Non-traditional abrasive machining process: Ultrasonic, Abrasive jet and abrasive water jet machining
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Lecture - 08
Ultrasonic machining – Feed mechanism, Head design and other aspects

Welcome to the 8 lecture of the online course there is Non-traditional Abrasive Machining of Materials. So, today after having discussed at length about the horn design etcetera, we will take up certain aspects of some other aspects of the machine, as regards the feed, the acoustic head design, and some other aspects. We also try to recapitulate and tie up the loose threads from previous days discussions.

So, let us start right away.

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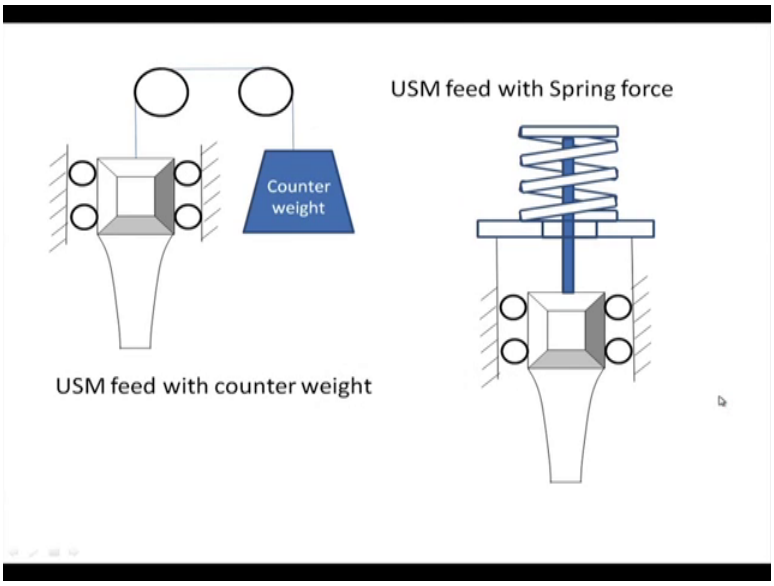

This shows one of the typical head designs I mean sorry feed mechanisms that we might be employing. Up till now we have come across one of the feed mechanisms in which a dead weight was being used on one of the hence of a weighing balance. And on the other side that it was pressing the work piece against the tool, I will just draw that figure to for a quick recapitulation.

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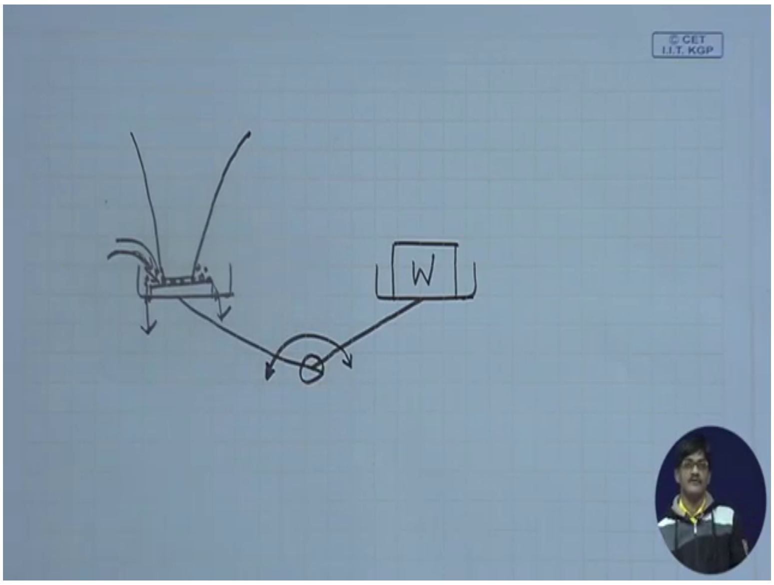

It was very simple, it was something like is pan there is at another pan. I put a dead weight of my choice we have these 2 are connected together and they have pivoted here So that you know it can un demo this sort of up down motion, weighing balance.

And on this side we had the end part of the horn the work piece here and the abrasive (Refer Time: 02:18) here. You might say that the abrasives and the slurry they must be changing the static load that had in mind when I put this particular w, but when these abrasives are put in there their weight is not very significant and in order to you know in order to remove any doubts about actual static load, there are some holes made here. There are some holes made here through which the particular slurry ok.

