Manufacturing Processes II
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Lecture No. 29
Abrasive Process (Grinding)

Start okay. Grinding machine is basically a machine tool. The distinguishing feature of grinding machine is that, it is using a grinding wheel which is rotor in nature and operating at a very high speed. This is primarily used for achieving high accuracy and high finish which cannot be otherwise achieved by normal machining. This is also one process which can be used on the work material which are hardened on which normal conventional machining cannot be performed. However with RND effort and advent of various techniques, machines and grinding wheel the face of grinding has been totally changed. As on now, this process can be efficiently used for not only grinding harden material for finishing purpose. But also, high stock removal is also possible not only on harden material but on soften material. Now broadly these grinding machines can be classified into 4 major categories. Number one, we have surface grinding machine. Number two, Cylindrical grinding machine. Three, internal grinding machine and the fourth one is tool and cutter grinder.

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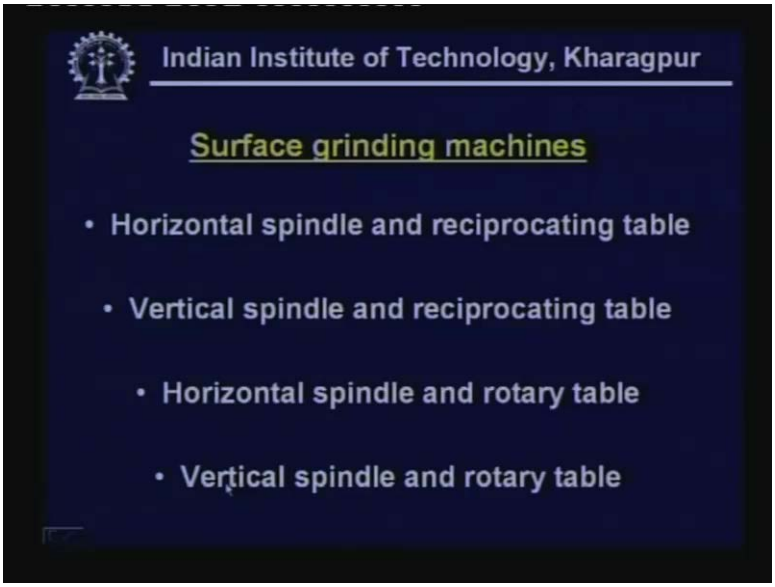

Surface grinding machines: In this particular category, at least we can see there are four machines. One is horizontal spindle and reciprocating table, the second one is vertical spindle and reciprocating table the third one horizontal spindle and rotary table and the last one vertical spindle and rotary table.

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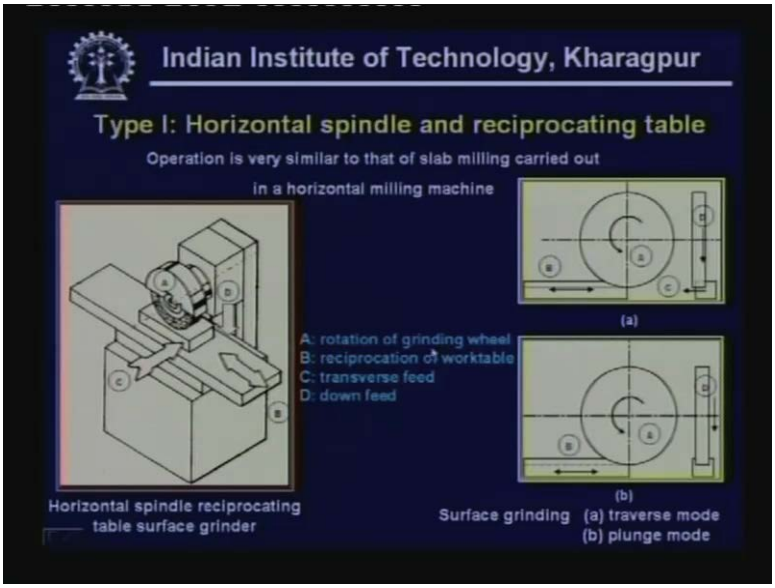

Now we see the machine which is known as horizontal spindle and reciprocating table. This is the schematic illustration of the machine. The basic parts are the column of the machine which houses the spindle, the wheel head, the base of the machine, the settle, the work table. Now here to accomplish this grinding action, we need at least four motions. This is rotation of the grinding wheel, then we have reciprocation of the work table, transverse movement of the work table and also the down feed of the wheel. Now this rotation of the grinding wheel that provides the primary cutting motion which is responsible for formation of the chip. Now to continue this grinding action over the entire length of the job, we need this reciprocation of the work table. Again to continue this grinding action over the entire width of the job, we need the transverse feed and the forth one that is the down feed that is necessary to have the removal of the thickness layer by layer.

Actually if this is the machine, where multi pass operation has to be carried out to reach the desired dimension. Now here, this is the spindle that motion to the spindle is imparted by a motor either it can be directly coupled or through a belt drive. This speed which is provided by the motor, it can be either a single speed or with some sophisticated electrical or electronic control, we can also have a variable speed drive. Then, we need the reciprocation of the table which is normally provided by a hydraulic drive. Now in the hydraulic circuit, we have a throttle valve and this throttle valve can be properly controlled to regulate the reciprocating motion of the work table. In addition to that in synchronization with the work table, this traverse feed can be also provided at the end of each stroke and which happens to be an intermittent feeding in the transverse direction.

Now the down feeding is necessary to provide the depth of cut that means, removal layer by layer and this down feeding is provided on the wheel head. Now in many machines, the transverse feed and the down feed can be provided in synchronization so that, at the end of each stroke this transverse feeding and down feeding is possible. Now with this machine, at least there are two modes of grinding. One mode is called traverse grinding where this traverse feeding or

the transverse feeding of the work table is necessary. In this case, the width of the wheel is less than the width of the work piece. So to cover the entire width of the work piece we have to provide the transverse feed. Now there is another mode of grinding which is known as plunge mode grinding. In plunge mode grinding, we do not provide the transverse feed. The whole grinding action is restricted to the full width of the wheel that is a shallow group grinding or in another option, the width of the wheel can be more than the width of the work piece. So in that case, this grinding can be done over this entire work piece.

