machining
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Lecture - 15
Practical Machining Operations: Turning And Shaping & Planning Operation

Hello students. Welcome to the course on Mechanics of Machining. Today is the 15th lecture. In this lecture, we will discuss details about practical machining operations. Till now, most of the time we talked in fairly general way we have not gone to specific processes.

Now, I will see that how those concepts can be applied to specific process like turning, planning and shaping. Turning as you know is performed in a lathe machine it is used to produce axis matrix components that means whole component can be in the form of a cylinder I can machine a cylinder or I can machine a cone and planning usually for machining of the rectangular jobs.

In this case, in planning I can produce mostly that plane surfaces. Shaping is also similar to planning difference between planning and shaping is that, in the planning actually the job is reciprocating and tool is stationary at one point and in the shaping tool reciprocates and job is stationary at one point that is the difference. But turning, planning and shaping all of them are performed by a single cutting point tool.

Here, single cutting point tool as you know that it will be having that side one two, two cutting edges that side cutting edge end cutting edge connected by a node radius, but usually the operation is done by only side cutting edge end cutting edge basically participates in a small v. Some portion of in cutting also participates in the cutting, but main cutting is usually by the side cutting edge that is why it is a single point cutting process.

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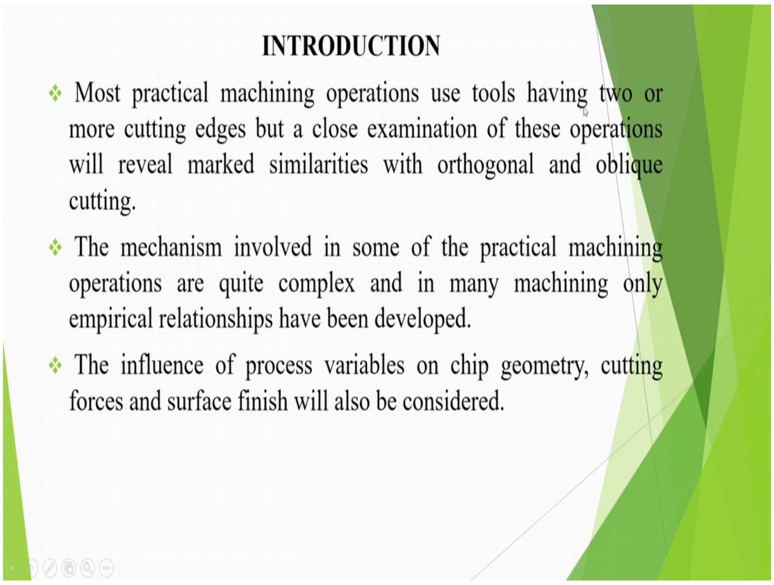

So, most practical machining operations use tools having two or more cutting edges, but a close examination of these operations will reveal marked similarities with orthogonal and oblique cutting. So, what your orthogonal oblique cutting we have studied, those can be applied in order to get fairly accurate estimate.

Mechanism involved in some of the practical machining operations are quite complex and in many machining only empirical relationships have been developed. The influence of process variables on chip geometry, cutting forces and surface finish will also be considered. We will discuss about surface finish also which till now we have not discussed.

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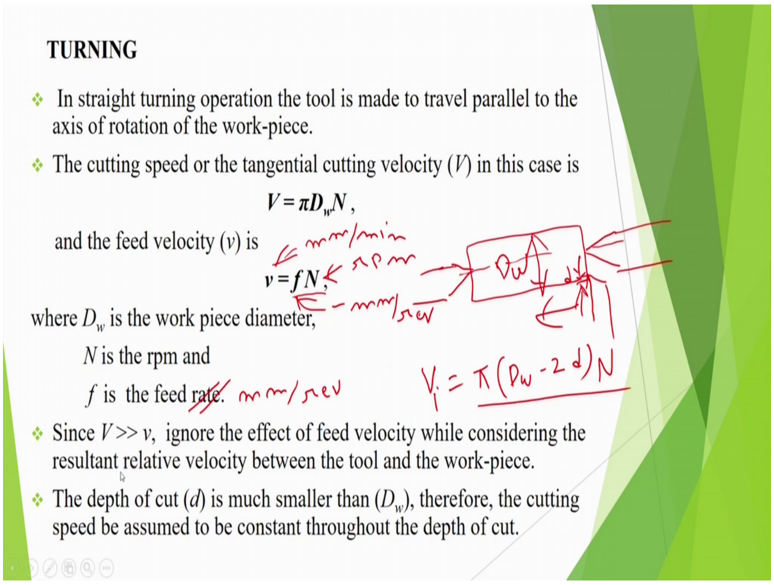

Now, let us come to the process of turning where we can produce a cylindrical or conical surface that means, this is suppose it is I am mounting a job between two centres, ok. It is mounted here this is check side this may be tail check side and my tool is cutting like this, job is rotating which is for providing the main cutting motion and speed motion is provided by the tool is moving like that we give some depth of cut here.

So, in a straight turning operation the tool is made to travel parallel to the axis of rotation of the work piece, this is the axis of the rotation and tool is moving parallel to it and it is straight turning. Cutting speed of the tangential cutting velocity in this case is this one V is equal to pi D w into N, cutting speed or it is basically tangential cutting velocity is defined like this pi D w into N that is basically peripheral velocity in meter per minute. So, V is equal to pi D w into N.

And the feed velocity v is v is equal to f into N because f is the feed actually instead of feed rate. I must share that f is the feed in millimetre per revolution usually they express in millimetre per revolution and if N is the rpm then product of this will give you millimetre per minute that means, that will be feed velocity. So, feed velocity may be expressed in millimetre per minute provided this feed is in millimetre per revolution and N is basically rpm revolution per minute, ok.

So, now D w is the work piece diameter suppose in the beginning you have diameter D w, N is the rpm and f is the feed that is millimetre per revolution. We generally do not say feed rate some people say feed rate if it is in millimetre per second, but we just say feed that means, it is millimetre per revolution; in one revolution of the work how much the tool will advance you know. Generally, it may be about 0.1 millimetre per revolution also.

Since V is capital V is much greater than V that means, cutting velocity is much greater than feed velocity we ignore the effect of the feed velocity while considering the resultant relative velocity between the tool and the work piece, that effect is neglected and the depth of cut d is much smaller than D w. So, depth of cut is there, but suppose I am having this depth of cut that is much small compared to this thing is small depth of cut we give.

So, we can assume that cutting speed is constant throughout the depth of cut that means, cutting speed we are telling pi D w into N. More precisely I be surface this speed will be pi D w by N, but at inside portion v I this will be pi D w minus 2 d because the diameter as we used by 2 d amount into N. So, internal that surface this portion we will experience that much velocity, but this 2 d is small compared to D w that is why we are we say roughly that d cutting velocities like that. But nowadays if you are making very small components etcetera and d is a small d is significant in comparison to d then you have to take care about this aspect.

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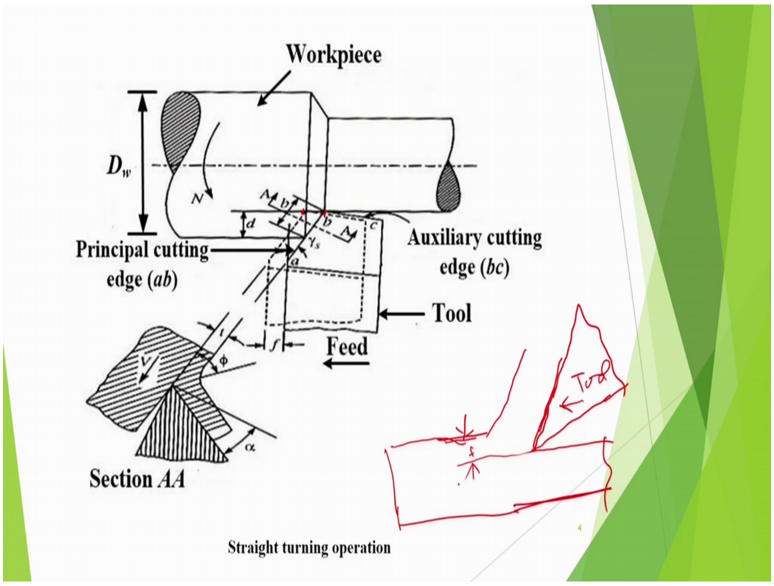

So, let us see that how the turning process goes on. This is D w, it is rotating at a rpm of N work piece is rotating tool is moving we are giving the feed in one revolution the tool will go from here, this edge is here, this will go here. So that means, this movement is f and we have got this cutting edge that is side cutting edge which is called principal cutting edge because it is mainly doing the main cutting.

And the second one is just auxiliary cutting edge it also participates little bit it may have some influence on the finishing, but this is auxiliary cutting edge and this is also shown here that bc is the auxiliary cutting edge, this is tool. Important point is this that what is the chip thickness here most of the students will confuse about that uncut chip thickness.

It is not that depth of cut d is the chip thickness instead what we have studied in the orthogonal machining they are used to be one chip thickness that means, uncut chip thickness that means, this was the portion and then here it was like this, like this it was like this because and this is the surface. So, suppose tool was like it this was a tool, ok. So, what was there that this tool is moving like this and this was called uncut chip thickness that was uncut chip thickness, right.

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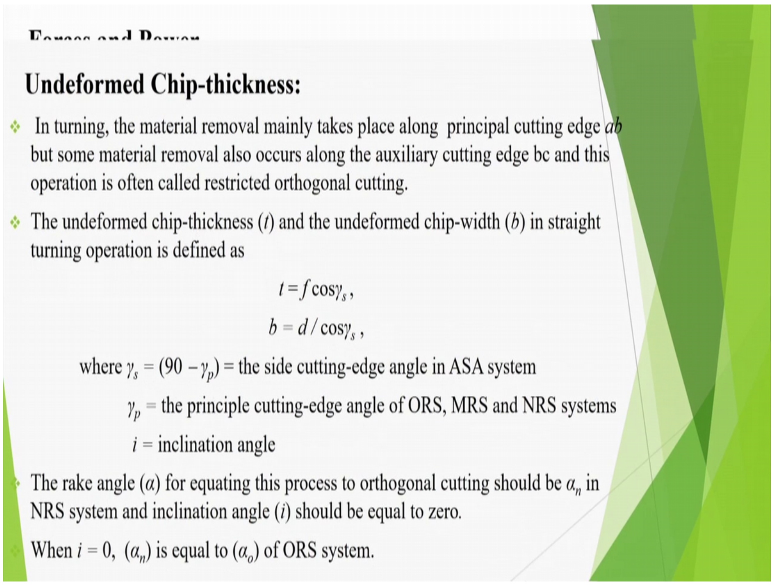

So, tool is because tool is digging and it is removing, and it is removing this much material. So, you may think that it is it is depth of cut here, but actually it is not so because the cutting edge is actually this side cutting edge here and it is digging like this, it is digging from the side. And in one revolution it is moving by a distance f so that means, that this one this distance should be this is the from in one revolution this portion has gone from here to here, ok, this much it movement has taken place. So, in a way the tool has taken this much depth in the orthogonal way that means, this should be uncut chip thickness is shown here.

So, with I take a cross section perpendicular to the cutting edge principal cutting edge then we get this type of picture. So, actually here t is the chip thickness that means, cutting is basically the side way. It is not in the depth way in the depth direction like this portion we will provide you the width of the chip, and this is the rake angle, rake angle alpha is this one because you are cutting like this, this is the surface of the tool and this is the normal tool that machine surface through you got here alpha also and you will be showing this thing here t.

