Introduction to Machining and Machining Fluids
Dr. Mamilla Ravi Sankar
Department of Mechanical Engineering
Indian Institute of Technology, Guwahati

Lecture - 20
Cutting Fluid Application in Machining Region

So, now we are going to cutting fluid applications in machining region, how we have to apply the cutting fluids in the machining region we will see now, still now we have seen the comparison between eco friendly cutting fluids, as well as mineral oils what is the rheological aspects what is the flow ability how the capillary action takes place and all those things, thermal aspects also we have seen and we also see the thermal aspects I mean to say that conductivity and specific heat of the cutting fluid all those things.

We also see here as a integral part of a some subject, at the same time we also seen the biodegradation, how the biodegradation will takes place between a mineral oil as well as bio cutting fluid. If we have seen all these things from the cutting fluid composition point of view, and now we have to see another aspect how to improve the performance for that purpose. We are moving into how precisely we have to apply and what are the parameters that we have to consider that particular aspects we will see in this lecture.

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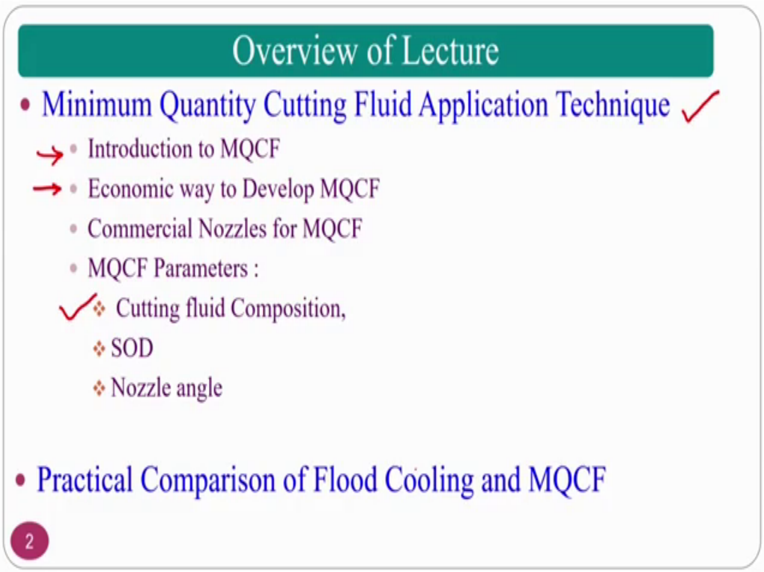

So, minimum quantity cutting fluid it is a one of the best techniques. So, we will see about introduction to minimum quantity cutting fluids and how economically we can develop this system and commercially what are the available nozzles, how to decide and the MQCF parameters that, what are the parameters that will decide the performance and all those things.

What are the minimum things that one should take care scientifically, so that he can come up with better solution for the performance point of view as well as from the ecological point of view. So, cutting fluid composition here we will see the thermal conductivity experiment again we will go through again just some glimpse at the same time we will also these stand of distance, how far we have to keep it and the nozzle angle at what the nozzle angle we have to. So, these are all about the minimum quantity cutting fluid, some of you may not have present in the previous lecture. Let me brief you that minimum quantity cutting fluid is a best process of compare to the flood cooling process ok.

So, if you have not seen you can just go through the videos what are the comparison between minimum quantity cutting fluid as well as flood cooling, and then you can read about this one or you can go about this one then, we go for the practical comparison of flood cooling process with respect to minimum quantity cutting fluid. This particular chapter mostly we deal with the those research oriented papers not with respect to the introduction that is available in traditional books and all those things

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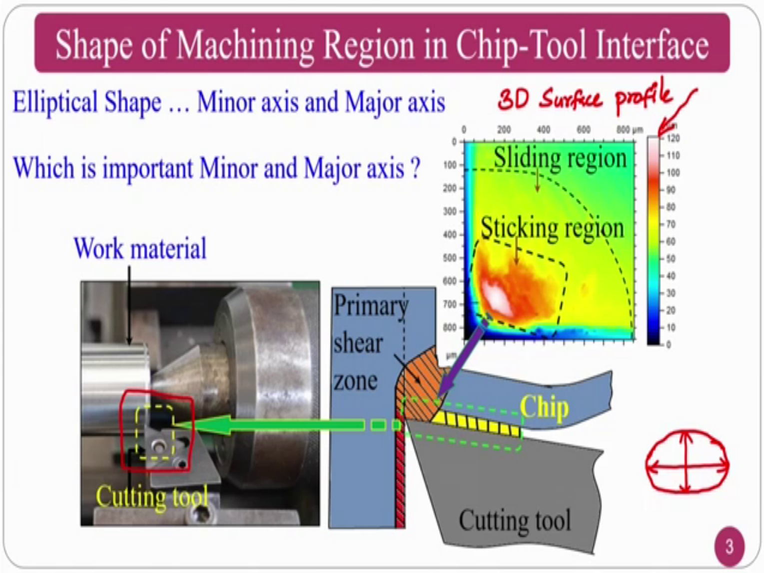

So, most of the people who may be interested in taking up this job as either project work, they can clearly follow how the things are working how you have to choose scientifically and all those things shape of the machining region and the chip tool interface. The first and foremost thing is what is the shape in the machining region, if you see the tribiological aspect this is the picture is known to you since they have shown one or twice in the previous.

If you see a machining region where the chip tool interface is there this is the region where chip tool interface is there. So, the chip is moving on the red surface, and it has a sticking region as well as sliding region and if you see the three dimensional surface profile of the cutting tool this one this is the 3D surface profile ok. Here normally what is the sticking region mostly we are concentrating about the sticking region and sliding region is slightly. So, the areal is a elliptical shape normally if you see here it is a elliptical shape where it will have a minor axis as well as major axis.

So, let me draw this in outside if you have a elliptical shape, you have a minor axis you have a major axis. So, your then which is important for you whether it is a minor axis is important or major axis is important from the cutting fluid, application since you are going to apply your cutting fluid in this direction, let me slightly erase the some other previous material. So, you are going to apply the cutting fluid in this direction, so like this.

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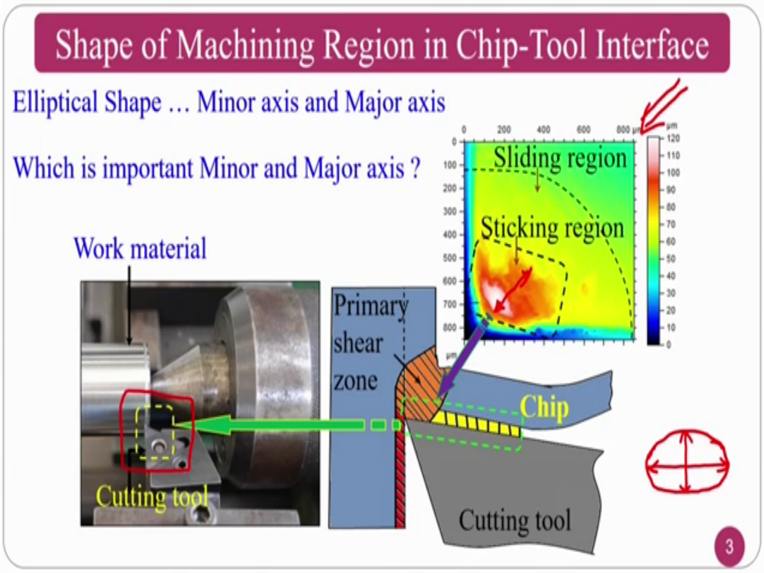

In that circumstances I am mostly worried about my minor axis, how to reduce my minor axis that is a concern for that purpose, how we have to go about and choose various parameters and all those things, that is what about the this particular class revolve around.

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So, various ecofriendly cutting fluids, if you have seen this is the just a glimpse compared to mineral oil based cutting fluid, sunflower oil, coconut oil, as well as canola then you can also look into the liquid nitrogen and all those things, but liquid nitrogen if you are going from the point of economy it may not be economic. So, you always can go with ecofriendly cutting fluids which are vegetable based cutting fluids, any combination of this vegetable oils you can go ahead and you can form your own cutting fluid or there are commercially available bio cutting fluids are there you can procure it ok.

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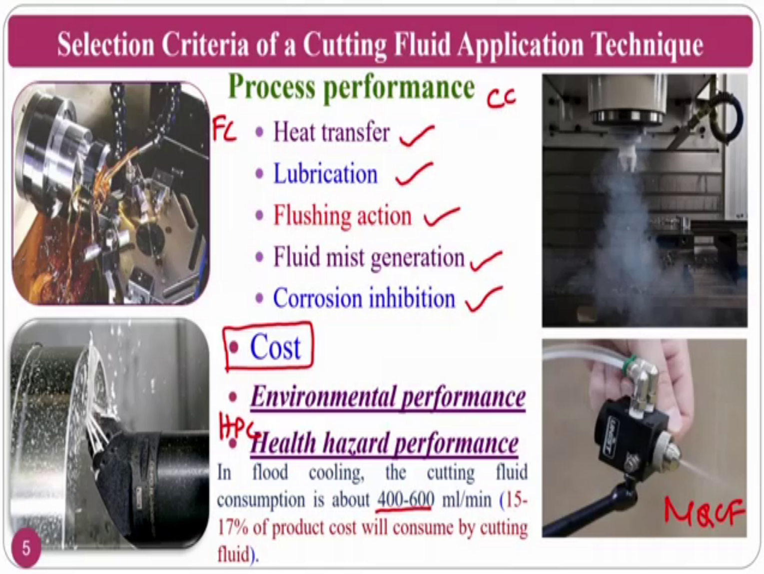

If you see here there are the solutions, flood cooling technique high pressure cooling technique this is the flood cooling technique. This is high pressure cooling and this is the cryogenic cooling this is a MQL or MQCF.

So, basically we go for MQCF, because normal in flood cooling is 400 to 600; that means, average it is been be 500 ml per minute in that circumstances lot of emissions will takes place consumption of cutting fluid also have 15 to 17 percent of the product cost in that circumstances normally we have to minimize the cutting fluid, but we have to maximize the performance for that purpose if the heat transfer performance factors we have seen heat transfer lubrication flushing action mist generation corrosion inhibition these are the things that also we have seen, and most importantly you have to generate this MQCF that is the minimum quantity cutting fluid set at the economical price and all those things.

So, that it will be environmentally friendly as well as it should not cause health hazards, looking at all these aspects we can design our system for economic as well as the product cost should be low and the performance should be better for that purpose we are going towards minimum quantity cutting fluid.

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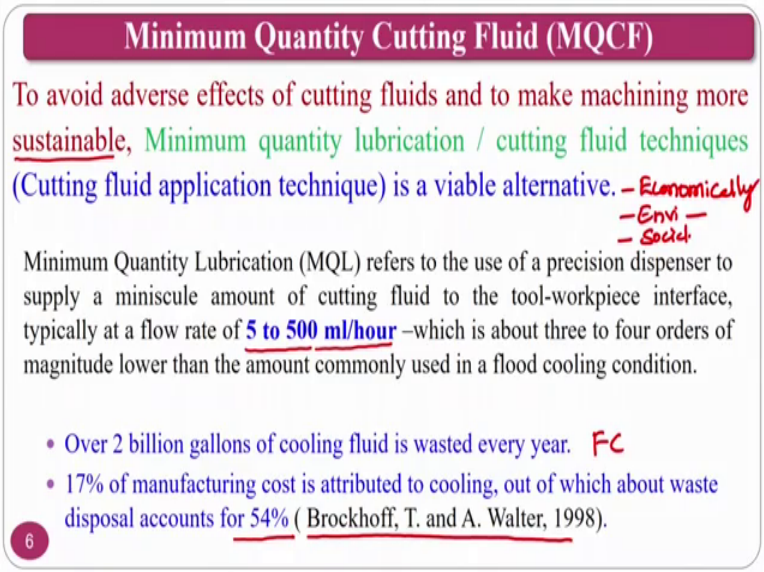

So, minimum quantity cutting fluid normally to make the more sustainable, sustainability can be defined in three ways one is it should be economically, friendly, environment friendly, and the third one is social friendly.

Economic friendly means it should be less cost, environment friendly means it should not cause any type of emissions or something at least it should emit minimum emissions, social friendly means it should not harm the end user, basically assume that I am making a rod with sharp edges what will happen if during usage operator or any common man who is using it. He may hurt this hands and fingers that should not be. So, for that purpose only normally radiusing and chamfering will be given. So, that is one of the examples of social friendly and all those things.

Minimum quantity lubrication refers to the precise dispenser to the supply of miniscule normally 5 to 500 ml per hour this is completely if you see per minute in a flood cooling it is 500 ml per minute. So, here normally 5 ml per hour, so it is very, very minimal, so 15 to 17 percent of the product cost that you are spending will be enormously reduced. So, that your product can be a competitive in the market over two billion gallons of cutting fluid is wasted per year using flood cooling basically flood cooling technique.

So, 17 percent already I said this is reference where 17 percent of the manufacturing cost is attributed to the cutting fluid, but about the waste disposal accounts for 54 percent; that means, wherever you are disposing your cutting fluid in a recycling of cutting fluid if you use in a flood cooling you recycle it recycle it recycle it and at last you may have to dispose it off to near river body or you have to dispose it to soil wherever you are digging and all those things.

So, transportation cost is the one thing at the same time you cannot dispose like that you have to do lot of post processing's if, so that you can dispose it off. So, that post processings plus transportation and disposing labor cost these are all include in this one disposal cost and all those things. This will be huge amount rather than if you can use a minimum quantity cutting fluid technique where you just spray it where the efficiency can be improved by the force convection process at the same time penetration abilities better because of its atomization.

So, this is having many better things at the same time new technologies are coming up nowadays, but whatever this technology is around 2002 to 2010, nowadays also many people are using and you can use this process for those people who want to carry out their work and only thing is that how to optimize. So, that the operators as well as the company people will get economically benefitted as well as environmentally friendly benefitted that much thing one can take up as a work.

