Manufacturing Processes II
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Lecture No.13
Concept of Machinability and its Improvement

Good morning. You are welcome to the course Manufacturing Processes II. Now today we are starting Module 3 that deals with Machinability connected with machining and the topic of today's lecture will be concept of Machinability and its Improvement. Now what are the specific instructional objectives or the contents of today's lecture?

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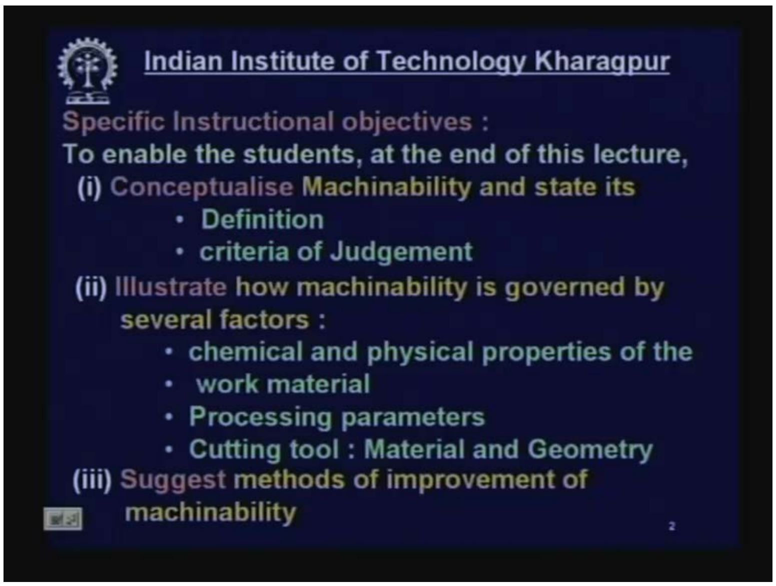

After hearing this lecture, the students should be able to conceptualize what is machinability and state its definition and what are the criteria of judgment of machinability? Next the student should be able to illustrate how machinability is governed by several factors. Chemical and physical properties of the work material itself, the processing parameters like cutting speed or velocity feed depth of cut etcetera cutting tool its material and geometry and this lecture will also enable the students to suggest finally the methods of improvement of machinability. How machinability can be improved?

Now before we go into machinability, let us again recall what is machining because machinability is the term used to qualify and quantify the machining ability of the work material or work material cutting tool together. So what is machining? Is already been discussed thoroughly in the previous lectures. Now I am reminding you that what are the purposes of machining?

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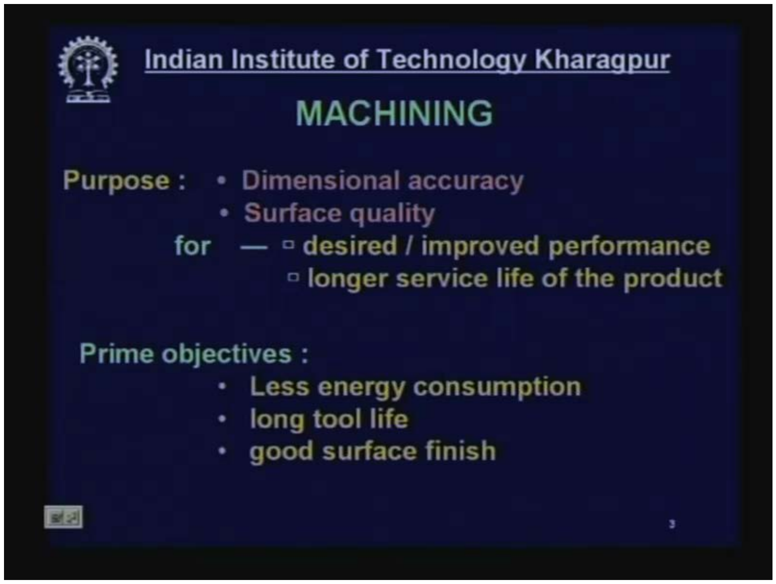

The purpose of machining is to impart the dimensional accuracy and surface quality to the job. After performing by casting, rolling, forging, we do not get appropriate dimension and surface finish those have to imparted by machining. Now this dimensional accuracy and surface quality is essential for the component to serve the desired purpose or to improve the performance and also for longer service life of the product. Now while carrying out this thing we have to keep certain objectives in our mind like the machining has to be done with a less energy consumption, long tool life and good surface finish. It may not be that easy to get all this things together but attempt should be made to maximize or enhance this energy saving improvement in tool life and surface finish.

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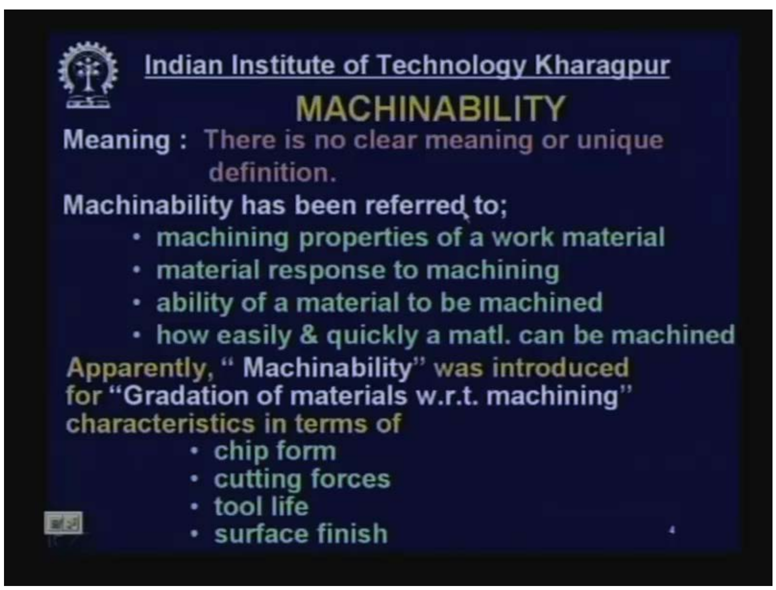

Now what is machinability meaning? Really even today, it is not it has not been possible to come out with a specific definition. There is no here you can see there is no clear meaning or unique definition, yet it is used basically as a qualitative term. Machinability has been referred to however many people are using this word machinability and utilizing for different purposes. When the minute mean by it, the machining properties of a work material that means, how do work materials behave in machining, then material response to machining almost same. Ability of a material to be machined, how a machine can be easily machined or it is a cutting tool or situation can be able to machine a material or another way it is referred how easily and quickly a material can be machined.

Now apparently machinability was introduced for gradation of materials. There are different types of work materials. How do they respond to the machining good or bad if good to what extent, if bad to what extent? So to some extent, some attempt has been made to quantify as well as qualitative. So 'gradation of materials with respect to machining characteristics' in terms of now what are the machining characteristics in what terms, we judge the materials and how shall we grade the materials in respect of chip form good or bad, favorable or not favorable, cutting forces tool life and the surface finish.

