Manufacturing Processes II
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Lecture No.12
Control of Cutting Temperature and Cutting Fluid Application

Now our course is Manufacturing Processes II and the module II is containing

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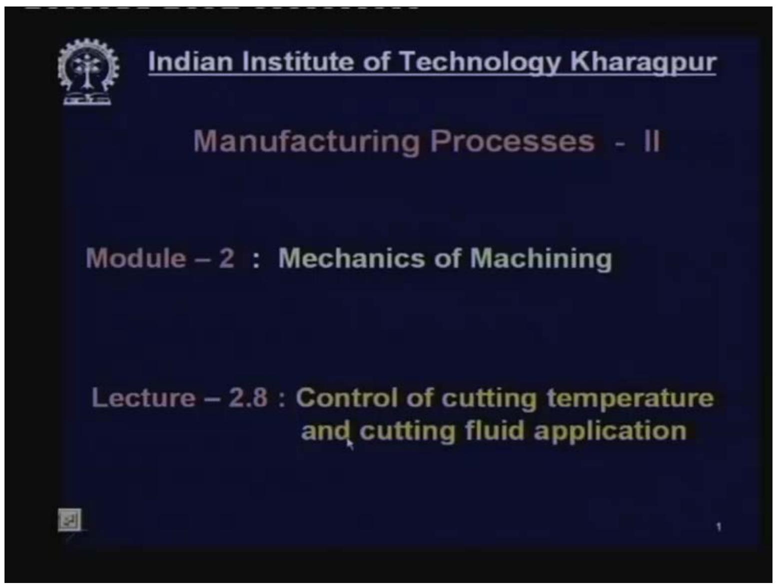

which is Mechanics of Machining and the lecture -2.8. In the previous lectures, you have heard that different aspects of cutting temperature that develop in machining and this cutting temperature is very detrimental for the tool as well as for the job and this has to be controlled or reduced. So our topic today is control of cutting temperature which is normally done by cutting fluid and so our topic also includes that control of cutting temperature and cutting fluid application. Now what are the course content within this lecture?

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Specific Instructional objectives: The possible ways of controlling cutting temperature, there are different methods, only three methods are very common we shall discuss. Then the purposes of application of cutting fluids what we apply the cutting fluid in the machining. To sort the purpose what properties the cutting fluid should posses next and next the principle of cutting fluid action. How does it work? The type of cutting fluid and how to select this cutting fluid for different purposes, different tool work materials, then demonstrate the methods of application of cutting fluids because effectiveness of application of cutting fluid depends upon how do we apply the cutting fluid.

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Now what are the basic methods of controlling cutting temperature? There are three basic methods .One is a proper selection of the cutting tools; the material and geometry both of which play an important role on the cutting temperature, magnitude and its effects. Next is proper selection of the process parameters. The principle of process parameter is cutting velocity and next to feed so properly they have to be selected. Keeping in view that metal removal rate remains unchanged and third but most important is proper selection and method of application of cutting fluid. Now first is the cutting tool.

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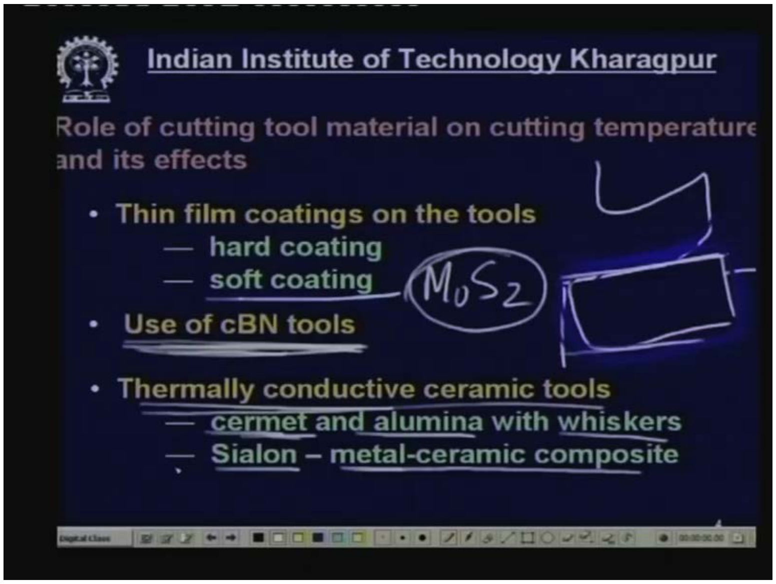

Role of cutting tool material on cutting temperature and its effects: The cutting tool material plays important role, quite significant role on the cutting temperature because if the cutting tool is not very hard and wear resistant, then it will undergo plastic deformation and wear, so there will be more heat due to friction, rubbing and cutting force. So, the tool has to be very hard, and wear resistant, and very stable, and the friction should be as this as possible. Some examples are given here. Say thin film coatings on the tools say carbide. In a carbide tool, say this is the tool on which the chip flows. Here is the surface were rubbing takes place.

Now, if there be a coating given here on the surface, then the chip will flow above this. Now this coating that is given not only in parts wear resistance and heat resistance but also this layer of coating provides anti friction, reduces the friction and if the friction is reduced, the cutting force will come down, cutting energy required will come down, heat develop will come down, as temperature will come down. So now the coatings may be this coating that is given on the tool can be hard coating or thin coating by chemical vapor deposition called CVD, or physical vapor deposition PVD and there are various methods of giving this hard coating of material like titanium carbide, titanium nitride alumina, and so on.

Carbides and many materials and sometimes the soft coating can also be given say moly disulphide molybdenum disulphide is a soft coating. This when pasted on the tool surface, this acts very well as lubricants- solid lubricant which helps reducing force and hence heat generation and temperature. Another example say use of CBN tools you know the CBN tool material is very very hard and chemically stable against work material and temperature because of hardness and wear resistance, the CBN tools remain very sharp all along and because of the sharpness, and its retention the cutting force does not increase. The cutting force remains slow and so cutting energy required also remains stable and the heat does not raise much. So, by using this kind of CBN tool which is very expensive, no doubt but helps reducing the cutting temperature.

Third is thermally conductive ceramic tools. Now ceramic tools are used widely now a days for machining various materials like steels at high speed, ceramic tools are non conductive. So the heat what is developed and received by the tool that remains confined at the surface. As a result, the heat the temperature at the cutting point become very high and the tool gets damaged. Now, by increasing the thermal conductivity of this ceramic tool heat is allowed to disperse throughout the matrix of the tool, so the cutting temperature comes down into the cutting tool. How it is done? So in alumina like ceramic some metal like titanium carbide hafnium carbide, titanium carbide are added they called cermet and sometimes silicon carbide whiskers or rods fine rods are added into that which not only infer toughness and a strength but also certain amount of thermal conductivity that improves the performance of alumina tool.

Another tool is Sialon- next is metal-ceramic composite. In ceramic like alumina or silicon nitride, some metal like aurum specially silver kind of thing is added which not only increases the thermal conductivity allowing dispersion of the heat through the matrix, but this silver functions will comes out at the top surface of the tool that function as solid lubricant and hence reduces friction, cutting force, energy and temperature. Now the role of cutting tool geometry

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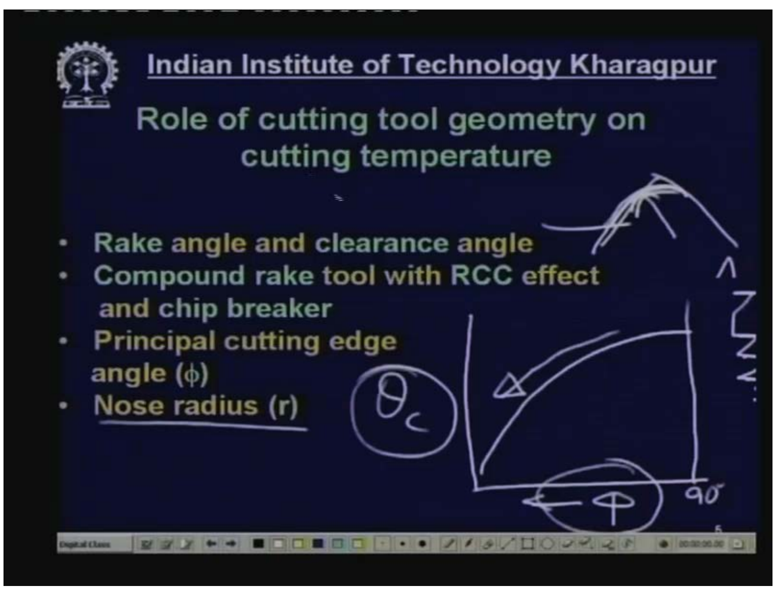

Now as we have heard number of times that along with the cutting tool material the geometry of the cutting tool plays also very very significant role on machinability of any material. Say for example: rake angle and clearance angle. Now when we machine say