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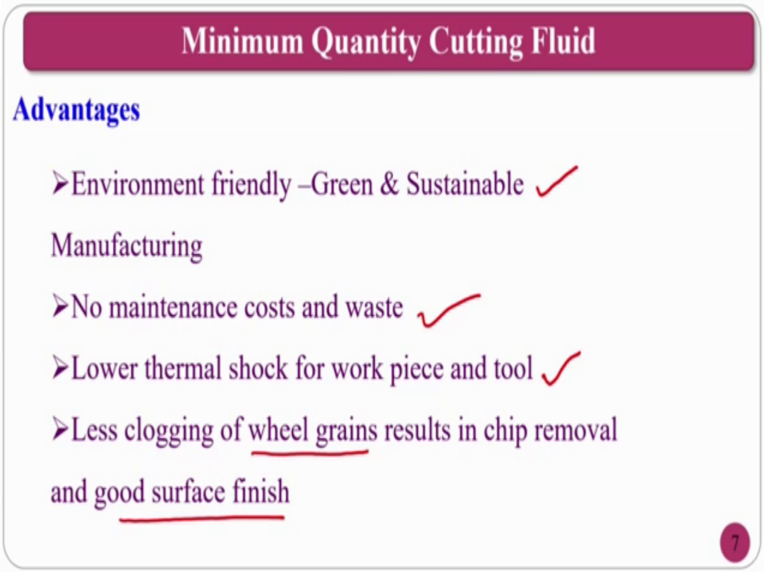

So, minimum quantity cutting fluid advantages it is environmental friendly green and sustainable manufacturing process no maintenance cost and waste because just it is a spray that you just spray it will goes off. So, there is no recycling process, there is no transportation, post treatment of disposals and all those things lower thermal shocking for work piece material, because thermal cooling will takes place by the force convection less clogging of the wheel that is represented to grinding operation, which we come across in the upcoming classes in.

Where we study about horning process super finishing process most important grinding way surface grinding, internal grinding, external grinding, centralized grinding, and all those things and even you get the good surface finish. Surface, finish is a qualitative statement; that means that you will get a low surface roughness value, so minimum quantity cutting fluid.

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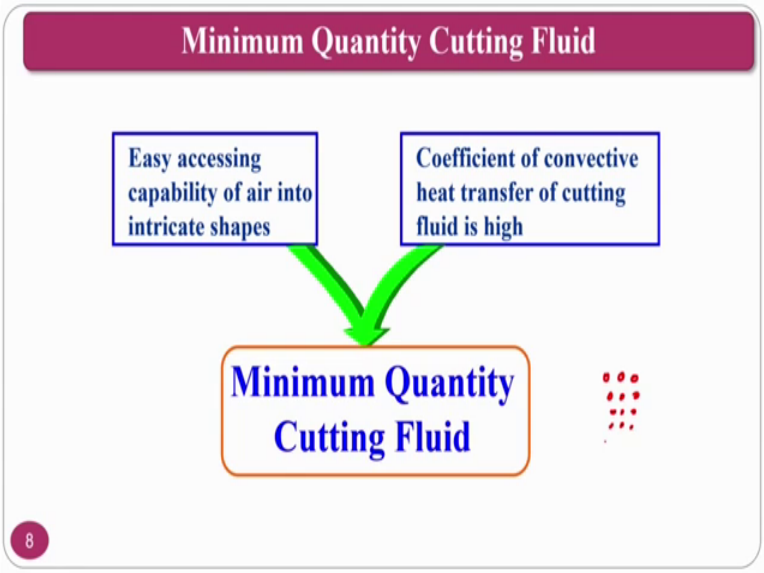

The beauty about this one as I said easy accessing capability of air into intricate surfaces is the one of the advantage, at the same time coefficient of convective heat transfer of cutting fluid is high. So, these two advantages one advantage if you see the one advantage easy accessibility of air into intricate shapes this we are taking assume that I have a flood cooling process where convective heat transfer coefficient of my cutting fluid is very high, but it cannot penetrate in another case air has low convective heat transfer coefficient, but it can penetrate. So, the advantage of air that is easy accessible to intricate regions I am taking, but I am not taking the low convective heat transfer coefficient of air.

So, I am taking the high convective heat transfer coefficient of the cutting fluid, but its inability to go into the machining region I am not taking. So, I am taking the positive of air penetration at the same time I am taking convective heat transfer coefficient of the cutting fluid, both I am mixing it and I am coming up with minimum quantity cutting fluid technique, this is about the minimum quantity cutting fluid if somebody has not followed in the previous classes you can follow from this particular slide.

So, the minimum quantity cutting fluid, here you will have a atomized gas it is not liquid it is a atomized gas, that is made up of high pressure air plus cutting fluid liquid. So, both will mix and come this mixing can be done in internal mixing as well as external mixing, I will come to that particular slide also this will mist which is a cutting fluid atomized mist will can penetrate and take out the heat by the forced convection process because you are sending with high pressure air.

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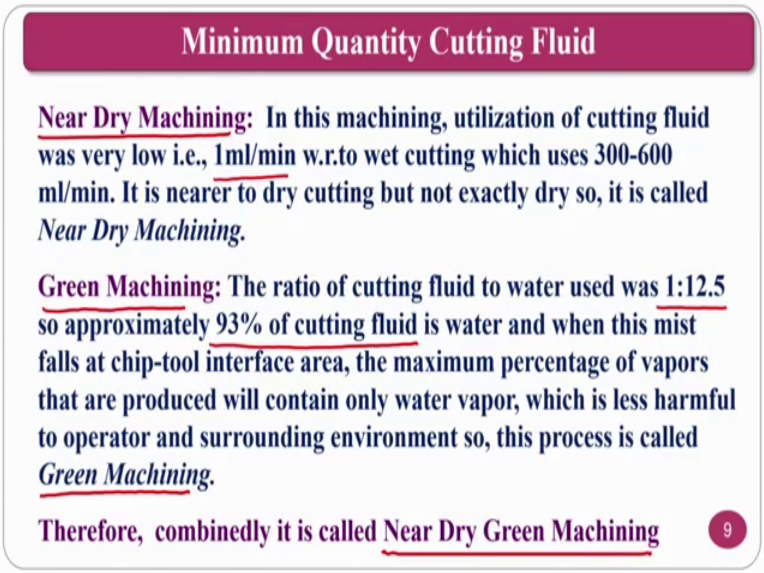

So, minimum quantity cutting fluid normally this also called as near dry machining process, this one because normally 1 ml per minute or 5 ml per hour these are many techniques are there depend on your nozzle type, mixing type and all those things. So, if you are using 500 ml per minute in a flood cooling if you are using 5 ml per hour or 1 ml per minute this is nothing that is near to dry machining, that is near to you are not using the cutting fluid, that is why this machining also called as near drying machining or some people, it is also called as pseudo dry green machining why it is called a green machining.

Now, you see the ratio of cutting fluid to the water is normally one is to 12.5, 1 is to 8, 1 is to 10, and all those things approximately 93 percent of cutting fluid emulsion is water, what if that is the case whatever it emit the major amount will be like water vapor or something so; that means, it is green or you can say it is near green machining process. So, that is why it is called as near dry green machining or near dry machining you can say people say minimum quantity lubrication, where they don't use the emersions, some people they say micro lubrication because the nozzles are specially designed at the same time they are going to send the cutting fluid very, very, very, minimally.

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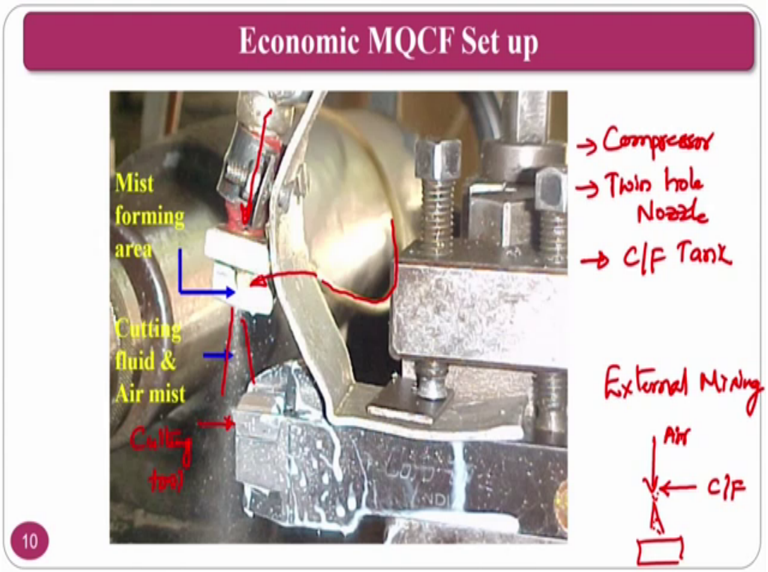

So, this is economic way because being a India developing nation many people come up I am economic solutions. So, the people who want to go and develop this type of set up you can easily develop the setup. So, if you can see you need some of the components like compressor you need, and you need a nozzle. Where two nozzle you can develop and in the system, I will explain where twin hole nozzle you require and cutting fluid tank.

So, what is your going to do here is your cutting fluid is coming from this pipe, you can see this pipe this is a pipe. Which is sending my cutting fluid horizontally at the same time compressed air is coming like this, and both are mixing externally. Here we are using external, mixing; external mixing you might have already seen this slide.

The external mixing is taking place by the virtue of pressure difference between your cutting fluid, which is coming certain height normally this cutting fluid is kept at a certain height in the next slide you will see from the machining region, by the virtue of gravity it is falling at the same time it will also suck because of air pressure air you are sending at five bar pressure seven bar pressure and all those thing, because of the pressure difference that is generating here one nozzle exit is like this another nozzle exit is like this both here you are coming cutting fluid another one here you are getting air compressed air.

So, both will mix here and divert in this direction, so machining region is here. So, in that way you will can generate the mix you can see here mix this is the mist that is formed and from the machining the exit it will falling a diverging. So, that you can design your system, so that it will fall on my cutting tool, this is the cutting tool this is about the machining system with minimum (Refer Time: 19:18) cutting fluid how the zoomed version look like.

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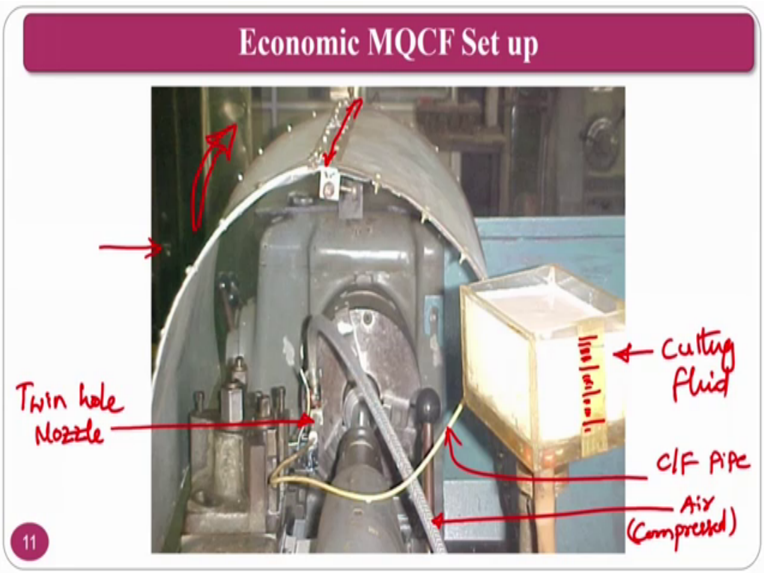

If at all I want to see the overview, how the overview it look like this look like this is the cutting fluid tank, cutting fluid tank this is and you can have a graduator scale here this is the graduator scale. Where the graduations are there, how you can measure the cutting fluid quantity how much is flowing and all those things this is the air pipe, this is the cutting fluid pipe, and this is the air which is compressed air, air is coming from this one.

So, this is the twin hole nozzle and you are generating the mist and sending which you can see in the previous slide this is how the mist is generated from this particular setup.

But the problem here is your work piece is rotating at certain speed and there may be a splashing takes place, for that purpose to keep the operator safe what we have done a shutter. Where, if there is any splash also it will fall on this one at the same time one thing is not visible here that is operator is looking from this side. So, this type this particular shutter has a transparent window where which is made up of a percepts.

So, that operator clearly can see what is going on in the machining region, at the same time once the operation is completed he need not to completely dismantle from the setup. He can just this is a hinge is there you can see here it is a nut system just you can lift that one, and you can take out your product is as simple as that one this will be movable.

So, this is about how you can develop with the existing materials in a small scale laboratory also, this is cutting fluid tank made up of percepts you can join this percepts by chloroform and you can make your cutting fluid tank you can put a small scale where the radiations are there and you can connect this cutting fluid tank with respect to cutting fluid and compressed air pipe.

And compressor you can put at certain part of your laboratory and you can get the compressed air, and twin hole nozzle you can develop using your stove nozzles also just you make aluminium twin hole nozzle just you fix it with your stove nozzles, that is what here the authors have done and splashing protection you can also done by some of the aluminum based sheets and all those things. So, this is about how you can develop economically.