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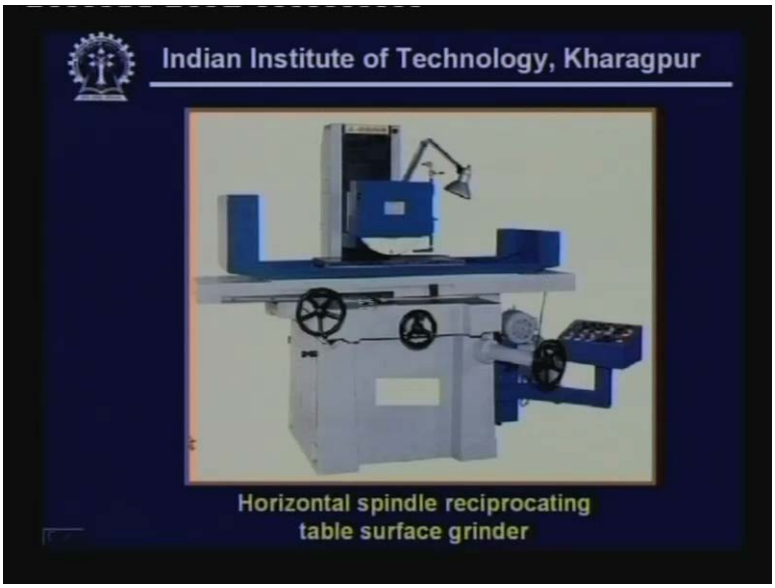

This is the actual photograph of a typical surface grinder. This is the wheel head, the column, the base, this is the work table. We can see three hand wheels one two three. This one is used for manual movement of the work table in the longitudinal direction. It can be of course automatically fit, this one this will be used for transverse moment of the work table and the third one that is to provide the down feed for the wheel this grinding wheel.

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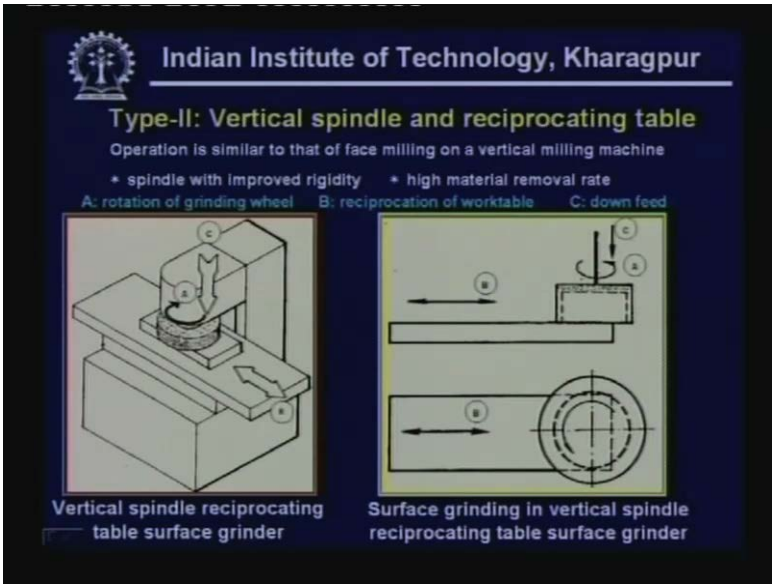

Now what we have seen in the surface grinder that is actually very similar to the slab milling operation very similar to the slab milling operation. But now we see the vertical spindle reciprocating table surface grinder. Here we have all the basic features of a grinding machine: namely the column, the base, the settle, work table and the wheel head. Here of course, the wheel axis that is vertical and also if we can see carefully the wheel it is a cup shaped wheel. What has been used in a horizontal spindle reciprocating surface grinder, that is a circular wheel and this one is the cup shaped wheel.

This spindle provides a better rigidity compared to a horizontal spindle surface grinder and this is used for those cases where high material removal rate is necessary. Now in this case also one ping should be noted that, usually that transverse feed is not provided. As we can see in this illustration, the diameter of the wheel is quite large. It covers the entire width of the job, as a result just by providing this reciprocating motion on this work piece the entire width can be well covered by the grinding wheel. Here also, we have the basic primary motion on the wheel, the feed motion on the work piece, and the down feed on the wheel head. Now we go to the third one which is horizontal spindle rotary table surface grinder.

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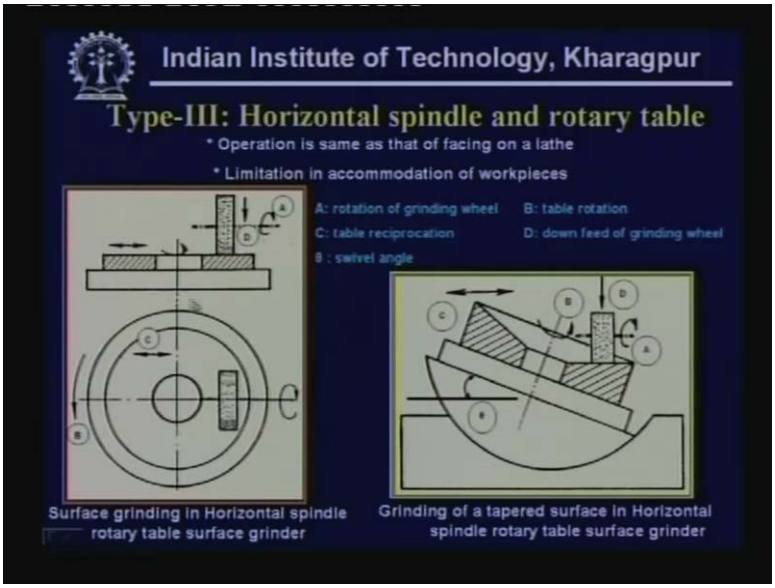

Here what we can see that instead of a reciprocating table this work table rotates. At the same time, provision is made to have reciprocation of this table. Actually, this machine is not commonly used because of some limitation in size of the work piece which can be accommodated. But one of the basic advantages we can recognize here, on this machine on the work table, we can put a cradle and this cradle can be rotated about one horizontal axis as we have seen this cradle has taken a slanted position and this can be done by just rotating by swiveling through an angle theta. What we achieve here? In this case we can see with this grinding wheel, we can generate or cut it taper on the work piece. Now following this same principle we can also get a concave surface or a convex surface on this work piece. So that is the special feature of this grinding machine.

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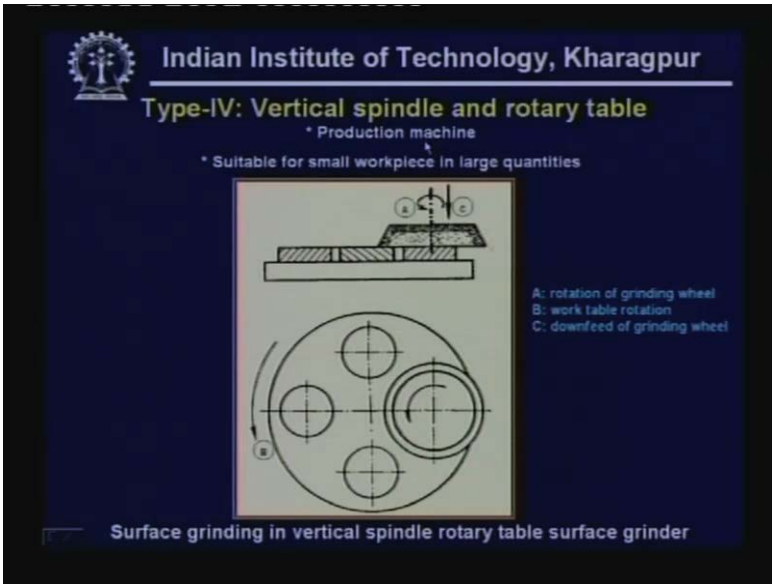

Now we go to the fourth one of its class that is vertical spindle and rotary table grinding machine. This is a surface grinder and this is a production type machine. What is the advantage? The basic advantage is that small size work pieces in large quantities can be accommodated in a circular form on this work table and this work table just rotates continuously along with the rotation of the grinding wheel. This grinding wheel rotates at a very high speed to provide the necessary grinding action and this grinding action is extended over the entire perimeter which is covered by the work pieces. So this is and we have this basic motion the down feed. As is the case with other grinding machines and in this case this is called the down feed to remove certain thickness from the work piece.