The remains of the slurry can remove itself white gravity. This was the one feed mechanism that we had already seen. The slide variation of this one when we come to the actual machine and this is one sorry, what is happening here? This acoustic head we are not showing anything inside it at this moment, we are only showing some slides by which you know rollers through which we can be fed downwards very smoothly and the horned and the head this together makes up the machine and it is having it is own weight. And the counter weight is slurry. So, chosen that it will be living a few kgs of weight to you know make this move downwards and get pressed against the work piece.

So, this is one pulley, this is another pulley, this is the rope and therefore, this count a weight is just one or 2 kgs less than the machine So that the machine have a tendency to go down under a weight under the effect of weight of one or 2 kgs of load which means you know 10 to 20 neutrons which is quite high for ultrasonic machining. Here we have another setup, in this setup we have. So, the disadvantages in this setup is that every time you go for a different load you put down this counter weight put another counter weight etcetera, and that way you have to choose the particular load. So, this one is USM feeding with a spring force.

As you can see here this is the spring and the spring is connected in such a way that if it is put under you know this is a sort of compression spring if it is put under compress it will try to apply a force. And so, that I mean it will try to expand if it tries to expand what will happen is it will start pushing this particular member downwards, is that So? Let us quickly check if it tries to expand no if it is fixed then this will be pulling it up.

So, if it is a tension spring if it is a tension spring in that what happens? Compression spring is that when compressed it will give you a reaction tension spring is that when it is pulled it will you a reaction. So, if it is pulled it will try to compress it itself and it will try to compress it I mean if it tries to compress it become smaller in size it will definitely push this downwards. So, we have a tensions spring which is you know expanded and then put here and this will press it downwards, because it is trying to become smaller ok.

So, the advantage of this is you can reset the loan by expanding this spring to a particular length, but the disadvantage is that, if the length of the spring is changing with you know passage of time as it is machine and as this is going downwards, the force which it applies will definitely change even it soughtly or slightly it will change because the length of the spring will define how much force it is going to apply.

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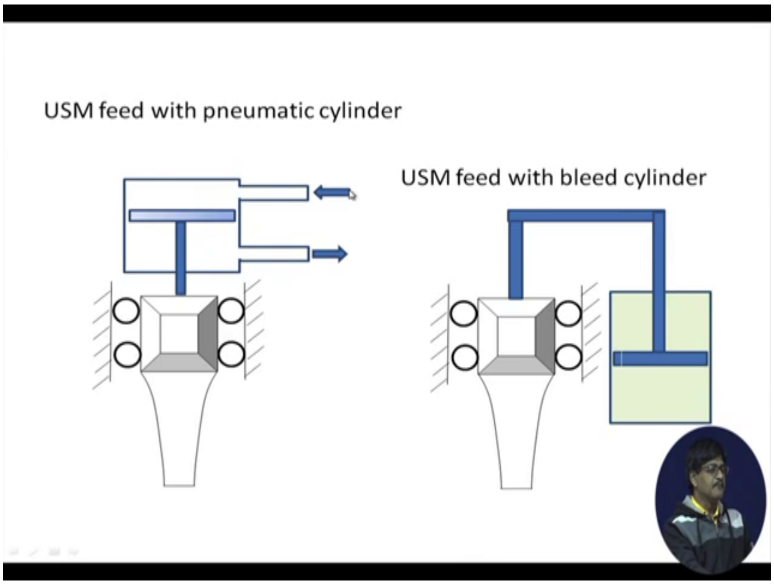

Then USM feed mechanism are also present with pneumatic cylinder, or hydraulic cylinder, just excuse me. So, pneumatic cylinder how does it work you might be having from a piston I mean sorry, from the power cylinder you might be having a hydraulic fluid or air at a pressure on this side and this one is connected to the some So that thus the piston will be experiencing a load force which will ultimately push it downwards and therefore, the whole body will also be push downwards.

Up till now you must notice something that is in ultrasonic machining we are always trying to apply a constant feed force, and this is contrary to the idea in say conventional machining of lead willing etcetera were we generally applied a constant feed rate. What you mean by this? On the (Refer Time: 08:08) if you apply automatic feed it will be constant with time, the displacement is you know proportional to time.