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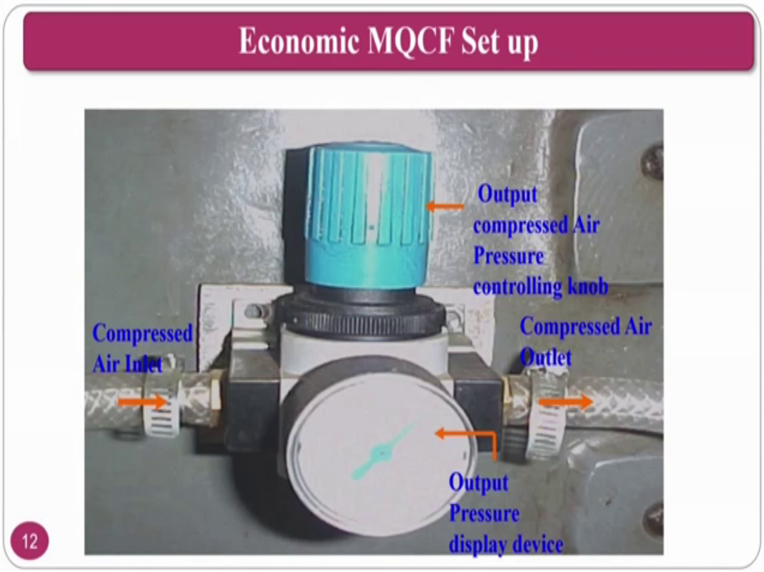

And you can also control the cutting fluid mist generation by these output pressure regulator ok, output pressure regulator knob is there just you adjust output pressure regulator nozzle and you can also check how the cutting fluid is sucking and what is the particle size that is the droplet size and all those things also you can measure, the droplet size measurement and simulation and all those things we will see in the grinding that is the part of grinding.

Where we will see the some of the simulations of some of authors how the particle generation with respect to atmospheric air pressure, what is the droplet size that is coming in the machining region from the minimum quantity cutting fluid and all those things we will see.

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These are the commercially available setups if you see till now, what you have done is how you can develop in the laboratory how with minimum cost you can generate if at all you have some money.

So, you can go up you can go ahead with purchasing of the nozzles where if you can see here, the nozzle system which is cutting fluid is there as well as you have the air is there both are mixing internally and sending the mist like this. So, this is one of the systems at the same time you can have another systems also where you, you can mix internally and send the spray like this everywhere it is spreading one. So, different, different companies will produce different, different nozzles and the mixing mechanisms.

These mixing mechanisms are patented by themselves they can have the internal mixing, external mixing in internal mixing also many varieties are there. So, different, different nozzle systems are different, different varieties are mixing is there just you have to choose a right variety of nozzle for your application. So, that your performance of the machining improves at the same time ecological aspects also considered during the performance testing.

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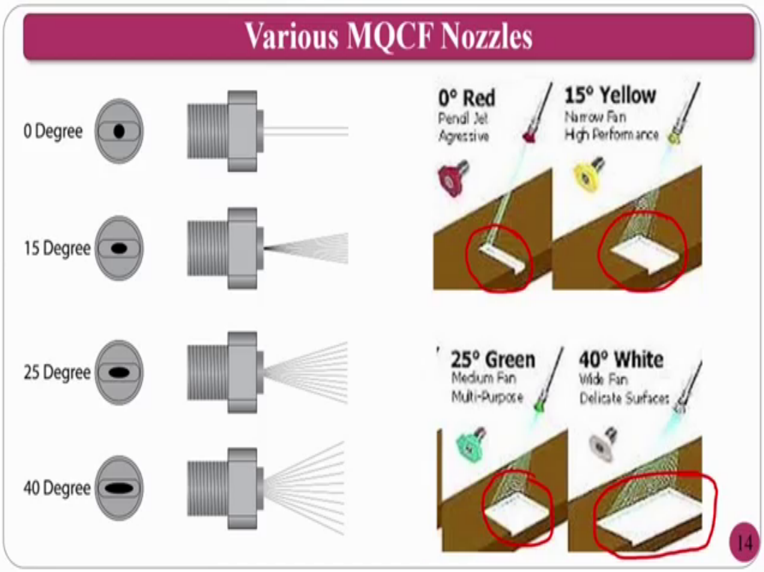

These are the nozzles how normally you can see it is 0 degree nozzle, 15 degree diverging, 25 degrees and 40 degrees. How these are practically shown during the machining operation you can see here. So, these are the nozzle, nozzles will be given some of the colors how to differentiate and all those things.

How this area how much area it will fall and other things you can check from this one, you can choose if you are going for a turning operation which one I want, if you are going for a milling operation which one I want, if you are going for a grinding operation which type of nozzles I want and all those things this will help you in choosing a right nozzles for your application ok.

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These are the other varieties of nozzles which you have seen already I want to emphasize two things; one is internal mixing as well as external mixing that is if the cutting fluid and air both are mixing outside the nozzle that is called external mixing. If both are mixing internally; that means, that within the nozzle system there is a mixing chamber will be there if there it is mixing and, and coming the mist outside that is called internal mixing, if it is mixing outside the nozzle it is external mixing it within or before the nozzle exit if it is mixing that is called internal mixing.

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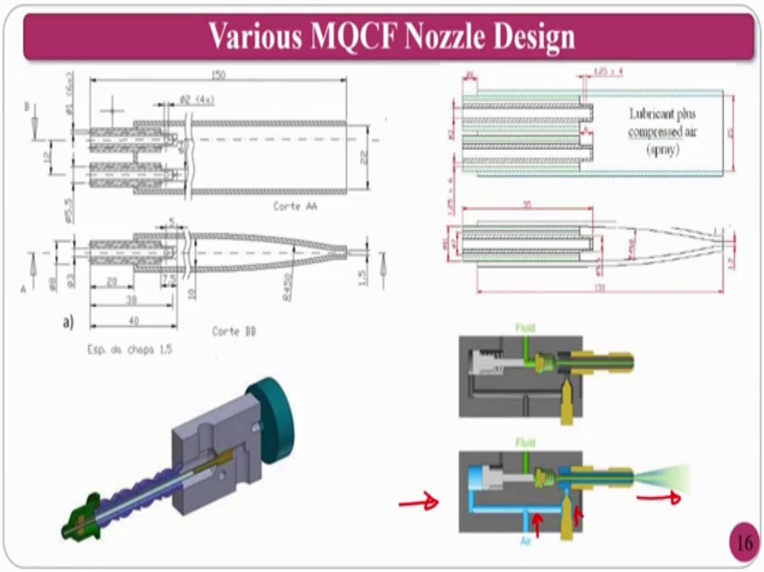

There are varieties of nozzle designs you can see I am just not going in detail about the nozzle mixing and all those things. If you see this pictures where the air is coming from here and cutting fluid is coming from here, both are mixing and here and this one internally as well as it is coming outside internal mixing operation is going on. So, like that many varieties of mixing technologies are there, because companies have their own patent technologies, that is why they have different, different people will have different, different nozzle designs.

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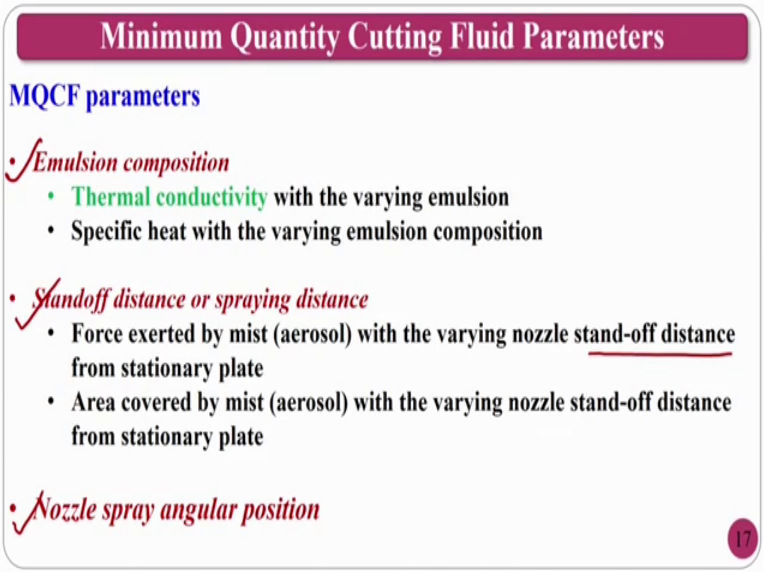

So, MQCf parameters that is normally emulsion composition, emulsion composition is one of the most important. And in this particular section I am just repeating some of the things that we have seen in the previous classes that is thermal conductivity measurement, specific heat measurement and all those things.

Just I will go through it not in detail, because in detail I have already gone through, the standoff distance force exerted by the mist that is varying nozzle standoff distance from the stationary plate area covered by the mist and nozzle spray angular position. How these are affect the minimum quantity cutting fluid, we know that the minimum quantity cutting fluid is a better from the dry as well as flood cooling within MQCF, how to go for betterment of this MQCF, how to improve the process performance by using variables that are affecting the performance of MQCF.

That is one is emulsion composition and second one is standoff distance that is force exerted by the mist that is standoff distance, at the same time how much area it is occupying, third one is nozzle spray angle these are the three looks like three, but within standoff distance also you have two more variables that is how much area it is covering and what is the pressure it is are what is the force it is exerting and all those things.

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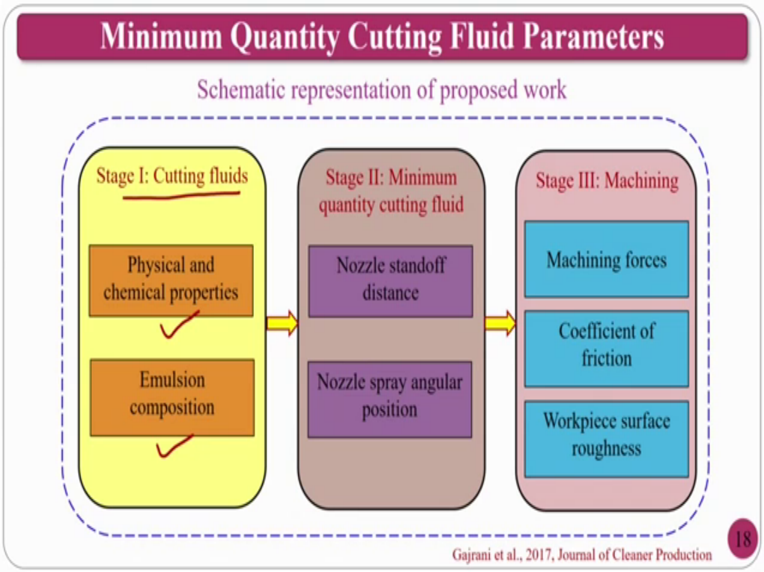

If you see the minimum quantity cutting fluid cutting fluid composition itself is one of the pathing, how to represent the proposed work; that means, that if I am doing the minimum quantity cutting fluid, in a scientific way how to propose that particular part of work to explain is physical and chemical properties, emulsion composition these all things then minimum quantity cutting fluid standoff distance, angular position, then we will go for the measurement of the forces coefficient friction then we had go ahead with morphology of the surface in terms of surface roughness tool ware and sticking regions sliding region and all those things we also seen.

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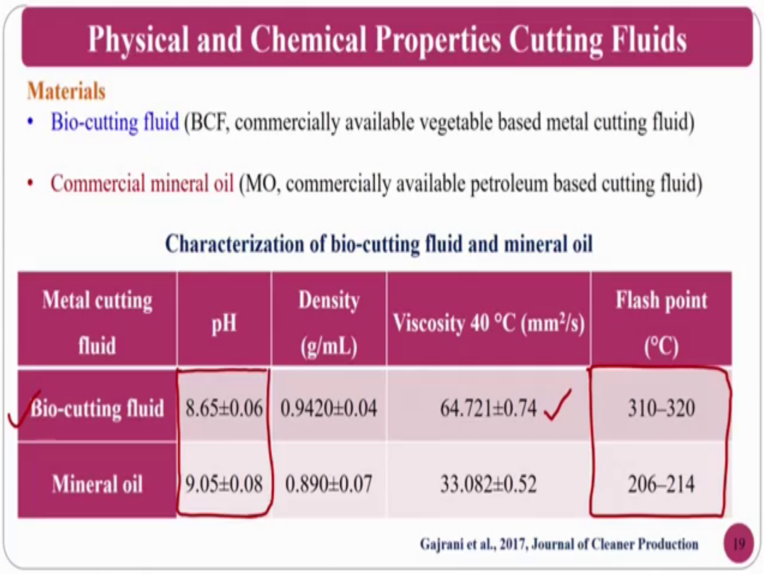

The first one we want to compare between mineral oil as well as bio cutting fluid for that purpose the first and foremost thing that we are going to characterize is there pH characterization, they if you see the pH characterization the bio cutting fluid and your mineral oil, normally the pH should be around 7, if it is around 7 there is no much problem. So, among this bio cutting fluid and mineral oil near to 7 is bio cutting fluid; that means, bio cutting fluid has good pH compared to the mineral oil.

Density wise the bio cutting fluid has slightly high if the density is high; obviously, viscosity will be also high, and the flash point if you see it is good for the bio cutting fluid compared to your mineral oil; that means, that fire catching ability will be slightly less compared to your mineral oil; that means, except viscosity it is having all better, but if you have a viscosity in a good amount that is higher side of viscosity; that means, it will also give me good lubrication from the point of lubrication also it will give, let us see whether the statement is true or false or neutral how it will going to in the upcoming slides ok.

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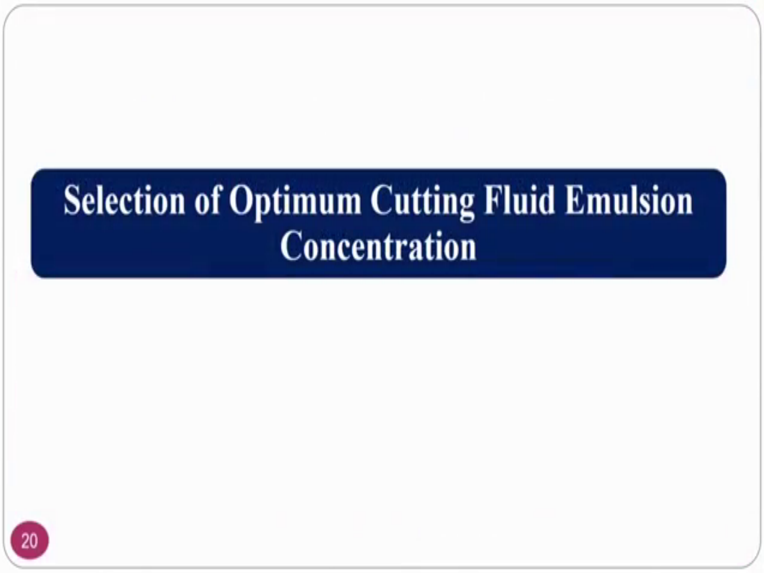

Selection of optimum cutting fluid emulsion, here I said how to select what is the composition that I want, this particular part I have taught already in the previous sections whenever I am teaching about thermal conductivity and all those things.