So, next, so in turning the material removal mainly takes place along principal cutting edge ab, but some material removal also occurs along the auxiliary cutting edge bc and this operation is often called restricted orthogonal cutting. So, undeformed chip thickness t and the undeformed chip width b in straight turning operation is defined as t is equal to f cos gamma s, where gamma s is the side cutting edge angle. If the tool is like this straight then side cutting angle is 0 and t becomes f so that means, uncut chip thickness is anyway equal to f in that case otherwise also it is f times cos gamma s. So that means, if high double the feed then my uncut chip thickness will double.

Depth will not have any influence, depth is I mean about the width of the chip should be is equal to d divided by cos gamma s. If you see carefully the previous diagram then you can make out width is in this direction, so that is why width is this, but it is d by cos gamma s because this surface is inclined at gamma s.

So that is why this formula you should always remember that t is equal to f cos gamma s and b is equal to d by cos gamma s and where gamma s is equal to 90 minus gamma p that is side cutting edge angle in a s a system you can say gamma s, and otherwise gamma p is the principal cutting edge angle of ORS, MRS and NRS system. Orthogonal rake system, maximum rake system, and normal rake system, and i is the inclination angle that we said the rake angle alpha for equating this process to orthogonal cutting should be alpha N in NRS system and inclination angle i should be equal to 0, when i is equal to 0 then alpha N is naturally equal to alpha 0 of ORS system. So, this you already know.

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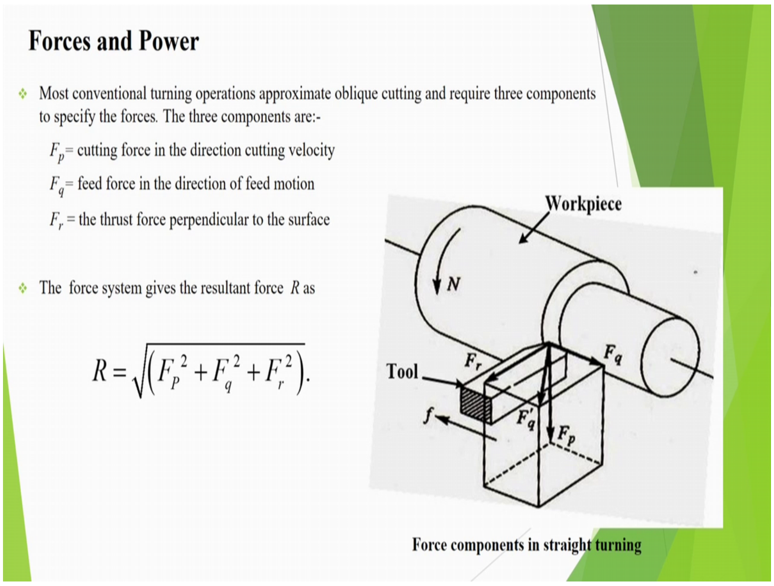

Now, let us see about the forces most conventional turning operations it approximate oblique cutting and require 3 components to specify the forces. These 3 components are what? F p is the cutting force in the direction of cutting velocity. So, it is job is moving like this. So, direction of cutting is like this vertical one, so that is called F p, that is the main force; F q is the feed force in the direction of feed motion that will come on the tool like this because this is the force which is coming on the tool by the job.

So, F p is downward F q is this one; F r is also directed towards this newly thing is applied on the tool that is why we have shown if we ask what is the direction of a fall on the job it will be just opposite by Newton's third law. So, you have got F q, F q, F p and F r. Naturally if we have these 3 forces the force system gives the resultant force R, R is equal to under root F p square plus F q square plus F r square, ok. So that is what we have obtained.

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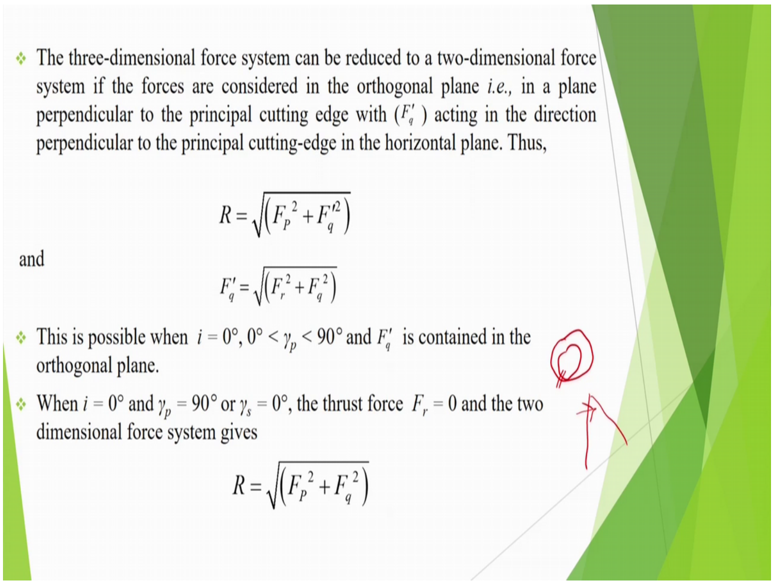

And then if we 3 dimensional force system can be reduced to a 2 dimensional force system if the forces are considered in the orthogonal plane that is in a plane perpendicular to the principal cutting edge with F q prime acting in the direction perpendicular to the principal cutting edge in the horizontal plane.

So, suppose it is some case of orthogonal cutting, if result in top F q and F r we have taken F q prime and this we considerize the first force. Remember the angle between F q prime and F p is 90 degree because F p is fully vertical and we are assuming that it is orthogonal type of cutting in which F q and F r both are horizontal plane. So, there resultant will be F q prime and this will be like that.

So, here this can be shown like this; R is equal to F p square plus F q prime square and F q prime in term is under root F r square plus F q square. This is possible when i is equal to 0 degree in inclination angle may be 0 degree and principal cutting edge angle may be anything between 0 to 90 degree. Usually that it may be 90 degree or something like that, generally 0 degree principal cutting edge is fairly uncommon and F q prime is contained in the orthogonal plane. So, F q plane prime is contained in the orthogonal plane that you have already seen here F q prime is here, ok.

Now, what happens when i is equal to 0 degree and gamma p g equal to 90 degree or gamma s is equal to 0 degree then the first force is F r is equal to 0 because now the cutting is taking place mainly here. So, it is cutting feed is there, but there is no depth of cut component here and the two directional dimensional force system gives this much, ok. We assume that it is pure orthogonal type of cutting case like we all machining a tube type of thing. So, it is machining and that side there is no resistance. So, F r is naturally 0, otherwise when i is equal to 0 degree and gamma p 0 or gamma s is 90 degree then the feed force component is 0 and then also you get this expression.

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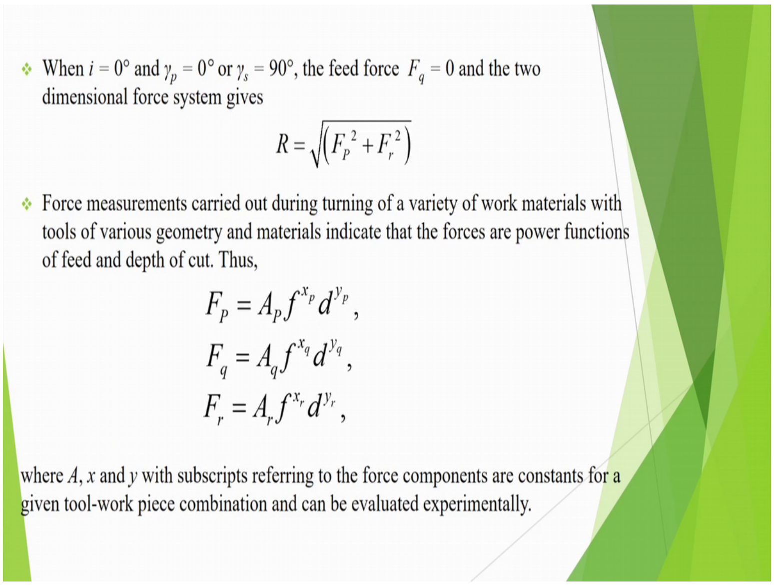

So, force measurements carried out during turning of a variety of work material with tools of various geometry and materials indicate that the forces are power functions of feed and depth of cut this has been found experimentally. So, we can say F p is equal to A p into feed time some exponent d times this one, F q is equal to also another coefficient f times some exponent d time some exponent and F r is also some coefficient f times something and d time to the power exponent something. A x and y with subscripts referring to the force components are constants for a given tool work combination and may be also the environment whether there is a coolant or not cool coolant is not there it may depend on even machine also. So, they can be evaluated experimentally that we can do, ok.

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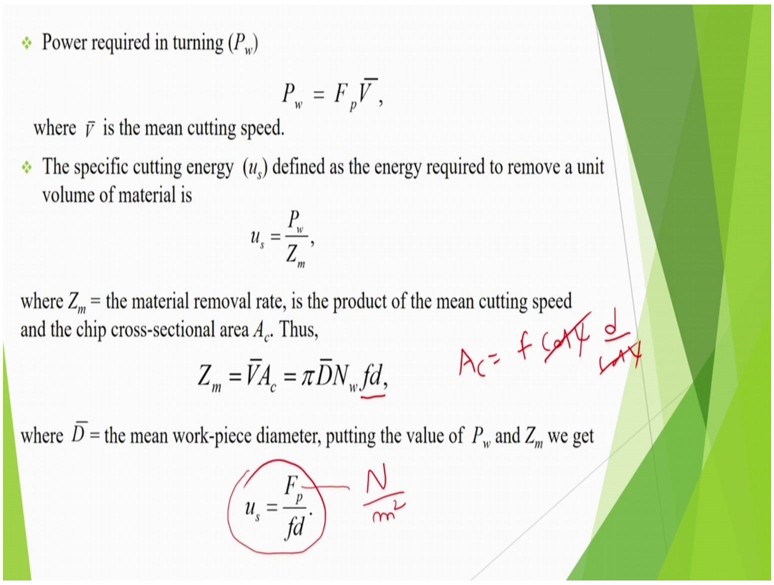

Now, power required in turning P w is equal to F p into V because main cutting force main, main power is that other force component are small. So, F p into V, and V is the main cutting speed. Other force means feed component feed force may be really small that will give some feed power radial component is basically pursue type of force because there is no movement in the radial direction, so that is also there. So, I am talking right now only about the main cutting power F p is the vertical cutting force multiplied by V is the main cutting speed.

Specific cutting energy u s is defined as the energy required to removed a unit volume of material, so u s is equal to P w by Z m. P w is the power and Z m is the material removal rate that is the product of the mean cutting speed and the chip cross sectional area. So, Z m can be written as V into A c that is pi D w pi D N w and cutting area is always f into d because otherwise also if you consider A c means chip area. So, I said that uncut chip thickness was what f cos gamma cos this one was there cos I phi use and another is d cos psi that is width.

So, cos psi cos psi anyway gets cancelled and you ultimately get f d. So, Z m is equal to this much d is the mean work piece diameter if I put the value of P w and Z m in this expression for u s, so that is F p into v and divided by pi D and w that is approximate that is v only and f d. So, ultimately you get F p by f d that is called specific cutting energy.

So, its unit is Newton and this is f if you take in metre or something. So, this is basically Newton per meter square unit is like that.

