Introduction to Machining and Machining Fluids
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Lecture – 11
Tool Wear and Tool life Part-3

So, we are looking at the advanced cutting fluids. Among that one we have seen till now the cryogenic based cutting fluids.

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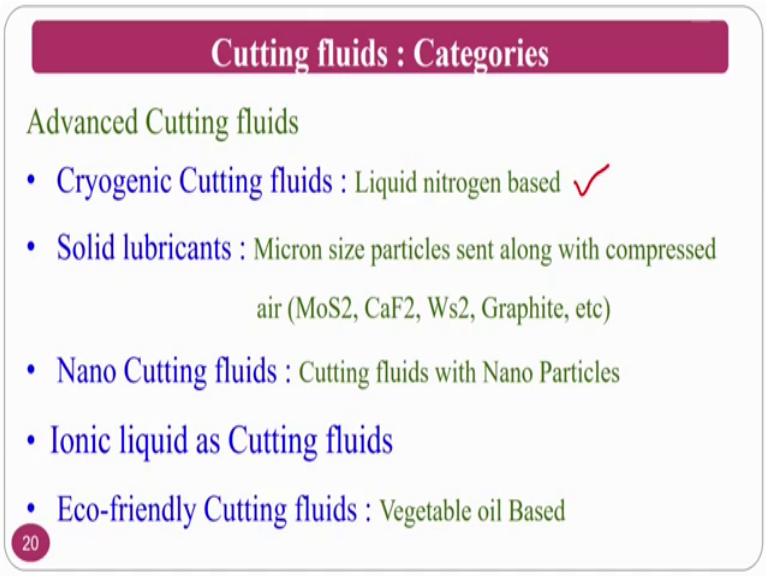

So, we now proceed to the solid lubricants and the nano cutting to fluid ionic cutting fluid ecofriendly cutting fluid.

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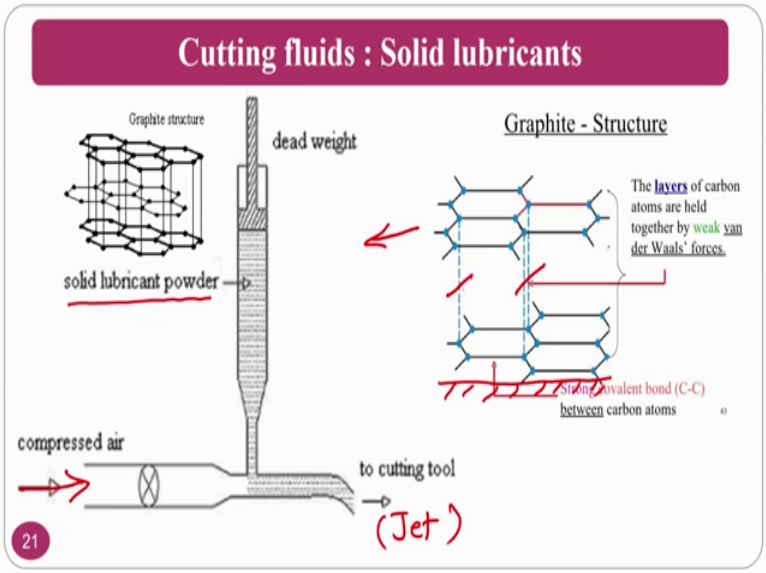

Just we will give you the glimpse how different cutting fluids are there that are in the machining process ok.

The solid cutting fluid or the solid lubricants basically ok. So, here air will be used as a cooling agent and the solid particles like a graphite, molybdenum disulphide, calcium dichloride and tungsten (Refer Time: 01:14) sulfide like that we will be taking. And if you see in the schematic the compressed air is coming from here and the solid lubricant powder current case assume that the graphite is there. So, graphite is fit like this. So, both will mix and come out as a solid lubricant jet basically it will come as a jet.

So, the air assists in terms of pressurizing at the same time. So, the particles will also go into the chip tool interface and workpiece tool interface indirectly I mean to say the machining region, the basically how the graphite act as a lubricant. So, if you see the graphite there is layer by layer formation is there where between the layers of the carbon atoms are held by the weak Van der waal forces ok. You can see the layers in between the layers we have a Van der waal forces these are the Van der waal forces.

So, among the carbons between the carbons in this one layer there will be a strong covalent bonding ok. So, whenever it falls in the machining region what is the advantages that layer by layer shearing takes place. So, this layer will share of assumed that it may rebind on the one surface it will shear also because by the breakage of Van der waal bonding which is a weak bond. This is how it will act as a lubricant as we have

already seen that graphite is a self you begin in terms of cast iron. So, they are normally the cutting fluid is not used ok.

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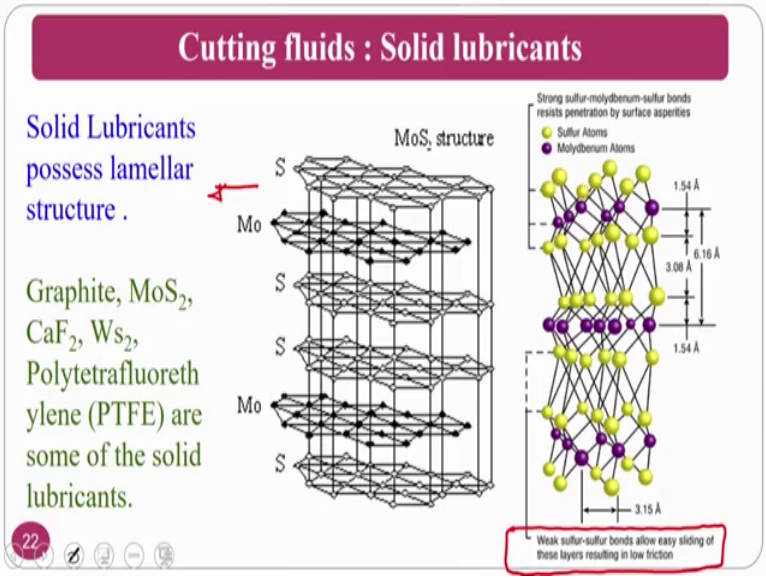

If you see the some other also as you have seen in the previous slide solid lubricant possess laminar structure. So, laminar structure in terms of not only graphite we will take some other common example because they are carbon based are there at the same time some of the carbons present in the work pieces also some of the work pieces here some other variety that is called MoS 2 molybdenum disulfate. Here this is also MoS 2, CaF 2, W s 2 and other one thing that can be used is PTFE normally polytetrafluoroethylene is also used. If you see this is one of the coatings normally used in the common utensils which are used in the mess or I mean to say in the kitchen ok.

So, just I we will speak about the MoS 2 structure. MoS 2 also will have laminar structure as it is specified laminar structure is there and here the shading takes place, whenever the shearing takes place in the in terms of graphite or in terms of MoS 2 layers by layers will goes off. Here also if you clearly see there is a weak sulfur sulfur bonding allows easy sliding of these layers ok.

So, sulfur assist in the MoS 2 to act as a lubricant because the bonding between sulfur sulfur is very weak that is what. In the graphite among the carbon there is a covalent strong bonding, another one between the layers of graphene there is a Van der waal weak bonding. So, whenever the chip tool goes off like this what will happen the Van der waal

force breaks and the top graphite layer goes off and bottom graphite layer may stay ok, because of the severe plastic deformation and shearing action.

So, here it is slightly different because the bonding among mo and s is good, but inter bonding between sulfur and sulfur is very weak. So, the sulfur assist in the form of solid lubricant, so that it will goes off a by shearing ok. This is about the solid lubricant ok.

