Manufacturing Processes - II
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Lecture No. 24
Forces developing and acting in machine tools

Dear friends, our subject is Manufacturing Processes II and we are continuing Module - 4 that is General Purpose Machine Tools.

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And our today's topic, lecture topic is Forces developing and acting in Machine tools .You know that during machining, lot of forces develop due to cutting action, friction, dead weight, inertia, etcetera and these forces are transmitted and act in different parts of the machine fixture tool work system. Now what are the contents of this lecture?

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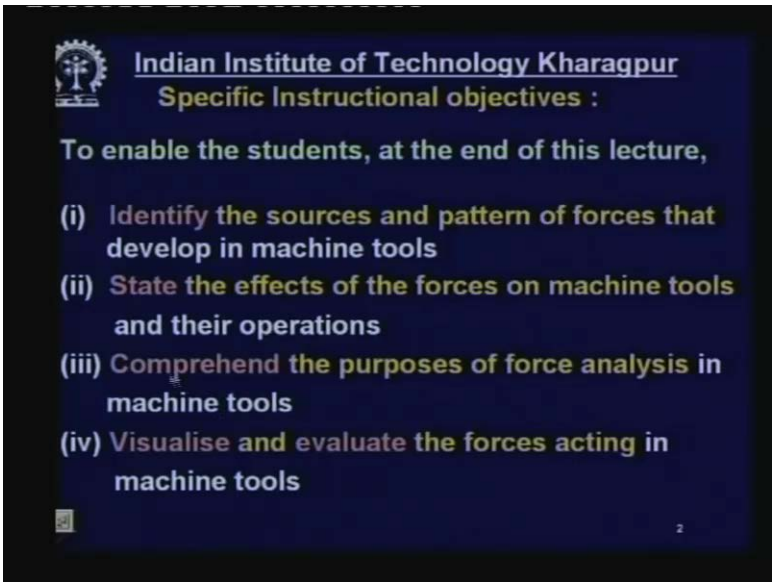

(i) Sources and pattern of forces that develop in machine tools. (ii) Next effects of the forces on machine tools and their operations functions. (iii) Next, purposes of force analysis in machine tools (iv)Actual forces acting in machine tools display of the forces acting in machine tools.

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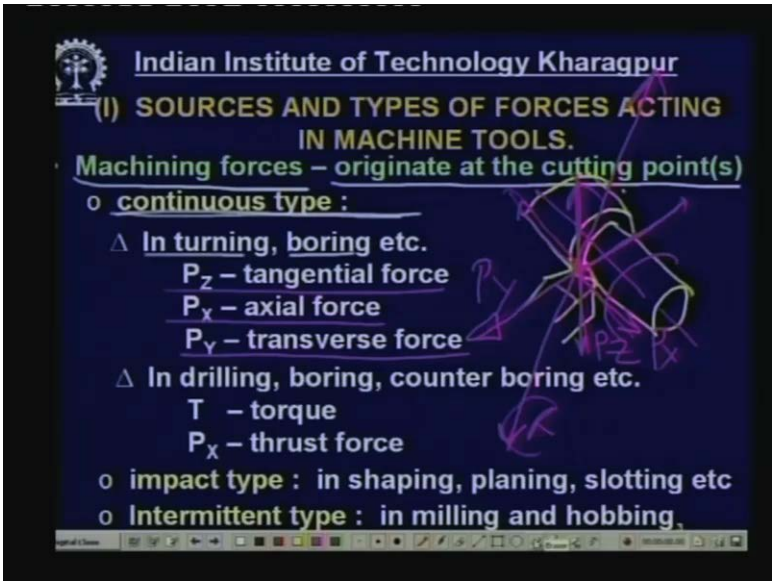

Now come to first sources and types of forces sources and types of the forces acting in different machine tools. We are considering general purpose machine tools. Now as I said that the sources may be machining number one, then dead weight, inertia friction and so on.

Let us start with the machining forces which originate at the cutting point that is at the tool job cutting point, junction point and these forces can be continuous type. That is in continuous type machining like turning, boring, drilling, this force will be continuous without any fluctuation and all this things. So in turning, drilling, boring, actually here you see. Let me show you suppose this is the tool and this is the job. Now the forces on the tool will develop in the direction of velocity vector that is the tangential. So this is called P z. This is tangential.