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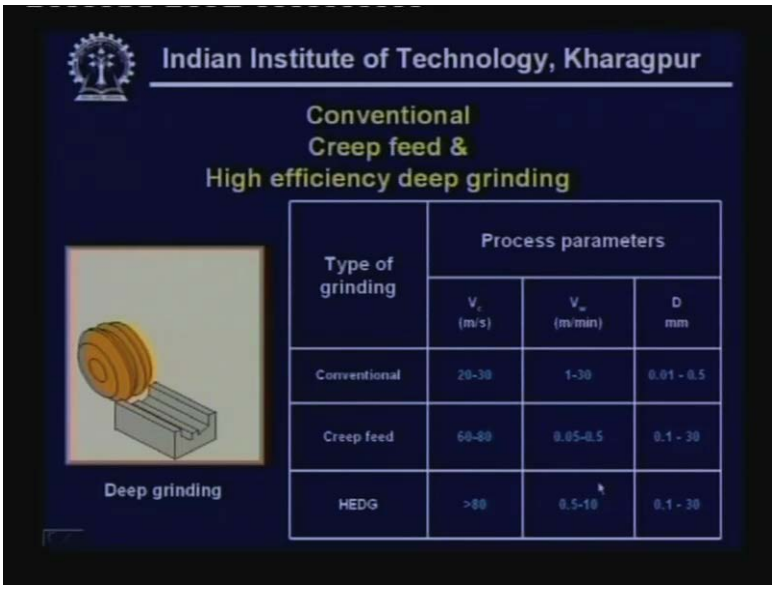

Type of grinding	Process parameters		
	V_s (m/s)	V_w (m/min)	D mm
Conventional	20-30	1-30	0.01 - 0.5
Creep feed	60-80	0.05-0.5	0.1 - 30
HEDG	>80	0.5-10	0.1 - 30

We can see that this surface grinding principle can be used at least for three machines. One is what just now we have discussed the conventional one which is a reciprocating one. The second one is the creep feed grinding and the third one is high efficiency deep grinding. If we look here, a wheel is engaged to have a deep grinding on a work piece. Now we can have our attention into the stable where we can see the working range is of various machines. If we see the conventional machine at least what we can find? The reciprocating motion is in the order of 1 to 30 meter per minute and that is drastically reduced in the creep feed. Creep feed means feeding of the job at a very slow speed that is why it is called creep feed and we can see the value its quite low compared to what we can see for the conventional grinding.

Actually conventional grinding is a multi-pass grinding whereas creep feed is a single fast grinding. Now what is the advantage? We can extract out of this creep feed grinding? The main advantage is that wheel need not rub over the work piece for a number of times during multi pass. In one pass we can complete the grinding, also during the engagement of the wheel with the work piece, there is some kind of impact and that can have some effect on the performance of the grit, their life, wear resistance and so on. So these are the two things which can be totally avoided in the creep feed grinding another thing is also there that's cutting velocity has been elevated from 20 to 30 meter to 60 to 80 meter per second. From the principle of grinding, we know that under a given set of grinding that means conditions that means this depth of cut and the table speed if we keep on increasing the grinding velocity then, the specific load per grit which is participating in grinding can be substantially reduced and that is where this creep feed grinding enjoys at and clear advantage over the conventional grinding.

So just by increasing this grinding velocity, we can reduce also the load per grit. As a result, the wear resistance of the grit or the grinding ratio of the wheel will be quite high compared to what can be obtained in case of conventional grinding. Now this creep feed grinding has been found to be quite effective in holding the profile of a grinding and this profile grinding needs a profile wheel and the holding the contour of the wheel is of extreme importance over a period of time that means holding the accuracy and in that respect the creep feed grinding is clear advantage over conventional grinding. Now we can see what we call high efficiency deep grinding. As we have seen here that, this V w and the D, these two are the parameters which controls the material removal rate in grinding.

Now in creep feed grinding that has been substantially reduced, but to gain some advantage by elevating this V w, what is the solution left only to increase the wheel speed? Just now, as we have understood that under a given condition, if we can elevate the grinding velocity then again load per grit can be reduced. Now if we increase this grinding velocity to a very high value load per grit can be reduced and that allows us to again elevate the table feed so that, the whole productivity can be augmented. However one thing should be remembered clearly that a conventional surface grinding machine where we have high velocity that cannot be just used by lowering the speed. It cannot be used for creep feed grinding. The reason is that here we have a large arc of contact. This large arc of contact generates high rubbing force, high temperature.

So in that case, creep feed grinder needs improve rigidity, high spindle power and last but not the least efficient cooling system for cooling the job and for lubrication. This high efficiency deep grinding which is used for improving the productivity there also we need extremely high rigidity,

stiffness, high power spindle and efficient cooling system and as on now, this speed can be elevated to a value as high as 200 meter per second. Already RND has been successfully carried out with a speed of as high as 500 meter per second. Actually this is a class of machine which is going to be a substitute for normal milling operation and this particular process can be called as abrasive milling, instead of just deep grinding. So this is one of the areas where which finds a lot of use for replacing the abrasive, this conventional milling by abrasive milling:

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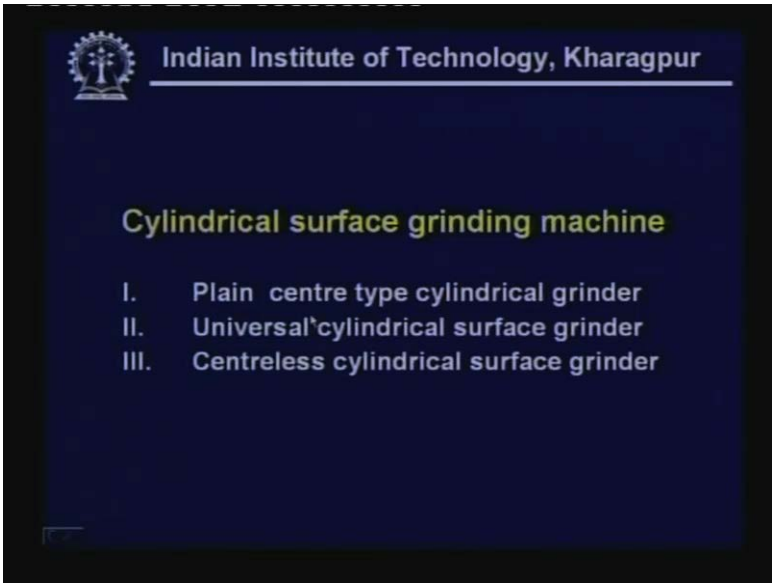

Now we go to cylindrical surface grinding machine. In cylindrical surface grinding machine, we see that at least there are three types of grinding machine. One is plain center type cylindrical grinder. Number two is universal cylindrical surface grinder and then the third one is centre less surface grinder. Now the plain center type surface grinder as we see here, this is very similar to operation just like turning in a center lathe.