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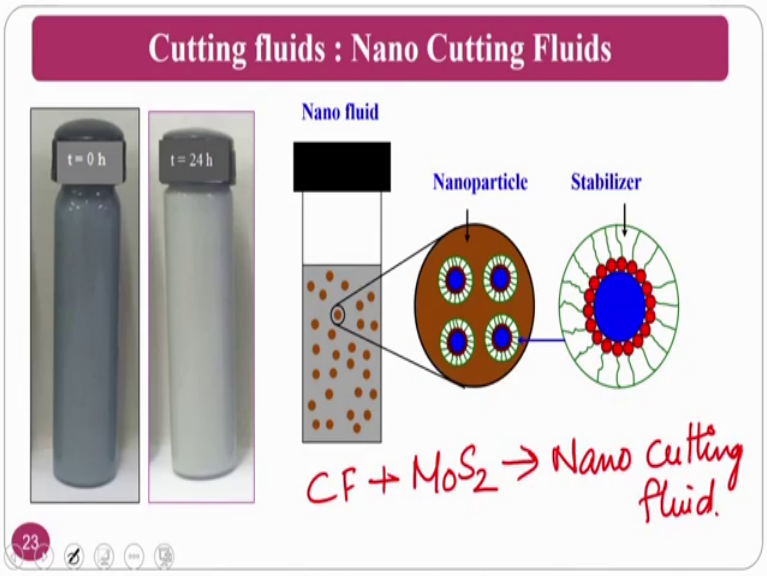

Now, we will move to the nano cutting fluids. As I said nano cutting fluid, if you see these are the fluids that are developed at our laboratory just for the introduction purpose and just giving you what normally we do is we take cutting fluid either it can be a mineral oil based cutting fluid are and green cutting fluid or something. For example, we are taking one liquid type of a fluid and then we mix with the nanoparticles. In the current case we have mixed MoS 2 molybdenum disulfate that is why I have slightly explained you in the previous slide about MoS 2.

So, MoS 2 is cutting fluid is there plus MoS 2 particle ok, MoS 2 particles are there if you mix it what will happen it will form the particle size should be nano. So, that it form a nano fluid I mean to say nano cutting fluid ok. So, this is the combination, but.

If you see there is a slight difference between two things that is at t equal to 0 hour and t equal to 24 hours this is the sonication time. Normally the sedimentation problem lot of the collide this is normally a collides basically. So, there will be always a sedimental

problem, there is agglomeration problem and all those things to avoid all these things whenever we want to do the machining text. Normally these are used in the machining system before that using we how to treat them for proper mixing. So, you can clearly is visible comparison can be taken from the two pictures, if you see this one and this one there is a slight difference.

In the second one what will be the uniform mixing is taking place, and these are not agglomerated and sub placed uniformly ok. So, that is what we want before we used in the machining process ok. How this nano fluids look like in the schematic ways? Nano fluid as I said it contains the CF 2 cutting fluid plus MoS 2 particles assume that I have a any particle. So, cutting fluid liquid is a plus we are using MoS 2 as a nano particle.

So, we have to use some other dopants also because like emulsifiers, stabilizers, functionalizers and many more as I said know in the previous thing we have to use rust inhibitors and all those things. So, those are all have to use. At the same time we have to in this particular thing we have we have use the emulsifiers, we have used the stabilizers, because this particle should uniformly dispersed at the same time it should I mean to say it should not agglomerate among the particles itself. For that purpose at the same thing it has two stable at particular location, for that purpose normally we will use the stabilizers and all those things ok.

So, if you see another advantage of nano fluid is contact angle ok. So, normally the contact angle if it is more what will happen? So, the area of contact is very less. So, if for that purpose normally we should go for better wettability. Normally if the contact angle is less; that means, that the fluid has a proper wettability.

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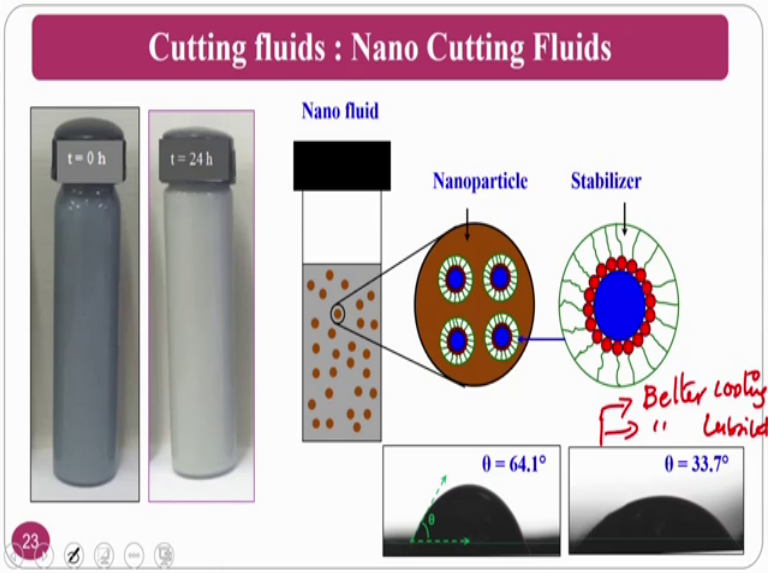

Assume and that I have this surface and I have this wettability and another case I have this wettability. So, in circumstances the area of wetting and other things is you can calculate and all those things ok. So, area of wetting is most important in terms of machining area ok.

So, if I want to take the heat from the machining area the contact available it falls it should have a proper contact area; that means minimum contacted; that means, at maximum wetting area so that I can take the heat out of that machining surface or the machining zone. At the same time if the two things if from this point of you I can say two things one is if the wettability area is increasing what will happen better cooling, cooling will be done and better lubrication also will be done ok.

So, these are the two advantages that you will get if you have a proper wetting surface ok. Whenever you add this one what this is the case one is before adding and case two is after adding the nanoparticles to the cutting fluid.

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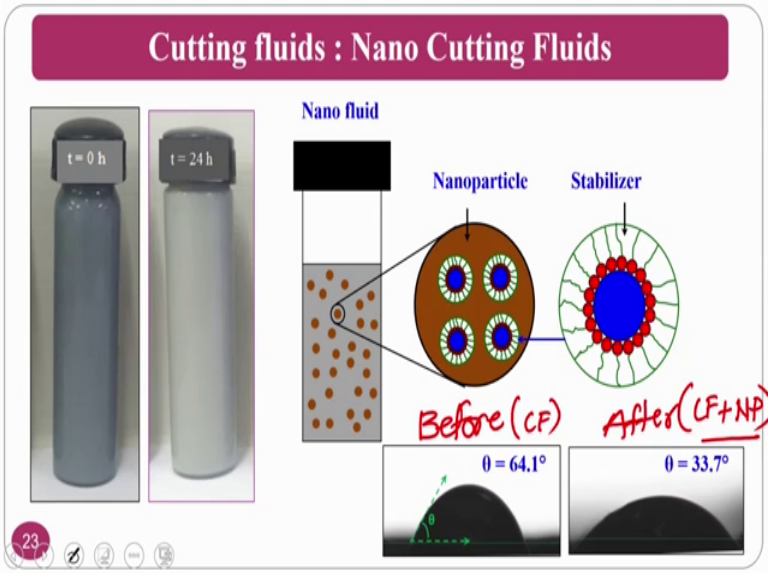

This is before and after, I mean to say cutting fluid with cutting fluid plus nanoparticle this is cutting fluid only ok. So, contact angle.

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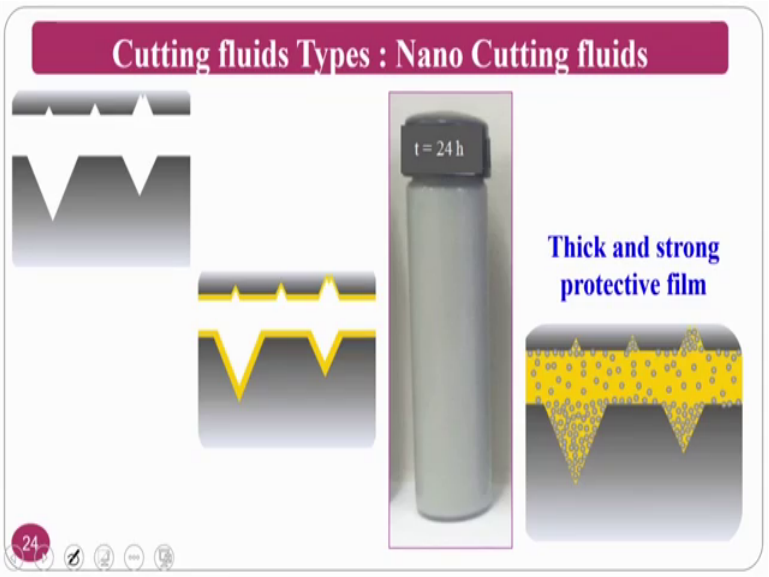

So, other advantage is if you see the only meeting surfaces tribological conditions just I want to explain you from the tribological conditions where the surface is only mating surfaces. In the second case normally you will have a normal lubricant or the cutting fluid wherever the application is there.

