Manufacturing Processes II
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Lecture No. 19
Kinematic Systems & Operations of Milling Machines

Welcome young friends! You are welcome to our course Manufacturing processes-II.

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Now we are going through Module number-4 which deals with General Purpose Machine Tools. Our lecture is this is number 2 under Module-4 lecture number 4.2. Today we shall deal with kinematic systems and operations of milling machines. Last time we finished drilling machine.

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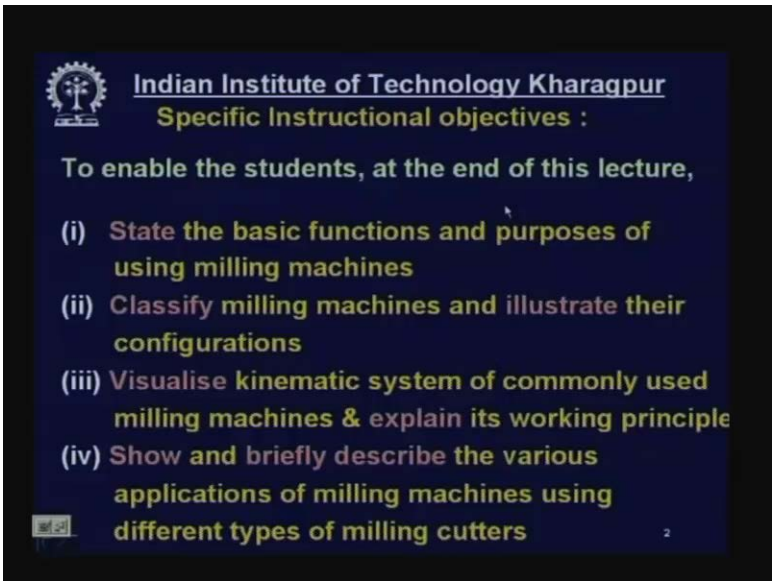

Now what are specific instructional objectives? After completing or attending this lecture or lesson the students will be able to state the basic functions and purposes of using milling machines, then classify milling machines and illustrate their configuration and applications. Visualize kinematic system of commonly used milling machines and explain its working principle. Fourth show and briefly describe the various applications of milling machines using different types of milling cutters. Now basic function of the milling machines:

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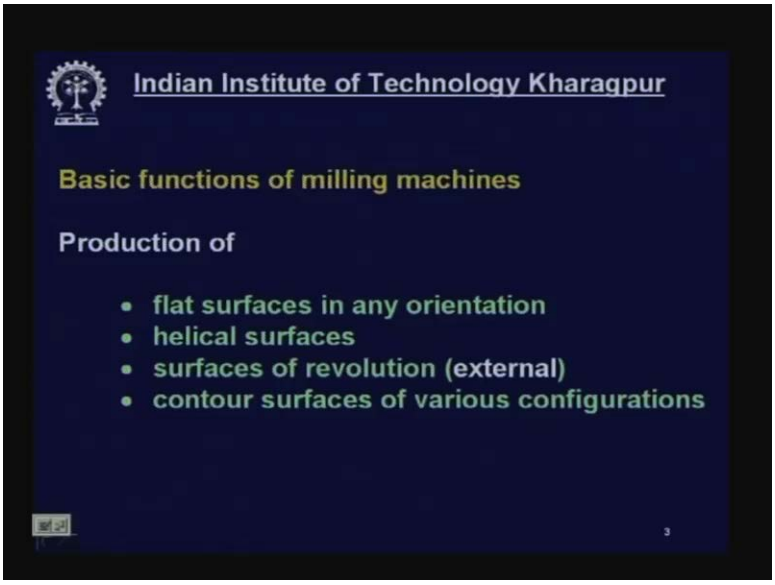

Milling machines like any machine tool, what is the function of machine tool? Functions of machining tool any machine tool are to produce geometrical surface that is a machine job which is bounded by some geometrical surfaces like flat surface, cylindrical surface, then contour

surface and so on. Similarly the milling machines are used produce flat surfaces in any plane the vertical plane, in horizontal, in inclined plane. So in various planes they will produce surfaces then helical surfaces. So helical surfaces are required say in gears or say drills, milling cutters, reamers and so on. Surfaces of revolution: Generally the cylindrical surfaces are surface revolution produced by turning but, by milling cutters also we can produce these surfaces of revolution in certain situations. Now milling machines also produces contour surfaces of various configurations like cams, cam then threads and so on.

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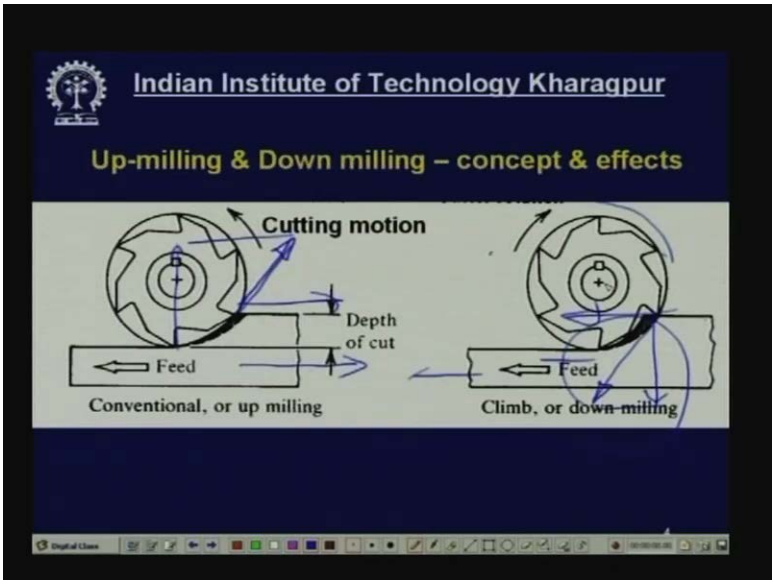

Now before we go to the milling machines, their classification, and etcetera; let us be familiar with two basic principles of milling. One is called up-milling and one is called down milling. Now this up-milling and down milling concept: Now this is milling cutter cross section of the milling cutters slab plain milling cutter which rotates in this direction and this is the work piece. Now this will be moving in this direction and the cutter rotates in the opposite direction and this will remove a material that means the forces will act in this direction main force. In down milling, the job rotates in this direction the work is also feed in this direction. So the force will act downward. Now this is up-milling and down milling. What is basic difference? This has to be understood. One is technical difference, one is apply difference because of the force going up with one of the component of these forces will try to or trend to lift the job from the fixture or jig.

So this situation needs you know strong clamping inc down milling the force acts in this direction. So the clamping will be more tightly performed but the problem with this down milling is, if there are many backlashes in this screw thread and the nut thread then there will be a danger. Since it is going up there is component like this in this direction. So job will be always pushed outward from the cutter, but in this case the job will be pulled in towards the cutter. So if there are many backlashes in this screw etcetera, this will be more problematic. So this has to be taken care of.

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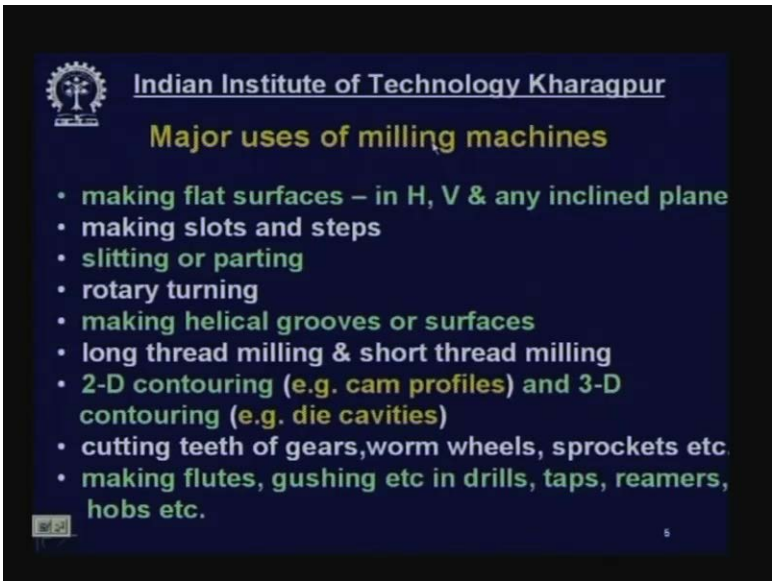

Now the major uses of milling machines: Making flat surfaces - in horizontal plane, in vertical plane, in any inclined plane, then making slots and steps. Now what does it mean? Say slots. This is a surface and you make a slot. So this is called slot okay and then the step. What is step? There is a surface now you make one protruded step. So this kind of surfaces can produce by milling. Then coming to coming to slitting or parting, this is parting a plate into two pieces or a strip into pieces just like cutting action. Now rotary turning: The turning is done by done in lathe like milling like machine by single point turning tool, but in some cases if required this turning operation that is production of surface of revolution can be done by rotary cutting tools which looks or behaves like milling cutters that we explained making helical grooves or surfaces. So when make cylindrical cam it needs some helical surfaces that flutes of the drills the helical surfaces and the milling cutters itself we did the helical surface.

So helical gear we cut the grooves by helical groove by special milling cutters long thread milling and short thread milling. Threads screw threads can be produced by milling cutter. One is call long short long thread milling likes long screws are press screws are manufactured by milling cutter and another, this even short threads of say small screws or bolts are manufactured in mass production by another milling cutter called the process called short thread milling. This will be discussed in detail 2 D contouring. For example, the cam profile the cylindrical cams or plate cams plate cams specially archimedean spiral cam and any profile cam and 3 D contouring like say die cavities in die, mold, press mold, or say injection molding, cast mold and all this molds cavities particularly 3 D type are manufactured by special milling cutter in milling machines. The cutting teeth of gears, worm wheels, sprockets, etcetera these are done by special milling cutter in milling machine. Making flutes say in drilling machine, gushing, etcetera in drills, taps, reamers, hobs, etcetera hobs is ream hobs is one basically isn't it. So here you see this is a hob, sorry this is worm like this and now if we just cut slots like this, then the cut slots then we produce the milling the cutting edges by this is called gushing which can be done in drilling in taps, in reamers, in hobs, this gushing is nothing but grooving. These are again done by milling cutters in milling machines.