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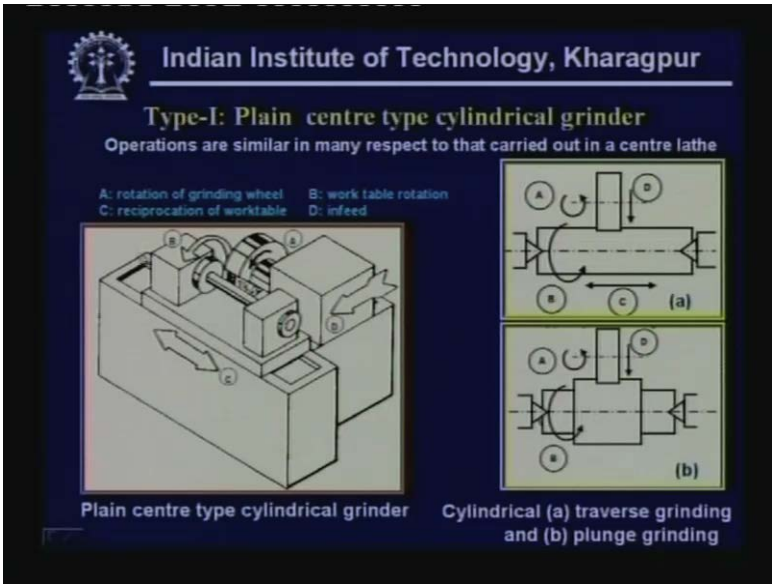

This machine has various parts like the base, the table, wheel head, wheel head slide, the headstock and the tailstock. At least four motions are required; rotation of the grinding wheel, work table rotation, then reciprocation. This is actually the rotation of the work piece, reciprocation of the work table and the in feed to provide the depth of cut. So this machine the wheel provides the necessary grinding action which is the removal of the chip then this reciprocation provides the necessary feed motion to extend the cutting action over the entire length of the job.

Rotation of the work piece is necessary to have the grinding action over the entire perimeter and in feed is required to have the depth of cut. This machine can be also used in two modes namely, one is the traverse mode where the table needs this reciprocation. We have another option that is the plunge cut mode. In the plunge cut mode, this reciprocation of the table is not necessary. Here a shallow group can be cut, covering the width of the wheel or the width of the work piece may be less smaller than the width of the wheel. So that the wheel can do the necessary grinding operation. Here also a motor is used for providing the necessary grinding motion and the table feed that means the reciprocation of the grinding table that is provided by a hydraulic drive.

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This is actually the grinding operation been conducted on a cylindrical grinding machine. This is the wheel which is quite large compared to the work piece which is held between to center supports, there is an application of the fluid. Normally the wheel diameter is quite large compare to the diameter of the wheel it is just to have enhancement of the wheel life so that, the grinding action is distributed over a larger perimeter of the wheel. So this gives us a longer life of the wheel. Now we go to the next one.

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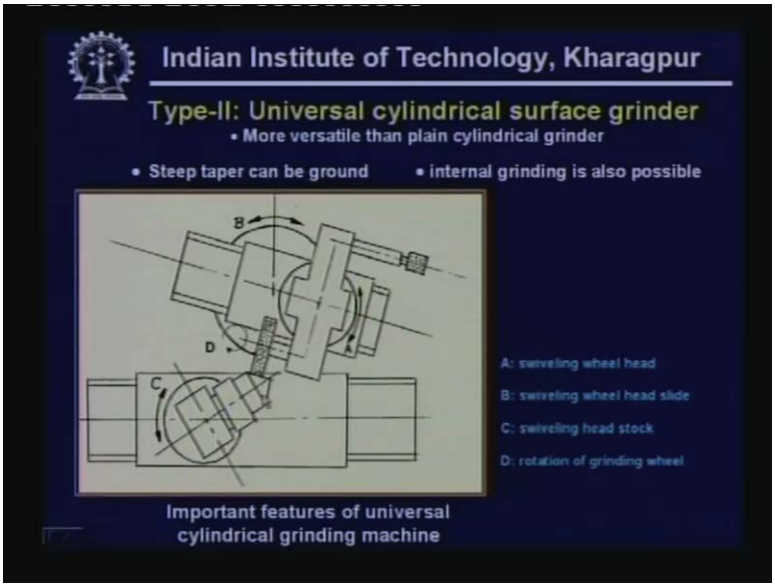

This is universal cylindrical surface grinder. Now what we have seen? In the plain surface grinder apart from straight cylindrical grinding, a small taper can also be ground just by

swiveling the table. This centers but when a steep taper has to be ground, then we need better flexibility, better versatility and that is provided in this universal cylindrical grinder. What are the important features of this? We can see we have a swiveling wheel head mount. In addition to that, the wheel head slide can be also swiveling, then we have further to this, we have the swiveling headstock. Now this allows us, to grind a steep taper as is illustrated in this figure. In addition to this, we have a special feature that means an internal grinding spindle is also provided that means on the work piece where OD grinding that means outside grinding is done. But in the same setup a bore grinding is also possible by just rotating this wheel slide in proper position and to use this small grinding wheel for the necessary bore grinding that is the special features of this machine.

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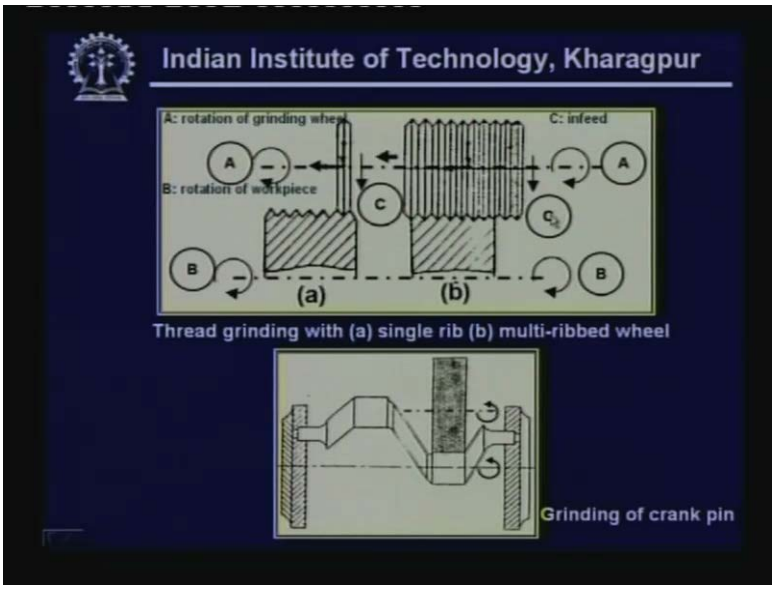

Now we go to a special machine which is dedicated for grinding of thread instead of machining direct thread grinding is also possible. As is illustrated in this sketch we can use either a single ribbed wheel it is a form wheel having the form of the thread confirming to the thread angle and her it is very similar to thread milling. We have the necessary rotation to provide grinding action, then rotation of the work piece and the linear motion which gives the necessary feeding and to get the helical profile on the thread. Instead of a single ribbed wheel, a multi ribbed wheel can also be used in this machine, and here that same thread grinding operation can be done with the use of this multi ribbed wheel.