In the third case whenever we see about this nano fluids it forms a thick and strong protective film in the tribological application in either bearings another tribological coordinations. If this is the benefit in the tribological conditions we can also impart by mixing with suitable cooling fluids in the machining process and you can use it ok. That is the beauty about the nano cutting fluid ok.

So, the thing is many researchers are working nowadays on the nano fluids in the machining. So, if any researchers who want to take up the research in terms of nano fluids or nano cutting fluids as your thing you can take up because, only thing that you should take care is what type of nanoparticles I am using. As I said in the previously that, some people are using metal nano particles, ceramic nanoparticles, and solid lubricant nanoparticles and other particles.

So, based on your application, based on your workpiece material, based on your tool material, based on what type of cutting fluid composition that you have you have to decide these nanoparticles. That nano particle should have chemical compatibility whenever you are mixing it and you should be very careful about these thermal properties of this nano particle before and after, how the thermal conductivity of the fluid is increasing or decreasing, whether the contact angle is increasing or decreasing, whether the thermal conductive heat transfer coefficient of this fluid is increasing or decreasing is all to be measured before you go to the experimentation in the machining process.

If that is, if you can take care all these things you can do a good work from the research point of view not only from the experiment not only from the basic knowledge point of view, you can also do some research in this area and telling about the current status after few years or something ok.

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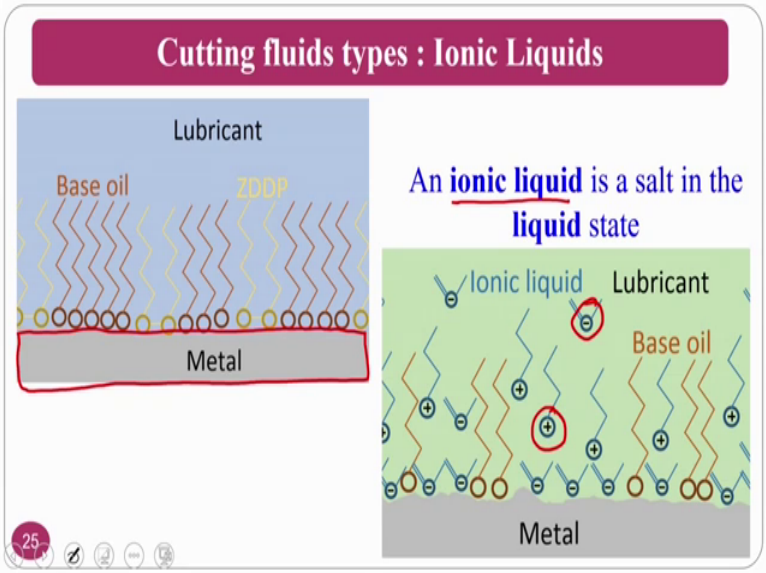

So, the other cutting fluids if you see these are the ionic cutting fluids. Ionic cutting fluids are normally the salts which are in the liquid states basically. So, just what are the lubricants normally whenever the lubricants are there if you are using if in the tribological condition. Material cutting is one of a tribological condition only because of the severe plastic deformation. So, this is the metal and whenever you use certain oils it will go and occupy on the surface wherever it is, but there is no charges in it.

But if you see in terms of ionic liquids as I said these are the salts in the liquid state. So, this will have negative as well as positive. So, these are normally used in the base oils as a additive or it can be used as a cutting fluid, can be used as a lubricant and all those things this will have a better effect that is what the some of the newly research papers are working on these things that is ionic liquids has a cutting fluids ok. So, if somebody is interested they can go and some of the research papers are coming in India like very few research papers are there. So, if you are interested if you are a PhD student or if you are a master student you can take up this ionic liquids also, but ionic liquid separation you have to be a bit careful ok.

So, there are a variety of ionic fluids. So, you should be a carefully using which type of ionic fluids that I want before that you do some literature which type of ionic fluid that is suitable for my workpiece tool material combination, and whether I can add water to it or not, whether I can make it emulsion or not, and what are the additives that I can we see if

I am using the additive, are these chemically compatible or not. These are all the things that can say.

So, see not only some of the basics I am teaching up at the same time many of the viewers may be from research point of view some of the PhD students or the masters students some of maybe the final year bachelor students who are looking for appropriate topic in the area of metal cutting and all those things.

Metal is not a very difficult job or something because many of the private institutions or small institutions to the medium institution, large institutions will have always the metal cutting operations like lathe milling, drilling and all those things. Only thing is that you should have a proper literature then if you can play with the good cutting fluid you can come up and followed by the characterization of your forces temperature and all those things, and before that your few characterize your fluid and all those things and you can make the what is the physics that is playing a major role in this one all those.

If you see that can be a good paper and as per the current state is concerned like, I mean to say 2017 and the 18 ok. Do not do much late and if you can take up now in upcoming 2 to 3 years you can have few good papers ok.

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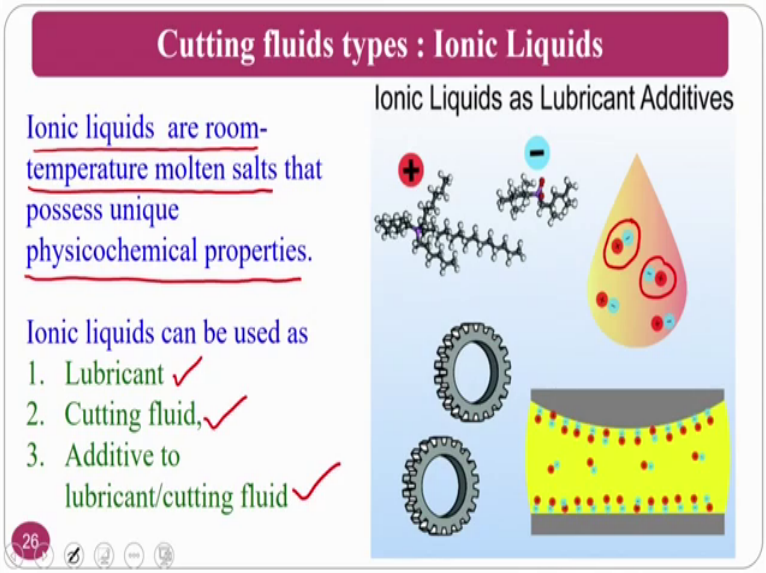

Ionic liquids as a lubricant addictive I already said these are the liquids ionic liquids at room temperature and molten salts ok. So, this process from physio chemical properties

which are unique in nature ok. As you can see in the previous slide I have said these are plus and minus charges will be there whenever you use it in the tribological condition or metal chip tool conditions or any gear system and all those things it will be beneficial. But the only thing is that you should take care about the cast of this one ok.

So, this can be used as a lubricant as a whole you can used as a lubricant. It is economic for you and if you can make in bulk you can use directly as a lubricant, if at all you are working in a metal cutting operation or if you are working in the tribological application or any other application you can use directly.

The second one is you can use as a cutting fluid. So, for the metal condition you can use whole some ok. Cutting speed you need lubrication as well as cooling in the lubricant you need only lubricant that is why I said in the tribological condition lubricant will used.

The third one is if at all you want to use it as in and in a separate additive for existing cutting fluid that also is possible that which I have just now told in the previous slide ok. So, it can also use as a additive. We assume that it is slightly expensive from the your point of view what you have to do is you just take the cutting fluid which is chemically compatible just you add it and you check this cut performance of this one so that is also a good choice to take up the job in the research ok. So, this is about the ionic liquids.

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Now, if we move to the ecofriendly cutting fluids normally nowadays people are extensively working on two areas in the metal cutting where one is because of the sustainability issues, because the ecofriendly conditions are the sustainability issues also accord uniform or equally play role as per the performance is concerned. I mean to say nowadays if at all you want to do a machining process you have to look in two ways which are equally important that this should be eco friendly as well as it should be good performance giving ok.

So, from the performance point of view as well as from the ecofriendly point of view it should be equal ok, then only go. Otherwise if your performance is very important if it is not ecofriendly then health problems and all things will come ok.

