Mechanics of Machining
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Lecture – 03
Machining Processes: Single Edge Tool, Types of Chips

Hello, students. This is the third lecture on Mechanics of Machining. Today, I am going to discuss about Machining Processes and particularly about the formation of the chips actually. As we told the traditional machining process involves the removal of the material in the form of the chips only. So, study of the chips is very important to understand that how the material deformation must be taking place.

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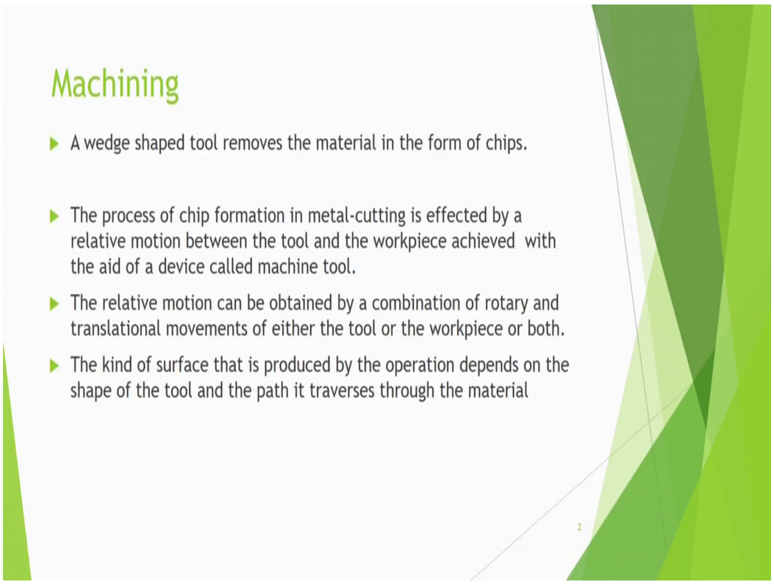

Now, I am highlighting certain things. Machining means there is a wedge shape tool that removes the material in the form of the chips. So, there is a tool which is wedge shaped for example, this is this one you can see there is a clear cut wedge is there this is the cutting edge and there are two surfaces which are meeting at the cutting edge. So, it is a wedge shape tool. So, machining is basically it involves the removal of the material in the form of the chips actually ok.

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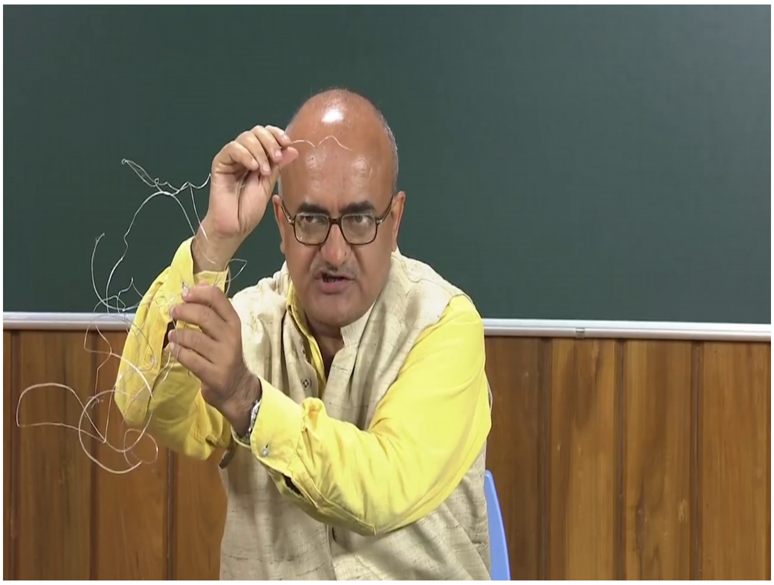

Chips are like material pieces. So, this is one chip. So, you are seeing that machining this process of chip formation in metal cutting is effected by a relative motion between the tool and the workpiece achieved with the aid of a device called machine tool. So, machine tool is that device that which causes removal of the material which does machining. For example, lathe is a machine tool, milling machine is a machine tool, grinding is a machine tool. So, these are the machine tools and this is only a typical tool ok, machine tool means there is a tool will cause relative motion between this one.

See I am putting this in my hand if I move it you know my hand can get cut also, but I am not moving just I am keeping at one place then nothing happens. So, actually there should be relative motion between the tool and workpiece that is the principle of machining. The relative motion can be obtained by a combination of rotary and translational movements of either the tool or the workpiece or both.

It can be translational motion my tool may be moving like this or sometimes the workpiece may rotate and tool is stationary like in lathe machine, so; that means, there is a rotary motion. There can be different type of combinations of the rotary and transitional movement. The kind of surface that is produced by the operation depends on the shape of the tool and the path it traverses through the material; how it traverse you will get different type of surfaces.

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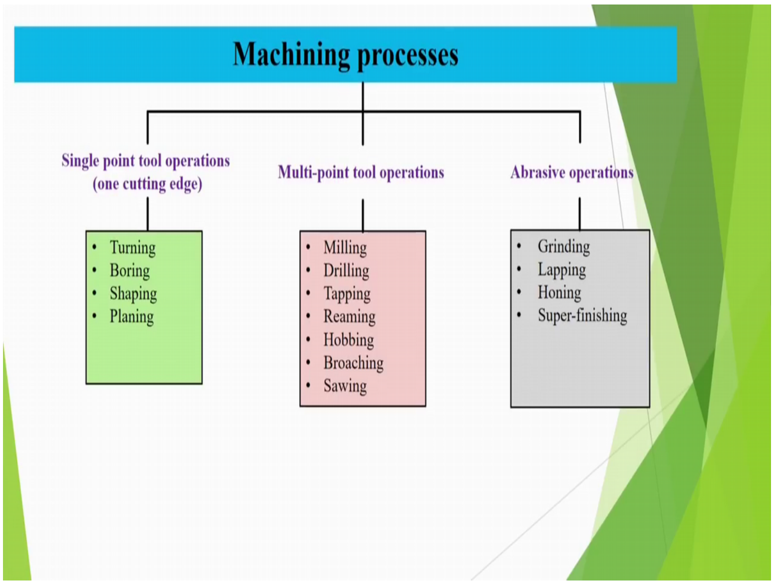

Now, machine processes can be classified into single point tool operations in which there is one cutting edge effectively there is one cutting edge that is cutting those type of process is there. For example, just see this is lathe tool, here there is a cutting edge that is the main cutting edge primary. It is mainly cutting the material, although there is a very small participation of this edge also that is secondary cutting edge.

So, very precisely in most of the lathe machine operations both the edges are participating, but the primary operation is done by this. So, we can say that this is a single point tool operation; these two edges are meeting at a point and this is a single edge.

So, in examples are we can do turning suppose reduce the diameter of a job by moving the tool we can do boring; that means, this tool kind bore inside the hole, that is also this one shaping in which the tool kind reciprocate like this like this and you can cut the material and planing is also basically same I shaping there is also single point tool, but instead of movement of the tool there is a movement of job, but the relative motion is same. So, there is no problem. So, these are single point tool operations.

Then there are multi point tool operations like milling there is a milling cutter in which number of teeth are there. Drilling, tapping, which is make use for making the threads, reaming which is used for finishing the holes, hobbing which is used for cutting of the gears and there can be broaching in which there are in a cylindrical tapered cylindrical surface there are number of tools and the depth of each tool in the material will be gradually increasing, then there is a sawing you know there is a saw by which we cut. And there are number of teeths there. So, these are multi point tool operations.

Then, there are abrasive operations in which in fact, very large numbers of aggressive particles are there. They are of random geometry and random orientation. Examples are grinding, lapping, honing, super finishing, these are the abrasive operations.

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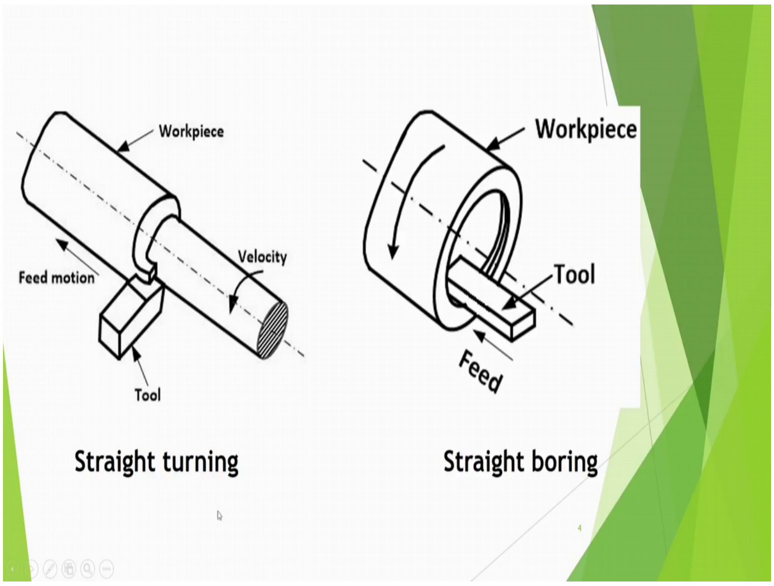

So, in this for example, you see in the figure there is a straight turning shown here. In this there is a tool and it is this is primary cutting edge and this is secondary cutting edge. Primary cutting edge is cutting, it is digging inside the material, workpiece is rotating. So, it is a tangential velocity is there that gives the relative velocity, there is a relative velocity between tool and job that is the primary motion and then simultaneously I am moving the tools also in the along the longitudinal excess of the job.

So, this is a feed motion now you how to understand one point that the that uncut chip thickness; that means, in one go that whatever the chip thickness is there that is caused by the feed suppose it is going 0.2 mm per revolution. So, that means, uncut chip thickness will be proportional to 0.2 it may be multiplied by some angle that point we can.

Later on understand, but this is the essential point not that the chip thickness is not equal to the depth of cut depth of cut is different you see the chip which cutting sideways. So, the chip width is basically is related to the depth of the cut, wherever the chip thickness is related to this thickness is how much feed motion is there that point has to be understood. Many people was confuse in that aspect they think that, if I increase the depth of cut my chip thickness will increase, but actually it is not so. Feed is having influence on that.

Similarly, here straight boring is shown here also the tool is rotating, here in straight turning you are moving on the external surface of the, cylinder here you are moving on the internal surface of the cylinder. So, otherwise you we think is same the feed motion is there tool is there and work piece is there. So, this process is also shown here straight boring; this can be straight boring can be performed either on a lathe machine or it can be performed on a boring machine also in a drilling machine also, you can put that attachment.

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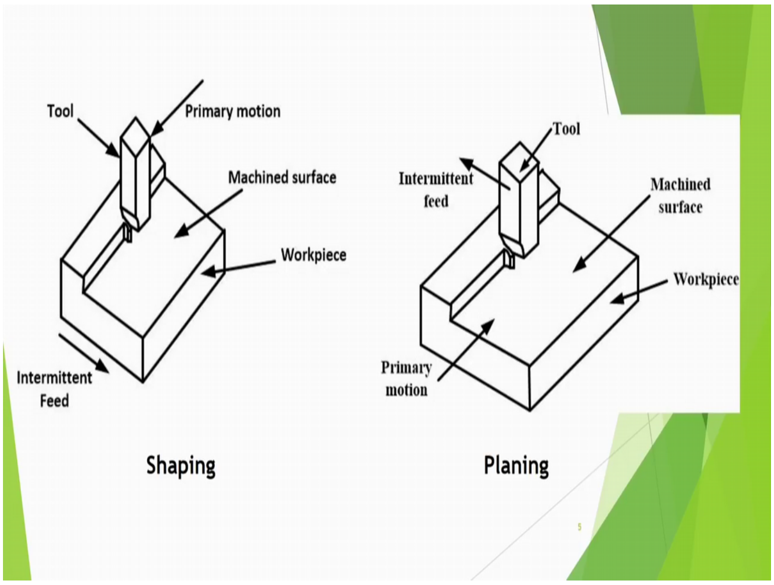

Then you just see the shaping. Here primary motion means the tool is reciprocating and some simultaneously in the crosswise direction we give the feed also, but the feed is intermittent in the lathe machine the tool is continuously moving, but here once one strop is complete then little bit. We move the tool towards the cross direction and then we get the feed here, you can very well see that in this case also feed will decide that how much will be the chip uncut chip thickness uncut chip thickness un consequently in the cut chip thickness. So, in a cut chip thickness will be different form uncut chip thickness, but it will be a function of uncut chip thickness.