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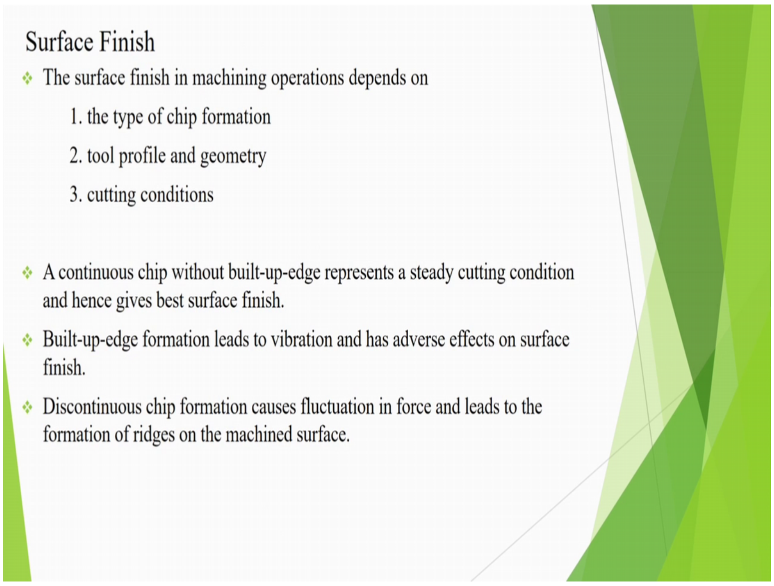

Now, let us discuss about the surface finish. Surface finishing machining operations depends on the type of chip formation, then it depends on the tool profile and geometry and also it depends on the cutting conditions means whether there is a coolant or not coolant. A continuous chip without built up edge represents is steady cutting conditions and hence gives best surface finish if the built up edge is there then you know built up edge is basically welding of some chips on the surface of the tool and then that material which got it held or will did that will break off and this type. So, this behaviour will be erratic sometimes that some material will stick to the tool, then that material will separate out and it will give another that effective angles will differ. So, it will be a non steady state type of process.

So, built up edge formation leads to vibration and has adverse effects on the surface finish because something is getting stuck to the tool then it is breaking in between this type of operation naturally will cause vibration, because suddenly somewhere more load will be there then just load will be there. So, this was be effecting the surface finish. This continuous chip formation causes fluctuation in force again because when I am cutting sometimes when lot of cutting is done there is a force then material has separated suddenly there is unloading, so it is that type of thing that you are putting some load then removing that load then again putting. So, it causes fluctuation in force and leads to the formation of ridges on the machined surface, but continuous chip is considered best.

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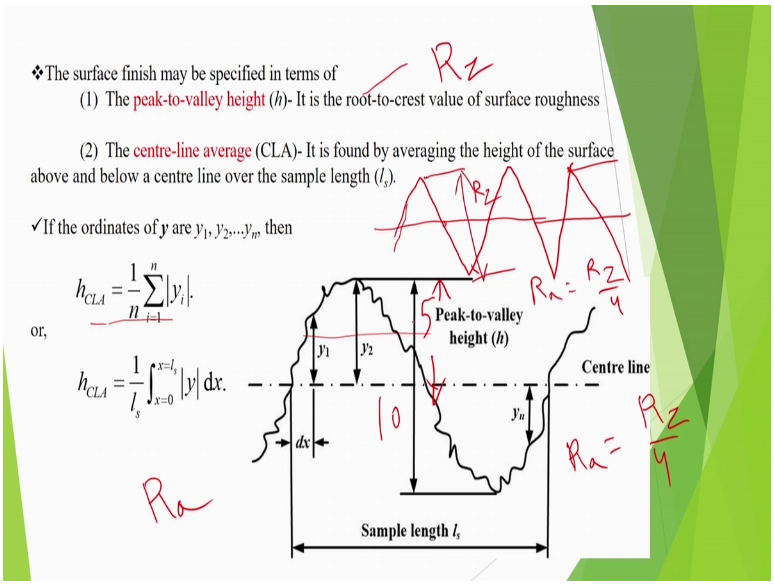

Now, let us see that how the surface finish may be specified in terms of peak to valley height. How do you define the surface finish? Because surface is uneven like sin b o some there may be some peaks there may be some valleys. So, how we can specify the surface? We can say peak to valley height, suppose this height peak to valley height is it is the move to root to crest value of surface roughness, ok. And we consider when we measured by any measuring instrument, we measure it up to some sample length.

So, suppose I have taken this sample length L s in that there is surface peak to valley distance is h it is expressed usually in micrometer and another is centre line average it is found by averaging the height of the surface and below a centre line over the sample length L s. Suppose sample length is L s I have the data of this one peak and valley I can easily find out the centre line. So, I can draw a centre line.

So, suppose this is the centre line above the centre line this is y 1 this is y 2 this is y n. So, all these things I add in absolute sense that means, positive and negative do not consider otherwise everything will should come out to be 0 because I am this side above the centre line it is positive below the centre line it is negative. So, we take the absolute value, so that is centre line average h CLA this is called i is equal to 1 to n if I take the measurement at n points.

So, we add them and then divide by n. Otherwise if you can know the equation that how you why it changing with x you can integrate between 0 to L s absolute magnitude of y integrate between 0 to L s dx and divide by the your sample length L s you get h CLA that is centre line average and this is also written as Ra value in this one that is also written as Ra value, ok.

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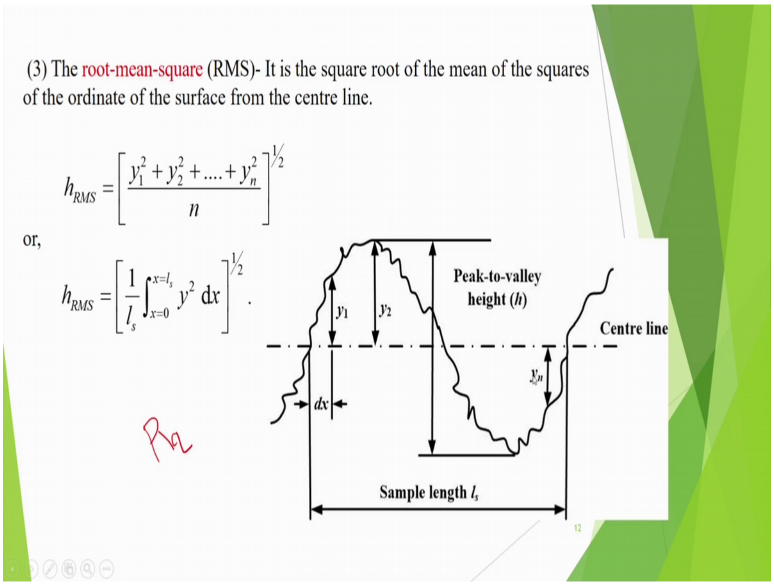

Now, root mean square RMS it is the square root of the mean of the squares of the ordinates of the surface from the centre line, so that is written as h RMS or it is also written as R q any times they write R q. In fact, this also peak to valley height is written as R z many times, R z that is peak to valley height.

So, root mean square is the square root of the mean of the squares of the ordinate of the surface from the centre line h RMS is equal to y 1 square plus y 2 square plus y n square divided by n and take the square root of whole thing or if it is a continuous variation you can say h RMS is equal to you integrate 0 to L s, y square dx and divide it by the sample length L s take this square root and you get this type of thing. So, you have got these things y 1, y 2 and y n and it has gone and this can be written.

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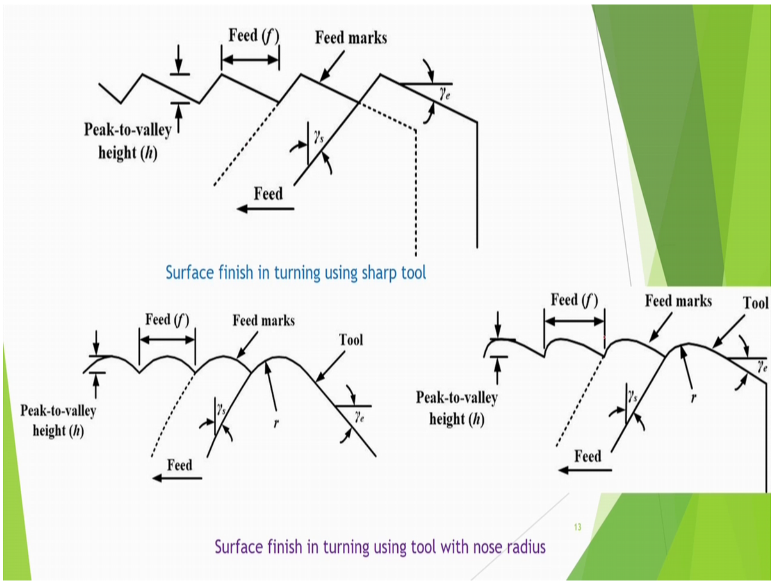

So, literally you can see that R z will be the largest among all these 3 measures R z is the largest, that means, it is from here to here, ok. If we sometimes we assume a triangular type of profile like this, like this, like this, like this. So, you can say that as far as the R z is concerned suppose I say this is R z, ok. Then Ra may be only R z by 4. Why? Because this is the midpoint and from here to peak height is R z, so average height is basically R z by R z by 2, by 2 because this is R z by 2 from here and this is the theme. So, this is rough variation between Ra and R z that, Ra is equal to assuming that the profile is triangular Ra is equal to R z by4, ok.

Suppose R z is 10 micrometer, then mean height is at 5 micrometer level and from there highest peak is at 2, at 2 suppose this is 10 this is 10 let me just say suppose this was 10. So, this would have been 5 from here to here right that is peak. But we are considering in Ra that means, in centre line average we are considering what is the average height that is 2.5 this one. So, Ra is equal to R z by 4 and R q also you can see.

Now, in surface finish in turning suppose you use a tool we which is very sharp there is no nose radius. So, it will keep moving in one feed it goes from here to here and you get feed marks like this that means, from here to here feed is like this. So, you get feed marks and because of that you get some peak to valley height your peak to valley height will be here. On the other hand if the tool is having a nose radius then in that case it will go here and here. So, feed marks, so it will generate this type of profile, so feed is like this, so this is feed and this is peak to valley height so that means, it will be like this. So, feed mark is this. Tool is gamma e this angle and this angle is gamma s, gamma s is the side cutting edge angle in American system and gamma is the N cutting edge angle.

Another case can be this that when the nose is not fully engaged some portion which cutting here in the case you get this type of picture, based on that you can find out ideal expression for roughness of the machine surface.

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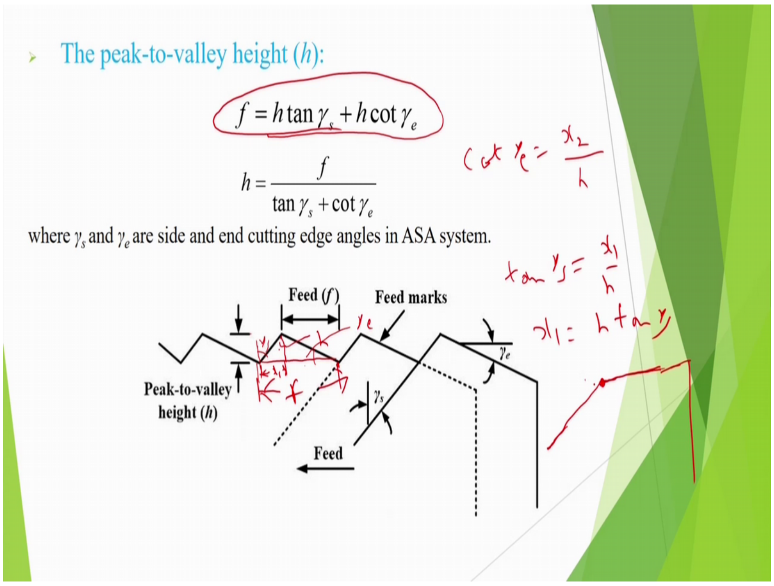

So, suppose the tool is very sharp then the peak to valley height h that is this one, f is equal to h tan gamma s plus h cot gamma e; h means it is basically peak to valley height h that is peak to that is R z, so this one. So, we can very well see here that this is the feed if I say from here to here this is the feed, ok. So, from here to here this distance is f, right and this height is h, we have seen this h, showed naturally that this is if it is this side it is gamma s.

