Introduction to Mechanical Micro Machining
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Lecture – 51
Micro Tools (Contd.)

Good morning again everybody and let us continue a discussion on fabrication of micro cutting tools. In the last class, we have seen different processes like a laser beam process, electric discharge machining process, and focused ion beam process. So, that, by this particular process is we can fabricate different geometry of the cutting tool with a different type of diameters.

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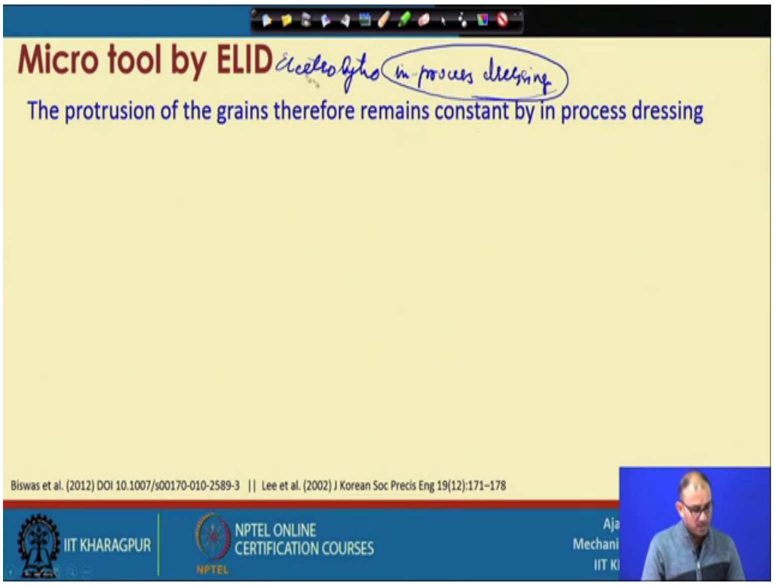

So, let us continue this further discussion and there is still one more process left that is called the ELID and that is called the electrolytic in process dressing. Process electrolytic in process dressing right. So, now what is the objective of this particular process that the objective is that the protrusion of the grains, should be remain constant throughout the, improve by the, in process dressing. So, when you do this is something, something like a grinding process only, but it has in process dressing post facility, because what we do in the grinding operation that when the, there is a wheel loading happen.

So, when there is a, abrasive particle is become dull then what we do that, we do some type of dressing operation here. So, by dressing what we are doing? We are re circling the abrasive particle. So, that we can actually create some new surfaces on to the wheel and then wheel can be efficient remove the material, but then we do mostly in the offline; that means, we stop the machine and then we do something out of there. But here the same thing, what we are doing it is in, in process dressing.

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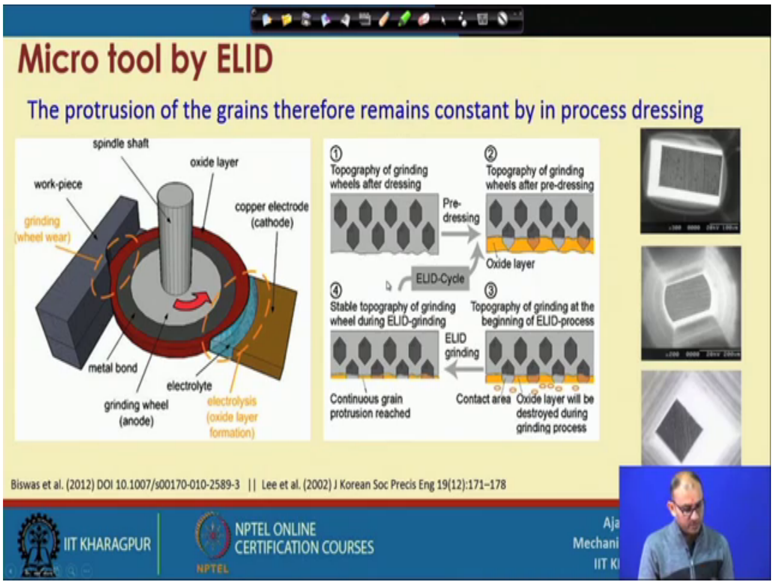

So, let us see what that mean right. So, this is the setup and now, what we are doing here that we have a grinding wheel, but here the grinding wheel is a metallic grinding wheel, because we have to create one type of electrochemical, circuit here. So, this is a anode, we can work, because we want to remove material from that part and this is the copper electrode and it is a cathode connecter with this and this particular location you are doing machining operation and at this particular location, what we are doing we are doing in process dressing part and this is the oxide layer; that means, the bonding material is the oxide material.

Then you can use the diamond particle or any other particles also, then this is the way it is happening that at one location, it is doing machining here and at the other location, what it is doing? It is doing depressing. So, continuously you are getting the, ray surfing of the edges and every time the proper reason remains constant and you are getting the good machining capability. So, this is the way, this particular process works. So, what is here that this is the initial, topography of the grinding will after dressing. So, you have dressed it and these are the particles. Now, what is happening that, because of this electrolysis or what is happening that it creates some oxide layer on this.

So, this is the oxide, what material we are using here, that is material is oxide. So, that creates a oxide film here. So, this is the oxide film and because of this oxide, oxide is actually very weak compared to the parent oxide material. So, when you perform the ELID operation what is happening that, it will remove this oxide film and along with that it will actually, dull out this particular particles also correct. So, now, once it reaches to one particular oxide film, film formation then this ELID will not continue, because it, it will, it will take a lot of time to reach to the face surface, but when you do machining at the time.

So, at that time, what is happening that, you are removing or you are deforming this particular oxide film, during the grinding operation. So, the thickness of this oxide film is reduced. So, once it is reduced then what is happening that you are getting a protrusion of this particle again here and now, the thickness is less right. So, now, as soon as you, once you get this particular less thickness then again your ELID cycle will start and then it will again further create the oxide wheel.