But in this case the load or the force is constant, why so? This is because if I apply a constant feed rate when is no guarantee that I will be actually removing that material due to the ultrasonic vibration active on the abrasives. If the rate of material removal is less than the feed rate that I select; that means, if I select feed rate to be constant, and if I select it by some automatic means it might know be equal to the value of the you know material actual material removed by means of a abrasive action, in that case they will be (Refer Time: 09:06).

The same case thing happens in case of idiom. In idiom what happens is that we use a servo mechanism we do not select an automatic feed. Because if we select an automatic feed which is higher than the rate at which material is sorry lower than the rate at which material is removed, in that case I am sorry, if in idiom we select a feed rate which is higher than the rate at which material is removed we will have a short circuit. And if it is lower then the machining will be slavish unnecessarily slavish.

So, here we understand that in these different cases we are trying to have a particular feed force, but it is not always So, you can also select a particular you know feed rate by use of a particular load. Let us have a look how it can be done. Here we have a bleed cylinder what is a bleed cylinder? Here a very small (Refer time: 10:21) through which liquid can pass one side to the other now why should it pass from one side to the other.

This is because this particular head which is exiting here it is connected rigidly to this piston and therefore, the weight of the head will try to bring the piston downwards. Now what you mean of the piston would have got down in a flash under gravity, but it cannot because this hydraulic fluid here is going to resist it is motion downward. So, what happens is the rate at which this liquid can pass through this very narrow (Refer Time: 11:00) that decides at what rate this will be fed downwards ok.

So, this sort of mechanisms also very popular because the whole this aperture which is present here it can be adjusted. If so, it can be adjusted we can have higher feed or we can have lower feed depending upon the diameter of this aperture. So, this is called feed with bleed cylinder. So, the load is being applied by the head and a you know the aperture controls the amount of fluid which can pass through. So, these 2 things interactive produce a particular feed rate. If possible I will set you a numerical problem on this also.

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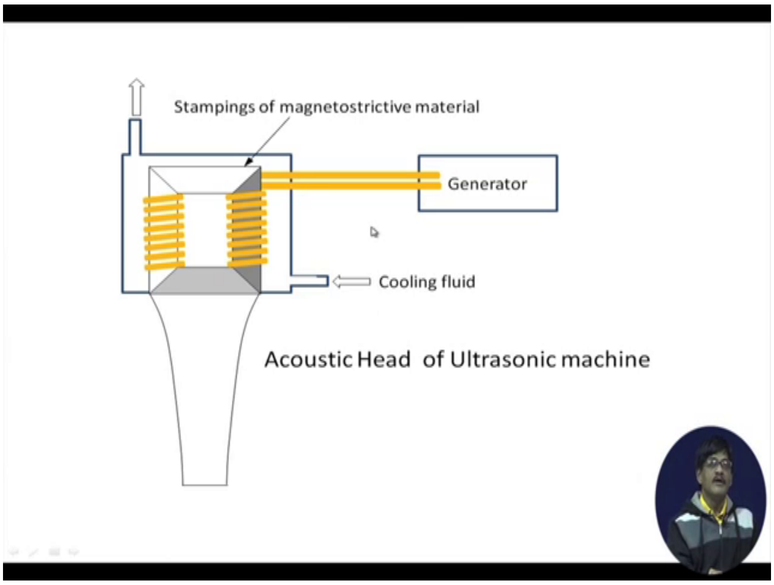

Now, we come to another interesting case that is the design of the acoustic head in this case of the all the possible designs like. Zoo, electric effect, acoustic, magnetostrictive effect we are dealing with a magnetostrictive acoustic head. What we mean by this in the first case? First of all whenever we are talking of vibration being given to the tool we have to first of all you know produce vibration. How do we produce vibration? This is done by you know by sum property of materials and I have I can mention 2 properties like physio traction and magnetostriction what do they mean? There are some materials which when magnetized and demagnetized will change their dimensions ok.

In a direction perpendicular to the direction of you know direction in which they are say electrically charged say physio electric pistols, if you apply a voltage on these 2 phases you will find that the dimension changes in the other direction same thing with magnetostriction. So, in magnetostriction what are we going to do? We are going to apply some coils around this magnetostrictive material and then we are going to apply a alternating magnetic field.