Actually force develops only one force at the cutting point that is resolved in to 3 components in x and y and z direction. For convenience of understanding, analysis, design and various purposes. So, this is the major component P z that is the called the major component or main component or it is also called power component. Then the axial force, this force acts in this direction along the axis of the work. This is called P x another transverse force normal to this P y. Now these are the forces P x P y P z which has got only one resultant force say R, and these are acting on the tool. Similarly as a reaction or rather R is reaction as action on the job the force will act in this direction which will also have similar type of components say P z P x and P y on the job and on the tool P z P x and P y.

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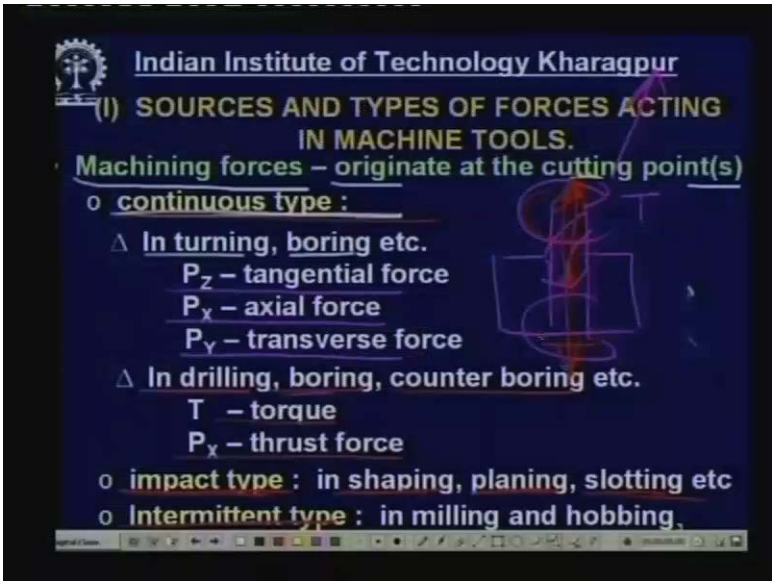

Now come to drilling. In drilling say this is the drill width and this is the work piece in which some hole is made. This is also a continuous process but here one torque is developed on the tool, as well on the job torque and a thrust force also develops. One force in the axial direction called thrust force which is very large in drilling and one force acts in the opposite direction as the reaction into the tool. So, these are the forces two forces torque and thrust developed in drilling, boring, counter boring and similar work. So what we produce? Torque and thrust. Now as just now we described all the forces that is under continuous type machining like turning, drilling, boring where the force do not fluctuate. But you know that is machine tools like shaping, planning, slotting. There is an impact when the cutting tool just contact the job at that point at high speed, there is a contact or impact. This impact

creates intensive force and its effects. These are called impact type machining or impact type force in shaping planing and slotting.

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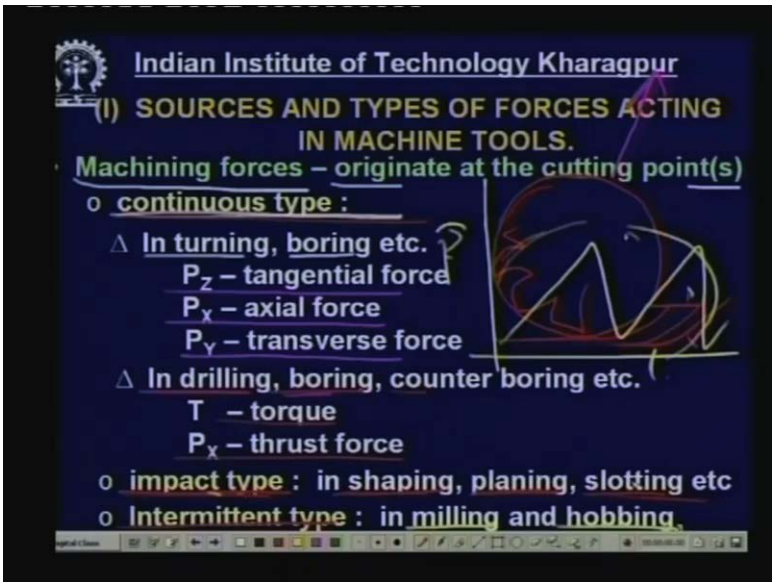