So, this is this angle may be gamma s right this is gamma s and this one is. So, this will become gamma is here; so this will become h, h into tan gamma s. So, tan gamma s because gamma s is like this, like this here. So, gamma s tan gamma s is actually tan gamma s. Suppose, gamma s is this that is basically this distance x 1, x 1 divided by h. So, x 1 is equal to h times tan gamma s.

Similarly you can say this one also here this is gamma e, so which one is gamma e that means, this angle is gamma e, ok. So, we say cot gamma e, cot gamma e is equal to this divided by cot gamma e is equal to x 2 divided by divided by h. So, therefore, x 2 is equal to h cot gamma e. I add x 1 and x 2 you get this type of thing.

So, f is equal to h tan gamma s plus h cot gamma e that means, if side cutting edge angle is more ok; now, so h becomes like this f divided by tan gamma s plus cot gamma e. Which indicates what? That if the feed is more your peak to valley height will be more so that means, it is directly proportional to that feed and if your gamma s is more that side cutting edge angle is more then it will be more flat type of thing and your h will be reduced, but if cot gamma is if gamma is more than in that case this will be increased, ok. So, gamma e can be adjust type of thing that means, if it is like this type of situation that it is more like this and gamma e can be like this that means, ideally if I can have like this then it will be doing evening out of the things, that means gamma if 0 in this case this is a tool in which gamma is 0 suppose it is cutting like that.

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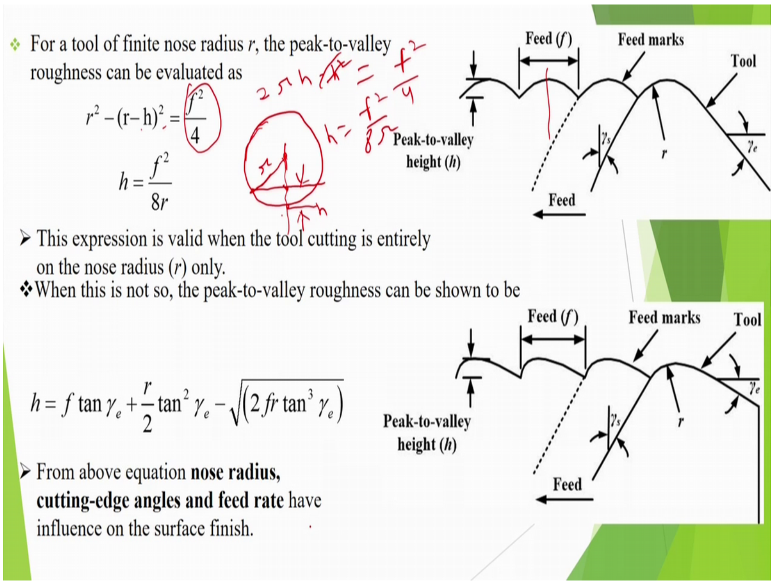

So, these all the expressions and for a tool of finite nose radius r the peak to valley roughness can be evaluated as this is feed f and peak to valley height is h, then these are the feed marks here, this is the tool here, this is gamma s and this one is gamma e here. But the it is only cutting at the nose, so if we make the expression like that then r square minus r minus h square is equal to f square by 4 that type of expression will be there this you can make the feed is f. So, this will be f by 2, f by 2 in that case cutting is this one.

Let me just make for your understanding suppose this is the feed this one I am showing in the reverse way I am showing, I am showing in the reverse way and this is like this is f and so what I am doing that suppose this is r and this height is say h, h. So, this becomes r this is r minus h by Pythagoras theorem, r square minus r minus h square will be f by 2 whole square, so that is f square by 4. So, it becomes r square minus r, so this becomes 2 r h, 2 r h minus h square but h is very small. So, neglect it. So, 2 r h is equal to f square by 4 and therefore, h is equal to f square by 8 r, where r is the nose radius is it not because this is the nose radius that circular one nose radius. And this is f is the feed.

So, this expression is valid when the tool cutting is entirely on the nose radius r only when this is not. So, then the peak to valley roughness can be shown to be h is equal to f tan gamma e plus r by 2 tan square gamma e minus under root 2 f r tan cube gamma e. This derivation will take some time based on the trigonometry only, but this is the expression presented here. From above equation nose radius cutting edge angle and feed rate have influence on the surface finish that is the expression is given.

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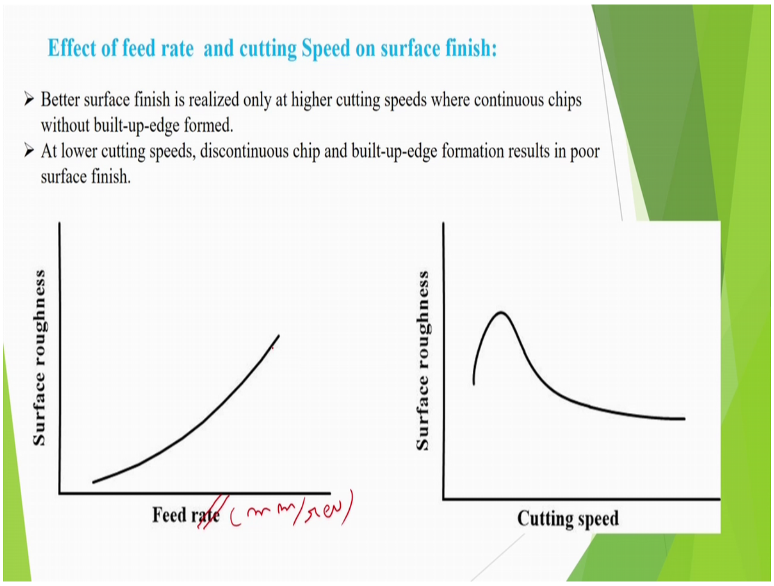

Now, what is the effect of feed rate and cutting speed on surface finish? What is the effect of the cutting speed that is also. See just a while ago we discussed about the cutting forces and if you see that in the expression i o e 10 that the cutting forces are dependent on the feed and depth of cut because they mainly influence, but the speed also has some effect. If speed increases generally the forces decrease because there is no built up edge form formation it is somewhat fast, friction is also less. So, some difference is there may be 10 percent, 20 percent, but that I am not taking into account you know.

Similarly, if you see these ideal expressions there the depth of cut is not coming into picture only the feed is coming into picture and cutting speed is there, but actually they also will have some effect. Experimentally, we have seen better surface finish is realized only at higher cutting speeds say because that time built up edge is not formed where continuous chip without built up edge formed, at lower cutting speed discontinuous chip and built up edge formation results in poor surface finish. So, surface roughness with feed actually it is increasing like that. Better to see feed actually not feed rate feed in millimetre per revolution, better to say that then surface roughness is the coming like that.

In the cutting speed, initially as the cutting speed increases built up edge formation starts because more temperature may be generated there more surface roughness increases, but after a certain point then the with cutting speed the surface roughness is decreasing, but as I o indicated that here the surface roughness is increasing with feed, but it may not be practically showed.

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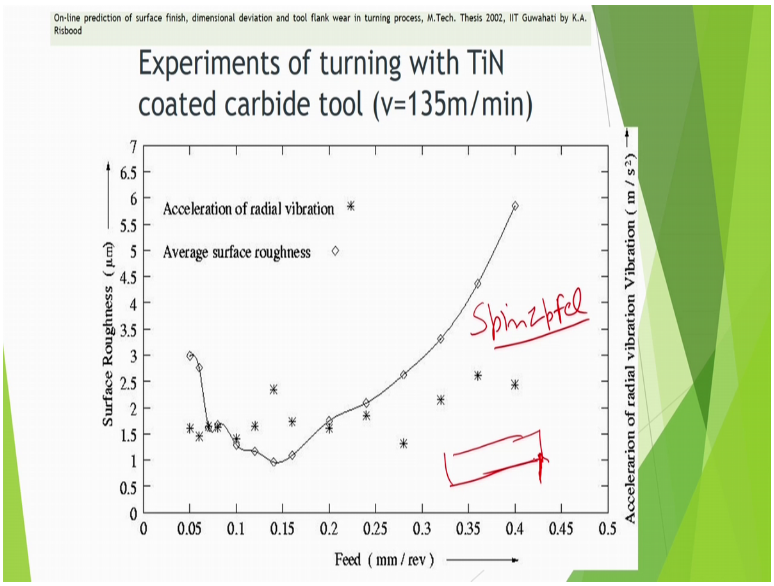

For example, one m tech student in 2002, he did sub work this was published also. So, he has done what he conducted experiments of turning with TiN coated carbide tool of the steel material and we are seeing this type of results. These stars are acceleration of radial vibration he measured the vibrations also and he also measured the u s surface roughness, that is Ra value.

It is seen that with feed in fact, up to about 0.15 millimetre per revolution with feed this surface roughness is decreasing. Here the surface roughness is about 3 micrometer, but here it is only 1 and after that it starts increasing edge we predicted theoretically that means, after that this one [FL]. So, this may be region may be y that, y with increasing feed surface roughness is decreasing.

In interestingly the vibrations have increased here, so you cannot say that it is due to vibration or something there has to be different region. So, different region can be this that if the feed is very small then there is no proper cutting action, no shearing action. There is just indentation type of thing and adjacent areas get drastically deformed. That type of phenomena is this one and plastic deformation occurs and that is why that you get this type of thing.

As you have seen that if there is a blunt tool and you dig it then it will deform the adjacent surface. So, this is generally also called this effect is spine z p fel, z p fel effect, that means I am cutting it like this there is no proper cutting action, but I put a small feed there is a ploughing type of thing here and there is some indentation. So, adjacent areas is getting drastically deformed, ok, so that may be one region.