You continue operation with this oxide film, it will reduce the oxide film by grinding operation again, goes to this location. This will continue for till the, you consume the grinding wheel. So, what is here objective that, every time you are getting a constant protrusion of the grind and that is the good reason for making using this particular process for fabrication of a different-different type of shapes on the micro cutting tool and. So, these are the different shapes, it is a rectangular types of, tool this is almost a square type, but spherical surface at the two location and this is the square type of tool.

So, now, you can see that this shapes are almost similar, to the, surface, what we are getting into that focused ion beam machining, but focused ion beam machine is actually more precise process, compared to this thing, because we have seen that grinding the, still there is a physical contact and because of that you can see this is the 100 micron. So, size of this one side, bigger size is more than 2 micron or 200 micron or something like of them and similar way here, it is the dimension is 100 micron.

So, this may be considered 70 micron or something. So, going down and down is very difficult, but still this is reasonable size of the cutting tool, which can be fabricated by ELID process right.

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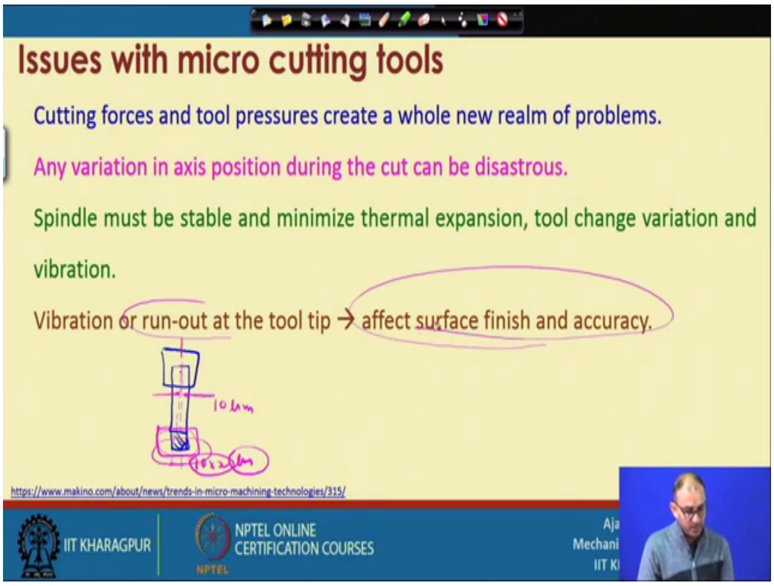

So, these are the different process and now, let us discuss there, what are the different issues with the micro cutting tool, because once you fabricate the cutting tool then you have to use this cutting tool for, final operation. So, when you operate at the time, you have to take care of some of the things. So, let us see this thing.

So, cutting force and the tool pressure create the whole new, realm of the problem, because in earlier cause, when you are using a micro cutting tool or bigger size of cutting tool, we actually do not pay more attention to the breakage of the cutting tool, but we pay attention to the wear of the cutting tool by studying the forces and the pressure, whatever it is creating on the part.

Any variation in the axial position during the cut can be disastrous, because now, you can see that we have seen in the geometric error, lectures, where we have seen that, if there is a shifting into the X Y or Z direction, your tool movement will not be a straight line. You may get the different-different type of additional moment and that additional movement will actually create a problem and it will create a, on even pressure, what the very-very high fluctuation of the force is onto the two hurting tool and that is very-very disastrous and it will break the cutting tool instantly. The spindle must be stable and minimize thermal expansion tool, change various and the vibration, because we have seen in the spindle also that what are the different ways, you can actually, you the spindle.

So, first thing is the it should be stable. Stable in the sense that, when you operate into the, operate in a, in the high speed regime at the time. There should not be any type of deformation within. The spindle thermal expansion is also, we have seen that, that the how thermal expansion play important role there. So, we can go with the air bearing, then thermal expansion will be very-very less, if you go with the ball bearing or the roller bearing, you will get some thermal expansion, because of the fiction and the height generation tool change variation that is also important, because we are not using same tool for all the operation, after certain operation you to change the tool.

So, what is the variable variation? In the, tolerances when you fit one tool and then use remove and another feet, another tool the vet, at the problem associated with those things and final the vibration, because vibration also important, because what type of ball bearing you are using? What type of preloading we are using? Depending what that you can actually control the vibration and those things, we have discuss in detail.

Vibration or run out at the tool tip, because and this affect the surface and accuracy. Now, you can see there are many ways, we can actually, see this thing. Now, see this is our cutting tool holder and our tool is held in this particular location and this is the cutting tool or cutting edge right. So, our objective is that, we are using this particular portion for machining. So, this is the portion which we are using for machining. Remaining part is just for the support only right. So, now, if you see that if you have a vibration or run out, now, let us consider run out only. So, if you are run out then, what is happening that support, this is the axis of the spindle and this is the axis of the cutting tool. Now, let us see something like this correct.

So, now, if you see that the run out here, it is very less right. Consider it is, if it is a 10 micron, but when you see at this particular level that how much it is yet that will be 10 multiplied by some X that, that depends on the, what is the total length of the, cutting tool. So, this particular now, to what is important that, we have to run out measure, the run out at the tool tip not to this location, because here you will get some run out, but this reading will be misleading. So, that is the reason that always measure, the run out at the cutting edge, because that is the actual run out that will play important role in the machining zone. So, that will directly affect your surface finish and the accuracy right.