We apply in alternate magnetic field, this will go on changing it is dimension excuse me. So, first of all it will become smaller larger smaller larger. So, if this happens a particular vibration will be setup and tuning can be done. So, that we have a frequency matching with it is resonant frequency. Now what do we have in this particular figure? We are showing that there is a first of all there is a encompassing body and inside it we having we having this magnetive magnetostrictive material.

So, this is that magnetostative material, but how the behave that in stampings of magnetostractive material. What is stamping? Stamping it means that we are going to have a stack of let me draw it here to make it clear yes. So, we are going to have a number of such you know separate layers of magnetostractive material.

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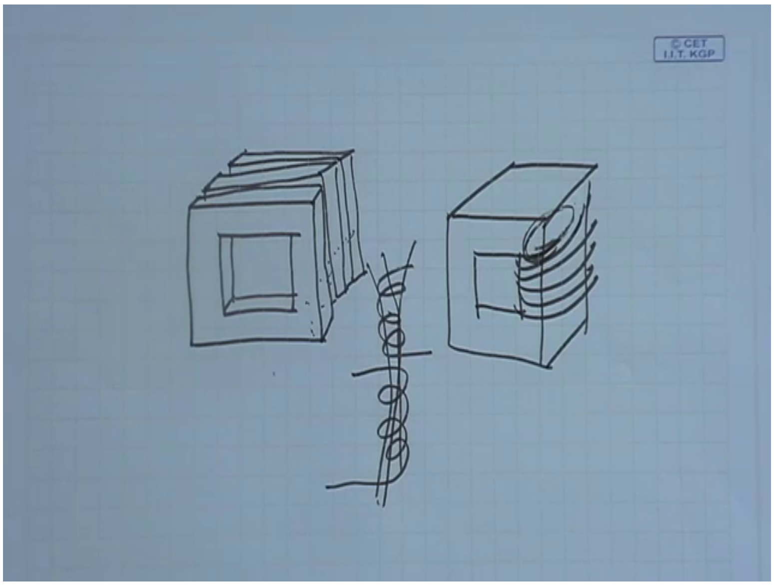

What kind of magnetostractive material? Say nickel or some alloy of nickel of iron in aluminum, some a lay of iron and nickel something like that. Different mangnetostrative can be used (Refer Time: 15:45) 2 etcetera etcetera, what we do with that? Now if we have such materials whole together in a block and we put coils all around it. We will be setting up you know if it is alternating this magnet filed. We will be setting up eddy current inside eddy currents will be going why because of self induction.

This will, you know if there is a coil, if there is a another coil, if there a magnetic lines of force passing through and interacting with this coil this will also start having (Refer Time: 16:38) of induced TMF here. Same thing this will act as a coil as a whole they will be raise of induced TMF which will you know drive a current here unnecessary wastage of energy. And ultimately we will have lot of material and lot of energy wastage.

So, what is the solution break them or separate them into separate laminar pieces of magnetic magnetostrtive material with insulation between. So, that they stop such eddy current long from circulating that is good. So, we may stampings of magnetostractive material. Stampings of magnetostractive materials they are used here and that brings the total wastage; that means, that heat produced from wasteful circulation of current, that is reduced, but we cannot reduce it fully that is why there is a jacket of cooling water all around. And water comes in water goes out and the head is get cooled. As we know from experience head always as to be you know at a low temperature in order to act properly. This is the generative which is sending that ac alternative signal.

And therefore, we generate this way this particular vibration. So, magnetostraction physio traction water typical physio electric crystals you can have PZT lead zirconate titanate. And so, many varieties are there I will be you know giving you some notes also supplementary notes which will have these details, which you can study yourself we need not you know use up our use full time of interaction going through all these details. So, I can promise you some notes in this regard.

