Computer Integrated Manufacturing
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Lecture 18
CNC Tooling

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So the next topic will be Toolings which are involved in CNC machines. So till now we were only looking at CNC, what are all the components of a CNC, what are all the options which are left in CNC machines. Now let us look at a very important component in the CNC machine is the tooling.

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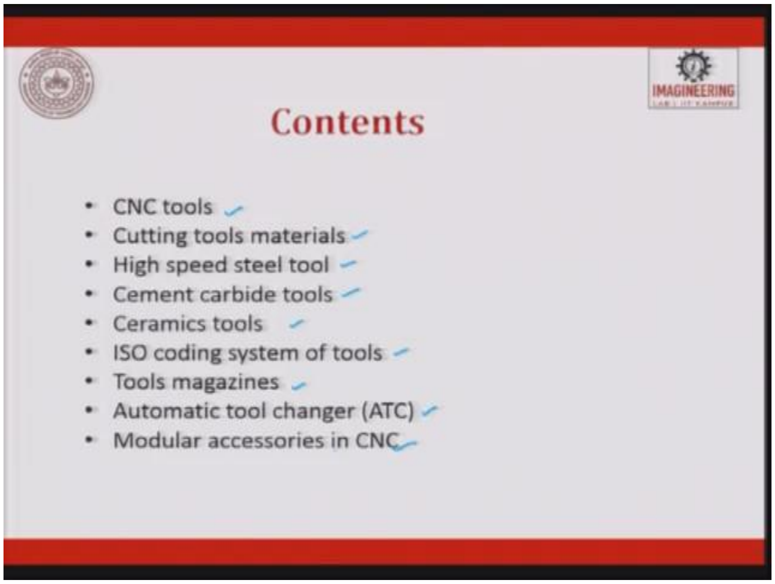

So in this lecture, we will try to see CNC tools. Then what are the different tool materials which are used. The most commonly used material HSS then cemented carbide then we will see ceramics. How are these tools? Like in normal lathe machine, we have a single point cutting tool, we have 6 angles and one nose radius.

So are we going to use the same coding or is there going to be a difference in coding? When you have many tools, how are these tools loaded? So we will see the tool magazine. Then when there are more number of tools and if the tools have to be indexed and brought under control, or should be attached to a drive, so we should have something called as automatic tool changing machines.

And then finally, we should see how modular accessories are used in CNC such that their productivity can be improved.

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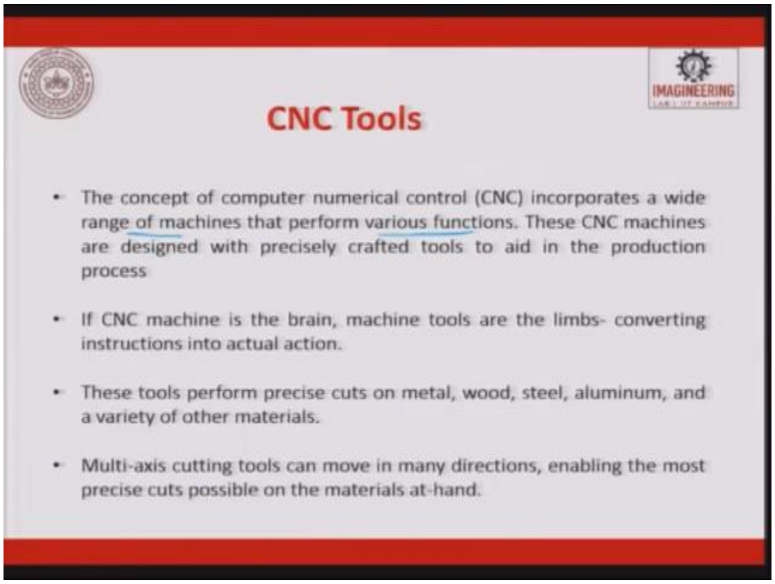

The concept of CNC incorporates a wide range of machines that perform various functions. These CNC machines are designed with precisely crafted tools to aid in the production process. Tools play very-very important role. If CNC machine is the brain, machine tool are the limbs converting instruction into an actual action.

These tools perform precise cutting of metal, wood, steel, aluminum, and variety of other materials. Multi-axis cutting tools can move in many directions, enabling the most precise cuts possible on the material at hand.

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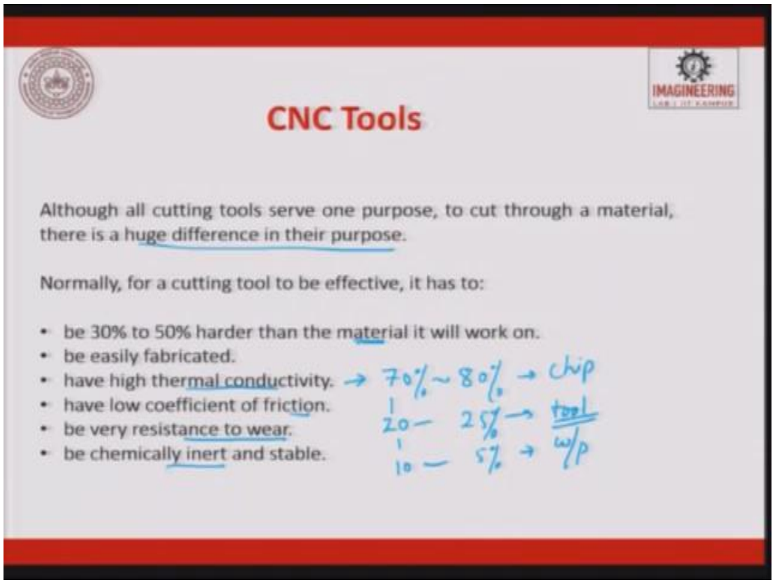

Although all the cutting tools serve one purpose to cut through a material, there is huge difference in those purpose. So some places, if there is a lot of variation in the tool in the work-piece material, so then the tool has to have enough of toughness. If it is a complex job machining, the tool should give us the flexibility of regrinding.

If there is going to be a huge depth of cut, then there has to be a change in the angle. If there is a huge depth of cut and it is a non-conducting material, the tool material has to take the heat, so it has to be made out of ceramics. So you see there are huge differences in the purpose.

Normally, for a cutting tool to be effective, it has to have 30 to 50 percent harder than the work-piece material. It has to be easily fabricatable, it has to have huge thermal conductivity, why? Because generally it is expected 70 percent to 80 percent of the heat goes by the chip and 10, maybe 20 percent to 25 percent goes by the tool and 5 percent, maybe 10 percent or 5 percent, whatever it is, goes by the work-piece.

So tool takes a significant heat portion, so that it has to have high thermal conductivity, then it has to have low coefficient of friction, because when it, it is a contact machining. In contact machining, the tool surface comes in contact with the work-piece surface. So there is going to be a huge friction. When if the friction is very high, the heat which is going to be generated is very high.

So there has to be a low coefficient of friction, then there has to a very resistance to wear has to be there. It has to be chemically inert, because what happens, while machining we also use cutting fluids. These cutting fluids try to dissociate and have elements which, traces of elements which gets diffused into the tool material. So the material has to be chemically inert and stable and high temperatures.

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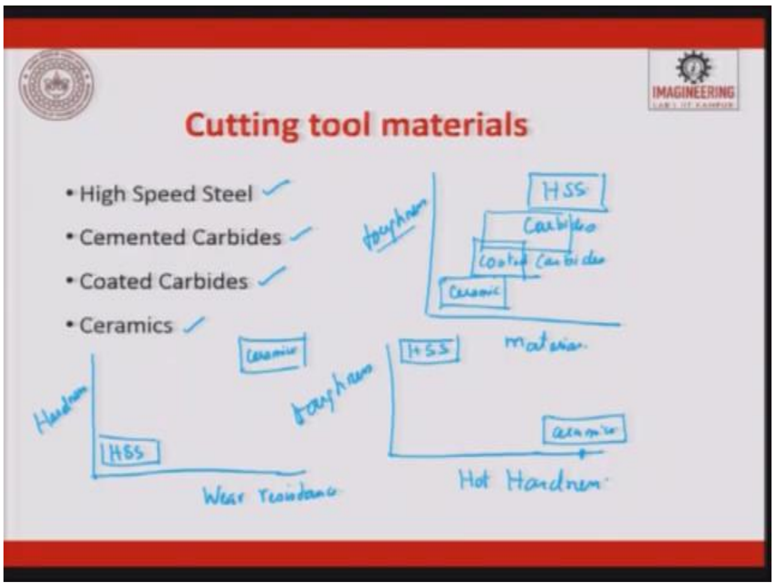

So the commonly used materials if you try to plot with respect to toughness and materials, whatever we have, so HSS falls here and ceramic falls here. So HSS has very high toughness, ceramics are here. Cemented carbides and coated carbides are here. So this is cement carbides, this is coated carbides, or it will overlap.

Okay so if you look at it, the toughness will be very low for ceramic material but the hardness if you try to plot, then this fellow will just. So if I plot it toughness versus hardness, then ceramic will be high here, will be very hard and the toughness will be very low. So it will be somewhere here, hardness high and toughness low.