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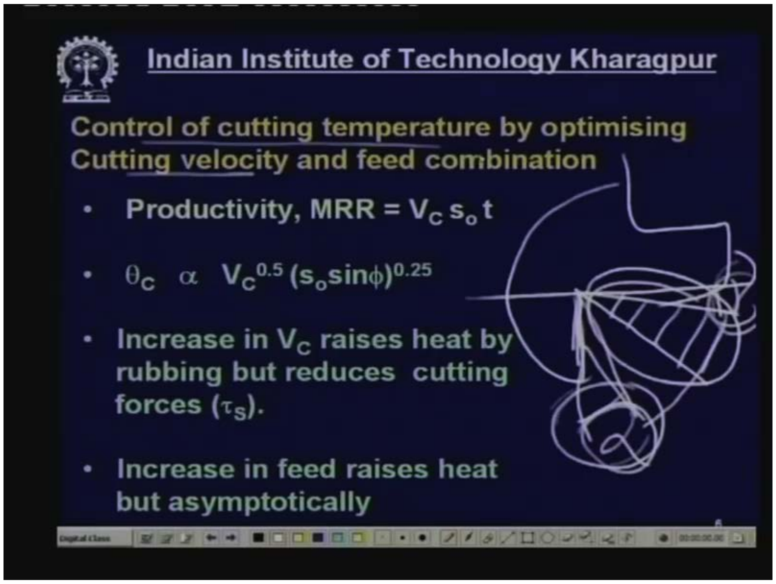

say this is the tool and chip flows like this. This is the rake angle and this is the clearance angle. Now why rake angle is given? You please recall. Rake angle is given to reduce the cutting force. If the rake angle is large and positive the cutting force comes down if the cutting force come down the mechanical energy required also becomes less and heat generation and temperature also come down. Similarly alpha, this alpha also play if alpha is not available then there will be lot of rubbing at the tool and the job. There will be lot of heat generation additional heat generation. If this clearance angle is too large, then the wedge angle becomes so small of the tool then the temperature of this tool will be very high.

So this rake angle and clearance angle and some other angles have to be chosen very judiciously if we wish the temperature be reduced but we have to keep something in mind control of cutting temperature by optimizing cutting velocity and just a minute. Now here the rake angle and clearance angle play important role. Now what about the compound rake tool and restricted content cutting tool? You see that what is compound rate tool the negative rake, positive rake and then built up edge sorry the chip breaker. So when the chip will flow it will flow like this and there is positive rake and negative rake this is called restricted cutting effect what the benefit that the contact length becomes less so the frictional loss which is converted into heat will be reduced and secondly the chip breaker will also control the the friction total friction by controlling the chip tool contract length.
So by imparting this kind of tool geometry the temperature can be controlled. Now, the principle cutting edge. What is principle cutting edge?

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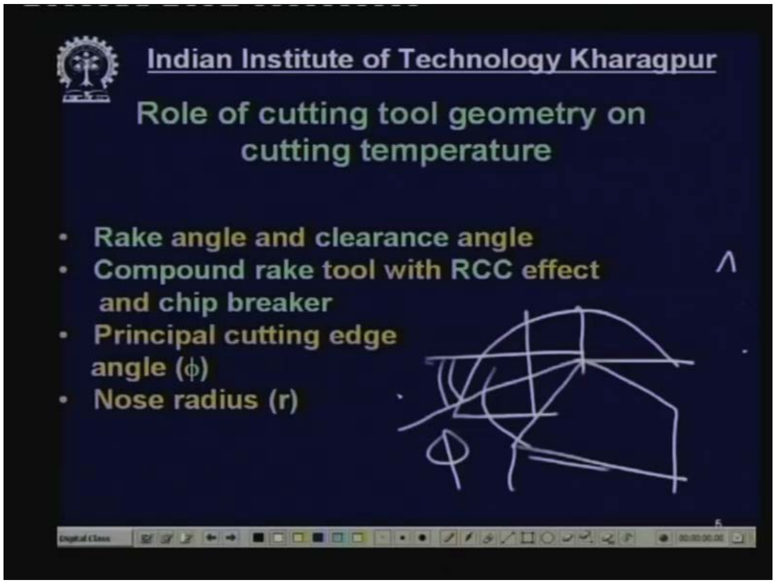

What is principle cutting edge? This is the principle cutting edge you remember that this is the cutting turning process and this angle is principle cutting edge angle. Now this principle cutting edge angle if it is less say like this, this much then temperature will be less and if it is large then the temperature will be large for example it is like this if you

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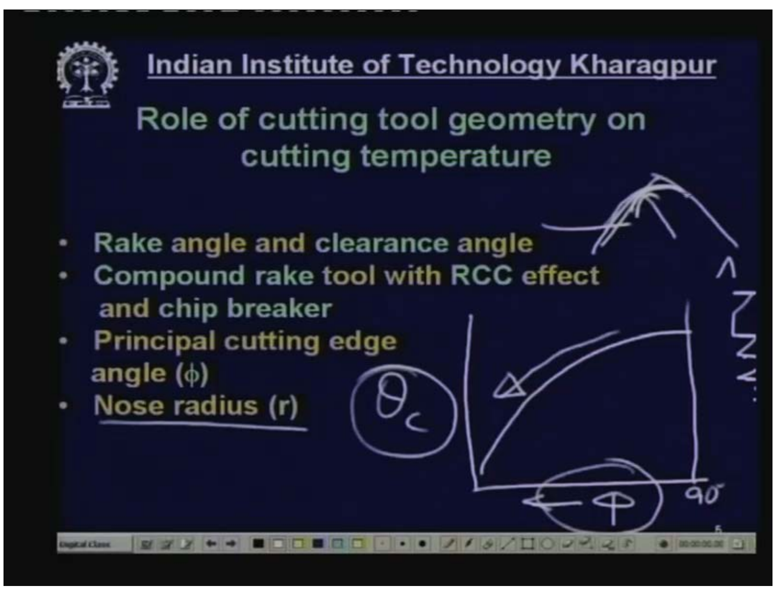

plot say phi of the cutting tool and temperature it will go like this. So this is maximum when it is 90 degree. So with the reduction in this principal cutting edge angle, the temperature can be reduced for same metal removal rate without changing velocity, feed, depth of cut occur we can control the temperature to some extent by controlling the tool geometry. Similarly the nose radius the nose radius of the tool if it is large nose radius then the contact length between the job and tool increases and that helps reducing the average cutting temperature. So this is how the temperature can be controlled by controlling the tool geometry. Next is control of cutting temperature by optimizing cutting velocity and feed combination.

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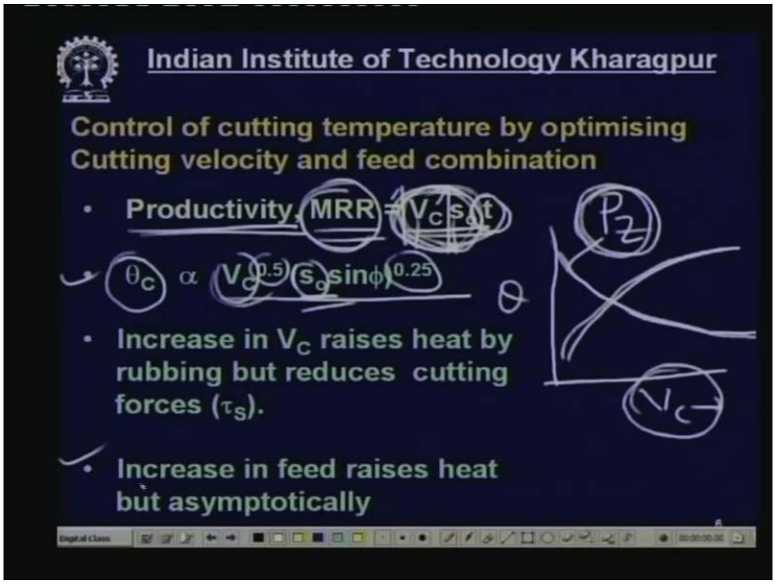

Cutting velocity and feed cutting velocity and feed these are the process these are the process parameters cutting velocity, feed and depth occur and product of these gives a metal removal rate or productivity. Now productivity cannot be hampered. We cannot sacrifice if we reduce velocity or feed then definitely the temperature will come down but we have to sacrifice the productivity. So that has to be retained. Now what we can do? Product keeping the product remaining same t is not in our hand it is it is beyond control but the velocity and feed can be controlled, either increased or decreased in such a way that the productivity will remain same that the product will the value of the product will remain same but the velocity can be reduced can be increased, the velocity of feed can be reduced or increased. But whatever we do keeping the product same.