Now intermittent type is another type milling where, suppose a milling, this is the milling cutter which has got number of cutting edges and this is the work piece. So it goes like this, chips are removed layer by layer. As a result the cutting force with time cutting force with time it fluctuates this is the force. So this is called due to intermittent cutting is a dynamic force or what is called fluctuating force develops for example in milling, hobbing and similar process. So these three conditions have to be remembered.

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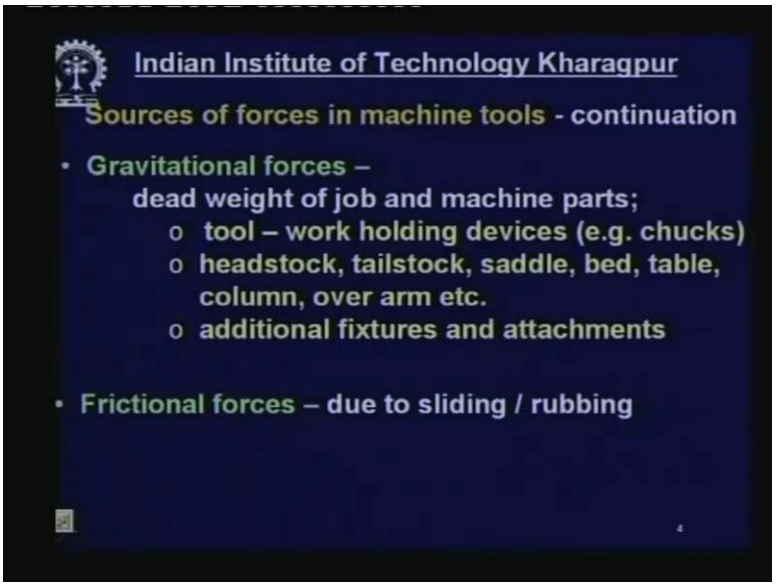

Next is gravitational force that is because of the weight. Weight of what? Dead weight of the job and machine parts; now sometime the job becomes so large is large that its weight is really considerable that acts on the supports, jigs, fixtures and so on and it has to be considered for force analysis. Not only dead weight of the job but dead weight of the machine parts large machine parts like say tool work holding devices for example chucks, vices and so on collets. Headstock and tailstock itself they are heavy and they rest on the table. So the entire forces act on the table and through the table on the foundation and so on.

So, these are to be considered weight of the saddle, weight of the bed, weight of table column over arm of milling machine, shaping machine. These are the things everything which are heavy. They are dead weight have also to be considered because they are distributed over the different parts of the machine and foundation. There may be some additional features and attachments which may be also quite heavy and their weights have to be taken into account. Next is the frictional forces; whenever there is a sliding, suppose the saddle the saddle heavy saddle under the cutting force you know slides over the lathe bed okay and on the heavy load so there will be lot of frictional force. This frictional force will cause lot of effects and will be transmitted to other components also.

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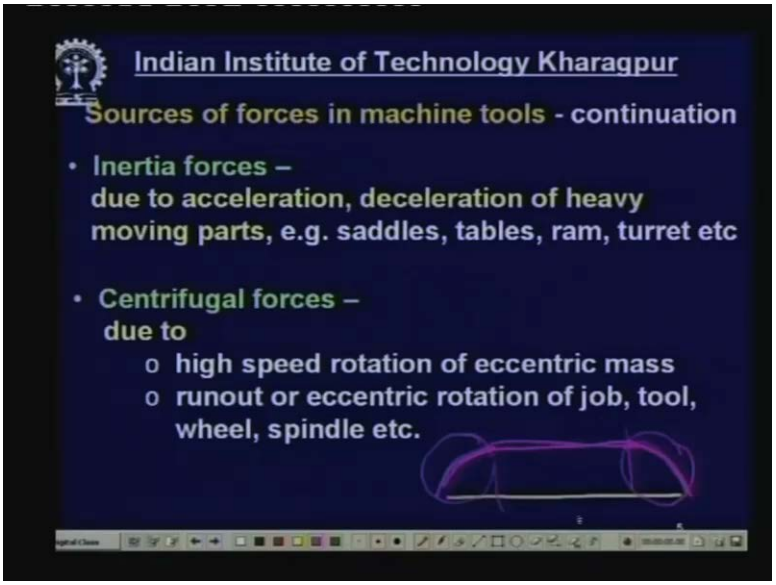