It will be just inverse curve. So here you will have ceramics and if you talk about HSS, hardness very low, toughness very high, you will have HSS here. So now and if I have to plot with respect to hardness, and hardness and wear resistance, so ceramics will fall here, ceramics will have very high hardness and the wear resistance is also very high. So here will be HSS.

I have just plot different-different graphs, so that you will know the properties which are important are hardness, in fact hardness I should change it as hot hardness, then wear resistance, toughness, all these things are important. Depending upon the single material property, you will see the presence of the tool material. So tool material plays a very important role and deciding the tool material for our requirement plays another important role.

So you will have high speed steel, you will have cemented carbide, you will have coated carbides, you will have ceramics. Today you have cermets also, where ceramics plus metal is also there. And again, in ceramics you will have coated ceramics. And finally, you will have diamond, the hardest material which is there in the mankind. So diamond is also used as a cutting tool material. In CNC, we use diamond tools also for machining.

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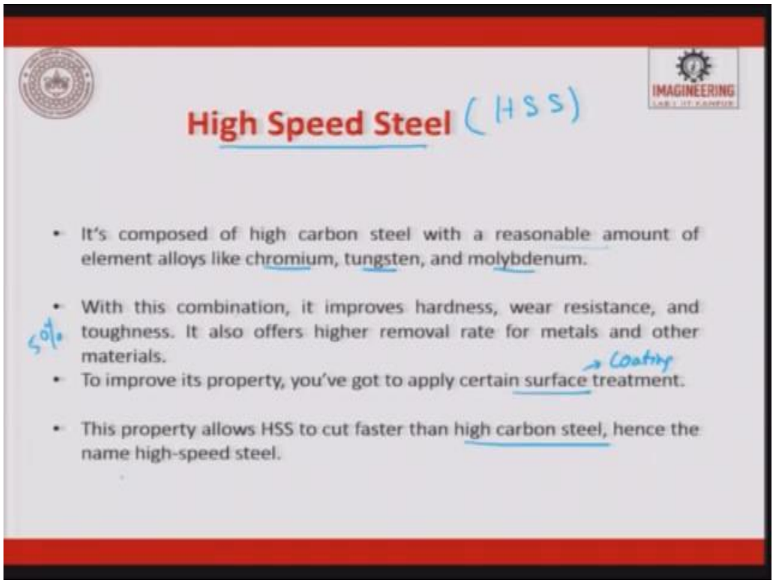

When we talk about high speed steel, the high speed name came from the ancient time, so we still keep continuing the same. So this is high speed steel. It is composed of high carbon steel with a reasonable amount of elements like chromium, tungsten and molybdenum. So they give the hardness and the cobalt which is present there gives you the toughness.

With its combination, it improves hardness, wear resistance and toughness. It also offers high material removal rate of metals and other material because it should have 50 percent harder than the work-piece. To improve the property, you have got to apply certain surface treatments like coatings of HSS are also tried today. This property allows HSS to cut faster than high carbon steel, hence the name high speed steel came in to action.

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So high speed steels are used for drills and which is used for broaches. Broaching is an operation wherein which the geometry is very complex. You can also use it for tapping where the thread geometry is complex. Wherever there is an impact load and there is a complex geometry, we prefer to go use HSS.

The main use of HSS continues to be in the manufacturer of various cutting tools are drills, taps, mill cutters, tool bits, gear cutters, hobbing. These are all peculiar operations or these are all non-common operations, hobbing for making gear, saw, planer and joint blades and router bits.

All these things use high speed steel, which is where there is a impact load and you will have a complex geometry which cannot be done by dying process or by compaction process. You need to have a grinding process after that.

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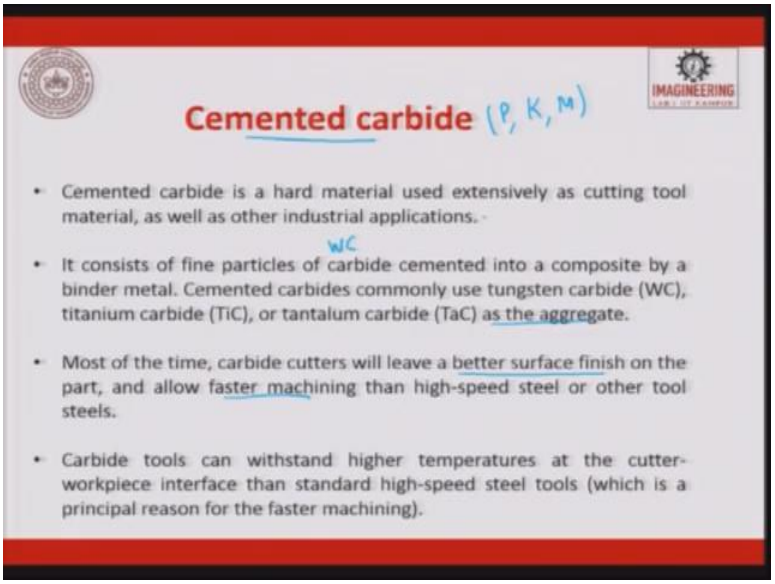

The next one is cemented carbide. There are several types of cemented carbide P type, K type, M type so many different types are there. The cemented carbide is a harder material, uses extensively as a cutting tool material as well as the other industrial applications. It consists of fine particles of carbide cemented, so it is, carbide is nothing but tungsten carbide cemented into a composite by a binding material.

Holding of this tungsten carbide is very difficult you have to apply very high pressure. So what we do is we try to add elements like cobalt to it, so that will add as a binder to compact. The cemented carbide commonly used tungsten carbide, titanium carbide, tantalum carbide as an aggregate is also mixed with it and then we try to make a cutting tool.

Most of the time carbide cutting tools will leave a better surface finish on the part and allow faster machining than high speed steel. Carbide tools can withstand higher temperatures as the cutter work-piece interface than the standard HSS tools. So carbide is the next level of HSS, wherein which we try to give the tool geometry to the carbide tools.

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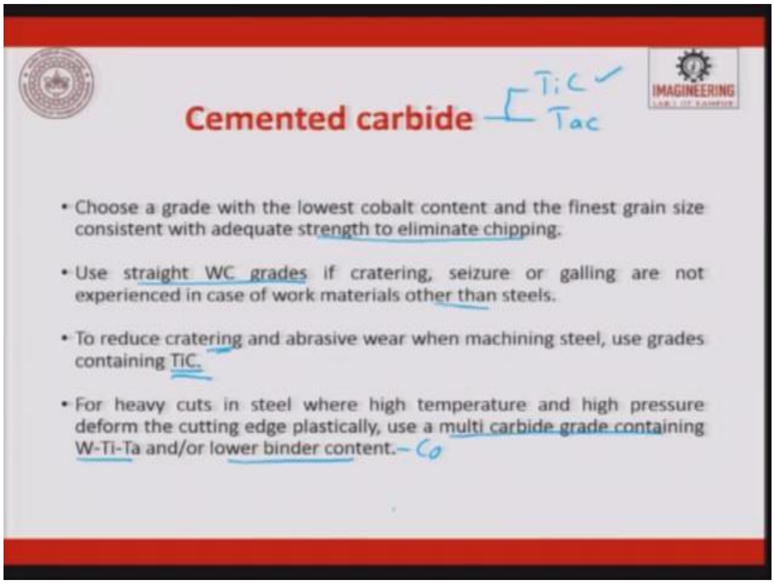

Choose a grade with the lowest cobalt content and the finest grain size consist with adequate strength to eliminate chipping. Use straight tungsten carbide grade if cratering, seizure or galling are not experienced in the case of work-piece material other than steel. So use straight tungsten carbide grade.

To reduce cratering, which happens on the surface and abrasive wear while machining, use grades containing TiC. Now what are these? We were talking about TiC, TaC getting mixed. TiC when you mix, the crater wear is reduced. For heavy cuts in steel, where high temperatures and high pressures deform the cutting edge plastically, use a multi-carbide grade containing tungsten, titanium, tantalum carbide along with low binder of cobalt, we try to get a better performance.

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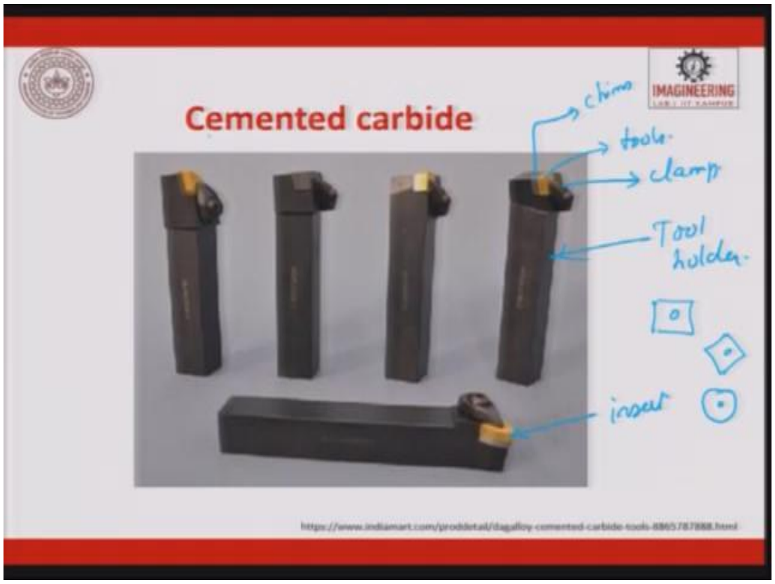

If you look at these, these are some of the cemented carbide tools. In HSS, the entire tool will be made out of HSS. When we come to cemented carbide tools, we will have a tool holder and then these are the tools. These tools are held by a clamp. The height are adjusted by chims or height adjuster.

