Introduction to Machining and Machining Fluids
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Lecture – 18
Rheology and Thermal Characterization of Machining or Cutting Fluids

Till now we have seen the various cutting fluids in the previous class. So, now, we have to study about their one of the important characteristics that are rheological characteristics, as well as thermal characteristics of this various cutting fluids. Among the cutting fluids that we have seen we are most interested towards two cutting fluids; one is the mineral oil cutting fluid, another one is a bio cutting fluid.

So, the mineral oil place a datum where it is as a reference and how we can improve in the bio cutting fluid that we will see from the point of rheological characteristics, that is a flow and deformation size as well as thermal characteristics.

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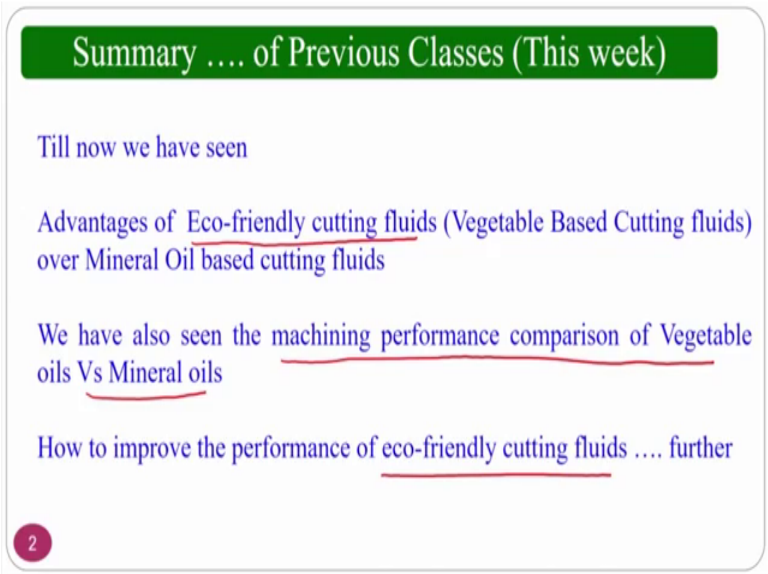

Till now what we have seen in the previous classes is advantages of Eco-friendly cutting fluids and like vegetable oil based cutting fluid over the mineral oil based cutting fluids. We have also seen the machining performance comparison of vegetable oils, cutting fluid versus the mineral oil ok; that means, we have seen the performance of a metal cutting from the point of biological cutting fluid, from the point of mineral oil also. How to improve performance of eco-friendly cutting fluids? Just in order to increase the performance of existing bio cutting fluids, if the performance is approximately similar as since we are working in this area and we have to improve.

So, the research somebody is taking up in this area what they have to do they have to continuously strive hard to improve the performance, improve the rheological performance, improve the thermal performance of that particular fluid, how to do that we will see?

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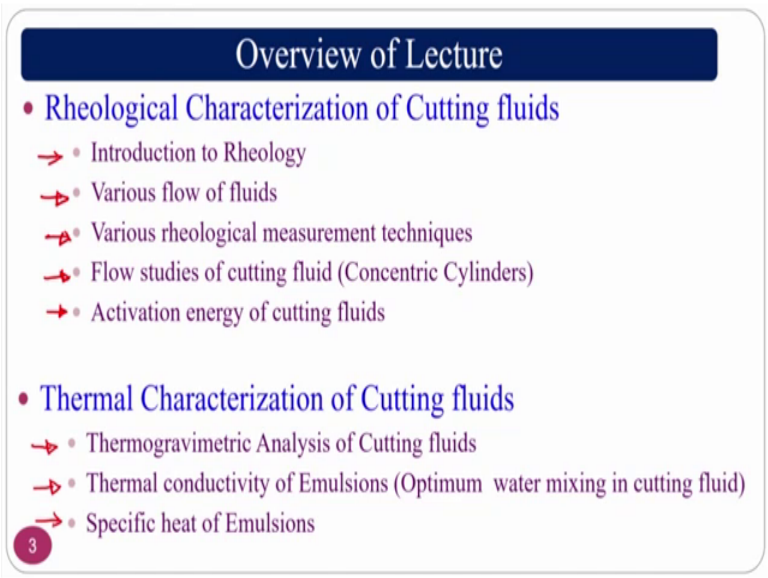

So, overview of this lecture we will see about the rheological characterization of cutting fluid coming to the first one that is a introduction to rheological various flows of the fluid various rheological characterization, and the measurement techniques followed by the flow studies of cutting fluid, that is a concentric cylinder as well as a parallel plate and all those things we will see, then activation energy and all those things we will see from the point of rheological characterization.

Then we go to the thermal characterization of the cutting fluids, thermogravimetric analysis we will see then followed by thermal conductivity and followed by the specific heat of the emulsions. What is the emulsion and all those things you have seen it, but we will see what is the optimum emulsion; for better thermal properties and all those things we will see?

The rheological characteristics of the fluids rheological characteristics is the most important, because if at all I want to study the flow properties of that one because cutting fluid has to penetrate or it has to flow into the cutting region. So, that is the main function, if it cannot flow nooks and corners of the complex machining region it cannot extract. So, the first and foremost thing that it should possess from the cutting fluid point of view is the rheological properties it can enter then the thermal properties can extract the heat that is generated in the machining.

So, that is why we have divided into two sectors one is rheology let it enter into the machining zone then thermal properties. So, that it can extract that is why these two play a major role in the machining arena for cutting fluids.

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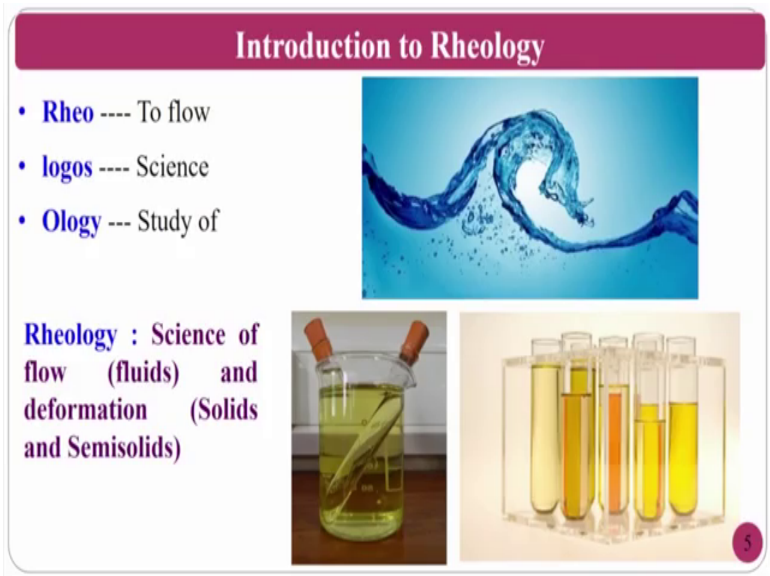

So, introduction to rheology as you all see the fluid flow in this particular picture; how the fluid is flowing and how the wave is taking place and all those thing these type of things? Whenever you shake your glass with water and all those things if it is a transparent glass and all those things that you can also observe this one, at the same time if you see the rheology normally Rheo means the flow logos means the science and ology means the study.

Basically the rheology is nothing thing, but the science of flow deformation. The science of flow deformation is nothing, but for the fluids you are studying up the flow for the solids or semi-solid you study about the deformation for the semi solids you can also study the flow properties. So, that is nothing, but the rheology. So, if at all I want to see the flow characteristics as well as deformation characteristics of any particular fluids, whether it is a semi solid or a liquid 1 has to do the rheological characterization.