So, you see that how much byte basically you have taken in the feed. So, suppose you have move this much; that means, that much distance will be shown and depth of cut which is basically shown from here to here that is the depth of cut. Depth of cut means it is from here to here, suppose this is this is depth of cut this will decide the width of the chip, ok; so, that is this one. So, you are getting the machine surface here and you this is the workpiece.

In the planing motion, workspiece is moving. So, primary motion is given by the workpiece intermittent feed is given to the tool or workpiece and then you are getting this type of shape. So, this will give basically again the plane surface. So, you have got shaping, you have seen planning.

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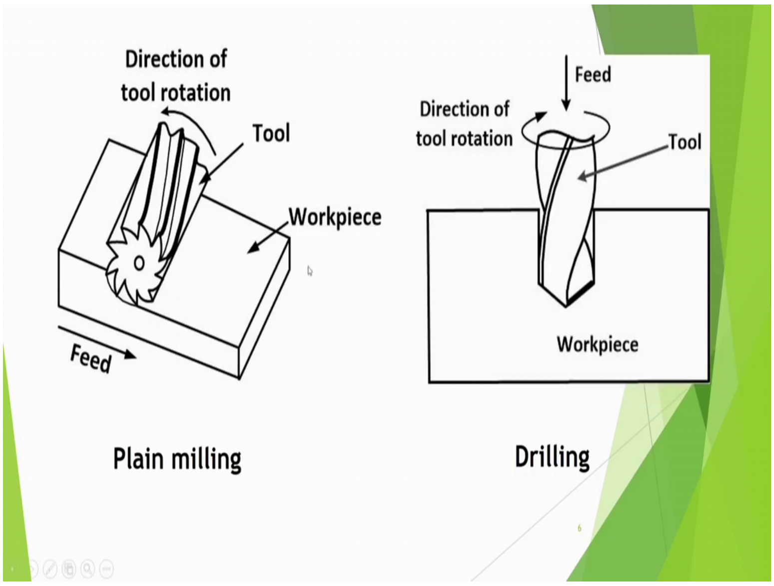

This is now multi tool operation. It is not a single tool, here multiple tools are there. Example is milling machine, it is a straight milling process you see the number of teeth are there it is a helical.

Milling cutter you have got 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11. I think about 10, 1 2 3 4 5 6 7 8 9 10, ten teeth are there. They are cutting direction of tool rotation is this that is giving the primary motion. Simultaneously, you are giving the feed to the workpiece and you are doing plain milling.

Then there have is a drilling operation, here there is workpiece then there are. It is a twist drill. There are two distinct cutting edges are there, this is moving and simultaneously you are giving the feed in the downward direction to the drill this operation is also under the multi tool operation.

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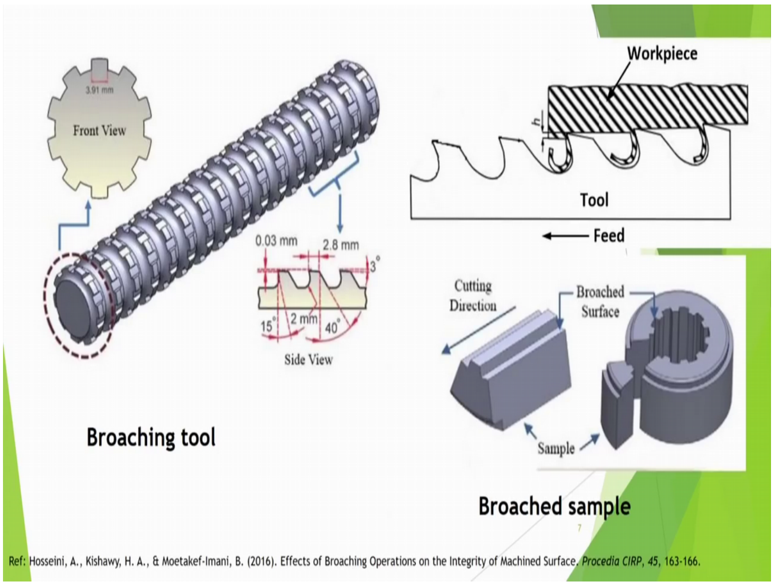

Now, this is again another example of multi tool operation broaching. Here I am showing you a broached type of thing, broaching machine is very much suitable for mass production. If you want to produce suppose thousands of internal gear then broaching is the best process. It is very fast here you have got a broach tool. Now, you just see that the broach is of the cylindrical shape and, but it is slightly tapered, so that basically the radial depth of to cutting tools will be increasing gradually.

So, initially we will take a small cut and then it will move then bigger amount of cut will be taken then more cut will be taken, like that we will step by step. We will remove the material this is the represent you yeah probably it is used to make this price. So, front view is having in the shape of these plain, if you pass the broach once through that. So, then you will be make in one basically is blind hole.

So, here it is the geometry of the cutting tool is shown here you are seeing that. This is the wedge shaped tool. So, this is a wedge shape tool, this one cutting tool and then here you are cutting and then after that this point is there it will it is cutting and this is one surface and this is another flank surface, this is top surface is the rakes rake surface and then it is whole thing is cutting. So, here it is the depth is only these are some clearances and some angles are set.

Now, this is the workpiece and tool simultaneously it is showing. So, this is depicting that how the basically the radial depth in the workpiece will keep on increasing; that means, there is a tooth rise that is defined as a tooth rise; that means, rise of the tooth. So, suppose here you are taking edge thickness cut here also this one cut. So, edge will become 2 edge, then it will become 3 edge like that. Gradually the height is increasing this is these teeth's points are not at the same level this is lower this is slightly up this is even up like that.

And, then you can have roughing teeth and you can have finishing teeth this is the cutting direction and broached surface is shown you see that we have been able to make is primes by means of this broaching tool, ok. So, this is the broaching operation.

Here in the machine you have to give only one motion that motion is given to the broach; that means, the tool and the feed is automatically obtained because of the different heights of the teeth.

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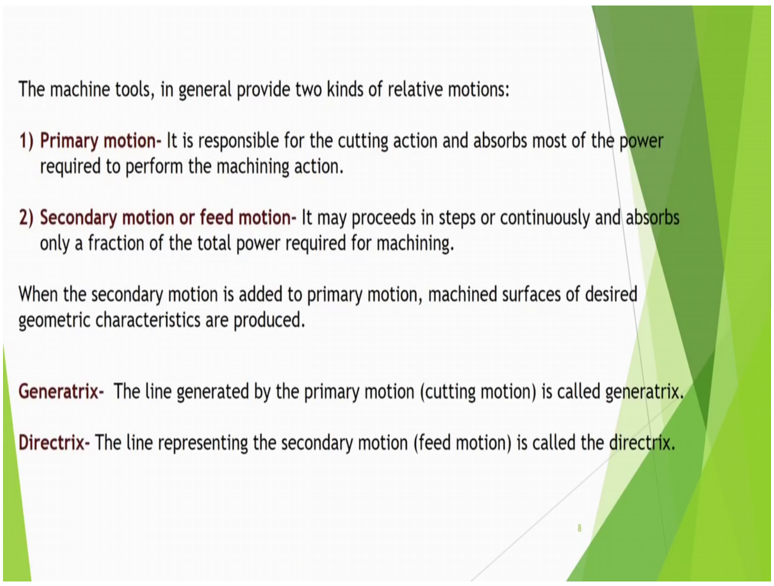

So, now so, any machine tool in general provides two kinds of relative motions; one is the primary motion it is responsible for the cutting action and it absorbs most of the power required to perform the machining action. So, there is a primary operations, for example, in a lathe machine primary motion is what that surface velocity of the job which is rotating because it is that is the primary motion if you does not rotate you will not be able to cut. Feed motion is just to take more raw material into it is gripe and then cut, is it not? Because if you keep on rotating at the same location, then material is already machined; so, you move a bit.

So, secondary motion or feed motion it may proceed in steps like in the shaper machine we do. In the shaper machine cutting tool moved like this and after that some it comes back then we impart a bit feed here in this direction, then again move then it comes back again we above avoid the feed in this direction move like that. So, this process happens that is intermittent feed or it can be continuous as you go in the lathe machine when the job rotates then simultaneously tool is also moving. That is why in the lathe machine feed is also specified in terms of millimetre per evaluation this must millimetre per evaluation and in the shaper machine. We specify the feed in millimetre per stroke this must millimetre per stroke.

So, the feed motion may proceed in steps or continuously and it absorbs only a fraction of the total power required for machining. So, it also take some power, but compare to the primary motion power, it is very small when the secondary motion is added to primary motion machined surfaces of desired geometry characteristics are produced, that is the basis actually. Whatever you shape you want to produce that is because of these combinations of these two motions.

So, we define one concept, very general concept so that we think and we done in a generalised way. We define the concept of generatrix and directrix generatrix means the line generated by the primary motion is called generatrix, ok. What type of line you are generating because of the primary motion and directrix means the line representing the secondary motion that is feed motion these are called the directrix.

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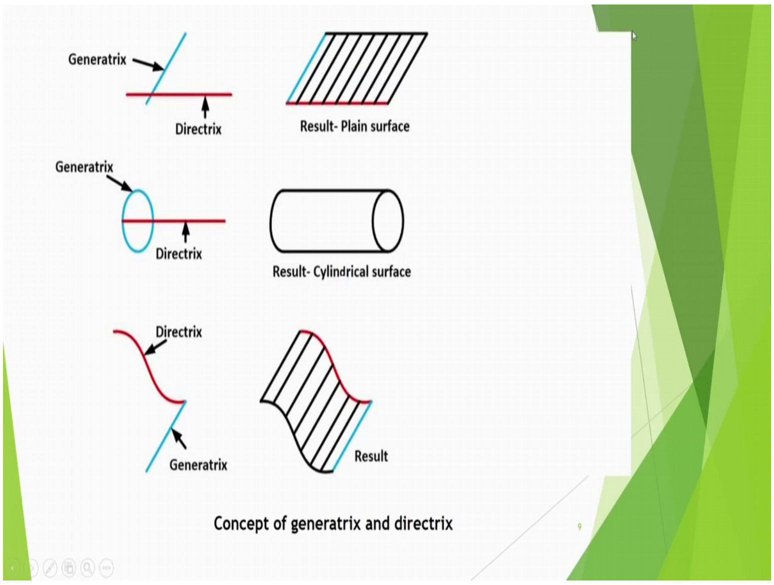

For example suppose generatrix is also a straight line like in a shaper machine. It is tool is moving a straight line and feed is also in a straight line. So, directrix means it is getting directed also in the transfers direction like this and here also it is going like this. In direct case, it is like this directrix is this. Generatrix is this it results plain surface you get a plain surface. It is not? Two lines can make a plain, so, it is you got the plain.

In the lathe machine you see generatrix is a circular because basically tool is moving relative to the job in a circular right. Suppose instead of the lathe workpiece you decide that my job will rotate sorry instead of the job you fix the job tool will rotate that is essentially the same thing. Then that tool will cover a circular path. Right now what is happening, tool is a stationary, but the raw material itself is rotating, but it is covering a circular path.

So, generatrix is a circle and directrix means this is tool is moving in a straight line. So, directrix is a line combination of a circle and line we will make a cylindrical surface if you straight number of generatrix on in the directrix direction you get a circular cylindrical surface.

Similarly, now you can of course, you can make three form surface complicated surface also by providing different type of motion. See I am having gereratrix straight line, but directrix I have given in the curved fashion. It is a curved line not a straight line. So, I have got curved type of profile may be ruled surface are you know that type of thing. So, any type of shape surface can be produced by the combination of the motions of generatrix and directrix.

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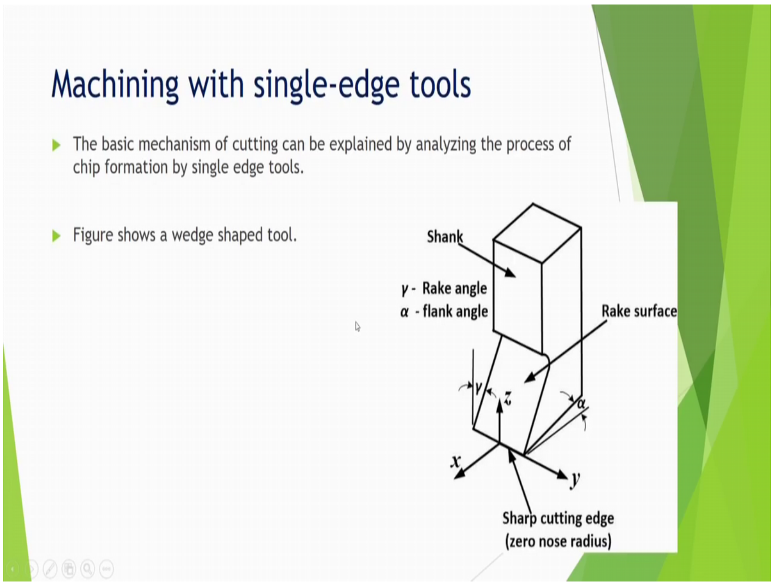

Now, let us concentrate on machining with single edge tools very idealized form of a tool typical tool I have shown. It is suppose there is a tool you might have seen a tool can be anything that suppose in the garden you also use lot of tools suppose you have a for digging the soil, you can have any typical, you can you speed by that speed, you cut the soil or any type of this one you can have seizer.