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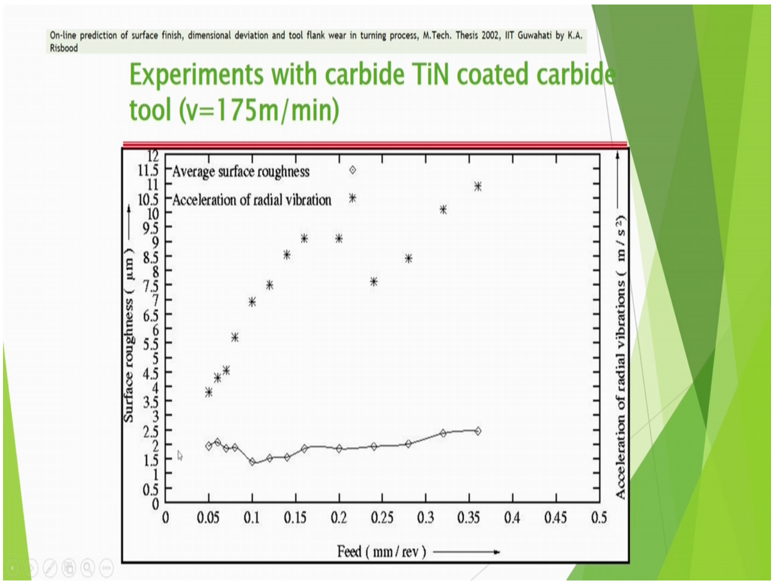

If you see that he did at 175 meter per minute at that speed at that time also little bit reduction was there, but you know that might it is not prominent. That means, here you can see in a very prominent manner that with feed increasing the surface roughness is decreasing. Whereas, in this case with feed decreasing that is feed increasing little bit decrease is there after that nearly it is constant with feed and overall by need (Refer Time: 39:12) so somewhat (Refer Time: 39:15) only because 175 and if we go to 238 meter per minute. Now, in this case this one here as 238, this is 1.5 power 2 and here, scale difference is there that is why you are it is appearing that is more, but actually it is lesser.

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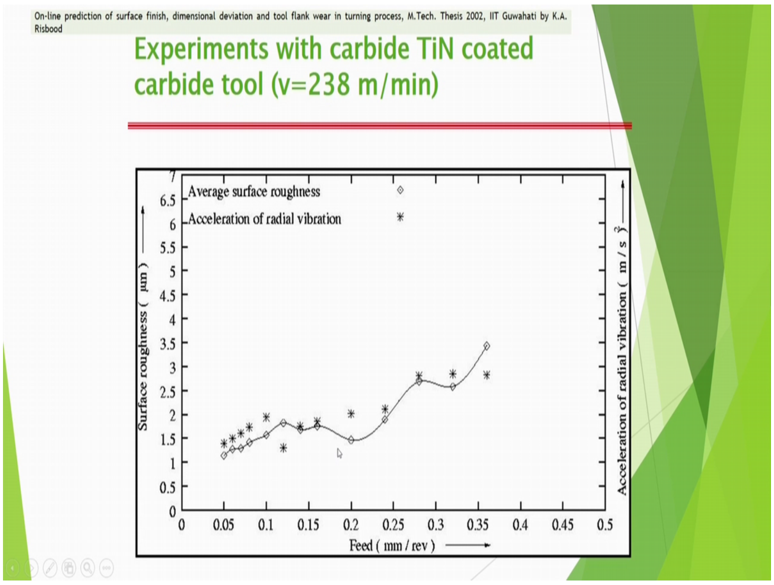

In this case it is something like 1 here, it goes up to 1 micrometer and this is what. So, this is you are getting this type of behaviour at 238 metre per minute. So, what I mean to say that practically there may be lot of this type of phenomena.

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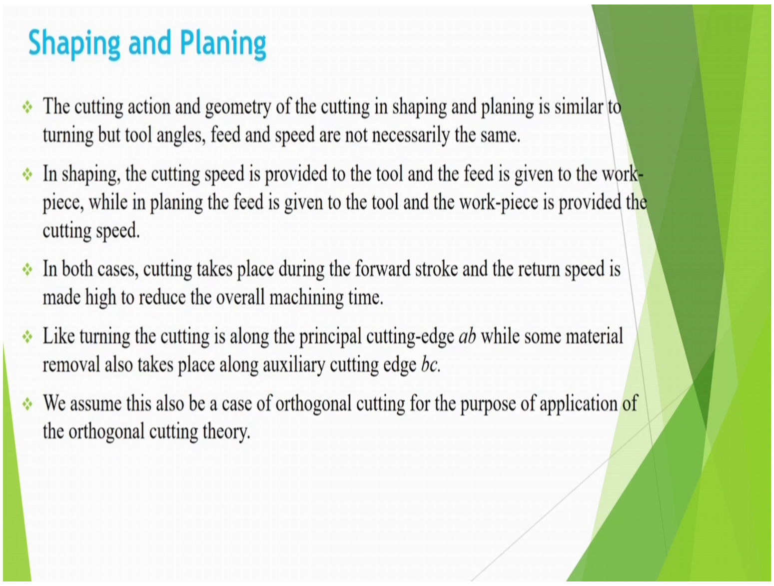

Now, going coming to this one, other causes like shaping and planning. In the shaping and planning the cutting action and geometry of the cutting in shaping and planning is similar to turning, but tool angles feed and speed are not necessarily the same. In shaping the cutting speed is provided to the tool and the feed is given to the work piece, while in planning the feed is given to the tool and the work piece is provided the cutting speed. In both the cases cutting takes place during the forward stroke and the return speed is made high to reduce the overall machining time. Like turning the cutting is along the principal cutting edge while some material removal also takes place along auxiliary cutting edge bc, we assume this also be a case of orthogonal cutting for the purpose of application of the orthogonal cutting theory. So, we are cutting like this.

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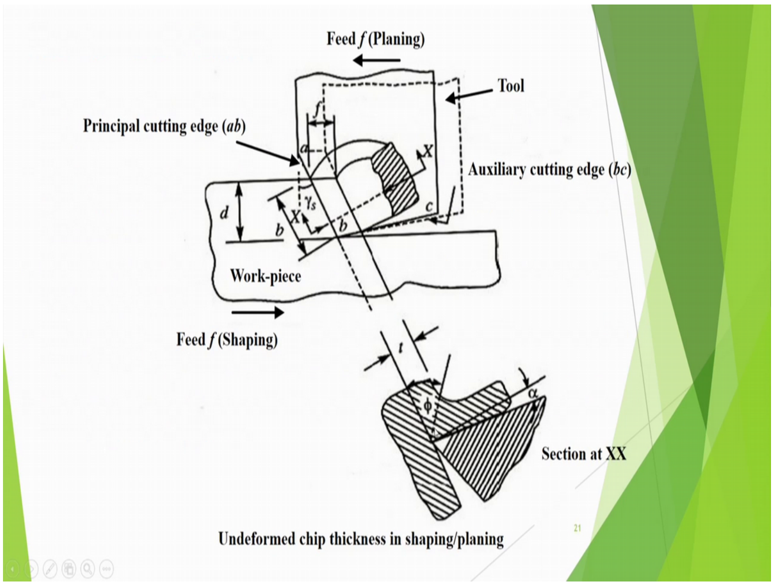

This is a shaping tool it is feed is given to the work piece and the job is like these. So, suppose the tool was here and then the tool h come here, these are the two positions of the tool this and this, ok. So, in that case like in turning know that this one and this one, this is chip thickness will be like this. So, this is t and this will be angle is shown here p. So, it is like this t is equal to f cos gamma s and b is equal to d cos gamma s, where gamma s is the side cutting edge angle.

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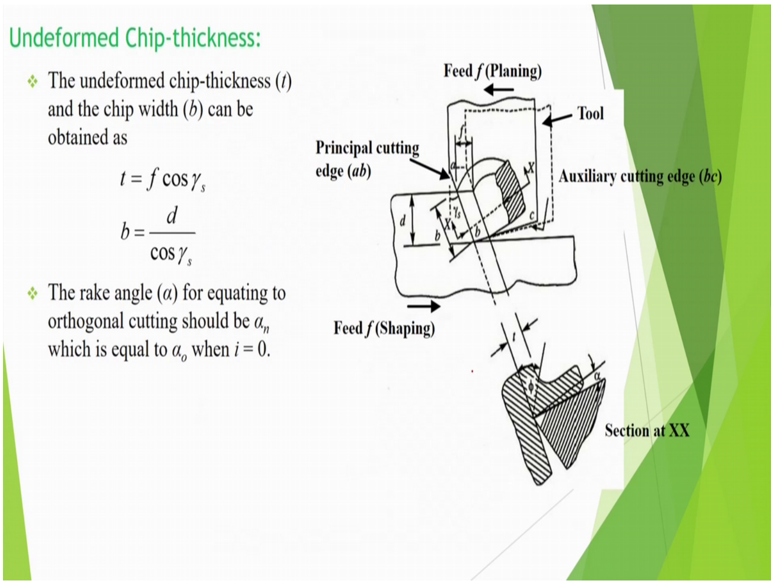

So, it is basically in the similar way rake angle alpha for equating to orthogonal cutting should be alpha n which is equal to alpha 0 when i is equal to 0.

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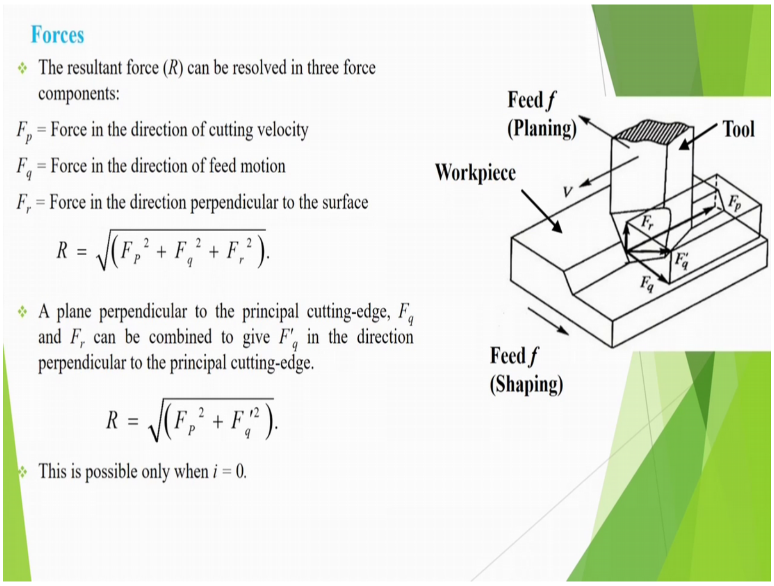

Forces are like that resultant force all can be resolved in 3 components here also, one is F p along the cutting speed direction, then force in the direction of feed motion and force in the direction perpendicular to the surface. So, R is equal to F p square plus F q square plus F r square.

Now, a plane perpendicular to the principal cutting edge F q and F r can be combined to give F q prime in the direction perpendicular to the principal cutting edge and R is equal to F p square plus F q prime square and this is possible only when i is equal to 0 that is this one for estimating the force components using orthogonal cutting theory t and b are evaluated chip thickness and width.

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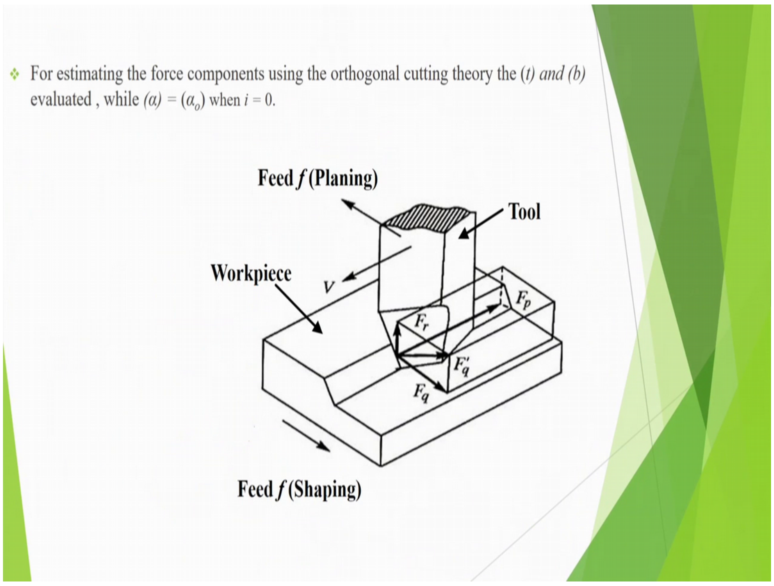

And then we surface roughness expressions are similar to turning peak to valley height for shaping planning with a sharp tool is given like f tan gamma s plus cot gamma e in the same manner.