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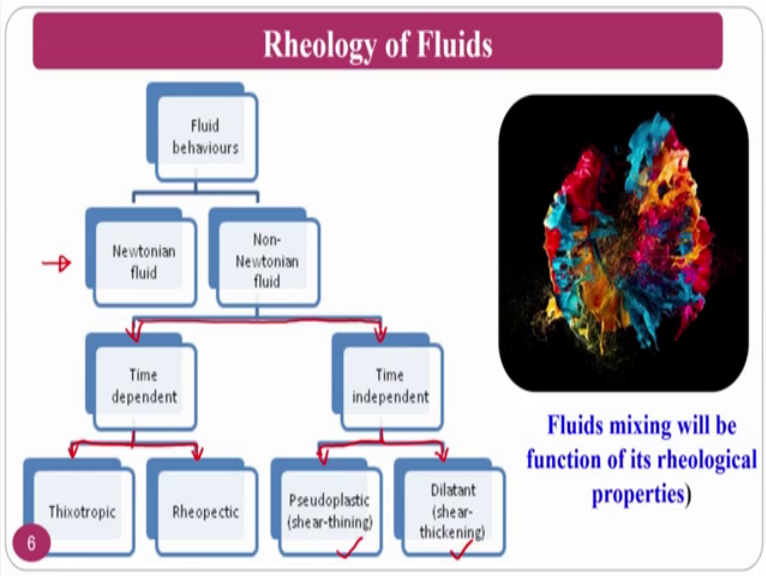

If you see the rheology of the fluids the fluid behaviors normally it can be divided into two; one is Newtonian as well as non-Newtonian fluid Newtonian fluid normally it will have a proportionally increment with respect to shear rate the shear stress will be proportional increase with shear rate, but it will not in terms of non-Newtonian fluids the non-Newtonian fluids most of the fluids are non-Newtonian fluids. That is why the non-Newtonian fluids again divided into two sectors that is time dependent and time independent.

In the time dependent if you see again there are two things what is thixotropic and rheopectic, in the time independent again it will divide into two things one is pseudo plastic as well as dilatant. Normally we study mostly about the time independent one that is called shear thining fluids shear thickening fluids and all those things in the upcoming slides.

So, the rheology particularly about this cutting fluids helps in proper mixing, as well as proper flow and deformation, whenever the intricate, complex regions of chip tool interface or work piece flank surfaces comes into picture. So, this is the beauty about the rheology.

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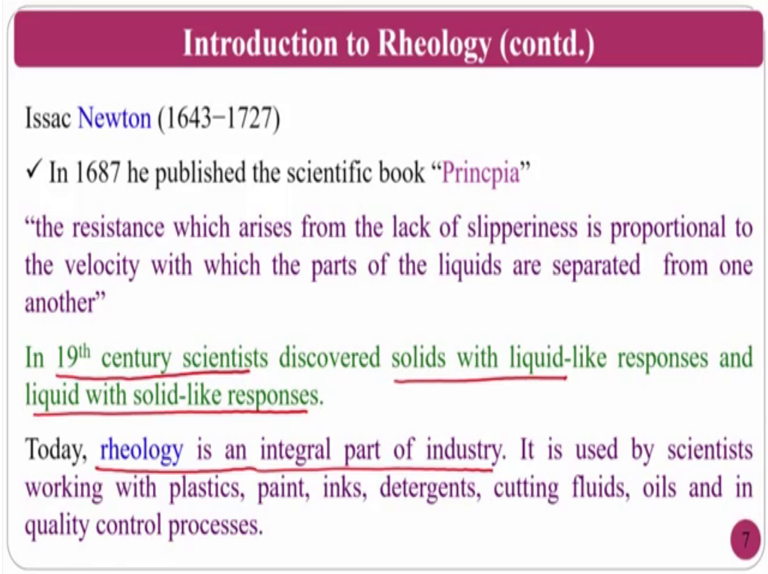

So, introduction to rheology we are continuing normally if you see Issac arise at Newton 1643 to 1727. So, he published the scientific book called principia and where if you see in the 19th century scientist discovered the solids with liquid like responses and liquids with solid like responses these are the changes that one can see. For example, if you see take the water if you go to the freezing temperature basically it will convert into solid.

At the same time the deformation characteristics of this when it is solid when it is a liquid is completely different, that is what to one want to say. At the same time today the rheology is an integral part of the industry, basically if you take any industry; like pharmaceutical industry or any other industry. It is for example, if you see the plastics or paints, you have how to spread the paint according to your wish.

If the paint is not spreading as per your wish and it is the delaminating then there is no requirement or if you are facing a lot of problem you take a brush and you take you just deep into the paint bucket and then you just put on the wall assume that it is very difficult. Because the energy required to paint on the wall is very high; that means, that you do not prefer the type of thing, why because you need better flow ability on the wall at the same time it has to spread easily on the wall and your energy consumption should be very less.

So, you need to study the flow characteristics of this paint. For example, if you see the pharmaceutical industry mostly the fairness creams everybody want to become a beautiful person or something. So, lot of creams are there. So, whenever a person want to apply the cream on their face what will happen you have to apply at uniformly, the cream has to deform uniformly it has to flow uniformly, because it is a semi solid normally this a semi solid complex suspension. So, has to flow deform and uniformly spread and the look of particular person, whether it is a male or a female does not matter that is it appearance should be beautiful or a handsome. That is why always rheology play major role in the pharmaceutical industry also like bio inks and inks also there.

Nowadays people are talking about 3 D printing people talk about 3 d bio printing. So, you have to deform or you want to flow the ink along with the cells properly, otherwise you cannot make a complex surface. Similarly, the cutting fluids also are one type of the suspensions because people nowadays are talking about Nano fluids and other things.

If you take the Nano fluid that is what you have seen in the previous classes, these are the cutting fluids or the emulsions with Nano particles ok. So, this also resemble similar to your paint or your pharmaceutical creams and all those things, but with low viscosity that is why it is more important to study about the cutting fluids from the point of rheology.

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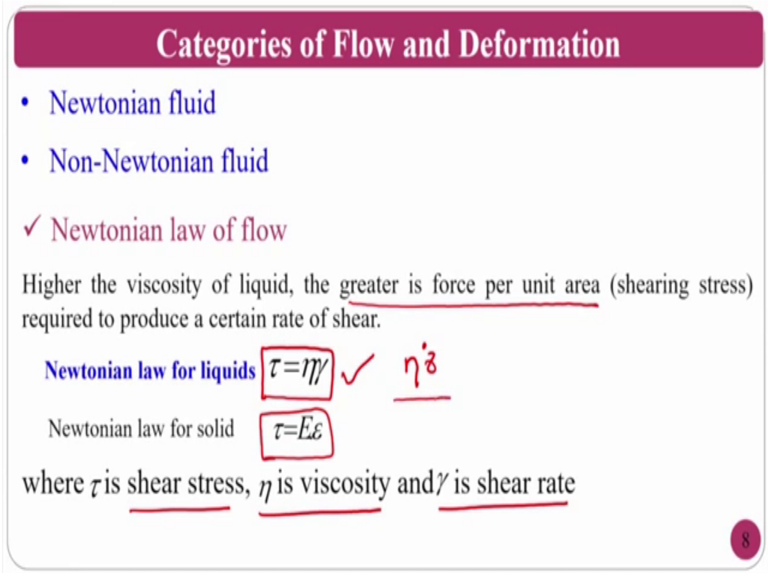

Categories of flow and deformation there are two categories one is Newtonian fluid and Non-Newtonian fluid, that we have seen already the Newtonian fluid the higher the viscosity of the liquid the greater the force per unit area is required, that is shear stress required is very high; that means, you always should put the less energy as a customer.