But, typically there is this solid metallic part which can be held either in your hand or in some other holder this portion is called shank in this potion is basically shank. Shank is not participating in the cutting shank is only for holding, ok. Then you have got some cutting edge this is a sharp cutting edge I have shown in this case I have shown zero nose radius.

In general, we will provide some small amount of nose radius also, never use how tool which is perfectly sharp. Because if you make perfectly sharp and assume that nose radius is zero then the contact area becomes zero and infinite amount of stresses we produce. So, this is a theoretical concept no infinite stresses can be there and immediately, but it will produce more amount of force. So, it is good that you should have sharp cutting edge.

But, if it is too sharp then automatically it cannot be sustained it will wear out soon you know because the stresses will be produced a large amount of stresses. So, material will be weared out and you will get all material deformation will be there so, but here ideally I have shown very small nose radius. So, zero nose radius, this is the cutting edge and that will be digging inside the material and then material will be removed them. So, this way you will be getting.

Now, here you can have suppose tool is moving in this direction. So, perpendicular to the cutting velocity you have got this type of that one plane this one reference plane and from this. So, this is the vertical plane tool is moving horizontally and this is this surface on which the chip will be flowing using that if you take this tool and you start digging in a soil the soil will flow on this surface which is called the rake surface.

So, rake surface is there and this angle is curved rake angled. Rake angle is important you have to provide sufficient amount of rake angle and the surface that is what show that the there should be easy movement of that. You imagine that I am cutting like that if I do not provide this type of angle there cannot be proper movement of that. So, you will require less amount of force if you increase the rake angle in this direction less amount of force will be required, but then if you do like that then this portion becomes very thin and it becomes weak.

So, if you increase the positive rake angle the tool becomes weak and this is the basically the rake angle, it is in this direction, it is considered positive. If it is zero rake angle means surface is totally vertical and negative means the surface is in fact, leaning like that. So, if you can imagine that if I cut it like that and my surface is also leaning like that. Then I will be requiring large amount of force will be required because you have to compression you have to do that. So, that is negative rake angle.

Then here opposite to that rake surface this side here in this side bottom there is a surface which is called flank surface flank means side is it not we say that this person is franked by able person; that means, he is in the side. So, flank is on the bottom that is basically if if I do not provide any implication of that it will rub the machine surface. So, we provide very small amount of angle and this is called some people called it flank angle some called it a relief angle because we give some relief to it and, some call it clearance angle because we give clearance. So, that it becomes clear.

So, this angle is here I have denoted by alpha and this is called a basically the flank angle. So, figure is showing a wedge shaped tool.

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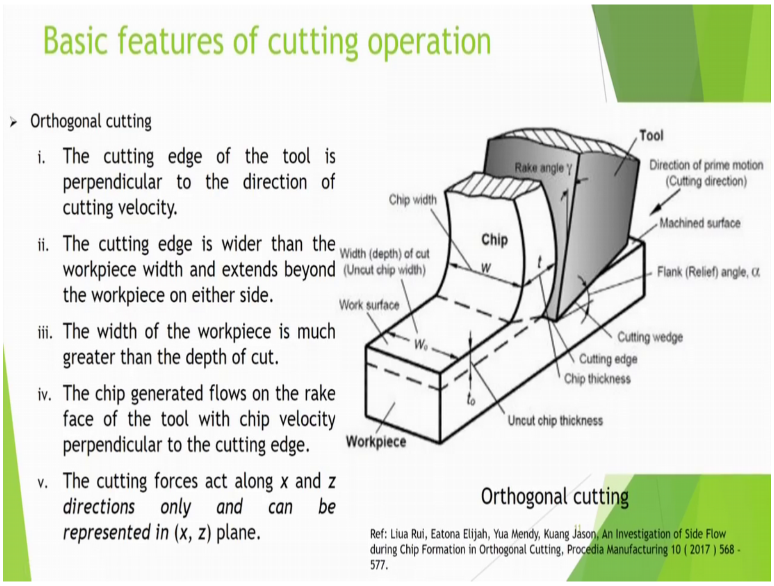

Now, there are two type of cutting operations one is the orthogonal cutting and another is the oblique cutting. Orthogonal cutting can be considered as 2 dimensional cutting. Here what you are seeing that there is a tool wedge shaped tool there is a rake angle, this is the tool and this tool is moving in the horizontal direction.

Now, there is a in this direction you see that cutting edge. Now cutting edge is totally perpendicular to the velocity direction velocity is in this direction and cutting edge is also in the horizontal plane, but it is in the perpendicular direction and then you are having flank relief angle is shown, gamma is shown, direction of primary motion in the cutting direction is this machine surface. You are getting behind and the workpiece material is getting removed in the form of chip, whatever comes out we are calling that as a chip because it is shape is like chip whatever chip. You eat it is the same type of like your potato chips. So, it is in the form of that type of chip. So, this is this one.

This one is the chip width width of the chip and this is the chip thickness, right cutting edge is also shown here. Cutting wedge is basically this complete wedge and this chip thickness has come, but it has come after removing some material then only it has come. So, that thickness which has not been yet cutted that means it is uncut, but ultimately this will become a chip that is called uncut chip thickness. Basically it is a chip, but it has not taken the birth in the form of chip yet. So, that is why it is called uncut chip thickness.

And, width depth of the cut is shown here this is uncut chip width uncut chip width is also shown then this is work surface and this is work piece. So, there are number of features here in the orthogonal cutting. One is that the cutting of the tool cutting edge of the tool is perpendicular to the direction of the cutting velocity. Second is that cutting edge is wider than the workpiece width.

So, we see the cutting edge is extending up to here whereas the work piece is you know up to this one only and it extends beyond the workspiece on either side then the width of the workpiece is much greater than the depth of the cut. So, here width is much greater. Here width is much greater and width is very small see t is small, t 0 is small W 0 is big. So, basically there is no much deformation in the width direction, only it is deformation is in the thickness direction. So, we can see it is a plane strain type of situation.

The chip generated flows on the rake face of the tool with chip velocity perpendicular to the cutting edge. Chip velocity is perpendicular to the cutting edge, here it is going like this and the cutting force acts along x and z direction only because width. There is very big and this is a free surface this side. So, there is not any force in that width direction in a state it is only in x and z direction. So, it can be represented in a 2 dimensional way and this is what we have proved about orthogonal cutting operation.

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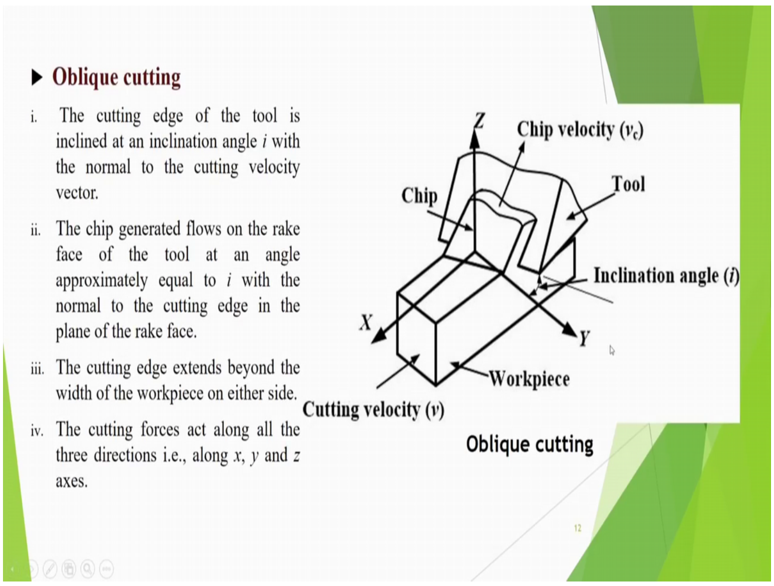

Now, in oblique cutting, now you can easily understand here; just we will be little bit tilt to the tool, so that the cutting edge is not now perpendicular to the cutting velocity. Cutting velocity is in the same direction horizontal, but the edge is now inclined. So, cutting edge of the tool is inclined at an inclination i with the normal to the cutting velocity vector normal to the cutting velocity vector is Y because cutting velocity is in X direction normal to that direction is Y. So, you are having that inclination angle i and in the plane of the rake face.

Now, here now what happens with the normal to the cutting velocity vector i that is inclination angle chip generated flows on the rake face of the tool at an angle approximately equal to i with the normal to the cutting edge in the plain of the rake face. So, normal to the cutting edge may be somewhere, but it will move chip will move in the incline direction that is i. Stabler showed this relation that more or less whatever is the inclination angle that angle chip will make a in the motion on the rake face also. That means suppose inclination angle is i chip will also make that i angle on that surface.

So, cutting force act along all the three directions in this case along X, Y and Z that is oblique cutting. Most of the cutting operations are basically oblique, you have lot of advantages here. You see here more effective area of the oblique cutting edge is there and the the forces are distributed here and that is why oblique cutting is proffered and orthogonal cutting more or less it is idealization. Many processes we not have orthogonal cutting. So, but we generally to understand orthogonal cutting because it is easier to understand.

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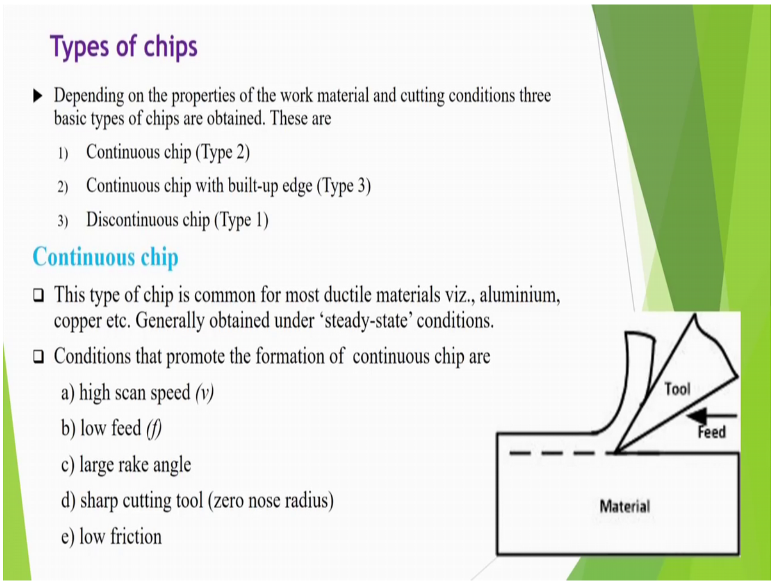

Then I am trying to discuss, what are various types of chips. Depending on the properties of the material and cutting conditions, you can get various types of chips. For example, you can get continuous chip set very continuous along particularly in ductile materials when they are machined at somewhat high speed, then you get this type of chips. You see that I am showing you some chips. These are aluminium material machined and you have seen that how big this chip is that, these are entangled. They are very difficult to handle also although this shows good amount of cutting because you are getting.

So, this one chip you see that how long. It is this one and it has become in the form of spiral it cut winded up and this chip is in this will this is that much length. If I open it I can show it got broken here, see even this much it that big. So, you can imagine that how much they can cause sometimes problems to operated they can actually the getting tangled in the tool. So, these type of chips are there. They are continuous chips they are type 2 chips.

Then we can get continuous chips with built-up-edge; that means, there can be adhesion of the chip material here in the tool due to high pressure and temperature on the tool itself you can observe that there will be some built up type of edge will be there. These are not desirable because sometimes it gets stuck and then it gets broken. So, this deteriorates this job quality and also may be sometimes the wear of the tool. So, this is called type 3 chip.

Then there are discontinuous chips. Discontinuous chips are you know that of very small segments, you see very very small whereas, it may be difficult for into see also from the distance they are called discontinuous chip, small chips. They get broken; these are called type 1 chip.