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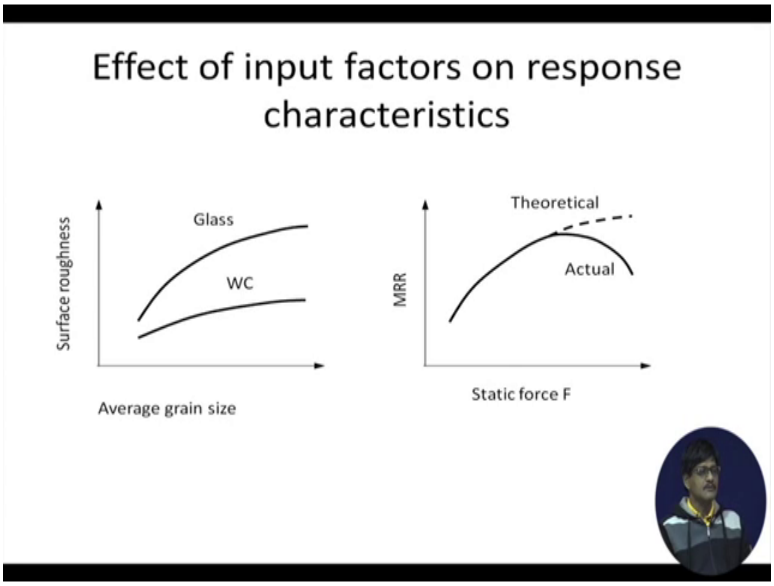

Now, we will come to a very interesting aspect of ultrasonic machining, which is the effect of different input factors on response or output characteristics. So, let us see if you look at this one for example, static force changing on this side MRR plotted on the other side. What is static force the force which is pressing the work piece and the tool to each other with the grits in between.

So, the theoretical curve is like this, now let us try to recall. What is the relation between MRR and static load? The relation the relation is that MRR is proportional to f to the power 3 forth. And this is the typical curve that we expect for that, but in actual practice we will find that it droops after reaching a particular maximum. That is with further increase in static force we do not find an increase in MRR, why is this So? This is because at higher loads the abrasive grits are crushed. If they are crushed they become abrasives of smaller size and they are not that effective in removing material, because the same expression the MRR is proportional to the grade size. And hence is in the grade size becoming smaller due to crushing the MRR comes down ok.

Now, let us see surface roughness with average grain size. And change in the grain size that is very good. So, with that I expect that the material removal rate will increase and it is increasing no doubt, but I find that tungsten carbide and glass, they are having different rates of removal. Why should this happen? What is the effect of material? One example how does the material affected. So, for that if you remember that tungsten carbide is having higher hardness than glass.

So, in the expression for material removal rate.

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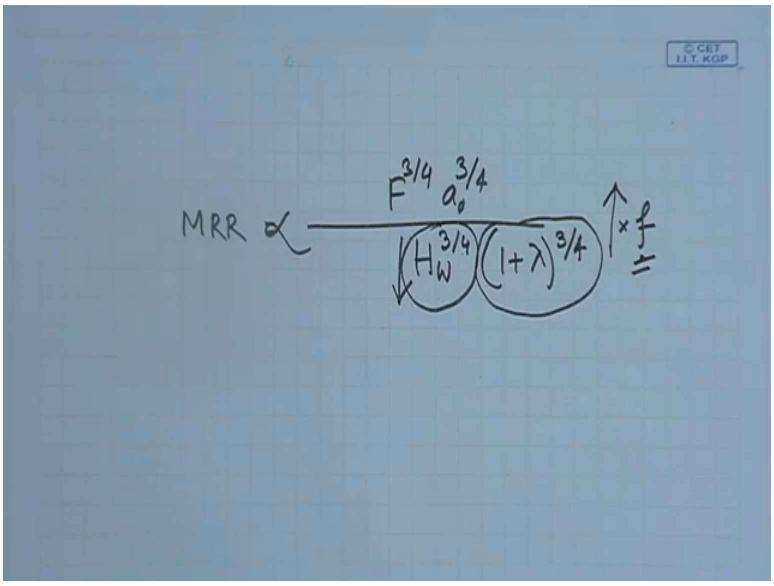

So, let us have a quick look. All such some terms are there like these, and we find that it has a bearing on MRR hardness the work piece. What about this? This is the ratio of the hardness the work piece to the hardness to the tool. So, that also is definitely important and therefore, this starts effectively. So, if it is h to the power 3 4 if this is lower. So, the rate of material (Refer Time: 22:59) will be higher, but if you notice, if you notice this is not dealing with MRR. This is dealing with surface roughness now this becomes important. Why should surface roughness in case of glass be higher, compared to surface roughness obtained for material tungsten carbide.

This is because the creators or the hemispherical chunks which are removed these are small in case of tungsten carbide due to high work piece hardness. So, it forms smaller creators this forms larger creators and therefore, the cumulative effect of having such craters on the surface leads to, that is gives rise to higher surface roughness for glass and lower surface roughness for tungsten carbide. So, clean reason is smaller creator's larger creators, being formed by the hemispherical chunk removal.