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Now come to classification of milling machines: Now milling machines are very versatile machines and can work large number of type of upwards by using various types of tools. So these milling machines are different type and cutters also very different type. So they need to be classified okay according to several aspects. Now when you considered classification, according to what we should understand. Say first say classification with respective according to purpose of use again you remember this can be general purpose, single purpose or special purpose. General purpose means any work on any job, of any size, any shape, by any milling cutter, wide range of milling of cutters. So this is most versatile. This machines most commonly used. But these are non-automatic and used for very small lot production or piece production. These are the mass production machine.

Now single purpose-only one kind of operation will be done repeatedly say only turn milling, only turning by milling cutter. Say only thread cutting in by milling cutter or only producing cams by cam milling cutter or slitting say parting on the so the single purpose these are semiautomatic and used for small lot production or batch production. Now special purpose milling machines-these are automatic milling machines where a definite number and type of operations are done repeatedly over a long time with certain attachments or systems special systems. This is used for mass or lot production. These are automatic. For example; short thread milling, die sinking, duplicating machines, duplicating production etcetera these are automatic.

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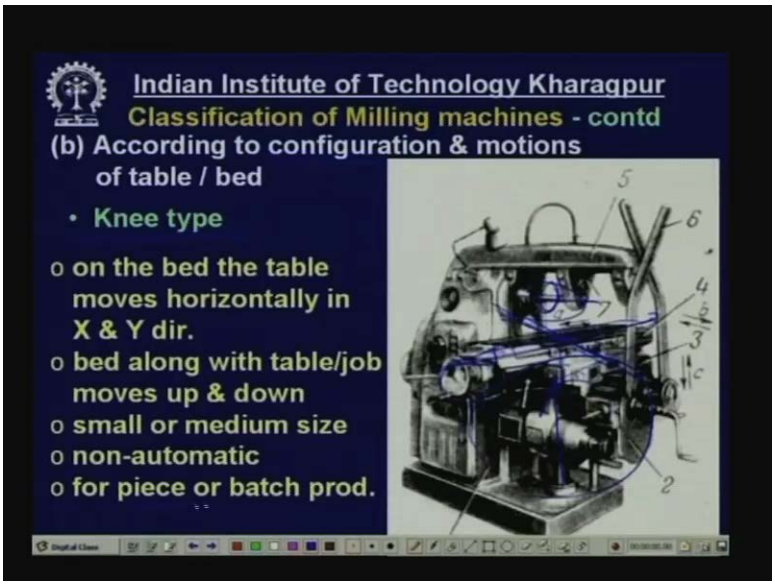

Now classification of milling machines according to configuration and motions of the table and bed: Now here you can see that, this is a milling machine. Very ordinary common type of general purpose milling machine and this is the bed this is the bed okay on which this is the table. Now this is the milling arbour shown were here on which is the milling cutter is mounted okay and this is knee type. According to configuration okay configuration say first is knee type. So the bed looks like knee and it is resting on a screws static screw and guided by the vertical guides. So this bed can move up and down. On the bed, that table can move in along X direction forward backward and along Y direction that is towards the operator and away from the operator. So this is longitudinal feed, this is cross feed and vertical feed is given on the bed and on this cutter rotates only in one position and that is mounted on horizontal axis milling arbor. Now on the bed the table moves as I told in X direction, Y direction and the bed move along with the table job in the vertical direction. So this keeps feed motion of the job in X direction, Y direction and Z direction. These are non automatic and these piece production or batch production type. So these are very common use.

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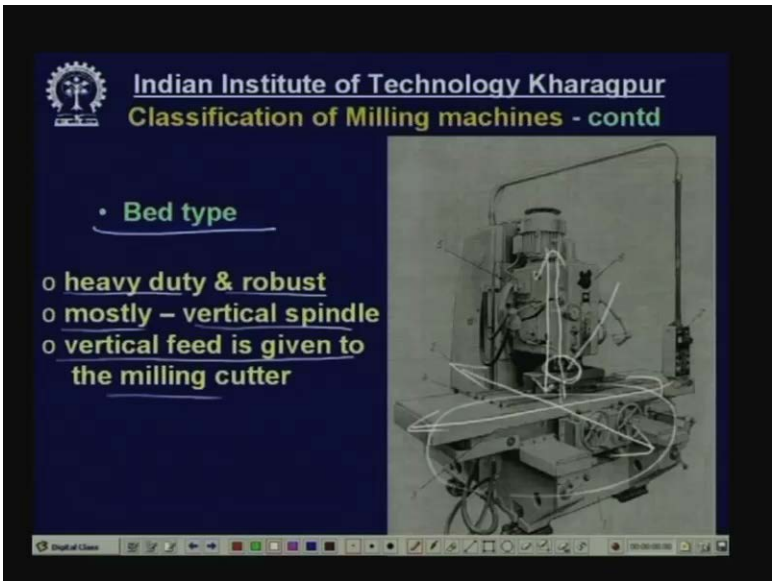

Now come to bed type: This is the bed type. Now this is the bed. Now this bed is very robust and ragged and rigid it is not resting on a screw it is resting on a base solid base. So this is very strong rigid machine and the cutter is mounted on the vertical axis spindle and cutter may be either say end mill type cutter or face mill type of cutter this is the more powerful and this can work at faster rate. These are the heavy duty and robust mostly vertical spindle but this can be slighted tilted in some machines and vertical feed is given to the milling cutter. So longitudinal feed is given to the table, cross feed is also given to the table, okay and the vertical feed is given on the cutters.

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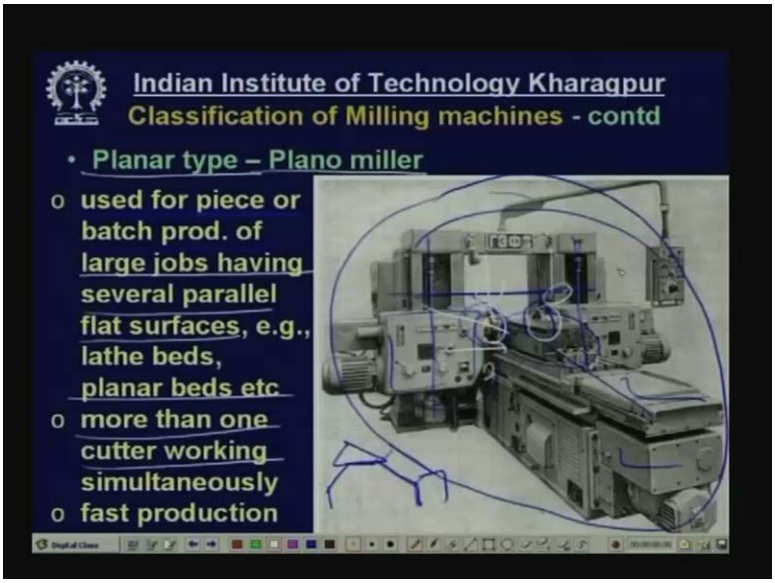

Now come to planar type-the Plano miller. Actually this is a large machine rather largest milling machine of this kind. Basically, it looks like a planing machine you see. This is the vertical rail, this is the horizontal rail may be and this is the bed on which the table moves on which the job is mounted instead of single point cutting tool or planing then is milling cutters say large number of milling cutters may be up to 6, 7 milling cutters can be mounted from this milling heads which can mount on vertical column or on the rail. So the bed which requires a number of surfaces to be made say horizontal surface, inclined surface, vertical surface like that. So this will be done by various milling cutters and all this milling cutter will be mounted by number of unit edge.

So large number of milling cutter even 8 milling cutters can work simultaneously and the job will be traveling slowly. So this is the called Plano miller. The high productive machine used for piece or used for piece production or batch production. Large jobs having several parallel flat surfaces like lathe bed, bed or table of ginning machines, planing machines. These are machine in Plano miller. Plano miller more than one cutting or tools or working simultaneously say one tool here, one tool there, there may be few more tools from different positions vertically or inclined or horizontally like that. The production is fast because of several cutting tools works simultaneously.

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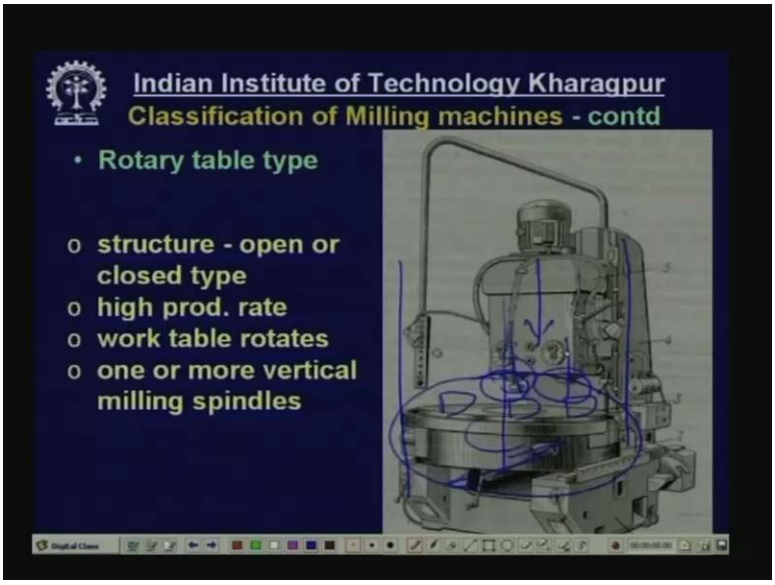

Now this rotary table: In the rotary table this is the table okay, on which the jobs are mounted. May be number of more than one job may be mounted and that will keep on rotating about the vertical axis and there are two spindles. On the spindles milling cutters are mounted. So the table will be moving and job will be done and this entire table can move along the cross feed also and a cutter can move vertically up and down. So this structure is open on one side or both side can be closed type, high production rate and work table rotates one more vertical milling spindles one or more. So there are two shown here. There can be more than 2 even either1, 2 or maximum 3. So this is the first production machines okay.