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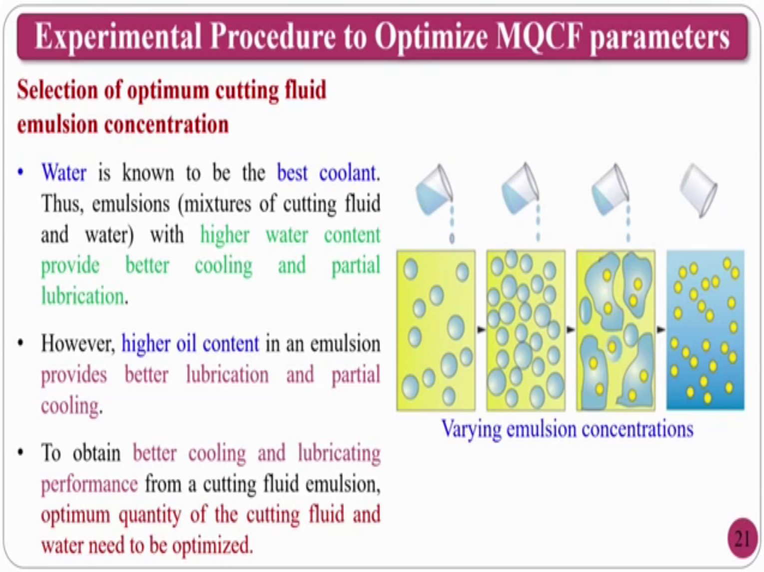

Emulsion composition and all those things, so water is known to be the best coolant. So, how to mix, how much water, you have to mix with respect to the cutting fluid that is what I have talk in the previous class.

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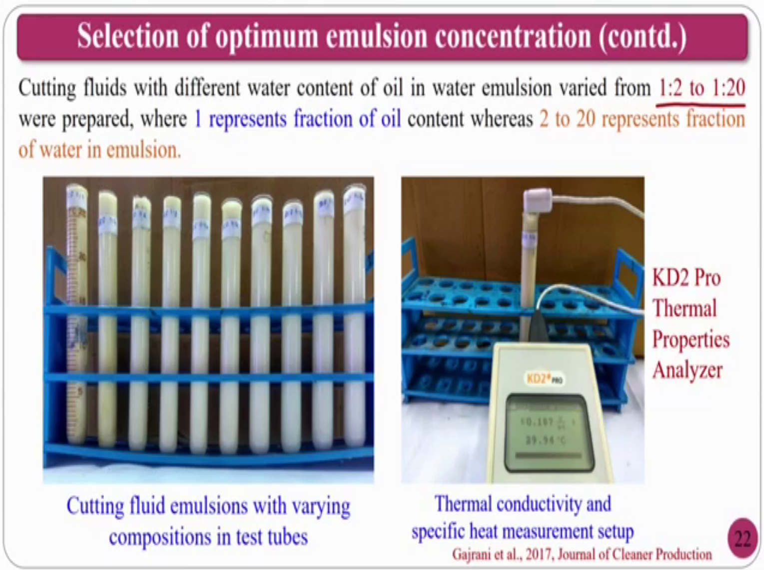

If you see this particular slide where, we took the cutting fluid and we mixed range from 1 1 is to 2 to 1 is to 20; that means, particular one liter of cutting fluid, 2 to 20 liters we have mixed in a ratio or extend normally we have done 1 is to 2, 1 is to 4, 1 is to 6, like that we have increased up to 20, and we used kd 2 pro thermal properties analyzer to measure the thermal conductivity as well as specific heat.

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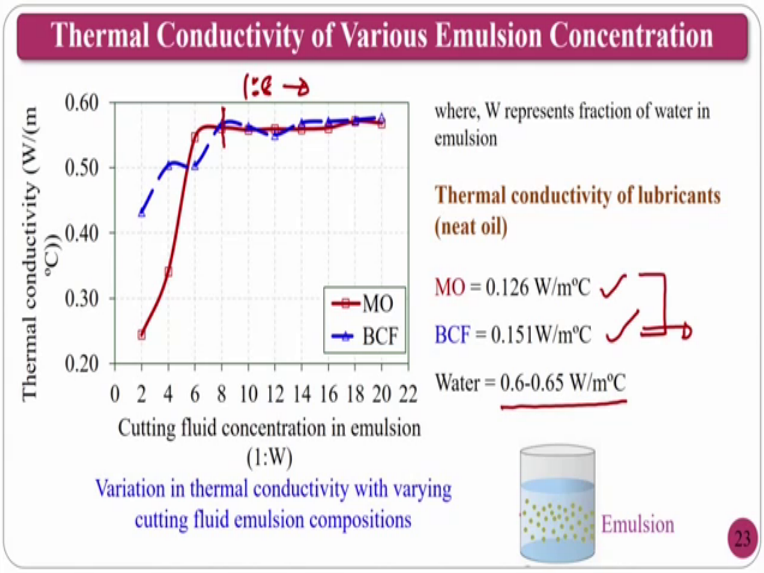

If you have seen the thermal conductivity normally above 8 liters that is 1 is to 8 there is no much change in thermal conductivity. So, if you can go for 1 is to 8 or 1 is to 10 or 1 is to 12 you will get lubrication as well as cooling because thermal conductivity is majorly function of water content.

Water has a good thermal conductivity that is about 0.6 whereas, mineral oil and bio cutting fluid as minimal compared to that one half, but among the mineral oil and bio cutting fluid you will have better value for bio cutting fluid only.

So, if at all I want good thermal conductivity I have to increase water, water, water, if I increase water what will happen my lubrication problems will come, that is why you need to choose optimum cutting fluid emulsion where water should be used in a better way. So, that the thermal conductivity will come as well as the lubrication also should come.

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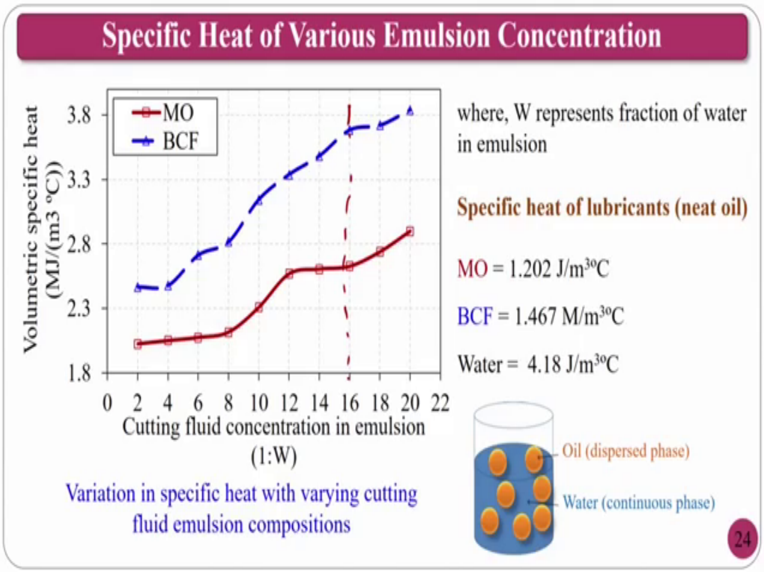

The volumetric specific heat is also is considerable. So, volumetric specific heat it should be as maximum as possible, in the previous slide if you have seen here normally above one point 1 is to 8 you will have a good value. Now if you see here the volumetric specific heat is up to 1 is to 16 it will be gradually increasing after 16 there is no not much; that means, that you can go ahead with 1 is to 16 also.

So, 1 is to 16 if you take what will happen you have thermal conductivity good at the same time specific heat also absorbing also very good, but if you go slightly below you may have the better lubricating properties, if and only if it is behaving as a good lubricant that particular part we will see in the upcoming.

We have selected the optimum composition, that is where thermal conductivity is better and specific heat should be better from this we have considered the cutting fluid composition, whatever the region whether you want one point 1 is to 8 or 1 is to 16 and all those things, now we are going to optimum standoff distance.

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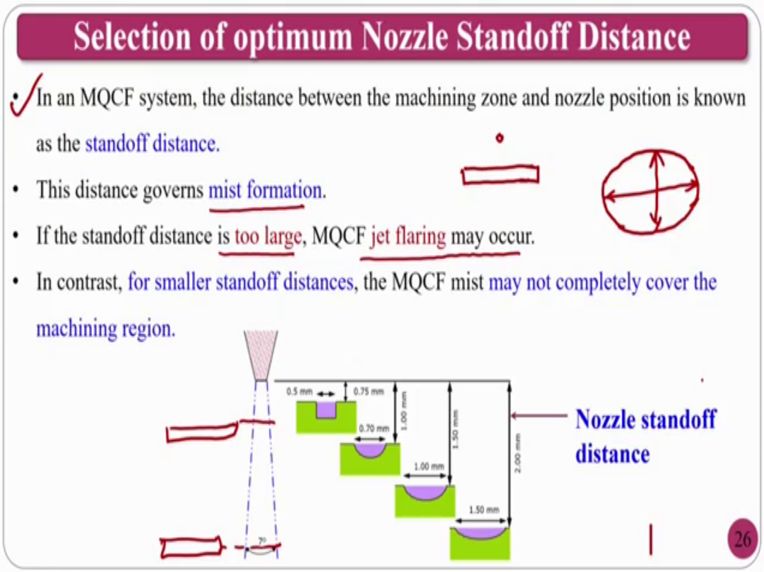

How far the nozzle has to kept in the machining region. So, if you see the MQCF system distance between machining zone and nozzle position is known as the standoff distance, this is the standoff distance how far you are keeping your nozzle from the machining region. This distance governed by the mist formation, how the mist formation the standoff distance is too large what will happen jet flaring will takes place; that means, that if your work piece is here, you will have this much only if your work piece is here what will happen you will have more flaring that is more diverging will takes place ok.

So, for the smaller distances MQCF may not be completely cover the machining region. So, you need minimum flaring at the same time it has to cover your machining region, since you have already seen the machining region that you are going to talk about is the machining region is approximate like elliptical surface you have a minor axis and major axis. So, in it has to cover that much particular area at the same time flaring should be minimum.

So, for that purpose how we can decide that what is the standoff distance optimal standoff distance? So, that it can cover this machining area completely in terms of minor axis, because major axis how one can cover that will also we will see that you can take your nozzle a slit type of nozzle; that means, that you have a slit type of nozzle. If you take like this what will happen it will cover your major axis, instead of going for a whole type of nozzle exit.

If you take a slit type of nozzle then it will cover your major axis only this will also diverges from the slit it will comes like this; that means, that my slit is covering my major axis and diverging in the perpendicular diversion cover my minor axis for that purpose you have to choose a right type of nozzle.

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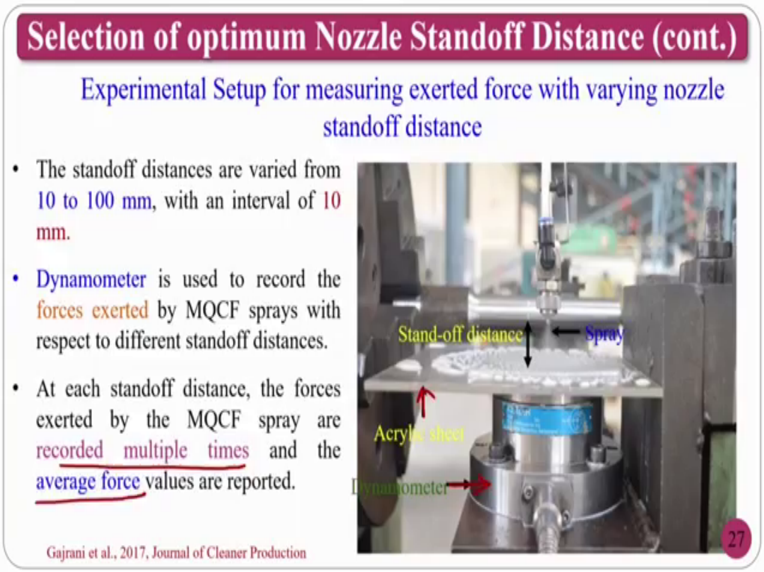

So, the selection of optimum nozzle, standing distance how you are going to select that is the standoff distances are varied from 10 to 100 mm with the interval of 10 mm; that means, that the experimental set up if you see here this is the dynamo meter and acrylic sheet is fixed on dynamo meter then you are putting your nozzle perpendicular to it and your spray with distance of 10 mm, 20 mm, 30 mm, so on, to 100 mm.

So, as the distance increases what will happen same time we have to do this experiment multiple times, because to get the good repeatability and accuracy values that is what it is recorded multiple times and average force values are reported or recorded.

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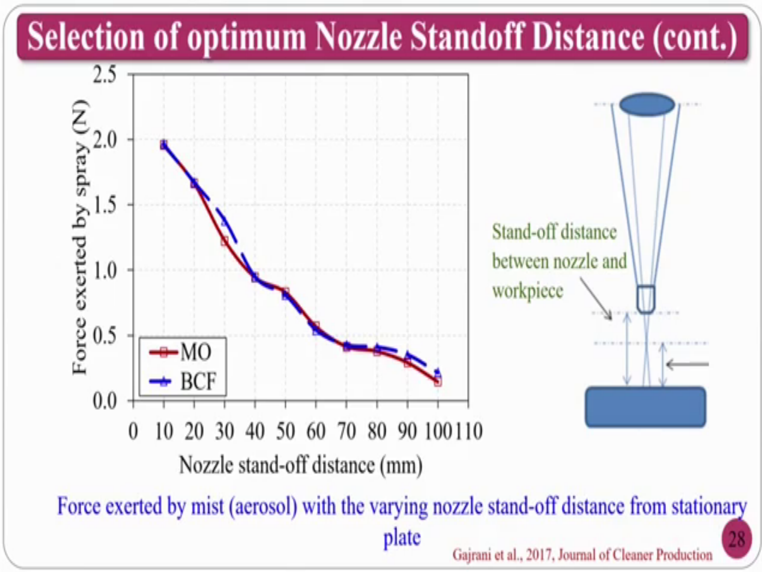

If you see that one as nozzle standing of distance is increasing; obviously, the force exerted by spray is going to decrease. If the distance increases the force decreases at the same time flaring that is diverging will also get.