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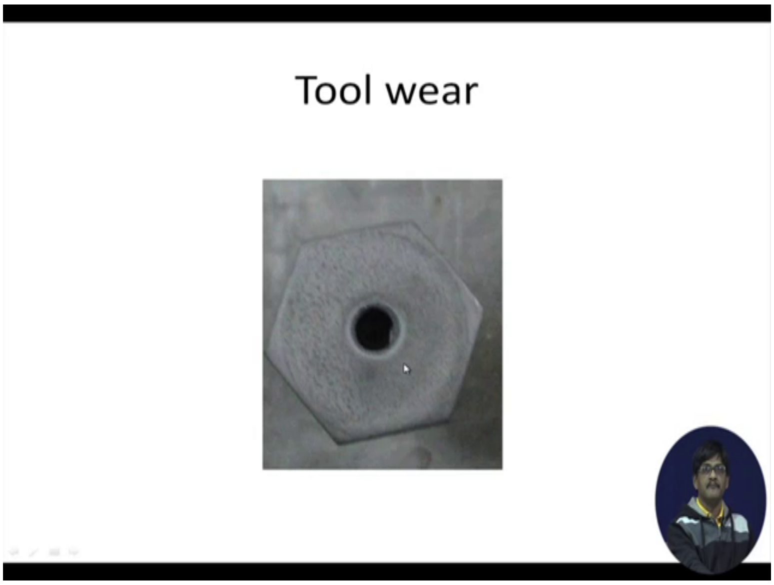

This figure of the tool showing tool wear you can see it is not a plane surface any more.

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These are some of the parts that we have machined and this clearly shows the clear surface of glass and the rather you know translucent or trans lighting phazy or hazy. Surface of the machine part of the glass machine by ultrasonic machining, these are done by that same tool that you saw just now right, some more.

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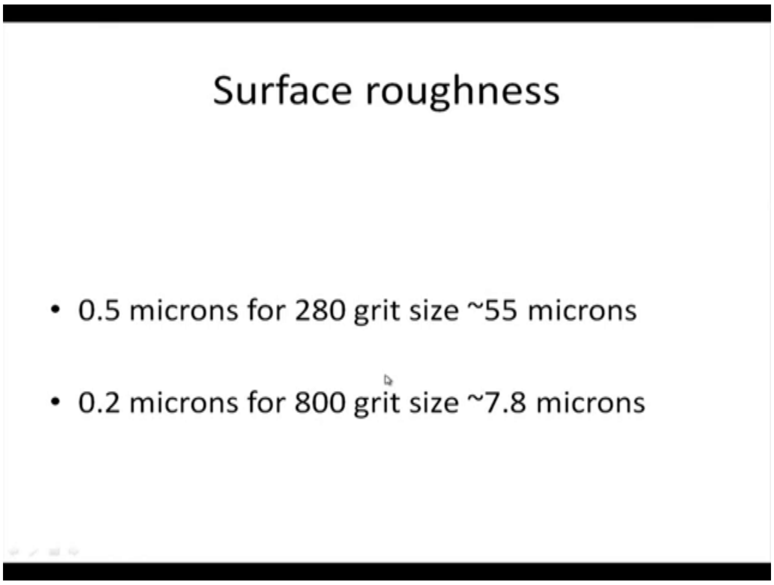

So, surface roughness some data if you have 0.5 sorry if you have 55 microns has the grit size which corresponding to the roughly to 280 mesh size then you will get a roughness r a value of 0.5 microns. If you have 7.8 microns as the grit size corresponding to 80 mesh size, it will give you a roughly 0.2 microns r a value 0.2 microns.