Some of the oils nowadays you see that canal oil, coconut oil and you can use the sunflower oil and all those things. Apart from it you can also use a neem oil, some of the people are using neem oil, caster oil, people think of mixing of these oils like coconut oil you can mix with this one and other things. But be careful that you have to use some of the emulsifiers, stabilizers and thickeners thinners suppose if your fluid is thick enough. So, you have to go for thinners and all those things. So, you should be very careful in mixing all these things because it is a completely a out of box for basic mechanical engine because it is comes and mostly it should be have a collaborator from the chemistry that will be better, if at all you are going to work in the area of cutting fluids and all those things. That is just suggestion for those people who want to take up the worked in the area of cutting fluids and all those things ok.

So, apart from these advanced some of the researchers also use high pressure air as also equivalent ok.

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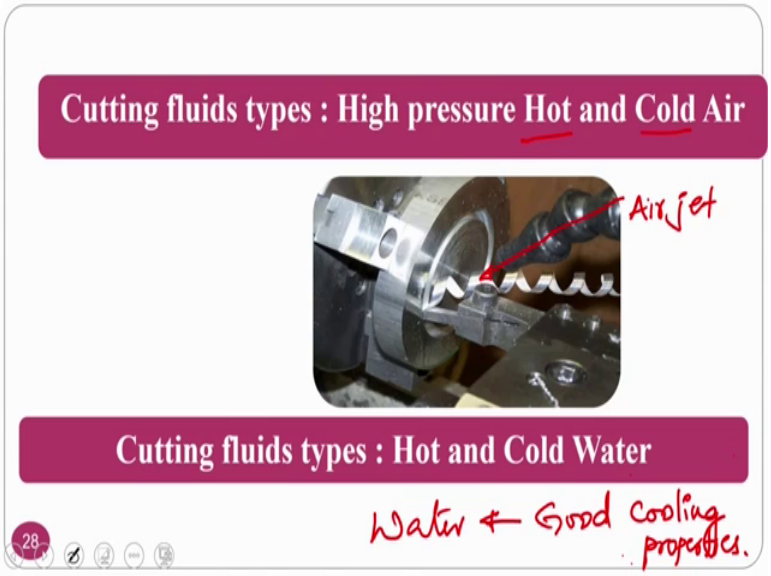

If you see some people they have used the hot air as a cutting fluid, some people they have used the cooled air as a cutting fluid ok. So, hot also if they have used that cold and also they have used. If you see in this picture anyhow this picture will come in the application area where high pressure.

So, you do not notice any new type of liquid here, but nozzle is there ok, so that means, what it is sending clearly the high pressure air jet ok. So, it is passing. And normally high pressure air jet are high pressure water or something in just I am going to talk about water and all those things. If you see the some other people are researchers I mean to say are also using hot and cold water as a cutting fluid they also send with high pressure hot and cold water.

So, that as you all probably know water is better coolant water is a good cool it has a cooling properties ok. But the only constraint is you should always use for non FE based workpieces like aluminum. If you see here if the machining of aluminum is taking place ok. So, you should be very careful in using the water as a coolant. Whenever you are using try to use for mostly for aluminum and non FE based iron based components ok.

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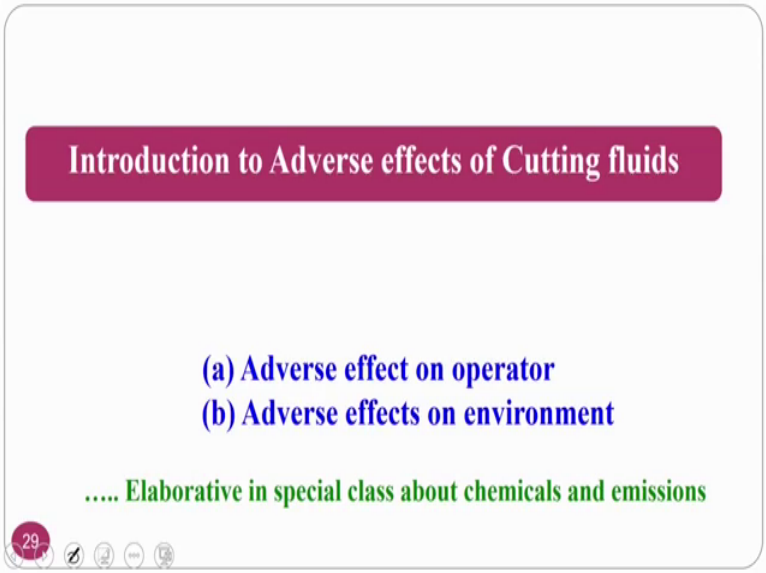

So, the thing that is from the previous is we have seen a variety of cutting fluids, where ranging from soluble oils to the semi synthetic oils to the synthetic oils, coming to the advance cutting fluids, cryogenic cutting fluids, solid lubricants, ecofriendly, nano fluid, as well as the air and all those things; simple to the complex or simple to the very advanced version of cutting fluids which we have seen.

But adverse effects of cutting fluid on operator as well as environment I will talk in a big way; however, I am just giving you some glimpse because just now I am talking about the different-different types of cutting fluids. So, I will just talk about what are the basic problems because of these cutting fluid emissions what are the things comes to the operator as well as environment ok.

So, I am already saying the elaborative special class about this chemical what are there and what are the emissions and all those things I will talk in upcoming classes ok.

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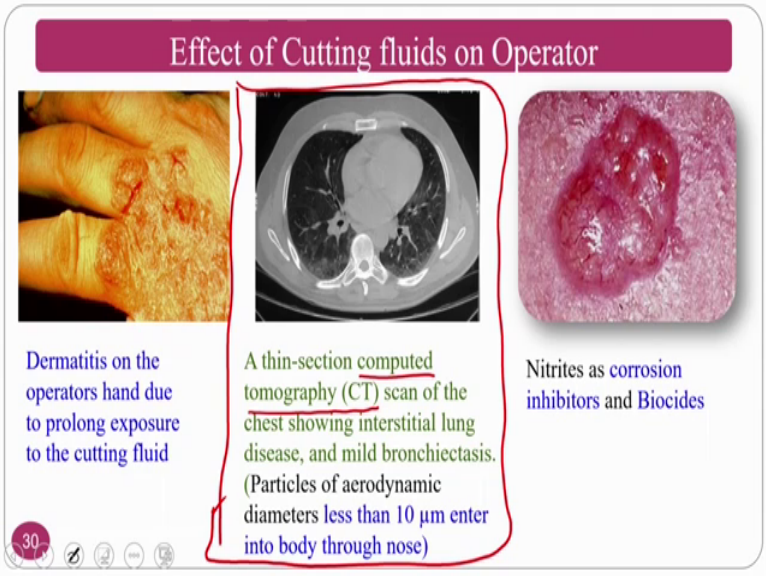

So, just I will give you the first glimpse or whatever the cutting fluid falls on a operator what will happen. So, if a operator is operating there is a assume that the workpiece is rotating with the high speed those flashing always takes place because the machining region is a part of workpiece rotation and all those interaction between tool and workpiece. So, because of which what will happen if it falls in the hand it causes the contact dermatitis where the epidermis and outerdernis of (Refer Time: 24:18) of the operator. If it is prolong exposure to the cutting fluid these type of problems you can see on the hand ok.

So, though this is about the one of the problem, this is a common problem because if you see the operator most of the operators this splashing will takes place. So, in order to prevent all these things one has to wear a apron, one has to take care of the gloveses with they before they are going to the operation or before going to do the machining operation I mean to say machining operation I am not [laugher] about the operation that we do the doctors do, ok. So, whenever do the machining operation they should be properly interest from the top to bottom so that it can be contact should be prevented ok, because that is why I am taking about this is a contact with dermatitis.

Contact dermatitis means whenever the prolonged cutting fluids falls on the operators skin that is epidermis ok, so this will affect ok, this will come because of the contact that me that is why this is called as contact dermatitis ok.

So, the second one is a thin normally what is here shown is a thin section of computer tomography that is CT scan many of the about CT scan showing the mild bronchitis and interstitial lunges diseases ok. These are CT scan of the lungs where particles are entered into the olivia region or the lungs region of the operator. I will come in the next slide how these particles will enter and all those things. So, then I will come back to you ok.

So, at the same time some of the chemicals in the cutting fluid always some of the like nitrides and nitrates and all those things this. These are come into the cutting fluid because of whenever you add some additives like corrosion inhibitors, monocytes, emulsifiers and all those things. But if the quantity that one has to add this type of additives to the cutting fluid if it a exceeds beyond the specified limitation by the national institute of health organizations and all those things. What will happen? It may lead to the uncontrolled cell culture that is cell growth in which is also called as a cancer and all those things ok. One should be careful about all these things ok.