In addition to this, these are the special application as we have already mentioned. This is a grinding of crank pin as illustrated in this schematic diagram, this pins which goes inside the crank and this needs also finish and this can be done on this cylindrical grinding principle only the feature which is different from the conventional plain cylindrical grinder is that we need a special chuck, a special job holding device, so that it can be correctly positioned. So that, this pin can come exactly in the center of the machine and the grinding wheel can now participate in grinding action. So this is actually grinding of crank pin in a crank shaft grinder.

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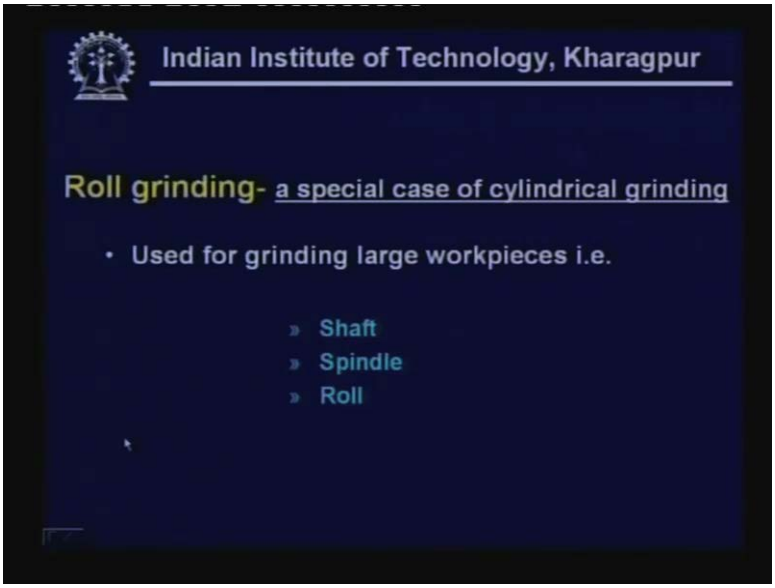

Now as an extension of this cylindrical grinding, we have also roll grinding machines. These roll grinding machines are quite large in size. These are used mainly to handle large work pieces like shaft, spindle and rolls which are used in rolling mills after machining in roll turning lathe, it needs further processing that is to achieve improved accuracy and finish and that can be easily, effectively accomplished in this roll grinding machine.

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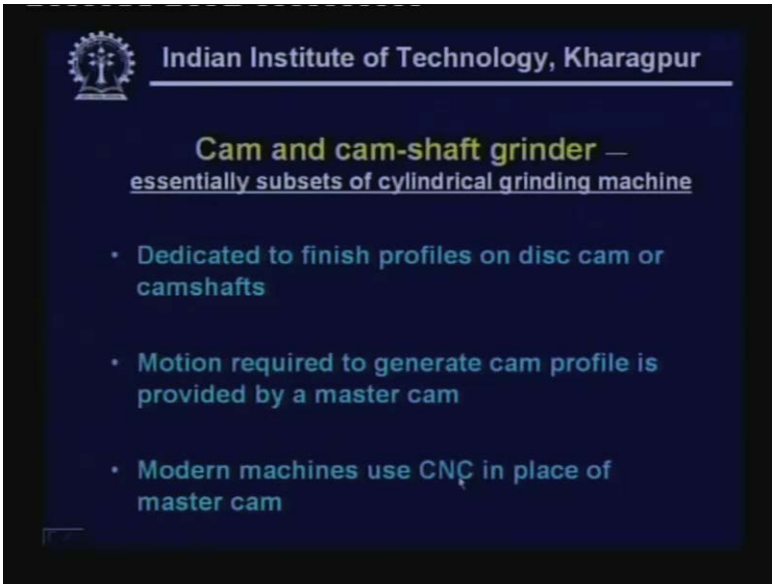

We have also subset of this cylindrical grinding machine and which is nothing but a cam and cam shaft grinder. Now we need to grind the cam which has a particular profile and that profile has to be followed during grinding. So these are all dedicated machines. This dedicated machines

are used to have finishing of the profile on a disc cam or directly on the camshaft. Now here what is necessary to generate the particular motion which follows the profile of the cam and for that, a master cam is employed to give this rocking motion in this particular machine. But the modern machines are equipped with a CNC which can be more flexible and effectively used to have the complicated motion of the grinding machine which includes the motion of the grinding wheel and that of the work piece in place of a master cam. So this CNC gives better flexibility and versatility.

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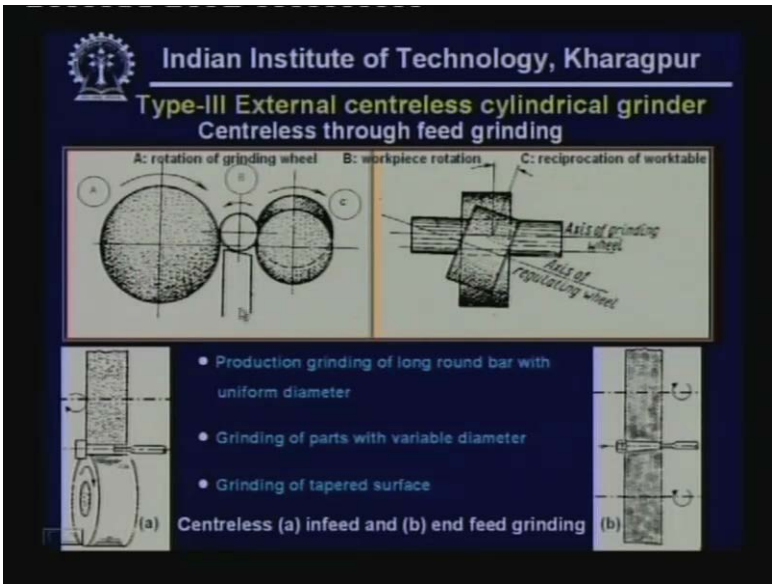

We have also the third type that means external center lathes cylindrical grinder. Now center lathes means, this machine does not require any center support either from the in the headstock or in the tailstock end. The basic features are shown here. We has the grinding wheel, then this is the work piece this work piece is supported by a work rest and on the right hand side, we have a regulating wheel. So these are the basic elements which are essential for this center lathes grinding. If we have a look into this diagram, we can see that axis of this regulating wheel is not parallel to the axis of the job or axis of the wheel either. It is little inclined, the whole idea is that we have to provide the necessary rotation to this work piece as well as the linear motion to provide the necessary feed.