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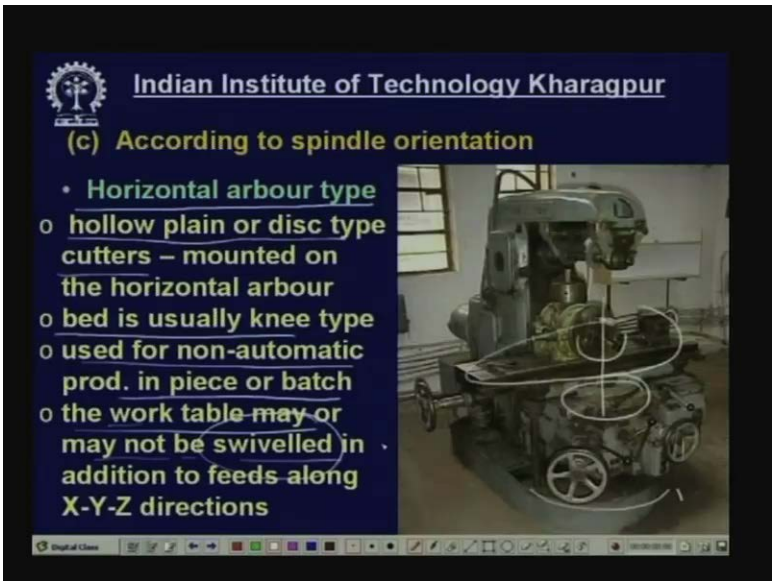

Next come to the classification of machine tools according to spindle orientation: Now you see the cutting tool is mounted on either the milling arbour which is normally horizontal or it is mounted on a vertical axis spindle through a call it or some adaptor. Now here according to the spindle orientation what is the direction of spindle? First of all, you see the horizontal arbour type, this is the most common. Here you see this is the milling machine: It is a knee type milling machine okay, this is the bed on which the table moves longitudinally and cross, manually and automatically and this is the arbour, horizontal arbour on which the cutter is mounted and axis is horizontal and job is mounted on certain device either vice or a milling head or indexing head and all the feed movements X direction, Y direction and Z direction through the table can be given.

What are the characteristics? Hollow plain or disc type cutters are used. The cutters should be hollow so that it can be mounted on the arbour bed is usually knee type as I told used for non automatic because there is versatile non automatic machine but very widely used for piece and batch production. The work table now the work table-this work table here this work table can be rotated slightly about this axis. This is the swiveling arrangement; say up to 30 degree plus minus it can be tilted depending upon the requirement. So it stated that the work table may be or may not be swiveled in the direction of feed along its X-Y-Z direction. In addition to X-Y-Z direction feed, we can have another slight rotation within a small range of angle okay.

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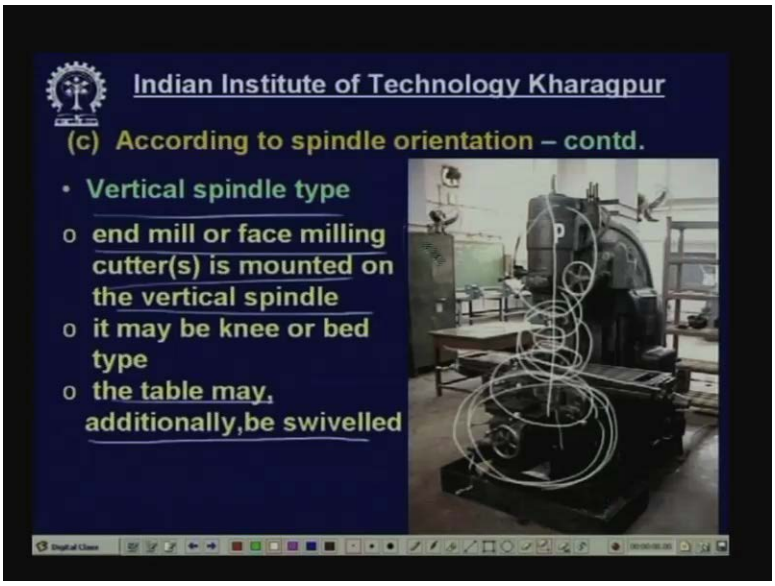

Then again according to spindle orientation continued vertical spindle. Now here you see that this is the spindle okay. This is the head milling head, this is the spindle on which the cutter is mounted here and this is the work piece which is the mounted on that table and table is mounted on the bed and this bed can be a bed type or it can be knee type. But main thing is, the axis of this spindle is vertical and what kind of cutters are mounted. These are either end mill type or shell mill type or face milling type. Later on you can see what are the different types of cutters. Now the vertical spindle characteristic end mill or face milling cutters are used spindle are always vertical it may be the bed may be knee type or bed type that table may have one additional swiveling movement. This can also have some swiveling movement. This table can be this table can be slightly you know rotated about this vertical axis say within plus minus 30 degree that improves the work ability of the machine.

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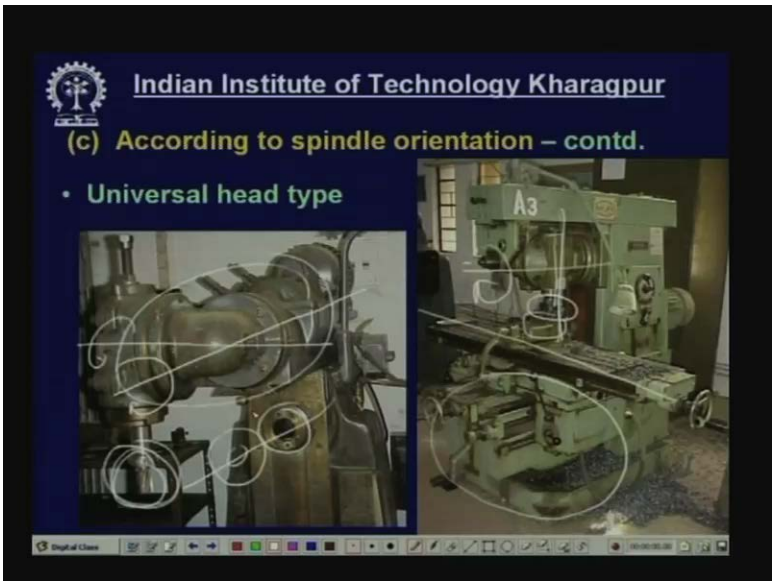

Now Universal head type; what is Universal head type? For the name implies, it is highly more capable. Here you see that, this is the axis of the arbour and milling cutters can be mounted on the arbour like this. But there if we have one attachment like this, now this is the axis of the cutter. So this is the cutter face milling cutter, work piece is mounted on this vice and vice is mounted on the table okay and it is knee type machine. Now this axis of the cutter can be horizontal, can be vertical, and it can be tilted also about this axis this can be tilted. So this can be tilted like this. So this is the X vertical axis and it can be tilted but this machine is a more versatile. Here you can see, this is the axis of the arbour and this can rotate about this axis. This is the cutter and then this can be rotated about this axis also so it is much more versatile. So this spindle can be tilted about around X axis, around Y axis also it is much more versatile. In addition to the system were you can mount say cutting tools like say end mill cutter, shell mill cutter, face milling cutter. You can also have another spindle for arbour on which some this type cutter can be mounted. So this is more versatile and capable machine.

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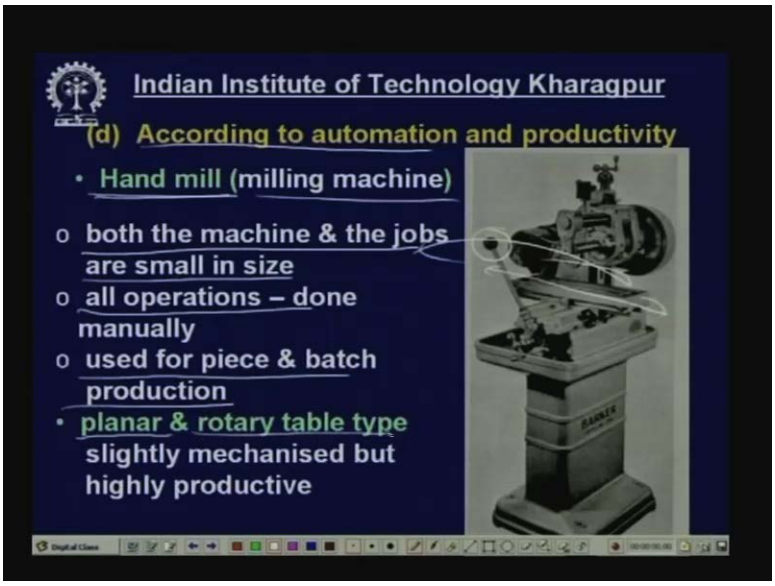

Now come to according to automation or degree of mechanization. According to automation or mechanization and productivity, now these machines shown were here it is called hand mill. Hand mill is most primitive milling machines. Everything is manually done and very low capacity the sizes very low the size job size will be of very small productivity also very low and quality will be limited because everything is done manually. Both the machine and the jobs are small in size all operations including the feed motion is also done by this lever which will be oscillated manually used for piece and batch production very slow production nor very accurate and planar and rotary table type sorry this is end of it. Now hand mill hand mill is one most non automatic a non productive. Next comes planar and rotary table type. This planar and rotary table type of little more highly productive and has a little degree of mechanization slightly mechanized but highly productive because of the power and the rigidity a robustness which allow. You know large depth, current feed and cutting velocity that make it productive though slow working but it is productive.