So, this is what you can expect without doing experiment also, but you can say quantitatively; that means, it will decrease that much you can say, but you cannot say how much it will decrease that is called quantitative value you cannot see for that purpose how much it is decreasing confirmation one has to do for that purpose the experimentation is done and though it is falling the similar trend what we are expecting now we know what is the standoff distance versus the force exert.

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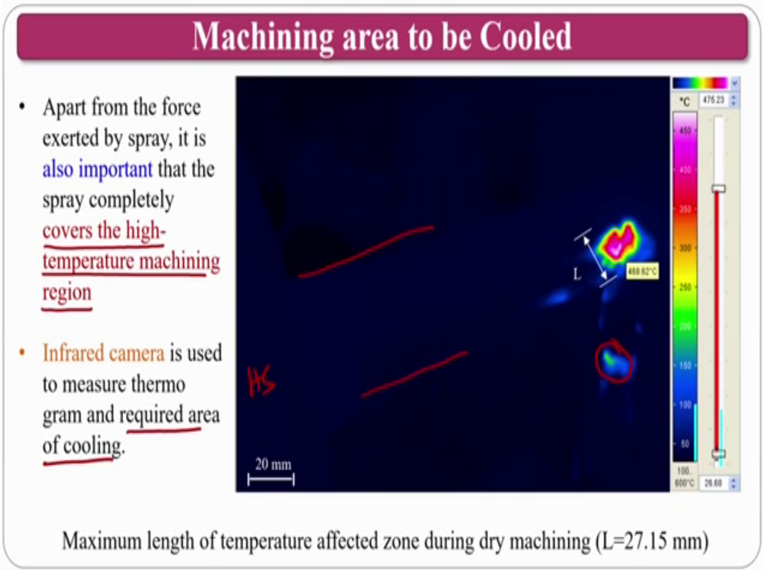

Now, we go ahead with machining area to be cooled with this force in our mind, we are going ahead with area to be cooled for that purpose as from the part of the force exerted by spray also important for the completely covering the high temperature machining region; that means, it has to cover the temperature region, we have seen in the first slide or the second slide where you have a elliptical region of sticking and sliding region to confirm it we also do with the infrared camera in the this particular slide.

Infrared camera is used to measure the thermo gram and required area to cool if you see the picture. So, this is the machining region I don't know how far you can see this one there is this is the head stock, and this is the rod that is the work piece is here and your tool interface is in this region, let me erase this particular section, so that I will explain you in detail.

So, this is what the chip is jumping from the machining region and this is the machining region machining region follows the elliptical, which is also we get from the first picture of this particular class where you have seen the sticking and sliding region and we want to cool this chip tool interface which is also proved by this particular thermo graphical image. Where you are going to have a elliptical shape, this is particularly the elliptical shape this region one has to cool.

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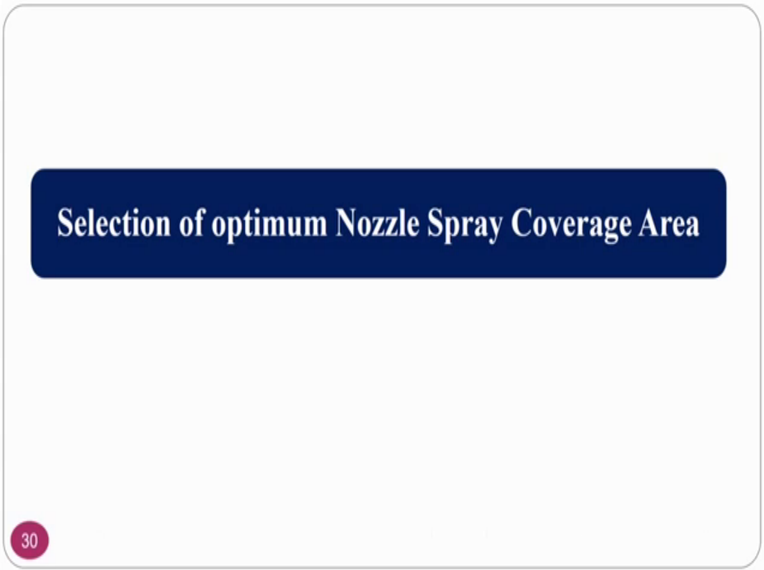

How to cool for that purpose selection of optimum.

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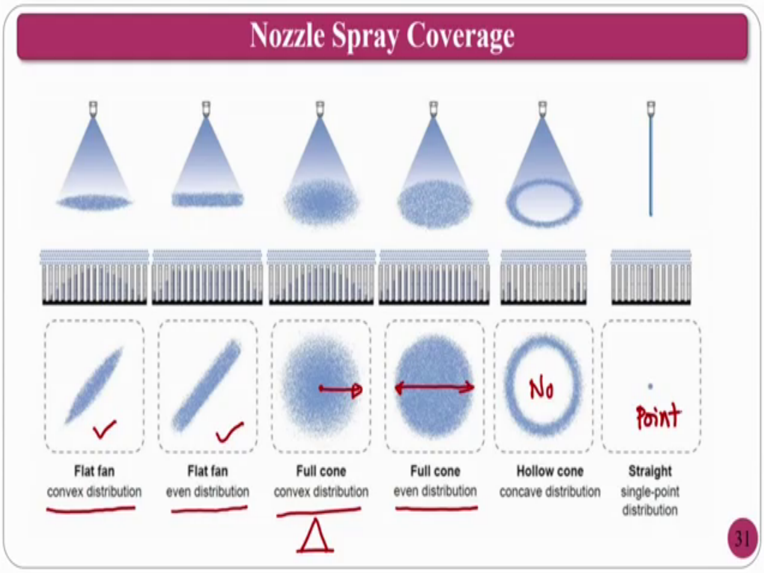

Spray which type of spray you want for that purpose the first one is flat fan this is the convex distribution this is how the distribution takes place, and the shape of the cutting fluid how it is fall is given here.

Similarly, flat fan even distribution is there. So, here the convex distribution is there here the flat distribution is there even distribution across that one full cone normally it is also will have a convex. Where the full cone is there and again full cone even distribution, I mean to say full cone means it is like this the density of the center is very high.

And the density goes to the periphery if the density is reducing, here it is even wherever you take it is completely even and the hollow cone if at all the some of the applications where you are looking you can have the hollow cone also where here no cutting fluid and you have on the periphery at the same time straight you will have a point coherent type, but it is cannot be coherent like lasers and all those things you will have still approximately a point type of thing that is a circle of small diameter will have ok.

From our previous literature of the thermo graphical image at the same time from the previous experience of the sticking and sliding region, now we have to choose which type of nozzle we want depend on their area of coverage. For that purpose for particularly for our application we want flat fan with convex distribution we can go ahead.

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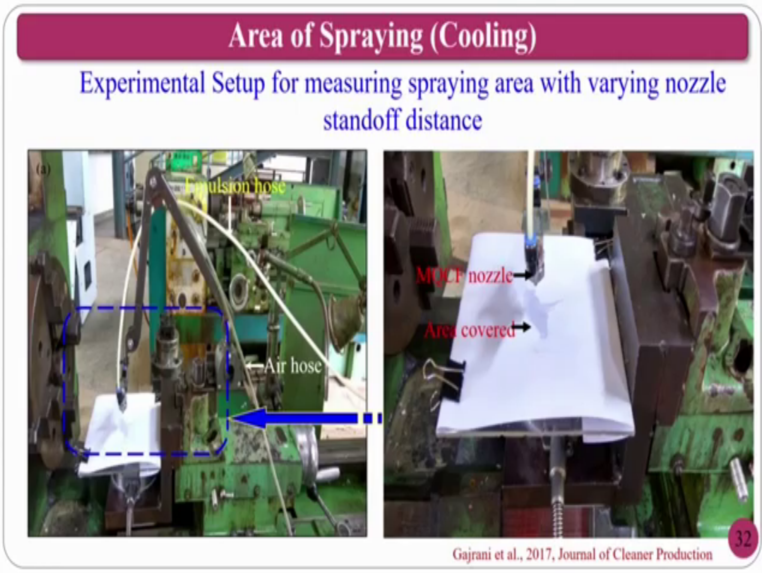

So, area of spraying how to check the area spraying, if you see for this particular purpose also since already we have seen a dynamo meter is there on top of it there is a precepts plate is there, on top of it we are just putting a chart and use just spray on it instantaneously you just spray and stop it and you immediately you have to put some focusing high resolution cameras.

And you have to take the images because once the spray falls on the chart it tries to spread in all directions to get a right image the photographers should be there in all the directions immediately they should be wait and they should be high without any time they should be catching the images.

So, for that we have worked a lot and different, different photographers are standing on the different, different directions to measure properly at the same time instantaneously the photographer will start before the spring starts and it will continuously takes in a spectrum of images and so that, we can take the required image as soon it fall on the machining region.

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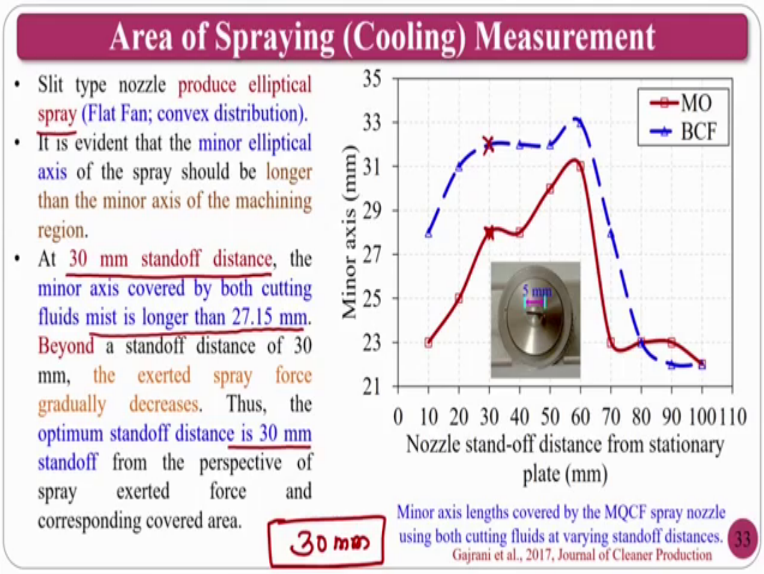

If you see that one, so the nozzle standing of distance and the minor axis we if you see here the nozzle just I am talking about the nozzle here, it has a rectangle type of slit that is which whose the length is around 5 mm.

And because of the divergence it will give me the required type of elliptical shape of the cutting fluid thing slit shape is produce elliptical spray is required for that purpose we have taken the flat fan. So, it is evident from the minor elliptical axis that longer than the minor axis, I want the thing should be the minor axis of my spray should be more than my machining area where the highest temperature is generating or nearby highest temperature is generating in the machining region.

So, if you see here normally at the 30 mm standoff distance the minor axis covered by the both cutting fluids mist is larger than 27.5 mm beyond the standoff distance 30 mm, the exerted spray force gradually decreases that is why optimum distance is considered to be the 30 mm or getting 27.15 mm; that means, from the thermal image we are calculating the minor axis, and the minor axis that I want is calculated from the spraying from that two things beyond.

Which I would not want because as you distance increases what will happen force is going to reduce I want the force also at the same time I want the minor axis to be covered, for that purpose 30 mm is considered from these two points.

So, you can see here at the same time minor axis in both we have to consider because we are going to compare, this that is why we are considering where as if you see mineral oil based cutting fluid there the minor axis is much less for the same standing of distance compared to your bio cutting fluid.

So, even the bio cutting fluid is giving more minor axis that will help those temperatures which are surrounded also. So, you may get some of the times that why the minor axis for the same pressure it is high ok, because of its spreading at the same time because of diverging for the same pressure it may have the cutting fluid, which is developed in the bio cutting fluid will have more spreading diverging compared to the mineral oil.

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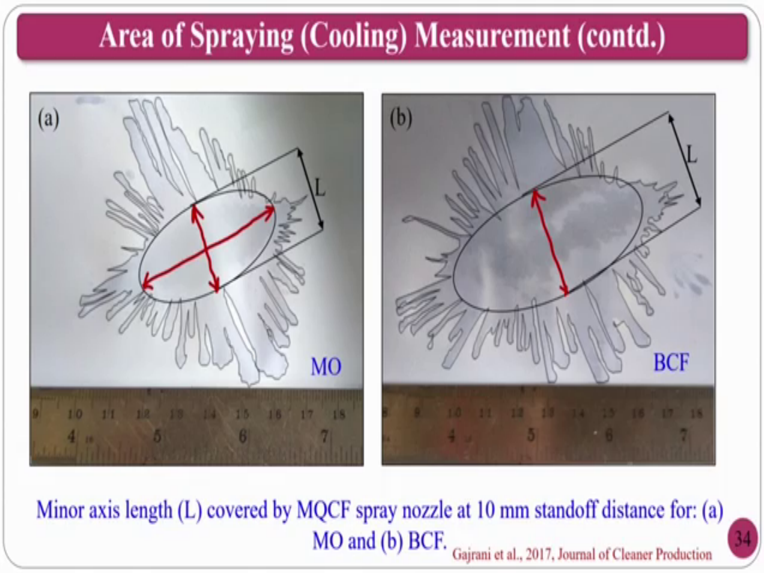

How we are going to measure this mineral oil based, if you see here whenever it falls we are taking the image as I said cameramen's are all over covered in all directions and they are taking the images. And they are reporting the images ok, I said before the spray starts they start clicking in a mode where continuously it capture the images and as soon as it fall those particular images we are taking for analysis purpose.