So, if you see the non-Newtonian for the liquids tau equal to n to gamma are some people they say n Newtonian viscosity into gamma dot. So, tau stands for shear stress bets stands for viscosity and gamma stands for shear rate. So, people also say that these are the gamma or gamma dots some of the books, if you are following about the basic rheology books if you see there some people give the gamma dot also.

So, gamma or d comma dot please considered as a shear rate shear rate indirectly means the full name for this one is shear strain rate for the liquids this is a equation, which you may see in the fluid mechanics also.

For the solids and other things this is a equation shear stress is nothing, but you are e into e epsilon. So, since we are talking about the liquids we are more worried about our cutting fluid that is why we always think about the shear stress equal to the viscosity multiplied by the shear strain rate it can be grammar or gamma dot.

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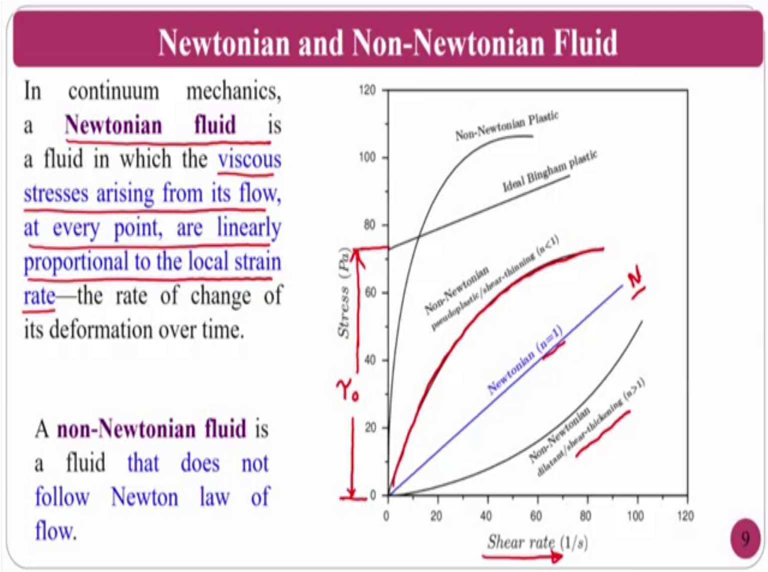

The Newtonian and Non-Newtonian fluid as per the continued mechanics is considered the Newtonian fluid is a fluid in which the viscous traces arising from it is flow at every point are linearly proportional to it is local strain rate that mean that, the stresses are linearly proportional to the local strains in the non-Newtonian fluid it is not. So, so if it the fluid is not following this Newtonian principal if the fluids are not following the fluids which are not Newtonian fluids are all not Newtonian fluids.

Most of the fluids follow the non-Newtonian behavior. We will see various flows since in the classification also we have seen it, the Newtonian is n equal to 1 which is you can see this is a Newtonian fluid and if the n is greater than 1 basically if you see here plotting the shear rate versus shear stress.

So, Newtonian fluid and Non-Newtonian fluid most of the things are Non-Newtonian fluid apart from that n all are non-Newtonian fluids. Non-Newtonian fluid the first one is shear thickening fluid; that means, with respect to shear rate the shear stress is gradually increasing that what it mean is if the shear rate is increasing means you will come up across the rheometer how the experiment is calculated or conducted and all those things are there.

Assume that I have a parallel plate rheometer and we have a fixed plate at the bottom the rotating plate at the top in between you have a fluid you gradually increase the rotation you just give the rotation to the top plate ok. If the top plate rotating at very high speeds; that means, as you time increases if you are increasing the rotations; that means, that shear rate is increasing just for analyzing.

So, if the shear rate is increasing; that means that your top plate is rotating faster and faster. So, you take the daylight and fluid that is shear thickening fluid as the shears rate is increases what is happening here is it is becoming thicker thicker; that means, that stress required is increasing that is called shear thickening fluid if you see the other 1 that is called shear thinning fluid most of the fluids follows shear thinning fluid.

So, shear thinning fluid are pseudo plastics fluid if the shear rate is increased with respect to time or what will happen the viscosity gradually decreases, that is what the shear thinning fluids thin means it is decreasing the viscosity or shear stress shear stress and shear rate are related to the viscosity, that is why sometimes I may speak shear stress sometimes I may speak viscosity both approximately correlated.

So, another one if you see that is called ideal Bingham plastic fluid another one is non-Newtonian plastic fluids just if you see here till up to certain stress there is no change in the shear rate; that means, this is called as tau naught.

Minimum shear stress later on it will act as a Newtonian fluid. For example, paste or a toothpaste if you open the cap and you just put up right what will happen the paste would not come outside for that purpose, if at all it has to come outside you have to apply certain pressure with your fingers then only it will come that a minimum stress that you are going to apply is your tau naught here.

So, that paste is a ideal examples are one of the examples for Bingham plastic fluid. So, that the floor starts after applying certain pressure or by putting your brush just, if you what will happen the flow starts like a Newtonian fluid that is called Bingham plastic fluid and good example is in the life everyday life what you are going to use as the paste Non-Newtonian plastic fluids, if you put it is grow gradually increase if you put more stress more stress what will happen the flow will increase that is about the Non-Newtonian plastic fluid.

So, from this one we have seen the dominance of Non-Newtonian fluids over the Newtonian fluid because Newtonian fluid common, Newtonian fluid all you known is a water and the Non-Newtonian fluids are mostly whatever available suspensions liquids honey butter these are all are non-Newtonian fluids.

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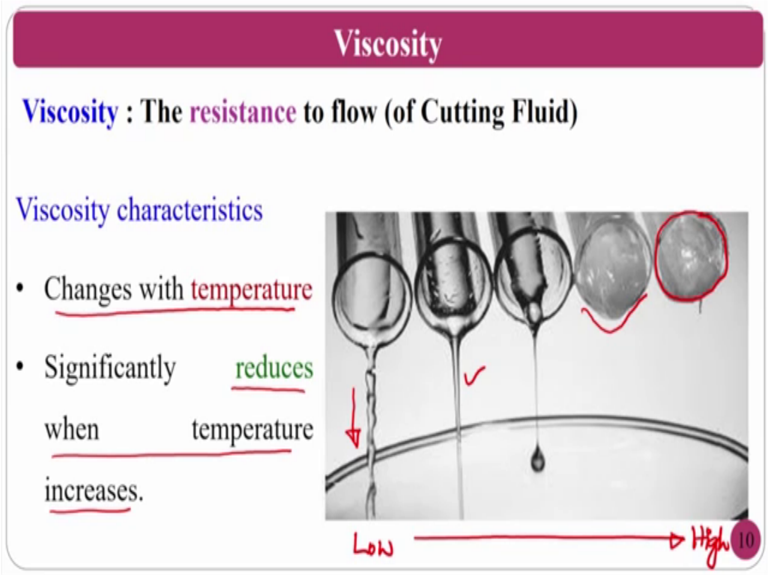

The viscosity is nothing, but the resistance to flow of the cutting fluid, if you see here in this particular picture the viscosity is low here and the viscosity is high here. For the same inclination or something whatever is given the flow rate that is falling from the test tube is gradually increasing from this to this that is why the viscosity is gradually increasing.

So, if you see here the inclination is same, but the thing is that of fluid inside the test tubes is different ok. So, if you see here the liquid is different if you see is second one the liquid is different as you move here, it is clearly you can see it is a semi solid. Here the semi-solid similar semi solid is there, but deformation is there ok. So, the viscosity is increasing if the viscosity is increasing. For example, from the cutting fluids itself we can say that grease is one type of lubricant and mineral oil is one type of lubricant the mineral oil has a low viscosity, but the grease whatever you use for your applications that is nothing, but high viscosity lubricant.