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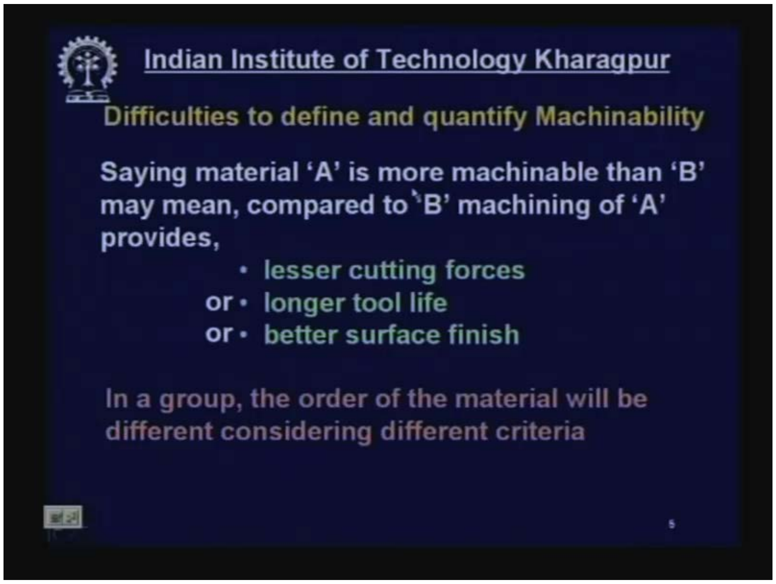

Now why it is difficult to define and quantify machinability? Here it is difficult. For example, say it is said that material 'A' is more machinable than 'B', it is stated that machine material 'A' is more machinable than material 'B'. What does it really mean? It can mean many things. It can mean that compared to material 'B' machining of material 'A' takes lesser cutting forces requires lesser cutting forces. So it is very good or it can mean that if we say that 'A' is more machinable than B than compared to 'B' 'A' provides longer tool life good it is desirable or it can provide better surface finish. But it is not possible to get all this things from one material. So, when you say that 'A' material is better than 'B' or more machinable than 'B' it can require lesser cutting force, provide longer tool life or surface finish but all of them may not be together that means if we take a group of material a number of materials in a group and we grade them with respect to the cutting power consumption.

Suppose we take a particular cutting tool, particular speed feed depth of cut or machining condition and then we measure the cutting forces. The material which will take minimum force will be graded one. Similarly we can make a sequence of you know the materials or the order of the materials in respect of cutting force. But, if we do this classification or ordering in respect of tool life then the sequence will change. The same material which provides lesser force may not be able to provide longer tool life. A different material can provide good maximum tool life. Similarly we grade the materials within the group with respect to surface finish the order will again change. So it is very difficult with what respect with what criteria, we are judging machinability, it is very difficult. In a group we say therefore in a group the order of the material will be different considering different criteria criteria means cutting force tool life surface finish economy and all this things.

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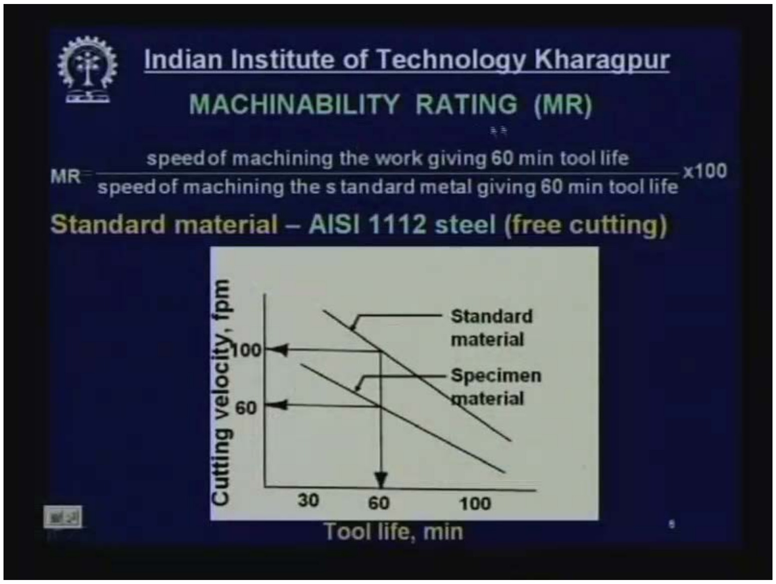

However Machinability Rating, a word has been introduced to quantify the quality of a work material or behavior of a work material in respect of machining. What is Machinability Rating? This machine rating is a quantitative term, it is a ratio of speed of machining the work, a test piece, any work material arbitrary work material giving 60 minute tool life. Now what is it? Now look into this diagram. Here with this is a tool life and this one shows the cutting velocity say feet per minute or meter per minute and this is the curve, that means with increase in with increase in cutting velocity, the tool life will be reduced. When the cutting velocity is low, the tool life will be long and this is the log log plot of cutting velocity and tool life.

Now this is the specimen material and this is the standard material. Now here you see speed of machining the work giving 60 minute tool life. Now suppose this is a 60 minute tool life the 60 minute tool life will be obtained if the specimen work material is machine at 60 feet per minute. For example, say but the same amount of tool life will be obtained if the standard material at 100 feet per minute. So it appears that the specimen material is less machinable than standard material because it provide it survives only 60 minutes when cutting velocity is only 60 meter per minute but a standard material can survive can provide 60 meter per 60 minute tool life even at high speed of 100 feet per minute high productivity. So in this respect the material this machinability rating of the specimen material will be the 60 the speed at which the tool life is 60 minute divided by 100 the speed at which the standard material provides 60 minute tool life.

So it is stated speed of machining the specimen work giving 60 minute tool life divided by speed of machining the standard material are better giving 60 minute tool life. So 60 minute tool life is the standard taken and at what speed it is obtained that is the measure of machinability. So in this case it will be say 60 divided by 100 that is 0.6 is the machinability rating in percentage that multiplied by hundred is equal to say 60 is the machinability rating of this particular material under consideration. Now what is the standard material? The standard material has to be very judiciously taken and should be followed everywhere globally. Standard material is AISI 1112 steel. It is free cutting steel, it is basically mild steel kind of chip material mild steel but having some additives which impart free cutting like lead or sulphur. Basically this is sulphur, and in addition to that little amount of tellurium is also added and this is called free cutting steel of particular grade AISI 1112 steel. This has been taken as a standard material and with respect to this; other materials have been compared in terms of the cutting velocity which imparts 60 minute tool life. But, this is very crude method. This was done earlier; it was expected also in some industries for sometimes. But nowadays it is not excepted because it has got lot of limitations, lot of drawbacks. What are those?

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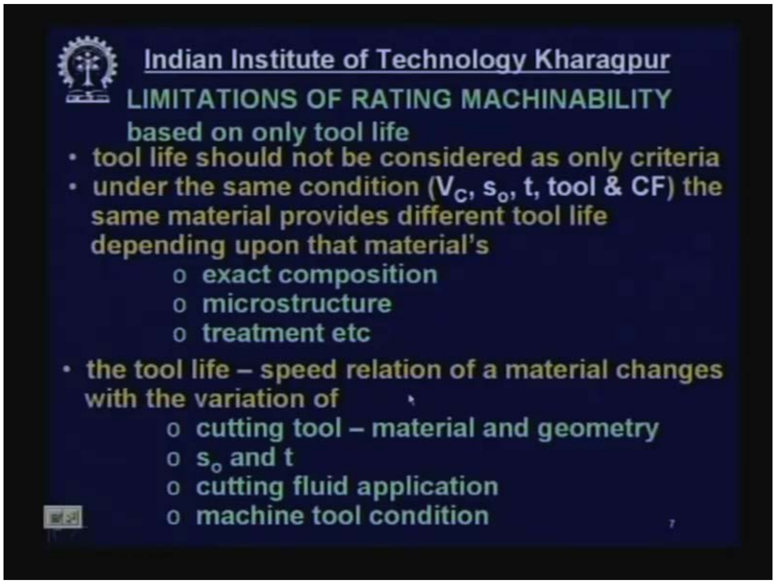

Limitations of rating machinability based on only tool life. In the previous diagram, you have seen that it is done with respect to tool life only that is 60 meter 60 minute given by

100 feet per minute and 60 feet per minute. Tool life should not be considered as only criteria there are many other criteria's like power energy cutting force tool life sorry and ah surface finish dimensional accuracy cutting temperature and what not all those things should also be taken in to account. Under the same condition that is under the same condition of machining of cutting velocity feed depth of cut cutting tool material and geometry and cutting fluid the same material provides different tool life depending on that material.