Now while this variation will enable reducing the temperature. While doing so, well optimizing or varying or controlling the velocity and the feed. Something we have to keep in mind. The important things which are number 1, that the cutting temperature is a function of the velocity and feed. Now here you see it is more susceptible to velocity because index is 0.5 and it is less susceptible to feed because index is 0.25. This is one thing to be remembered. Second increase in velocity. Now if we increase the velocity, then what will happen? Suppose we increase the velocity, then the cutting temperature will increase because the rubbing speed increases more energy is input. So heat will increase and temperature will rise, but at a same time with increase in velocity, the cutting force comes down. So this is the cutting force. Now, when the cutting force comes down, the mechanical energy requirement comes down. So this way the heat generated is reduced.

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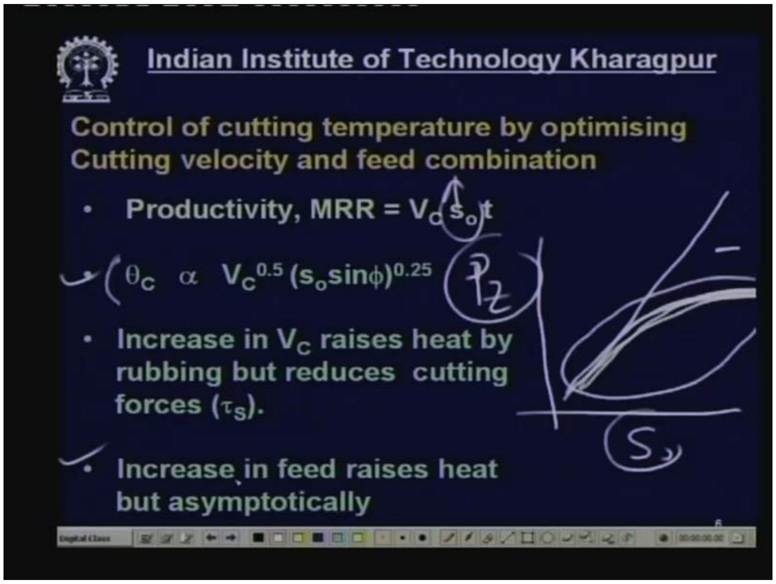

So here we find that increase in velocity has got two effects. One it raises the temperature, it helps also to reduce the temperature both way. So we have to find out the total effect. Third, increase in feed how does it affect? If we increase the feed, then force say P z main force that according to equation, it should go straight like this. So as we increase feed, then the energy will increase and temperature will rise. But practically, it goes asymptomatic. So, we have to take into account this in relation asymptomatic ness of the force with increase in feed. So keeping all these factors in mind, we have to select velocity and feed in such a way that optimizes the selection such a way that temperature becomes minimum. But keeping in keeping in view that MRR the metal removal rate of productivity does not change. We cannot sacrifice that. Next we find the purposes of application of cutting fluid in machining and grinding.

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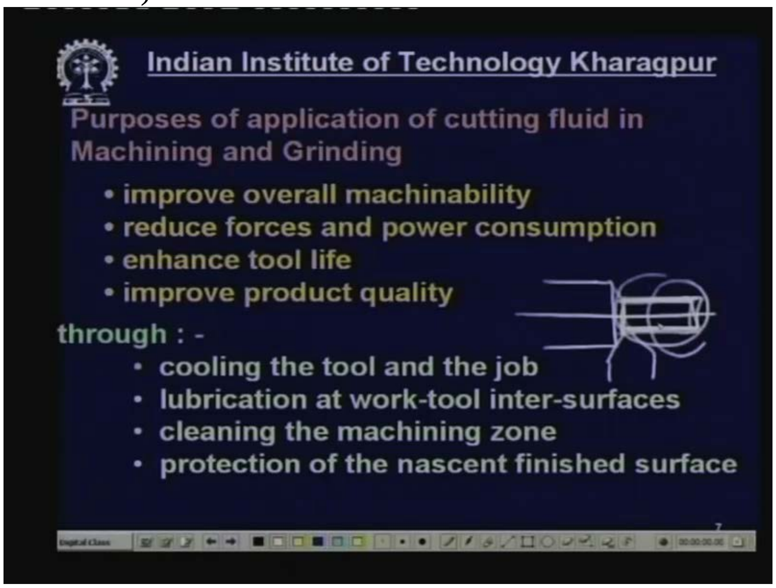

Now what are the purposes? Very clear, the aim of application improvement of overall machinability ease of machining, reduce cutting forces and power consumption. So that will help in power saving energy as well as heat generation enhance tool life, tool life will improve improve product quality. So, in all the way we are getting benefited if the cutting fluid are applied and but before application it has to be properly selected. So, we achieve all these benefits through application of cutting fluid through some processes what are those? Through this cutting fluid application provides these benefits through cooling cooling the tool and the job. Then lubrication at the work tool and chip tool inter surface at the rake surface and the flank surfaces.

So at the rake surface and flank surfaces. So were rubbing takes place and heat is generated here and here. So there has to be lubrication to reduce the force friction force and heat generation. Then third purpose is cleaning the machining zone. In the machining zone, this is the machining zone were lot of chip particles and débrides develop and this debris or chip particles if remain in position they produce lot of damages to the job as well as to the tool. So this debris has to be removed immediately by washing away the particles by application of the fluid and this is cleaning and finally protection of the nascent finished surface.

When machining is done, once a machining is done, suppose this is a rod we machine and produce the finished surface. So this is the finished surface now these finished surface which is very nascent and if it comes into contact with some gases like nitrogen oxides sulphur dioxide, hydrogen sulphide which are present in the atmosphere or oxygen this will be spoiled. So there will be thin layer of cutting fluid struck on the surface which will protect contamination of the surface from the gases detrimental gases present in the atmosphere. So this is how cutting fluid gives us the benefits.

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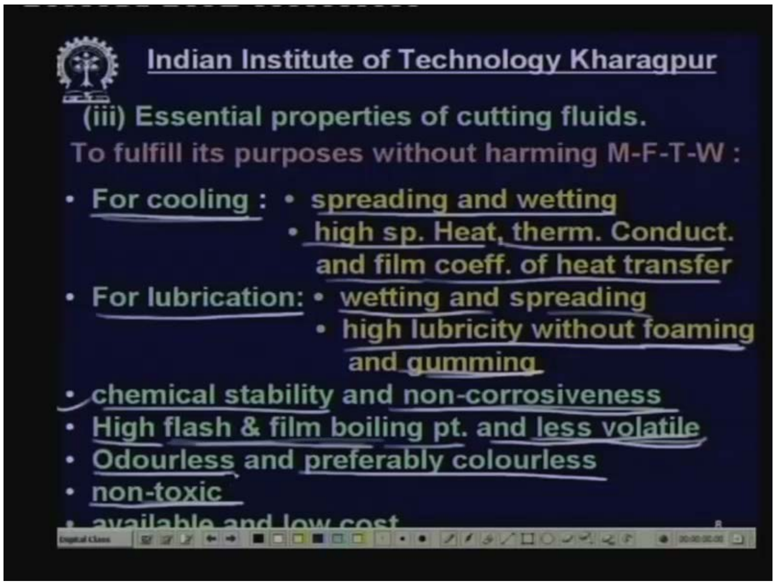

Now to fulfill the purposes for which cutting fluids applied, the cutting fluid should should possess certain qualities, certain properties. What we say? Essential properties of cutting fluids to fulfill its purposes but without sacrificing or damaging machine fisher tool work system that is it should not rust the machine tool part it should not mix with the lubricating oil and so on. So what properties needed? Main properties: The main properties needed for cooling purpose spreading and wetting. First of all the cutting fluid should spread immediately over the tool surface and job surface and it should wet the surface otherwise it will not transfer the heat.

Second it should have high heat carrying capacity that depends upon high specific heat, high thermal conductivity and high film coefficient of heat transfer. These three values if high, then the heat carrying capacity will increase and you know water has got all these properties and this is essential for the fluid for lubrication purpose what property we need? Again wetting and spreading property it has to spread the cutting fluid then high lubricity, it should be oiliness has to be there but without foaming and gumming because if the cutting fluid undergoes foaming and gumming under the high pressure and temperature then this will hamper the lubricating effect. So this has to be prevented that kind of fluid has to be selected.

Next is chemical stability; this cutting fluid should not decompose or change under the temperature and this should be also non-corrosive. It should not corrode the machine parts and tools and jobs, high flash and boiling film boiling point so that it remains stable up to a high temperature and it should not be volatile. It should not evaporate out, it should not be volatile. Even if it is volatile less volatile and it should be the the cutting fluid should be odorless. There should not any smell, bad smell or any kind of smell and preferably colorless that is transparent why transparent because if it is transparent, then the visibility will be there the worker the operator of the machine can see what is going on exactly at the cutting point. So it should be as far as possible transparent but odorless is a must, then nontoxic. This cutting fluid should be should not harm the operators like skiing you know or it should not be harmful to the eyes or respiratory system and all these things so it be non toxic and available and low cost. The cutting fluid you may select but it should be available, otherwise how can we use it and of low cost is obvious it has to be available and economic. Now what is the principle of cutting fluid action?