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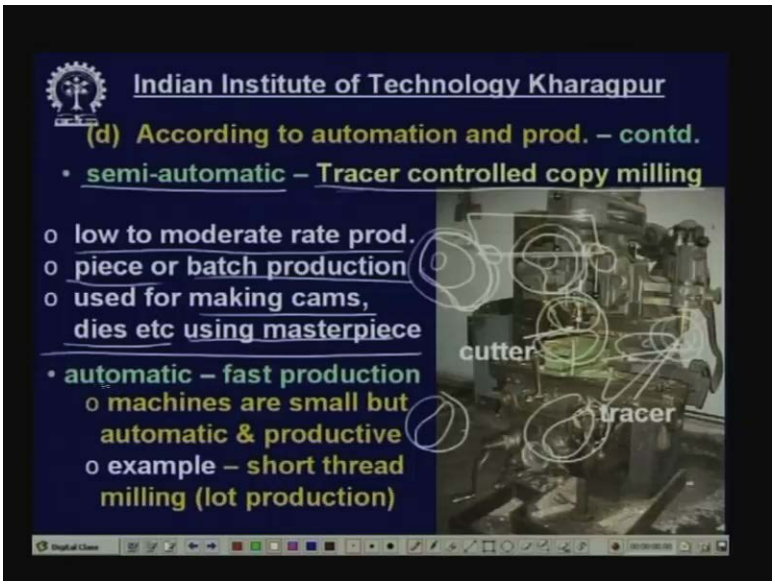

Now semi automatic; In semi automatic this is semi automatic machine semi automatic tracer controlled copy milling. Now tracer controlled copy milling; suppose you want to produce a cam a cam with a lobe. Now this will be done by you take another blank and then you take the one follower and the cutter. So this will follow this path this profile. This cutter will follow this also follow this path and produce the cam. So exactly just like copying, you know you take a master piece and that will be copying. So this is the cutter and the blank will be mounted here on a shaft and this is the tracer which will be traveling along master piece and the movement of this one say X-Y-Z movement then X and Y. These two movements will be taken by this cutter and this will produce the job. If this be like this, will also be produced like this okay. Now this is low to moderate rate production, medium rate production, piece or batch production is possible used for making cams mainly dies using master piece etcetera.

Now next is automatic which is very fast production much more that this is semiautomatic which I describe. Now this is automatic. In case of automatic, the work will be much faster much faster production and machines are small but automatic and there highly productive. For example; say short thread milling short thread milling on say a bold small screws and you have to produce the thread okay. This will be done very quickly at very fast rate and this is the special milling machine automatic machine.

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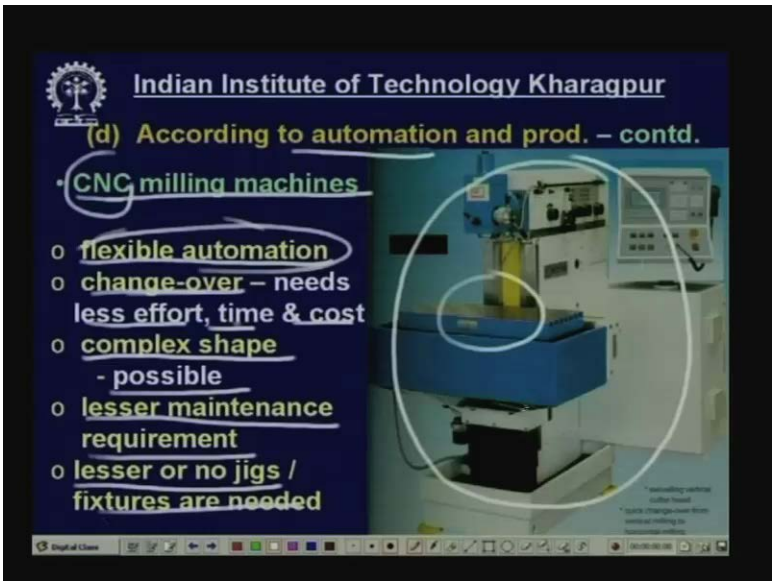

Then CNC; What is the full form of CNC? Computer Numerical Control; this is modern machine modern milling machines. Now this is automatic. No doubt but this is flexibly automatic were the job can change very quickly and the change in the product will be taken care of by writing program, a suitable program and that program will enable see you in producing one job to another job to another job. So this flexible automation will cause change over from one product to another. Less effort, less time and less cost. So this is very good for flexible automation. So change your cost effort time will a very less and this is characteristic of CNC machine is modern machine milling machine. Complex shape jobs can be easily done much better than other machines less or maintenance and requirement because this machines are computer controlled electronic hardware and software.

So the mechanical number of parts is very small. So wear and tear will be much less and maintenance required maintain will be also much less and lesser number of jigs and fixtures or no jigs are fixtures are required at all sometime. So these are the advantages of the CNC milling machines. Now this is another improved version of CNC milling machine. CNC milling machine does only the mini activities but this is the machining center which enables in addition to milling work, drilling, boring, counter boring, counter sinking, tapping various kind of work can be done. So drilling machine, boring machine are milling are combine in to one. So, this is called machining center all right. It is called sorry.

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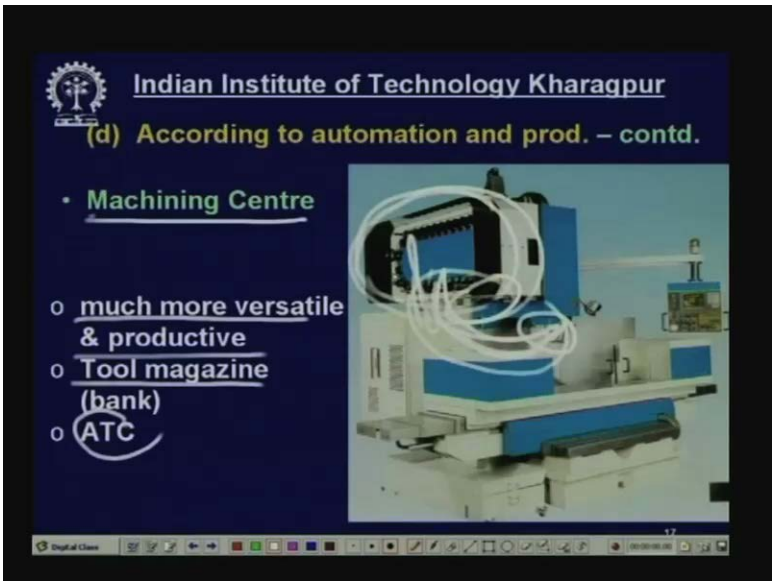

This is the machining center all right. In the machining center, this is the machining center. Here you see large number cutting tools are placed in bank called magazine and this is the spindle were the tools are fitted and one after another the tools are replaced okay. The replacement of that tools or change of the tool is done very quickly may be within 1 second and this is very versatile, flexibly automatic machine which can do lot of drilling work, milling, boring etcetera. Much more versatile and productive, tool magazine is there up to 250 cutting tools can be preserved and this character by having ATC Automatic Tool Changer. So there is device which enables very quick change of cutting tool from the spindle to the bank. So this is most modern very modern machine tool.

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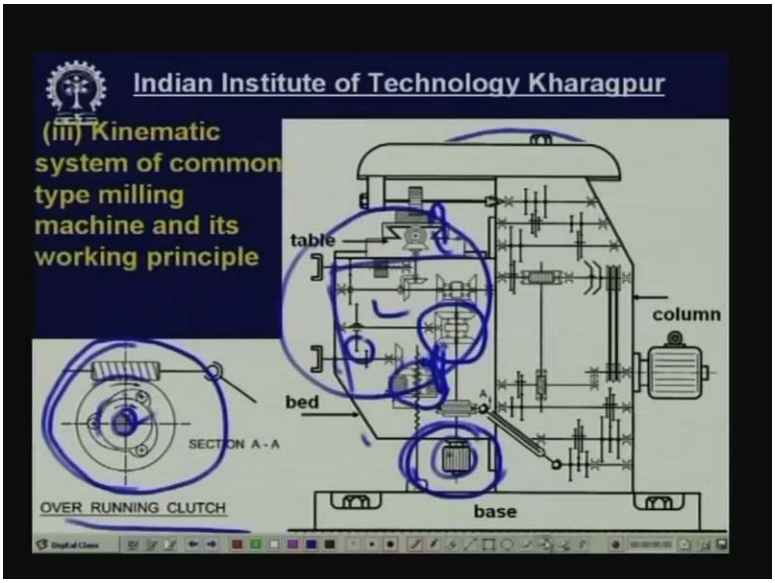

Now come to the kinematic system; kinematic system of common type milling machines and its working principle. This is very versatile. Now as I told that there are different types of milling machines may be say few dozen types of milling machines all right and different types milling machines will have certain difference in there Kinematic system. What is Kinematic system? I remind you, kinematic systems are comprised are comprised of number of Kinematic chains having number of mechanisms. So this is Kinematic system chain. What are there? From the motor, power goes from the bell pulley system, then a clutch, from clutch to worm and worm wheel or it trends to be give speed gear box comprising large number of cluster gears then comes to the spindle. So this is the all the movements are accomplished by number of Kinematic chains and each Kinematic chain posses this number of mechanisms. So the kinematic structure deals with transmission and transformation of motion from the source to the… this is the cutter okay.

Now the first motion as we transmitted from the motor to the cutter. Rotation only so this will go from the bell pulley then the clutch, from clutch to the shaft from this shaft to this shaft, from this shaft to this shaft, then from this shaft to this shaft this is the spindle and in the spindle, the milling arbour is fitted. On the arbour, the cutter is fitted. So this rotates on this and this can be this can be rotated at different rpm by changing the speed with the help of this cluster gear. This is called speed gear box were the clusters are shifted to the change there position and now the job has to moved feed motion how many feed motion are there. This is a longitudinal feed in this direction. Let me clear it, this is the cutter. This this is the chop piece. This will have some longitudinal motion, then a cross motion and this has to move up and down as and when required. So three feed motions are required. This is X, this is Y and this is Z.

How this will be accomplished? Where from the motion will come? Say from this spindle from the lower shaft were the power comes in motor. This is coming to this shaft okay. This shaft from this shaft it is reduced worm and worm wheel because feed motions are very low. So it is coming to this shaft with again there is reduction by worm and worm wheel by cluster gear, the motion splitted into 2 then again it is splitted into 3 then again splitted by 3. So 3 into 3 into 2 total 18 number of speeds by which the shaft can be rotated. Now this motion is transmitted to this shaft. With the help of this mechanism called telescopic shaft and ended with to universal joints and now this worm and worm worm rotate this worm wheel that rotate this shaft. So power comes into this gear. From this gear to these two gears which fully mounted. Now by operating this clutch left and right, this shaft can be made to rotate as clockwise, anticlockwise and that power goes into this screw through the bevel gears.