So, now, I have just to talk about what is there at the middle. In the next slide if you see this one mold mild bronchiectasis and all those things. What about the, how this will be come to the operator ok?

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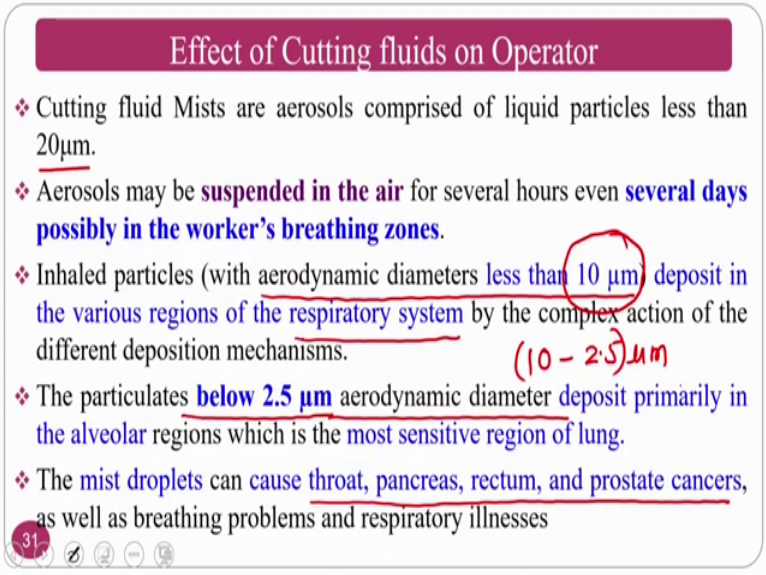

So, whenever the cutting fluid mists is there cutting fluid mists are aerosols; that means, that when the cutting fluid falls on a machining region where the temperature is very

high what will happen it try to evaporate ok. Some part of things you have evaporate ok. Comprises of liquid particles less than twenty microns normally different sizes are there.

So, aerosols may be suspended in the air for several hours, even several days possibly in the work breathing zone. Assume that if a person if the operation is going on; that means, a machining operation is going on in that circumstances what will happen there is a spectrum of the cutting fluid aerosols will be developed ok. So, that ranges from some few microns to some hundreds of microns ok.

So, like it maybe less than 20 microns, less than 10 microns, approximately 2 microns, 2.5 microns and all those things. But the same time these are the aerosols which are like a small nano particle or micro particle airs which may suspend in atmospheric air or if a person is operating like this assume that a operator is bending and the experiment machining operation is going on in this way. So, it will splashes and it may go into the nostrils of the operator ok.

So, in that case the normally inhaling acceptability of the human is less than ten microns of aerodynamic diameter of the particle. If the particle or the aerosol size is less than 10 microns it can go into the nose and deposit in various regions of the respiratory system by the complex action of different deposition mechanisms ok. That means, operator can inhale this one ok; that means, that it will go into the nose not into the lungs that should be no get point here ok.

If you see if the particle size is below 2.5 microns of aerodynamic define it can go into olivia region of the lungs which is a sensitive part of it ok. If it is 10 microns or less than time microns that I mean to say between 10 to 2.5 micrometers you can breathe, but less than 2.5 microns or equal to 2.5 microns it can enter into your olivia region of your lungs which is more sensitive ok.

Anyhow I will show a picture in the next slide because of the material here I am unable to show I will show in the this mists droplet us can cause throat pancreas rectum and prostate cancers ok. You, we will this occupies and causes a lot of different different cancers to the operator.

Now, I will come to the point where less than 2.5 microns particles are aerosols will go into and occupy the olivia region of your lungs ok.

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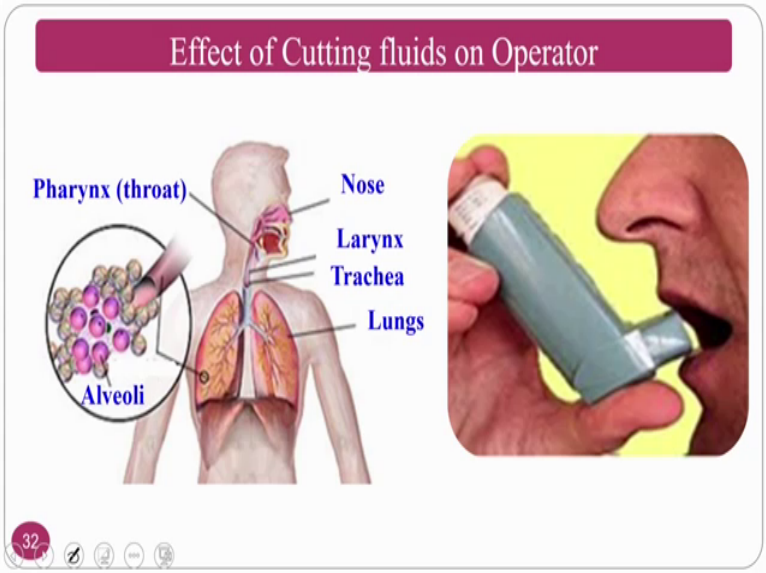

These are the lungs and if you just zoom it you will find the olivia region and if the aerosols goes and occupies this region that is slightly dangerous ok. So, that should be taken care ok. That is why and at the same time it will also causes some of the asthma, irritation in the breathing and all those things ok.

So, these about the operator and the surroundings ok. If you see the surroundings normally what the people will do? In the workshop you are using the cutting fluid you are recycling it, recycling it, recycling it again and again and again and again what will happen the cutting fluid will destroy its lubrication property goes bad its cooling property goes bad and all other properties goes to bad not only this it will also start emitting very dangerous vapors ok. That is why after some time whenever the workshop people or other people wherever they feel that it has to be thrown what will happen the first thing what they will do is they will just dump into the nearby water bodies that causes the water pollution. If you see a portion of this one ok, so it will causes the lot of water pollution.

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The what about the fishes whatever the frons whatever the living organisms that are there in the this one this will affect lot of things. And if some people will if we consumes that fishes or frons and all those things, so it may also affect the humans who are around that water bodies. Some of the people also do they just dig the earth in the premises of the company and all those things and they just dump it into that one. So, that causes the soil pollution. So, water pollution, soil pollution at the same thing because of the vapors and operator, so environment, because of this there is an environmental pollution and water pollution is there, and soil pollution all the pollutions are there ok.

So, in order to save all these things what are the thing, one has to take care what I mean to say is, why I am explaining all these things tomorrow you may be a staff in a certain company and workers will be there I mean to say the supporting staff who are the operators you should help them in protecting from all these problems. So, if you do not wear all these things if you may get these type of problems and all those things that ok.

Elaborately when we I will teach there, but my concern is if you are watching or not watching that particular lecture sometimes some people may miss that some that particular lecture. I just appeal to you is the human life has a good value because a operator is working in a company. So, he has his own family something happens to him its family will be in a difficult situation. So, if he may be a major earning member in the live in the family. So, you always as a engineer it is our primary responsibility to give the

safety to the operator. So, at the same time help the company in not dumping in the like a water pollution or soil pollution and hope you help the operators also ok.

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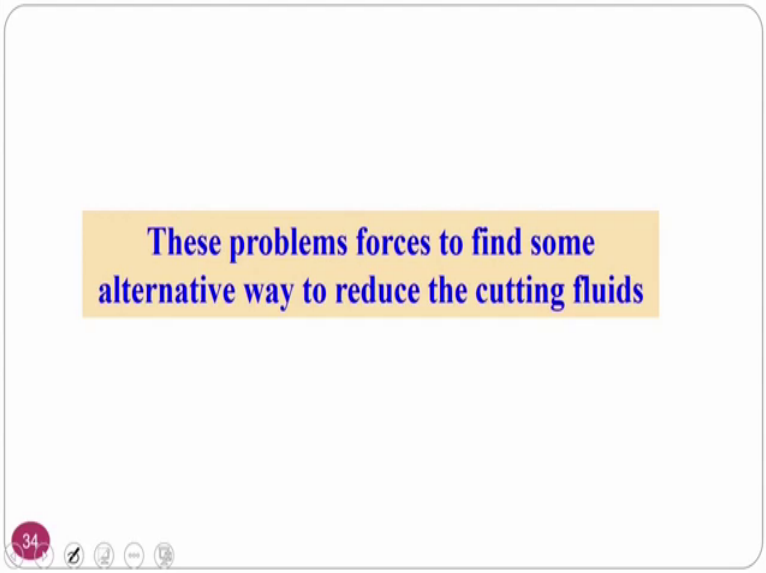

So, these are the problem forces some of the alternative ways ok. So, why these problems comes? Whenever you are using huge amount of cutting fluid then only these problems comes. So, either can you reduce the cutting fluid by having the same performance if that is so, that is good. Can I do not use cutting fluid if I can do the machining operation there is also fine. So, this comes that another variable that is called cutting fluid application technique. So, whether how to overcome all these things or which process is not good which cutting fluid technique is suitable for what application which cutting fluid technique is suitable for what application and all those things ok. So, which cutting fluid technique will give lot of emissions and all those things also we will see ok.