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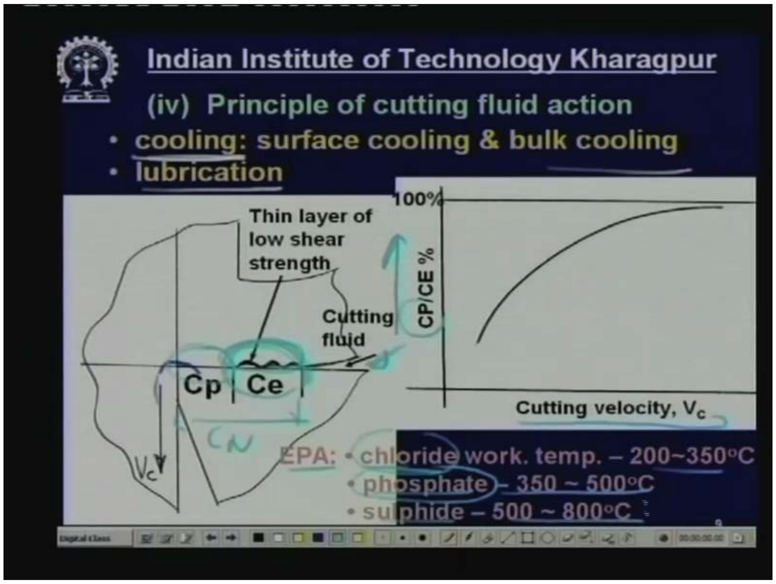

How really it works? So it has got four purposes from bottom protection of the surface, cleaning the surface that is washing away, then lubricating and cooling. Now how does it cool? The cooling it does the cooling it does by the coolant whatever we use the cutting fluid that has to reach in the rubbing zone. These are the rubbing zone. This is one rubbing zone and this is another rubbing zone that is the chip tool interface and this flank surfaces. Now here the cutting fluid has to reach to take away the heat from the sources. If it cannot, atleast from the outside this will heat this is a bulk cooling. This will be able to cool the entire job and tool to remove the heat from the cutting zone to some extent. The lubrication; For lubrication were lubrication is necessary a for friction reduction where friction takes place where there is a rubbing were rubbing takes place two places. One is the chip tool interface were tremendous amount of rubbing takes place and high pressure and temperature and at the work tool interfaces that is flank surface.

These are the areas were these cutting fluids should reach to cause lubrication or oiliness but how does it work? This is the contact length. These are chip tool contact length this much and this is called natural contact length. This chip tool contact length has got two parts; one part is plastic contact length which is bulk contact or solid contact and other one is elastic contact through high points of asperities. Now the cutting fluid when applied, it can reach within this elastic contact zone but it cannot reach in the plastic contact zone. So and again it has been found, that it increase in velocity when the cutting velocity is increased the entire contact length becomes plastic were cutting fluid cannot reach and if it cannot reach it cannot lubricate.

So here you can see that, with increase in cutting velocity the ratio of plastic contact length to elastic contact length gradually increases and becomes hundred percent after at certain point at a very high speed and the elastic contact zone totally disappears and the cutting fluid cannot enter at all and lubricating effect disappears. So, it is stated that it increase in velocity the lubricating effect gradually diminishes. So at high speed lubricating type of cutting fluid is not preferred, cooling type fluid has to be selected.

Now how does it work really at this zone and this zone this elastic contact zone, the cutting fluid is pulled by the capillary effect or the viscous or capillary effect or surface tension and when this cutting fluid which contains some chlorine, chloride, sulphide or phosphate that reacts with the work material or the chip material at its bottom surface under high temperature and pressure.

The reaction product the physical reaction that takes place produces an another layer of material and the chip tool interface within this elastic region which is very soft in nature which is you know low shear strength and functions as solid lubricants. Therefore with the elastic region, the friction decreases drastically because of this formation of a low shear strength film by physical reaction between the fluid or that of the fluids and the work material. Sometime this provides the phosphate or sulphide, kind of additives are deliberately added in large quantity to enable reduction of this friction under heavy cut. These are called extreme pressure additives which can be chloride which can be phosphate, which can be sulphide.

If the cutting temperature is low say around 200 to 350 degree centigrade like when you machine say mild steel by high speed steel. Then chloride type of extreme pressure additive can be added to at the two impart more lubricity or lubricating property. If the temperature is moderate, then phosphate is better and at high temperature say high heavy cut or machining very hard and strong as steels, then sulphide type of extreme pressure additive is added into the cutting fluid to impart more friction resistance by lubrication.

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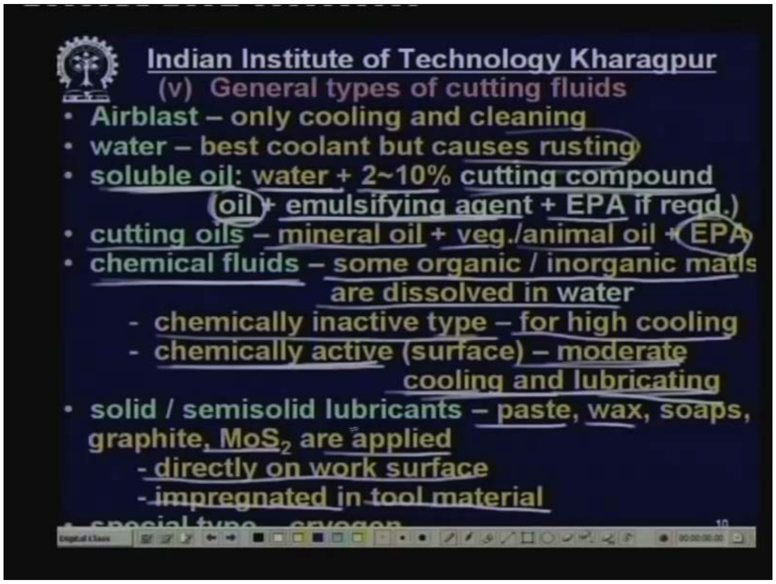

So what next? The general types of cutting fluids; Now we have seen the what are the purposes of application of cutting fluid, then we have seen what to serve the purposes, what properties the cutting fluid should poses and then what are the different types of cutting fluids available and develop so far. We have to be familiar with them and we should also know their characteristics, the characteristics of those fluids and then we have to select very properly. What are the different types of cutting fluids normally used?

We used Airblast. Airblast is used were when cutting fluid in the liquid state cannot be allowed or cause problems like only cooling and air blast is given only for cooling and cleaning not for lubrication, then comes water. Water as we know, having the maximum specific heat. it is it is the best you know cooling agent. So best coolant but it is its lubricating property is almost nil and it also causes rusting to the machine parts. So in that way, water is not preferred but for cooling purpose water is best no doubt. Then what is soluble oil? Soluble oil to impart some anti rusting property to impart some anti rusting property little oil is added into water and this is called soluble oil. This is also called slurry its looks like milk you know in milk fat particles remain suspended and for which it looks white.

Here also oil little amount of oil is added into water and it is dispersed by atomization and it looks like milk. So this oil is generally used for imparting some lubricity and anti-rusting characteristics. Now what is soluble oil then water basically 90 to 98 percent and 2 to 10 percent cutting compound, this is oil cutting compound. What is comprised of? Basically oil some emulsifying agent like detergent which breaks the oil into fine globules to remains suspended and some extreme pressure additive like say chloride phosphate or sulphide if required is also added for heavy cuts, then cutting oils. The cutting oil is basically mineral oil in which some vegetable oil, animal oil etcetera are added.

In addition to that, if required for heavy cuts some extreme pressure additive is also added. This together is called cutting oil. Now the chemical fluids open used what is this this is basically water based chemical fluids are water based mainly water and this is very suitable for some kind of material like aluminum pure aluminium pure copper which are soft but aluminum and copper and their alloys are very sticky because of this stickiness it is very difficult to machine. It causes a lot of friction and this built up formation and entangling. So some fluids have to be used these are called chemical fluids somewhere some organic or inorganic material are dissolved in water why?

Now the this chemical fluids are again two types chemically inactive type or chemically active type chemically inactive type which does not chemically act with the work material or tool material and this is basically used for high cooling where high speed machining of ah material where high speed temperature develops which has to be cooled then chemically inactive type chemical fluid is preferred but if we one lubricating also along with cooling then chemically active type where the fluid chemical fluid is preferred and this fluids are suitable for aluminum and copper, and this moderate one for cutting copper at heavy cuts because this gives moderate cooling effect and lubricating effect. Now sometime, the solid lubricant is also used. Solid or semisolid lubricants not neither liquid nor gas.