So, viscosity characteristics that it changes with respect to temperature most of the cutting fluids will change with respective temperature. As the temperature goes into the cutting fluid what will happen the molecules gain the energy this is called as a thermal energy and it try to move apart. That is why always the cutting fluid fumes whatever you have seen which is going to the operator nose and all those things these are because, it gains a energy and move apart and distance between two molecules will gradually increase and the force of attraction between those two molecules as a distance increases will goes down.

That is why mostly the cutting fluids viscosity will decrease with respect to temperature this cutting fluid significantly reduces when the temperature increases that is what I said. So, the temperature as it increases inter molecular distance of this molecules will increase.

So, inter molecular force of attraction will decrease that is why the liquid will become gas and it force various methods to test the viscosity.

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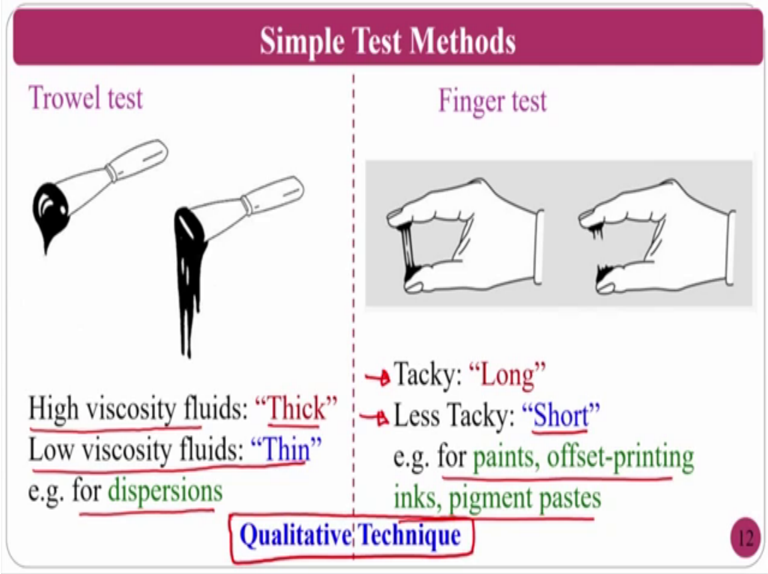

So, simple test in the previous olden age are whenever the standard reo meters are not there the people used to use trowel test, that is called just to take the viscosity of the high viscosity of the fluids thick and they say low viscosity of the fluids as a thin fluids for the dispersion just the take a strip wooden strip or metallic strip and just they put into the liquid or semi-solid and just they take out and they say depend on the visibility test they can say that, whether it is a thin or whether it is a thick fluid.

But only thing you have to observe here is it is a qualitative statement there is no quantity, whether it is viscosity is x or y you cannot say you can say only this is thick fluid this is a thin fluid you hope you understand what is the difference between a qualitative statement and a quantitative statement? The qualitative statement goes by like this Ramu is a good boy that is a qualitative statement Ramu is 80 percent good boy is a quantitative statement ok.

So, if you are quantifying by particular value that is nothing, but quantitative value here the people can say whether it is a thick or thin, but they cannot say the viscosity is this much or viscosity is this much quantitative value they cannot say. The second one is finger test take this one and just move on or move a part both thumb and index finger. So, you can feel the tacky which is nothing, but the long less tacky then it is short for example, paints and offset printing inks and pigment pastes these are all done.

Normally, by the finger test in olden days nowadays everything is used to by the commercial rio meters to test the rheology, but these are the old test again this is also the qualitative statement only one can give ok. These people during our childhood be might have also played with our bubble gum after chewing sometime just take like this and like this so, but do not do that people might have done.

In fact, I have done it at childhood since our childhood we do not have very good exposure to the bubble gums or whenever we get we used to make bubbles and all those things, but particularly from the health point of view do not make the bubbles or do not going fit into your fingers and the just expand, then after that you just put into your mouth and chew again do not do all this things, because bacteria or the microorganisms, which are in the atmospheric conditions will easily stick on the bubble gum if it comes out like you just blow the bubble and it will blast and again you take inside. So, organisms will come and it will go into your intestine and causes lot of problems.

So, that is a practical point of you, but from the course point of you this you can do by the finger test anyhow, I want to convey that these two techniques are the qualitative techniques, but not quantitative techniques.

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To standard viscosity measurement, if you see there are oscillation viscometer these are the second versions or the primary versions for the quantitative measurement, vibrational viscometer and there are called falling piston viscometer there are this is a third one and the fourth one is rotational viscometer, which nowadays mostly people uses it the advanced version and falling sphere viscometer there are different, different types of there and among these rotational is very common.

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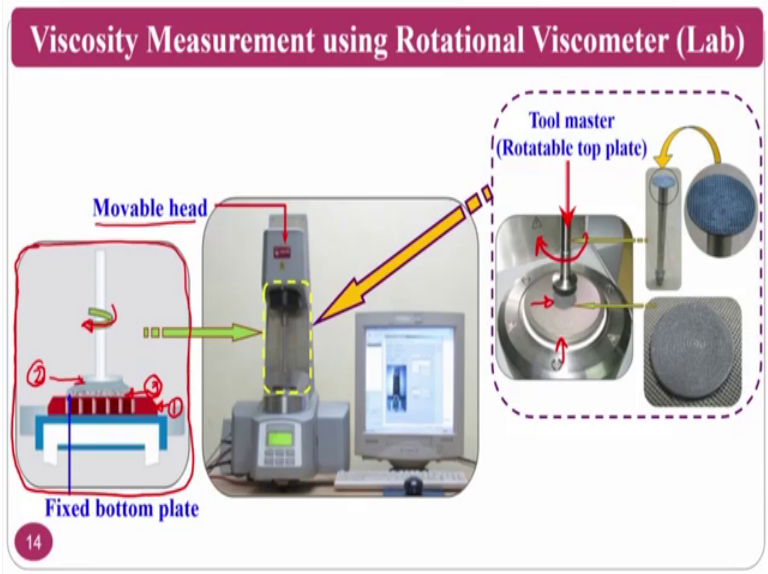

If you see the rotational viscometer or the standard viscometer what currently what we are using at our laboratory to test the rheological properties of the fluids is Anton Paar MCR 1 0 2, and we can also use Anton Paar series that is a Anton Paar is a company which produces the rheometers just do not take in other way that I am advertising or something, there is a t a instruments also produces this viscometers. So, many companies are there who produces this for instance what I am showing in this picture is Anton Paar rheometer this is the schematic view of the rheometer this one is the schematic view of the rheometer.

This is the fixed bottom this is this one is a fixed bottom one and this is the rotating plate 2 and in between there is a medium this is called 3. And the bottom one having temperature increment or decrement options also, because some of the cutting fluids or some of the fluid that one want to check may be interested to check at higher temperatures also.

So, for that purpose there is a temperature increment and decrement options and you give the rotation to the top plate by keeping the bottom plate constant that is about the shears strain rate, if at all I as I already said that my bottom plate is there my top plate is there in between I am having my sample not this it has to cover the complete space of the top plate, because the top plate is smaller one compared to the bottom plate that is why always it should occupy the circle or if you go to concentric cylinders it has to fill up to certain point what do you do is you just give rotation to the top plate, but bottom plate is fixed that is about the rheology that you do.

If you see this one the second picture shows the commercial rheometer this is a head that is a movable head and this is the bottom you can see here, but we are not using the same cutting fluid here to explain the rheometer or the rheology physics we are using a semi solid in this particular.