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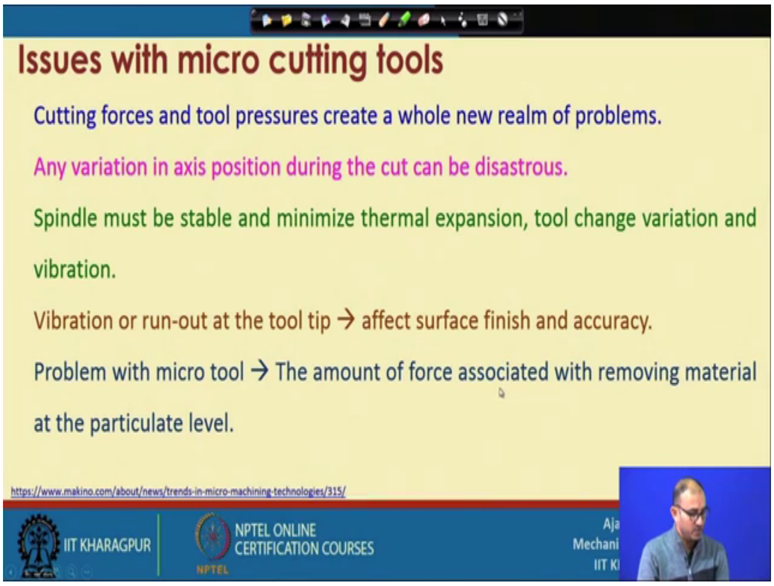

Problem with micro tool that amount of force associate with the removing of material at the particular level. Now; that means, whatever material, you are removing from that, where this material is going. So, if it is coming out as a chief that how efficiently chip is created and how efficient it is coming out of the machining zone. So, that will decide that how much amount of forces are actually, you are playing with this particular material.

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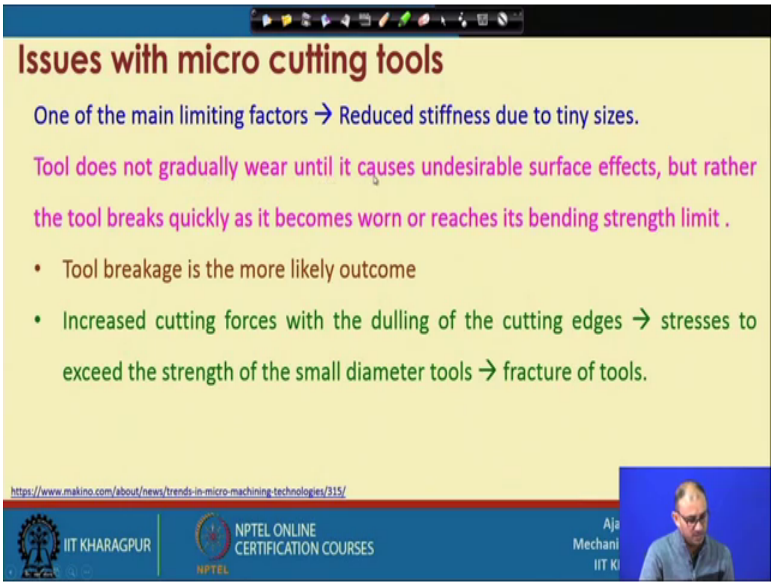

So, one of the main problem or limiting problem is the reduced stiffness with the tiny sizes, because when you go smaller and smaller. Now, grain size of that cutting tool also play important role, you cannot use a bigger size of cutting tool, when the diameter itself is a 100 micron or something you have to go with a micron size or the sub micron nanometer size of green size.

So, that more amount of grains available and you can get the little bit higher stiffness, but still the stiffness is not high as compared to the conventional sense. So, that is the limiting factor, you cannot reduce the size beyond, the certain limit right and another problem that tool does not gradually wear until it causes undesirable surface, effect rather the tool breaks quickly as it becomes worn or reaches to the bending limit or bending strength of the limit.

So, now mostly, if you do conventional machining operation, what is our objective, the we study the tool wear right, because we know that the breakage of the tool will take more time compared to the wear of the tool, but it is execute reverse into the convey con micro cutting that here, you can easily read. That particular limit of the, breaking strength compared to the study of the wear. So, in the study of micro machining, what is our objective? Our subjective should be to reduce the breakage of the cutting tool not to the wear, because you can study the wear only when you, ever the breakage of the cutting tool. So, here that is what is problem.

So, our here that is on the tool breakage is the more likely outcome. So, mostly our objective is to save the tool first and then you will do the, wear characteristic or the wear study to. So, that what is the total acceptable life of the cutting tool.

So, what happened? Why this thing happened? Because when you cut with a, dull cutting a, then you are cutting versus will be very-very high and stresses extend the, exceed the strength of the small diameter cutting and then it will fracture. So, this is the way, this is the, our reason what is happening, because of, and what is happening with the cutting tool of the, this particular size.

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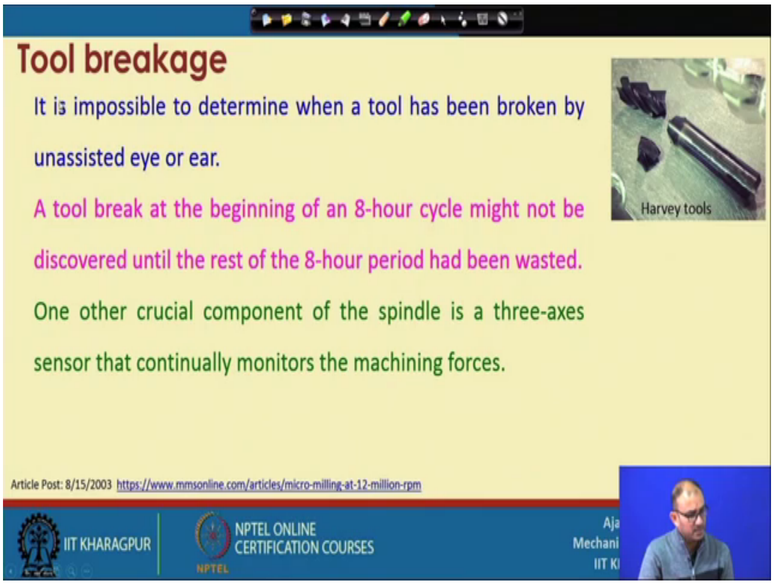