These are little like paste or wax or soaps or graphites or say material like sulphide are applied. How is it applied either directly on the work surface or impregnated or dispersed into the tool material and this materials functions as lubricants solid lubricant at chip tool interface. At the chip tool interface friction take place and if this sulphide or solid lubricant in a very thin layer reaches or remains then the friction will come down and the cutting force will come down and sometime sorry some special cutting fluids are also applied. For extreme cooling like say cryogenic fluid, that is liquid nitrogen, liquid carbon dioxide these are used. These are used mainly for cooling purpose extreme cooling because the temperature is very low minus 196 and another important aspect of cryogenic cooling is that environment friendliness because oil type cutting fluids you know creates problem and it is very hazardous and creates pollution where cryogenic fluid like liquid nitrogen and liquid carbon dioxide does do not create this kind of problem sorry now the selection of the cutting fluid. So the special type I told cyogenic fluid like liquid nitrogen and liquid carbon dioxide, liquid nitrogen is cheaper easily available and low cost so it can be used. Now the principle of cutting fluid action which has been described.

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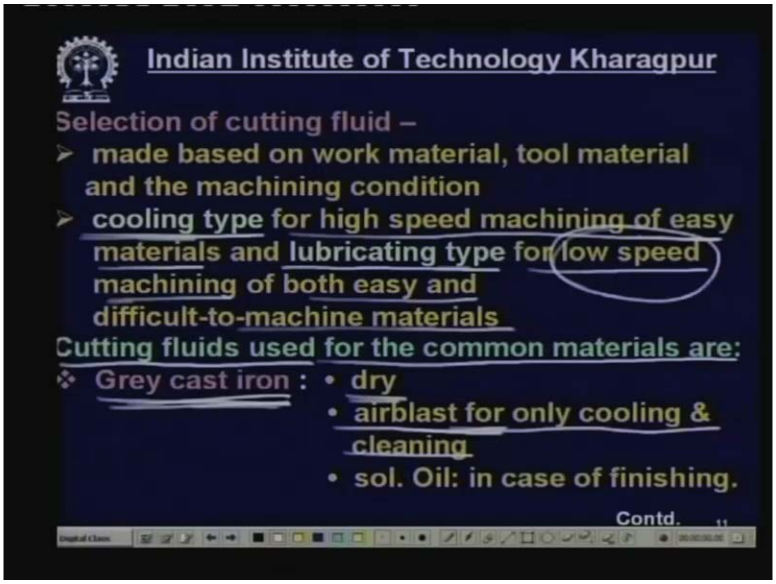

Next is selection of cutting fluid. How shall we select the cutting fluid? because when selecting the cutting fluid, two points have to be kept in mind that the cutting fluid is selected based on the work material, tool material and the machining condition because the behavior of the cutting tool depends upon the work material, tool material, and machining condition all fluids are not suitable for all work material or all tool materials or all machining conditions. You will gradually see, then cooling type. Basically we need cooling and lubrication from the cutting fluid. So, the cooling type cutting fluid is suitable for high speed machining of easily machinable materials materials like say steel low low low carbon steel or low alloy steel by carbides or high speed steel and we should take lubricating type for low speed machining of both easily and machine easy and difficult to machine materials like say hard steels or strong steels or other materials.

Why at low speed that chip tool contact is elastic were these at the asperity joints, the cutting fluid is dug in, but at high speed machining, the cutting fluid cannot enter at the chip tool interface. So there is no chance of any lubrication. Only cooling is possible that is why it is rightly stated that cooling type should be chosen for high speed machining and lubricating type for low speed machining specially when the work materials are very tough, hard and strong and there is a chances of built up its formation. Now, let us have some example: Cutting fluid used for common materials; Say grey cast iron is one of the most common and widely used engineering materials. What shall we use? What kind of cutting fluid we should use for grey cast iron? preferably dry because if we take say any cutting fluid in the liquid form that mixes with the dusty particles or chips of the cast iron and that forms a material like a paste and this paste causes problem. Not only that, it increases the friction and damage of the tool.

So this fluid should be avoided in machining grey cast iron, which produces very fine tiny discontinuous chips with graphites, but were cooling is very much required. Suppose when the machine grey cast iron by say carbide or ceramic at high speed, lot of heat will be generated that has to be removed that can be done by air blast is a dry is also air blast for cooling and cleaning purpose but no lubrication. But when we machine or grind even grey cast iron for finishing purpose surface finish and surface integrity, then little amount of oil can be mixed with water and that can be used carefully for finishing purpose. Otherwise for machining grey cast iron, it has to be done either dry or with air blast. Now for steels what shall we do with steels?

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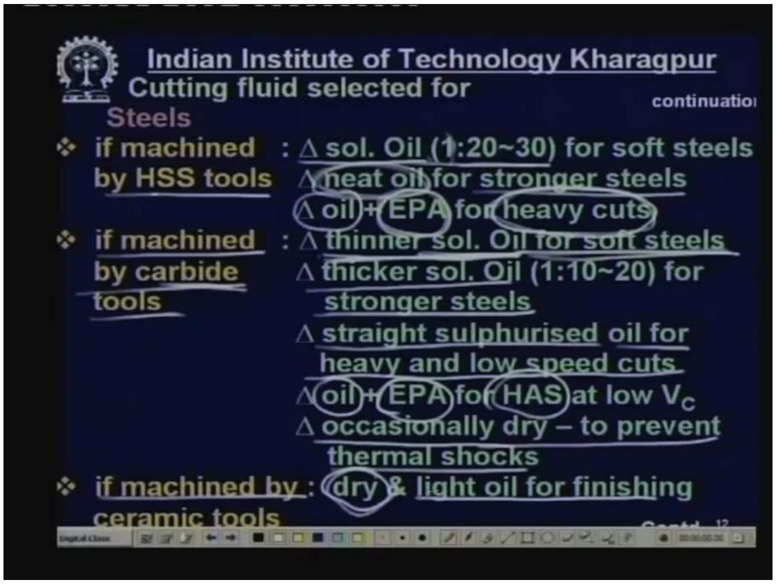

Now again, steels are of different types you know mild steel, plain carbon steel, alloy steel, within plain carbon steel low carbon steel and alloy steel, low alloy, high alloy steel and so on and steels are machined by different materials also may be machined by high speed steel or say carbide or ceramic. Depending upon the kind of steel and the kind of the tool used the cutting fluid has to be selected. Not only that, whether it is low speed or high speed that will also matter. So, all these three factors should be kept in mind while selecting the cutting fluid. For example say if machine if the mild steel if the mild steel is machined by a high speed steel, you know high speed steel cannot withstand high temperature, heat machines at low speed. Now when machined by high speed low speed soluble oil, medium medium grade soluble oil has to be used.

What is the ratio? (1: 20 to 31) is cutting compound or oil and 20 to 30 percent water and is a 30 times. So one part is cutting compound or oil, and 20 to 30 parts water. So it is very diluted and this has to be used for soft steels, that is low carbon steel, low alloy steel and we should use neat oil for stronger steels why because little bit oiliness or lubricating property is needed. So oil is added or alloy is used but we have to use extreme pressure additive along with the oil while cutting high pressure and temperature that is large force, where the lot of chances of friction and built up edge formation. So there is a heavy cut and extreme pressure additive will enhance the lubricity of the cutting fluid and that will help machining say hard steels and high alloy steels and so on by high speed steel. But if machined by carbide, what is the feature of carbide? Carbide as such is brittle number one carbide can withstand very high temperature these are the two.

Generally when machined by carbides if machines at high speed, so high temperature will develop but carbides are brittle. So if there were a thermal shock in the tool or fluctuation the cutting temperature then the tool may break by thermal thermal fracture. So these things have to be kept in mind. Keeping that in view, we have to select thinner oil thinner soluble oil that is water and oil, thinner that is 1:40 like that for soft steels, low carbon steel, low alloy steel because here oiliness is not required. What is needed? Mostly cooling purpose, then thicker oil that is one part and 10 to 20 parts water, for stronger steels which need which is machined as slightly lower speed and needs lubrication, then straight sulphurised oil straight oil no soluble oil for more lubrication property and heavy and low speed cuts, then if it is a heavy cut or high alloy steel, then extreme pressure additive has to be used along with the oil to get more lubrication.

But, as I told you at the beginning, occasionally the steels are cut by carbide on a dry condition to prevent thermal shocks if it is machined at high speed especially soft steels at high speed. Now, these steels are also machined by ceramic tools. Ceramic tools are more brittle. So more care has to be taken but ceramic tools are used that even at a higher speed. So there will be more heat generation and more temperature and because of high speed, the high temperature will be high and the entire contact length of chip and tool will be plastic contact length. So, there is no chance of entry of cutting fluid and lubricate and chip to interface. So better either you cool it by soluble oil or light oil or dry preferably dry.