Now if we can have little inclination on this regulating wheel, a component will provide the necessary rotation as can be this component can be resolved this velocity can be resolved into two components. One along this tangent and one along the axis. So this tangential component gives the necessary rotation and this axial component gives the necessary feeding. This particular grinding techniques is suitable for grinding long bars. So, this is center lathes grinding and it is known as through feed grinding through feed. But, there are occasions where this particular work piece has a larger section like a head at the end. In that case, through feeding is not possible but in that case we have to go for center lathes grinding but just by in feeding the wheel. We can do the necessary grinding that means reduction of the size or rectification of the size and from the right hand end, there is a stopper which controls the basic length of the grinding wheel of the

work piece. We have also the end feed grinding, as illustrated here in this case, this is particularly used for grinding a taper on an work piece. We have this feeding, there is a stopper which controls the length. However in this case, we need the particular taper form also done on the grinding wheel as well as also on the regulating wheel.

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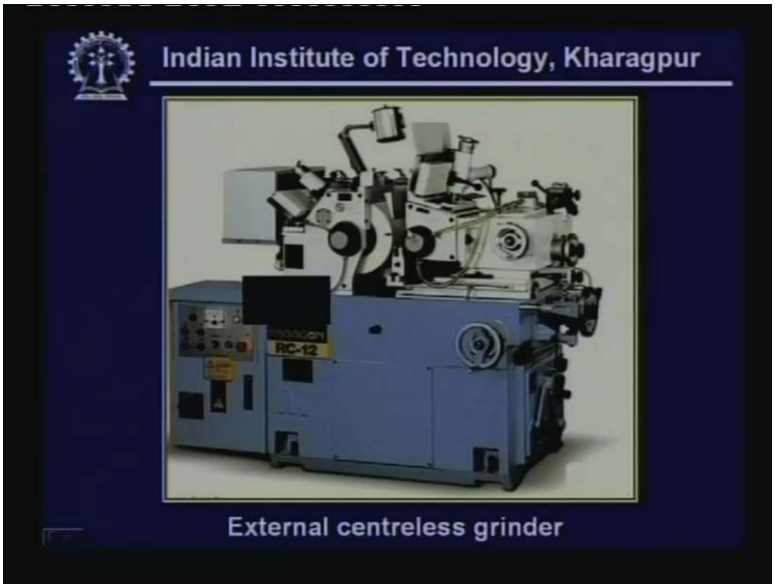

So this is the actual the picture of a center lathes grinder there we have the grinding wheel and this does not have any center support so long rods are used for grinding in this machining.

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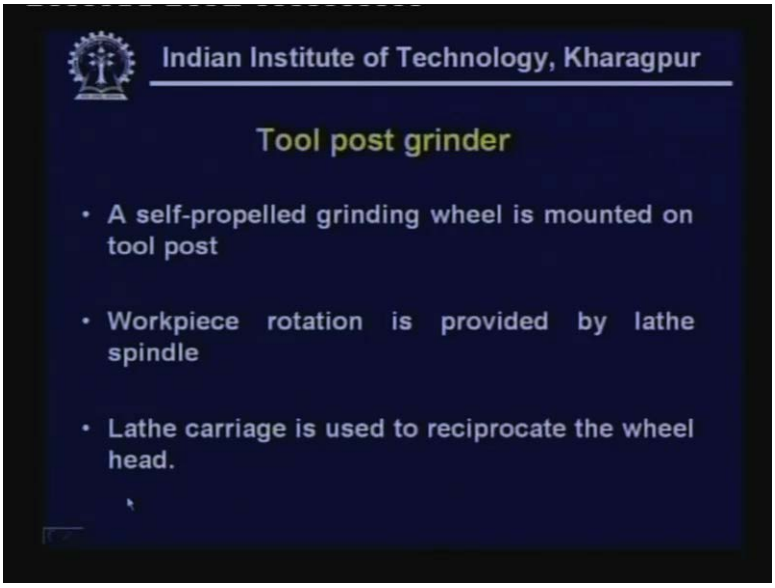

We have also a tool post grinder. This tool post grinder is actually an add on. It is an add on means, it is a self-propelled grinding wheel which is used for grinding a small round piece on a work piece which is turned again in that lathe. Now in this case, what happens? Just that tool post is removed, and there on the tool post this self-propelled grinding wheel is used. Now this grinding wheel used can be used employed for the grinding action, but one ping should be kept in mind that this tool post grinder along with the lathe should not be considered as a substitute for the cylindrical grinder.

The reason as follows, the grinding machines need much improved rigidity, stiffness, ruggedness and those things are consider during the very design stage of the grinding machines. That means, the accuracy and the surface finish which are expected from the grinding machines those are dependent on the basic design of the machine in a very big way. Now the lathe is not constructed or designed following the same logic or principle. So, this tool post grinder can be very easily used to do some job where such accuracy or finish is not that demanding. This much we can say. Now we go to the next one that is internal grinding machine.

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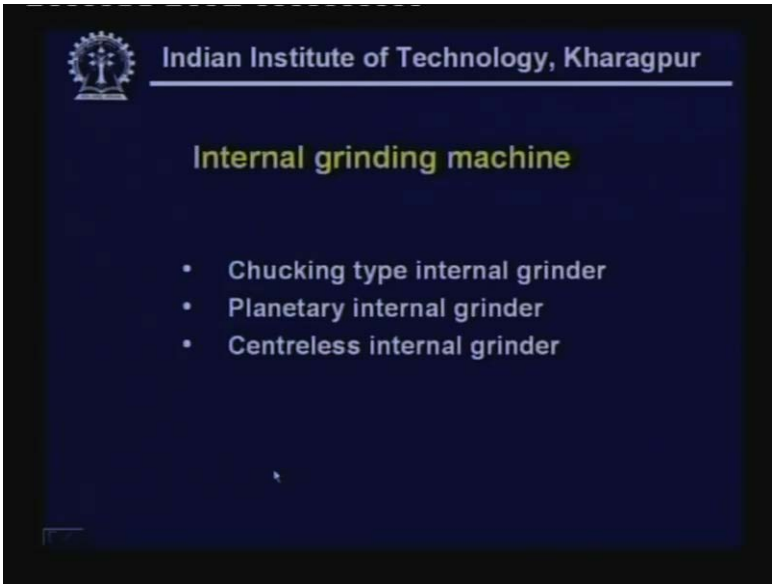

These internal grinding machines are working in the same way as machining a bore in a particular lathe. Now this internal grinding machine can be just chucking type internal grinder, we can have planetary type internal grinder or also we can have center lathes internal grinder.