A first thing that is impossible to determine, whether the tool has been broken or a broken by the unassisted eye or ear. So, now, we know that size of the cutting tool is very-very small. So, you cannot get anything, in terms of some noise signal or some type of process signal that what is happening, whether tool is there or not. So, what is problem, because of that, that suppose, you are starting a eight hours of cycle and your tool is broken in the, one first meet itself and you do not have any type of work, work. We can see the feedback device is order, some type of, of the, the what we can say that it is some type of, accessories or the force measurement system in such a way that it will give you this type of signal.

So, you are starting 8 hour cycle and within the 1 minute to your tool is broken, but you will get that information once, you complete the 8 hour of cycle right. So, once you know that the tool is broken and you have already wasted 8 hours of time. So, what is things? What we have to do here that, we have to invest something on the, not tool monitoring or the process monitoring system.

So, if you install one sensor or three axes sensor that is, may you considered as a piezoelectric sensor or some type acoustic emission sensor, which will continuously give the signal of the machining process right, because we know that whenever there is a material removal, you will get some force reading, if you get force reading, you are sure that your tool is in contact with the work piece.

So, you have to invest, not on to the machine, but you have to invest something on the auxiliary accessory. Mostly, it is related to the sensing of the cutting process that is by means of some type of sensors.

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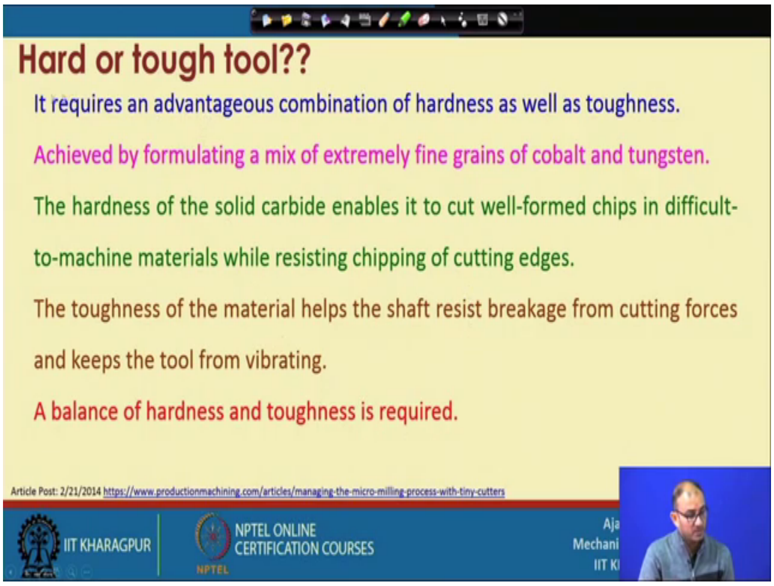

So, another things is the, what you, we need hard tool or the tough tool right. So, what we need the, we need the actually compromise between the hardness and the toughness. So, it requires advantages combination of hardness as well as toughness. So, how you can get the both the things done; that means, you have, it can be achieved by formulating a mix of extremely fine grain of the tungsten and the cobalt, because we know that tungsten, carbide you are using and then cobalt is the binder of that particular, material.

Then hardness of the solid carbide enables it to cut well form chips in difficult to machine material, while resisting the chipping and the cutting as. So, what is the use of this carbide? Carbide will actually, it is very hard material. So, it will actually resist the cutting edges; that means, cutting edge sharpness will return for a longer time and toughness of the material helps in the shaft resist, the breakage from the cutting forces and keeps the tool from vibrating.

So, hm, why mean it; the, toughness also here, because we do not want to break this thing, because hard material will break very easily, but if you is toughness here that may even, if there is a little bit amount of bending for vibration, it will actually written that particular thing. So, what is the require? We need a balance of hardness and the toughness, because both the things cannot be achieve simultaneously.

So, you have to sacrifice the hardness by putting some more toughness. So, that tool will not be broken during the vibration or some type of, high amount of bending lot. So, that is the way, we have to think about the, what should be the composition of the tungsten, carbide tool in such a way that, you can get the required properties done.

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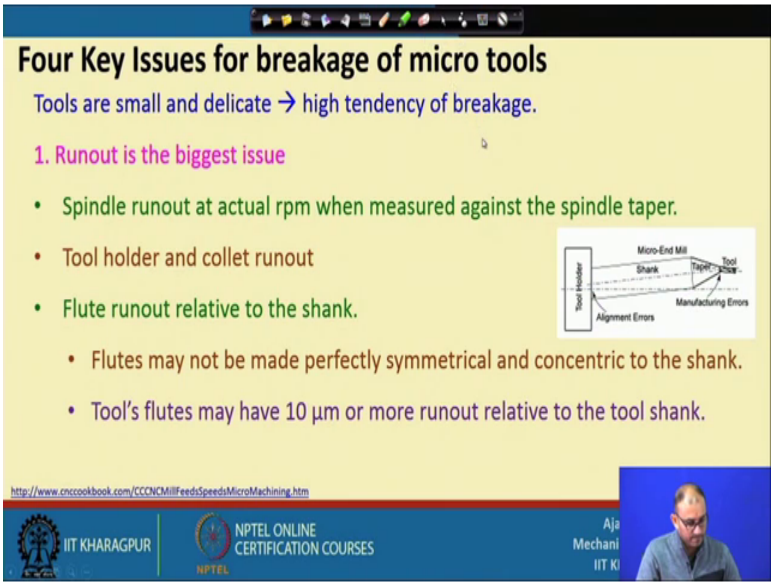

So, there are different issues of the micro, better the what are the four issues of this? Four issues are the mostly related to the tool setting and all these. So, smaller the tool, tools are small and delicate. So, there is high tendency of breakage. So, first thing is the run out. So, now, is the biggest issue compared to all other issues, because we know that this avoiding, this thing is very-very difficult, because we are doing lot of setup and settings during the different-different positions.