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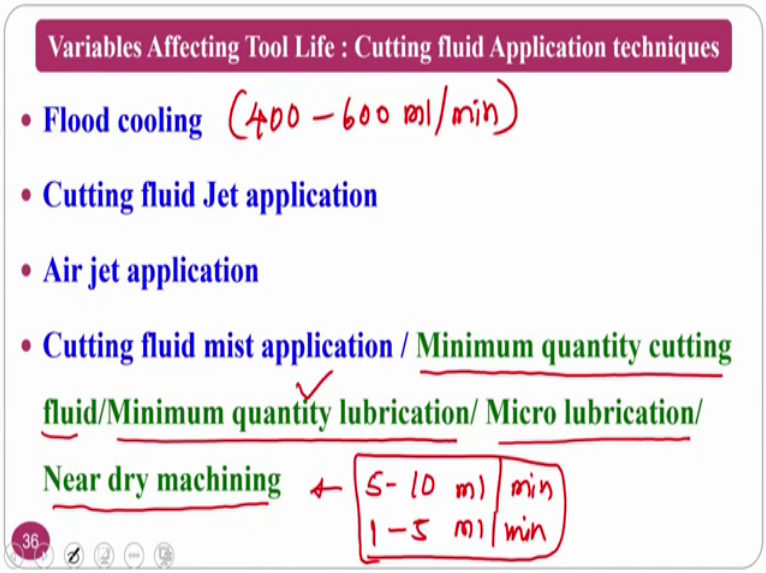

Cutting fluid applications, the first one is the flood cooling application where normally 400 to 600 ml per minute consumption of cutting fluid huge amount of cutting fluid will be used here ok. So, this is one of the culprit any how we will talk about this one.

So, cutting fluid jet application that is called where still more higher cutting fluid is used, but you will send with the high pressure ok. In the flood cooling it is by the virtue of gravity air jet application normally instead of liquid type of cutting fluid some people they will use air jet which I have seen in the hot air and cold air application.

Another applications are cutting fluid mist application that is mixing of cutting fluid with the air and you are carrying out the operation. Some people they will called as a minimum quantity cutting fluid process, minimum quality lubrication is one of the famous word that you can see in the minimum and some people they say micro lubrication. And some people they contradict MQL is not micro lubrication micro lubrication and MQL are both are different. Some people say that the pseudo dry machining, some people they say near dry machining, why they say near dry is instead of using 400 to 600 ml the air they will be using 5 to 10 ml, ml per minute.

Even some of the cases research papers are there where they have used 1 to 5 ml per minute ok. In this circumstances if somebody is using 1 ml per minute where 600 ml is a maximum and 1 ml it is approximately minimal that is why it is near to dry machining that is why the name came near dry machining process ok. So, do not confuse between

MQL near dry machining process. Some other papers you also see pseudo dry green machining. So, a paper is they are all with the name that is also similar to this one ok.

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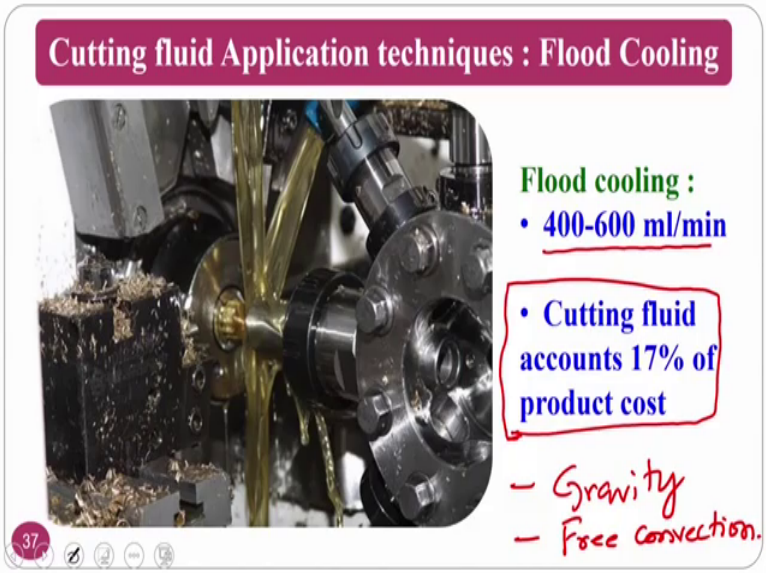

So, the first one is flood cooling where you can see the coolant or the lubricant that is flowing like a water that if you pour water from a glass it is ok. So, by virtue of gravity it falls ok. So, it falls in the machining region by the virtue of gravity ok.

So, normally I said it is 400 to 600 ml per minute is the consumption, it is the consumption. If you see in that way it is average on average it is 500 ml per minute which is a huge amount of the cutting fluid that is going into the machining region and we use it recirculating.

The basic problem here is free convection takes place because the solid body is there a fluid that liquid is falling and it is taking away some of the heat it is not because it is not going into the machining interior zones. So, it takes away partially the heat. So, what will happen? So, thermal cracking will takes place, in proper combustion will takes place, and all those things at the same time it is falling by virtue of gravity it is free conviction ok. So, the free conviction means the convective the heat transfer with conviction is low force convection it will better ok.

So, the cutting fluid account 17 percent of the product cost this is another big drawback of this process is if my product cost is 100 rupees, 17 rupees will go for the cutting fluid

consumption itself. So, if I can minimize the cutting fluid or if we can drop the cutting fluid then I can be competitive in the market by selling my product of the economic price compared to other people who are using the cutting fluid ok. So, I can sell at even less price still I am at the profit ok. That is why this process is a not a good process. However, most of the industries currently in India are using this process ok.

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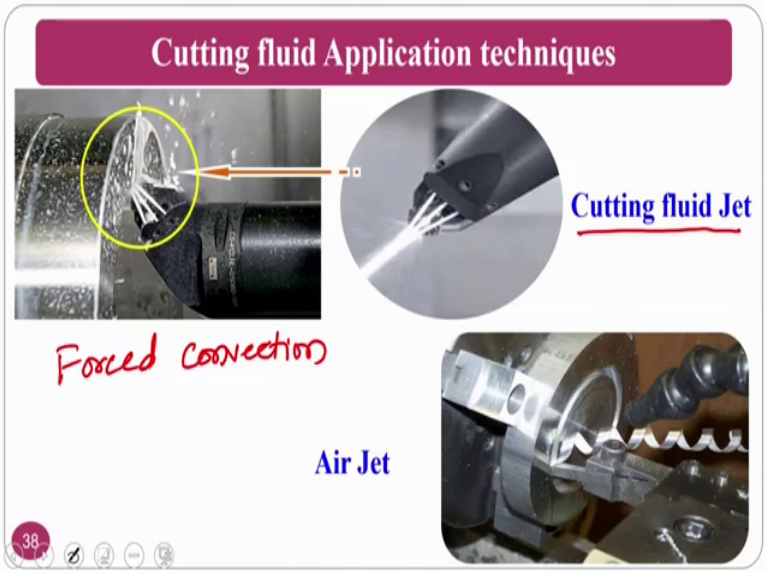

So, second one is jet application cutting fluid jet application ok. So, where you can see here where the high pressure jet is send or into the chip tool interface. If you see here chip tool interface it is sending in the machining region. Normally here in the flood cooling it is by virtue of the gravity it is falling here you are pumping with very high pressures, so the convection will be higher side to the flood cooling. But the advantage here is forced convection ok.

So, the advantage that you are going to get is there in the flood cooling it is free convection here it is the forced convection. So, heat transfer will be better in this way. At the same time the drawback of this one is consumption of cutting fluid is still higher compared to flood cooling.