So you can have, this is a clamp, you can see here. So here is an insert. This is, earlier in HSS it used to be a solid tool. Solid tool completely made out of HSS. Now we realize that why should we make the complete tool of the same material where only the tip comes in contact with the work-piece.

So now we have started focusing towards inserts. So all the geometry what we are, which we wanted to give to the tool is given to the insert and that is mounted on a tool holder. So today we buy inserts and tool holder, it is not a wear and tear material. So we buy only inserts and keep replacing inserts.

Okay, and these inserts are also rectangle, square, diamond-like depending upon the loads and the material they also have and they also have a circular one. So circular one, they have infinite cutting points, so here you might have 4 cutting points, here you will also have 4 cutting points. If you swap it, you might get another four. So might have 8 cutting points.

So these inserts are playing a very important role for machining and they are made out of cemented carbides.

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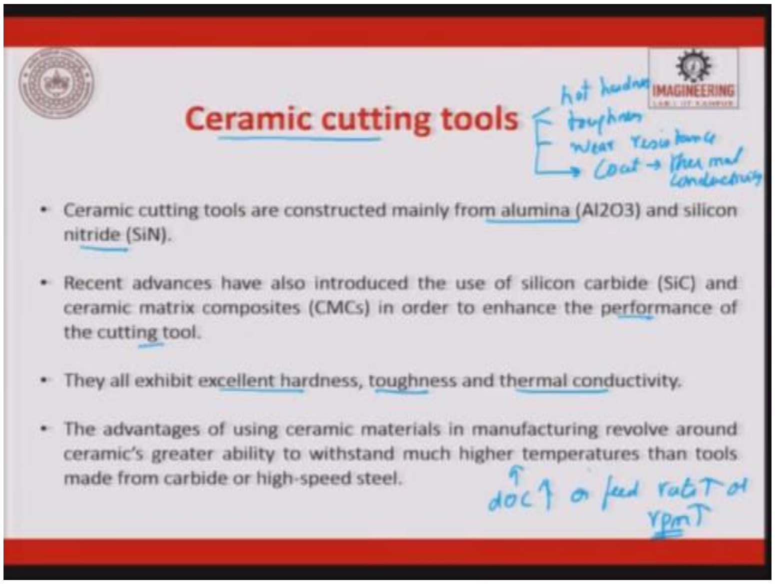

When you go next step and you can also have a coating on top of this ceramic of this carbides in order to prevent them from wear resistance and high thermal conductivity, right. So next is ceramic cutting tools, ceramic cutting tools mainly consist of alumina and silicon nitride. You can also have silicon carbide.

Recent advancement have also introduced silicon carbide and other ceramic matrix composite in order to enhance the performance of the cutting tool. So the cutting tools are very small, kept on an insert. So now they are trying to play with the properties wherein which they look at high hot hardness, they look for toughness, and they also look for wear resistance.

Any material which gives all these 3 properties, they will be happy to have. The material which gave all these 3 properties are ceramic. So ceramic you cannot make a block. So what we do is we make small inserts. So that is why all the CNC machines uses only insert based cutting tools. So they all exhibit excellent hardness, toughness and thermal conductivity.

In order to enhance the thermal conductivity property, we go for coating. This is only for thermal conductivity. The advantage of using ceramic material in manufacturing revolves around ceramics greater ability to withstand much higher temperatures than carbides and HSS. So when does the temperature goes very high?

When the DOC is high or feed rates high or RPM high, RPM will generally lead to a higher productivity, feed rates higher productivity, depth of cut also higher productivity. All these three parameters on a lathe machine will try to increase the temperature. At higher temperatures, the tool gets deformed so you have to sustain it for a longer time.

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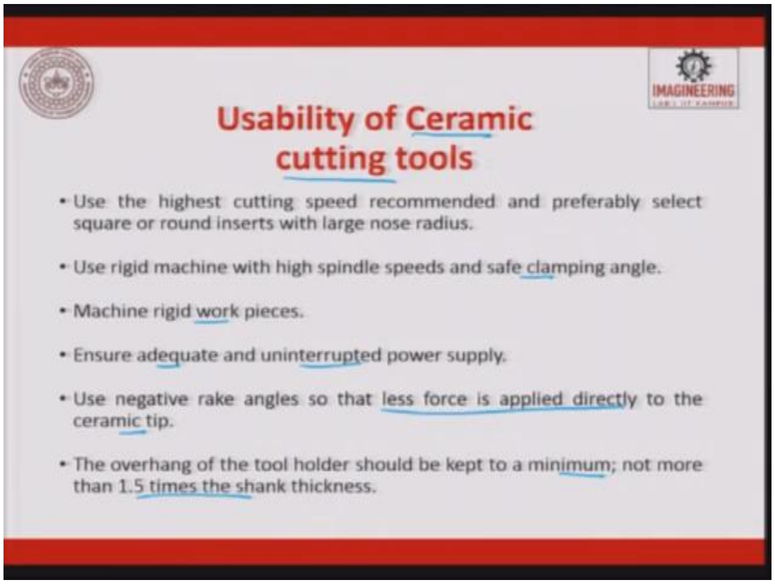

So the usability of ceramic cutting tools, use of highest cutting speed recommended and preferably select square or round inserts with large nose radius are always preferred in the ceramic cutting tool. Use rigid machines with high spindle speeds and safe clamping angles.

So the machine holds the work-piece very rigidly, ensures adequate and uninterrupted power supply, because ceramics cannot withstand impact. So the toughness property is low when there is interrupt, power supply interrupt then there will be a stop of the machine, there will be a huge impact load on the ceramic tool which will damage it. So use negative rake, so that less force is applied directly to the ceramic tip.

So you will have negative rake, lot amount of material is there in the tool so it can withstand shock. The overhang of the tool holder should be kept to a minimum, not more than 1.5 times of the shank thickness. So this will try to dictate what should be the bore when you are, the length of the bore which you can do using these inserts.

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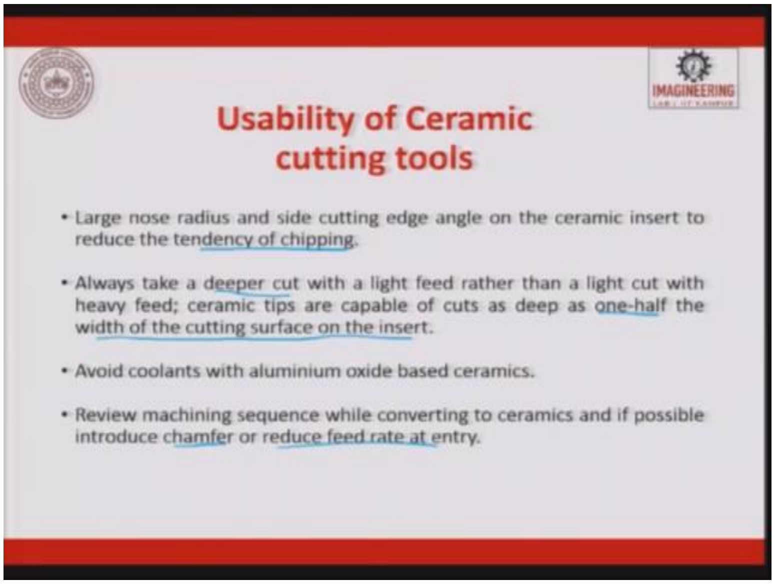

Large nose radius and side cutting edge angle on a ceramic insert reduces the tendency of chipping. This chipping because ceramic when the toughness is poor, so if a crack gets initiated, next immediate thing what happens is the chipping of the cutting tool. So that is removed.

Always takes a deeper cut with a light feed rather than a light cut with a heavy feed. It is a combination which we are playing. Ceramic tips are capable of cuts as deep as one-half the width of the cutting surface on the insert. Avoid coolant with alumina based ceramic tools, because they, when coolant is at high temperature then it will have a thermal shock, it will shatter or it will chip off.

Review machining sequence while converting to ceramic and if possible, introduce chamfer or reduced feed rates at the entry. So as soon it enters, no impact load, slowly it enters and then it increases the speed.