So, spindle run out at actual RPM when measured against the spindle taper right. So, this is what is we are talking about this spindle run out that is another thing that the tool holder and the collet run out right. So, now, if you see this particular thing. Now, it has a two things, first thing is that when you are holding the, this is the tool and then you are holding this tool into the tool holder. Now, see that the axis of the tool holder and the axis of your cutting tools are not coinciding. So, this is called the alignment error.

So, this alignment error can be reduced by using a proper tool holder or we can use some type of, spindle without any tool holder or; so, so those things are available. We will see in the next few slides. So, this is called the tool holder and the collet run out right. So, this is the tool holder, there is a collet available here and on the collet you are putting the cutting tool. So, this is the first thing, which is happening between the tool holder and the collet and this is a fluid run out, related those things right. Now, this is the second one, you can see here this one, this is the, cutting tool and this is the shank ok.

So, what happened that when you fabricate this particular tool, at that time, we have seen lot of different processes, but if those processes are not that much precise or the high resolution, processes then what is happening that, you will get one another run out, with respect to the, shank with the fluid. So, that is the within the cutting, we are not talking about in the alignment of this, but this is the manufacturing error right. So, what is happening here, the tool may not be made perfectly symmetrical and concentric with the shank. So, right now, if you see at the, this tool is not concentric with the shank diameter right. The tools fluids may have the 10 micron or more run out relative to the tool shank.

So, that depends on, which type of manufacturing process you are using and depending on that, you will get the different-different tool run out; that means, that run out with respect to the flute and the shank. So, you can see that these are the different way, different ways by which you can get the run out into the system as. So, that you have to find some of the ways by which you can reduce the alignment error and you to also make sure that you are, whatever process you are using for fabrication of this cutting tool, those processes are very-very, finely tuned, otherwise you are end up with this type of, cutting tool errors right.

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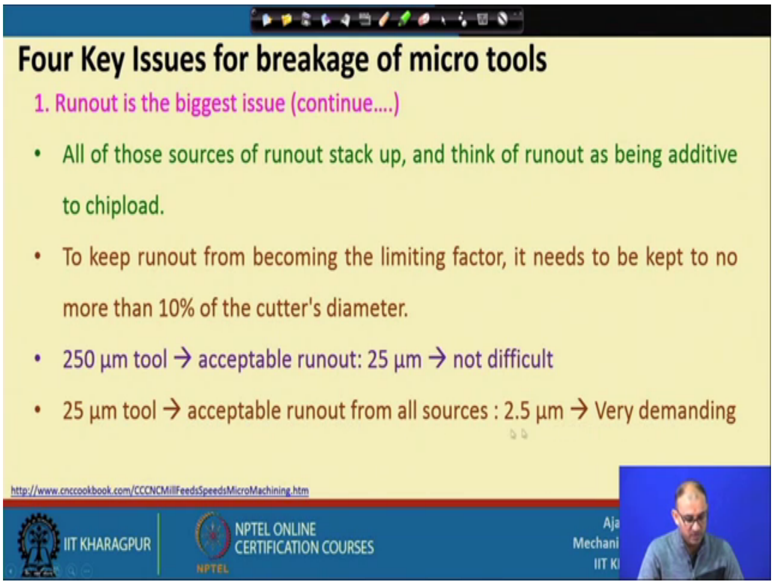

So, let us continue to the, all of this source of errors takes up. Now, what here, we have seen here that there are two; one is the alignment error, another is the manufacturing error, but those two things will not place separately, because both the things will be actually combined with each other and it will stake up and total runout will be very-very high at the, at later stage.

So, runout will be being additive to the chip load. So, now, what is happening that one, tool has a run out and both the location, the alignment run out and manufacturing run out then, because of that, you are total run out to be extremely high and it will directly affect the chip load that how much, chip is removed in a, by one rotation or by one fluid. So, what is the thumb rule that, to keep the run out from becoming the limiting factor. It needs to be kept with, keep to not more than 10 percent of the cutter diameter right.

So, when you are talking about the diameter of a 100 micron then, let us say consider the, it should not be more than 10 micron or, run out. So, now, when you are talking about 250 micron diameter then what is that? You have run out acceptable, run out is 25 micron. So, that is not very difficult to get that run out 25 micron, but when you go down and down let us consider the diameter is 25 micron now. So, by this thumb rule what is our objective that now, the total run out from all the sources should not be to more than 2.5 micron and that is very demanding.

So, now, you can say the going smaller and smaller, in the diameter then what is happening, then the requirement of the precision of the fabrication process and then the alignment process everything actually become more and more demanding and those things should be very-very precise. So, that we can work with in this particular, domain. So, that run out can be minimized.

Now, you can see, if it is 2.5 micron, run out then 25 micron plus 5 micron, you consider plus or minus measured 2.5. On both the side it will be 5 micron. So, you cannot create any features less than 40 micron, still you are, even though your diameter is the 25 micron right. So, this is the problem with the run out.