So if we say the that machinability rating of say a machine mild steel is 60 or say medium carbon steel is 60 that may not be correct because what kind of steel in what condition that steel was taken what is the exact composition because if the composition slightly changes this machinability rating will change. Microstructure if it is different then the same material can have different microstructure a co structure will give lesser force and longer tool life and microstructure. If it is fine, then the cutting force will be large and tool life will be less treatment if the same material is harden its machinability rating will be low if the same material is annealed softened the rating will be high so it varies from the condition to condition over the same material.

In the previous diagram, we considered tool life and cutting velocity relationship as the base of material machinability rating. But the tool life versus cutting velocity relation of the material changes with the variation of that does not remain same for the same material work material. The relation between tool life and machinability cutting velocity does not remain fixed. It also depends upon the cutting tool. What kind of cutting tool you are using? If you take a high speed steel, you will get one characteristic if you take carbide or ceramic the relationship will be different cutting tool both material and geometry play significant role feed and depth of cut if feed is different the same material and cutting tool will provide different machinability rating.

Cutting fluid application: If we do not apply cutting fluid or if we apply cutting fluid, the machinability rating will be widely different and how do we apply cutting fluid that will also matter what kind of cutting fluid you are using that will also affect the machinability rating, then machine tool condition the power of the machine tool, the rigidity of the machine tool, compliance of the machine tool, then stability of the machine tool all these things will also effect machinability of a particular material. So there is no end of it there are lot of controversy lot of debates and all this things but we have to come to a concurrence to some extent or somewhere.

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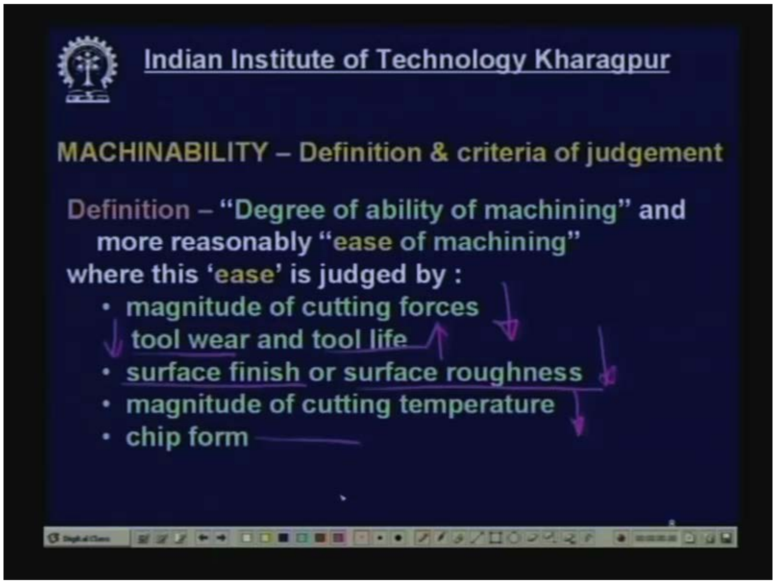

So ultimately people have been inclined towards a definition like not a clear cut definition even then, a definition MACHINABILITY- Definition and criteria of judgment that has to be considered. Now definition – "Degree of ability of machining" whether a material can be machined or not, is it able to be machined or not, if it is able then what is the degree of ability of machining and more precisely it can be we can use the word more reasonably "ease of machining" how easily the work material can be machined? Now the word easy or ease is also very controversial. What is easy to be may not be easy to use or a person A or B so this easiness or the word ease has to be you know defined what is how do you measure ease and the measurement of ease is the criteria of judgment of easiness of machinability.

So how do you define that the machinability means "ease of machining" which is judged by magnitude of cutting forces, tool wear and tool life, surface finish or surface roughness, magnitude of cutting temperature, chip form. Now our attempt should be always to improve the machinability that is less cutting force, less cutting temperature, longer tool life good surface finish. So machinability has to be improved. How do you understand? What is meant by improvement of machinability? When the magnitude of the cutting force will come down then when the machinability or the magnitude of cutting force will come down it indicate that machinability is improved.

Tool wear and tool life; When tool life is increased that indicates improvement in tool life, tool wear when tool wear rate is reduced machinability is improved. Surface finish is better that means improvement surface roughness. If reduced then we mean that we have achieved more machinability. Magnitude of cutting temperature; It should be as low as possible for improvement of machinability, chip form it should be favorable or unfavorable. If you want favorable means short but uniform chip with less contact sharp, without built up edge then this will be called favorable chip and machinability is to be considered better. This is how it has to be judged.

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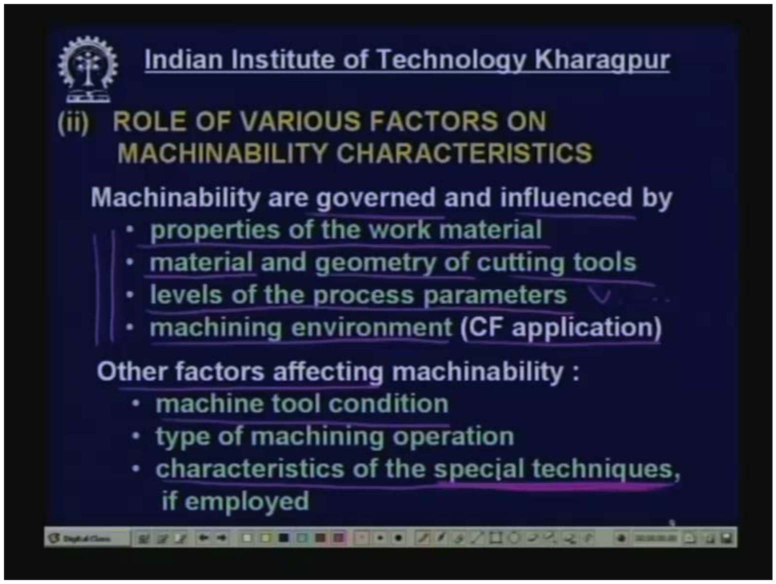

Now let us see the role of various factors on machinability characteristics. Anyway we shall use the word machinability. Machinability are governed and as well as influenced by properties properties of the work. Now ability of ability of machining a material. It does not depend upon simply the material property. Suppose you want to cut a log into two pieces, now how this will be done easily? It depends not only on the material, it depends upon the cutting tool that you are using the cutter. If it is a dull cutter, then more energy will be required more force will be required if it is a sharp cutter then the cutting will be easy. Similarly in machining the ease of machining or ability of a material to be machined depends not only on itself it depends upon the cutting tool also the velocity the feed the cutting condition environment and so on.

Let us examine, what are those factors and how do they play role on machinability characteristics. So now let before we proceed, let me summarize again, machinability means ease of machining which is judged by that the machining force has to be reduced. This cutting temperature has to be reduced and the tool life has to be enhanced. Surface finish has to be improved or surface roughness has to be reduced and so on this is machinability. Now this has to be improved all the time. Lot of research is going on always to improve machinability of different material. Now it is better to say instead of machinability machinability characteristics of a tool work combination that is more appropriate material that is chemical property, physical property and mechanical properties all properties. Material and geometry of the cutting tool substantially levels of the process parameters like cutting velocity, feed, depth of cut. Depth of cut has got minimum effect but velocity and feed has got effect.