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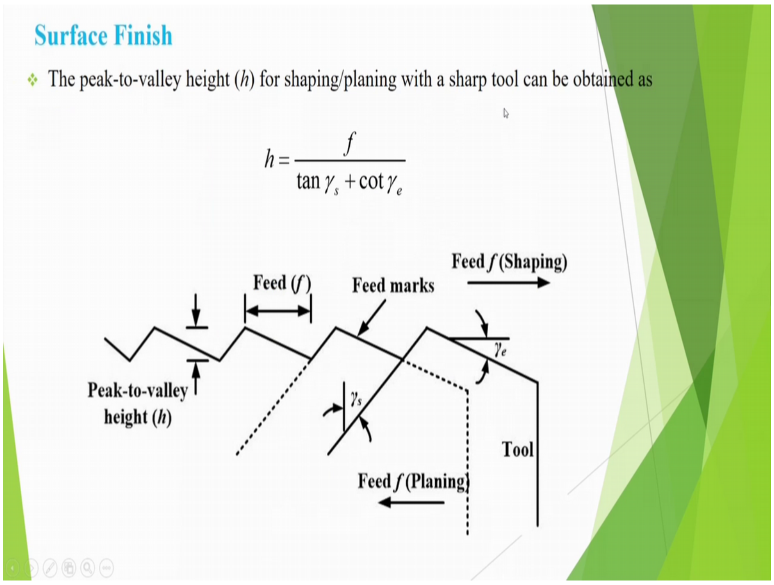

And this way similarly if the tool is having nose radius there similar type of expressions can be obtained.

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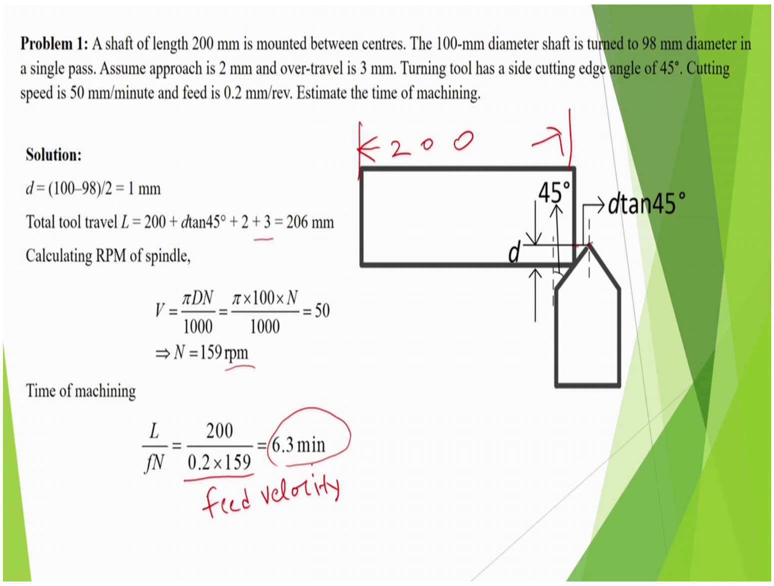

Now, let us discuss one or two problems here. Suppose a shaft of length 200 mm is mounted between centres 100 mm diameter shaft is turned to 90 mm diameter in a single piece, assume approach is 2 mm and over travel is 3 mm turning h tool has a side cutting edge angle of 45 degree, cutting speed is 50 millimetre per minute and feed is 0.2 mm per revolution estimate the time of machining. These are somewhat realistic data I have given. How it will be solved? Suppose the cutting is taking place in one pass.

So, shaft is having 100 mm diameter and it is and we how to turn up to 98 mm, so that is why 100 minus 98 divided by 2 is equal to one millimetre that will be depth of cut. Then the total tool travel will be how much? That it will be 200 a total tool because 200 is the length of the shaft, so that means tool has to certainly travel 200 from here to here at the same time this will start touching here itself. So, this distance also you how to account for that means, touching will start here and this is nothing but d tan 45 because this angle is 45 degrees side cutting edge.

So, 200 plus d tan 45 plus 2 mm is the approach that means, 2 mm before you have to start and over travel the means after cutting edge occurred then also it will move 3 mm, so that portion has to be added and it comes out to be 206. Then you calculate rpm of this spindle because cutting speed is fifteen metre per minute, so V is equal to pi DN by 1000 put that data here pi into 100 by N by 1000 and this is equal to 50. So, then N is equal to 159 rpm. Then time of machining will be L divided by f N and this will be 200, this is 0.2 into 159 this is nothing but the feed velocity f N is feed velocity. So, length divided by feed velocity we will be this thing and it comes out to be 6.3 minute, ok, so that is what.

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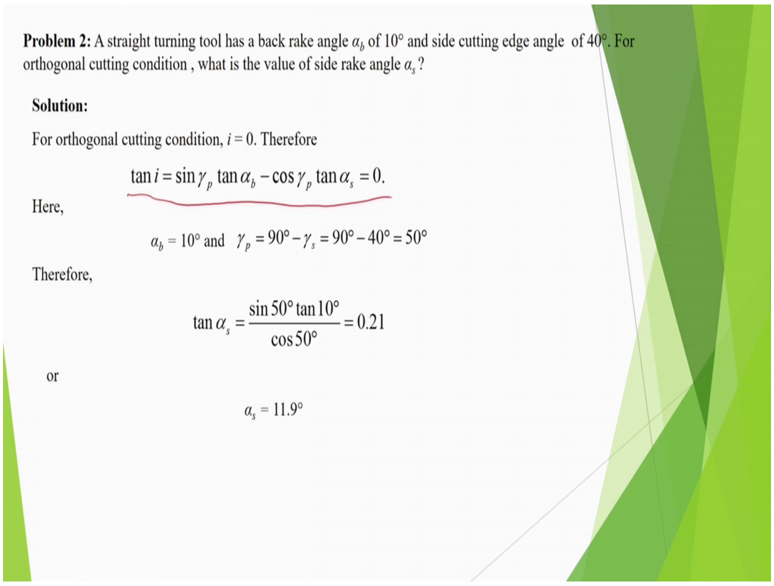

Now, go to problem 2, a straight turning tool has a back rake angle alpha b of 10 degree and side cutting edge angle of 40 degree. For orthogonal cutting condition what is the value of side rake angle suppose we have done this.

So, for this you know that for orthogonal cutting condition i is equal to 0. Now, you have to remember this formula which I talked long back that tan i is equal to sin gamma p tan alpha b minus cos gamma p tan alpha s that should be equal to 0. So, just you have to substitute the value you see here alpha b is equal to 10 degree and this one if you put that then you get alpha s is equal to 11.9 degree. So, if you how this type of situation then the i will be equal to 0 that is the value of the side rake angle, ok.

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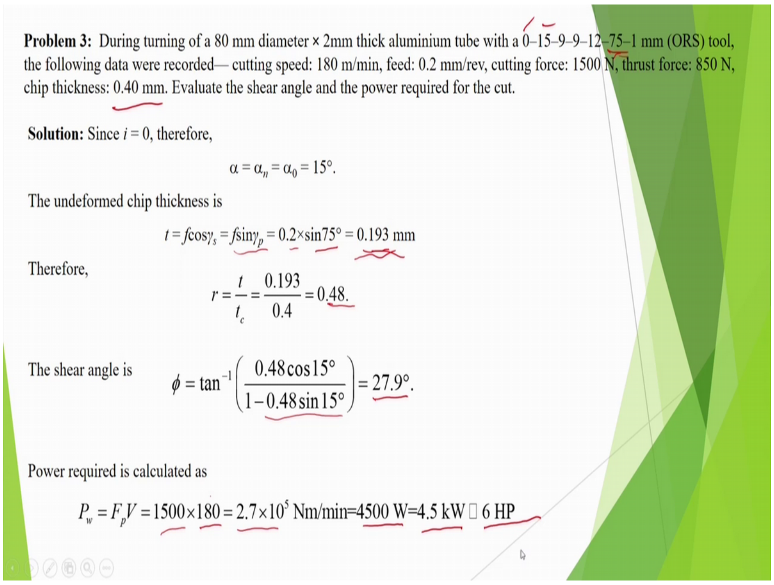

Problem third during turning of a 80 mm diameter into 2 mm thick aluminium tube that means, it is a aluminium tube. Now, with a 0 this ORS system these are the tool data the following data was recorded cutting speed was 180 meter per minute feed was 0.2 millimetre per revolution cutting force is 1500 Newton, thrust force was 850 Newton, chip thickness is 0.40 millimetre. Evaluate this shear angle and the power required for the cut since I is equal to 0. Therefore, alpha is equal to alpha N that is equal alpha 0 equal to 15 degree only. So, this is equal to 15 because i is equal to 0 anyway this is i is equal to 0 and this is rake angle 15 degree.

So, undeformed chip thickness will be t is equal to f cos gamma s or f sin gamma p principal cutting edge angle and this is 75 pm it is given 75 from tool signature I o sin.

So, 0.2 into sin 75 this becomes 0.193 and therefore, r is equal to t by t c. So, we can say 0.193 divided by 0.4 chip thickness is 0.4 that means 0.193 was this uncut chip thickness and cut chip thickness was measured that came out to be 0.4. So, r is equal to 0.48 therefore, shear angle is that formula r cos alpha divided by 1 minus in alpha we put it here we get phi is equal to tan inverse this much. So, it has come 27.9 degree.

Then power required is tabular calculated as P w is equal to F p into V and 1500 is the force was measured and cutting velocity was 180, 180 meter per minute. So, this came out to be this is Newton meter per minute because this is meter per minute, so Newton meter per minute, but you know that in 1 minute there are 60 second. So, divided by 60 and simplify that you get 4500 watt or you get 4.5 kilo watt or you get approximately 6 hours power, ok. You know that formula also for converting kilo watt to hour's power. So, this has been done.

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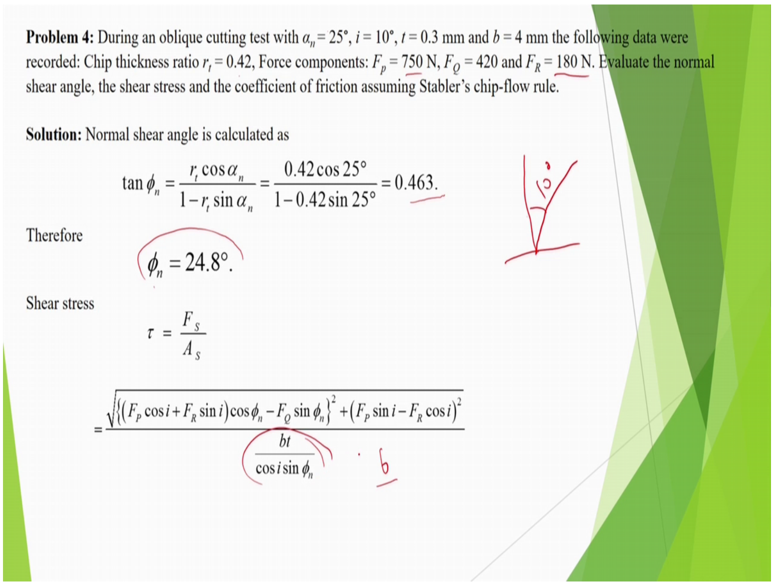

Then during an oblique cutting test with alpha N is equal to 25 degree that means, normal rake angle is 25, i is equal to 10 degree, t is equal to 0.3 mm and b is equal to 4 mm, the following data were recorded. Chip thickness ratio was 0.42, force components F P was this much, F Q was this much 420 and F R is equal to 180 Newton. Evaluate the normal shear angle the shear is stress and the coefficient of friction assuming Stabler's chip-flow rule.