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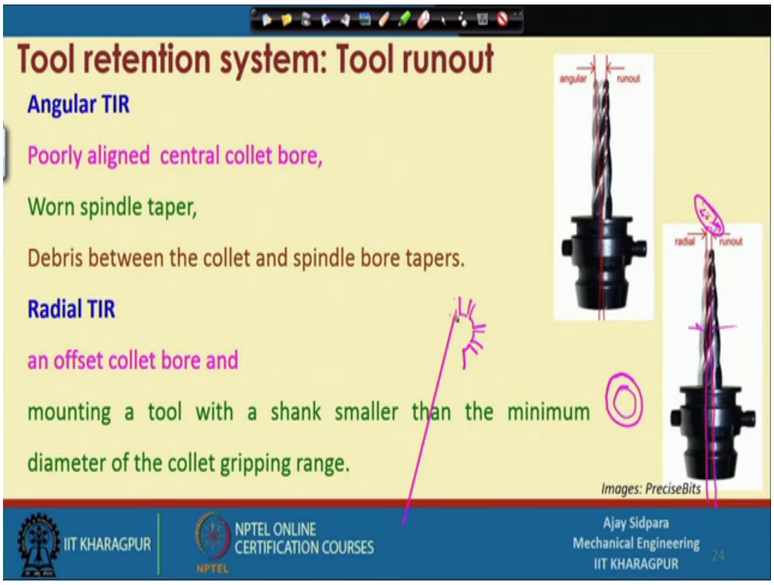

So, what are the different type of run out? One is called the angular total indicator run out. So, this is called the angular run out right. So, now, you have angle. So, now, there is always one point through which the both axis are actually separating. So, this is call angular, because it has some angle. So, this is called angular run out, it may happen between the, spindle to the, collet also and from collet to the workpiece also.

So, what are the reasons for these thing that poorly aligned centre a central collet bore. So, when you are actually making the system for this collet, it may also create a problem, because, that collet is not actually align, where exactly with their worn spindle taper, because if you are using some type of mechanical that the ISO or (Refer Time: 21:13) kind of thing then what will happen the, because of the friction there is a wear of the taper also and then the straightness and the eccentricity of that taper will be lowest and then your end up with angular THM debris between the collet and the spindle bore taper.

So, if some debris is that then you will not get a full contact around the taper and, because of that you are, will get this along around. So, when you do machining with this type of things, what is going to happen that you instead of a circle part, what you are getting, you will get some type of oval type of geometry and before you get oval type sometime, very high chance that your tool will be broken, because it, one location, it is getting more stress compare to the other location and there is another one is called the radial run, total indicator. In this case what is happening? The, it is not actually younger.

But is a complete shifting of the, of the two access. So, this is you consider the, spindle axis and this is called the tool axis. So, there is a parallel thing. So, that is why it is called the radial run out, if you do operation with this thing the, suppose, you are diameter is 25 micron, then you will get the diameter of 30 micron. If this thing is a 2.5 micron right, but still that is mostly not happening, because that, much 2.0 mega itself is sometimes more-more than enough to break your tool.

So, what are the reasons for this thing, that and offset collet bore that, your collet bore itself is offset. The, you are not actually getting where this thing with respect to the spindle axis, then mounting a tool with a shank diameter, the smaller than the minimum diameter of the collet gripping range.

So, now everywhere, now, if you see this type of ER collet. So, ER collet has a different-different thing here. So, now, here what is happening here that ER collet has a different-different type of gripper. So, these are the gripper, which will hold the cutting tool at the later stage right this, which is like now, cutting tool actually place in between these two. So, when you are holding.

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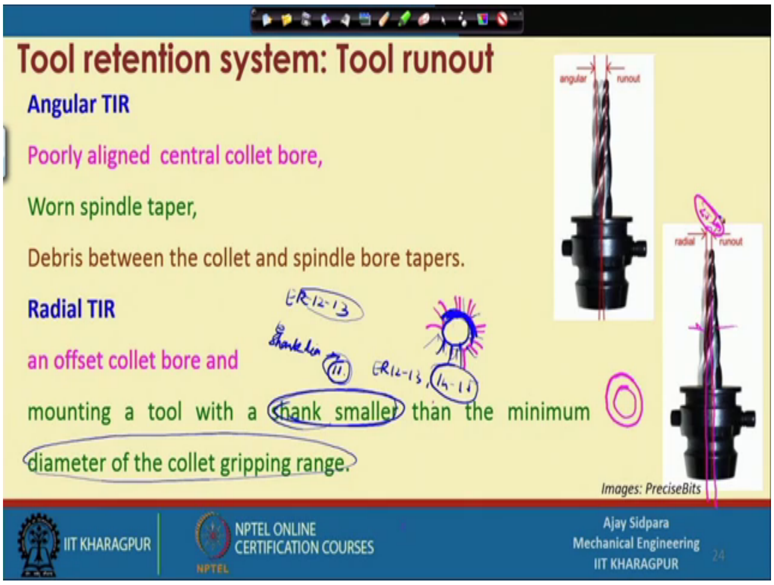

Now, this particular thing is given by E R 12 13 year, 14 15 something like this right. So, your diameter, whatever diameter of this particular tool, that the same diameter should be within this part right. Now, if you say that you are using E R 12 13 and you are using a same diameter consider. You are using same diameter of 11 or something right.

So, what is happening in this particular case that your tool is actually give by the, a few, this particular, support only, but it is not actually matching at the centre, because ultimately when it is gripping from all the sides. At the time it will remain at the centre. So, it will make sure that it is at the centre, but when you are tool same diameter is smaller than the minimum diameter range of this range is 12 to 13, but your diameter is 11 here. So, it will be grip by a few, few this particular grippers only, but not from the hold the location and then you are end up with the rdail run out.