So, mineral oil is there as well as bio cutting fluid also is there and you can see the minor axis measurement as well as major axis measurement, major axis which we are not bothered about, but the minor axis we are taking here for the BCF minor axis is much better compared to the mineral oil based and all those things.

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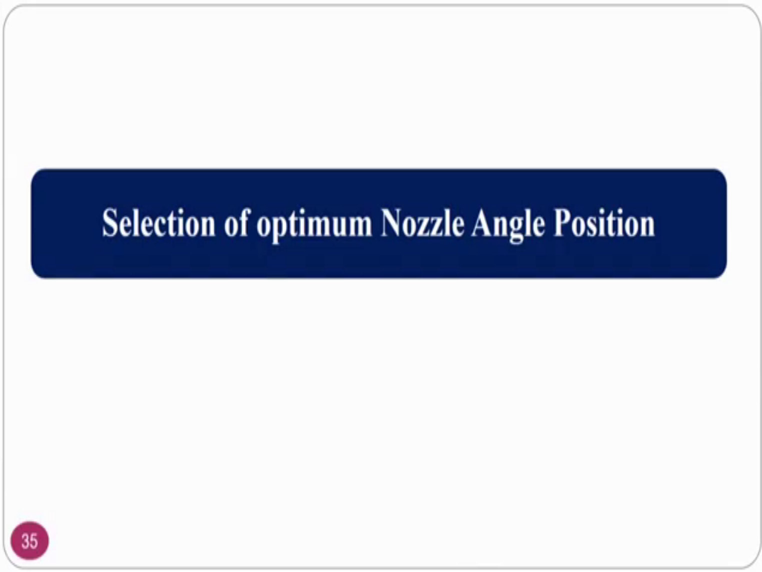

The selection of optimum nozzle position till now we have seen the composition optimization we have to optimize the composition. So, that it will give you the good thermal conductivity and specific heat, second thing we have to generate minimum flaring, but it should cover the minor axis of the machining region for that purpose we have to play with standoff distance of nozzle from the work piece or the machining region that also we have done. So, in that we have seen the force exerting as well as we are also seen the area covering minor axis from this we have optimized our 30 mm as our standoff distance.

Now, we are moving to the angular position because if I have a machining region if I put my cutting fluid angle like this it is none not of use, if I can put like this it is not of use for that purpose we have to use optimum nozzle angle. So, that in between chip tool interface should go and it should break the pre matured chip or it tries to decrease our minor axis of sticking and sliding region that is our major motto for that purpose.

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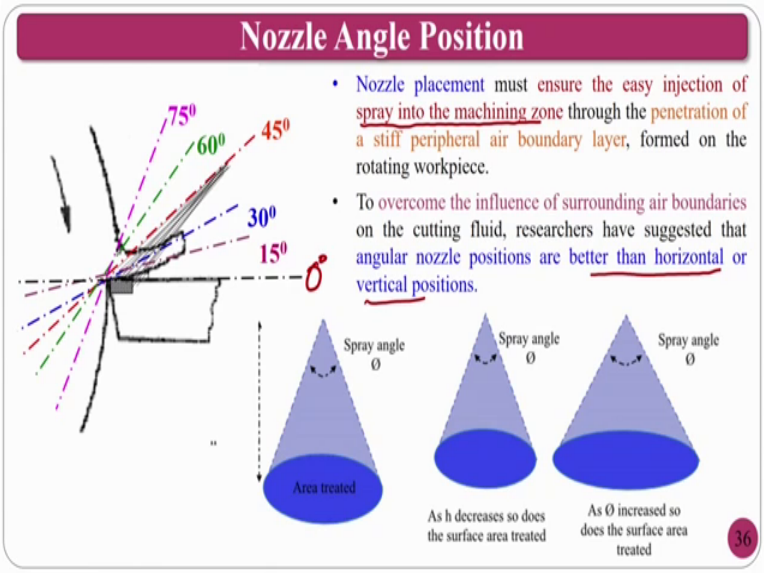

How the nozzle angular position will help us. So, the nozzle angular position if you see here this is 0 degrees, from which a horizontal 1 from 0 degrees is we go ahead the testing is done between 15 degrees to 75 degrees and sometimes it is also done.

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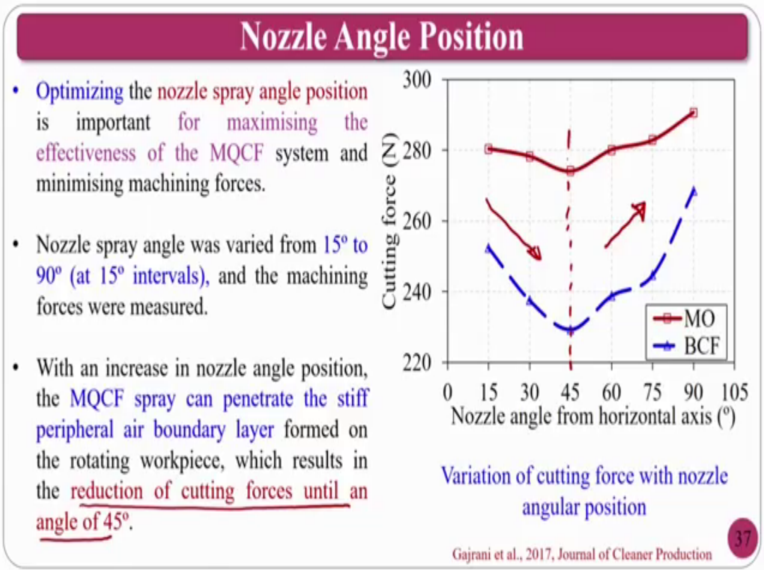

For the 90 degrees also so, nozzle placement must ensure the easy injection of spray into the machining region. It has to ensure that my nozzle angular position should be directing my cutting fluid mist into the machining region that is chip tool interface region, penetration of stiff peripheral air boundary.

Boundary layer formed in the rotating work piece it has to form a boundary layer on the work piece, to overcome influence of surrounding boundaries on the cutting fluid researchers have suggested that angular positions are better than horizontal or vertical. So, some of the researchers in the literature they have conveyed that horizontal and vertical are not good. So, you have to choose some of the angular positions for that purpose the examination is conducted or the comparison is conducted for the different, different spray angles ok.

So, spray angular position if you see, the angular position and with respect to cutting force is calculated at different, different angular positions and we are going to find where it is minimum optimizing, the nozzle spray angle position for maximizing the effectiveness that is minimizing the cutting force at 15 to 90 degrees is done at 15 degree interval.

Normally at 45 degrees it is observed that the minimum amount of cutting force is exerted ok. Now why I require minimum amount of cutting force is another question I will come to that question with increasing of angular position MQCf spray can penetrate stiff peripheral boundary layer, forming the rotating work piece and reduces the cutting until the angle of 45 beyond which it is going to increase till 45 it is decreasing trend after 45 it is increasing trend.

Why it got minimum, if my cutting force since the cutting force is nothing, but you are kicking down the chip if, if I send again the force on the tool what will happen the tool is already thermally soften. If somebody might have studied about what jet machining abrasive water jet machining and all those things, if you water jet machining which is a advanced machining process there the machining takes place or the erosion mechanical erosion takes place by the water jet.

If I have more force what will happen already my tool which is there which is thermally softened, if my jet is impinging on it not only the machining operation can remove the material this also helps in removing the material, that is why it should be minimum for that purpose the experimentation is done and it is considered to be 45 degrees which is optimum for generating the minimum force. So, that with the cutting fluid mist jet which is falling the erosion on the tool takes place less, for that purpose we always choose the minimum point that is here that is 45 degrees.

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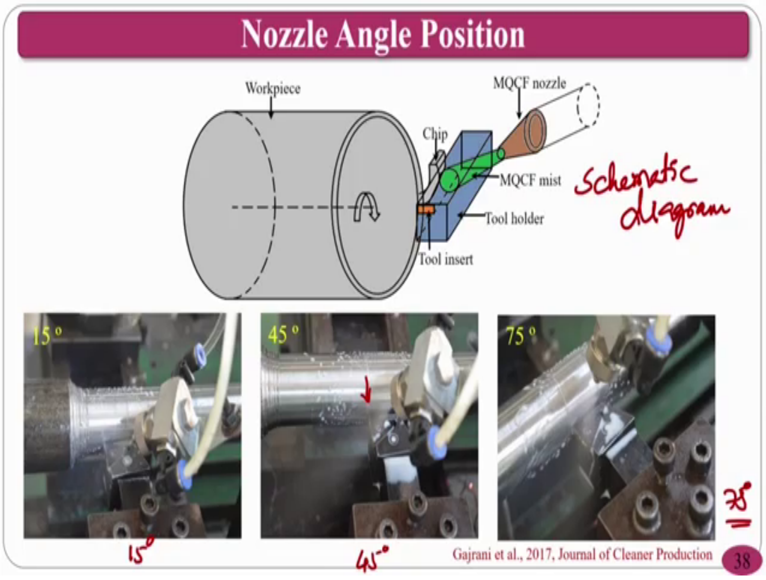

You can see here three angular positions which are given, one is 15 degrees another one is 45 degrees, and the another one is 75 degrees how it look like. So and how the mist is generating on the machining region if you see for the 45 here the machining region is taking place. And cutting fluid mist is falling in the machining region this is the schematic diagram, to explain the region how it is falling and other things ok.

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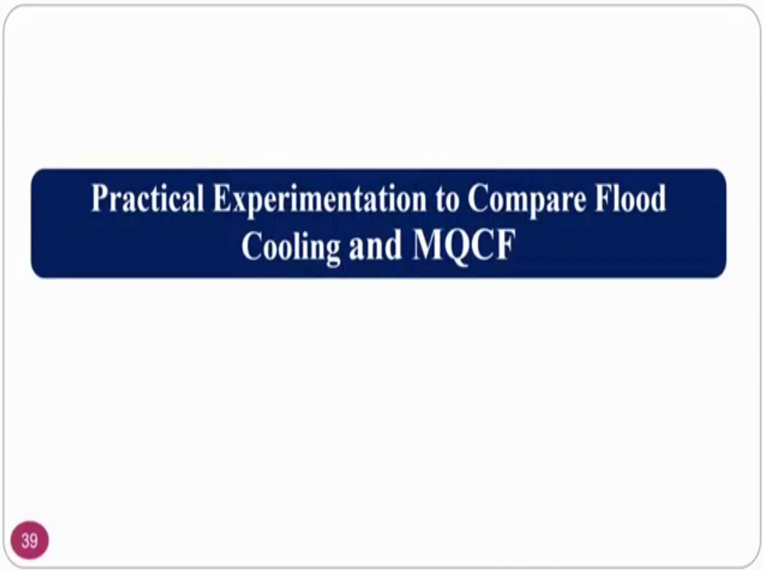

So, now we have already seen the composition as well as standoff distance and angular position from that, how we can implement this in a practical situation and it is not a single parameter that will decide. It is multiple parameter at the same time combined effect is another thing to be understand, we have to understand the how the nozzle angular position plus standoff distance plus composition play a role and 2 parameters effect 3 parameters effect and all those things also play major role for that purpose just a preliminary experimentation is carried out and we demonstrate.

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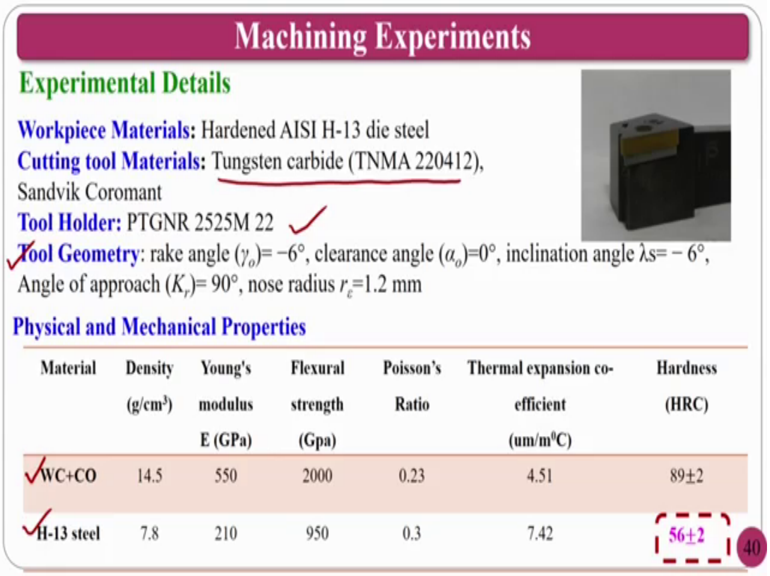

How the MQCF is better for that purpose work piece material we have taken the hard steel, which is around 56 HRC, normally the work piece is taken then case hardening is done by some of the techniques. So, tool material is taken that is tungsten carbide tool material whose coating is done on a flank surface, that is why we are concentrating on the crater surface that is nothing, but the rake surface tool holder this is geometry and tool geometry is given here and the work piece and tool are given here.

Work piece is tungsten carbide and H 13, if you see the hardness it is 56 plus or minus 2, because it is hardened work piece. We have taken from the supplier then we have done the hardening and then we have done the machining operations for here, if you see the density and modulus fluctuals and thermal coefficient of expansion and all those things are given in the table for your kind reference.