So, this is the tool master which is a small and this is the fixed bottom plate and in between you have a sample this is the sample ok. So, of you give the rotational speed to the top plate that is this one. So, that it will rotate and this is a fixed bottom end and will assist for keeping your sample.

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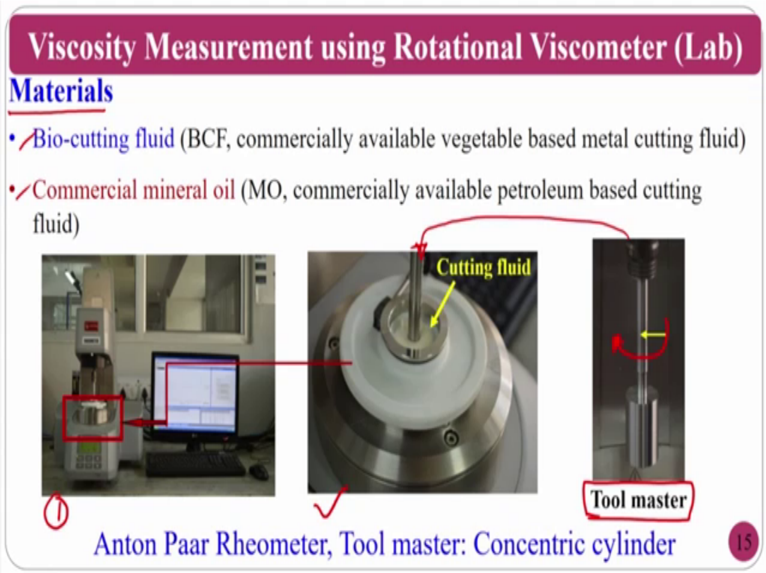

So, this is how the experiment will takes place, but this is for the semi solids and all those things normally you will use the parallel plate rheometer, but if at all somebody want to do the radiology of the liquid normally plan parallel plate is not used. Whatever we have shown in this particular slide is to explain you how the physics of the rheometer goes on? That is what we want to say for that purpose easily understanding is by the parallel plate rheometer ok.

The same thing we can extend to the concentric cylinders in the current viscosity measure using rotational viscometers whatever we have done at our laboratory for explaining you, the materials which we have taken in this particular conditions are two; one is Bio-cutting fluid, another one is commercial mineral oils.

As I said this is a liquid or a liquid emulsion, because you have to mix with water and also things you cannot use a parallel plate rheometry, because it may splash out when the you give the shear rate and all those things for that purpose we have to move to some of the advanced tool masters that is one of them is concentric cylinders.

If you see here in this picture you have a concentric cylinders, where the cutting fluid is filled beyond the tool master the tool master looks like this. This is the tool master and you have a hollow at the bottom. So, just you go and put here and so, that it should cover completely then you give the shear rate; that means, that you give rotation to the tool master. So, you can calculate the viscosity.

How the viscosity will be calculated. Normally if you see the figure one this figure one what will happen there will be a torsional sensor will be there on the top, assume that you have given certain RPM assume 15 RPM or 20 RPM it has to rotate at that particular RPM at the air.

Whenever you are putting a certain liquid in it what will happen it cannot rotate whatever the given RPM, for that purpose it need because it is resisted by the fluids viscosity for that if at all I want to rotate at the given RPM it has to put extra torque to rotate. That extra torque it has a internal software to calculate and it will you in terms of the viscosity shear stress and also those things, that is how probably this type of rheometers are working.

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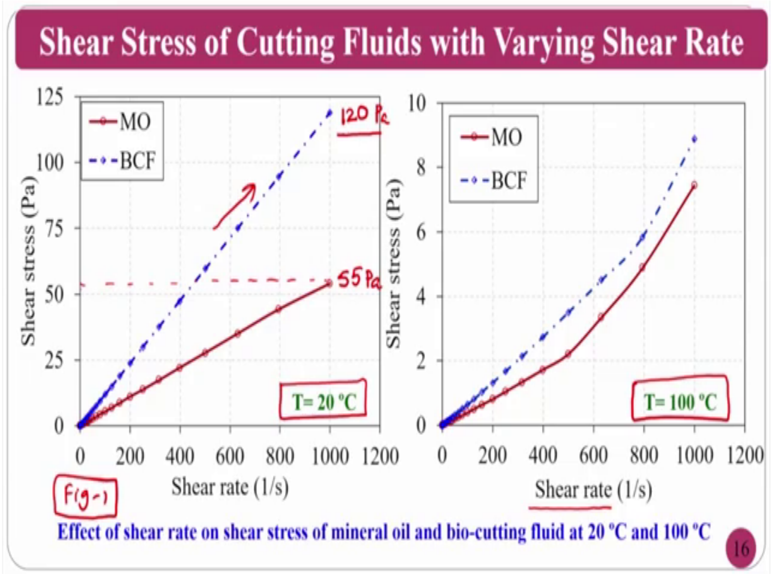

Shear stress if you see the shear stress versus shear rate in for the mineral oil as well as bio cutting fluid, the shear stress required for the bio cutting fluid is higher compared to the shear stress required for the mineral oil based cutting fluids. Normally it required around 55 and this requires about 120 or something 120 Pascal and this is 55 around 55 Pascal at a 20 degrees. What it shows it shows that bio cutting fluid is much viscous compared to your mineral oil ok.

So, in order to improve the viscosity you have to play with respect to the water, water is a Newtonian fluid if you put it what will happen the viscosity will come down. So, how much water you have to put to make the emulsion that, you have to see and check with respect to thermal properties and then you have to come back to the rheological properties. Striking balance between thermal properties and the rheological properties from this particular point of you flow ability of mineral oil is better compared to the bio cutting fluid.

However if you see from the other point the lubricating characteristics of the bio cutting fluid is much better than this one, because the viscosity is very high means the lubricating characteristics is very high, probably the second one is shear rate verses shear stress at 100 degrees.

So, at room temperature or this is at room temperature or 20 degrees temperature approximately we are seeing, if you see both the fluids both the fluids are following the Newtonian rent ok.

So, what will happen these cutting fluids whenever it is exposed to the machining conditions, like with respect to shear rate; that means, that shear stress verses shear rate at 100 degrees it is not following the Newtonian rent like gradual straight line increment like the figure 1. It is not going like a straight line one it is going like a non-Newtonian fluid that is called shear thickening fluid, but at particular temperature.

So, I am not talking about the temperature variation at his particular moment, but I am talking about the shear rate variation with respect to shears stress the shear rate is increasing at 100 degrees temperature the shear stress is gradually increasing, because at elaborator temperatures whatever the volatile things are gone and it is increases it is thickness or it increases it is thixotropy, it becomes some thickly liquids that is why at higher temperatures the viscosity gradually increases; that means, it follows the shear thickening fluids.

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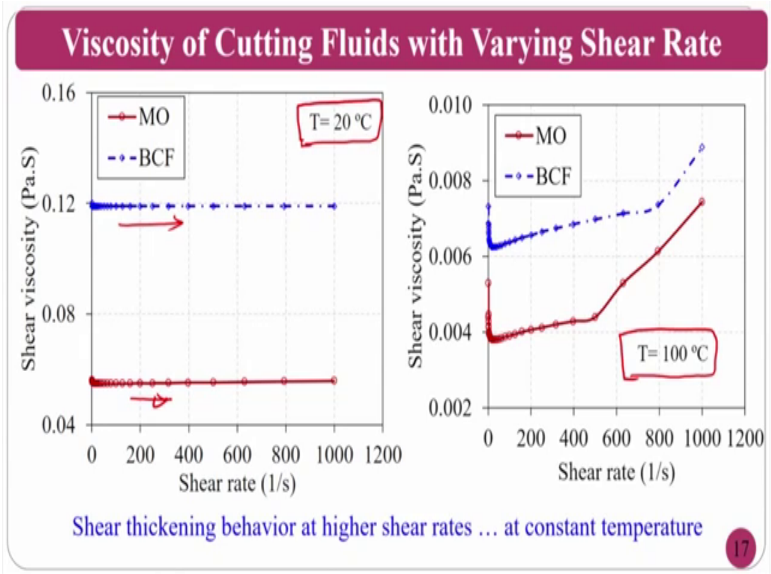

As at 20 degrees temperature you have seen in the previous slide that the linear proportional increment that is why the viscosity is completely linear here for the both of fluids.