What is Stabler's chip-flow rule? Stabler's chip-flow rule says that the chip inclination angle will be equal to the inclination angle of the miss chip flow direction will be equal to the inclination angle of the tool. So that means, chip-flow direction will be 10 degree. Chip will flow if the cutting edge is like this normal to the cutting edge is this chip will flow like this about 10 degree from here.

Normal shear angle is calculated as tan phi N is equal to r t cos alpha n divided by 1 minus r n sin alpha n that means, 0.42 is given here chip thickness ratio cos 25 degree because it is alpha n is mentioned 25 degree 1 minus 0.42 sin 25 degree it comes out to be 0.463. So, phi n came out to be this. And shear stress was F s by A s and expression for F s again you have to use that in 3 dimensional, one we have used those expressions F p cos i and all these things and here, A s is naturally bt divided by cos i by sin phi n you know oblique cutting we know that it is related like this. So, this becomes a A s in the shear crane b by b by sin phi n and this will be t by cos i. So, you get this type of expression.

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$$= \frac{\sqrt{\{(750\cos 10° + 180\sin 10°)\cos 24.8° - 420\sin 24.8°\}^2 + (750\sin 10° - 180\cos 10°)^2}}{\dfrac{4\times 0.3}{\cos 10° \times \sin 24.8°}}$$

$$= 204.72 \text{ N/mm}^2 = 205 \text{ MPa}$$

Coefficient of friction is calculated as

$$\mu = \frac{F}{N}$$

$$= \frac{\sqrt{\{(F_P\cos i + F_R\sin i)\sin\alpha_n + F_Q\cos\alpha_n\}^2 + (F_P\sin i - F_R\cos i)^2}}{\{(F_P\cos i + F_R\sin i)\cos\alpha_n - F_Q\sin\alpha_n\}}$$

$$= \frac{\sqrt{\{(750\cos 10 + 180\sin 10)\sin 25° + 420\cos 25°\}^2 + (750\sin 10 - 180\cos 10)^2}}{\{(750\cos 10 + 180\sin 10)\cos 25° - 750\sin 25°\}}$$

$$= 1.86.$$

And then if you put these expressions here then if pi substituting are these things you get this one, cos i is known sin phi n is also known. So, you get 204.72 Newton per mm square or 204.72 means 205 mega Pascal, 1 Newton per mm square is mega Pascal. Coefficient of friction is calculated as F by N, and expression for F on the tool is surface is given like this, expression for N is this you put it that. So, coefficient of friction is coming 1.86. You see that effectively this is very high coefficient of friction, so that is what we have obtained.

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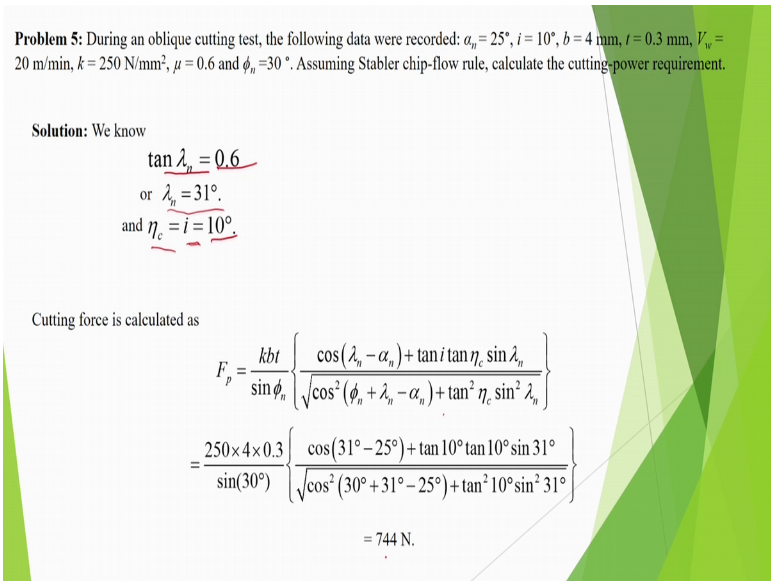

So, this is now, let us see another problem during an oblique cutting test the following data were recorded alpha n is equal to 25 degree, i is equal to this much, b is equal to 4 mm, t equal to 0.3 mm, V w is equal to 20 meter per minute and k is equal to 250 Newton per mm square that see this one shear stress and mu is equal to 0.6 f N is equal to 30 degree, assuming Stabler chip-flow rule calculate the cutting power requirement.

So, in this case we know tan gamma n, lambda n is equal to 0.6 that friction. Friction is 0.6 this is friction angle, normal friction angle this will give you lambda N is equal to 31 degree. Eta c is equal to inclination angle because of Stabler chip-flow rule and this use 10 degree that means, chip-flow direction is this. Then the cutting force is calculated as kbt divided by sin phi n and because k is the shear strength b t by e sin phi n like this and this one is multiplied by this component. So, this expression we derived and we have to put all these things then naturally you got eta c is known 10 degree, i is 10 degree, lambda n is 31 degree, we got 744 Newton.

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So, cutting power is equal to then we get P w is equal to F p into V that means, cutting power is 744 into 20 and that becomes 14880 Newton per minute that means, 248 watt or something.

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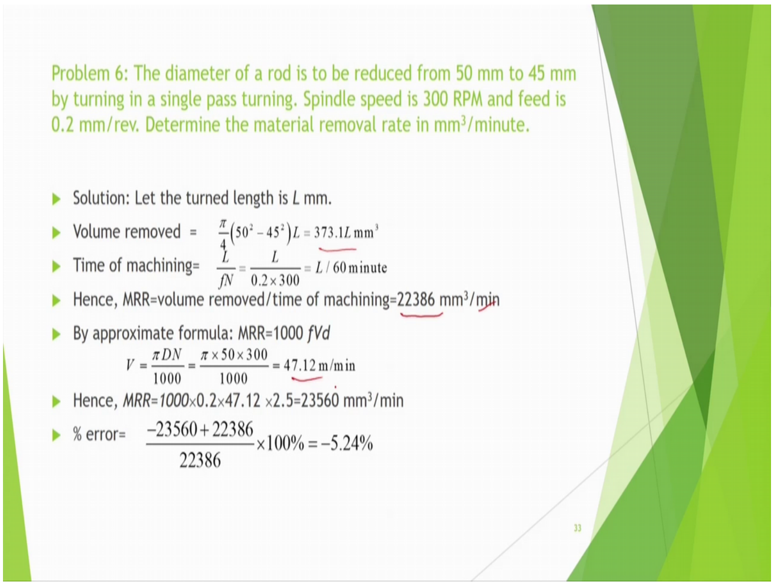

So, this is this one then there all some other questions like this. Suppose the diameter of a rod is to be reduced from 50 mm to 45 mm by turning in a single pass turning, spindle speed is given 300 revolution per minute feed is 0.2 mm per revolution determine the material removal rate in millimetre cube per minute.

Now, solution let the turned length is L mm then volume removed is how much pi by 4, 50 square minus 45 square because 50 mm diameter has been reduced to 45. So, volume removal is pi by 4, 50 square minus 45 square into L that much has come, L is the length. Time of machining is L by f N, so it is L by 0.2 this much that means, this much minute.

Hence MRR is equal to volume removed divided by time of machining, we put it there L L gets cancelled and you get 22386 millimetre cube per minute. But if we do by approximate formula MRR is equal to 1000 fVd and here V is equal to pi DN by 1000. So, this comes out to be this one D is 50 and this is 300, 1000; V it has come here then MRR is coming 1000 into 0.2 into this much into D is 2.5 that is coming 23560. So, you see that there is a differential, there is a difference in this these things there is a difference. So, percentage here is actually percentage here is minus this much plus this that means, we are getting somewhat into 100 percent that means, we are getting 5.24 percent error, ok.

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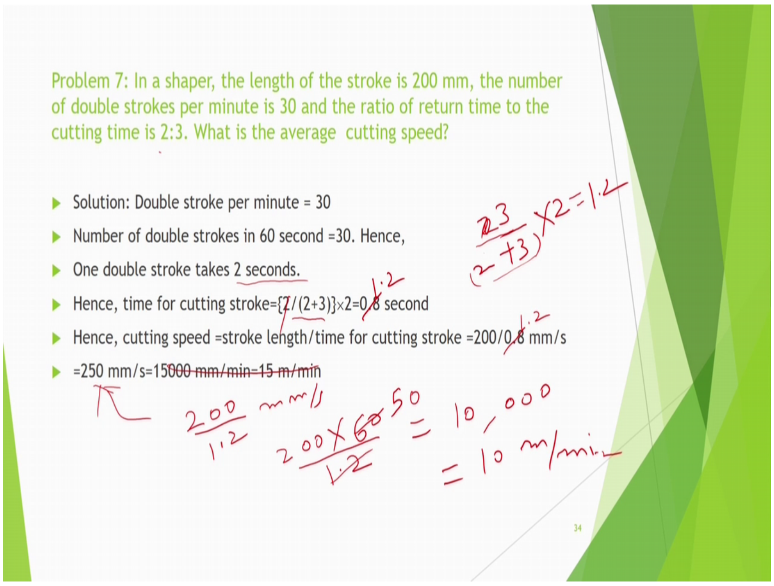

So, let us see the problem 7. In a shaper the length of the stroke is 200 millimetre per minute, the number of double stroke per minute is 30 and the ratio of return time to the cutting time is 2 is to 3. That means, it is cutting in 2 cutting ratio of return time it is returning in 3 minutes, but cutting is 2 minutes something like that. So, ratio of return time to the cutting time is 2 is to 3, or cutting it is taking 3 minutes or returning only 2 minute fast. So, what is the average cutting speed?

So, the solution is like that double stroke per minute is 30 because it is said that double stroke per minute is 30 number of double strokes in 60 second is 30. Hence one double is stroke takes 2 second. Like that we can argue. One double stroke takes 2 second, hence the time for cutting stroke is 2 divided by 2 plus 3 because cutting is this one. So, time one double stroke takes 2 second, double stroke has taken 2 second then time for cutting stroke cutting is return is done at a first term rate, so that means, it is it is this one cutting stroke it is 2 time for cutting stroke is this much 2 divided by 2 this one, 2 by 3; actually it is it should be 3 divided by 2 plus 3. That means, 3 divided by because total time is suppose 5 minute out of that 3 minute is for cutting. So, 3 by 3, 5, but actually it is not too late it is 2 second so that means, 1.82 second. So, 1.82 second, 1.2 second is for cutting, hence cutting speed is equal to stroke length divided by time for cutting stroke.

Return is only in 0.8 second. So, this is actually 200 divided by 1.2 and that can come out to be this one 200 divided by 1.2, ok. So, this becomes 200 divided by 1.2. So, you can find out that how much it will be millimetre per second, millimetre per second. So, if we want to find out in millimetre per minute, so 200 into 60 divided by 1.2, ok. So, this can come out to be 12 5, za 5 and 50, so it becomes 10 and this is 1000. So, it comes out to be 10 meter per minute right, it was earlier printed along it is not 15 meter per minute it is actually 10 meter per minute. That is how that this answer has come, so we may have to sometimes estimate that cutting stroke and all that thing.