So, continuous chip means, this type of chip is common for most ductile materials namely aluminium, copper; generally obtained under steady state condition. So, there is not much fluctuation in the cutting force etcetera, that is why it is quality may be better of the machine surface.

So, conditions that promote the formation of continuous chips are high cutting speed is basically cutting is speed v. Then low feed, feed is generally low; then large rake angle because so that there is a easy large positive rake angle a smooth flow of the material and sharp cutting edge; that means, when there is a zero nose radius and low amount of friction that also promotes the formation of the continuous chips.

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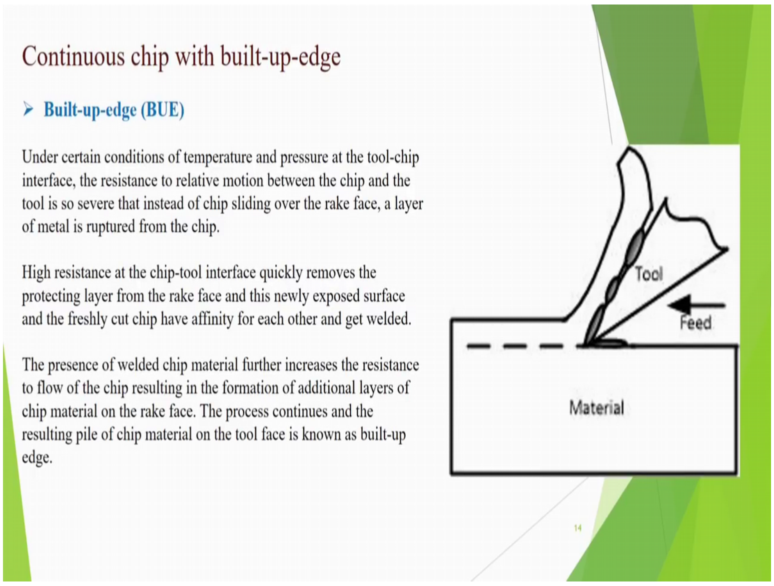

Now, continuous chip with built-up-edge your seeing that here, there is some built-up-edge. Some portion gets adhere to the chip also, this is the feed. Under certain conditions of temperature and pressure at the tool chip interface, the resistance to relative motion between the chip and the tool is so severe that instead of chip sliding over the rake face a layer of metal is ruptured from the chip.

So, high resistance at the chip tool interface quickly removes the protecting layer from the rake face and this newly exposed surface and the freshly cut chip have affinity to each other and it will get welded. Even if you how got coating, but that coating will get removed and then there will be welding of the chip with the tool surface.

The presence of welded chip material further increases the resistance to flow of the chip resulting in the formation of additional layers of chip material on the rake face. The process continues and the resulting pile of chip material on the tool face is known as built up edge. So, you get of here built-up-edge type of things your nose also effective nose radius may also increase who may get this type of phenomena.

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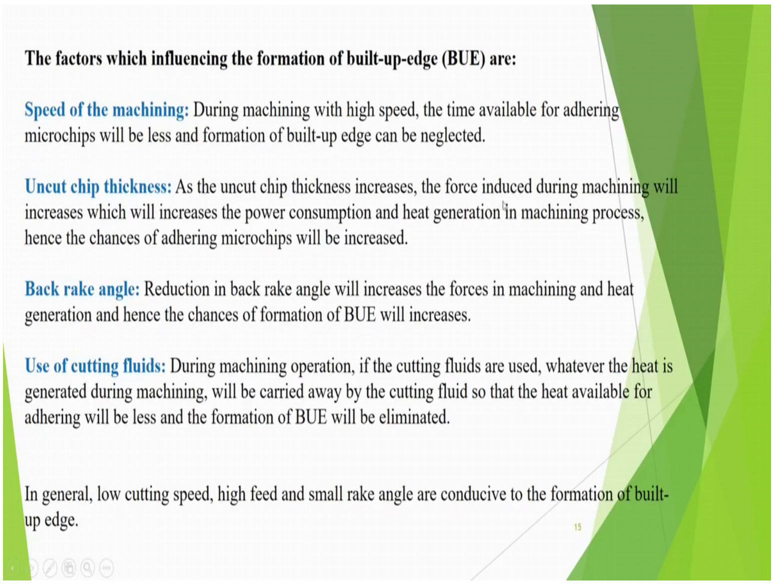

The factors which influence the formation of built-up-edge are speed of the machining that is important. During machining with high speed the time available for adhering microchips will be less and formation of built-up-edge can be neglected. So, formation of built-up-edge can be neglected that is why that is a speed helps in eliminating built-up-edge.

Then, uncut chip thickness; as the uncut chip thickness increases the force induced during machining will increase which will increase the power consumption and heat generation in machining process. Hence the chances of adhering microchips will be increased; that means, if you increase the uncut chip thickness in that case, there will be built-up-edge formation.

Back rake angle- reduction in back rake angle will increased the forces in machining and heat generation and hence the chances of formation of built-up-edge will increase. Then use of cutting fluids during machining operations if the cutting fluids are used whatever the heat is generated during the machining that will be carried away by the cutting fluid. So that the heat available for adhering will be less and the formation of built up edge will be eliminated.

In general, low cutting speed, high feed, and small rake angle are conductive to the formation of built-up-edge, ok. So, built-up-edge has to be mostly avoided.

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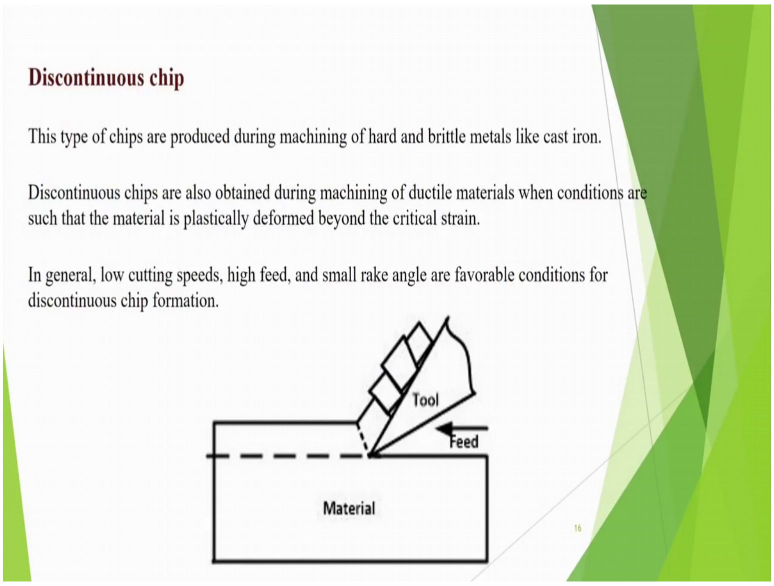

Discontinuous chip- this type of chips are produced during machining of hard and brittle material like cast iron. If you machine cast iron, you will get the small. Sometimes you will get chips in the form of the small. It will look like a powder type of thing. So, discontinuous chips are also obtained during machining of ductile materials also sometimes when conditions are such that the material is plastically deformed beyond the critical stain. So, sometimes you get for example, if these cutting speed is very low high speed is there and small rake angle is there, then this favours the formation of discontinuous chips.

You are seen that schematic diagram. Here I am showing you know discontinuous chips these chips are suppose they are segmented.

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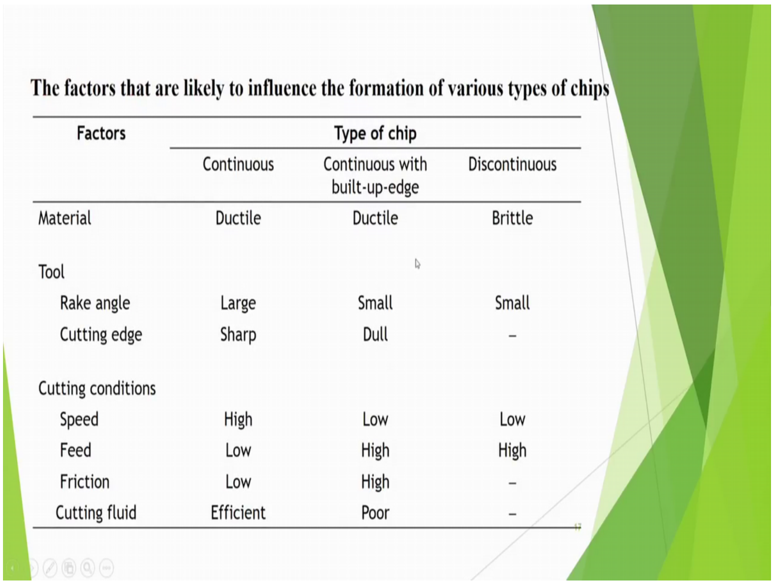

The factors that are likely to influence the formation of various types of chips

Factors	Type of chip		
	Continuous	Continuous with built-up-edge	Discontinuous
Material	Ductile	Ductile	Brittle
Tool			
Rake angle	Large	Small	Small
Cutting edge	Sharp	Dull	–
Cutting conditions			
Speed	High	Low	Low
Feed	Low	High	High
Friction	Low	High	–
Cutting fluid	Efficient	Poor	–

So, this is; so, it is giving just summary of this one. You can get in a standard text books like in GK Lal; so, this type of table the factors that are likely to influence the formation of various types of chips about the material. Suppose, material is ductile more chances are that you will get continuous chips or you can get continuous chip with built-up-edge.

If material is brittle you are likely to get discontinuous chip then tool rake angle if rake angle is large you get continuous chip if it is small you may get built-up-edge or if it is small then, you can get discontinuous chip cutting edge. If it is a sharp, then you have chances of getting continuous chip. If it is dull, then you may get built-up-edge.

And, cutting conditions if is speed is very high you get continuous chip. If it is low you can get built-up- edge or you can get discontinuous; if the heat is low, then you get continuous chip; If it is high, you can get either built-up-edge or you can get discontinuous chip friction. Suppose it is low, then this is continuous and if it is high of friction, then you get discontinuous chip rather you get continuous chip with built-up-edge.

And, cutting fluid is if it is efficient, it will cool the material. There will be not be any welding etcetera. So, you get efficient you may get continuous chip or you may get here in this case; if the cutting fluid is poor, then you will be get continuous chips with built-up-edge.

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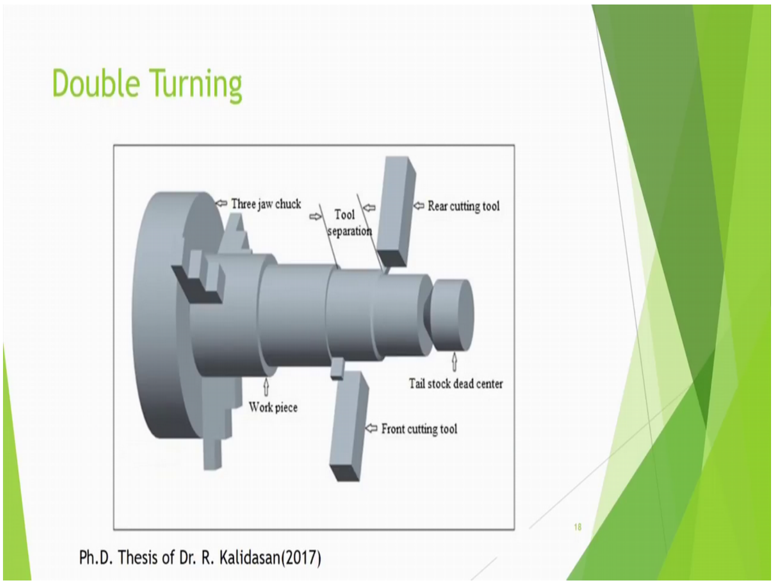

Now, here it is shown here that you are seeing that that double turning this is work of my PhD student R. Kalidasan, he worked on double tool turning.

So, what he did that he cut simultaneously. There is a this is a lathe machine on which on the lathe machine lathe machine is not shown here, but three jaw chuck is shown in which the job is held and there is a front cutting tool which is moving in this direction, rear cutting tool is moving in another direction opposite side. This is in the tail stock; this is tail stock and there is a dead centre here this is not rotating. This is fixed and they tools are separated.

So, you see, simultaneously it is doing cutting suppose it has taken 2 mm depth of cut. It enable one has taken 2 mm depth of cut after both the tools have passed, then your depth of cut has become 4 mm.