You can do it by dry or air blast and for finishing purpose, sometime little oil can also be added in that case the ceramic tool has to be high performance ceramic with adequate strength and toughness otherwise this will fracture into pieces because of this water base or soluble oil or water base oil. Next let us see aluminum and its alloys. I told you already that machining of alu materials like aluminum its alloys and copper and its alloys are very difficult why they are soft no doubt their shear strength is low, but they are very very sticky and they remain struck with the you know tool surface and forms lot of built up edge scissor and all these things at very very large amount of friction. So, because of that it becomes difficult and you know this cutting tool also gets spoil because of such high temperature and all these because of the friction temperature also rises. So what is done?

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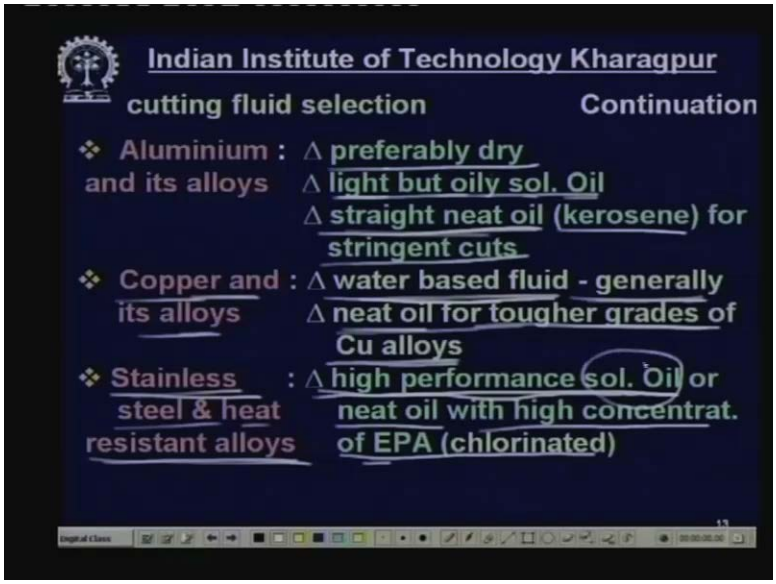

Special care has to be taken that aluminium and copper are very reactive. So aluminium and copper have to be preferably machine dry, if feasible do it by dry condition but you can also use light but oily soluble oil light. It should be light that is the amount of oil should be very less, but that oil should be no oily type say it not only mineral oil little bit compound oil and this has to be used, but we can use straight neat oil like kerosene for stringent cuts. It has more complicated cuts or say firm tools and other things when you machine firm tools the cut threads are forms then little straight neat oil is needed to lubricate the tool as well as the chip interface.

Now again the copper and alloys; Copper and alloy and its alloys water base fluid is best. Water based fluid but water based fluid is called is called chemical fluid were now the as you told you the chemical fluid are of two type active type or inactive type what kind. If it is a high speed machining then generally generally we use inactive type but if it is heavy cut tougher grades then neat oil and copper neat oil or you see we can you may active type water base or chemical fluid can be used. So chemical fluid inactive type should be used for machining copper and its alloys at high speed and where the force is not much less and neat oil or this active type chemical fluid for tougher grade of copper alloys.

Now stainless steel; important material and heat resistance alloys like nickel alloy or titanium alloy. These are very difficult to machine and create lot of friction and chances of built up edges which damage all these things. So prevent this has to be prevented so what is recommended? High performance soluble oil that is, thick oil with extreme pressure additive or neat oil with high concentration of extreme pressure additive. High performance soluble oil is a good amount of oil in water. May be, 1:10 in that ratio or neat oil with high concentration of extreme pressure additive. Now this can be mixed with soluble oil also. So this is necessary to enhance lubricity and prevent friction between the work material and the tool. Now the effectiveness or the benefit of the cutting fluid application depends not only on how do you select, depending upon the work material, tool material, cutting velocity or feed or nature of cut, heavy cut feed cut, it also depends how do you apply the cutting fluid. Now, when you say how this type method of application of cutting fluid?

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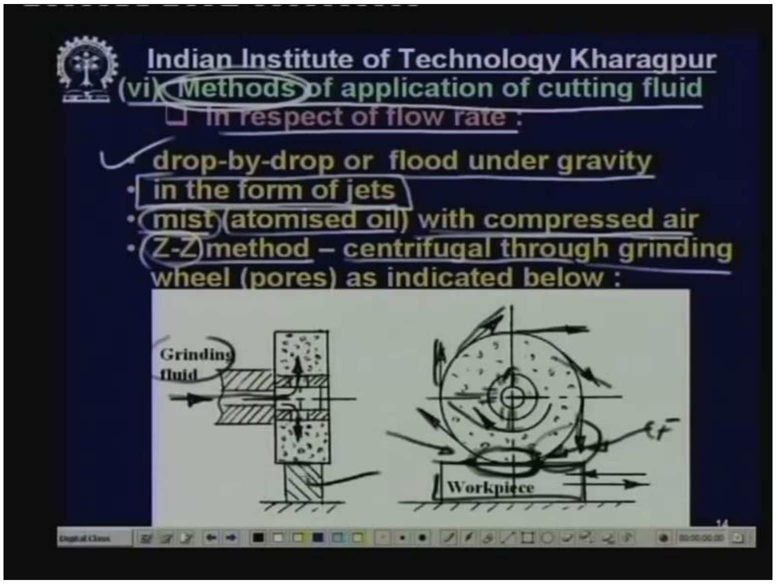

This method of application of cutting fluid that is very important that also govern the effectiveness of the cutting fluid action. Now with this method, actually our understood in respect of flow rate. What are the different methods of cutting tool application in respect of flow rates? It can be drop by drop. You apply the cutting fluid drop by drop just like a miser at the cutting point and from the top surface under gravity or it can be applied as a flood you know as a flood under gravity. So lot of a stream of cutting fluid will be flooding profusely the cutting zone in take away heat and the lubricate is under flood under gravity. Now sometime, we use in the form of jets, so that the cutting flood is enable to reach or go close to the chip tool interface or work tool interfaces by slightly lifting or shifting the chip.

So this makes the cutting fluid action very effective in the form of jet but the consumption is high and here it is little expensive. Mist that is, mist with compressed air so with compressed air, some liquid is mixed in atomized state. So liquid is first say oil is atomized and by compressed air and then projected at the cutting point that economizes the use of cutting fluid, but it makes effective and this is applicable for lubricating purpose mainly for lubricating purpose but the jet for cooling. Now there is another method called Z-Z method. This is basically centrifugal process through grinding wheel or pores.

Now this shows this Z-Z method. Actually this lated Z-Z comes from the abbreviation of the name of the inventor of this method, a German method where German scientists have developed this method. So this is called Z-Z cooling. What is the principle principle is it is grinding is applied in grinding process. Suppose this is the job this is the job this is the job then this is the surface of the job which has to be finished by grinding and this is the job on the other view this is the other view side view this is the work piece and this is a grinding wheel instead of applying grinding wheel is a cutting fluid in this way normally conventionally we apply cutting fluid in this direction in this place or from here but in Z-Z method we have to make it more effective. What is done?

Cutting fluid is sent through the sent axially and there is a bush which has got holes, radial holes, number of radial holes here and through the holes the liquid goes inside the wheel. The wheel is porous because of the pores the pores are filled with oil, because when it rotates at high speed, the air enter up into the pore are thrown out. So vacuum is created. This evacuated spaces are filled with oil or cutting fluid and then it goes out centrifugally at high speed tangentially when it rotate in this direction and a part of the cutting fluid which is at the cutting zone or the grinding zone very effectively. Normally cutting fluid which we apply at a 3 to 4 percent is effective. Remaining are real simply confluence it does not reach the cutting zone the remaining part of the cutting fluid that cools you know from outside by bulk cooling but not reaching at the cutting zone but if we do it the Z-Z method say more amount of cutting fluid will really reach at the cutting zone, where temperature is maximum. So this is more efficient. But, is very expensive no doubt. But as of when it can be attempted. Now the method of application of cutting fluid again in respect of direction.