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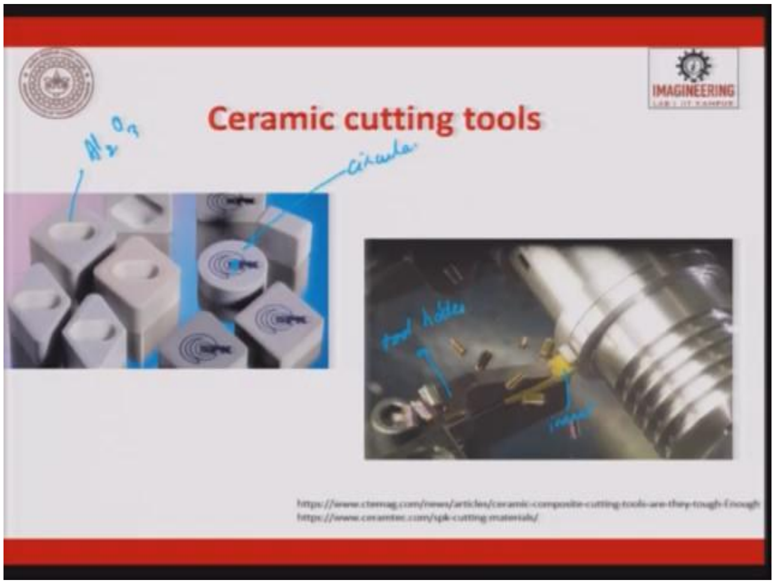

So these are some of the ceramic inserts. These are all alumina, so this is all square or cuboidal. This is all circular. So circular, the advantage is it has infinite cutting edges. And you can help self-rotating, self-propelling inserts and you can also have inserts with clamp. So this is a turning operation done. Here is an insert, so the insert height and all you have to calibrate it and keep and this is a tool holder.

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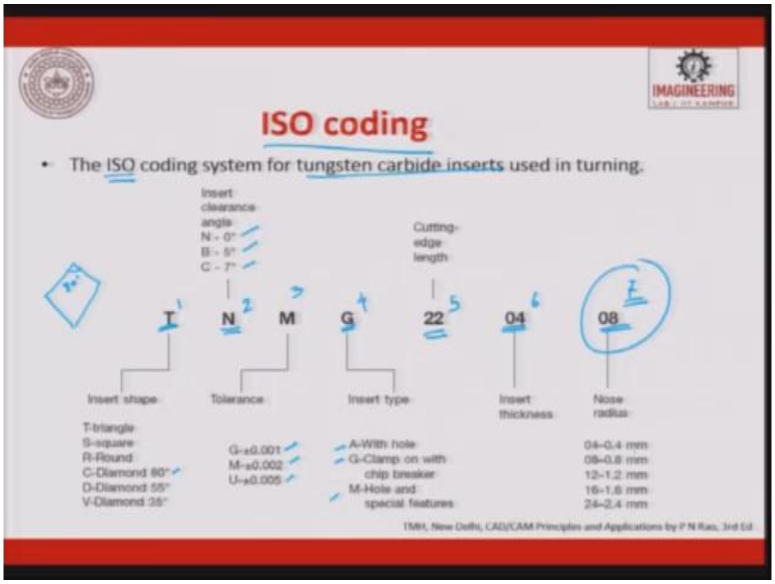

So like the 6 cutting angles and 1 nose radius which is given to a tool for the specification, here we also have ISO codes for tungsten carbide insert. This is a typical example I am taking, but it differs and varies from company to company you are supposed to look at the company catalogue.

So for a tungsten carbide insert, which is used for turning, this is what is a nomenclature which is followed. First digit, T stands for the shape of the insert, so this tells you there are so many different shapes, triangle, square, round, diamond, in diamond you can have diamond. So this is what they are talking about, 80 degrees, 55 degrees, 35 degrees and then we talk about N.

N is the clearance angle, you can have 0 degrees, 5 degrees and 7 degrees. These are the different insert clearance angles you can think of. M, which is talked about the tolerances, which is G, M, U, 0.01, 0.02 and 0.05. Then we have an insert type which is with hole, so that means to say inside how is it getting clamped with hole? A clamp on a chip breaker and a hole with a special feature A, G, and M type.

This talks about the cutting edge length and this talks about the insert thickness, this talks about the nose radius. So nose radius can be from 4 means it is 0.4, 8 means it is 0.8, 12 means it is 1.2, 1.6 is 16, 2.4 is 24. Larger the nose radius, more will be the strength of the material, so the chipping can be avoided.

So this is the typical ISO coding system which is followed for an insert. You will have shape, then you will have clearance angle, then you will have cutting edge length and the nose radius.

Rest all, you can see the tolerance which is given and insert how it is getting clamped. So you will have 1, 2, 3, 4, 5, 6, and 7, the same like your single point cutting tool, nomenclature which is done, 6 and 1. The last is always for the nose radius, here also it is for the nose radius.

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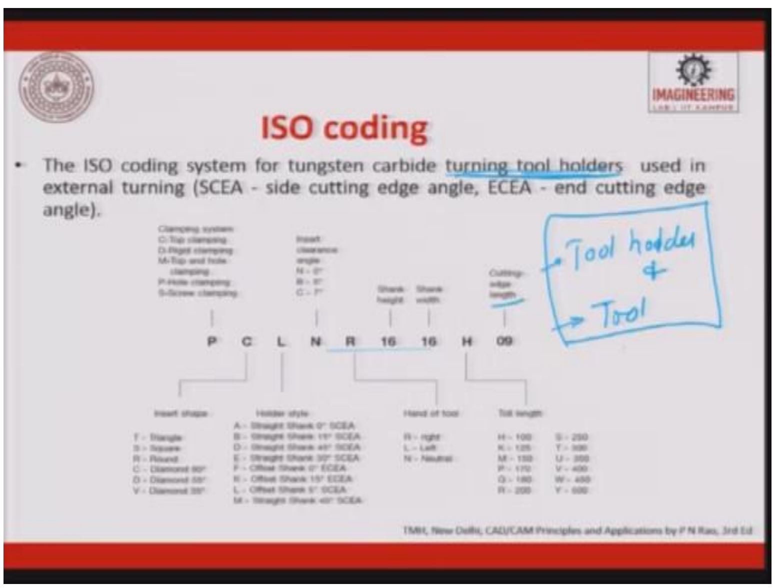

So ISO system for tungsten carbide turning tool holder, that was for the tool and here we are talking about the tool holder used in external turning. So you will have the similar digits which are followed. So you will have P where which talks about the clamping system, top clamping, rigid clamping, top and hole and then you have screw type.

Then C, talks about the insert shape, because in the tool holder you should have that groove. Then L talks about the shank, so which is straight shank, offset shank, talks about the clearance angle then it talks about the right hand or left hand tool. You have right hand tool, you have left hand tool depending upon your requirements you chose.

Then you will have shank height, then shank width, then you will have tool length and then you will have tool cutting edge. This is all for a tool holder. So tool holder and tool is very important and this today you can buy this in the market. So when you go for CNC machine, the first thing is when you talk about tool, we will talk about tool angle and then we will tool insert nomenclature and tool holder nomenclature.

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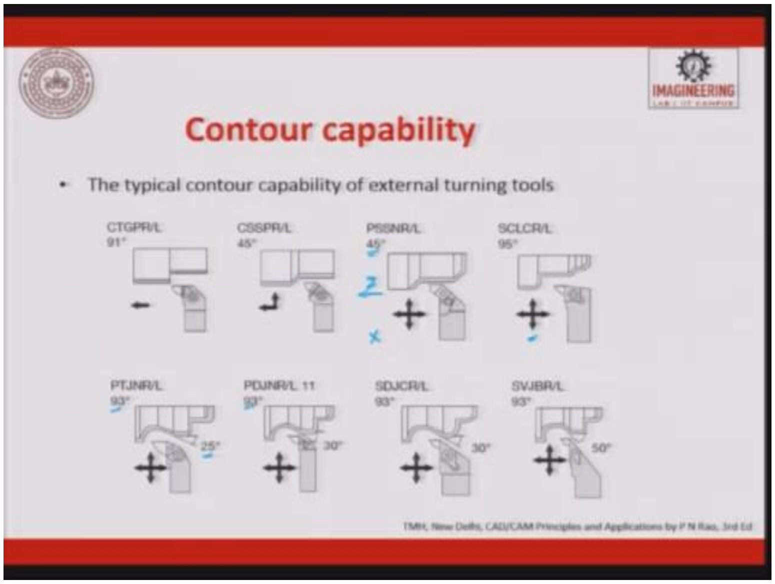

So the typical contour capability of external turning tool is it can do a step, it can do a slope, a taper, it can do this, a slope and a taper. So you can see how it moves, it moves in one direction, it moves in both direction, it can move up and down. This is X and this is X and this is Z, so it moves in both at 45 degrees.

At 90 degrees it gets it here. Then you can also try to have a profile on it. So this is 93 degrees, all these things are 93 degrees. 25, this is at which the angle enters inside 30, 30 and 50 for making it.