So, the viscosity of BCF that is bio cutting fluid is higher compare to the mineral oil cutting fluid, but if you see at elevated temperature that is 100 degrees temperature which is maybe a temperature that normally experience whenever the people are using like soft work piece materials, there it is not a straight line it follows a non-linear trend and there also the bio cutting fluid shows higher value compared to this one; that means, that even at elevated temperatures the lubricating properties of bio cutting fluid is much better, but flowing characteristics are not up to the mark of the mineral oil.

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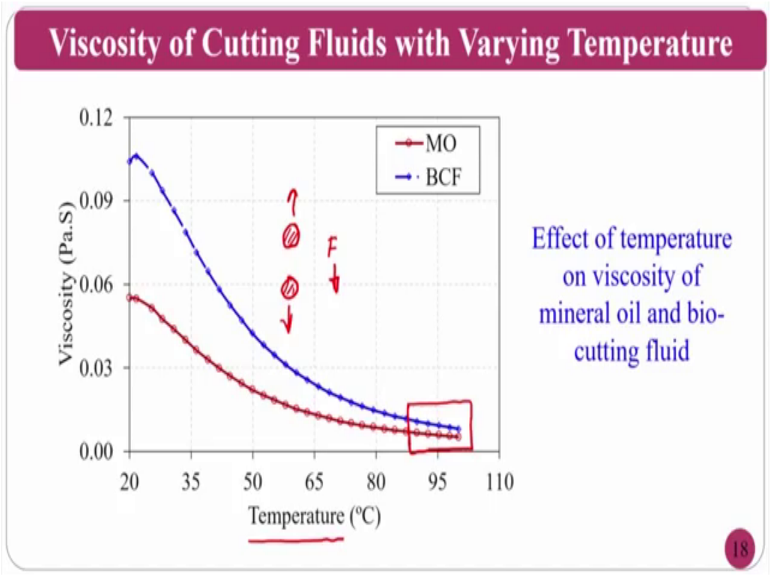

Now, we will see about the variation in with respect to temperature, if you see the variation with respect to temperature both the fluids are decreasing with respect to temperature; that means, that whenever you are increasing the temperature the particles in two particles intermolecular distance is going to increase with respect to temperature; that means, that intermolecular force of attraction goes decreases that is the viscosity gradually decreases.

If you see at 100 degrees are above ninety degrees approximately both the fluids have approximately similar viscosity. Even if you have seen in the previous slides the viscosity of the bio cutting fluid is much much higher at room temperature, but the natural condition that is that higher temperatures, which is the machining region both the fluids will have the same viscosity that is a beauty about the bio cutting fluid.

That means it is viscosity is decreasing, but if you see at room temperature viscosity is very high; that means, that gradual change viscosity is very high for the bio cutting fluid; that means, it will have better lubricating properties as well as better flowable properties, that is what I want to say from this particular slide.

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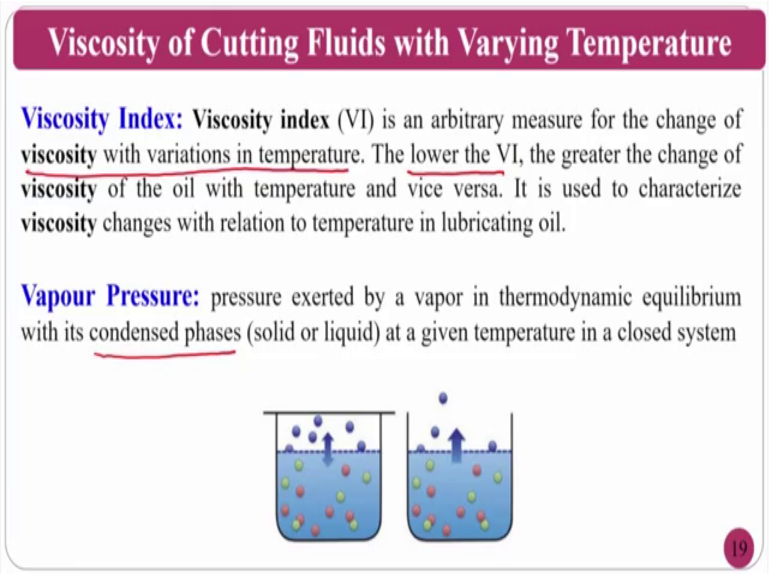

The viscosity index, the viscosity index is arbitrary measure of the change of viscosity with respect to the temperature ok. This we have to study that change of viscosity with respect to temperature what will happen if the viscosity index is very high, normally if you see the viscosity lower viscosity index greater change of viscosity of the oil with respect to temperature and vice versa. Why I want to introduce this term is if the viscosity index is higher; that means, that it would not change much viscosity at a higher temperatures also if the viscosity index is lower what will happen the fluid will change it is viscosity with respect to temperature.

We will describe with respect to next one that is called Vapour pressure this is the pressure exerted by the vapor in the thermodynamic equilibrium with respect to the condenser faces; that means, if I am sending a cutting fluid into the machining region the cutting fluid has to penetrate into that region at the same time, because of the temperature it will change itself into the vapour because intermolecular distance will increase, because of gaining of the thermal energy that is why it will convert into the vapour. Whenever you convert into the vapour what will happen it exerts pressure assume that I have a chip like this and cutting tool like this in between my fluid jet will come ok.

This is a fluid jet if the fluid jet will come what will happen vapour pressure kicks off, but it cannot kick down cutting fluid, but it has chances to lift up the chip. So, that the new cutting fluid can penetrate into the region, at the same time the viscosity index what I am talking if the viscosity index is lower what will happen the viscosity it will change if it will change easily. And this capillary action will be very easy if the viscosity is low what will happen the cutting fluid can penetrate into the complex regions of the machining region, that is why vapour pressure it has to exert and viscosity index should be lower.

So, if you have seen in the previous slide where the temperature variation the viscosity with respect to temperature is high for the viscosity change is very high for the BCF; that means, that from this particular value to this particular value it is coming ok; that means, it has ability to easily exert certain pressure on the in terms of machining region exclusively on the chip.

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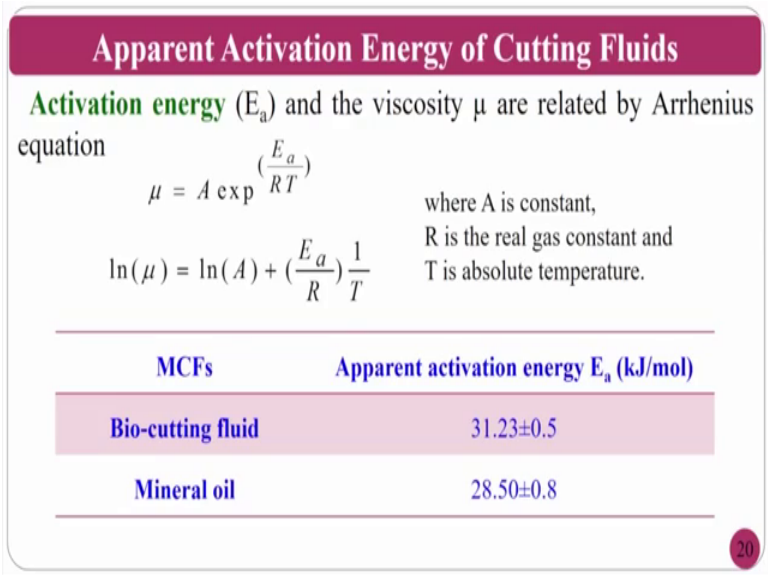

If you see the apparent activation energy of the cutting fluid the relation between the activation energy and the viscosity are related by the Arrhenius equation that is called mu equal to a into exponential of E a by R T, where A is a constant R is the real gas constant and T is absolute temperature and E a is nothing, but activation energy whenever you take the log in both sides you can convert like this.