So, another one is air jet cooling since I am talking about high pressure jet. So, some people they also send the cold air or cold water also they will send and hot air also some people they are using hot air as a cutting fluid in machining of titanium alloys also, ok. So, you can use if at all somebody people are working because the as I said that titanium

temperature conducting is very low. So, the temperature that you are sending by hot air or something will stay on the surface itself you can do the machining process very easily. So, this is about the air jet.

The advantage if you see with the air jet and flood cooling; the flood cooling you have a cutting fluid or a high pressure cooling you have a cuttings fluid where convective heat transfer coefficient is very high, but it cannot penetrate into the interior zones of the machining zone. On other side you have a air; that means, compressed air where it can easily enter into the intricate regions. If I combine both normally what I will get is minimum quantity lubrication or minimum quality cutting fluid.

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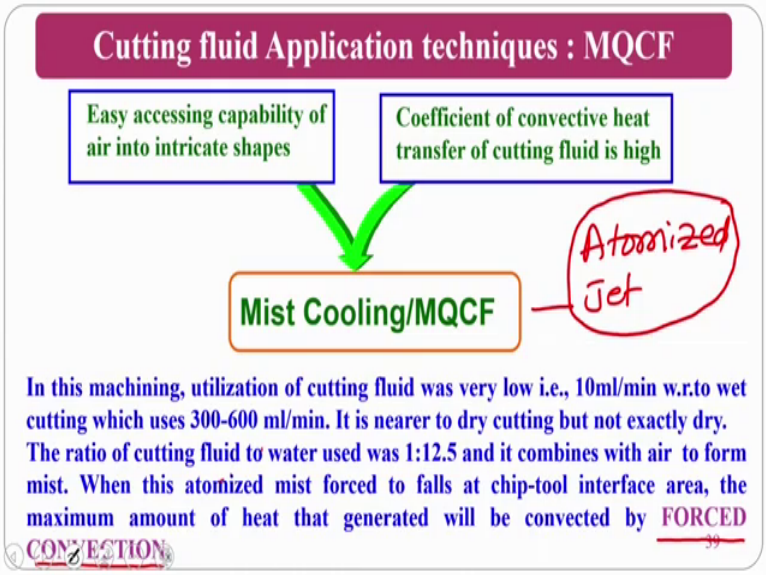

Let me explain you in one case what I am getting is easy accessible capabilities of air into intricate shapes; that means, I am using a highly compressed air which has can enter into the intricate regions of my metal cutting I mean to say if this is the metal cutting. So, it can enter like a jet it can enter like a jet.

So, on other condition I have a cutting fluid whose convective heat transfer coefficient is very high, but it cannot enter. Here conductive heat transfer coefficient is low, h value is low, h value is high, but it can penetrate easily, but it cannot penetrate easily. So, advantage of penetration, advantage of high convective heat transfer coefficient whether we can combine both or not is the question. If we can combine these then we are at the good condition where you can penetrate into the intricate regions at the same time you

can also get the heat out of it ok. That is called mist cooling or minimum quantity lubrication or minimum quantity cutting fluid ok.

So, what I am taking here is here I am taking the easy accessibility of the cutting fluid, I am taking at the same time convective heat transfer coefficient of cutting fluid I am taking, I am mixing and I am atomizing and I am sending into the machining region ok. So, whatever I am sending here is a jet that is atomized jet ok, it is an atomized jet.

So, atomized jet can penetrate into the intricate regions and it can extract the heat because the convective heat transfer coefficient because I am sending atomized particles of the cutting fluid whose convective heat transfer coefficient is very high. At the same time since I am sending any pressure I am extracting the heat by forced convection.

There are three advantages one is penetration into intricate regions, second one is high convective heat transfer coefficient, third one is an extracting by the forced convection. Because of this process has a huge application, and many other papers you can see already many people published in terms of milling in terms of drilling in terms of turning process in even in terms of grinding process also many people have published work ok.

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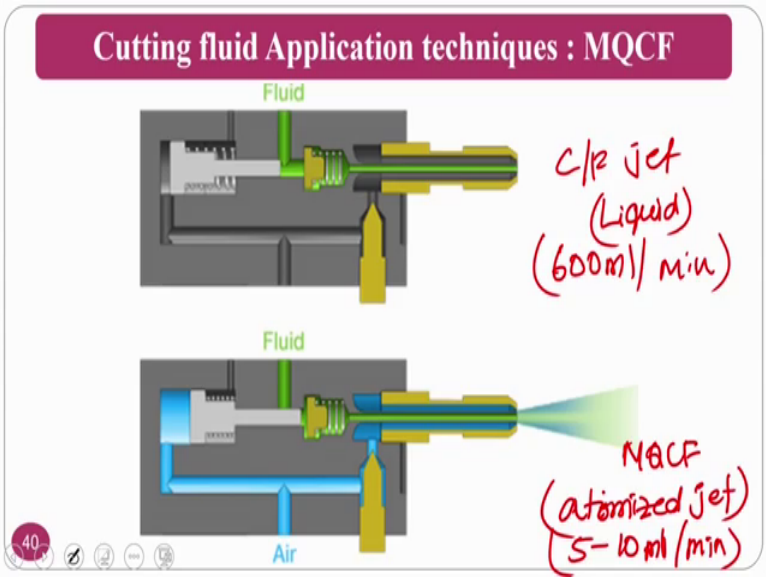

So, in the normal condition is high pressure cutting fluid jet this one if you use MQCF jet ok. So, you can see here normally the it will be a liquid here, here it will be a atomized jet, ok, well good, ok.

So, you can here another advantage is normally the consumption of cutting fluid is less. Here the cutting fluid consumption will be more than 600 ml per minute about 600 ml, here normally it will be like 5 to 10 ml per minute. So, advantage that you are going to get is the product that you can sell in the market will be at competitive price and the quality of the product will also be will be good ok.

So, these are the beauty and advantages of this one. However, the initial investment of getting this minimum quantity lubrication, nozzles and the pump maybe a costly; however, many of the researchers has already demonstrated that you can develop your own nozzles. There are internal mixing nozzles, there are external mixing nozzles and you can also develop these nozzles in your small small workshops also. So, some of the papers also shows that very easily can be economically developed minimum quantity lubrication things.

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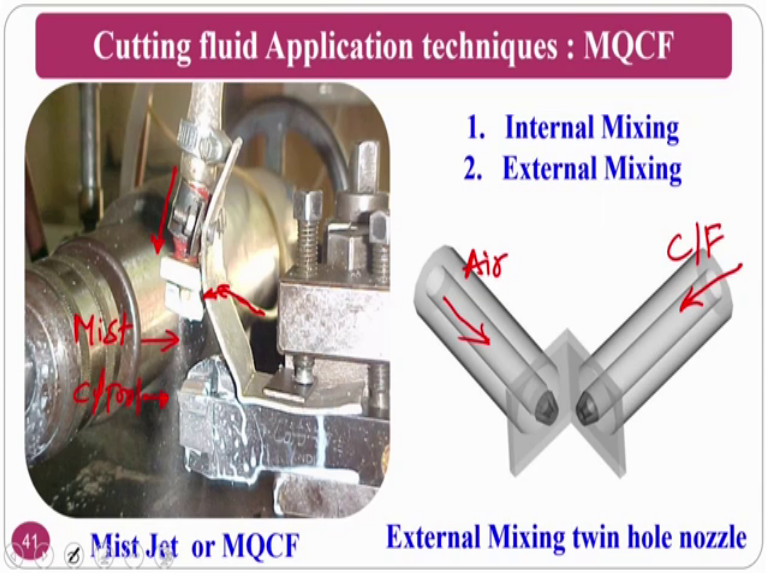

You can see here one of the thing that is published in our research papers where you can see a twin hole nozzle is there where from one you can send the air, another one is the cutting fluid. So, cutting fluid will fall by the virtue of gear if you see here this is the nozzle twin hole nozzle cutting fluid is coming like this air is coming like this ok, my one another it is usable or not I can draw here parallally. So, air is coming like this, cutting fluid is coming from the small pipe if you can clearly see here it will come like this ok.