Next is inertia force; now inertia force in say reciprocating machine the cutting tool and the ram of the shaping or the table of the planing machine the table work table of the grinding machine they move like this the velocity is like this velocity profile. So they are more or less constant at the middle part but at the ends either they will be acceleration or retardation. Because of this retardation and acceleration multiplied by the mass which is traveling which will which will cause lot of inertia force that may be also large and has to be taken in to account. Due to acceleration deceleration of heavy moving parts for example, saddles tables of planing machine, grinding machine, Milling machine, ram of shaping machine, turret slide in turret lathe and so on.

Now sometimes the centrifugal forces are also become the source forces acting in the machine tool and they develop due to high speed rotation of eccentric masses. Now if there are lot of rotary mass, the job rotates the spindle rotates the gear rotates the clutch rotates. And if there be eccentric mass and that rotates eccentrically at high speed, lot of centrifugal force will develop and that will also act on different parts of the machine tools. Sometime this spindle this shaft or spindle may be perfectly all right concentric but because of the misalignment, they may rotate eccentrically. They may rotate eccentrically or the spindle is like this the drill rotates perfectly all right but the spindle may rotate eccentrically. Now all these things will create centrifugal force which sometime becomes quite considerable in size.

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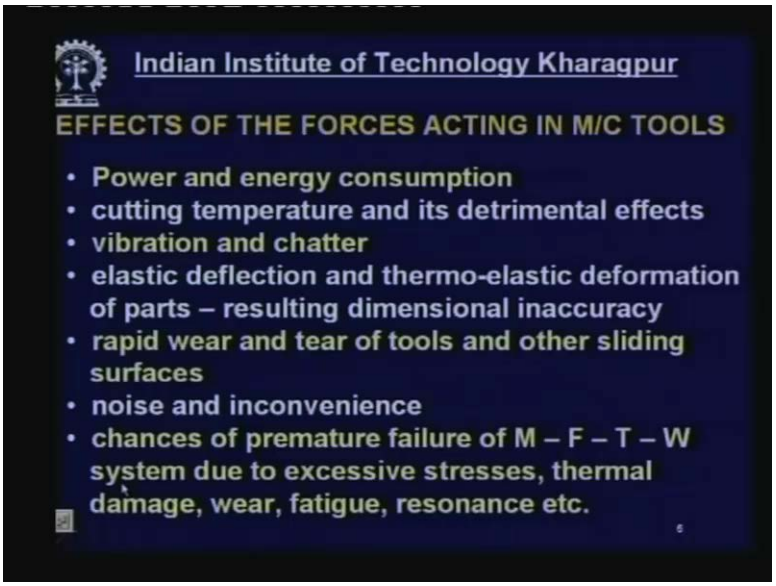

Now come to, we have been acquainted with the forces that develop and act in machine tools conventional. Now why we are taking interest, what are the effects of the forces that develop and act in machine tools let us examine. Power and energy consumption is related to the cutting force, force in to cutting force in to that is P z in to cutting velocity is a power and that in to time is the energy consumption. So more force means more energy, more power consumption, it has to be economized cutting temperature and its detrimental effects. Now this energy mechanical energy that is expanded through the force is mostly converted to heat that raise the temperature of cutting tool job and other parts also and this temperature is detrimental and may cause lot of problems.

So the force cause this effects because of large force or fluctuating force, there may be vibration and chatter in the machine tool which is very detrimental and this has to be controlled, this has to be understood, measured checked and so on. Due to the force elastic deflection and thermo-elastic deformation of parts take place. Now here is a rod long rod now when it is subject to a load force it with undergo bending it will undergo bending. So, because of the bending the accuracy of the product will be lost. Beside that, because of thermo-elastic deformation either contraction or expansion because of mechanically or

thermally the accuracy will be also lost. So the tolerance will be not maintained, rapid wear and tear of tools and other sliding surfaces.