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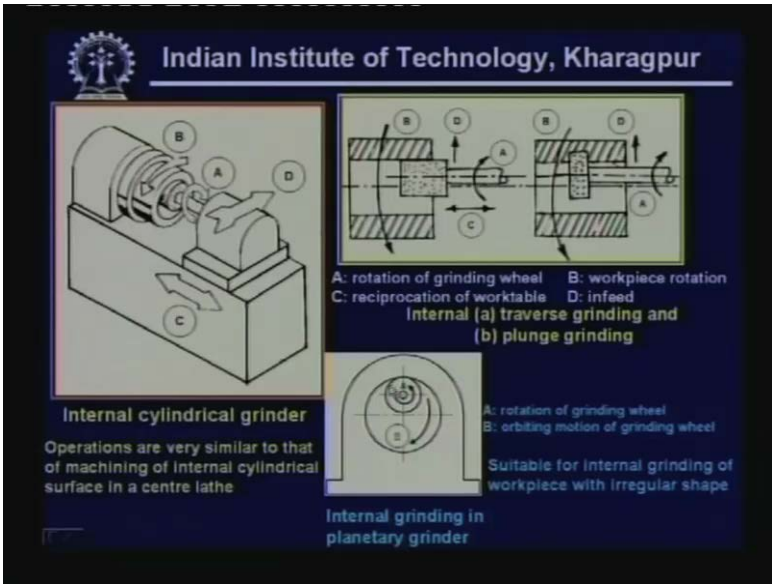

Now here we can see the schematically this chucking type internal grinder. This is a chuck which holds a job which is already having a hole. So this is the chuck of the machine. Here we have a wheel head, this is the base. Now the work piece has a rotation, work piece rotation then we have rotation of the grinding wheel then we have the reciprocation of the grinding wheel. Now in this machine, the rotation can vary from several thousand to just hundred thousand. It depends upon the diameter of the wheel diameter of the wheel may vary for say for example from 20 to 25 millimeter to as low as half a millimeter and that is why to have the proper grinding speed, we need the high RPM on the spindle.

Now in this case also, this reciprocation of the grinding wheel that gives us the necessary grinding action over the entire length of the job. We have two modes of grinding. One is the traverse mode where the wheel has to reciprocate over the entire width of the job or we have plunge cut grinding where we need grind a grove as has been illustrated in this figure, where we do not require any reciprocation of the wheel and this is known as plunge cut grinding. So this is a chucking machine but we have a planetary internal grinder. This is one example of a work piece which is not cylindrical. This outer surface is not cylindrical it is having an odd geometry.

Now if we allow it to rotate, there can be some balancing problem. Now to get rid of this, this is held stationery and the grinding wheel is rotated at the grinding speed to provide the necessary grinding action. But at the same time it orbits. It has an orbiting motion to continue the grinding action over the entire perimeter of the work piece and this way this handling of this job with odd geometry can be quite effective. So this is for irregular shape job. We have now internal grinding which is taking place in actual practice.

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This is one wheel which is used from this grinding action and to have high speed operation to get the benefit of speed we have to use just not conventional aversive wheel but super aversive wheel like cubic boron nitride or diamond. We can safely use cubic boron nitride for grinding ferrous group of materials and for grinding ceramic or non-ferrous material, we can have diamond wheel. So these wheels can provide very longer life and efficient operation, good integrity, surface integrity, good accuracy on the job. So this is one grinding operation internal grinding operation which is taking place in practice. We have also internal grinding operation but without having any support of the chuck.

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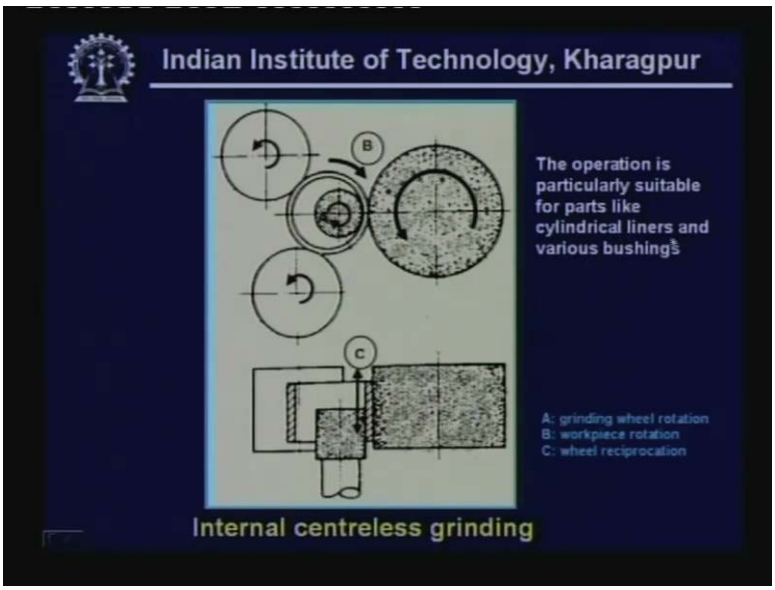

Just we have seen the chuck is used for holding but here we do not require any center support. So this is useful for those cases where we need to grind a long cylinder liner or a bush which has a through hole and it is like a tube. So, internal surface of a tube can be ground by the application of such machine and such technique. This small cercal that shows actually the internal grinding wheel internal grinding wheel we have regulating wheel, we have the supporting wheel and we have a pressure wheel. Now this three gives the necessary support. Now the rotation of the wheel grinding wheel is quite high compared to the rotation of the work piece. Now the rotation of the work piece is provided by this regulating wheel which has sufficient friction between this two. So, that provides the necessary rotation. Here to provide the necessary grinding action, we give this reciprocation on this wheel surface. So this is actually the internal center lathes grinding principle. Now we have tool and cutter grinder grinding machine.

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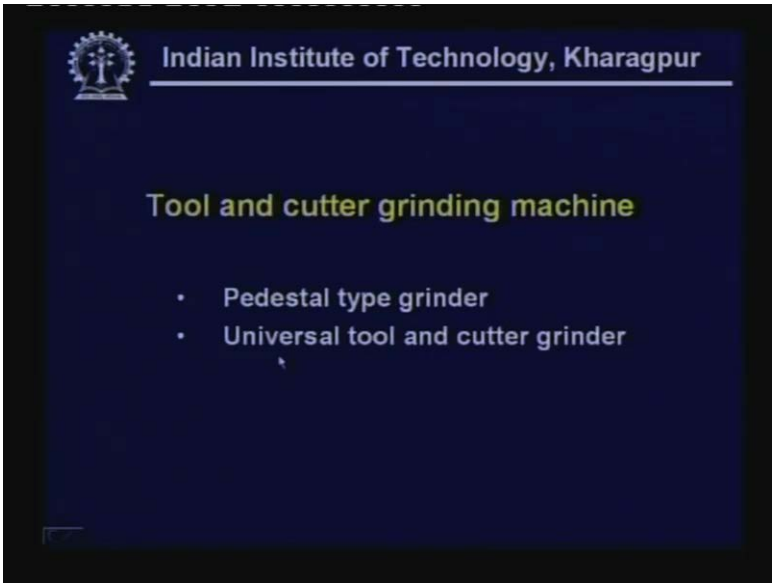

Now tool and cutter grinding is necessary for two reasons. One to sharpen the cutter or the tool which is already blent. Another to produce these tools with proper geometry, after the heat trigment hardening, this needs proper geometry on the cutting point or the tip of the tool and that needs proper grinding and this is used for actually the production of the wheel and in this case we have at least two types of tool and cutter grinder. One is the pedestal or bench type grinder and another is the universal tool and cutter grinder. This is actually a bench type tool and cutter grinder which can be used for grinding very simple single point turning tool which are used in lathe or shaping operation.