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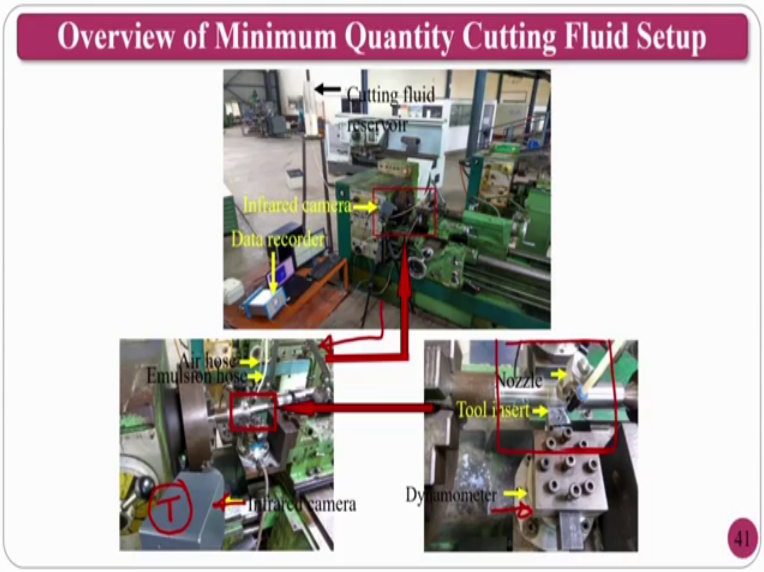

The overview if you see this is the machine, at the same time this machine into the machining region zoom up is done in the machining region, here then this zoom up is done here. So, that you can see the cutting fluid mist how it is falling in the machining region, in this region you can clearly see and you can also see the temperature measurement here it is in the second picture this is t stands for temperature measurement here the dynamo meter also is there this is the dynamo meter and this is the infrared camera is there here also it is already indicated.

So, you can catch up the temperature that is in the machining region at the same time you can also measure the forces that is what I want to show for particular machining applications. Whenever you are machining with minimum quantity cutting fluid as well as flood cooling, this is the two things at the same time minimum quantity cutting fluid of the mineral oil as well as bio cutting fluid how we can compare this 4.

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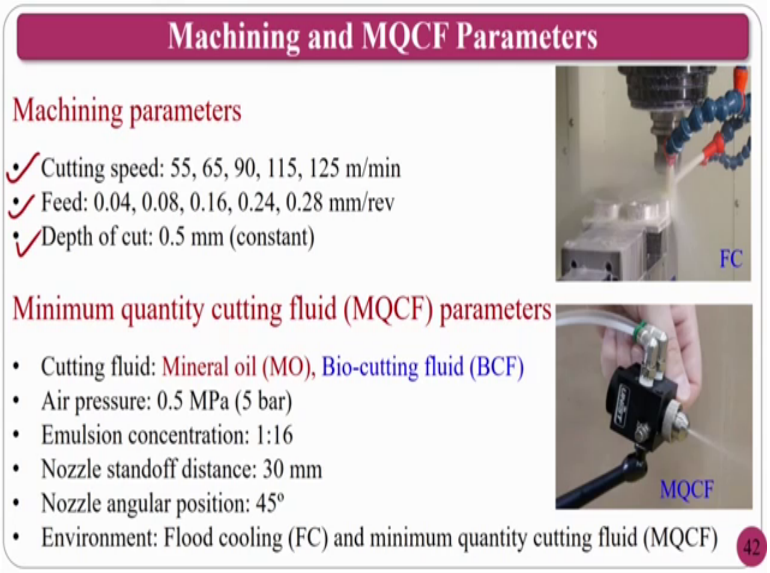

Preliminary experimentations, so cutting speed feed and depth of cut are used in this range and the minimum quantity cutting fluid and bio cutting fluid are used.

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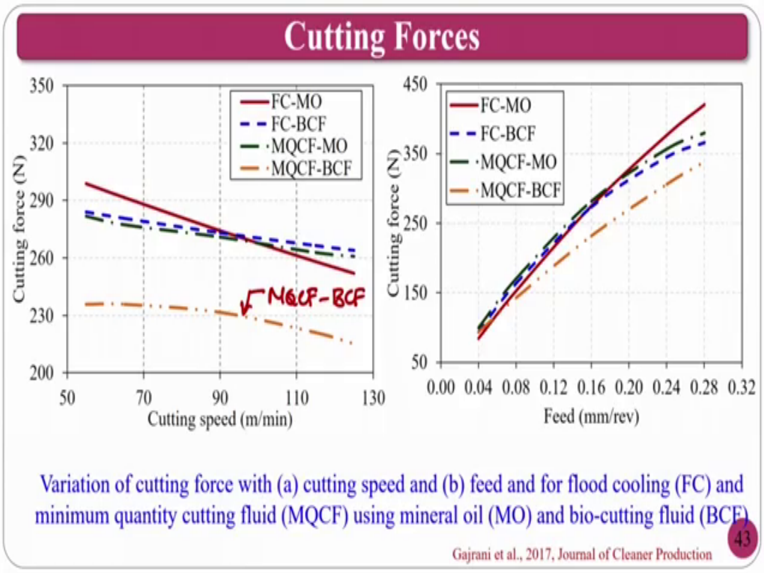

If you see here the cutting force versus cutting speed and flood cooling FCS stand for flood cooling, MQCF stands for minimum quantity cutting fluid, so.

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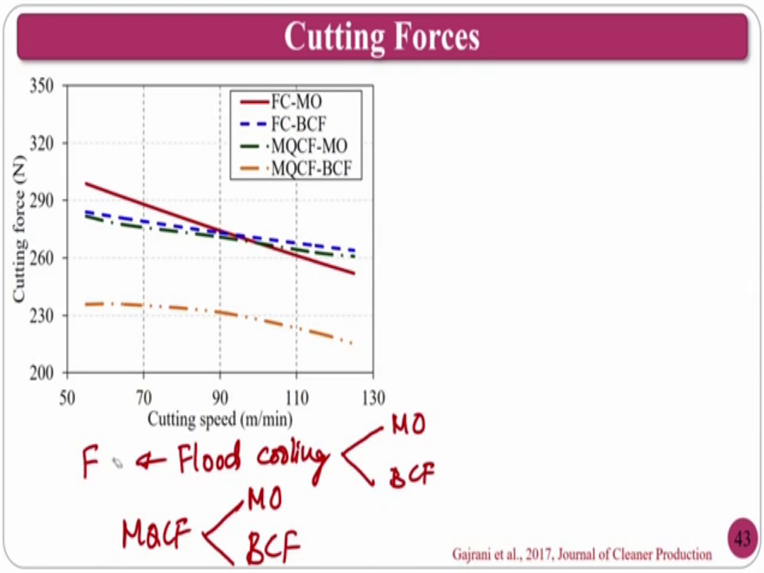

In flood cooling two types of cutting fluids are used that is mineral oil as well as BCF, in MQCF also you have used two types one is mineral oil another one is bio cutting fluid ok, that that should be noted here let me erase because in next slide you will get all the things that is about the all the graphs will be compared like that.

If you see the comparison of the cutting force what is our requirement our requirement should be minimum, force that to be generated during the machining operation for that purpose if you see the least curve that is called MQCF for BCF is giving less; that means, that whatever if things that I want, which I want to prove that is coming good here also you are going to get bio cutting fluid with minimum quantity cutting fluid is giving better results because, it has a better cooling ability as well as better lubricating ability.

So, that the tool can maintain its original hardness at the same time sharpness radius also, so that the forces can be minimum in other case minimum quantity cutting fluid with mineral oil slightly better.

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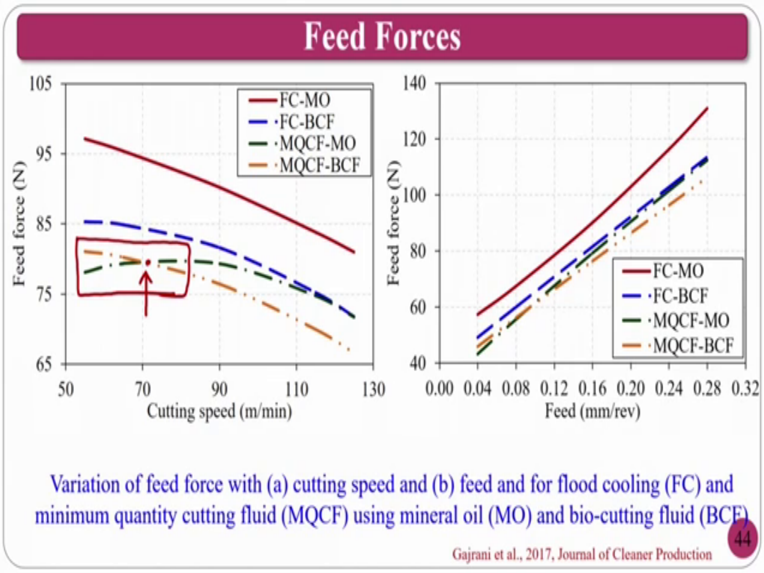

But the flood cooling is lot better as you have seen in the force convection (Refer Time: 59:07), Feed forces similar things are there, but only one noting point here is your minimum quantity cutting fluid mineral oil plus minimum quantity cutting fluid bio cutting fluid in this range there is a cross over at this particular point so; that means, if you want just concentrate I am erasing this one if you see this region.

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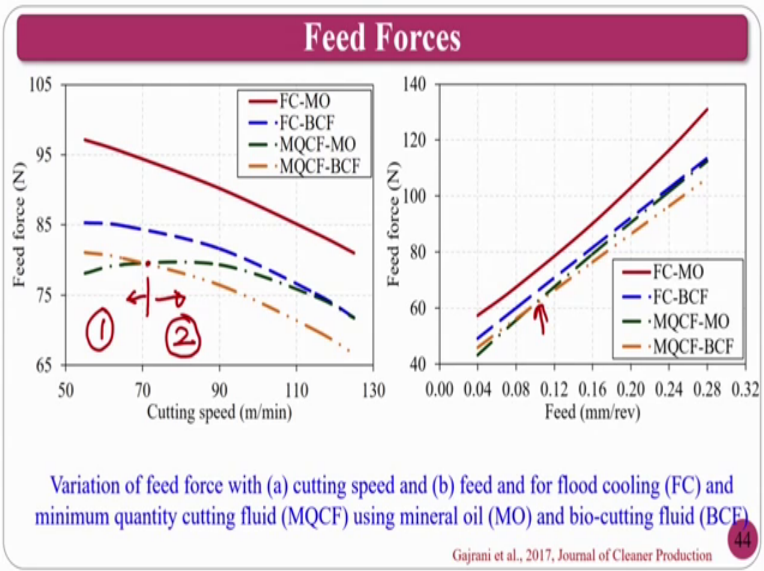

If you see this region the cutting speed is low in this region, region one and region two if the cutting speed is low; that means, my rubbing action is high that in that circumstances my minimum quantity cutting fluid with the mineral oil is giving better result; that means, that forces are less; that means, that mineral oil possesses good lubricating characteristics compared to bio cutting fluids; however, bio cutting fluid is having better lubricating properties because at higher speeds the temperature phenomena will be higher.

So, it is having a better cooling abilities that is what I want to convey from this particular the same thing you can also see here the crossover is there. So, same attributes here also; that means, bio cutting fluid has better cooling properties whereas; mineral oil has better lubricating properties at different, different speeds.

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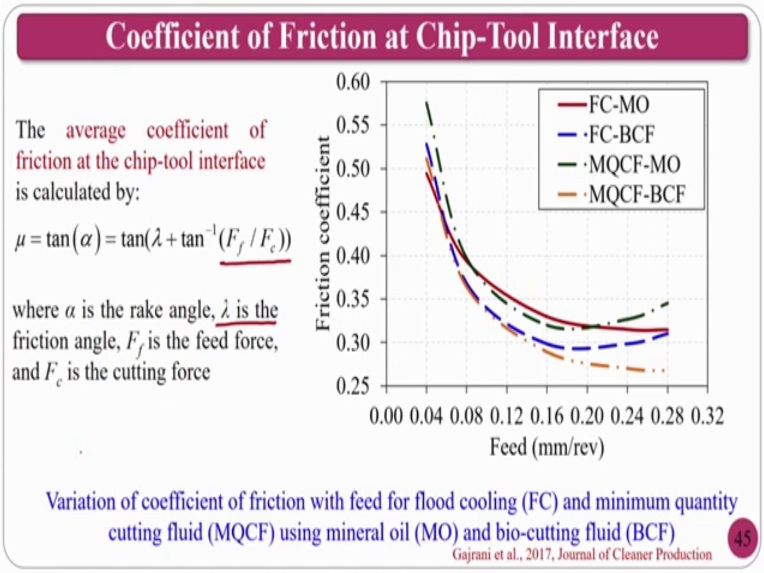

Coefficient of friction also calculated from the equation tan alpha equal to tan lambda plus tan inverse frictional force by the cutting force and all those things. So, if you see in this case also normally MQCF gives better results; that means, that friction is less at higher feed rates if the friction is less friction coefficient is less; that means, that my power which is consumed in the machining processes will be used for useful purpose rather than the waste it is one of the power that I am giving input is equivalent to shearing plus friction. So, the frictional amount will go reduce means my useful amount of energy in terms of shearing will be high.

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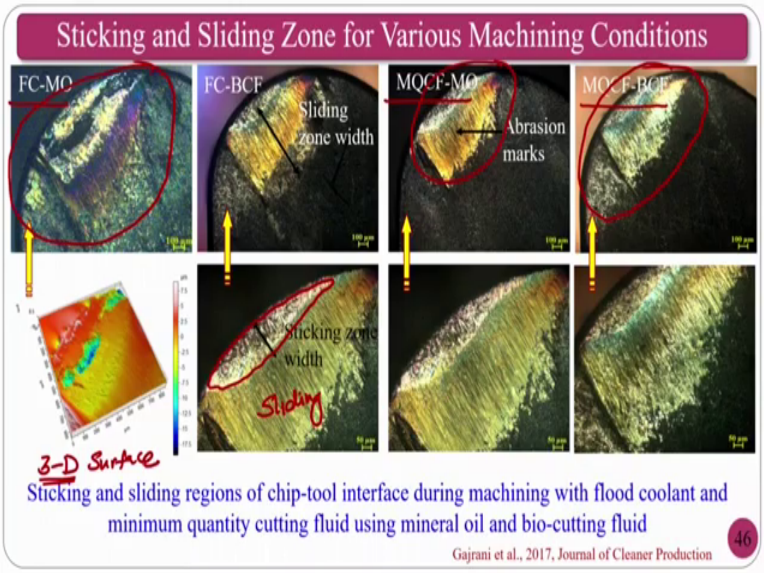

Sticking and sliding regions if you see in the flood cooling with mineral oil normally. It is shown here at the same time bio cutting fluid has well as minimum quantity cutting fluid this is the sticking region. If you see in the second one it is clearly shown this is the sticking region, and this is sliding region.