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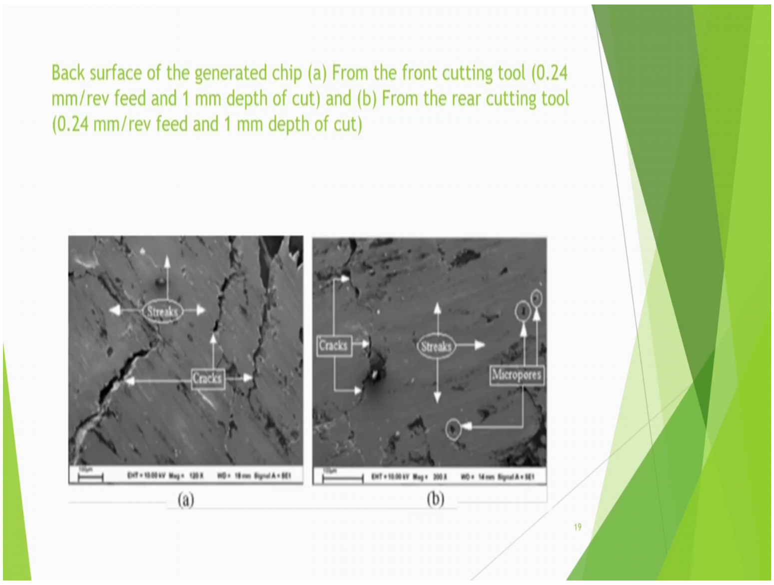

So, heat it lot of the study even on the chip shape sheet micro graph. He took that scanning electron microscope pictures. Some of these pictures are shown here; it is the back surface of the generated chip from the front tool and from the real cutting tool. In fact, he took the feed quite large 0.24 mm per evaluation is a high feed and 1 mm depth of cut here; you are seen that he got the formation of the cracks also here.

And, there are streak lines; that means, due to rubbing of the chip you get streak type of some parallel marks those are called the streaks. Here also cracks streets and some micro pores have been shown here.

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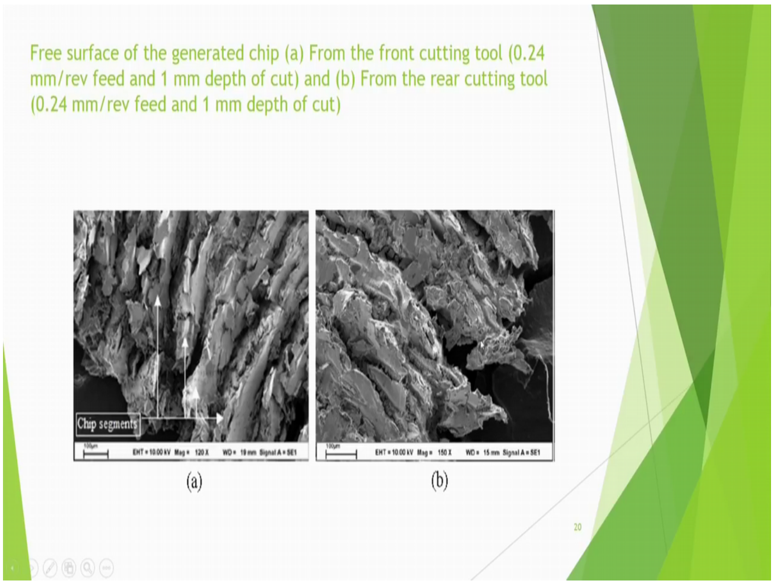

And, then three surface of the generated chip is also shown here, he is finding some segments here. These are the chip segments; that means, they are cutting he also this is this one he observed in both the cases.

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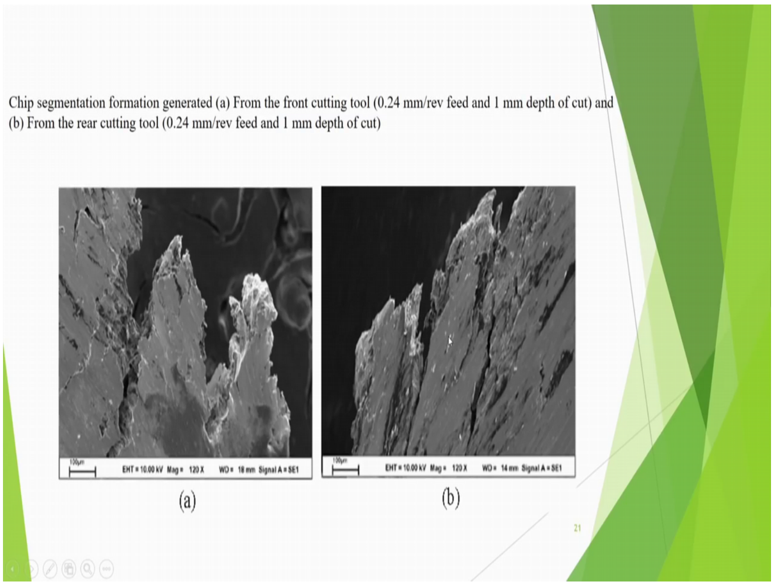

And, then chip segmentation is shown nicely here. This is the he is getting certain type of somewhat chip depending on the conditions, so that these type of shapes are shown.

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Here one thing I have not shown, but we can also get sometimes this type of effect that actually formation of a chip, you need minimum undeformed chip thickness minimum uncut chip thickness. If that is not there then chip will not form instead a small triangular portion that should have n been removed is left and this is called the spanzipfel due to this surface roughness increases.

So, you get spanzipfel effect. So, that thing you can observe sometimes that suppose you are doing machining at a very low feed uncut chip thickness will be very small uncut chip thickness, will be very very small. So, there will not be proper cutting action proper sharing will not be there tool may rub against then and it may cause little bit plastic deformation, then you will get the surface finish which will be very poor.

And, then as you increase the feed, then cutting action become proper, then you get a good surface finish and after that after a certain point. Then if you further increase the feed, then the surface roughness increases due to geometric effect. So, usually we understand people think that surface. If I want to get good surface finish my feed should be low, but here I want to point out that if you are doing the machining of the particularly ductile material, then if you cut at a very low feed you know say 0.02 mm per evolution you may get spanzipfel type of phenomena and your output may be counterproductive.

So, that is what that point has to be this one we have seen that, but suppose you are doing at say 0.08 mm per evaluation or 0.1 mm per evolution, that is fine. After that if you further increase the feed then the surface roughness will deteriorate as will be also discussed in somewhat later class.

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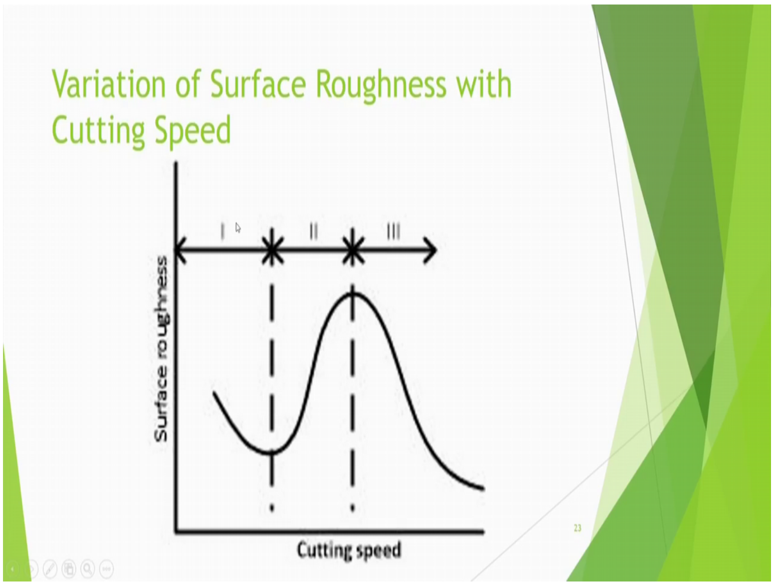

Now, here I am showing diagram surface roughness you know that surface is not smooth; you sometimes surface height is more sometimes surface is height is low. So, we measure surface roughness measurements things, we will discuss more in detail that what are various measures of surface roughness, but in a common sense view you understand that what do we mean by smooth surface and what do we mean by rough surface you know.

Sometimes you machine by a tool and observe that surface roughness of that particular tool is very means of with that particular tool, you get a poor surface roughness, but sometimes you get very good surface roughness.

So, here it is shown that suppose in the beginning I am having cutting speed is very low, surface roughness is high may be discontinuous chips may be forming. And then, as you increase the cutting speed, then there will be continuous chip formation will be there, then the surface roughness reduces. But in this region in middle region, built-up-edge formation may be there that is why the surface roughness is again increasing this may cause built-up-edge formation.

Now, if you how used a particular cutting speed after that further increase in the cutting speed does not provide sufficient time for the built-up-edge formation and that is why with increasing cutting speed, now the surface roughness starts decreasing. So, that is why you are getting and you keep on increasing the cutting speed till your limit of the machine. Then usually the if you keep on increasing, then the built-up-edge formation will not be there and it is observed that the surface finish is improved may be if you increase too much then the surface finish may deteriorate also may be vibrational aspects may come, but in general that we get high cutting speed.

So, this is a good sign that mean we want more productivity also and we want more surface finish also good surface finish and with high production rate. So, it is better to operating this region. Here also you can get a very small surface roughness at somewhat low speed, but you will be not getting high production rate. Here you will be getting high production rate also. That is what it is shown here.

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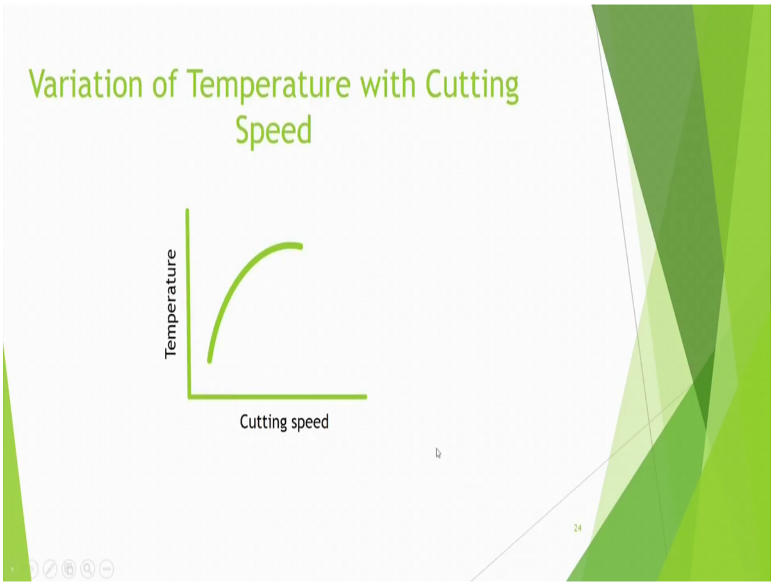

Then variation of temperature with cutting speed; now, this is a cutting speed is increasing, then you see that the temperature will increase temperature at the cutting interface; that means, the tool work interface. Now, that is another thing that how much workpiece temperature will increase, how much the chip temperature will increase and how much will be the temperature at chip and workpiece interface, how much temperature will be at chip tool interface; these things are different.

Most of the heat is carried away by the chips. So, may even if you increase the cutting speed, may be that much increase of the workpiece temperature may not be observed in proportionate. So, that is why it is not a linear curve it gradually reduce that at high cutting speed, you see more or less temperature is not significantly changing with the cutting speed. Why? Because most of the heat is though more heat is now generated, but that particular heat will be taken away by the chips. So, you get more or less same type of things, but in the beginning if your cutting speed is low.

So, if you increase the cutting speed more amount of power we generated which in term increases the temperature of the workpiece because power is dissipated in the form of the heat. Mostly if you do any plastic deformation then about 95 percent of the plastic deformation power that will go as a heat and only about may be 5 percent will increase the internal energy of the workpiece, that is this one. So, variation of temperature with cutting speed has been shown here.