So this screw this leads screw will rotate resulting the longitudinal feed of the table along with the job. Now the power can also come into this clutch. From this clutch to this gear or this gear from this two gears either clockwise anticlockwise, the power will come into this shaft. Now this gear can be connected here or there. If it is connected here by shifting, then this gear will rotate and this screw will rotate. This nut will move along with the nut this whole thing will move crosswise. So this is how cross feed is obtained. You can do it manually also. How is the vertical feed of the table obtained? The power comes into this shaft okay, this shaft. Now this gear will be connected with this shaft. So this shaft will make this shaft rotate. So this bevel gear will rotate this bevel gear all right. So this is nut. So this nut will rotate again the screw. This screw is fixed.

So this nut will move upward and downward depending upon the direction rotation. So direction rotation can be control by operating this clutch. So the whole bed can be moved up and down along with nut and this will enable movement of the job vertically upward downward. This is how all the motions are done. Now this motor is used for quick traverse for setting the job. For setting the job so job the table has the sometime very quickly to the cutter and that it is done by with help of this motor with the help of this over running clutch his is called over running clutch all right. This is shaft of the motor and this is when this worm rotates then it rotates worm wheel that worm wheel when rotates this three rollers get jam into this space friction jam and then this disc is rotated transmitting motion to the shaft okay. Now when it is not required, this motor is operator high speed this will rotate directly and that will help get all the feed motions rapidly all right. This gives you this quick traverse motion this one and this over running clutch together.

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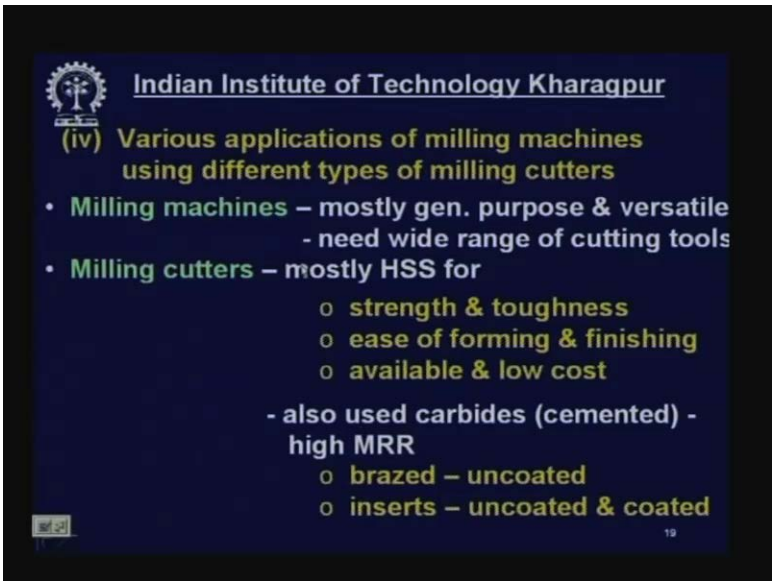

Now come to various applications of milling machines using different types of milling cutters; now you can see that what are the various types of milling machines exists like lathes, okay and along with the milling machine there are different types of milling cutters and with the different type of milling machines and milling cutter wide range of work can be done. Various types of work that you have already observed now you can see again with cutters.

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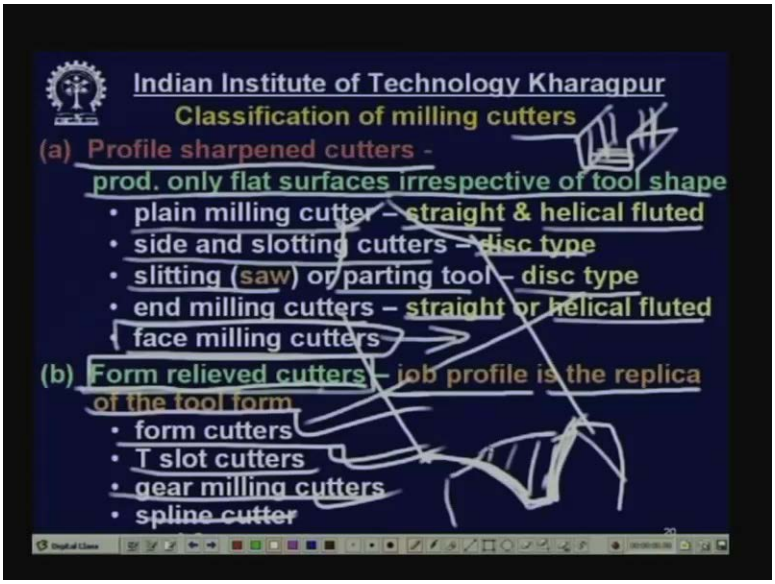

Now classification of milling cutters, classification of milling cutters; Now as I told you the milling cutters are different types. Basically there are two classes of milling cutters. One is called profile sharpened milling cutters other is called form relieved milling cutters. Profile sharpened milling cutters-they produce only flat surfaces irrespective of tool shape. Whatever the shape of the tool the surface that is produced or surfaces those are all flat suppose even if it is it produces slot like this it produces one horizontal surface and two vertical flat surfaces okay. So there is one. It produces flat surface second plain milling cutters. For example; it can be straight fluted or helical fluted. The example will given immediately next slide and slot milling cutters is disc type slitting saw or parting tool these also disc type. End milling cutters straight fluted or helical fluted face milling cutters which are large cutters these are used for making flat surface and large jobs and second one is form relieved cutters. These are form cutters actually to produce job to different forms of the surface likes cam cam surface like say archimedean spiral cam or say involute cam and all this things say and slots grooves gear teeth and so on.

In this case this form relieved cutters characterized by the flat that is job profile that you will obtain is nothing but the replica of the form of the tool. For example; suppose you want to produce the gear tooth okay. The gear tooth how do you produce? We remove this material from in between so the cutters shape will be like this is the shape of the milling cutters. It is the disc type cutters when this will rotate this will removed materials you will observe that form of the tool is the replica of the profile of the job to be developed that is characteristic of form relieved cutters the for example form cutters, T slot cutters, gear milling cutters, spline cutters and many others.

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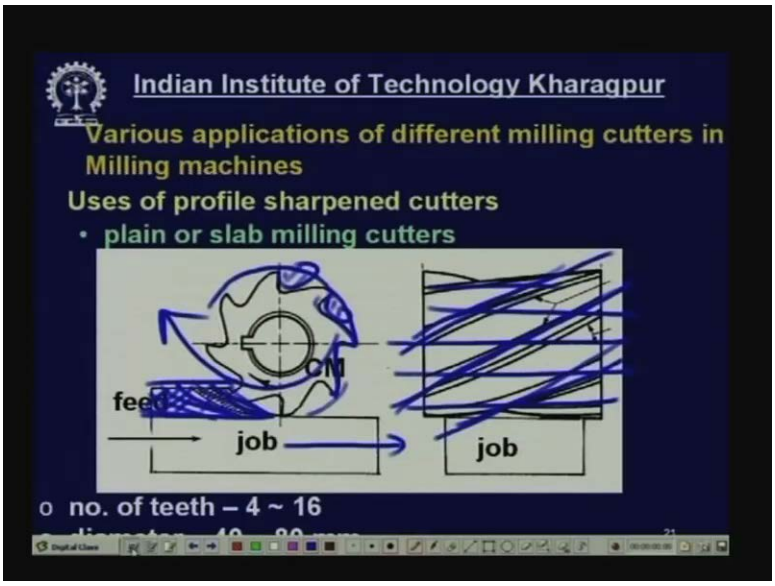

Now let us see the different types. Various applications of different milling cutters we are passing through. Now first let us start with uses of profile sharpened cutters. This is the profile sharpened cutters. It looks like a cylinder, hollow cylinder hollow cylinder. This is actual view and this side view but these are the teeth okay. Here you can see the teeth. This is the helical fluted. This is the helical fluted. How the actually originally this was disc like. Now this material has been removed by what is called gassing and then this cutting edge is developed. These are sharp cutting edge is developed because of removal of this materials and this is called gassing. So we produce teeth one two three four five six eight teeth so these are the teeth. Now this can be straight also. If it is straight, these are called straight fluted plane or slab milling cutters. If it is helical it because more effective then this will be called helical fluted plane or slab milling cutters. So the job will be moving in this direction. Cutting tool rotate in this direction and this material will be gradually removed like this. Gradually it will be removed by tooth one by one by rotation.

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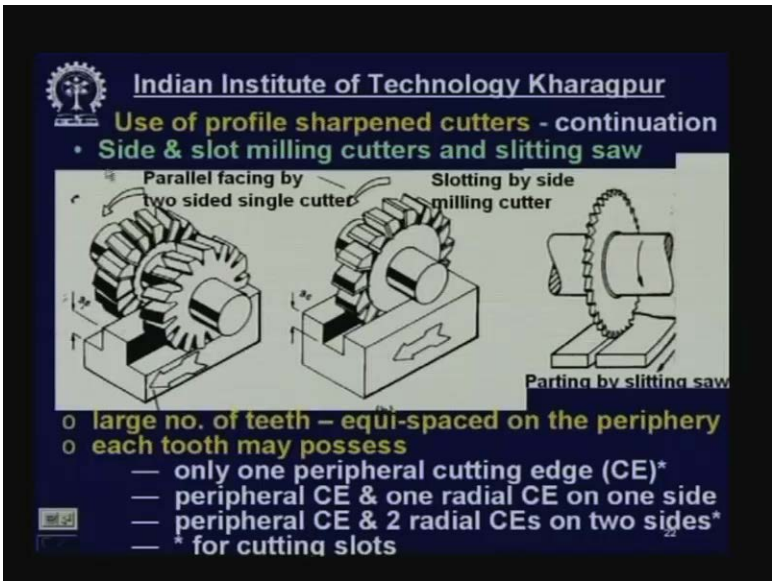

Next is now still we are discussing profile sharpened cutters okay.