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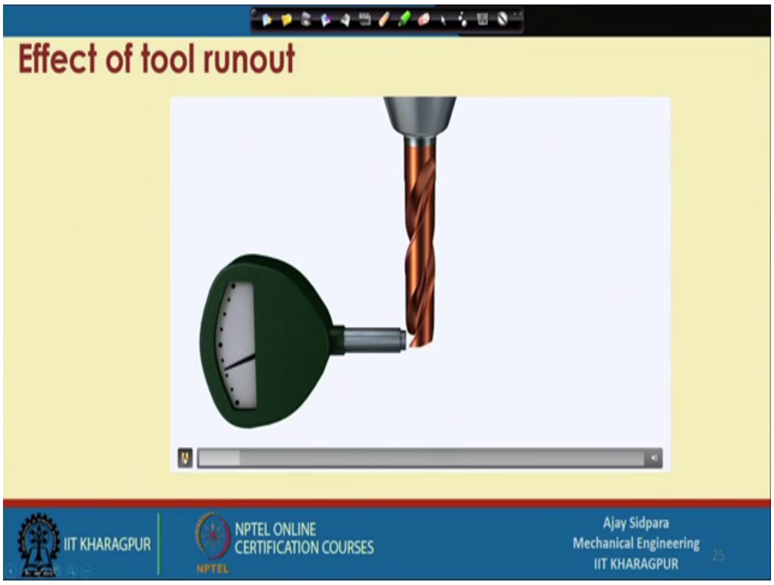

So, what is problem with this particular thing. Now, you can see that this is the run out. Now, you can see that when it rotate. So, at the time your dial gauge is moving at different location. Now, this particular tool as a run out right. Now, we are using this tool for doing a drilling operation or the cutting operation, what is happening here.

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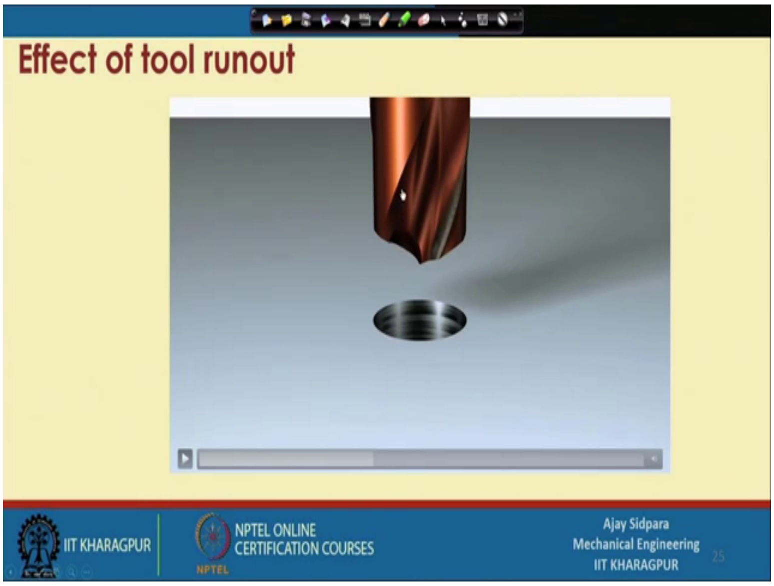

At this location that only one cutting edge will do all the operation or that cutting edge will not come into action at all. Now, you can see this particular cutting edge is completely free, because of this run out at work, whatever all the work is done by the one cutting edge, what is the problem? Because of that, that first thing is that your tool life will be sacrificed that you cannot use this tool for a longer time, because whatever that chip load capacity or chip load calculation, we have done this. All the thing is done by considering that you are both the cutting edge will participate in to the machining operation, but that is not happening here.

Only one cutting edge, it taking all the load of that and that cutting edge will quickly worn out and within a small duration. You have to replace this particular thing right. This is happening at this location and what is happening here that, your also getting a different type of, surface here.

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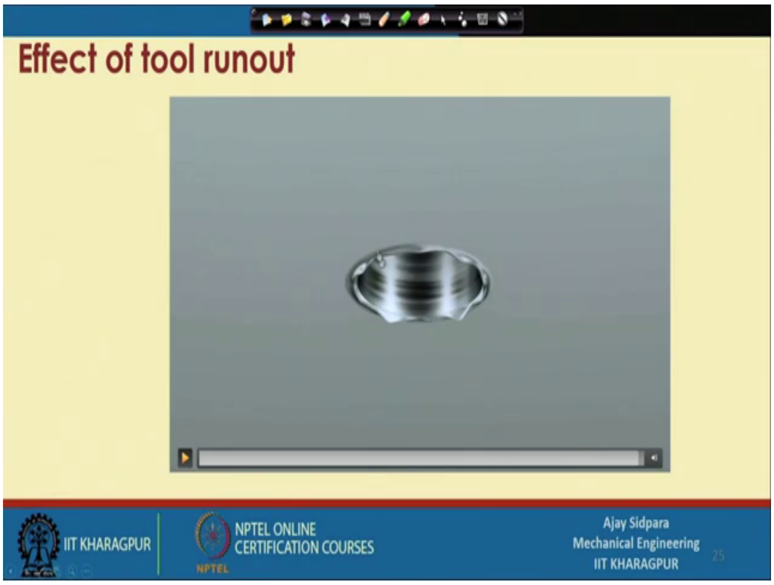

And if you do the same continuously then, what is happening that you are end up with the burr formation also, because you know that before it is reaching to the end surface, you have told that edge is already, worn out and that worn as we know that the cutting edge radius is very-very high now and because of that you are not maintaining the uncut chip thickness to the cutting edge radius, for that the relation and because of that efficient material remote will not take place. So, there are two is used one, is on the material side; that means, you are end up with the burr formation and some type of material integrate is to another, is on the tool side that you are tool life is very-very short in this particular case, when there is a run out ok.