Machining environment like cutting fluid application - if should we apply or not? Or what type of cutting fluid, how do we apply and so on that we shall we will discuss later on. What are the other factors? These are the major factors that govern that govern machinability. Other factors that also effect or influence machinability those are machine tool condition. If the machine tool is very bad not rigid is very complaint or where it has got lot of backlash and then the quality of the product will be very bad. The type of machining operation whether it is turning or milling or say rimming that also matters. If it is rough turning, then the quality of the job will be less but the cutting tool life will be good if it is a finishing operation, tool life will be less but finish will be good.

So the machinability also depends upon the type of machining operation is that up machining or bulk machining or finish machining or it is a turning or it is a thread cutting or rimming or drilling like that characteristics of the special techniques now sometime we apply special techniques in my previous lecture I told you about the several special techniques like say cryo-machining, then stress machining and dynamic machining, hot machining, magneto machining etcetera sometime we use it. Now application of this technique and how do we apply and all the aspects of the special techniques if we apply will also affect the machinability of the product say machinability of inconel is very poor, machinability of pneumonic or any tool is extremely poor. But if we apply hot machining, the machinability improves. So this technique plays a very vital role.

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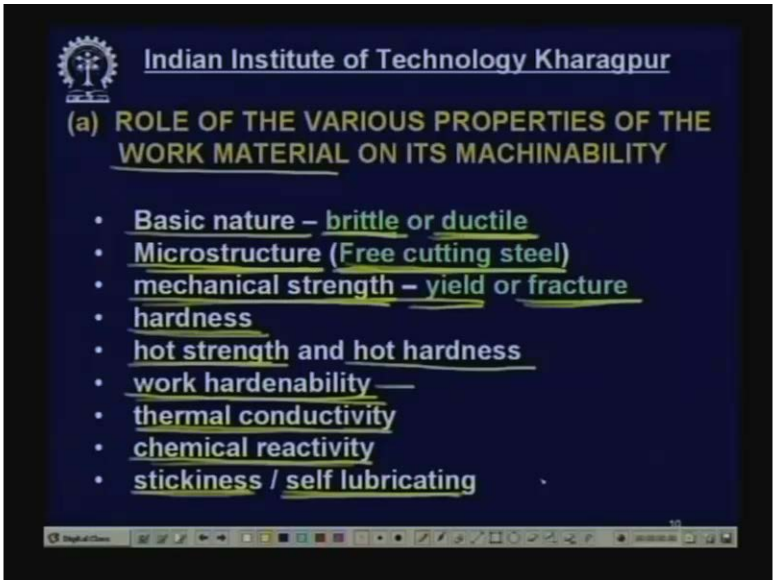

Now role of the various properties of the work material: Now let us start with the work material work material on machinability. Basic nature of the work material: Is it brittle or ductile? Yes if it is brittle say cast iron like cast iron, then cutting force will be much less cutting temperature will be much less because the fracture itself will assist machining and less contact between the chip and the tool will reduce friction. So temperature will come down and tool life may also improve. But ductile metal, though it is soft but for long continuous contact the temperature will be high, the tool life may be reduced and ductile material even if it is very soft like say aluminum or copper may cause problem and reduce machinability by inducing some problem say built up edge formation or clogging or entangling with the job. This may create problem, so brittle materials are easier to machine ductile materials also easy but if it is too ductile or too soft may be problematic.

Now the microstructure: As I already told microstructure, if it is coursed microstructure then the machining will be easy. If it is discontinuous structure, then because of stress concentration, there will be the brittle brittle fracture because toughness will fall machining will be easy, but ductile material is very difficult say mild steel, pure copper, pure aluminum and there alloys. So what is done? Sometime they are converted into the free cutting either say if it is steel say free cutting steel what what is it? They are basically two types of free cutting steel. In mild steel for example; certain amount of lead is added and that is made to disperse throughout matrix. This dispersed lead particles which are very soft function as discontinuity and solid lubricant that help reduce the cutting force by lubrication and if it can reduce the cutting force the power consumption energy energy consumption will reduce temperature will fall and tool life will increase. Like lead, sometimes sulphur is also added if we add sulphur in say mild steel or similar material then this sulphur will react chemically with the manganese present in the steel that will produce manganese sulphide.

So manganese sulphide is very soft and when this is present in dispersed form, this acts like boids or discontinuity and when it comes at a chip tool interface it causes solid lubrication so it improves not only that the morphology of this manganese sulphide inclusions play role on the solid lubricity and all this things and the morphology is favorable changed by addition of some material like tellurium and tellurium is best possible material which favorably controls can be used to control the morphology of manganese sulphide by adding sulphur to react with manganese present in steel. So these are very easy to machine. Now mechanical strength: mechanical strength. It is obviously this is the mechanical strength is very high the cutting force will increase and the constitutional problems also enhance.

Now when you say strength, it is yield strength or for ductile material and fracture strength or brittle materials hardness if the work metal is very hard then it will be difficult to machine the machinability will be reduced through increasing cutting force, cutting temperature, and wear. The wear tool will undergo wear very fast, then hot strength and hot hardness. Now usually, the strength of the work material comes down during machining due to high temperature. When you machine at high speed, at higher speed because of the high temperature the strength of the material slightly falls and that helps machining and improves machinability. Because this if the strength falls, shear strength then the cutting force will fall down and other benefits will be there. But, there are certain material which remain stronger even under high temperature for example say inconel titanium 6 aluminum 4 vanadium alloy these materials remain strong even under hot condition. But other materials like steel they become soft. Normal steel say plain carbon steel or low alloy steel they become soft with increase in cutting temperature or cutting velocity work hardenability. Some materials undergo work hardening during machining.

You know that machining is associated with plastic deformation due to plastic deformation of straining high grade straining this work hardening takes place and if the work material becomes work hardened by first pass, then the next machining pass will require lot of force to machine. Say for example, high speed steel, high manganese steel, high chromium steel these are work hardenable and they are very difficult to machine. Thermal conductivity of the work material also plays important role. If the thermal conductivity of the work material is high, then this will absorb the maximum amount of heat from the cutting zone and the cutting tool will not be very hot and as a result the tool will remain sharp for longer time and machinability will be favorable. Chemical reactivity- if the work material is very chemically reactive with the tool material then the tool will undergo very rapid wear and tear so tool life will fall and because of dull and damage of the tool the surface finish of the job will also be jeopardized.

Now stickiness or of the work piece if the work metal is too soft and too sticky like say pure aluminum, pure copper, they are extremely difficult to machine even if they are soft because of the stickiness. So this has to be overcome then again self-lubricating. There are certain materials which behave self-lubricating. So this is very favorable that reduce help reduce the force and energy consumption cutting temperature and so on. For example, say free cutting steel number one grey cast iron were the graphite present is in the form of flex that function as solid lubricant in between the chip and the tool. So this is how this material of the work work piece can help changing or converting this machinability sorry improving the machinability of the material.