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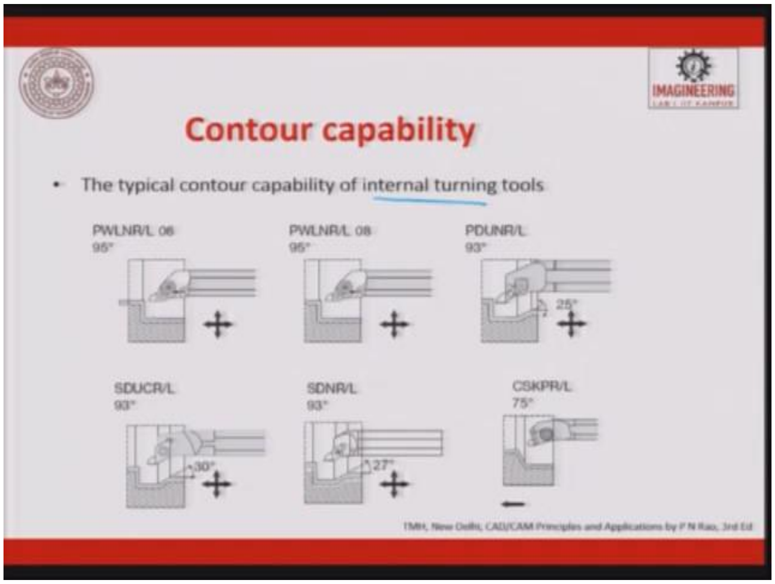

So if you want to make internal threads, it is also possible. So these are some of the variations to your, just for your knowledge.

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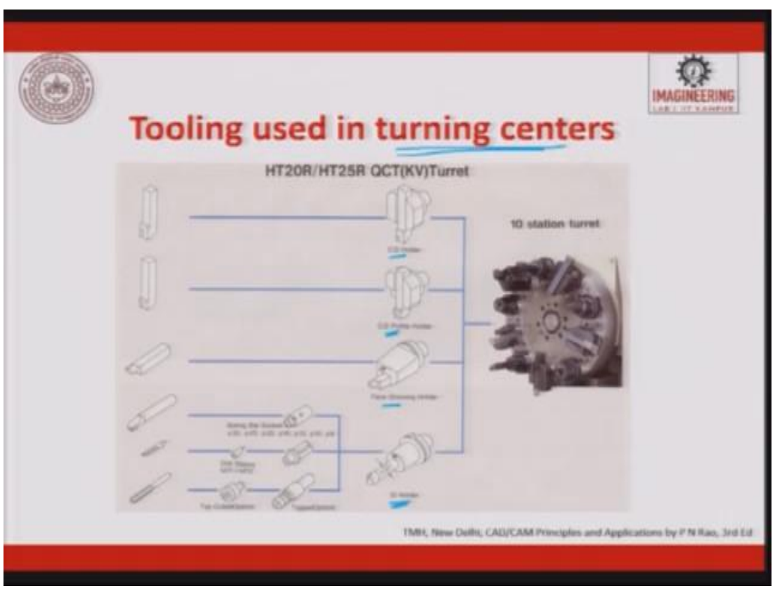

So a tooling used in a turning system, we are only trying to take a turning system. So it has 10 stations, so it is called as a turret which holds all the tools. So you can have OD holder, this is the OD holder, this is the profile holder, see on the top you can have this profile holder. Then you can have face groove, which is held, then you can have a ID holder, these are all OD, OD holder.

This is face, wherein which it is mounted on the face, the tool is mounted on the face. You can have a ID holder, inside a ID holder you will have a socket. Inside the socket you will have a tool. So you can have a drill sleeve, then you will have a drill, then you can have a tap, a tap collet and then you can have a tap. So these are all for internal and these are all for external OD and this is for a face. So you can have tools which are mounted, the inserts which are mounted on a turret.

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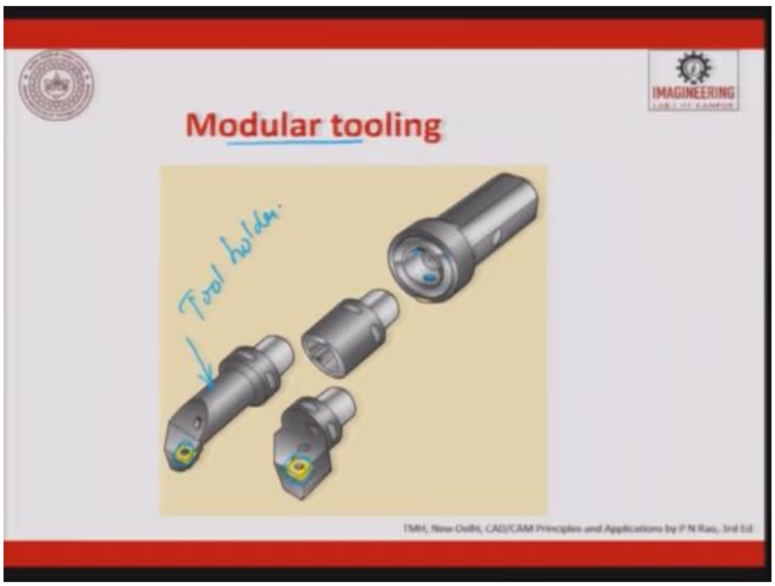

So when we talk about CNC, we always talk about the tooling and here in CNC we try to follow modular tooling, so you will have a sleeve. Inside a sleeve which is ball loaded, so this is pushed inside, inside the collet and then this part is located, either you go for this insert or you go for this insert depending upon your requirement. This is the tool holder. These are the modularity which is used such that you can choose any tool to be mounted on the spindle.

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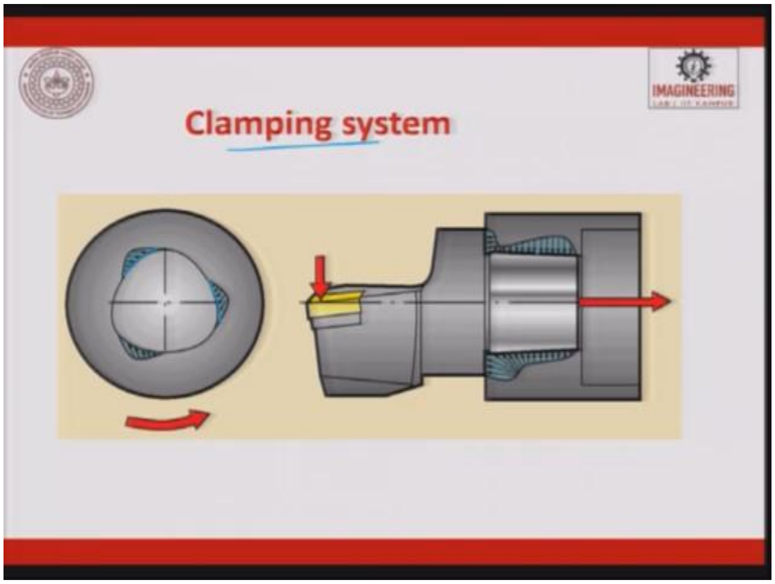

So the clamping system you can have a clamping system like this. So here you can see these, this is used for machining. And here you have made some small grooves, so these grooves are used for clamping it.

If you go and look at the example of a typical pressure cooker which is used domestic, you will have at an angle you can go and lock it and then it gets locked. So this is a typical clamping system which is done. You can use hydraulics, or you can use spring loaded for clamping.

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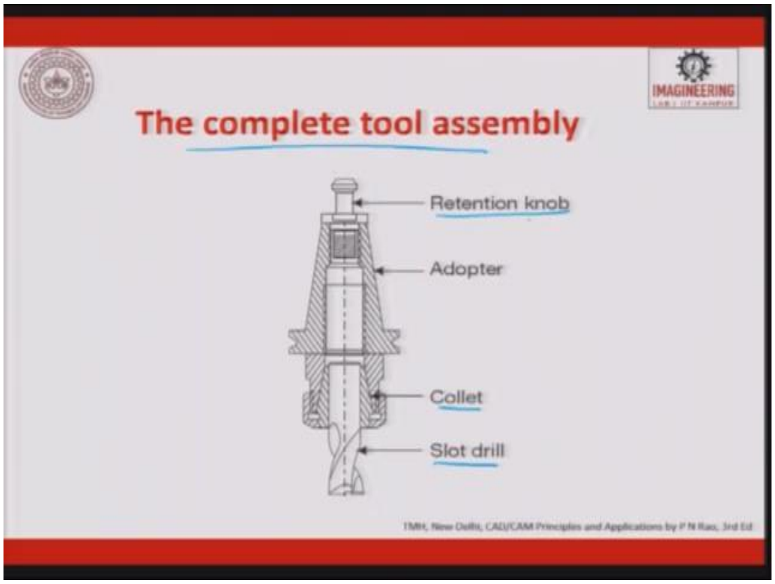

When we look at a complete tool assembly for a milling cutter, you will see or a slot drill, so this is a slot drill. This is fixed inside a collet. This collet has an adapter, this is an adapter, this is a collet. So this is a collet. This collet is spring-loaded. So you can press fit it and then get it removed.

So then you hit it from the back or you shake it, it comes out. So next you, this collet is attached to an adapter. This adapter in turn is attached to a retainer mob, retention knob. So this knob is used for locating it on the machine tool. So this is retention knob.

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So this is the retention knob. It looks like this. The retention knob as used in the tool of tool assembly for clamping and releasing purpose as used in a CNC machining centre. This is a retention knob.