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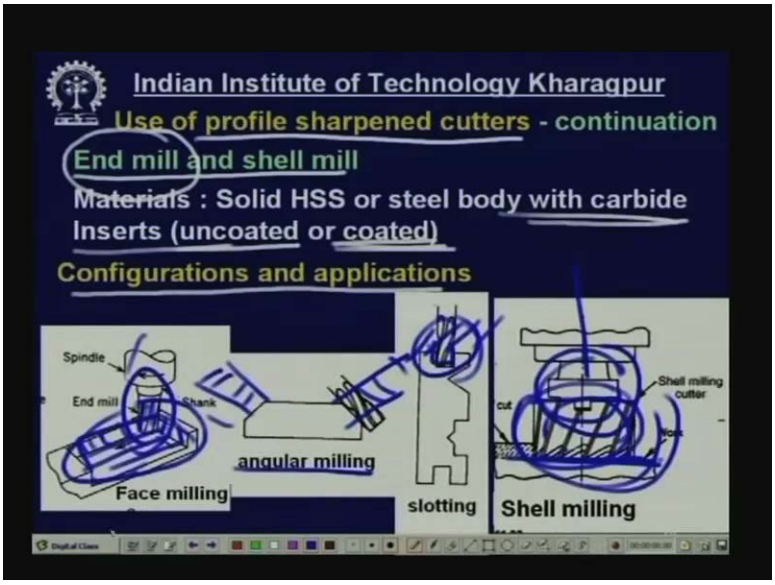

Profile sharpened cutters which produces flat surface. Now end mill and shell mill: What are the materials of the slab milling cutter. In the previous case, mostly high speed steel but this can be carbide also. Why high speed steel because this milling cutters are intermittent cutting tools. So there is jerk or vibration and therefore the cutting tool material should be tough enough and high speed steel is very tough and you see the geometry of the milling cutters are very complex and manufacturing of this thing is very difficult. So the high speed steel can be easily formed like forging then rolling, machining, heat treatment, grinding and all these things are very easy to do and it is very tough and strong. So most of the milling cutters generally made up high speed steel

but sometime carbides are also used either in the form of brazing or some centered carbides are clamped and if clamped it can be uncoated carbide or it can be coated by titanium carbide, titanium nitride etcetera.

Now the configurations and applications of end mill cutter. End mill cutters are nothing but it looks like a rod okay. It looks like a rod this one and at the end there is cutting edge developed and this produces what are the applications? Here you see the face milling. Here making a pocket which is made of number of flat surfaces and this one is angular angular milling it produces this flat surface say this flat surface this flat surface is making and this is making a slot. This is a slot okay this is making a slot. Now this is shell milling, this end milling cutters of generally small in size may be say 1 millimeter to 40 millimeter. But when the diameter need to be large for the purpose of making you know machining large flat surfaces, then we use shell mill cutters. The shell milling is different from end mill in the fact that the cutting portion of the cutter is separate piece and that is clamped into the spindle through an adaptor okay. This is likely larger in diameter is a source of hollow which is fitted into the adaptor. This is also used for flat surface and the larger surfaces.

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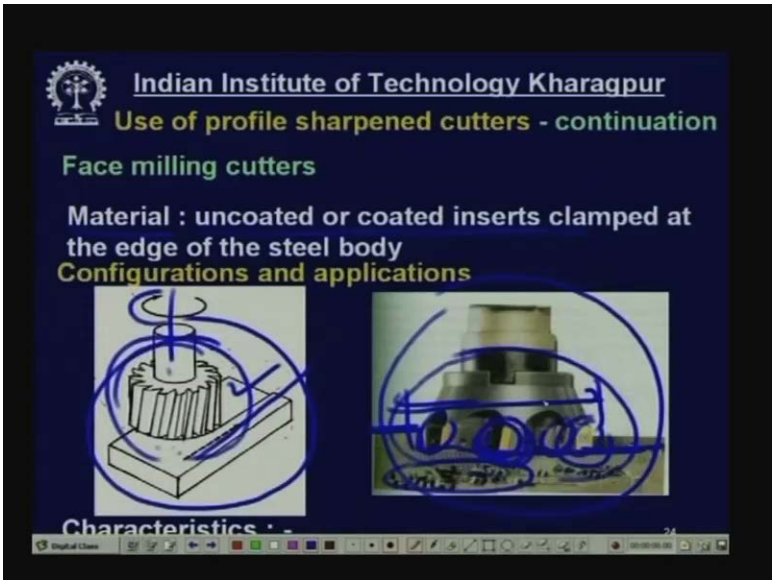

Then use of profile sharpened cutters. Again face milling cutters; now face milling cutters are really this is for profile sharpened cutters which produces flat surface but what is difference? Difference is this is industrial type and very wide surfaces can be produced. Very long and wide job surfaces can be flat surfaces can be produced and a diameter of the cutter here you can see this is the principle of cutting action. This is the cutter, this is cutting tool and axis is vertical. It rotates at high speed and job moves in this direction at the material this is surface produced. So materials are getting removed. Now this shows an example okay. This is the cutter and these are the cutting tooth okay this is a carbide clamped carbide and in this case these all coated have you seen and this is produce in the flat surface and this the original surface and this is the flat surface piece producing and is removing material very quickly. These are the chips okay the diameter of

the cutter make the vary from say 18 millimeter to or 2800 millimeter such a large value and this kind of cutting tools are used for making flat surface of large job say machine tool bed machine tool tables say lathe bed or say bed or table lock planing machines and so on. In a Plano miller, this is also used in Plano miller or in straight ah robust milling machines the material uncoated or coated inserts this kind of high speed steel or now absolute. For nowadays, all these face milling cutters are provided with clamped type carbide inserts preferably coated carbides inserts that will give more productivity and can run at higher speed and can machine stronger materials.

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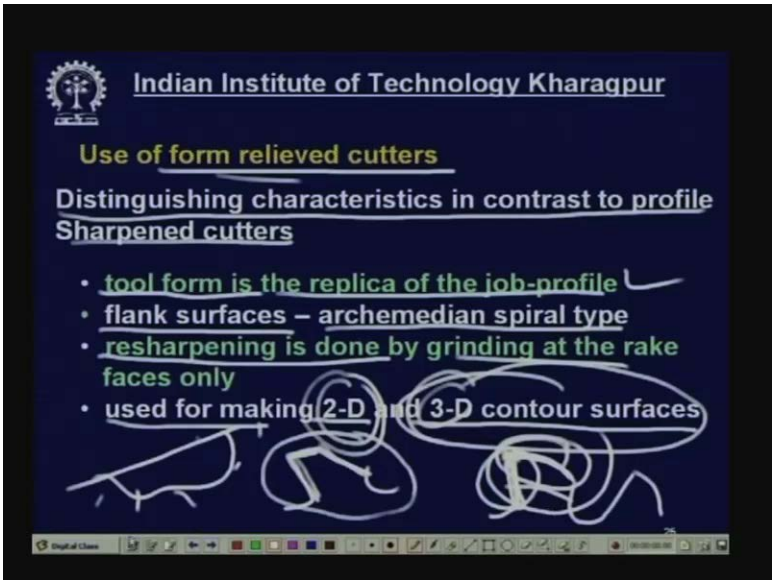

Now use of next is form relived cutters; what is characteristic of form relived cutters? Form relived cutters say for example say this is one tooth of the milling cutters. This is the configuration of the cutting tooth of profile sharpened cutters were this is the rake surface and this is the flanks so primary flank, secondary flank. These are all flat surfaces okay but in case of form milling cutter, this is archemedean spiral, flank surface is archemedean spiral and when it is to be sharpened then the material as to be ground here only. So grinding re sharpening is done by grinding on the rake face only. These are the can the flank surface is archemedean spiral. So the distinguish characteristics of in contrast to profile sharpened cutters what is characteristics of form relieved. 1. Tool form is the replica of the job profile that is number 1 just like gear milling cutters flank surfaces archemedean spiral type as shown here re sharpening is done by grinding the rake surface only used for making 2 D and 3 D contour surfaces nor for flat surface. So form milling cutters are not use for flat surface. There use for making non flat surfaces not even non even say surface of revolution it produces contours either 2 D or 3 D archemedean spiral this kind of have to produced by two D cutters form cutters 3 D say it die a die has got a cavity this cavity has to produced that is done by 3 D contour cutting tools.

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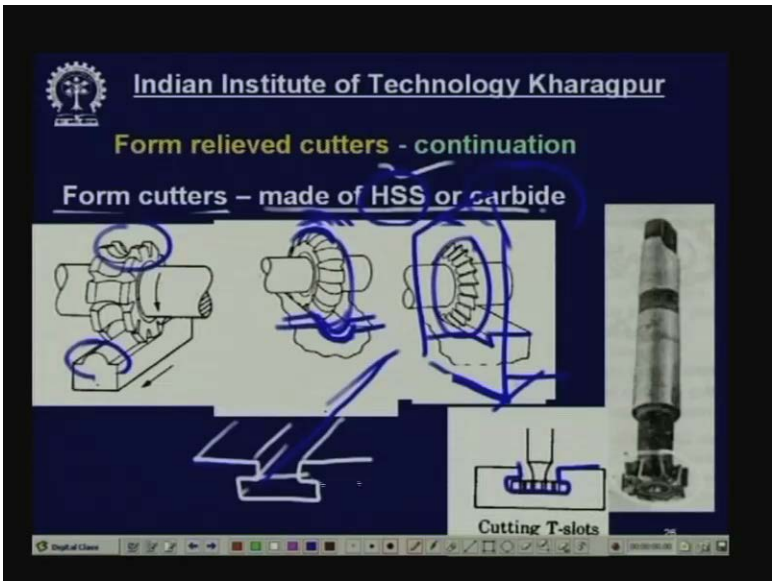

Now you see the different types of form milling cutters. Form milling cutters simply called form milling cutter say form cutters form cutters. These are made of high speed steel or carbide. Normally high speed steel mostly because the forms of the tools are very peculiar you see very complex shape. This complex shape cannot be you know attributed to carbides or ceramics very difficult. So high speed steel can easily you know convert into such kind of complex shape cutter but in some cases when this cutters but slightly standardized then carbide tools can also be used and if the cutting tools very small in size then solid carbide can be used or make it by the modern method but anyway these are made of high speed steel specially occasionally carbide for very small tool or very large. What is it is producing? What are the doing? Now see the applications.