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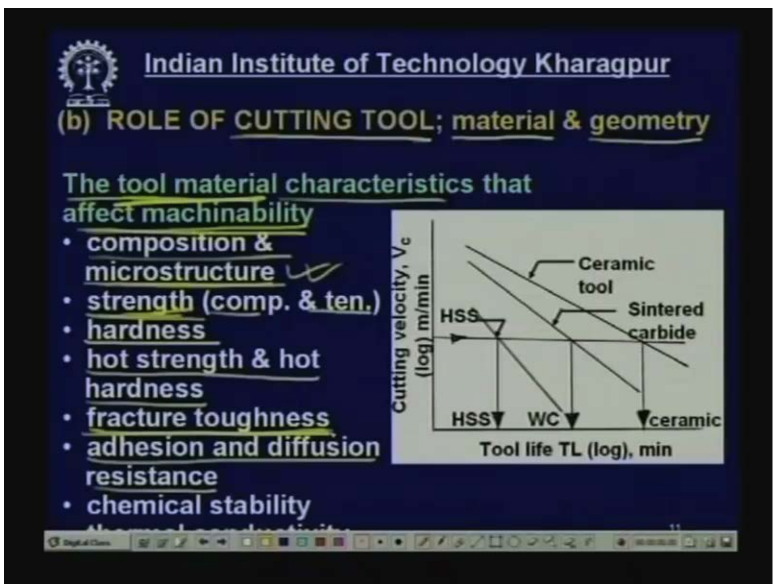

Now come to role of cutting tool; material and geometry. Now the cutting tool cutting tools now both material and geometry are equally important. They play very significant role. So I said earlier I am repeating that simply saying machinability of a material A is such and such is a wrong statement. It is better rather to say the machinability characteristics of these work material and tool combination, because tool plays very very significant role. Machinability of a work material drastically changes depending upon by which kind of cutting tool material in geometry you are machining. Anyway, let us see what are the roles of the tool work, tool materials characteristics that affect machinability, composition and its microstructure of the tool material. If the composition, if the microstructure is very fine very fine structure, then its hardness and fracture toughness will be high and life will be longer. If the composition is favorable which can withstand high temperature and can resist diffusion or adhesion the tool will long will live longer so a good machinability. Strength the tool should be strong enough it should not brake or yield or melt or plastically deform under the action of the forces so strength of the work material particularly compressive strength as well as tensile strength play vital role on machinability. Hardness- the tool should be very hard. It should not wear out by abrasion very quickly then tool life will fall machinability will fall.

Now hot strength and hot hardness; the tool material should not only be strong and hard at ambient temperature. They should retain the strength and hardness at high cutting temperature only then it will be successfully able to machine the particular material. Fracture toughness. Yes, there will be lot of vibration, jerks and stresses various types of stresses and there is a chance of fracture failure fracture fracture sorry by fracture. So the material should have high fracture toughness adhesion and diffusion resistance. Due to high temperature and pressure at the cutting zone between the chip and the tool, adhesion and diffusion take place between the chip and the tool material and both are detrimental. Both adhesion and diffusion accelerate the rate of wear of the cutting tool. So the tool will fail very quickly. So the tool material, if it is adhesion and wear diffusion resistant it will serve better like say ceramic tools.

Now the chemical stability: The tool material should be chemically stable. It should not chemically react with the work material or the environment. If it is, then machinability of the work material will fall drastically. Now here you can see one of the diagram that how cutting tool material plays vital role on machinability. So machinability is judged. The main criteria is the tool life. So this is tool life and cutting velocity. So we have plotted cutting velocity versus tool life in log log scale and these are the curves you know this is for high speed steel this is for carbide and sintered carbide and this is for ceramic for same cutting velocity. If you machine the same materials and mild steel, if you machine mild steel by different cutting tool then for a same material here the high speed steel tool will provide a tool life this much only. If it is carbide, the tool life will be almost double. If it is ceramic then the tool life may be even two times or three times that means the tool life of same material under same cutting velocity will be different for different cutting tool material.

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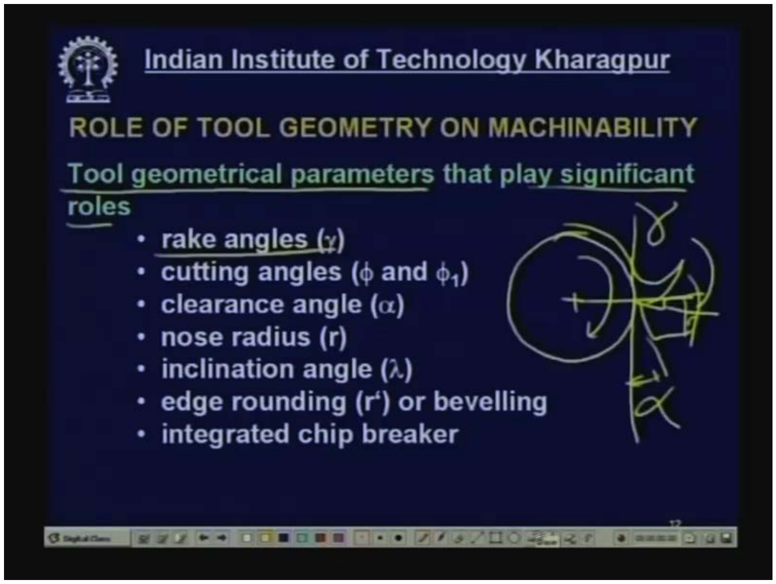

Role of tool geometry on machinability: This also play equally important role on machinability. Now tool geometrical parameters tool geometrical parameters that play significant roles. What are those? Rake angles. I am reminding you what is rake angle? If this is the work piece rotating in this direction, if you place the cutting tool here and then this angle is rake angle. The slope of the rake surface because the chip flows like this and this is the clearance angle. So this is alpha and this angle is rake angle. You have learnt it already so let me remind you. Now how does it play role this rake angles that will be discussed in the next frame. Now the cutting angles;

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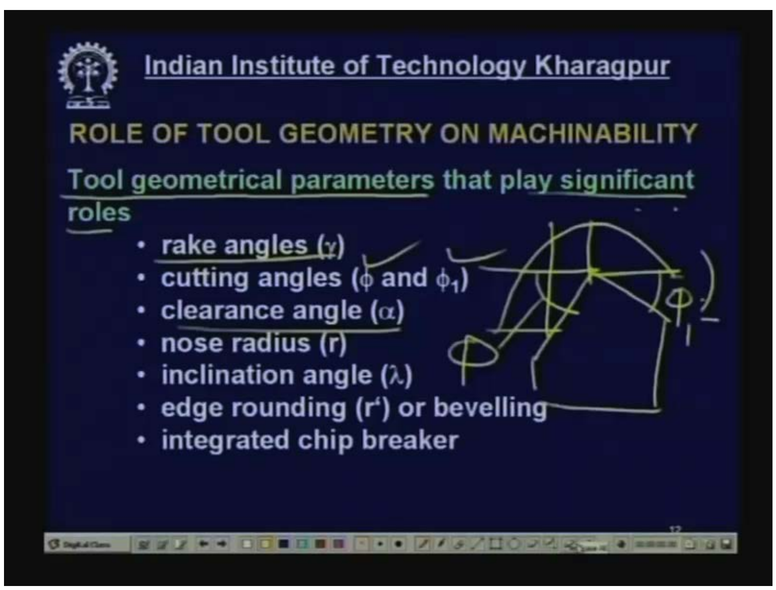

What is a cutting angle? If you measure a cutting tool like this and do turning operation then this angle is called main cutting edge angle, principle cutting edge angle this one and this is called auxiliary cutting edge angle phi 1 this one. Clearance angle I already explained and then what is nose radius?