So, the sliding or friction force is proportional to the forces that develop at the cutting point and on the slides and guides. So if lot of wear and tear takes place, the quality of the machine will fall lot of noise and inconveniences are created by the forces chances of premature failure. If the force are really very large and there are chances of premature failure of the machine fixture that is chucks, vices, tool, cutting tool holder etcetera and the work piece and its holders system. Due to excessive stresses because of the forces stresses will develop and than thermal damage, wear, fatigue, resonance will occur and may cause failure in to the machine fixture tool work system and all these are caused by the forces that develop in to the machine tool. If you do not use the machine tool, there is no force there is no problem. But if you use it then there will be forces and all the forces will be taken care of. Otherwise, if they are too large may cause so many problems.

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Now purposes of force analysis; why should we learn force distribution, force development force acting, effects of the force and all these things. How can you utilize this knowledge, what for we should learn the magnitude, direction, location, pattern of the forces etcetera. If we know all the magnitude, direction, location of all the forces acting develop and act in the machine tool that will enable us or you estimate power requirement. How much power or energy will be required to machine that will be determined from the force and once you know the power requirement, you can select the motors. So it is a part of the design. Now design the machine fixture tool work system. Now what is meant by design? Design means selection of the material of the component and the dimensions determination of the dimensions such that. Suppose this is the machine element it has to be designed, what is meant by design? Design means selection of this material and dimensions such that, this component will not fail under the due to stresses caused by the forces during function that is force will develop.

Due to the forces, stress will develop and we have to see that stress does not cause failure that is not exceeding the strength of the material or the body. So the force analysis has to be carried out for the purpose of design. Not only in machine fixture tool work system, design machine tool foundation that also requires knowledge of the forces. Evaluate process capability of machine tools. Process capability means ability to hold the dimension accuracy or minimize or control the dimensional deviation. Now the dimensional deviation or inaccuracy is caused by force and the lack of rigidity of the machine tool. Whatever be the rigidity, the force is nil. There will be no deformation, no problem. So we must know how much force is acting that multiplied by the compliance will give you the dimensional deviations and we have to check whether that is within tolerance or not.

Now assess machinability characteristics; Machinability. What is machinability? Ease of machining. What is easing? Ease that is ease is judged by cutting magnitude of cutting force. If the cutting force is large machinability is poor if cutting force is less machinability is good but at the not at the cost of productivity for same productivity. If we can reduce the cutting force that we can say that machinability has improved and machinability is characterized by temperature tool wear tool way tool life, surface tension and so on. But, the main criteria by which machinability is judged is magnitude of the forces. So we should know the forces and there distribution determine role of various machining parameters and optimize.

If we optimize or reduce the cutting force, we must know about the roles of variation of the different parameters on the forces. So that we can control the parameters and get lesser force, better distribution favorable distribution of the forces to make design easier and better and performance of the machine to improve, comprehend, need and way of improvement in design. Now time to time whatever we do, we have to try to improve the design of the machine tool, its performance, its safety, service life machine tool or the machine etcetera all of which depend upon the magnitude, pattern and distribution of the cutting forces. So if we know all these things then we can think of how to improve these aspects of machine tools. Now let us come to real analysis of forces acting during machining in different general purpose machine tools.

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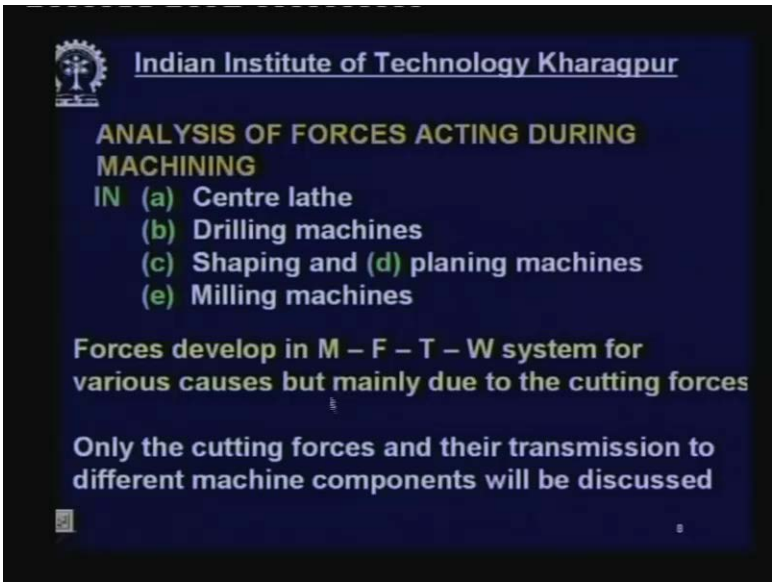