In this case in this case you see this surface is produced this surface. So it is like this so this kind of surfaces becoming the product so this is the shape of the tool. Now you want a surface like this a groove. So this is the shape of the tool. Now this configuration of the form of the tool is replica of the profile of the job wanted. Suppose you want to produce a B groove but inclined say like this, a groove like this. So this cutter has to be like this. So this is the cutter. It can be double V also. Now again say the T slot, T slot cutters. You know in this machines in some machines various machines T slots are there. These are called T slots okay. Measuring machine tool beds produced why because these are used for mountain clamping bolts, T bolts and these are this groove this lower groove is produced by this kind of cutter. It is called T slot cutter is also form cutter. This enables producing production of this kind of grooves and this is called long grooves or cut called T grooves are T slots or cut.

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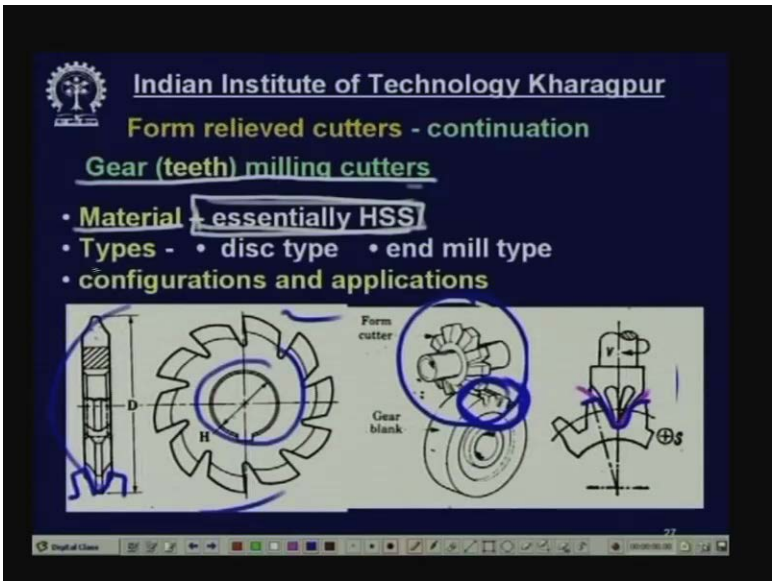

Next is gear milling cutter is very common type of form milling cutters of form relieved cutters gear milling cutters. So we have got gear teeth milling cutters. What are the material? Again the form cutter is essentially high speed steel very rare you know gear milling cutters are made of carbides only in case of very small module gears a small size gears small cutters are required and its cutters are made of solid carbides. Otherwise these are made of high speed steel now this gear milling cutters here you see this is the form of the tooth two tooth. So the material in between in has to be removed by a cutting tool of this configuration so this cutter can be a disc type here you see this form. So this will produce the tooth gear here also this type mounted or milling arbour or it can be end mill type here you see this is end mill type when the gear tooth or very large that is module is very large and the gear may be say 30 feet diameter or say it 40 feet diameter. The teeth are say about 50 millimeter 60 millimeter height then this kind of cutter is used.

End mill cutter but even then see the profile of job the profile of the job this is the involute okay. Now this involute has to be produced by that kind of profile of the job profile of the tool. So profile of the tool this is the profile of the tool and this is the profile of the job so they are similar it is characteristic of form milling cutter. So you can produce the teeth of gears not only gears teeth of say straight to spar gear, helical to spar gear external and then the teeth of worm wheel can be cut. They are splines can also be cut okay this as got various applications.

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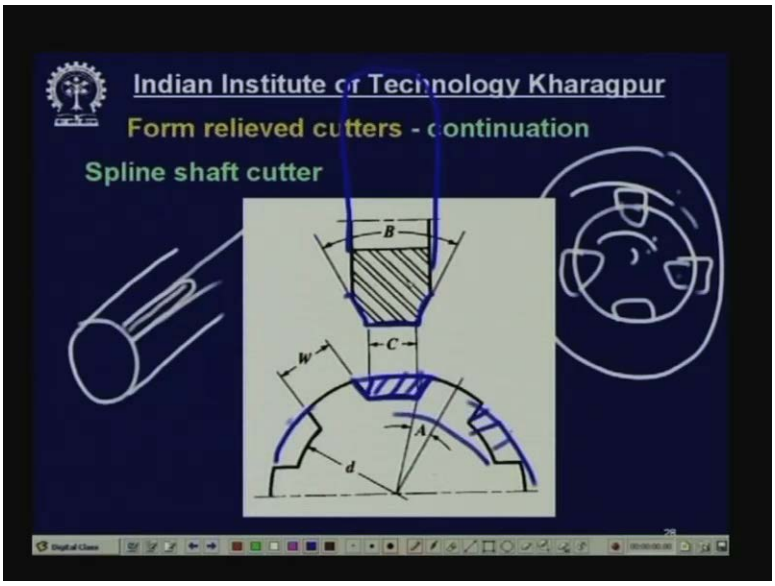

Now next spline; what is spline shaft? Spline shaft, this is shaft suppose okay. Now for sometimes for some reason we need some key way for fixing or it can be number of key way. So in this shaft they are can be number of key ways on the force side or suppose like this or it can be having some protrusion and there is a disc. So this disc can slide axially the disc can slide axially but the rotation will be transmitted from this to that or that to this this is called spline shaft. So basically this is a rod this shows a rod. Suppose this is a rod of long length and the original material a cylinder. Now this portion of the material has to be removed, along the length parallel to the axis. So this is the milling cutter which has got a particular form which resembles this shape and this material removed after and indexing this will be done one by one. So this is another form milling cutter.

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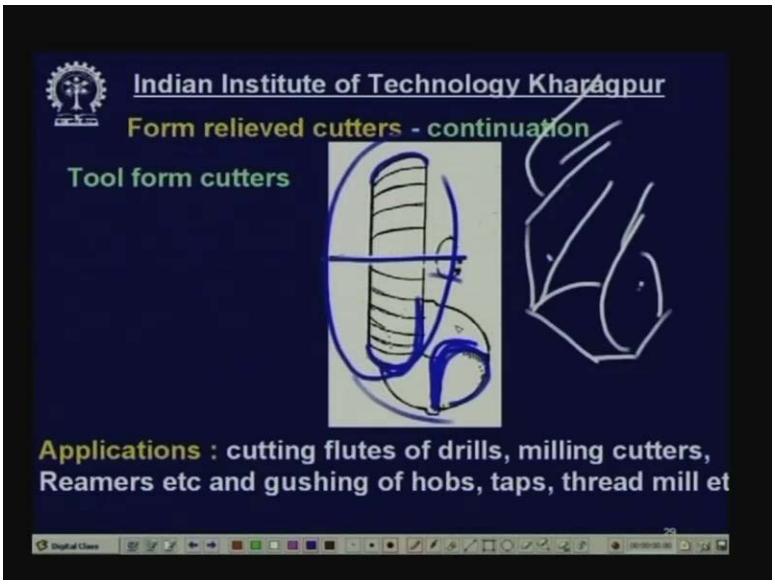

Now the tool form cutters; the form cutters form relieved cutters can be used to produce suppose this is the drill, what is the drill? These also solid high-speed steel rod. Now this groove has to be made. This grooves you see that in drills, this is are drill. So this is boundary by flutes isn't it. So there are number of flutes are there. So this flute, this flute so the grooves have to be cut. So these grooves are cut by milling cutters, these milling cutters. This is the milling cutter and the shape of form of the tool exactly the replica of the group. So first, this groove has to be made and this groove has to be made. So, in this way different type of milling, form milling cutters are used to make different types of flutes and different cutting tool like drills, reamers and milling cutters and so on.

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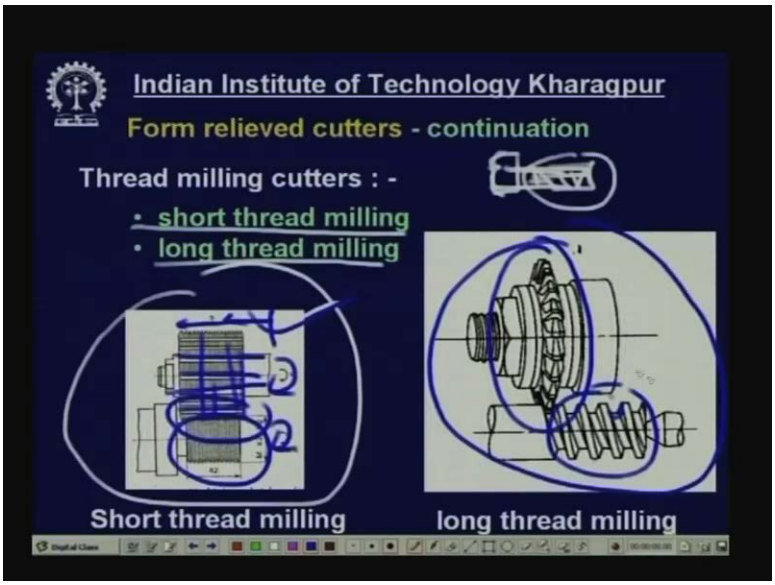

Now thread milling; now milling cutters can be used for cutting screw threads I have already mentioned but how it is done. Now here you see that, short thread milling, long thread milling. Short thread milling means suppose small bolts are to be made and the thread has to be cut here okay and huge number of pieces have to be made. This screw threads have to be cut okay this is done by this method this is the cutter okay this is the cutter okay and this is the job. So the cutter has got anular cutting edges and this is called gushing this gushing is used to produce the cutting sharp edges and that will produce the thread what are the motions. So this cutting job will rotates slowly. As it is done in single point chasing, the cutting tool is also rotate at little relatively high speed and then they will be motion like this. So this will rotate this will rotate and move in this direction slightly and that will produce the entire thread.

So this will be done very very quickly very must fast production and this is another example say long thread milling long thread the long screws likes a lead screws, feed rods, power screws or power press. This having large threads okay have to be make with a large depth and width. This is a done, this can be done by single point tool but it is better if you want to improve the productivity. This kind of cutter can be used because the contact will be intermittent the cutting fluid can be used which will be a in a very effective because they this the instead of continuos

contact like turning this intermediate contact this will allow entry of the cutting fluid you know for lubrication and cooling very fast and here you can rotate the cutter faster. So productivity will be high force part tooth will be less and the cutting fluid action will be much better. So this is non thread milling. So some worms worms are also made. The hobs are also made by this long thread milling process by rotary cutting tool. These also called rotary turning okay.