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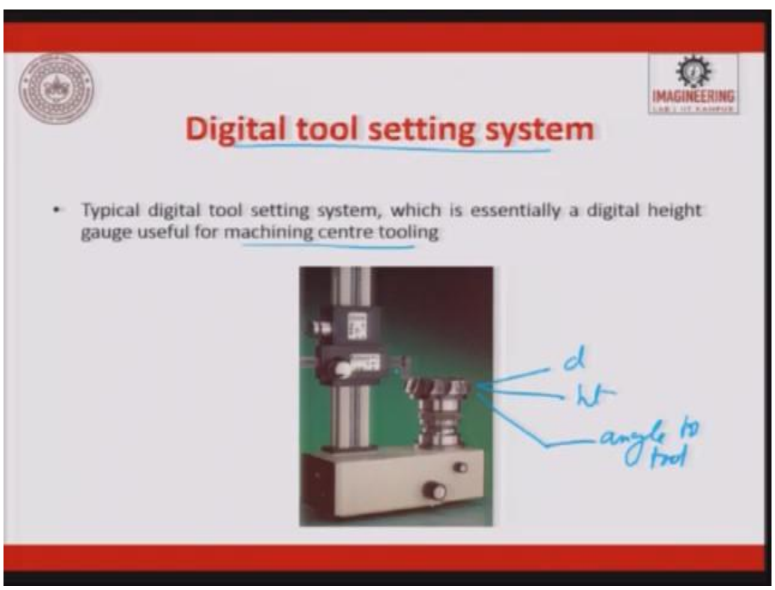

So while inserting the tool, insert inside a tool holder, it is not so easy. There are so many angles which are to be maintained apart from the height and the diameter. So when we use this CNC machines, in the CNC machines itself you will always have a digital tool setting system. So this will check for diameter, this will check for height and it will also check for angles to tool. So that it is exactly set and then you do.

Tool setting is a big challenge, insert setting inside a tool is a big challenge. So here it is really a skilled job. So typical digital tool setting system which is essentially a digital height gauge useful for machining centre tooling arrangements or tool angle maintenance.

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So today we also have tool setter integrated into a CNC machines. So you have a knob which is attached. This is a tool and this is an arm which is attached and here is a tool setting device, which gives you the measurements. So if you want to check the height of the tool, diameter of the tool, you can check it and accordingly this will be entered into the register.

And CNC program when it calls for the tool, it takes rest of the data and then starts using it for machining. So typical tool setter integrated with the CNC turning centre helps to correct the position of the tool.

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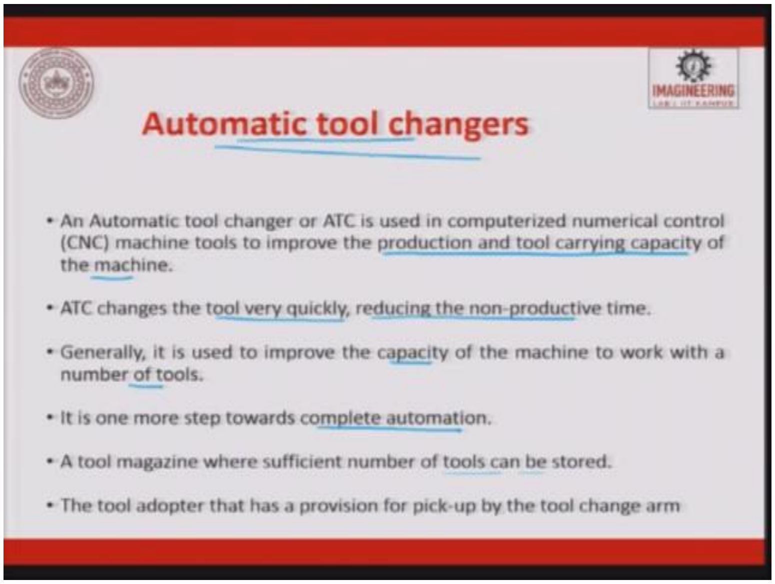

So now we have seen about the tool material and then tool holder modularity. Now let us see a very important thing which is called as automatic tool changer. So like we saw automatic pallet changer for improving the productivity, we will also see here automatic tool changers. This is to change the tool from one to the other, such that in a single setting you can do multiple machining operation.

An automatic tool changer or an ATC is used in computerized numerical control machine tool to improve the production and tool carrying capacity of the machine. ATC is used for tool changing quickly and reducing the non-productivity time. Generally, it is used to improve the capability of the machine to work within a number of tools. It is one more step towards complete automation is having this automatic tool changer.

A tool magazine, tool magazine means a place where lot of tools are being stored. A tool magazine where sufficient number of tools can be stored, we all should have an automatic tool changer. A tool adapter that has a provision for pickup by the tool change arm is called as an automatic tool changer.

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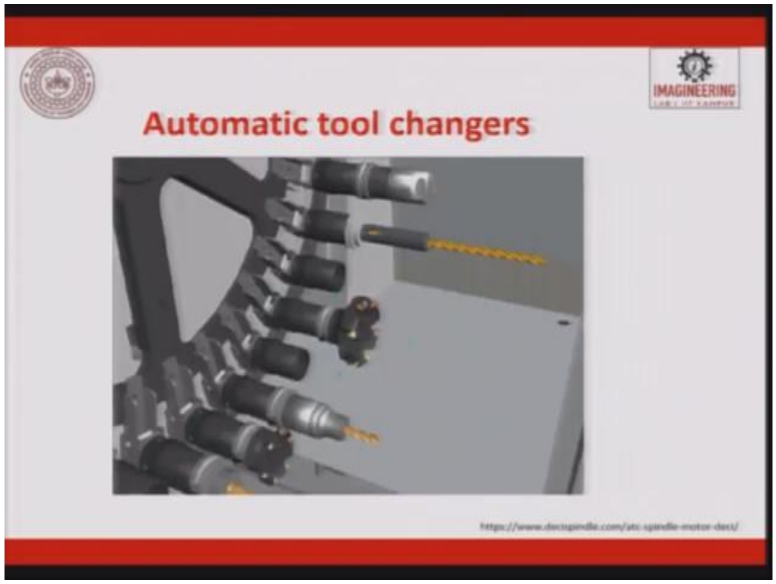

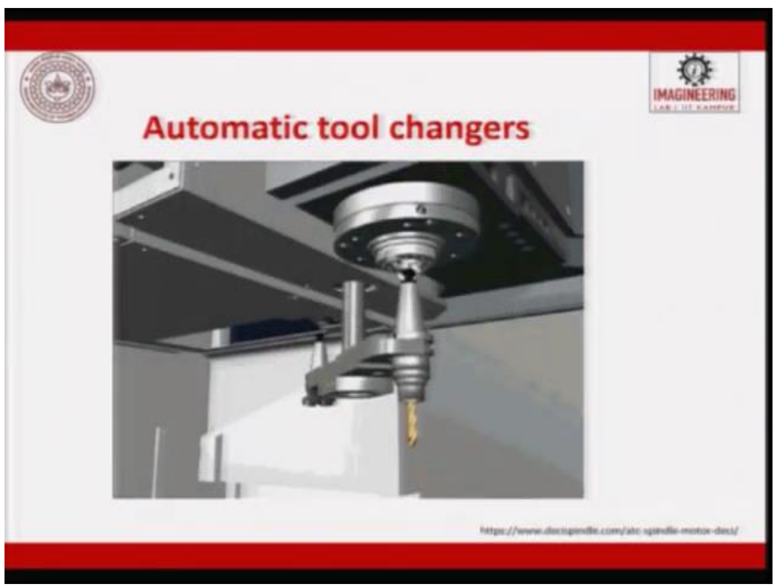

So you can see here automatic tool changer, this is the automatic tool changer, ATC. So a tool which is now removed, removed from it, removed from the spindle. This is mounted and this is put back into the system and this starts doing it. So this is an automatic tool changer.

From the magazine, a tool is removed and from the spindle it is removed, an arm which just swivels around the axis and it is used for. This is predominantly controlled by pneumatics or hydraulics. This automation helps to load multiple tools in a CNC machine for machining.

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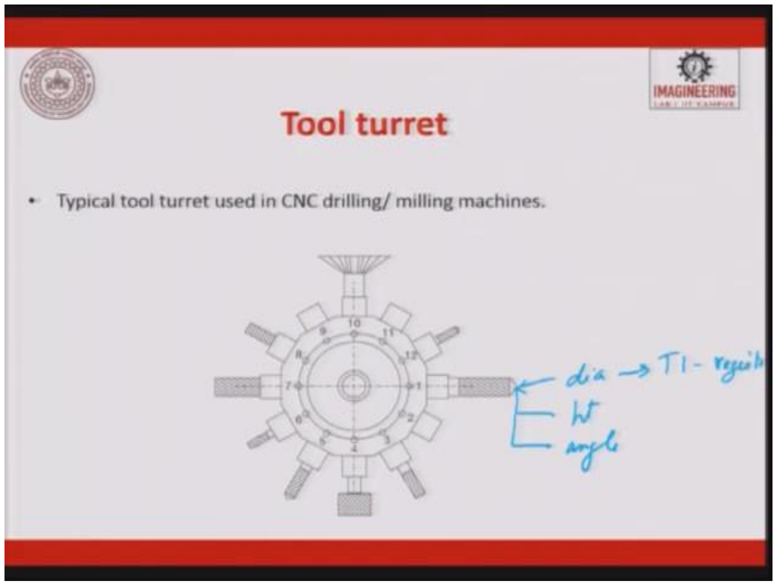

A typical tool turret used in a CNC drilling, milling machines, they will have 10 turrets, so 10 different tools. So the tool diameter varies, the tool height varies, the tool angle varies. So all these things are varied. So depending upon the requirement, each tool has a number and then it has a register. So in this register, all the tool details are stored.