So, both are mix at the exit of the nozzle that is called the external mixing because of the pressure difference between two nozzles because here compressed air is coming here the cutting fluid is coming by the virtue of gravity. That means, that my cutting fluid tank is kept ahead slightly at the height on the lathe machine just I am keeping on the above the certain height so that the cutting fluids falls by the virtue of gravity. Compressed air I am sending in this one direction where. So, you can see the mist formation this is cutting tool edge, cutting tool and this is your mist ok. So, your mist is falling on the cutting edge you should divert that one then you do the machining operation ok.

So, here the angle is for the better showing purpose only it is shown, but you have to bend this l angle is there this angle can be bendable you can bend according to. So, that the jet inclination will be proper into the machining zone, that is one has to take care. This is about external mixing.

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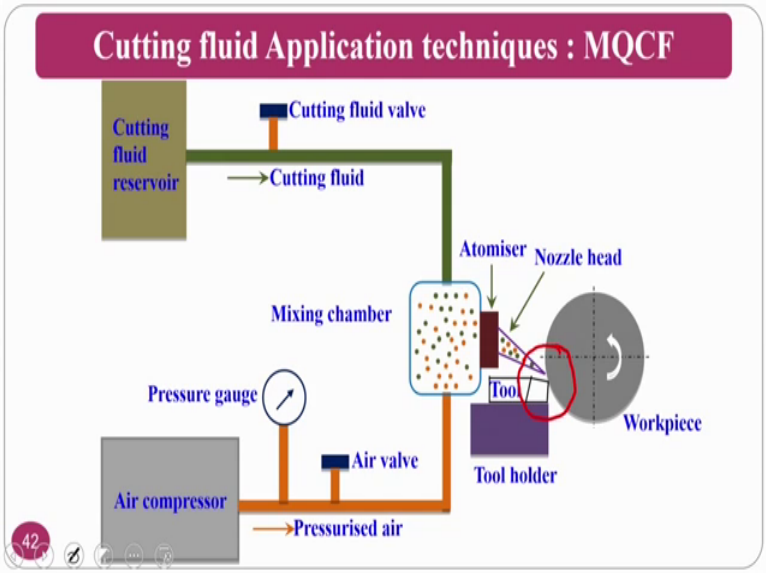

You can also do the internal mixing of these things. So, if you see the cutting fluid reservoir will be there and you are sending the cutting fluid and you are sending air compressor air just you mix in the mixing chamber then you just divert into the machining region ok. This is the internal mixing.

Normally internal mixing is slightly better compared to the external mixing. So, development of internal mixing is the design and all those things will be slightly complicated compare to the external mixing that is why external mixing I prefer if at all

people want develop the your own external mixing as I shown in the previous it is simple you develop it in air.

Normally nowadays internal mixing puzzles also available at economic price like 8000 to 10000. So, you can also get only thing in the previous case and in this case you will need a air compressor ok. So, that is the only thing that I have you have to do ok. So, you can do atomizer and you can send into the machining region if this is the machining region that is falling ok. So, this is about the internal mixing of the minimum quantity lubrication.

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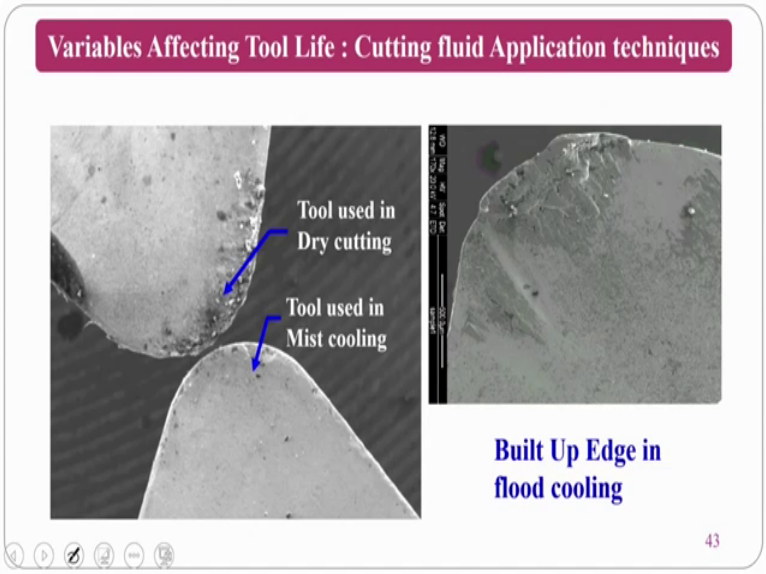

If you see the performance this is for the same cutting conditions if you see dry conditions this is the dry condition and this is the tool mist cooling conditions.

So, if you see the tool cutting edge from the nose and all those things it is completely I cannot see it is what, but it is metallurgically destroyed for the same conditions if you see them a it is approximately better condition compared to the dry tool ok. So, if you see some of the other conditions like cooling conditions it may not penetrate. I said now liquid cannot penetrate into the machining region because of which there is a possibility of built up edge formation and all those things.

This is the beauty about the mist cooling compare to flood cooling and all those things. I can get best performance with a minimum cutting fluid and with minimal environmental

pollution that is the best process. So, people can think off, but many people have published here. So, what is the new thing that you have to do and all those thing you have to see.

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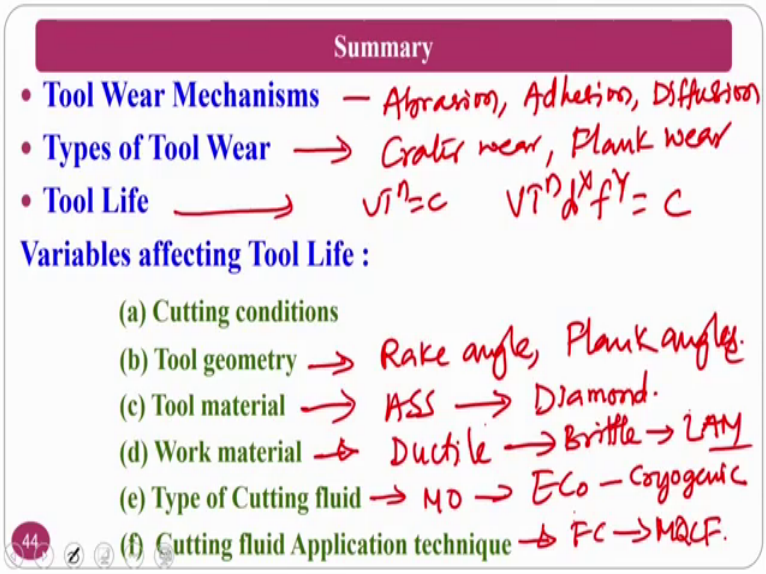

So, let me summarize. So, we have seen in this chapter tool wear mechanisms, tool, types of tool wear that is crater wear and flank wear, tool wear mechanisms such as abrasion, adhesion, and diffusion. Tool wears, normally two tool wears one crater wear, two flank wear.

Tool life normally we have Taylor tool life equation. I mean to say VT power n equal to constant modified Taylor tool life equation where people can incorporate them VT power n power x f of power y equal to constant where n and c are material constants, where are material combination constraint; that means, that work piece material and tool material combination.

And we have also seen the variables of it take the tool life that is the cutting conditions that they feed how it will affect velocity, how it will affect and all those things. Tool geometry like rake angles flank angle and all those things, these are the two angles that will affect in a great way ok.

Tool materials we have studied from HSS to all the way to diamond, where the tool materials and the workpiece materials if you see we have seen from the ductile to brittle

to serum directly high brittle materials, ductile materials, softer materials, ceramic materials and all those things how to machine the ceramic materials. Like in laser assisted machining and all those things we have seen.

Type of cutting field we have seen mineral oil based cutting fluid to ecofriendly cutting fluid and cryogenic also. The cutting fluid application techniques we have seen flood cooling to MQCF, this about the summary of what we have seen in the tool wear and tool life chapter. So, it is a very useful chapter from the B.Tech point of view, from the M.Tech point of view, and PhD point of view. I am just giving you the introduction what is the theory meaning behind it ok.

So, as I am already emphasizing you there are many courses that are coming up and some people are taking from Kharagpur also. I do not know what they are teaching, but I can say from IIT, Guwahati from our Institute side there is a one course on mechanics of machining where they will teach you completely mechanics process. So, that is why I am teaching you the introduction part ok. So, the theory part of this one where you can grasp basic knowledge. And with this knowledge you can go pre course to the mechanics point of view which is mechanics of machining. It may be taken in this semester or next coming semester.

Thank you.