We have chosen four machine tools. Centre lathes, drilling machines, shaping and planning machines milling machines. Now friend if you understand if you or all of us understand the analysis of force or pattern of distribution, sources of distribution of the forces and then the methodology, then we can estipulate this knowledge and do the force analysis for other types of machine tools easily. So these are basic machine tools which fundamental machine tools we should learn about that. Now again forces I already told that forces develop in machine fixtures tool work system for various causes and reasons like machining forces that is cutting forces, friction forces, inertia forces, dead weights and so on.

But mainly the cutting force that is the major forces okay but mainly due to the cutting forces. Since time and space is limited onward, we shall discuss only the cutting forces and there transmission to different machine components will be discussed. Other forces will not be discussed onward that you can do it easily later on. Now let us start with centre lathe, forces acting in centre lathes.

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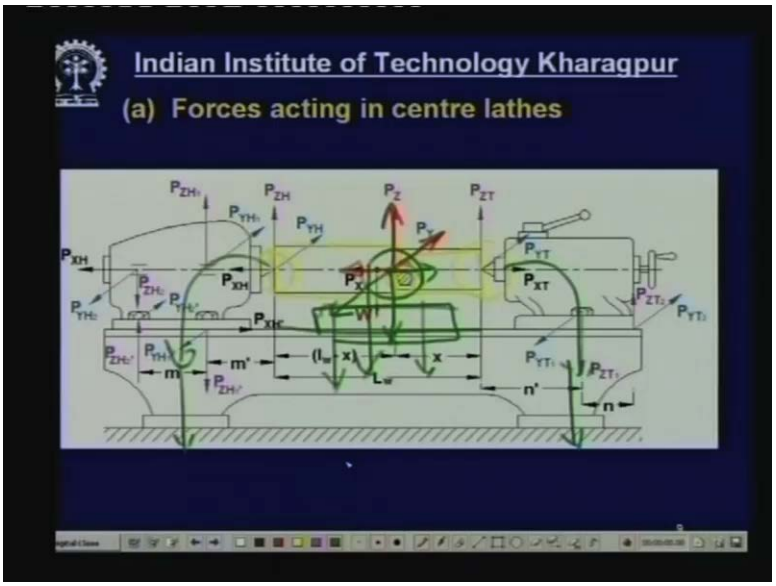

Now this looks this shows a centre lathe. This is the job work piece a straight turning. This is the cutting tool, the job is held in between the headstocks centre, tailstocks centre all right and here you can see due to the cutting process at this point at a distance of x say from the tailstock and total length of the job is L w. Now here the main force that acts on the job during machining is this one this is called P z tangential. One is radial transverse force Py which is responsible for vibration and dimensional deviation and so on. Another force is axial P x. So these three forces, actually there is only one force which is resolved in to three components for convenience of all purposes. So P z P y P x out of which P z is the largest, P y is the medium and P x is the smallest. But, on the tool as a reaction as a reaction on the tool the force of P z will be acting in this direction, P z will be acting in this direction on the tool. P y in this direction and P x in this direction. Their direction and magnitude are same, but the senses are different. If it is in this direction and the tool will be off the direction.