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A CNC drilling used in a tool turret, this is what is a tool turret which is used. So for drilling operation, this is a CNC machine. This is an interface where you can write program, you can see simulations here.

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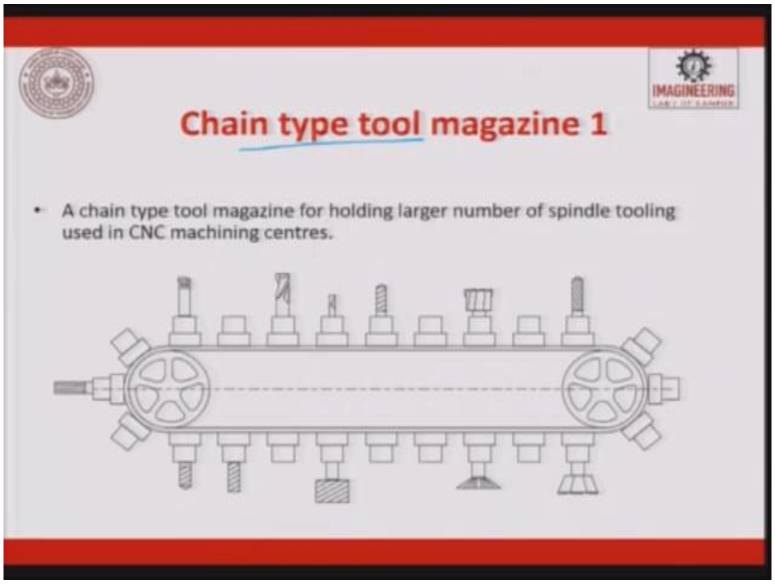

So there is a chain type tool magazine. You can have more number of tools, so you will have something like a chain type. A chain type tool magazine for holding large number of spindle tools used in a CNC machines.

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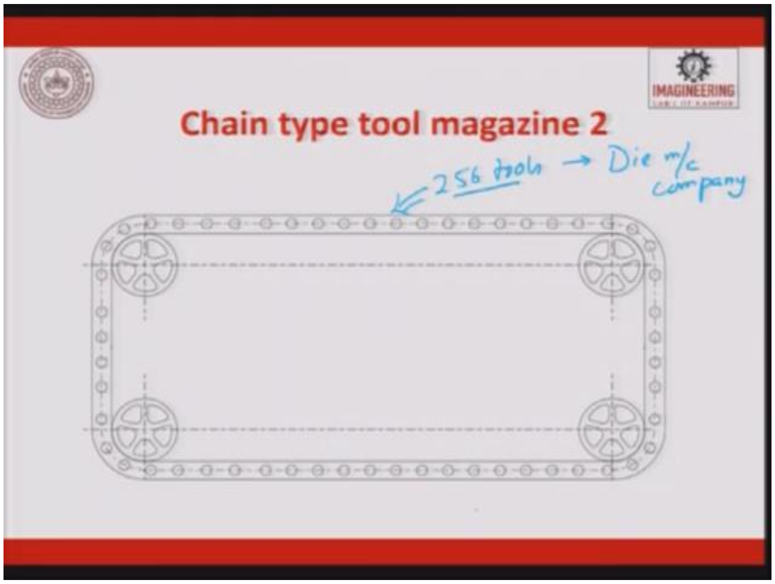

So if you want to have more, you can have, today we are talking about 256 tools to be held in a die manufacturing company, where you will have 256 tools mounted on a single CNC machine.

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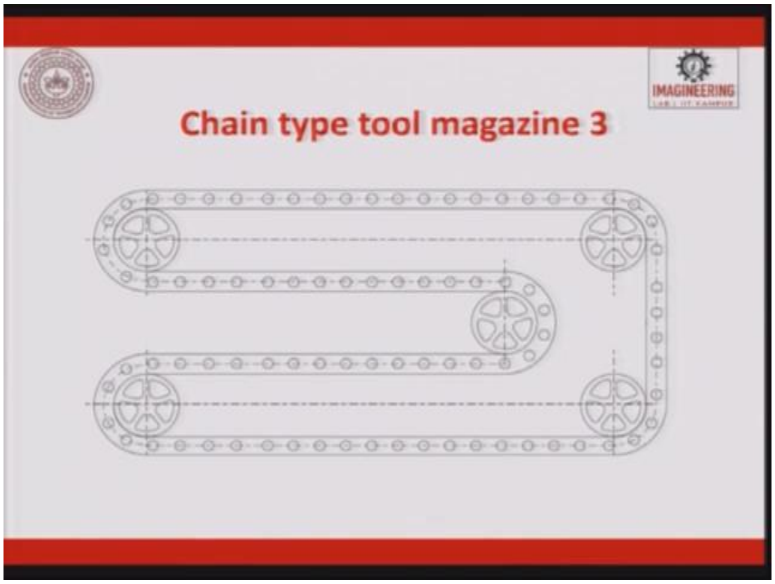

So more, more type of complex. So this is a chain type, so you will have more number of tools which are loaded.

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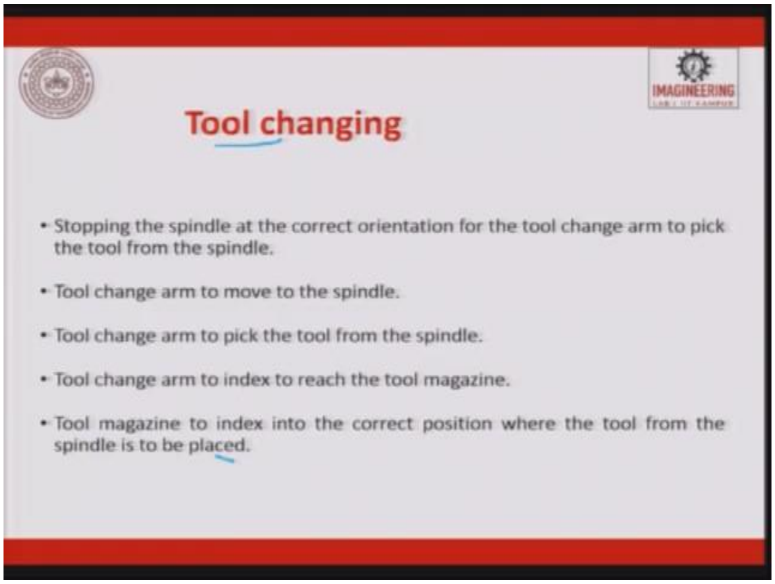

Tool changing, stopping the spindle at the correct orientation to, for the tool change arm to pick up the tool from the spindle. These are the steps which are involved. Tool change arm to move to the spindle, then the tool change arm to pick the tool from the spindle, the tool change arm to index to reach from the tool magazine to reach there.

The tool magazine to index into the correct position where the tool from the spindle is to be placed. So removing it from the spindle and placing it at the location at the exact location so the chain indexes can come to that point, so you can press and keep your spindle.

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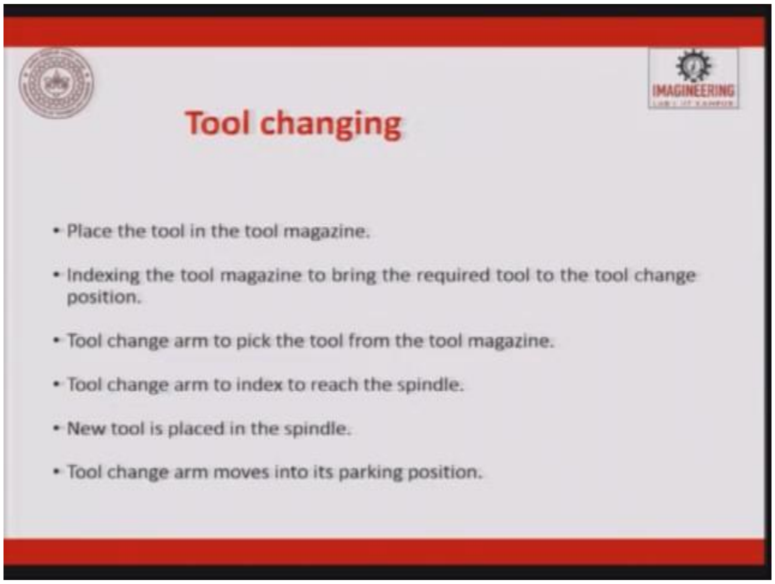

Place the tool in the tool magazine. Indexing the tool magazine to bring the required tool to the tool changing position. Tool changing arm to pick the tool from the tool magazine. The tool changing arm to index to reach to the spindle. A new tool is placed in the spindle. The tool changing arm moved into the parking position.