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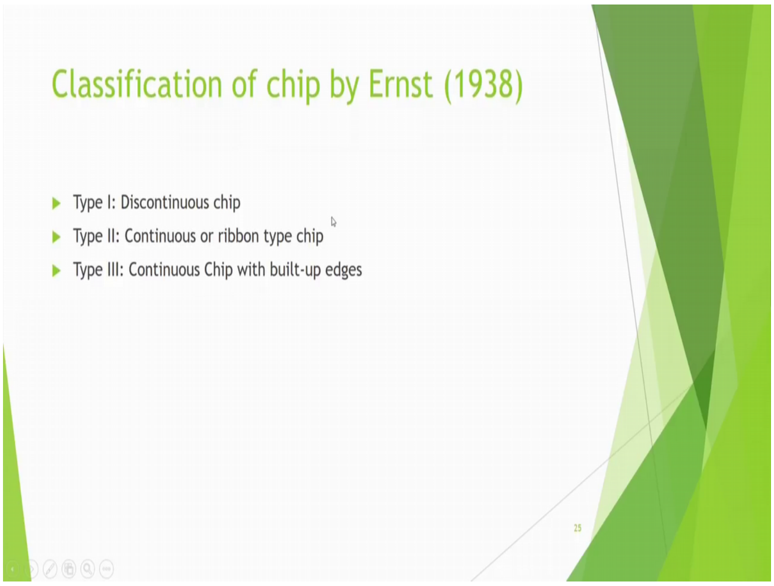

This classification of chip was earlier done by Ernst in 1938. Ernst and Merchant we will talk much about merchants circle, these people in a way started force calculation some simple mathematics of the chip formation in the around 1940s. So, they are n that sense, they are diagonal.

So, the Ernst defined the chips in three categories type I means discontinuous chip, type II continuous or ribbon type of chips you see that this is a ribbon type of chip. This is like a ribbon you know. This is so, this is this is called continuous chip and then there is a continuous chip with built-up-edge; that means, it also forms we built-up-edge that thing is there, but we have not shown here. it will not be visible from that long distance. So, this is what that thing we have not brought here, but you have seen the figure already.

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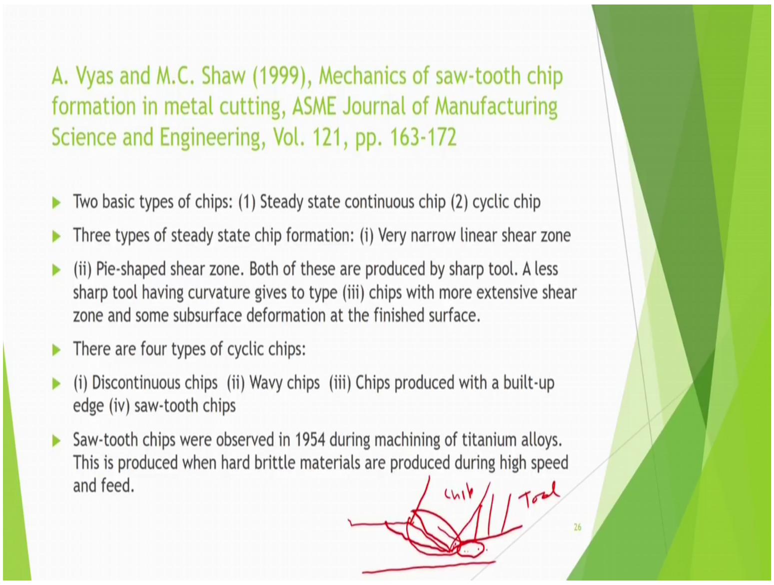

There is one good paper by Vyas and Shaw which was published in a ASME journal of Manufacturing Science and Engineering in 19 9 1999, volume 121. It is about 10 page paper in which he has classified the chips into two types, one is steady state continuous chip like this and other is basically the cyclic chips.

Three types of steady state chip formations are may be that very narrow linear shear zone; that means, when the chips is forming chip formation takes place like this. So, there is this material is there. So, this is a shear zone so; that means, cutting tool is here this is the tool is producing the chip, but the chip is getting sheared, but along a narrow zone and then there can be other type of phenomena in which there is you get a pi shaped shear zone growth of these are produced by Shaw; that means, shear zone maybe like this extending from here like in the form a the pi.

Then chips with more extend to shear zone and some surface deformation of the finished surface; that means you can have this zone can extend and there can be some deformation on this. This surface also these type of phenomena can be there. So, these are thing we one can be study in detail.

There are four types of cyclic chips discontinuous chips, they are called cyclic because one by one particle has been broken another particle broken another one has done. Then wavy chips you can get wavy less and then chips produced with built-up-edge then you can get saw tooth type of chip like a saw tooth you get.

This is observed that is a fourth type of. In fact, chip that is observed they were observed in 1954, first during machining of titanium will rise. You know titanium material is very important because of it is very favourable property. It is good for you use space industries compared to it is weight it is strength is more during that machining it and it is basically somewhat hard and brittle material. So, this is when hard and brittle materials are produced during high speed and feed then you get saw tooth type of chip.

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So, saw tooth chip like this one typically a schematic diagram, I have shown here they are also called segmental chips and increase in cutting speed has generally two opposing effect strain rate increases enhances saw tooth formation. Because as you know the strain rate increase we will have tendency to increase the flow stress of the material, more difficulty in cutting, but the thermal softening has opposite effect; it reduces it.

Saw tooth chip causes great variation in cutting forces and chip flow speed at tool face. Because it is saw tooth. So, chip thickness it exchanging here. So, sometimes the force will be high sometimes the force will be low. So, then there will be fluctuation. So, therefore, saw tooth chip causes vibration.

So, therefore, these chips cause vibrations and they increase tool wear they increase surface roughness. They have to be avoided means you have to chose those type of condition that saw tooth chip should not be generated. Sometimes, you can comment about the condition of the machining operation by just by observing the chips. In future with intelligence and self one can make those types of devices which can adoptively adjust the parameters based on the observation of the chips. That is why it is important to study that what type of different type of chips are there.

So, saw tooth chips are generated in machining of titanium in austenitic strain less steel and nickel alloys. So, sometimes when we get these type of chips you know, they are creating lot of problem, they get entangled, they can reduce this workpice. So, although continuous chips are very good and it is good sign, we should aim at that, but if they are very long then they will create problem.

So, I want continuous types of chips, but I do not want that long I want small. So, can they be broken of course, they are brittle they sometimes can be easily broken also that is what this one. So, we try to keep we need chip-breakers. Chip-breakers can be put on the tool.

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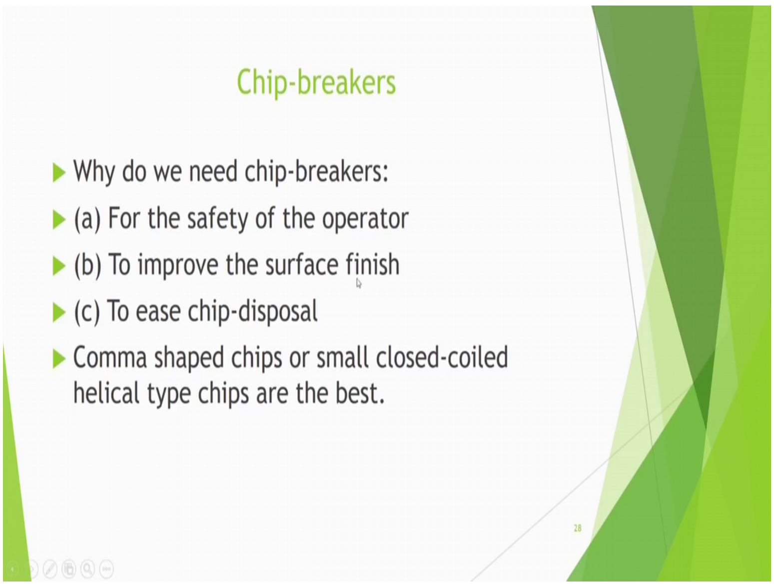

Why we need to break the chips? It is because of the for the safety of the operators to improve the surface finish and to ease chip disposal. These are the three main important things. The safety of operator because operators and it can come then improve the surface finish because otherwise these long chips, they can again entangled with the workpiece. It can spoil the workpiece surface and also we need easy chip disposal you see that even handling of these things is also very difficult whereas, these types of small chips, we can easily take and we can handle.

So, that is why comma shaped chips or small closed-coiled helical type chips are the best from handling point of view and all these things.

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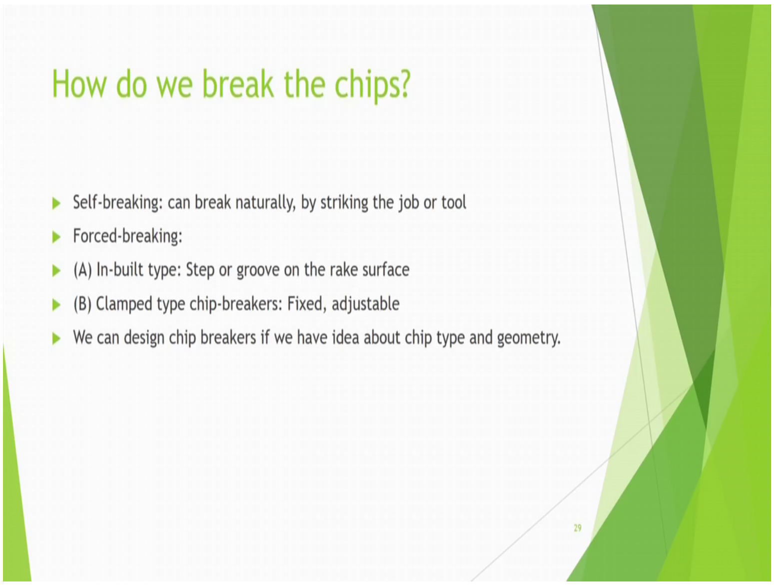

So, how do we break the chips? We can do self breaking; that means the chips generally by adjusting the cutting parameters. We adjust the cutting parameters in such way that the chips can break naturally; that means, by or by striking the job or tool. That means, the chips have come, but they will come and they will against this one and the hard chips will break or suppose the chip is going or it is very hot certainly the coolant jet is also falling on that. That coolant jet will cause sudden quenching and cracking will take place and the chip will break.

So, that type of thing can be done, but we sometimes we use forced breaking; that means, we can put the chip breakers. So, they can be inbuilt type; that means, on the cool surface rake surface, we can make a small group and the rake surface or we can make a small step that type of thing can be done that which called inbuilt type.

Or we can clamped some projection type of thing here that is clamped type of chip breakers. It can be a fixed or it can be adjusted also depending on the chip geometry. We can design chip breakers, if we have idea about chip type and there geometry; then we can design the chip breaker that how much height of the chip breaker will be best. So that it can be cramped here and it can break you see here also there is a small amount of group.

And, suppose this is the rake surface, now what may be happening that the chip is going like this and here suddenly it may be breaking actually. So, that means, this is possible that here it can break. So, it is a basically inbuilt type, but we can have clamped type of chip breakers also these are.

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Now, there is a one paper which was published in Advances in Mechanical Engineering very recently 2016. It is open axis journal and under the creative common licence, we can also use it for any purpose. We can take the photograph and we can displace. While you have taken something from this paper, in this paper he has done finite element analysis of chip breaker geometry in tuning process.

You know finite element is a good technique by which you can find out stress distribution, temperature distribution it is numerical technique. Now what is number of packages are there like anxious abacus many packages are there? In that we can do finite element analysis. So, he has tried to find out that which type of these authors try to find out which type of chip breaker is good. It is a schematic of the 6061 aluminium alloy before cutting and it is cutting with the chip breaker. So, you see because of the chip breaker that the chips are getting broken here.

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And, then next entity diagram of the different chip breakers without chip breaker tool is like this. Then you can have square chip breaker here or we can have elliptical type of chip breaker is they are it is this one. I hope this is visible these are just photograph.

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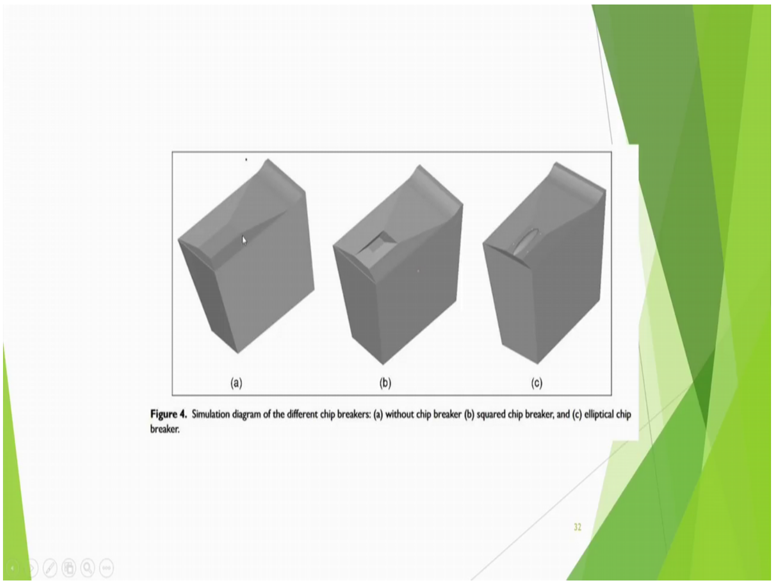

But, here is a bigger way it is shown that without chip breaker in PM model, they have taken a squared chip breaker and they took the elliptical chip breaker.