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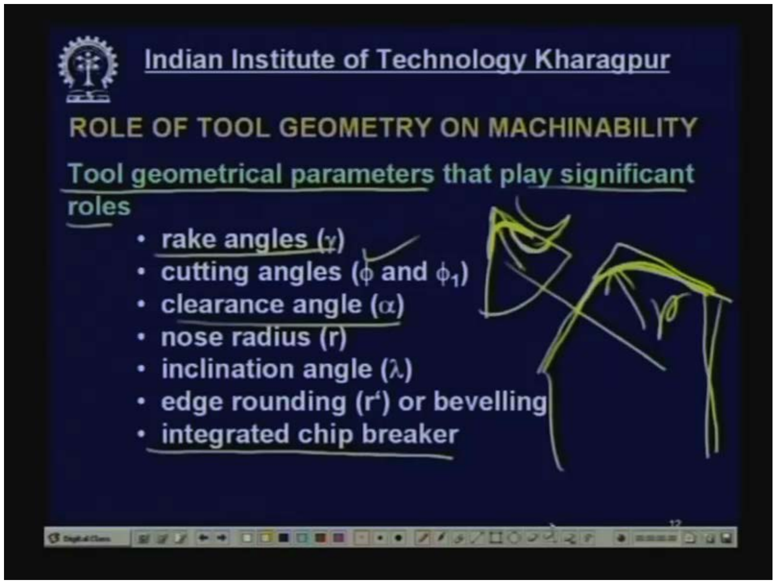

The cutting tool instead of keeping it sharp like this, it is rounded when it is rounded like this then it its performance improves that will be discussed later on. This is called radiusing of nose radius r, inclination angle of the cutting tool; edge rounding this cutting edge is not sharp. It is also this cutting if you take a section here then we will get a section like this. So this is the section now this sharp edge is rounded this is called edge rounding say 20 micron to 40 micron that also plays role on machinability or cutting ability of the tool and integrated chip breaker you remember what is chip breaker particular in the chip breaker is that here some groove is made so the chip will come here and break. So these are the various examples now we shall discuss in detail more detail.

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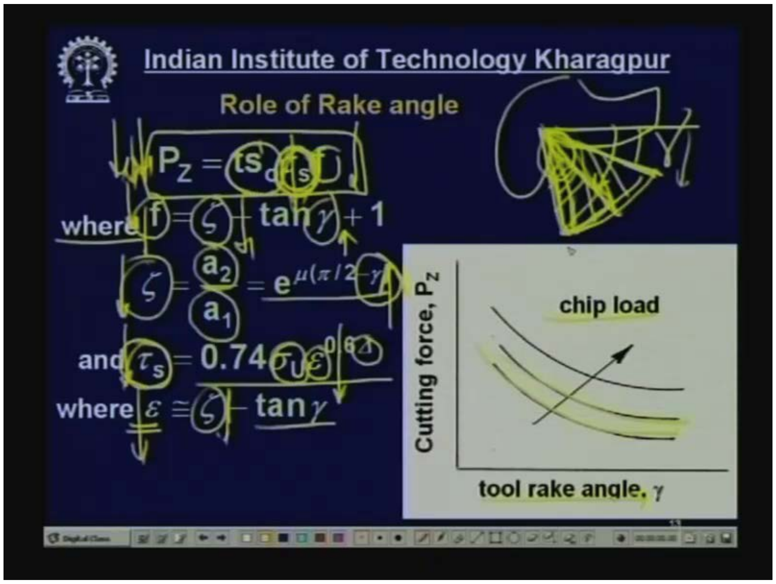

Now role of rake angle; what is rake angle? This is a cutting tool chip flows like this then this is the rake angle the slope of the cut to the surface. Now we know that P z, the main cutting force is given by depth of cut and feed product its called chip load which is the measure of productivity, shear strength of the work material under the cutting condition and a form factor. This when What is form factor? It is zeta minus ten gamma plus one. What is zeta? Chip reduction coefficient gamma is the rake angle. So if rake angle is increased then ten gamma will increase and the f will fall if f is decreased the cutting force will decrease so machinability improves. Now beside that, what is zeta? Chip reduction coefficient that is given by a 2 by a 1 that is actual chip thickness and the thickness of the chip before cut is again given by e to the power mu e to the power mu multiplied by pi by 2 minus gamma that if gamma rake angle is increased then zeta will fall if zeta falls f will fall if f falls the P z will fall so machinability improves.

Now what we see that with increase in rake angle the increase in rake angle the machinability improves through increase in reduction in cutting force, not only that this shear shear strength of the work material here that is also effected by rake angle. For ductile material, it is given by this expression 0.74 sigma u than ultimate tensile strength of the work material, ductile material epsilon is the cutting strain and delta is percentage elongation. Now what is cutting strain? It is approximately equal to zeta minus tan gamma tan gamma is very small zeta. Now if zeta if gamma is increased this gamma is increased like this then zeta will fall if zeta falls the cutting strain will fall if cutting strain falls the strength will fall if the strength falls this force will fall so we get improvement of machinability.

Now in this diagram you see that if you plot the cutting force say P z versus the rake angle then this with increase in rake angle, this force will gradually decrease like this for different chip load but again, we should remember that if the rake angle is too much increased say this much rake angle increased then what is the tool remaining tool wedge angle. The tool wedge becomes very very thin so this will make the cutting tool very weak alright mechanically weak and this may break so this is danger. So we should not increase the rake angle beyond certain limit. Beside that what heat will develop that will remain confined in a small volume, so temperature will be high. So if we keep it wide, then large area or large volume of the tool will absorb the heat and temperature will be less and it is a temperature that controls the tool life not the heat.

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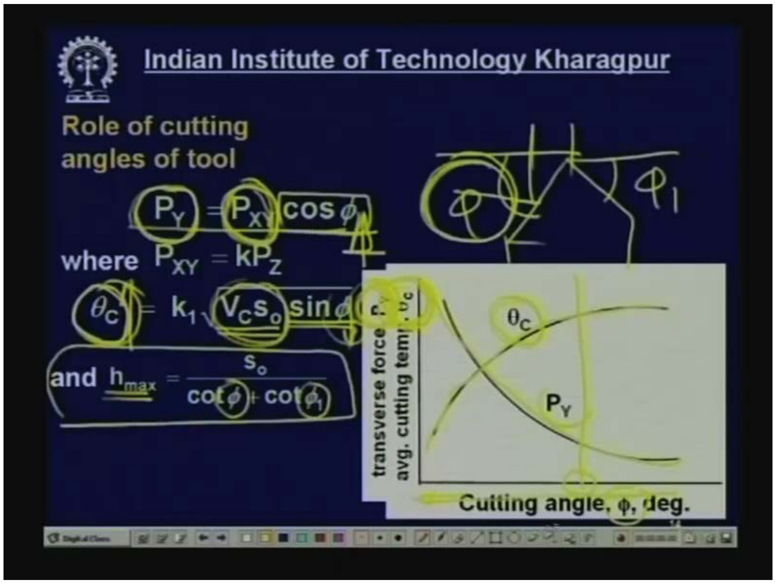

Now let us see the role of cutting angles; Cutting angles of the tools, what are the cutting angles? I showed you earlier that if this be the cutting tool turning tool for example and this is the job, then this angle is phi and this is phi 1 auxiliary cutting angle. Now let us examine say P y there is another force the radial component of the force. They are in turning say there are three forces P z P x and P y. P y is the transverse force which is the most detrimental in respect of and because it causes dimensional inaccuracy by plastic by elastic deformation, it causes vibration and lot of things. So P y is detrimental, it should be reduced as far as possible this is driven by this expression P y is equal to P xy multiplied by cosine phi P xy is proportional to P z and P z is proportional to the productivity.

So we cannot sacrifice productivity P xy has to be there but, whatever be the value of P xy for productivity P y should not be allowed to increase because it is detrimental. How can we control it? Here is another component cos phi. If we increase the angle phi, then say up to 90 degree, the cos 90 is 0 so whatever value of P xy P y will be zero so by controlling this phi we can control this magnitude of P y. Here you see that P y that is transverse versus the principle cutting edge angle it decreases like this. So phi should be increased say up to 75 degree 80 degree and 90 degree if possible to control P y but on the other hand, what we find that the cutting temperature which is also detrimental if it is very high is proportional to velocity and feed, root over if the velocity and feed are increased for the sake of improvement in productivity there cutting temperature will rise which is harmful but there is another component phi if phi is reduced than whatever be the value of velocity and feed this value of temperature will be controlled reduced and then the effect of the cutting temperature on cutting tool and job will be less detrimental. So cutting temperature has to be reduced by not by sacrificing velocity or feed but by reducing phi so here you see that if the angle phi is gradually reduced then the cutting temperature decreases.