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Here we do not use any fixture or voice. Only it is the skill of the operator, which determines the accuracy of the geometry which can be transferred on the grinding on the work piece that means the cutting tool. So if some high level accuracy or finish is necessary then, this type of grinding machine cannot be recommended. So this is basically used for occasional grinding of the tool with very geometry like turning tool or shaping tool. Now we have the grinding machines which are actually used for tool and cutters grinding but these are called universal tool and cutter grinder.

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These are the universal tool and cutter grinder where we can use a three dimensional vice. It is a fixture which can be swiveled in space in three orientations. It has three axis, one vertical, one in the transverse direction and another in the longitudinal direction and with this three, the particular geometry of the cutter can be set and here no particular scale is necessary. The person who understand the basic geometry of the grinding of the cutting tools or the cutter can easily set a vice in proper angle for the necessary grinding action and the grinding wheel will simply generate a surface according to that proper setting and in this case, even a single point turning tool or a complex cutter like end mill cutter, reamers, hobs, this thing can be ground on this universal tool and cutter grinder.

Nowadays of course, we use various types of grinding wheel normally for grinding steel we use aluminum oxide grinding wheel. Here we can see it is a cup shape grinding wheel which can be made up aluminum oxide. Here we can see a peripheral wheel which is used for grinding one end mill cutter and this is used for grinding a face mill cutter and here we can use one aluminum oxide wheel. So this is basically made of high speed steel. But nowadays, this single point this grinding wheels made up aluminum oxides these are nowadays replaced by cBN wheel and for grinding this cutters or the tools raising bonded cBN wheels are efficiently used and at a high speed giving better life accuracy and surface integrity on this particular tool.

The reason is that cBN wheel because of their high surface conductivity, they generate less cutting temperature during grinding and that is indeed beneficial to the quality of grinding and surface integrity which is achieved during grinding of this tool end cutter for grinding ceramic or turbine tools we can use the same machine but there normally we recommend silicon carbide wheels of green variety which is having higher purity compared to the silicon carbide of grave variety. But, even then the wear on this silicon carbide wheel is much higher to the work piece that means in this case, cemented carbide aluminum oxide is not recommended for silica for grinding this cemented carbide, but with the advent of diamond in various grades, the things have been improved further.

Nowadays, this grinding can be performed by this diamond wheel and these are called raising bonded diamond wheel and have a good friability. Particularly this is essentially for grinding the cemented carbide where this wheel should be free cutting in nature. So that even under dry condition, accurate grinding, precision grinding without any defect in grinding or crack formation on the cemented carbide that can be achieved by this diamond wheel tats all. Now I discuss the questions set in exercise twenty nine state basic advantage of creep feed grinder over a conventional surface grinder. The greatest advantage of creep feed grinder over the conventional grinder is extended tool life. It also provides form holding capability over a longer period of time. This is because of a single pass grinding compared to a multiple pass grinding in conventional grinding.

Now to achieve that we have to work with a very high speed and this high speed can be achieved or accomplished by the use of super abrasive of grinding wheel compare to conventional grinding wheel. Now for this super abrasive grinding wheel where we employ it for heavy depth grinding, a special class of wheel have been developed. These are all single layer wheel and with this single layer wheel we can have this single pass grinding like creep feed grinding. Now in this single layer grinding, we can have an either galvanic bond or a blaze bond. This galvanic

bond has the advantage over other type of bond in that the crystal protrusion is quite high compare to other type of bond and that provides large chip clearance space because during this heavy depth grinding, one has to consider the length of the chip to be handle by each grit before this chip is thrown out.

If we cannot provide this large protrusion then there could be a problem of chip clogging. Now we have various types of conventional bond like resin bond, vitreous bond or metal bond. Now these wheels are not suitable for creep feed grinding, rather the single layer wheel like galvanic wheel is a better choice, but with advent of blaze bonded wheel we have steel better use of this super allusive wheel in creep feed application. In this blaze bond wheel we can have not only very large protrusion as high as 80 percent compared to only 30 to 40 percent galvanic wheel but also the grits are can be arranged in a particular spacing almost it looks like an abrasive milling cutter.

So then according to the need of grinding, this space can be designed to handle this chip accommodation. So what we can say that this creep feed grinder is advantageous conventional to a surface grinder. In that the grit protrusion I would say that, wear resistance of the wheel can be enhanced or form accuracy of the wheel can be also enhanced. In addition to that, the profile accuracy can be well mentioned. So, in summary what we can say if we like to use a creep feed grinder, the wheel should be also properly chosen. Now we go to the second question: Specific application of a planetary grinder. As we can see in planetary grinder, we provide a complex motion that means two motions are provided on the grinding wheel. That means in this case, the work piece does not rotate at all. This is necessary when the geometry is not very regular as for example a bracket the bore has to be ground.

In that case, the outside surface is not symmetrical and if we allow it to rotate that can cause some imbalance in the system. So when the work piece having some odd geometry, in that case we have to provide this complex motion in the wheel which has both rotation about its axis and another orbiting motion about the axis of the work piece. So that is the very specific application of the planetary grinder over plain internal grinder, chucking type grinder, then we have the third question what is the what is the characteristic feature of the universal grinder? Apparently the universal grinder is doing the same job as that of a plain type of grinder but we have at least few features which makes it quite different in construction compared to a plain cylindrical grinder.

One is that, it has a swiveling head stock. Number two it has a swiveling wheel head and number three it has a swiveling wheel head slide, the fourth one which is also an important feature a wheel head for internal grinding. Now, with all these features, we can do grinding on a very steep taper. In addition to that if it is so required that on a job where external grinding is done and if that work piece also requires some finishing of the hole or bore inside it, that can be done in the same setting by an internal grinding attachment that is the greatest advantage of this universal cylindrical grinder.

Now there are fourth question: state the disadvantages of center lathes cylindrical grinding machine; now since the one disadvantage we can identify, since there is no center support, it would be rather difficult to have say the concentricity with the basic center that is one of the disadvantage, then if a job has a large diameter compared to its width normally what we have

seen in case of a center lathes grinding that diameter is rather small compared to the length of the work piece. But, if we get a work piece where the diameter of the job is quite high compare to the width of the job in that case, getting the stability of the job with those supports the work rest regulating wheel that becomes one greatest difficulty. In addition to that, you may not maintain the perpendicularity of the work piece. That is also another limitation of the center lathes grinding but the fifth question is transverse feed provided in vertical spindle, reciprocation table surface grinder.

As we have already seen that in a horizontal spindle, reciprocating surface grinder grinding can be conducted in two modes that mean either by provided a transverse feed to accommodate the entire width of the job that means, to extend the cutting action over the entire width of the job. In that case the width of the wheel may be lesser than compared to the width of the job or the work piece. But in case of vertical spindle reciprocating table, surface grinder we do not provide the transverse feed. That means it is not given this lateral movement to cover the entire width of the job in fact what we have seen a cup shaped wheel is used in this particular machine and that diameter is so chosen it is almost like use of a face milling cutter in a milling machine. So it is very similar to that face milling operation. So a cup wheel can be conveniently used and it can be effectively used for covering the entire width of the job and any transverse motion is not required.

Thank you very much.