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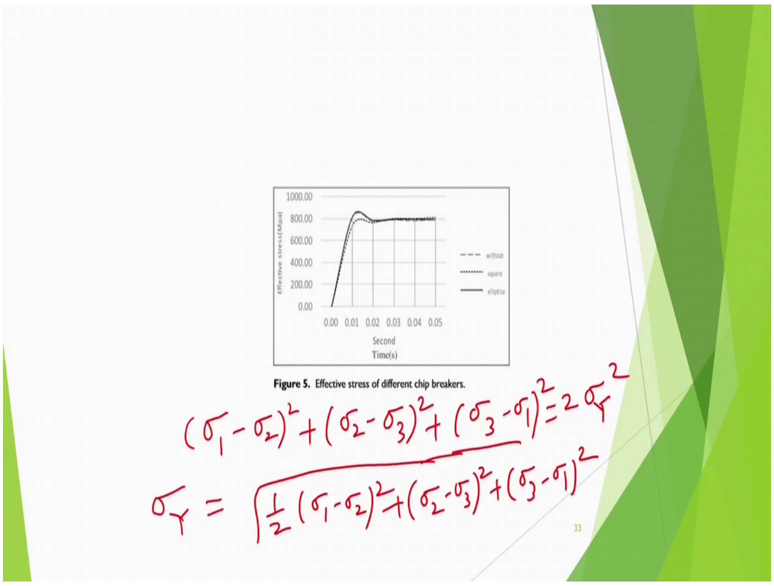

And, after that they have obtained effective stresses of different type of chip breakers. What do we mean by effective stress? Effective stress is the combined measure. In the last class I told you about the three principle stresses: sigma 1, sigma 2 and sigma 3. So, and we said that one yield criteria was there sigma 1 minus sigma 2 is square plus sigma 2 minus sigma 3 square; this is one mises criteria plus sigma 3 minus sigma 1 square is equal to 2 sigma y square.

So, in a way that material will plastically deformed if this condition is achieved. All I can see that sigma y is basically under root half and then I can write sigma 1 minus sigma 2 whole square plus sigma 2 minus sigma 3 whole square plus sigma 3 minus sigma 1 whole square. So, this thing on the right hand side can be curved as equivalent or effective stress.

That means, it is the combined effect. Combinely even this quantity becomes equal to sigma y then the yielding will take place like that you can have this is called one mises equivalent strain. Here they have really not mentioned that what is effective stress in this diagram. Maybe in the paper the might have writ10 that we they have use von mises type of effective stress. Similarly, there can be other measures of that. So, this is effective stress of the front chip breakers has been done.

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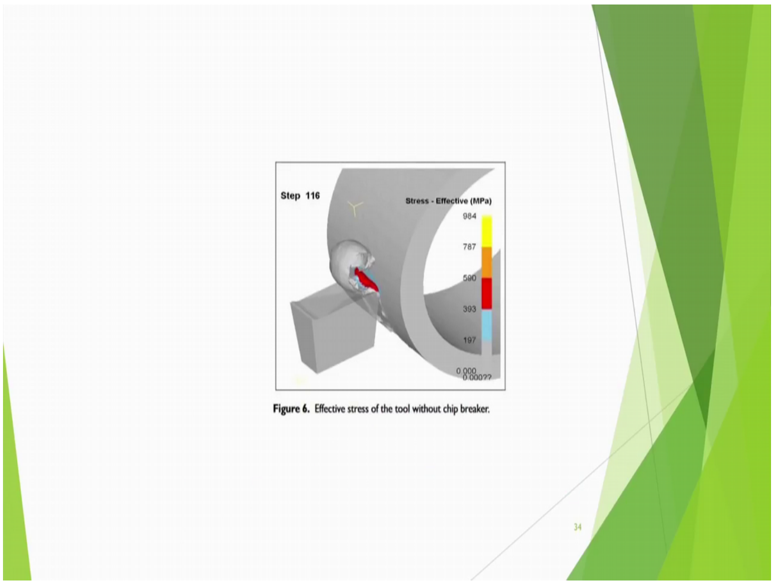

Then they have obtained this is the stress effective stresses have been plotted. These are the contour type of things where they are remove the stresses that is shown here. I am just showing these type of things that you can understand that you can apply scientific principle and mathematical techniques to your machining processes.

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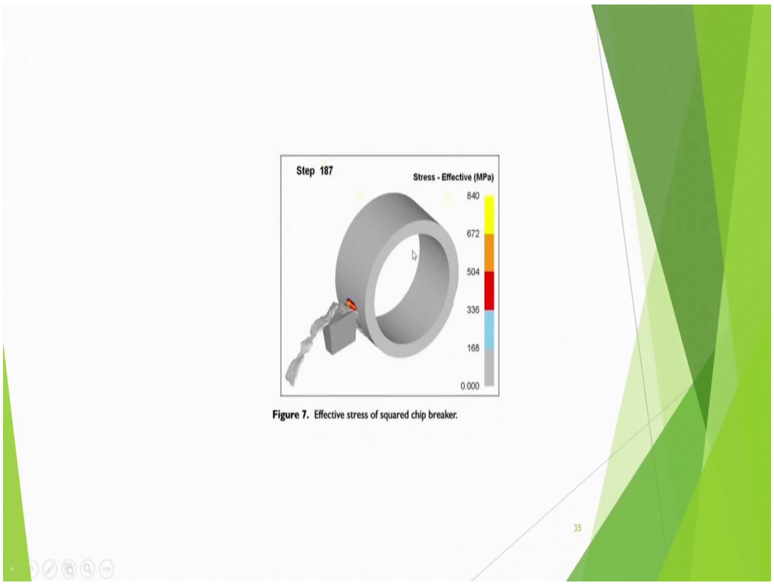

And, here effective stress of squared chip breaker has been showed. It is 840 here slightly reduced.

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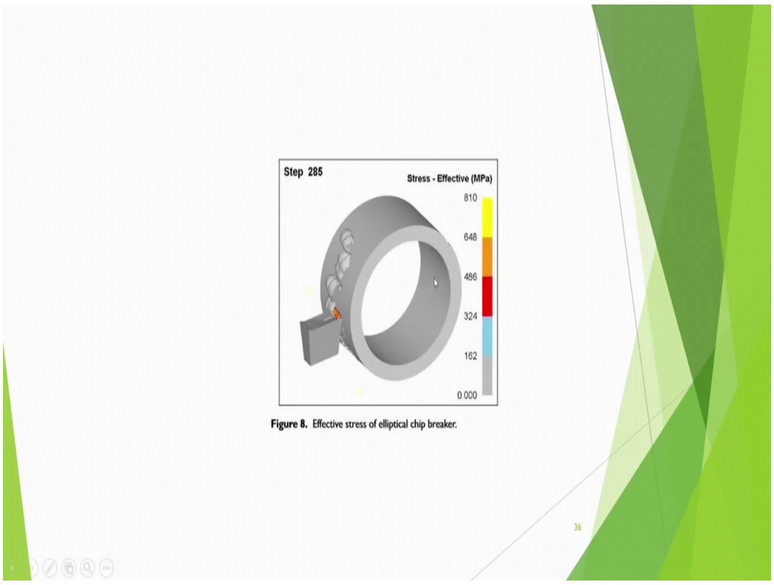

And, then again it reduced with elliptical type of thing, here you are getting 810.

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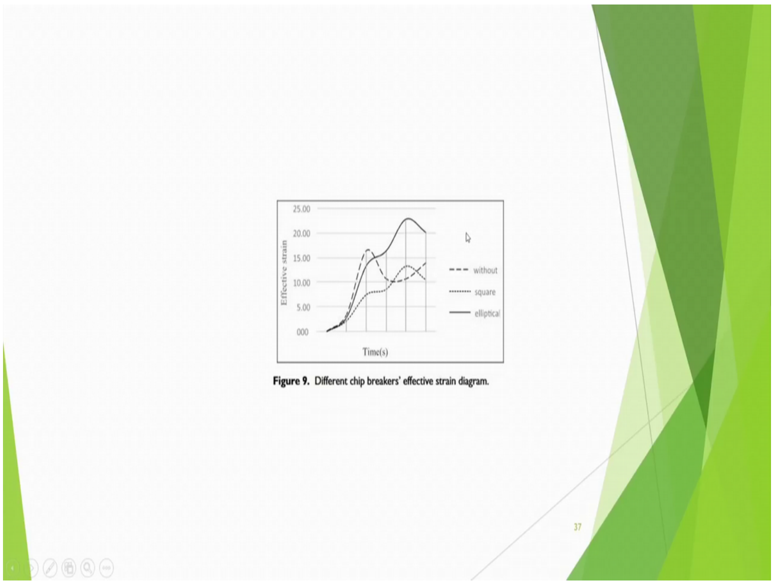

And, then different type of chip breakers effective strain diagram has been obtained just like we define effective stress combination of the stresses, we give one measure. Similarly, effective strain is also defined that has been plotted here.

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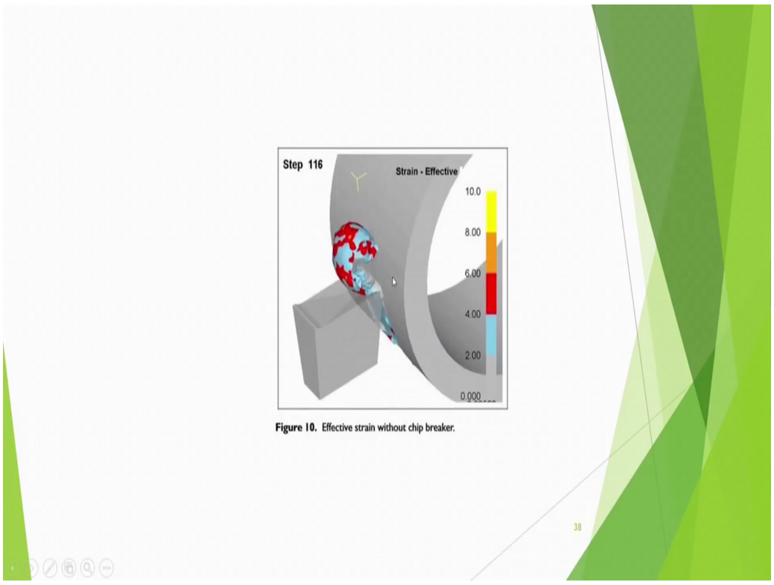

And, effective strain without chip breaker.

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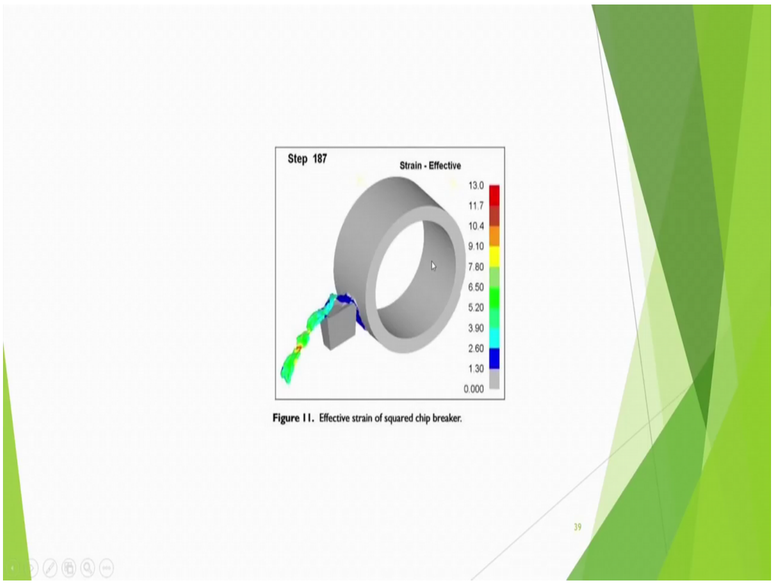

Then, effective strain of squared chip breaker.