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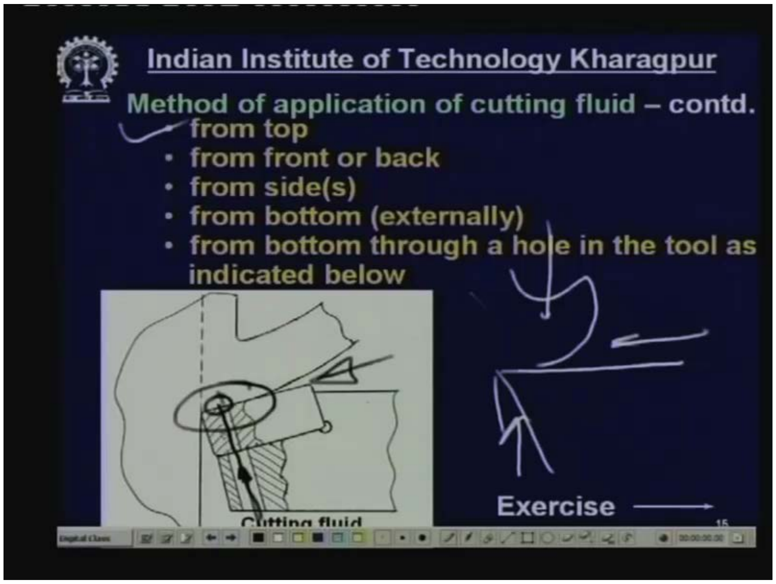

Now it can be applied from top of the surface say this is the machining going on by the cutting tool. So you can apply the cutting fluid from the top, or from the side or from both the sides or from front, or from back or even from the bottom. So the cutting fluid can be applied from different directions and depending upon that the efficiency will be different. Of course it depends upon what kind of machining is going on? For grinding, for turning for milling, the way will be different. Now this is the cutting tool. Now what are the methods? What are the common directions we follow from top? So this is the cutting tool and this is the work piece and we put from top cutting fluid here. From top or suppose this is the cutting tool this is the cutting tool and this is the chip flows. So you can give it from top, from front, from bottom, and from the sides. So these are the various ways of applying cutting fluid as mentioned from top, from front or back, from side or both sides and from bottom externally you know by flooding and here is another method shown over here from bottom through that tool. Because of the main problem, that is the main source of heat is chip tool interface rubbing in this region.

So the cutting fluid here does not reach if applied conventionally. So what is done? Through hole is made through the cutting tool and cutting fluid is passed through this, pushed it under the high pressure and it reaches at the chip tool interface to some extent and that makes lubricating and cooling more effective that helps lubricating and cooling much better. So this is how the cutting fluid has to be learnt what the purpose of the cutting fluid application, what properties it should needed it should need, it should it should possess and then how it has to be selected that all these things have to be done very carefully, because if the selection of the cutting fluid is wrong then, instead of benefit it can create more problem. So it has to be selected very carefully.

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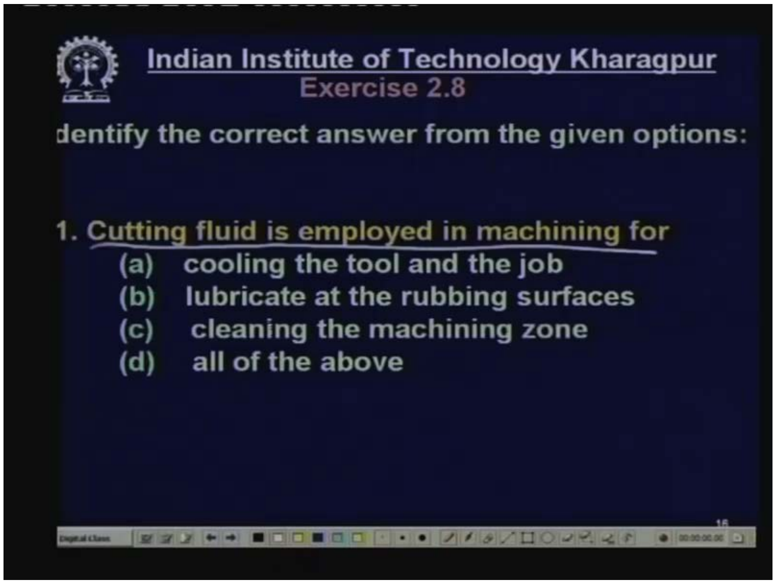

Now there are certain exercises given for the purpose. After going through this lessons that you have heard now you can have some questions and we have I have given you some say objective type of questions. So there is a point given and there are four answers, a question is there and there are four possible answers and one of them is correct. You have to identify the correct one. So identify the correct answer from the given options four options are given. For example, say cutting one question number 1 or the point number 1. Cutting fluid is employed in machining for cooling the tools and the job that is one. second answer lubricate at the rubbing surfaces and cleaning the machining zone or all of the above that is three which one is correct? Definitely you know cutting what is the purpose of cutting fluid cooling lubricating cleaning. So all these are essential that the answer is d. This is how the answer has to be found out. What is the next one?

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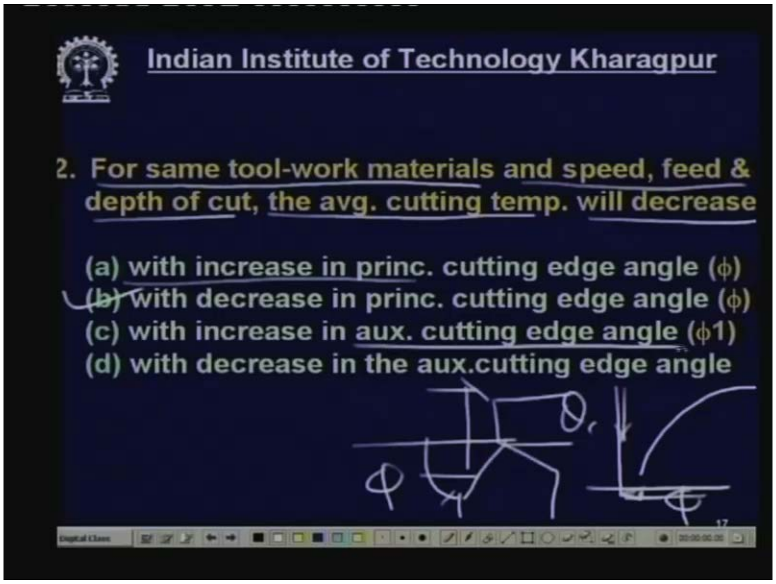

Another one for example say for same tool-work materials and speed feed and depth of cut, the average cutting temperature will decrease how? With increase in principle cutting edge angle, what is principle cutting edge angle? Just observe; This is the turning process, this angle is principle cutting edge angle with increase in principle cutting edge angle. You remember that that if the principle cutting edge angle and temperature it goes like this. So the temperature decreases with the decrease of with decreasing the cutting temperature decreases when the principle cutting edge angle is decreased with a decreasing principle cutting edge angle this is the answer and the auxiliary cutting edge angle has got no rule. This angle phi one has got no rule on temperature. Yes, this is more important and when it is low, then the temperature will be low. So this is correct answer. See another.

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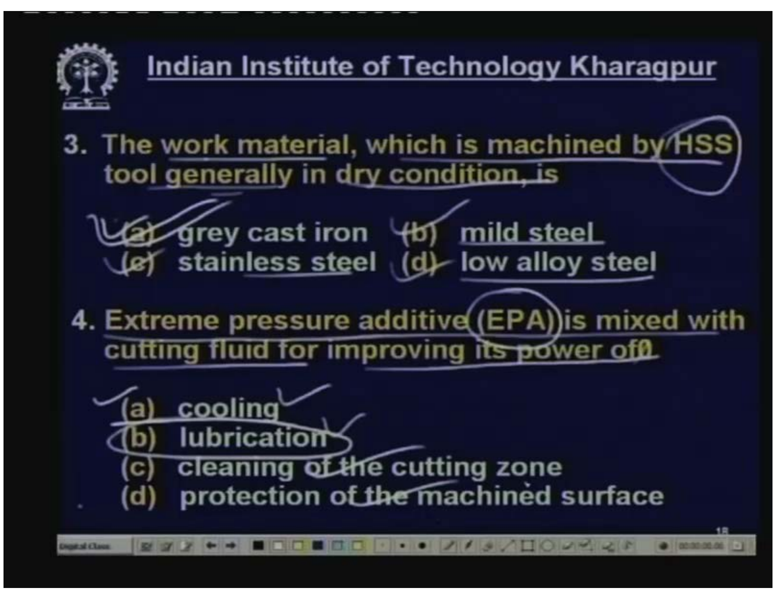

The work material, the work material which is machined by high speed steel tool geometry high speed steel tool generally in dry condition. The work material which is machined by high speed steel generally in dry condition is cast iron one answer possible, mild steel, stainless steel and low alloy steel. Now it is very clear that high speed steel is prone to solid solution of built up edge etcetera mild steel, stainless steel these are continuous type of chip. They need lubricant and cutting cooling but grey cast iron it should not. So this is the answer. Extreme pressure additive is mixed with cutting fluid in improving the power of lubrication. What is that power of cooling? Extreme pressure is additive for what purpose? Is it for cooling? Is it for increasing lubrication property? Is it for cleaning? Is it for protection? You understand that this is for lubrication purpose to increase lubrication purpose.