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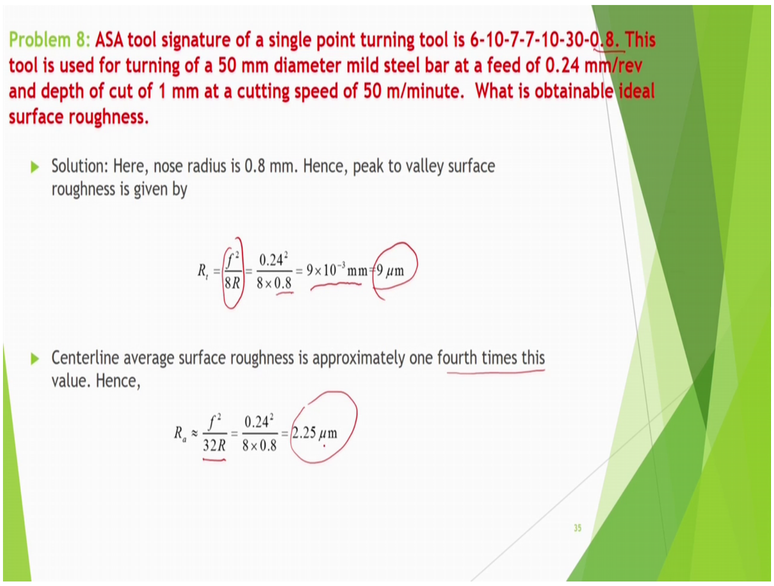

Then let us see one or two problems on the surface roughness. Suppose ASA tool signature of a single point cutting tool is this much, this tool is used for turning of a 50 mm diameter mild steel bar at a feed of this much 0.24 millimetre per revolution and depth of cut off 1 mm at a cutting speed of 50 meter per minute. What is the obtainable ideal surface roughness?

So, nose radius is 0.8 hence peak to valley surface is given by f square by 8 R that formula. So, we put 0.24 square divided by 8 nose radius is 0.8 it is given here in tool signature. It comes out to be 9 into 10 to the power minus 3 mm that means, 9 micrometer. But centre line average surface roughness is approximately one-fourth times this value hence Ra is equal to f square by 32 R that means, it is 2.25 micrometer, so that is the answer, ok.

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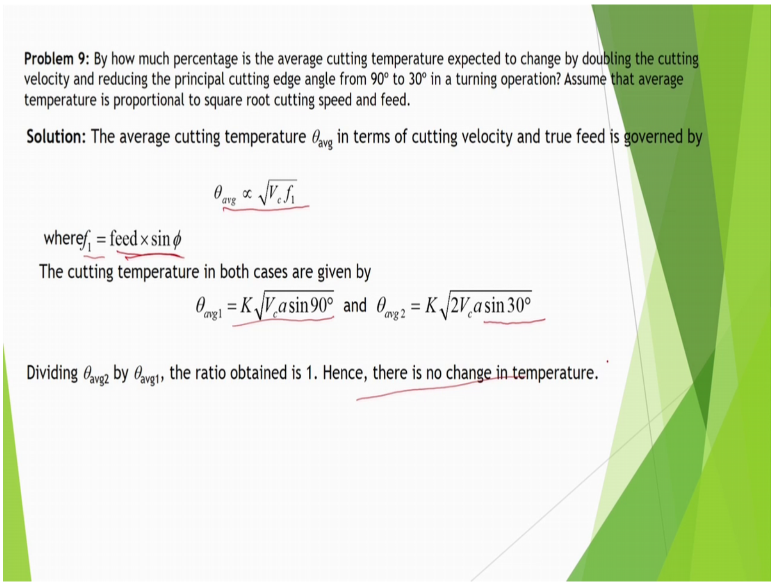

Then by how much percentage is the average cutting temperature expected to change by doubling the cutting velocity and reducing the principal cutting edge angle from 90 degree to 30 degree in a turning operation? Assume that average temperature is proportional to square root of cutting speed and feed.

So, assume that average cutting temperature is proportional to square root of V c and f and f 1 is equal to feed into sin phi because this is the uncut chip thickness sin phi. So, cutting temperature in both the cases are given in one case it is this much phi is 90 degree another case is basically this one 30 degree. So, dividing this one the ratio is obtained as 1 so that means, by that means, there is no change in temperature, ok. That is the answer.

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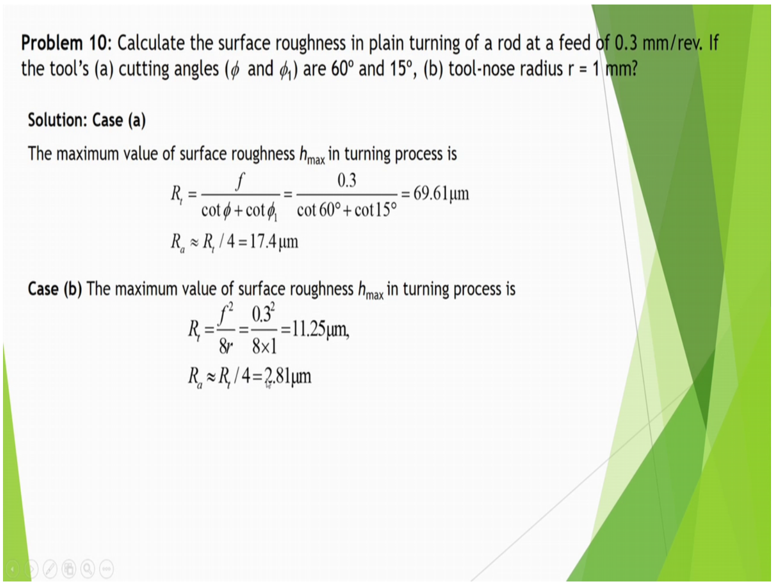

Then calculate the surface roughness in plain turning of a rod at a feed of 0.3 mm per revolution if the tool is cutting edge angle are 60 degree and 15 degree tool nose radius r is equal to 1 mm.

So, in this case angles have been given, cutting angles and then this is principal cutting edge angle and this is side cutting edge angle, maximum value of surface roughness just plugging the formula R t is equal to f divided by cot phi. If it was side cutting edge I would have return 10 psi or something. So, this is 0.3and this ones would comes out to be 69.61, but Ra is equal to R t by 4. And if the tool nose radius if it is cutting on the tool cutting nose then it is maximum value of surface roughness is f square by 8 r, put it there it comes out to be 11 micrometer roughly and Ra is equal to R t by 4 that means, 2.81 mm.

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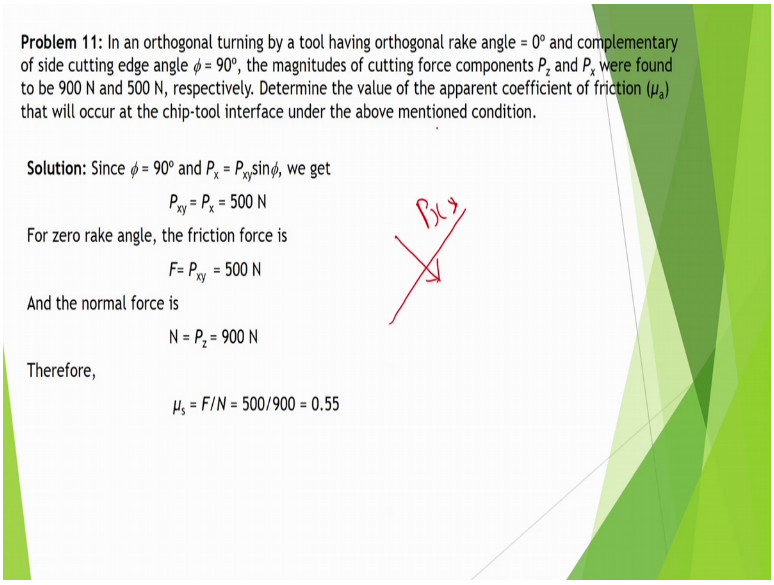

Then you see that one is in an orthogonal turning by a tool having orthogonal rake angle 0 degree and complementary of side cutting edge angle phi equal to 90 degree, the magnitudes of cutting force components P z and P x were found to be 900 and 500, respectively. Determine the value of the apparent coefficient of friction that will occur at the tool chip tool interface under the above mentioned condition.

So, in this case phi is equal to 90 degree P x is equal to P xy sin phi, so that means, that is the P xy is equal to 500 and 0 rake for 0 rake angle the friction force is f is equal to P xy only that is 500, normal force is N is equal to 900. So, apparent coefficient of friction is F by 9 and this really thing. Here we have used that type of thing that suppose this is P xy, P xy means this thrust component and it has got two components P x and P y, so that type of thing.

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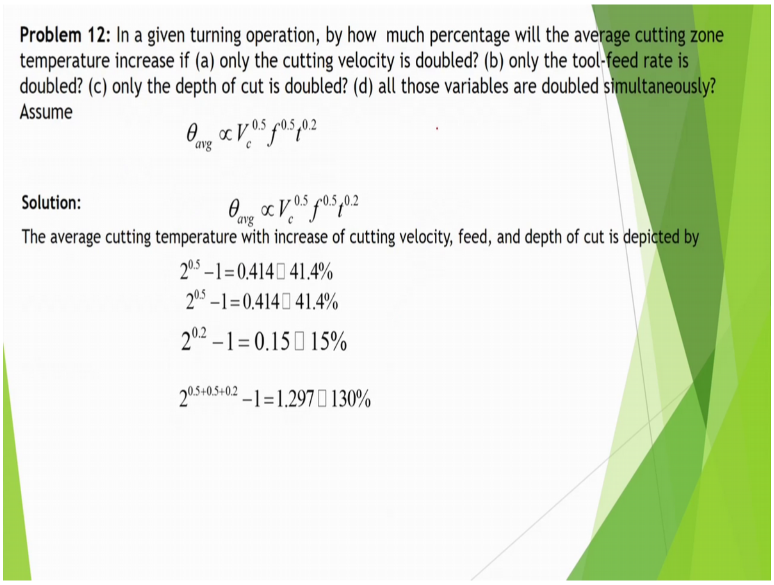

We has been used in a given turning operation by how much percentage will the average cutting zone temperature increases if only the cutting velocity is doubled, only the tool feed rate is doubled, only the depth of cut is doubled all those variables are doubled simultaneously assume theta average is equal to which is this one V c to the power 0.5, f to the power 0.5 and t to the power 0.2. Here t is the basically related to width of the chip, ok. So, this is tool depth of cut basically.

So, average cutting temperature with is depicted by 2 to the power 0.5 minus 1 and this will be 41.4 percent, similarly you have to just plug in the value if the tool feed rate is doubled then it will be 2 to the power 0.5 minus 1 that means, 41 percent and then 2 to the power this one. And if you V thing is doubled then that effect will be here that means, it will increase by that much amount, 130 percent.

So, such type of problems are there these problems you can practice. Essentially we have told you about that how you know simple expressions can be obtained in the turning, but practically things will be means somewhat different that is why it is not necessary that you will get really accurate solution because your machine condition may be different, so many factors are there, but at least you will get some idea that how what are the magnitude of the forces. So, this much for today, and we will discuss about some more machining processes we have to discuss about milling also. That we will discuss in the next lecture.

Thank you.