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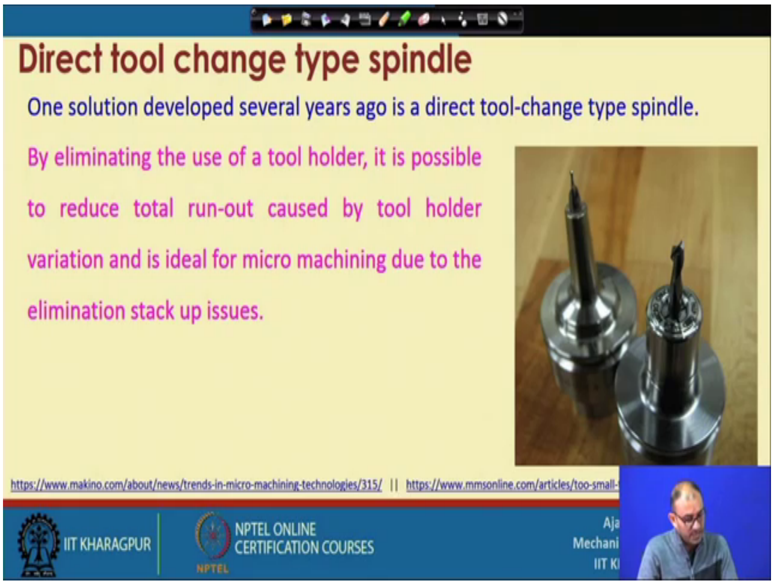

So, what are the ways, you can actually reduce this particular thing, the one thing is called the direct to change type of spindle. Now, you can say this particular spindle, it does not have collet. So, this particular thing actually, you can eliminate complete the tool holder. So, the tool whatever is that has directly fitting into the spindle. So, by that way you can reduce the total run out right. So, this spindles are readily available and by that way, because what is our objective, our objective is to reduce the minimum joint right.

So, if you reduce the number of joints then what is happening here that we can actually going in a more safer zone, where we can, we ensure that number of joints are less. So, the possibility of a, cumulative run out is also less, because you are completely avoiding tool holder; that means, tool holder to the collet. It is completely avoided and then only you are left with the fabrication issue of the cutting tool.

So, this is one of the way, the direct tool change type of spindle available where you can actually get the things done very easily then how to measure. So, there are different type of sensors available by which you can actually, do measurement of the run out. So, this is the capacitance type.

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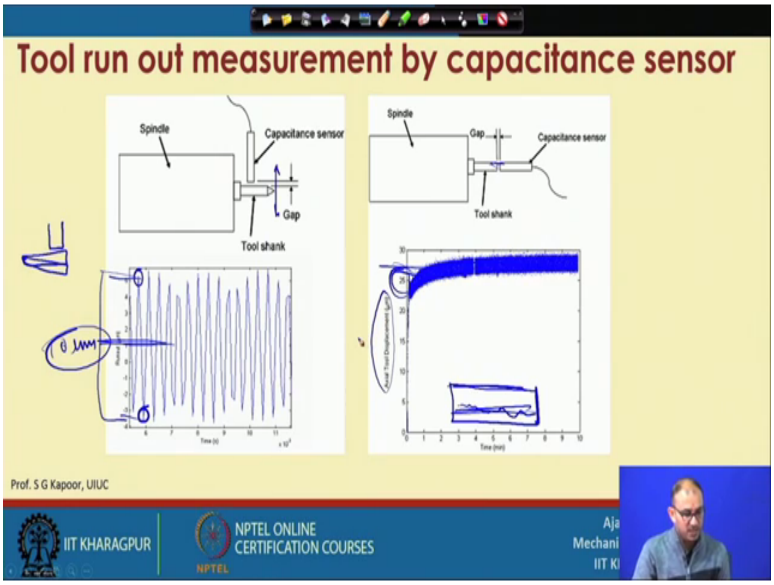

So, here this is the spindle and motor and you are putting a capacitive sensor here and you can put at any location depending on the measurement of the run out and then you rotate your spindle. So, when you rotate your spindle, what is happening that your capacitance will change, because now, we know that your capacity. One plate is here and this is the another, workpiece and now, considered this is the run out portion. So, now, you are spindle will move in this and this direction correct.

So, when it is very near to it get that, that time it will actually give one of the, one type of signal here and when is away from that it will give another signal right. So, within that rotation what is happening, the decision say, micro segment. So, when you rotated at the time, it will give one signal. So, this particular thing will tell you that, what is the, radial run out. So, this is in this direction correct. So, if you see this is moving within a plus or minus 5 micron almost something like that.

So, this is much amount is the run out. So, run out is the 5 micron here. So, this is about the radial part. Now, this is about the axial part, because we have to see about the Z axis also, if you are doing machining with a constant dept of cut, if you do not know that what is your axial, the run out then what is happening that you will not get that constant depth of cut, but you will get a variable part.

But here what is happening that if you put the capacitance sensor here, then whatever the difference in this thing is there, then it will be actually captured by this particular axial displacement micron. So, now, you can see this particular signal will tell you that you have, axial displacement around 25 micron.

Now, you can see that if you are machining with this particular surface and now, you have a 25 micron is a radial and something 5 micron at that particular diameter. So, if you are moving with a plus or minus 5 micron; that means, you are actually working with a 10 micron of range right. So, any diameter more than, less than diameter of the actual cutting tool plus this thing you cannot make right.

So, that is, not possible here other than that, that there is a variation in the depth also, you will get the different-different depth at the different location, depending on this particular band, whatever this band is that much variation you will get at the Z direction. So, by this way, there are different other sensors are also available by which you can do measurement in mostly, a conventional where is the, put the dial get with a 1 micron of accuracy or something resolution and then you can get the, by touching the things, you can get, but these are called the non contact type of thing. So, you do not require any type of additional set up into the machine. So, let me stop it here, then we will continue this lecture in the next class.

Thank you very much.