Now here it is very interesting to note it was discussed earlier also in the previous lecture you remember that if you decrease phi or say rather increase phi from 0 towards 90 degree then the P y will gradually decrease favorably but temperature will rise unfavorably otherwise if you if you decrease it you will get the results. Now you to judiciously select what should be the cutting angle if it is ah such that the P y is more detrimental than the rise in temperature than higher value of phi is desired. If the temperature becomes more predominately detrimental then lower cutting angle should be preferred this is how it has to be justified. Say for example, if we machine by high speed steel steel by high speed steel which cannot withstand temperature, the cutting angle should be low. If it is carbide which cannot withstand vibration or due to P y then angle should be large. So this phi is so important in respect of P y the vibration, surface quality of the product, machine tool condition as well as temperature which governs the quality of the product surface integrity and tool life. This is another thing to be noted that this phi and phi 1 both also govern the surface roughness.

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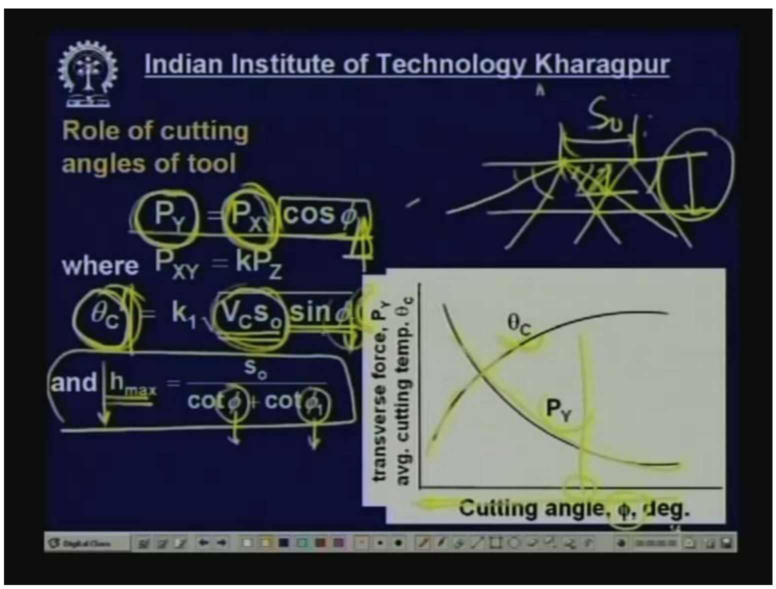

This surface roughness you remember that, if you take a sharp tool then in between the tool this material remains uncut and this is the measure of surface roughness. So surface roughness h max becomes so large but if we make it round or the angles larger sorry angle smaller this angles smaller then say phi and phi 1 h max is given by it depends upon the feed this distance between this two. Let me draw it in a clean way. If the tool is sharp and this angle phi 1 and phi then this is the surface roughness. This is the amount of surface roughness. But if we take smaller angle, then this will be the roughness. So with the reduction in the equation also states that this is feed if we just connect this feed S o and the phi and phi 1 they will become h max. The h max will be expressed by this expression which indicates that if phi and phi 1 are reduced gradually then this value of h max will gradually decrease, surface finish will improve. So this phi and phi 1 play so significant roles. Now what about clearance angle? Clearance angle of the cutting tool;

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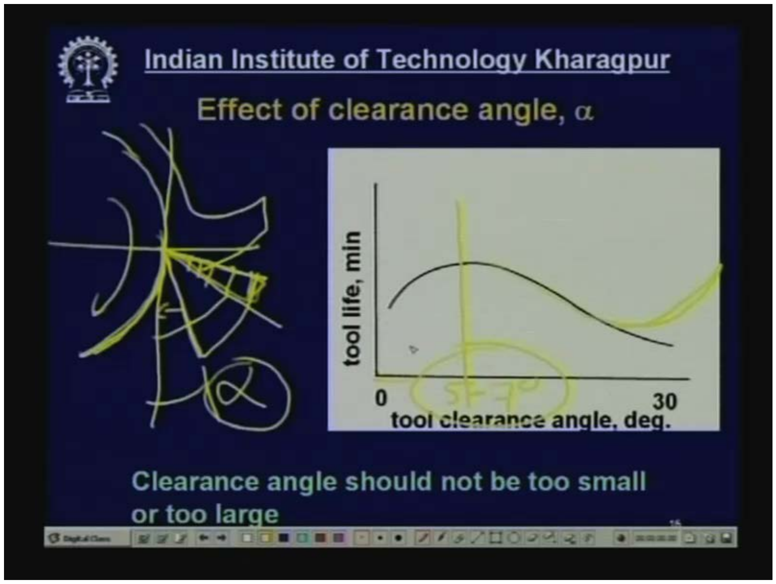

Suppose this is the part of the work piece getting machine rotating and this is the cutting tool and the chip is flowing like this then where is the clearance angle? This is the clearance angle alpha. This clearance angle play why it is given, to avoid rubbing because between the finished surface and the flange surface of the tool they should be widely apart for that some angle is provided this is called clearance angle and this has to be always positive. Now if this angle is very small then this will be inadequate insufficient to avoid rubbing and the tool life will be reduced because of the rubbing action a lot of flanker will take place and the quality of the surface will be also damaged because of this rubbing action.

If the angle is too large if the angle is too large then the tool become very thin and this life will be it will be very weak thermally as well as mechanically. So the life will be reduced and the tool may break. Now this diagram depicts this thing. If you plot tool life versus tool clearance angle this is the optimum say 5 to 7 degree. If it is less than that than the tool life will gradually decrease because of rubbing action and if we increase it then this will improve but it can if it is too large than it can decrease again. So this clearance angle should be very carefully chosen for getting desirably high machinability. Now come to role of tool nose radius; nose radius what is nose radius?

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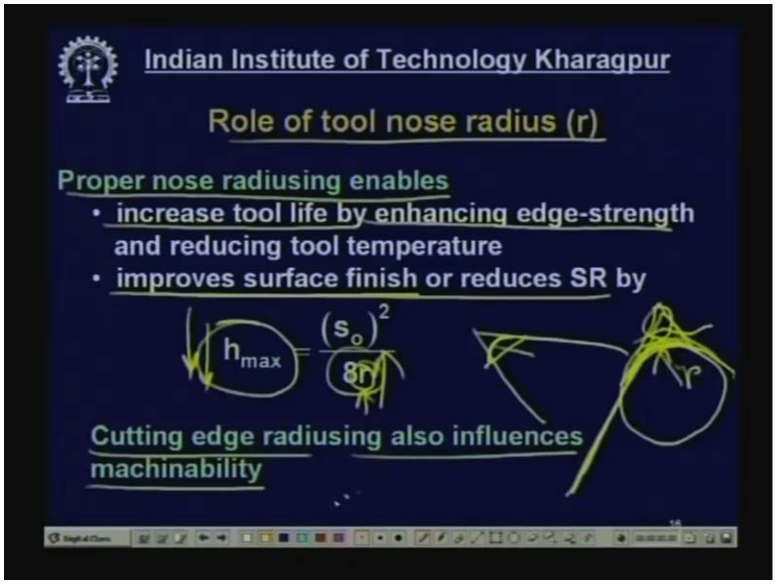

This is the tool, this is radius. The sharpness is reduced and this is r and the surface finish the or the surface roughness will be proportional to feed square that is the measure of productivity and the eight r, r is the nose radius. If nose radius is increased then surface roughness will decrease and surface finish will improve. Now role of tool nose radius; proper nose radiusing how does it help? proper nose radiusing enables proper means adequate if you make it too large then again more problem will arise some other problem this helps in increase in tool life by enhancing the edge strength. If it is very sharp this will be very weak and this will break and this is very detrimental. So this will give strength mechanical strength of the cutting edge and reducing tool temperature. Since the heat will be distributed over wider area unlike here the temperature will be reduced that is a favor.