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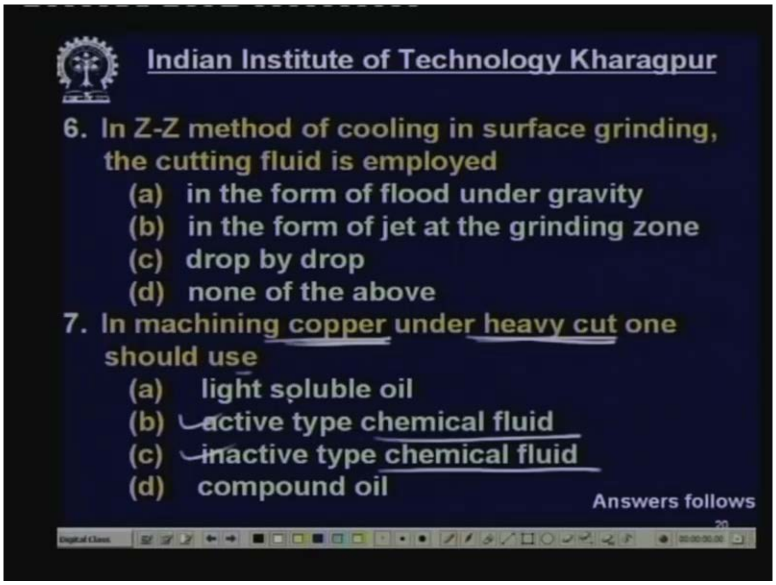

Now here you see the Z-Z method of cooling is surface in surface grinding, the cutting fluid is employed. Z-Z not in Z-Z method of cooling is surface grinding is employed in the form of flood under gravity. In Z-Z method how the cutting fluid is employed in the form of flood and gravity or in the form of jet at the grinding zone, drop by drop or none of the above then it is sent through the pores centrifugally of the wheel. So none of these. Therefore this is the correct answer (d) and last 7, in machining copper in machining copper you remember which is very soft and sticky under heavy cut one should use what kind of light soluble oil, active type chemical fluid, inactive type chemical fluid and compound oil.

Now definitely this chemical fluid will be used that is water base fluid for copper and its alloys and which one active or inactive type since it is heavy cut so active type is preferred so this is the answer. So this you can see in the next page.

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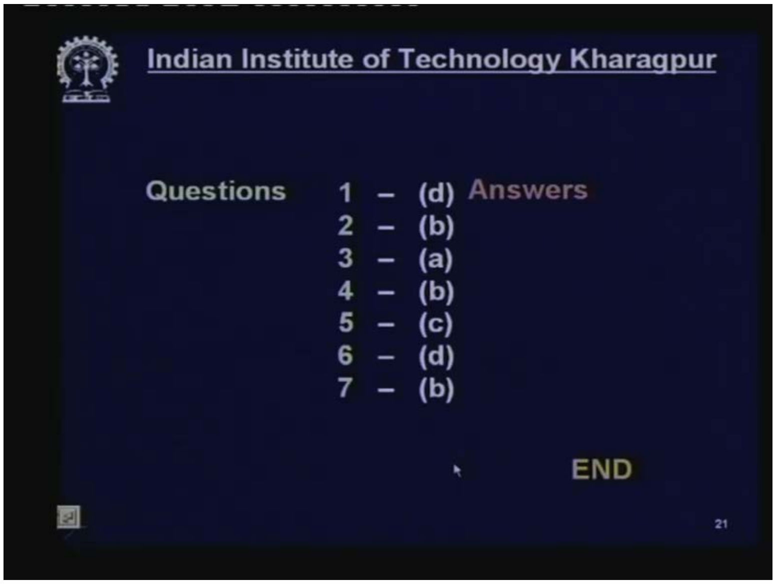

So these are the answers of the questions what you can see you can find out many more questions in many books here and there and try to solve those problems. So this ends.

Thank you.

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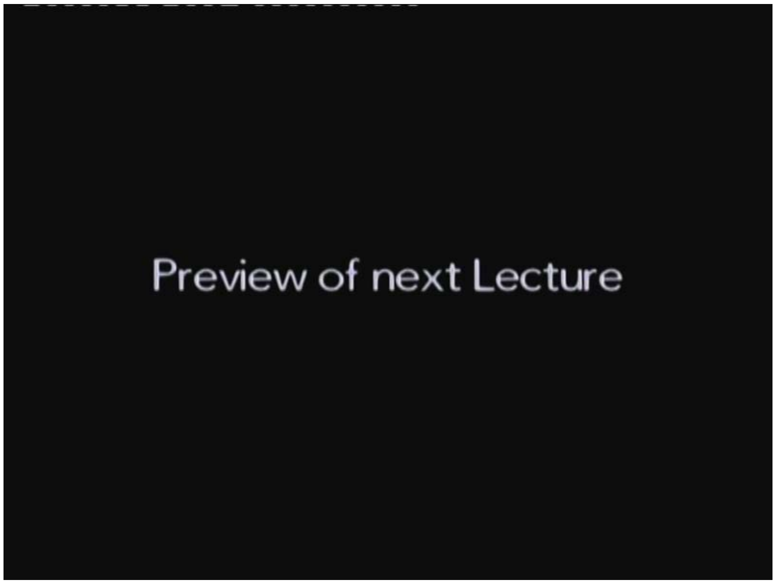

Now today we are starting Module-3 that deals with machinability connected with machining and the topic of today's lecture will be concept of Machinability and its Improvement.

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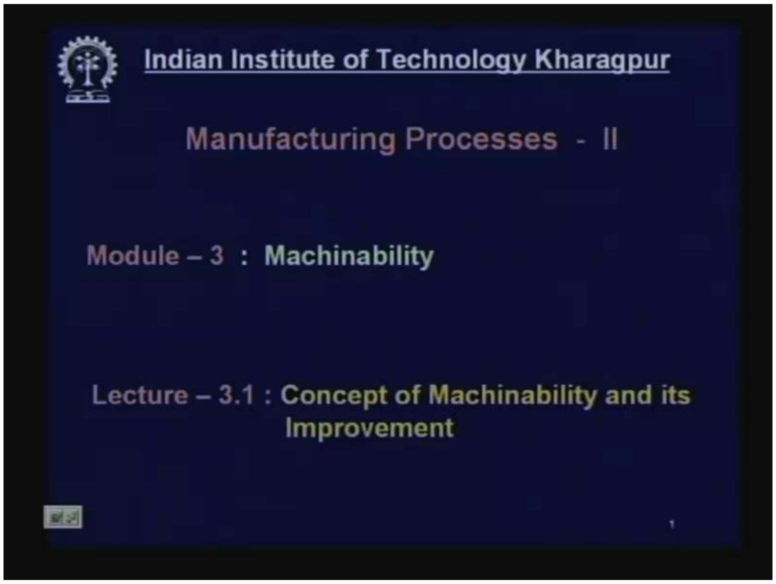

Now what are the specific instructions of objectives or the contents of today's lecture?

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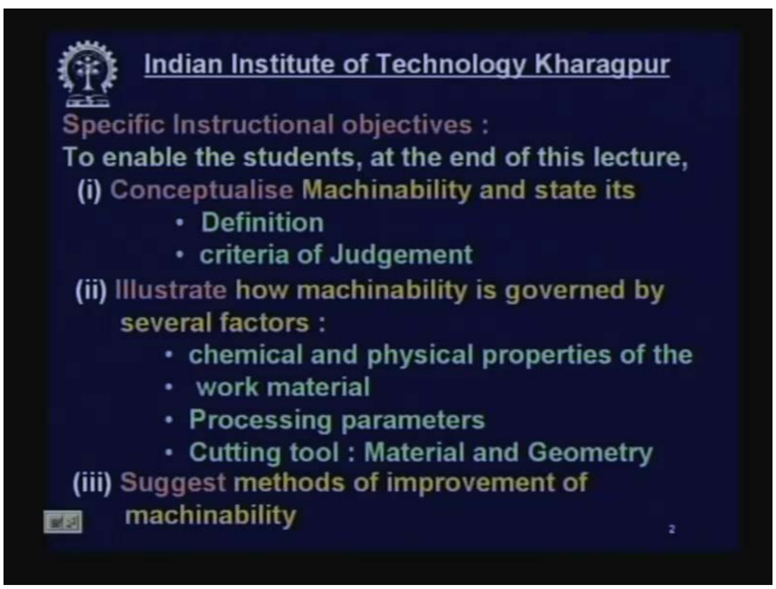

After hearing this lecture, the student should be able to conceptualize what is machinability and states its definition and what are the criteria of judgment of machinability. Next, the student should be able to illustrate how machinability is governed by several factors, chemical and physical properties of the work material itself. Their processing parameters like cutting speed or velocity feed, depth of cut etcetera. Cutting tool: Material and Geometry.