The apparent activation energy for the bio cutting fluid is very high compared to the mineral oil in that circumstances the activation energy required to change is higher to the bio cutting fluid compare to the mineral oil; that means, that it would not change it is form before mineral oil changes; that means, that mineral oil has high tendency to change it is low apparent activation energy it will change, but bio cutting fluid will have need more activation energy to change it is form that that is what here I want to say.

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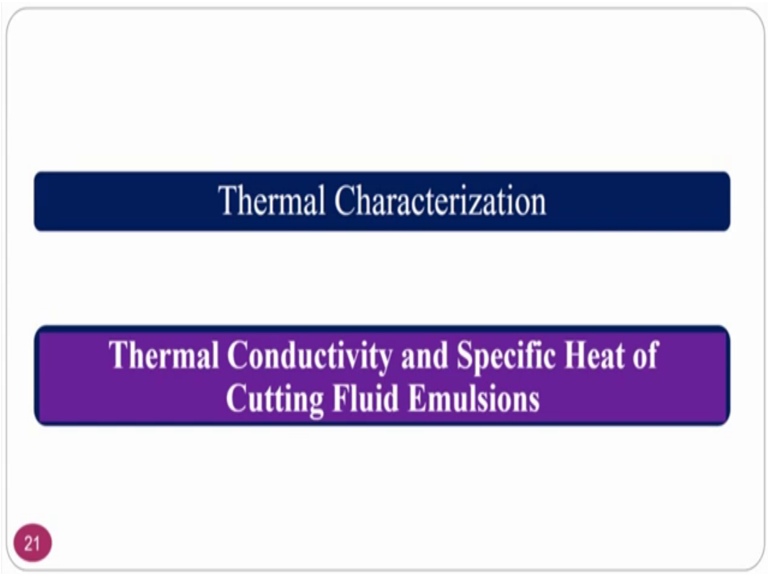

Now, we move on to the thermal characterization.

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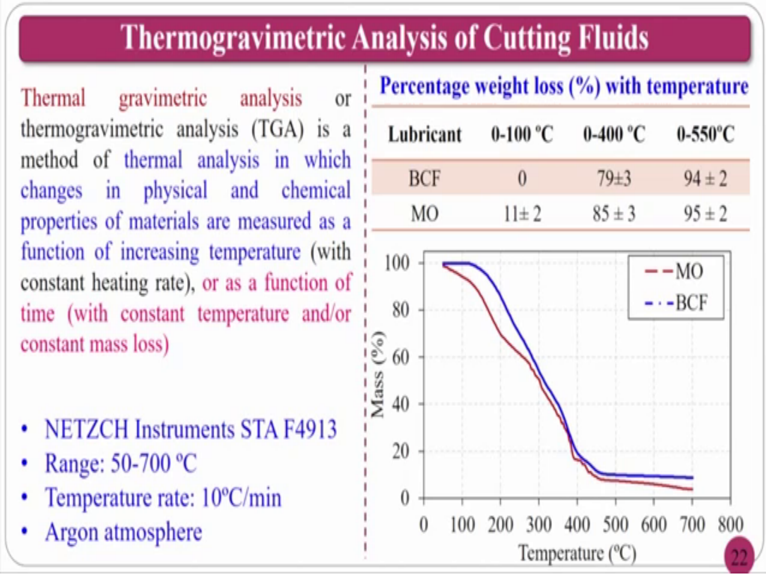

Here we will see the thermal conductivity and specific heat about the emulsions and all those things, thermal gravimetric analysis of the cutting fluid, if you see TGA is a method of thermal analysis, which changes the physical and chemical properties of materials, measured the function of increasing with respect to temperature.

Whenever you have certain cutting fluid you just put this cutting fluid and change with respect to temperature and measure the mass as well as you can also measure what are the gases that is availing out. If you see here with respect to temperature the mineral oil started changing with respect to as soon as the temperature is increasing the red one is starting to change.

But if you see the bio cutting fluid there is no change up to this particular portion; that means, that it is still stable at that particular range of temperature like up to 120 130 degrees there is no change. If you see the table column here up to 100 degrees there is no change in BCF that is 0 and, but the mineral oil has already consumed or it is gone about 11 to 13 percent or a 10 9 to 13 percent.

If you see up to 4 hundred degrees temperature what is happening 79 plus or minus 3 percent is gone, but various other thing is maximum of 88 percentage is gone receive 550 degrees approximately both are same; that means, the degradation with respect to temperature having better from the bio cutting fluids compared to the mineral oil.

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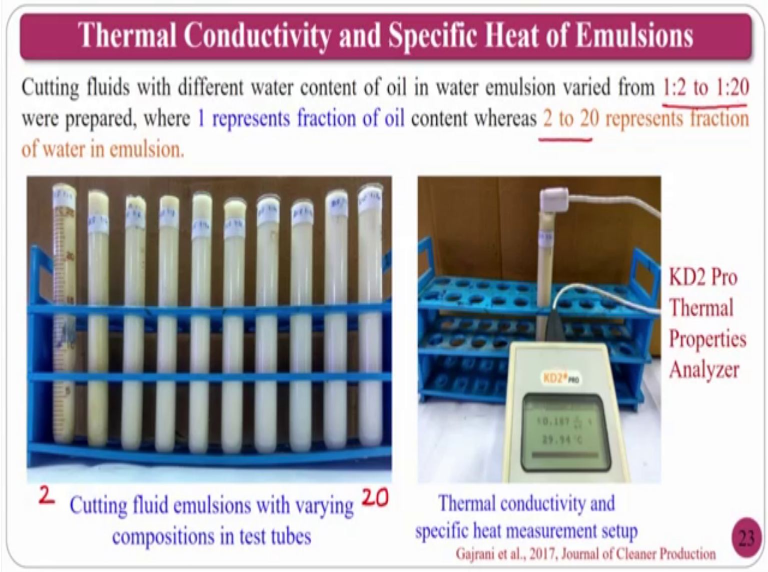

So, now we have to check which is having the good thermal properties for that purpose what we have done here is the emulsions are mixed from 2 to 20 a percent of the that is one is to 2 to 1 is to 20. So, 1 litre of cutting fluid to the 2 litres of water ranging from that to 1 is 1 litre of cutting fluid to 20 litres of cutting fluid.

Now, my major ambition for this particular slide is what amount of water that I can add to the cutting fluid is the question mark. For that purpose we have used k d 2 pro thermal properties analyzer which will give the thermal conductivity of the cutting fluid as well as the specific heat.