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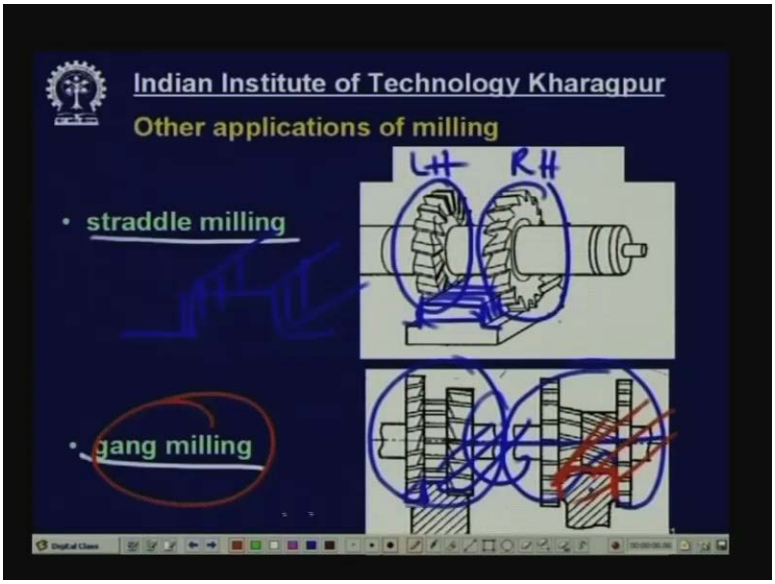

Then other applications of milling in addition to what I told. 1. For example, is called straddle milling. Actually here suppose you want to produce this surface. This surface sorry this is already there. You want to produce this surface and this surface these two surfaces. This is two vertical surfaces at given distance then you take one side milling cutter here one and another side milling cutter here suppose it is left hand type. So this will be right hand type okay side milling cutter and this will cut the slot here and here so this will be this will produce surfaces like this. So this vertical surface and this vertical surface. Now gang milling; what is gang milling? This is also a fast product suppose you want to produce a surface like this and this is called long surfaces okay. So number of milling cutters are mounted tightly on the milling arbour and they will move simultaneously they will rotate in the arbour and the job piece will move perpendicular to the direction or horizontally and you get all this this surface this surface this surface and this surface all the surface together and along the length. So this very fast production. This is called gang milling.

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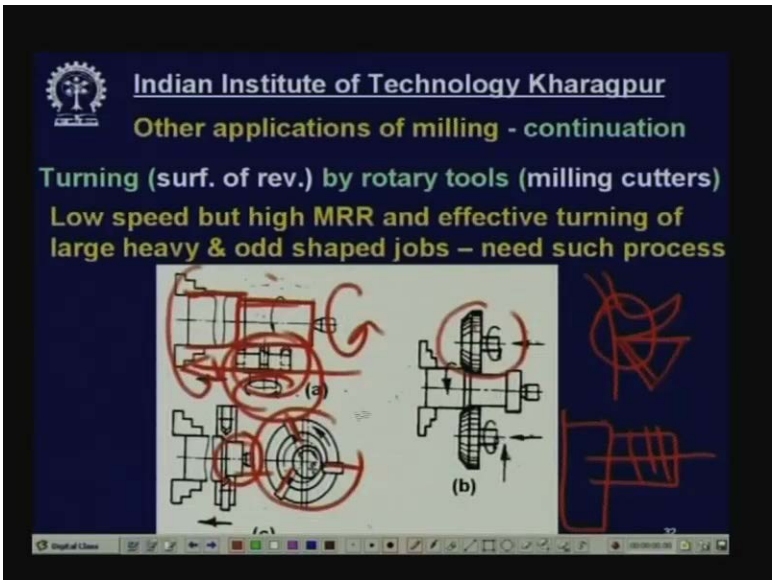

Now I told you that turning turning operation by milling cutter. Now this is the job. This was the original rod of large diameter of irregular size. Now is the finish diameter. What we normally do? We do in turning process by single point tool were the tool and the job the chip remains in continuous contact because of that a tool undergoes very rapid heating and wear and tear but in this case instead of single point tool we use a milling cutter or say milling cutter here and that will give intermediate contact and the job will be produce. So this will keep this will rotate in this direction the tool be travel in this direction job will rotate in this direction. So this is called rotary tool. This is normally used when the work piece is very large, very heavy and very odd shape for which it cannot be rotated at high speed okay because of the odd shape and eccentric mass but work has to be done faster at large with large depth and feed.

So the job will be rotated in the face plate, in the lathe like machine. But a cutting tool will be a milling cutter. There are two milling cutters for balancing or this can be a ring like having cutting, tooth insight milling cutters like and that will do this turning operation that is called surface of the revolution. This is not very common but for odd shape jobs and specially when you want to cut say screw threads or the alter screw thread external screw threads on very odd shapes job. Suppose there is very odd shape job. This is odd shape job okay and you have to cut threads here. Then this kind of process is used to milling thread milling cutter rotary cutters are used for cutting the thread.

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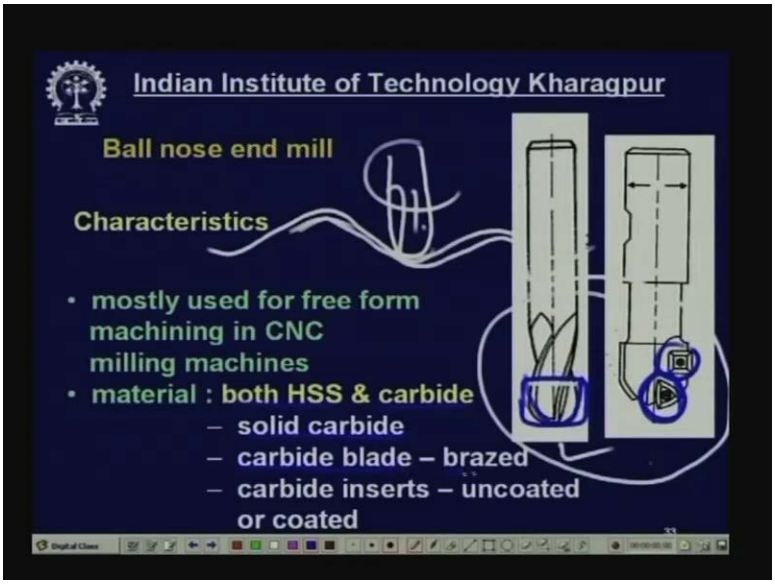

Now the ball nose; now this is the ball nose. You have seen the ball nose. End is like a hemispherical. Now this is used for machining free form 3 D surfaces. Suppose there is a die. In the die, you have to make a cavity okay, you have to make a cavity for molding or say injection molding or pressing like that. How this will be made? This will be made this kind of cutter. Suppose this is the cutter okay this is a cutter, spherical cutter and this is the surface. So this will be traveled. This will rotate and this will be moved along this surface by program in CNC machine. So these kinds of tools are normally used in CNC milling machines. This can be high speed steel or this can be solid carbide if it is small or on this surface you can just fit 1 carbide piece 1 carbide piece by brazing here and then you make it round on a carbon steel or you can on the carbon steel you can mount number of inserts carbide inserts. This inserts may be say coated type or uncoated type all right. So the materials will be both high speed steel or carbide. If carbide solid carbide, this can be carbide blades you brazed and carbide inserts. For example; this one either uncoated or coated.

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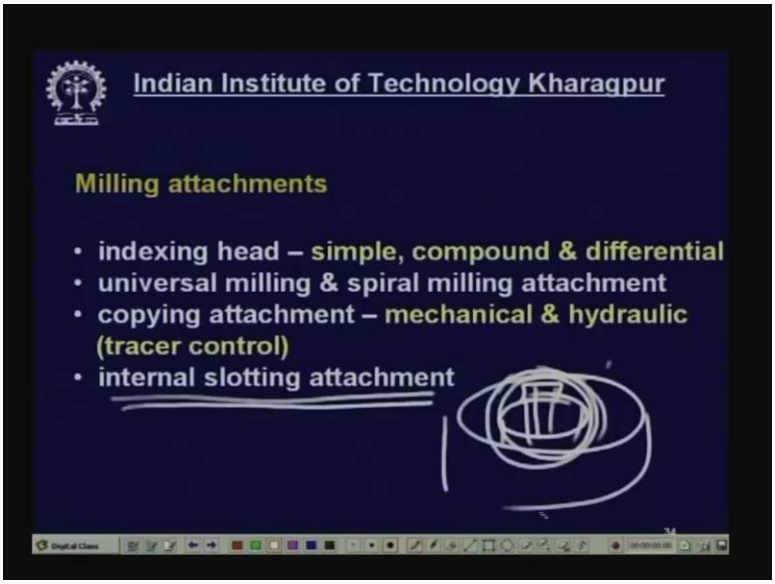

And lastly you see that the milling attachments, the capability or the work ability. A milling machine can be further enhanced by using certain special attachments. For example: so you can see from books also that indexing head. All of you are familiar with this indexing head which is use to hold job and rotate it to by this given angle say 30 degree or divide in to 20 pieces or 30 say for cutting the teeth it has to rotated by one tenth or one twentieth of the revolution so on. This indexing head can dividing head can be simple type, compound type or differential type depending upon the requirement horizontal milling arbour or the spindle. Some attachment can be fitted which will allow this spindle not another spindle to hold shell mill cutter or end mill cutter or face milling and then remain vertical or to be tilted position for incline machining or it can be tilted in this way also. So about X axis it can be tilted, about Y axis it also can be tilted, and this makes it very versatile.

Now internal slotting attachment; what is internal slotting attachment? Suppose you want here is disc okay and there is hole already done. You want to make slot inside. So this can be done in a milling machine. Normally it can done in slotting machine or broaching machine. But in milling machine can also be done with the help of an attachment called internal slotting attachment. So friends thank you very much for today lecture. So next day we shall discuss about other kind another kind of machine tool.

Thank you.