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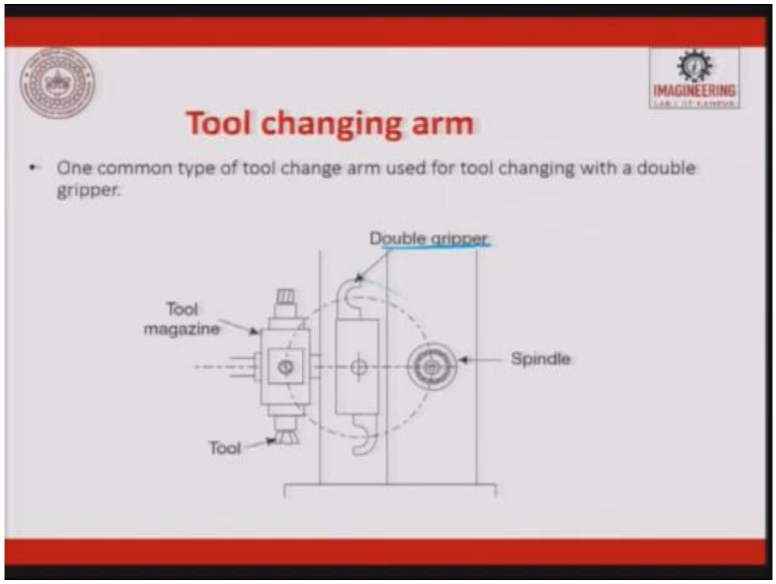

So this is what is the double gripper attached to an ATC, automatic tool changer. Tool here, tool magazine here and then this is the spindle where this comes and removes this and puts it back into the magazine.

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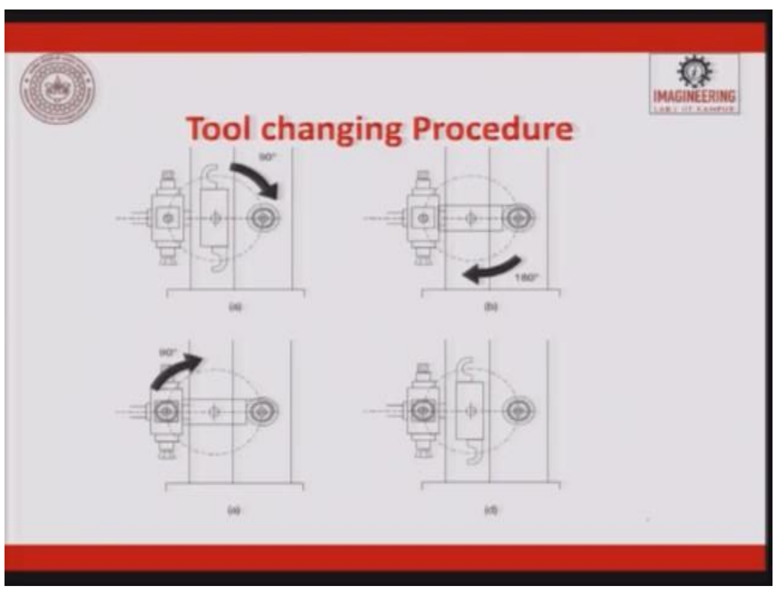

So these are procedures which we explained inward are clearly explained here. So it has to index 90 degrees, 180 degrees, 90 and 180 to get it.

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So a disc type tool magazine. This is a tool magazine which is disc type and this is how does it change is given here.

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So you can have a drum type tool magazine. These are drum type tool magazines okay. So drum type, which is used in CNC machines.

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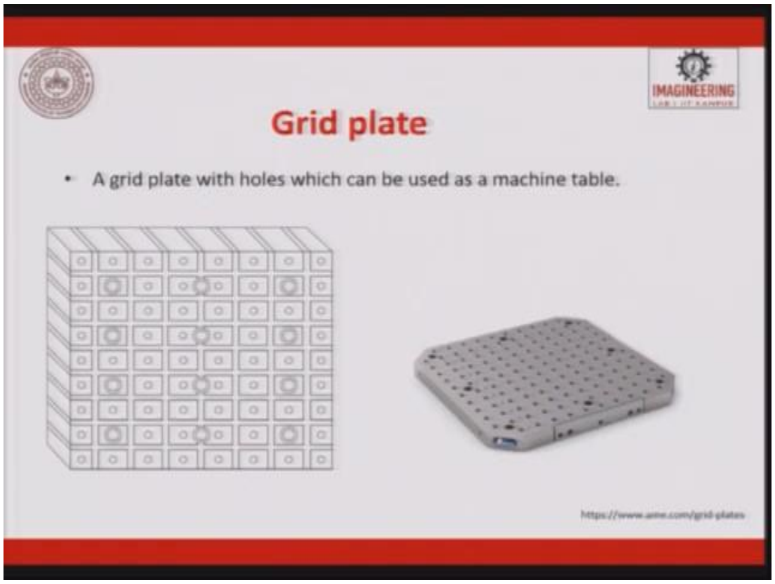

So these are the grid plates which I have already discussed in the palettes. So grid plates with holes which can be used as a machine table which we discussed in automatic tool changer.

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And you can also have a tombstone wherein which this is used to be mounted on top of a table, so different faces can be used for machining.

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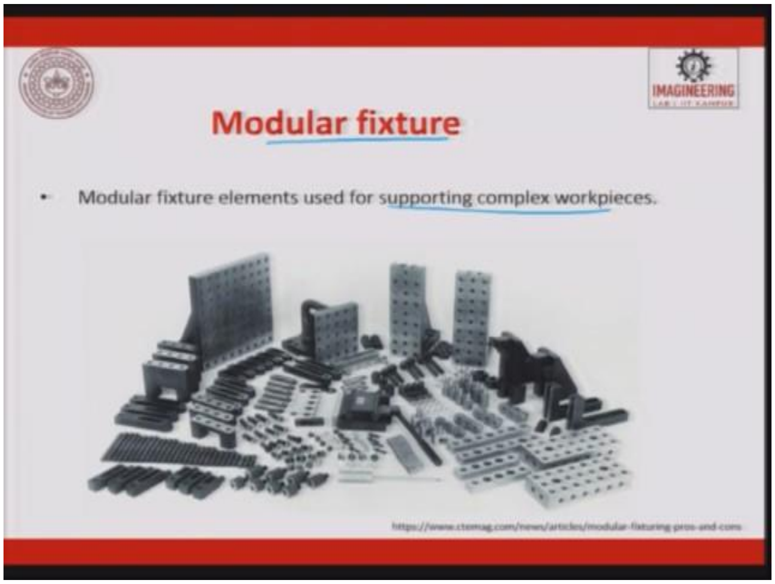

So today we talk about modular fixtures. These are all the components of a modular fixtures. So all these things are used to develop a fixture and support a complex work-piece. So this makes the CNC machine versatile to hold any type of shape or geometry.

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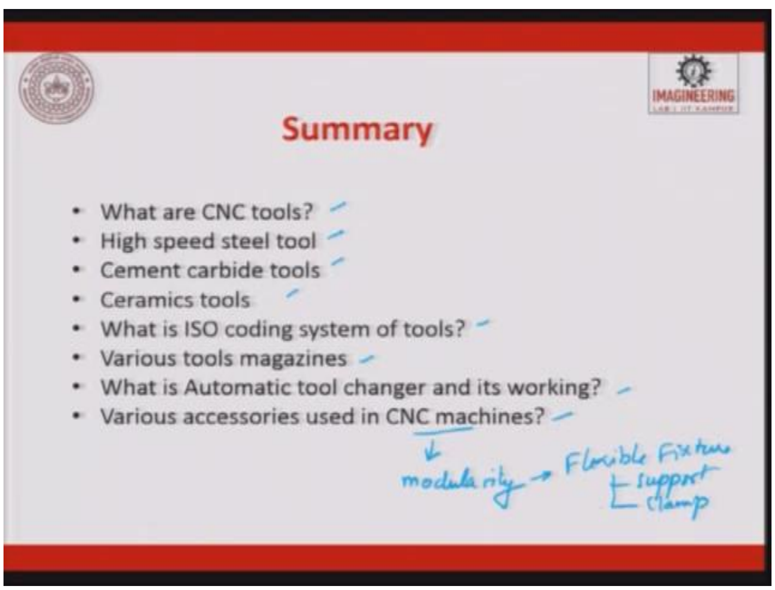

So to summarize what we discussed in this. We saw about a CNC cutting tool. Then we saw different types of tools, then the code which is used for tool, cutting tool, then we saw a code which is used for insert, then various tool magazines, how does a ATC work? And what are the various other accessories which are used in CNC machines? which is towards modularity.

Okay we saw the flexible fixturing, so where it has to support and clamp a work-piece, a complex geometry work-piece. So thank you.