And you can clearly see the sliding marks on the this one, if you see the minimum quantity cutting fluid with the bio cutting fluid the sticking and sliding regions are less compared to flood cooling, you can compare flood cooling mineral oil MQCF mineral oil this region as well as this region this is completely color change and all those things so; that means, that flood cooling with mineral oil is not a good option MQCF, can improve even with mineral oil at the same time if you see the MQCF with mineral oil as well as by bio cutting fluid it gives better at the same time you can even see that color change also.

So, it is red hot region in the mineral oil wherever you are using. You can see in the three d image, how the peaks and valleys are formed in the three dimensional space. Here in the optical micrographs you may not see the third dimension, but for that purpose three d surfaces also taken, but we have shown for the only one application.

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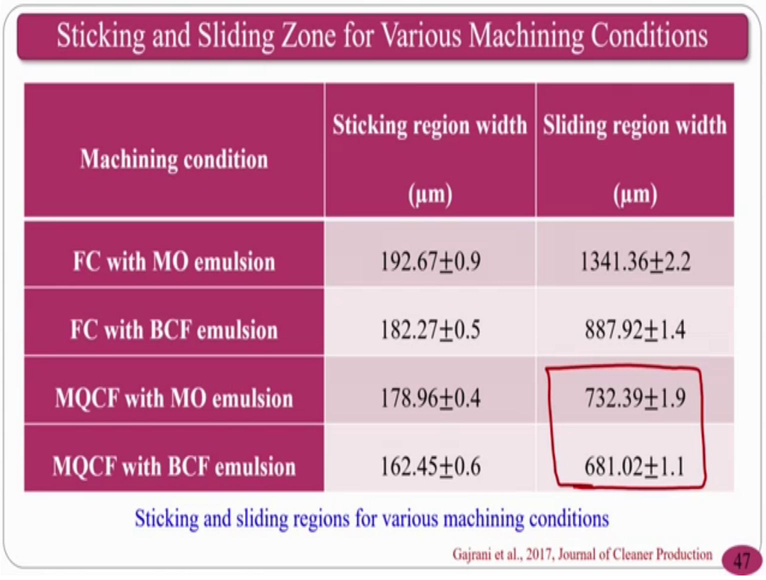

Sticking and Sliding Zone for Various Machining Conditions

Machining condition	Sticking region width (µm)	Sliding region width (µm)
FC with MO emulsion	192.67±0.9	1341.36±2.2
FC with BCF emulsion	182.27±0.5	887.92±1.4
MQCF with MO emulsion	178.96±0.4	732.39±1.9
MQCF with BCF emulsion	162.45±0.6	681.02±1.1

Sticking and sliding regions for various machining conditions

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Sticking and sliding zones are calculated values if you see, it is MQCF with BCFS much, much less compared to the other things it is minimum. So, what I mean to say is bio cutting fluid with minimum quantity cutting fluid application gives better results compared to others.

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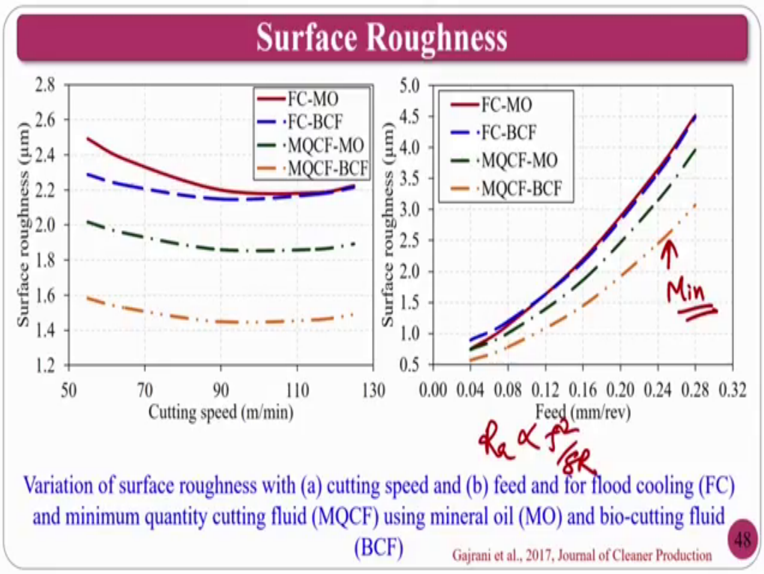

Variation of surface roughness with (a) cutting speed and (b) feed and for flood cooling (FC) and minimum quantity cutting fluid (MQCF) using mineral oil (MO) and bio-cutting fluid (BCF)

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For the ecological aspects as well as for the performance point of view if both things are giving better, why cannot we use this as a good alternative. If you see the cutting speed versus surface roughness at the same feed versus surface roughness both the conditions normally it is giving you the better results the cutting speed there is no much change;

however, your Ra is proportional to f square by 8 R; that means, it is proportional to your feed.

So, as a feed increases your surface roughness increases irrespective of any type of cooling; however, with respect to the bio cutting fluid in the minimum quantity cutting fluid this gives the minimum value ; that means, it is better from the point of surface roughness as well as the tolerances if the surface roughness is better; that means, that low surface roughness surface finish will be very good; that means, it will shine at the same time the tolerances will be better that is about the this particular slide.

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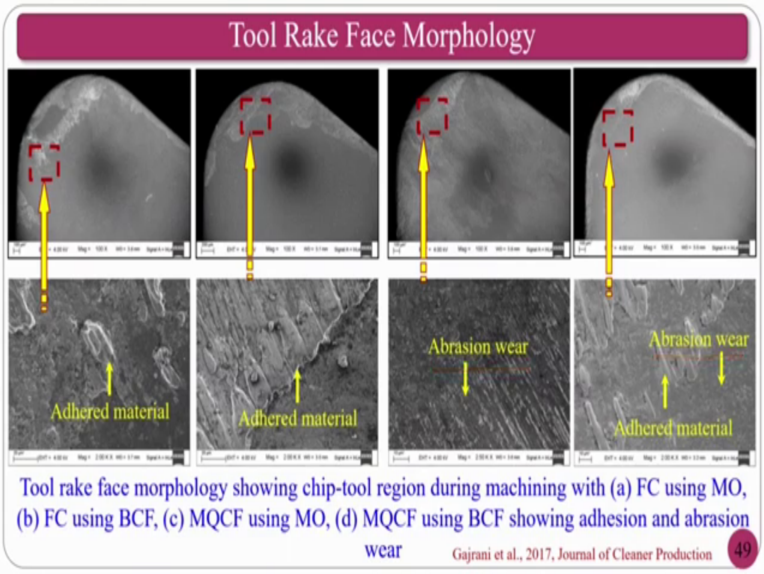

Tool rake morphology in terms of scanning electron microscope if you see here adhered layer is there adhere wear is there and abrasion wear is there. So, as I was telling that minimum quantity cutting fluid with bio cutting fluid, the lubrication is not that much good, but the lubrication property of minimum quantity cutting fluid with mineral oil is slightly better that is why, adheration and abrasion is slightly comparable in mineral oil as well as bio cutting fluid, but still if you see the top four figures we are in the better region if at all somebody want to use the bio cutting fluids.

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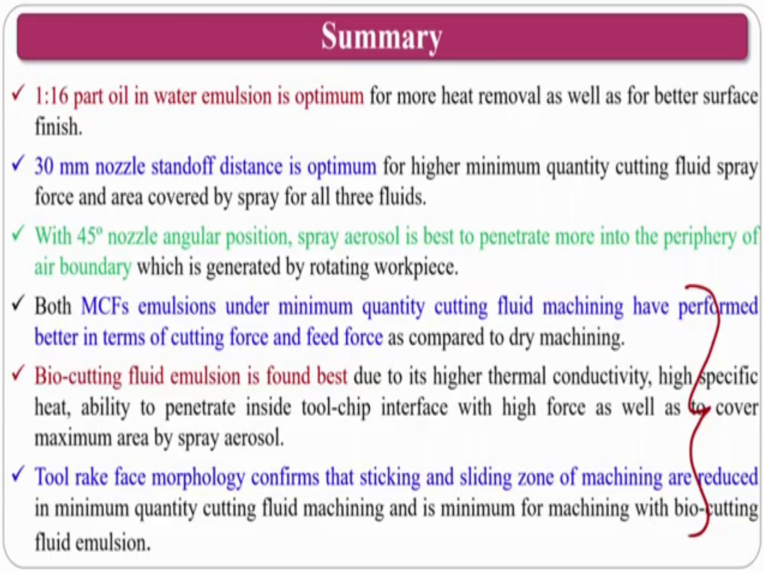

Summary, so one is to 16 percent oil water emulsion is optimum that is the composition because we have seen from two points one is thermal conductivity as well as specific heat thermal conductivity after 1 is to 8 it is stabilizing. So, any cutting fluid you can take after 1 is to 8. So, whenever you come to the specific heat there after 16, everything is normal that is delta that is change in specific heat is not much from this particular two graphs thermal conductivity as well as specific heat, you can go ahead with one is to sixteen as a composition.

Thirty mm nozzle standoff distance is optimum because you have to generate as much as force, but to separate the chip and a tool at the same time you have to cover the minor axis, from the both point of view 30 mm nozzle standoff distance is better. The third one is 45 degrees, 45 degrees generates minimum force on the tool because this is the direction that it has to go. So, it will directly impact on the tool which is thermally softened if your machining for hours and hours, for that purpose in a long term keeping an eye on it as same time the cutting fluid should go into the a chip tool interface and it helps by the action of capillary action at the same time it has to divert certain angle where it will penetrate in between chip tool interface for that purpose 45 degrees is a good one.

Both minimum quantity cutting fluid emulsions are, so bio cutting fluid next all the things are same the bio cutting fluid gives better surface morphology as well as the surface roughness and other things also very good that is why from this particular conclusions we can say that bio cutting fluid is much better from the compared to our mineral oil.

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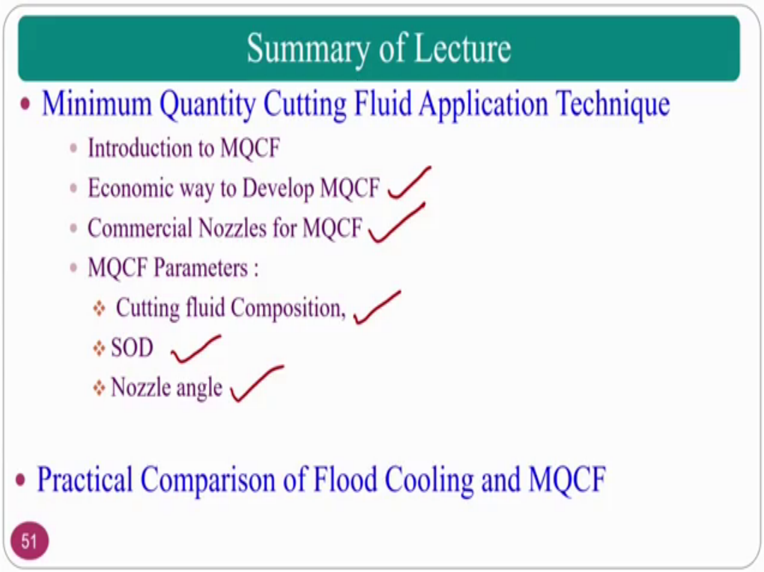

And summary of the lecture we have seen in introduction to minimum quantity cutting fluid economic way to develop MQCF, commercial nozzles, standoff distance or the parameters like standoff distance cutting fluid emulsion nozzle angle and all those things at the same time we have also seen the comparison with respect to the practical situation.

So, this completes today's lecture, so today's lecture is more informative from point of research. So, those people who are interested to take up the research they can take up by using your own bio cutting fluids you know what are the bio cutting fluids since I am talking about many, many lectures on what are the oils you can play with oils, you can mix the oils, based on the thermal conductivity you can (Refer Time: 01:08:09), it to prove you can take you can measure the thermal conductivity of different, different cutting fluids.

And you can use it and you can generate your economic way of nozzles and you can use it and the dynamo meters normally available in the academic institutions you can use chart and all those things spraying nozzle you can develop or you can even purchase for 8 to 10000 rupees. And you can check this can be a good work, but only thing is that how to improve the process,, how to improve the quality, if at all you are looking from the point of paper publication how, lot of papers are there how to improve the quality of your paper and you can compare with the existing literature what they have not done.

And how I can improve most important thing is that how I can improve the quality of your research paper and how to improve the quality of the standard of the operator, most important whether you get a publication or not, but human kind is what the intention of this particular lecture.

Even though you are going to give you the good solution for the operator from the ecological point of view you are protecting the operator. At the same time you are protecting as a mechanical engineer as a manufacturing engineer the performance; that means, the profits of the company.

So, the bottom line of the story is that being a manufacturing engineer at the soft flow, what you can get from this particular slide is even though you use the bio cutting fluid which is economy which you can make from your laboratory you can save your operator as a human you are doing very good job, at the same time you are as a mechanical engineer as a manufacturing engineer you are also giving better and better performance to your owner. So, profits also you are getting at the same time you are saving the operators health and system as well as surrounding pollution also.

Thank you.