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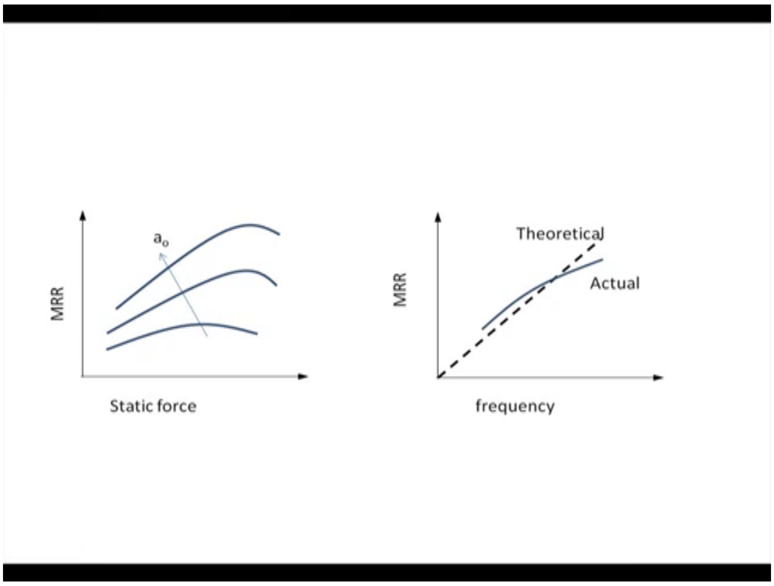

Now, let us have quick look at the effects of you know MRR sorry, effect on MRR by the different inputs factors. It is being already seen that is static curve arising to a high level and when drooping down. So, we need not visit this one. So, mean let us take a look at this sorry frequency the theoretical effect is that frequency should I mean MRR should be directly proportional to the frequency, because MRR is if you look at this expression once again.

It is directly proportional to the frequency. So, if frequency is on this side therefore, the MRR should come have come as a straight line. But actually it comes this way, why? This is because when we are deriving the expression for MRR in that case we make an assumption, that is 4 times the amplitude is covered in the time period and a proportional amount of time will be required to cover the delta t plus delta w, that is an assumption, because of which this discrepancy occurs ok.

I just repeat we during the derivation we had assumed 4 times amplitude divided by the time period, must be proportional to delta t plus delta w divided by delta t, that is actually an incorrect assumption, and it is reflectance is coming here.

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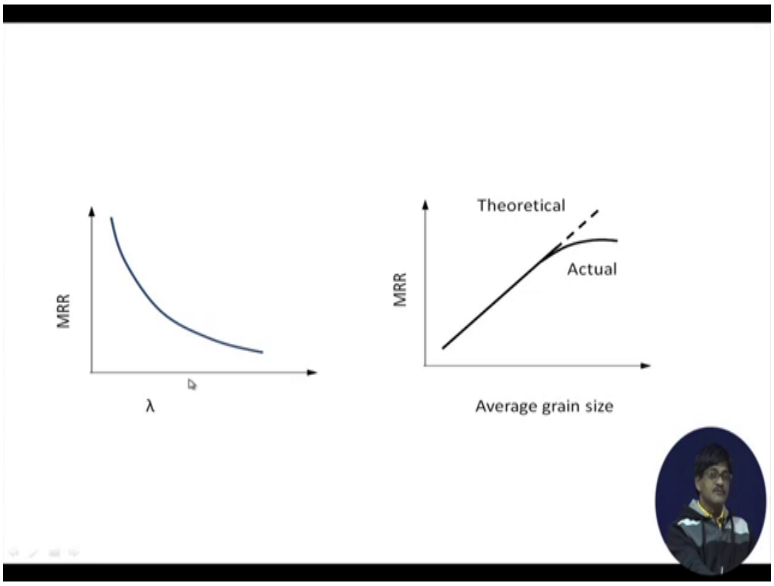

This is lambda; that means, work piece hardness to tool hardness. So, if the work piece hardness to tool hardness increases; that means, work piece is becoming harder and harder. So, tool will be taking the most of the indentation because it is deformable it is softer and therefore, MRR comes down ok.

Tool is taking most of the beating and therefore, MRR comes down literally. [FL] average grit size if it goes on increasing MRR is going to go up theoretically yes, but actually it is found that it starts drooping, why should it go up because once again in this expression we have d here. So, it should be proportional, but instead of that it actually droops.

Why? There are a number of reasons for this one is crushing when it is becoming more or less equal to the amplitude. It shows the crushing tendency and also it finds difficulty to enter the gap between the tool and the work piece, because it is large in size compared to the amplitude. So, there are some more you know of such effects to be discussed, but we have roughly reached the time for; I mean time limit for this particular lecture.

So, we will continue this in the ninth lecture.

Thank you very much.