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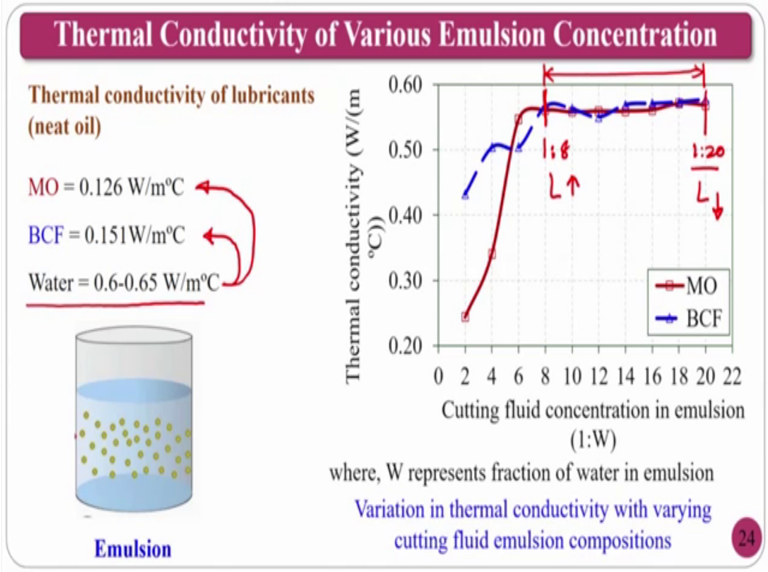

Thermal conductivity of the lubricants normally mineral oil if you see mineral oil thermal conductivity of the mineral oil is 0.126, but the bio cutting fluid is 0.151.

However water is very high. So, now, how much water one has to add for making the emulsion with respect to the water increment what will happen; obviously, the thermal conductivity will increase, because 0.6 is going to sit here and 0.15 or it is going to sit on 0.121 it is going to increase.

That is why the thermal conductivity of the emulsion gradually increases, but it reaches to a optimum value at 1 is to 8 after 1 is to 8 the thermal conductivity of the cutting fluid is approximately same so; that means, that from this particular experiment one can say; if you go for one is to 8 you have optimal thermal conductivity plus since 1 litre of cutting fluid is mixing with 8 litres of water compared to other one assume that I am going to take 1 is to 20 here 1 is to 8 here 1 is to 20 here the water content is very high.

So, the lubricant properties will be gradually decreases, but here lubricant properties will be much better, that is why from this particular graph you can choose the value based on your lubricating characteristics only, because the terminal conductivity characteristics are approximately similar in this region. Now, what whether we can choose 1 is to 8 or whether we choose 1 is to 20 that we will see from the point of specific heat.

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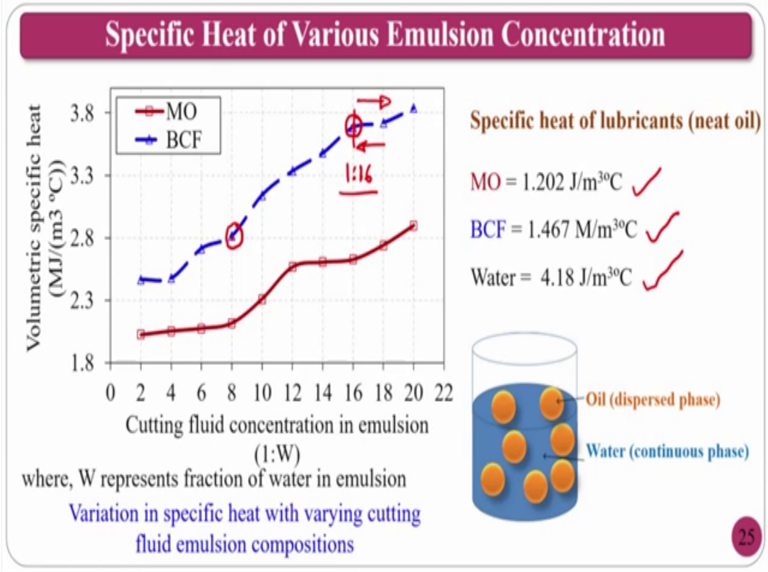

Now, we will see the specific heat one the specific heat of the lubricants mineral oil is 1.2 bio cutting fluid is again 1.467; that means, approximately 1.5, but water will have higher that is called 4.1 or 4.2 approximately.

If you see this one the specific heat will gradually increase irrespective of the mineral oil or the bio cutting fluid with addition of the water, but after seeing 1 is to 16 there is no much change in this region. So, there is no much change that is means from the conductivity point of view you can choose any value after 8, from this particular point you can choose 1 is to 16 to have the specific heat volumetric heat will be better at 1 is to 16. So, 1 is to 8 is good after 188 is good. So, if you choose 1 is to 16 you will have the thermal conductivity properties better, because you have seen 1 is to 8 beyond 1 is to 8 it is good.

If you choose 1 is to 8 what will happen you will have this much volumetric specific heat if you choose 1 is to 16 this much volumetric specific heat that is means that if you are going beyond this 1 what will happen you are not gaining much, but the thing is that lubricating characteristics will lose because your water content is going to increase.

So, optimum conclusion from these 2 thermal characterizations is if you go for 1 is to 16 you will have better thermal conductivity, as well as volumetric specific heat anyhow with respect to mineral oil these values are much much higher compared to your mineral oil ok.

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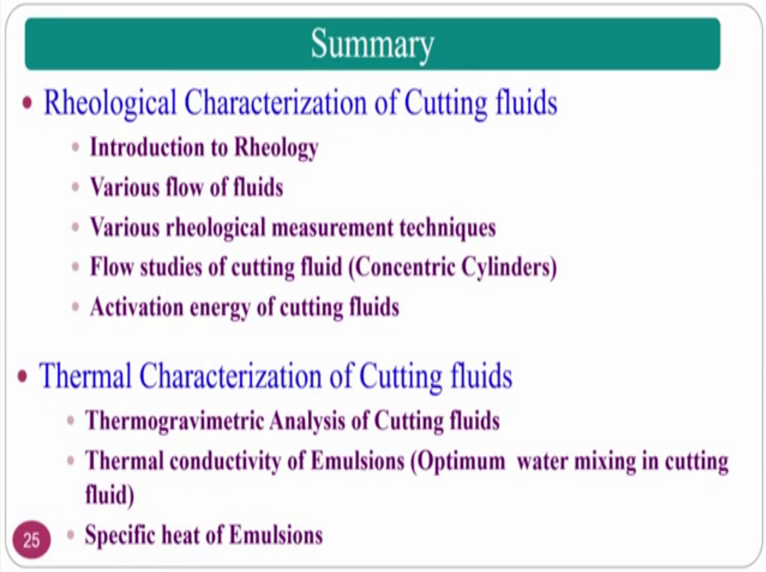

Summary today we have seen the rheological characterization of the cutting fluid, which is introduction to rheology, various fluid flows, and the various equipments that are used the flow studies of the cutting fluid using concentric cylinders, where we have studied of the basics about the parallel plate rheometry

However the application of the cutting fluids which we have seen is from the concentric cylinders, then we have studied the activation energy of the cutting fluid, then we form proceeded for the thermal characterization where we have seen the thermogravimetric analysis that is percentage of mass change, then thermal conductivity and followed by specific heat of the emulsions.

And from the these study the emulsion composition is better if a person can choose in between 8 to 10, if at all you are choosing common mineral oils that is available and bio cutting fluids. So, the bottom line 1 can take up from this particular for the research point of you is that they can choose between 8 to 10 or 12 litres of water you can mix with respect to the 1 litre of cutting fluid and you can perform, because that is the best range that is given from the thermal conductivity point of view, as well as you should mix as minimum as possible for the highest thermal conductivity.

So, that the lubricating property of your mineral oil will be remain in a good condition ok, that is about from the research point of you from the B-tech people point of view it is a set books in books it is not available, please go through the slides and follow the slides that is about today’s class.

Thank you.