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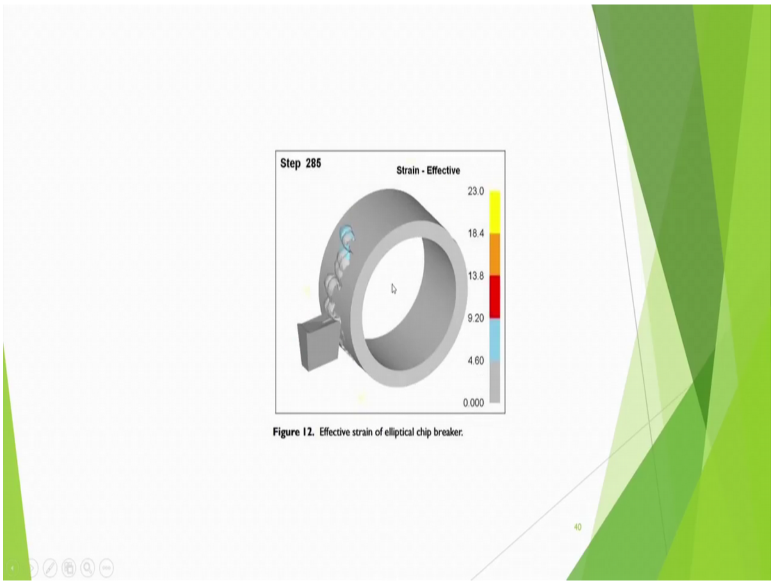

And, this is elliptical chip breaker.

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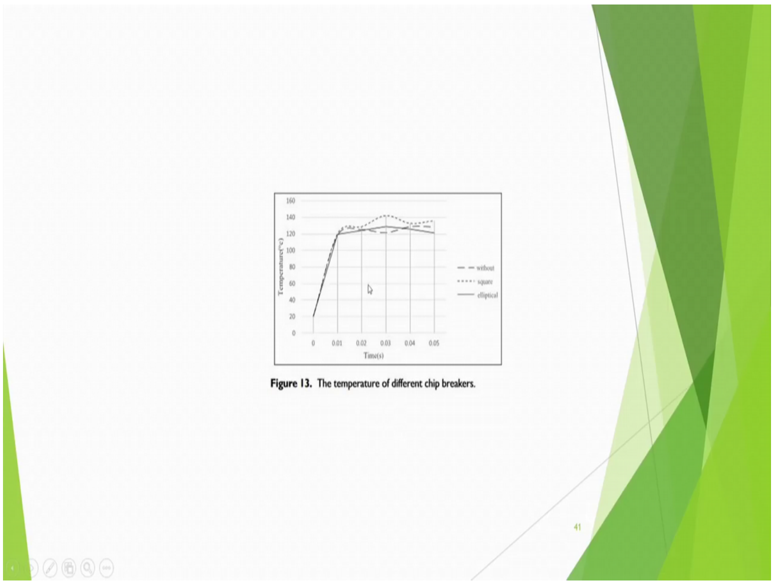

And, this is the temperature of different chip breaker. So, you see without chip breaker you are getting this type of distribution. This is on the without in bottom this side and here you are getting the squared and, with elliptical shape you are getting really not much difference in the temperature may not be that much significant.

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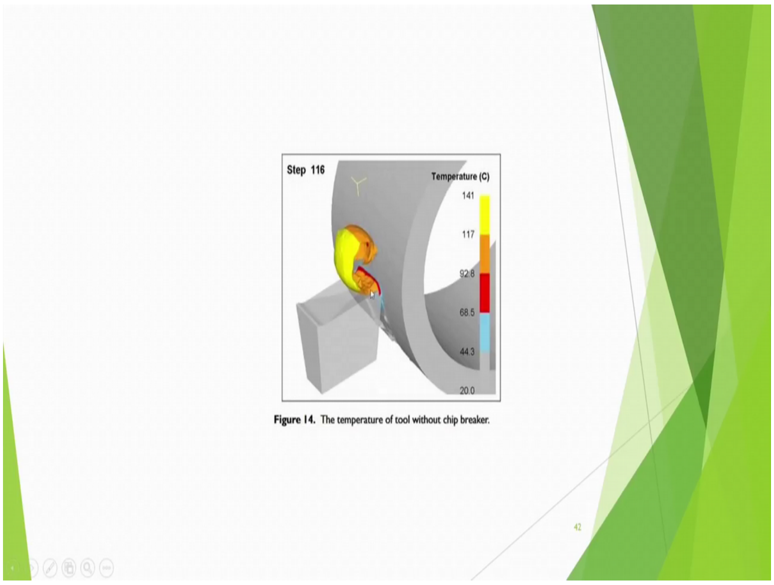

Figure 14. The temperature of tool without chip breaker.

And, temperature of tool without chip breaker is shown here.

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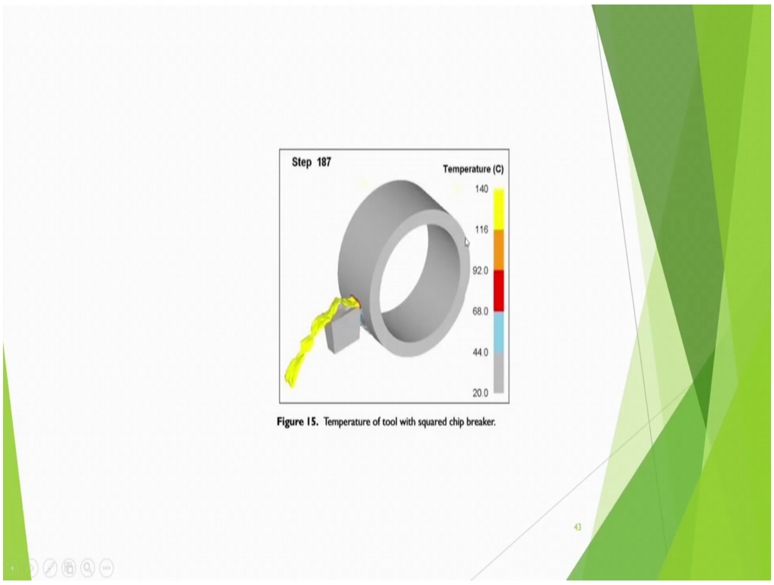

Figure 15. Temperature of tool with squared chip breaker.

And here 140 maximum bar.

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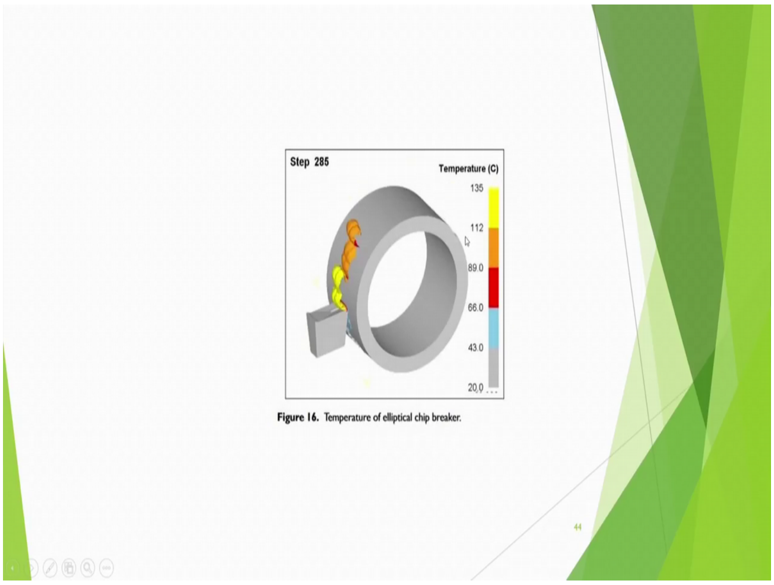

Here 135.

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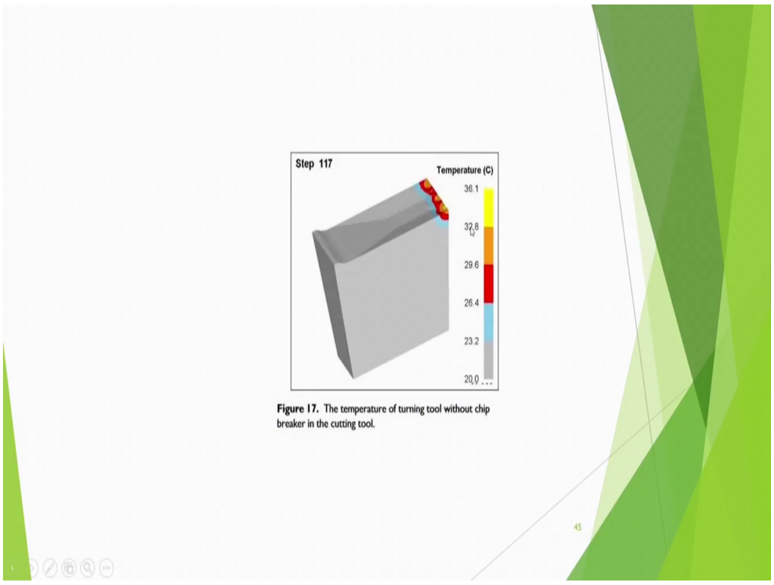

More or less it is same temperature of turning tool without chip breakers in the cutting tools. They have shown 36.1.

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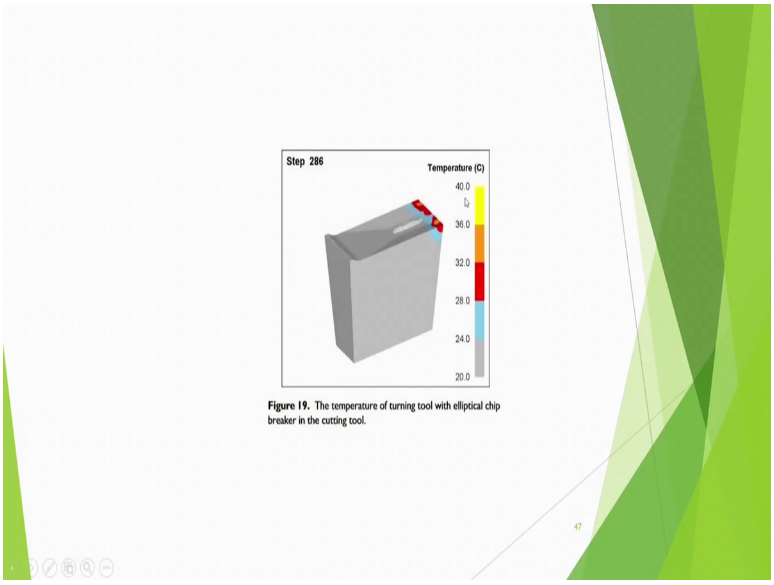

Then it is 40 with squared chip breaker and then elliptical chip breaker this bar is shown.

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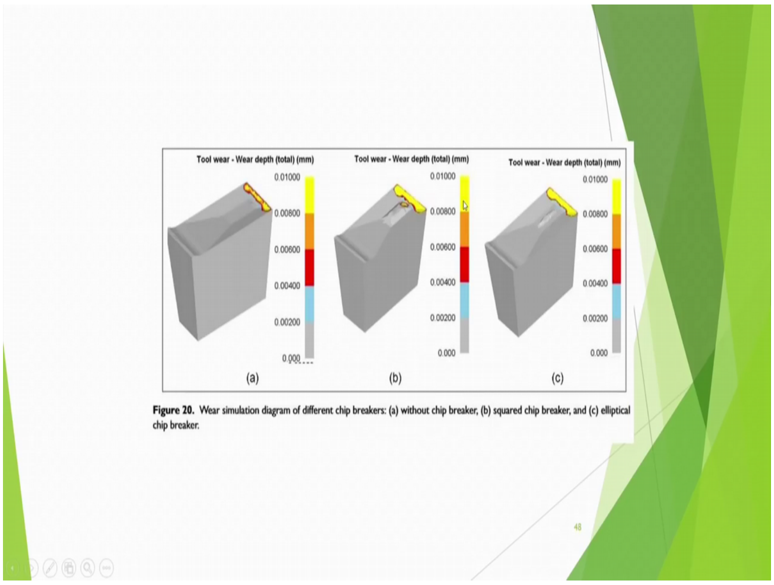

Then they are showing wear simulation diagram for different type of chip breakers without chip breaker and a square chip breaker and elliptical chip breaker. So, chip breaker it appears that is not basically reducing the wear per shape and, but may be that that in detail one has to study this paper. But this has been demonstrated here that people are trying to apply the fundamental principles of the science and they are trying to understand that is what is happening inside the material, how the chip is getting formed and how we can design efficient chip breakers.All these types of things you know people are studying. So, this much will be for today.

Thank you.