Now improve surface finish. Now here you can see that, if we can give larger nose radius the surface roughness will be decreased and finish will improve. So this improves surface finish. The cutting edge radiusing also influences machinability. Now here you can see that it improves now the cutting edge radiusing what is that? This cutting edge which is not really very sharp it is also rounded by 20 micron to 40 micron or it is beveled sometime. So this also improves the strength of the tool and machinability or machining power. Now role of the process parameters, cutting velocity, feed and depth of cut; Increase in cutting velocity. Now it has got two effects: It raises the cutting temperature and reduces tool life this is obviously but it also helps reduces cutting force because of softening of the work material prevents built up edge formation and improves surface finish and tool life it improves surface finish increases metal removal rate for material like ceramic tools.

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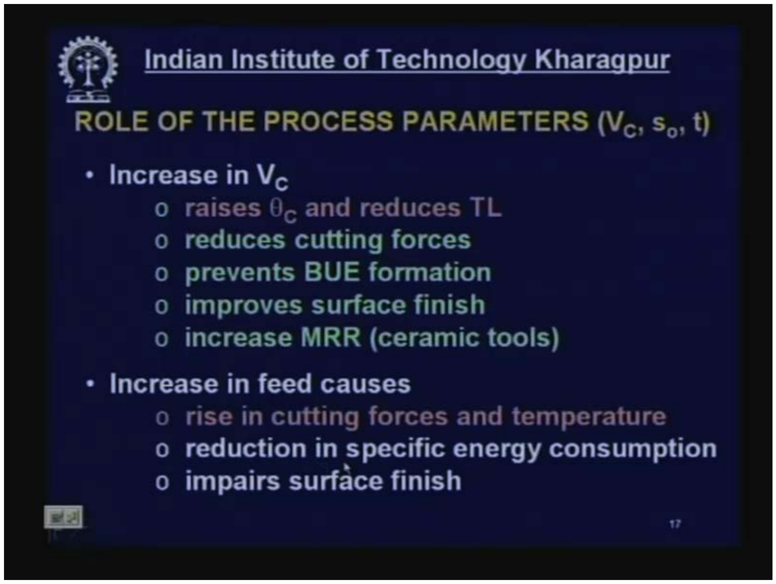

Now increase in feed that also has got two effect detrimental and favorable detrimental rise in cutting force and cutting temperature impairs surface finish but it helps reducing the specific energy consumption. Now which one is predominate that has to be identified and accordingly it has to be decided whether feed has to be reduced at the cost expense of velocity or it has to be increased reducing cutting velocity. So the velocity and feed should be judiciously you know decided they are apportionment. Now the role in the cutting fluid role or purpose of cutting fluid application on machinability;

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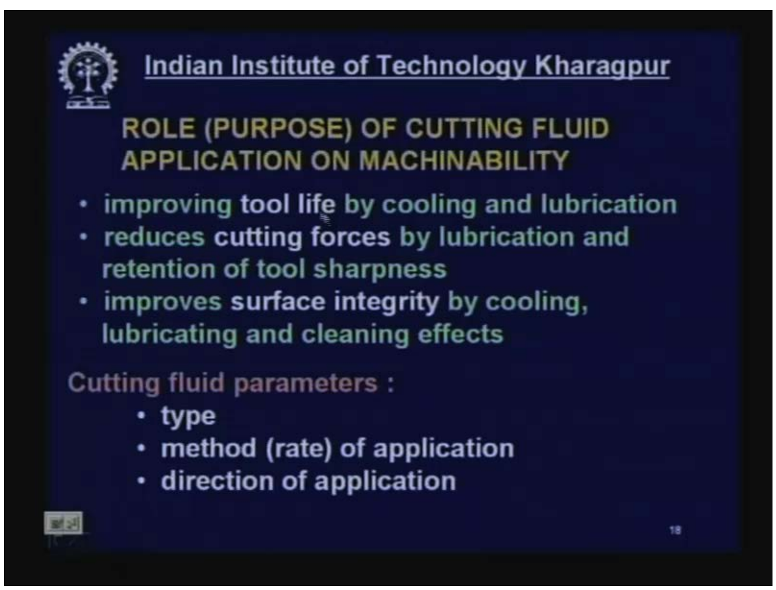

Role is very good. So for the same purpose but it achieves that role or the purpose the cutting fluid is applied. What are the purpose or what the roles of cutting fluid application on machinability. See improving tool life it rest it improves the no remarkably the tool life by cooling and lubrication. Next the cutting fluid that is applied lubricating and by cooling reduces cutting forces by lubrication and retention of tool sharpness. If the tool remains cool, then it will then retain its sharpness by preventing plastic deformation and wear. Improves surface integrity by cooling and preventing, other say built up edge formation, etcetera, lubricating and cleaning the effects. So these are the beneficial effects of this cutting fluid application in respect of tool life, cutting force and surface integrity and all of which are nothing but the criteria of judgment of machinability. So machinability is substantially improved by this process if judicially selected.

The cutting fluid parameters: Now the cutting fluid parameters are also to be taken into consideration. What type of cutting fluid you are going to use that will depend upon the tool material work material and type of rough machining or finish machining. How do we apply drop by drop or by flat or by jet the direction of application from top from back from front this all this things will matter this thing will decide the effectiveness of cutting fluid application. Now you have heard you have seen that so many parameters work work material parameters, the properties, physical, chemical, mechanical properties then the process parameters cutting velocity and feed, the tool parameters geometry and material play important role and then the cutting fluid application and so on. Now, let use summarize. Possible methods of improving machinability of a material or a material tool combination;

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So machinability means ease of machining. So we need we wish that material be easily machined. So we want machinability should be improved should be high and that also we also know that machinability improvement means reduction in cutting force reduction in temperature improvement in tool life increase in surface finish and so on. How this can be achieved? This figure shows that here we can see that favorable change in microstructure and properties of the work material like proper heat treatment, like proper additive inclusions, and other treatments. So proper selection and application of the cutting tool material and geometry. Levels of the process parameters better we see select high speed at the cost of feed but when we will select this velocity and feed, we should keep in mind that not at the cost of productivity that has to maintained. Then cutting fluid what type of cutting fluid that is the properly selected and applied.

Application of special techniques as I told you as and when required like say hot machining, curve machining, stress machining, dynamic machining, etcetera. Now those should been should not be used everywhere. Those technique should be used if essential only, where the machinability of certain material is really very poor like say exotic materials naiad, inconel pneumonic, high speed steel, high manganese steel and so on feasible. All techniques are not always feasible it has to be feasible and economically viable and finally we should also see that special technique should be environment friendly. It should not pollute the environment and should not be hazardous to the operator. So if we can select and employ this parameters and techniques and environments properly, we can improve machinability substantially through reduction of cutting force and its consequences, cutting temperature, then surface finish, improving surface finish reducing tool wear rate that means improving tool life and improving surface property surface finish. Not only surface finish the surface integrity as a whole and we can also get very favorable chip. So this has to be done.

Thank you very much.