So all these forces acting on the job and the tool will now be transmitted to the headstock, to the tailstock. Through the headstock to the bed, from tailstock to the bed and again the cutting tool which receives the forces is resting on the tool holder. So tool holder will also subjected to the same P x P y P z. The tool holder is mounted on the tool post. So the tool post will also be subject to same forces, then tool post on the compound slide, cross slide, saddle, carriage all of them will be subjected to sources. Now the saddle will be moving along the bed. So when a saddle receives all the forces that will be again transmitted to the bed. So the bed receives forces through the tailstock, headstock. Through the tailstock and through the saddle all this forces and the forces that received by the bed will be again transmitted to the foundation. So this is how the forces are developed at the cutting point and distributed among the major parts in a way this will be shown and discussed. Now it will be discussed and these forces will help us design of the components of different major elements of the machine tool.

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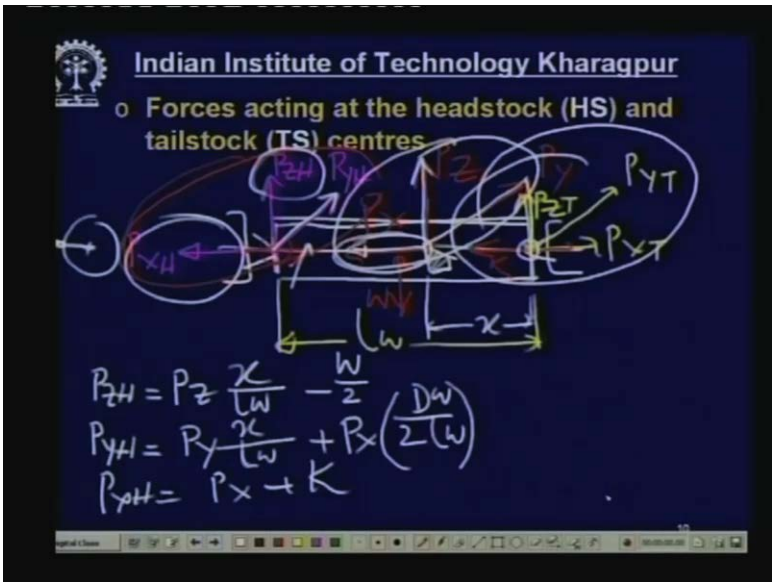

Now let us see the forces acting at the headstock HS and tailstock centre. How this will be done? Let us take a job, a rod and this is getting turned, held in the tailstock centre and here is the headstock centre and suppose at a distance x from the tailstock end, there is a cutting tool. Now due to the cutting tool, I am drawing the same figure what will happen? On the job a force will act this is P z P z a transverse force will work P y and one P x. Now due to this force act develop on the job, that will be transmitted to the headstock centre and tailstock centre. What will happen at the heads headstock centre? This will be created here the force, one another force will act in this direction, another force will act in this direction. Suppose this is called P zH headstock, P yH headstock and this is P xH. Similarly at this point at the tailstock centre a force will be developed that is P zT. T for tailstock one P y tailstock and Px tailstock all right.

Now how much will be the force, how shall we decide? Suppose the length of the job is L w. Now remember when we hold the job, we apply an additional force here for tightening the job is'it? So that acts in this direction this direction suppose this is called K and the job is heavy. So it has got its own weight and suppose that weight is W which is acting suppose at the centre. Now determine these three forces P zH, P yH and P xH acting at the headstock Centre. How will you do that? Very simple say P zH, P zH it will be how much? Take moment so this is this is the sources of the forces that will be distributed in headstock and tailstock Centre. Now we are now taking P z this P z take moment about this point what is the moment about this point P z. P z in to x that will be divided by this length L w. So this is the force P z H which you can determine taking moment about this point. So P z in to x is the moment divided by this distance momentum.

Now there will be another force this w. This w will be distributed suppose equally on the headstock and tailstock centre and this will act in the downward direction. So this will be w by two minus. Similarly P yH P yH. Similar to Py, this Py multiplied by x momentum divided by total length L w. Now here Px, the force that is acting here that is not acting

through the centre but this force acts at the periphery. So this force acting in this direction multiplied by the arm gives a moment. So P x in to D diameter work piece diameter by 2 divided by L w. So these are the forces acting. Now what is P xH? P xH will be equal to Px this Px plus this tightening force K plus K. So this is how the forces are being determined at the centre. Now similarly find out the forces. These forces P z sorry let me just clear it.

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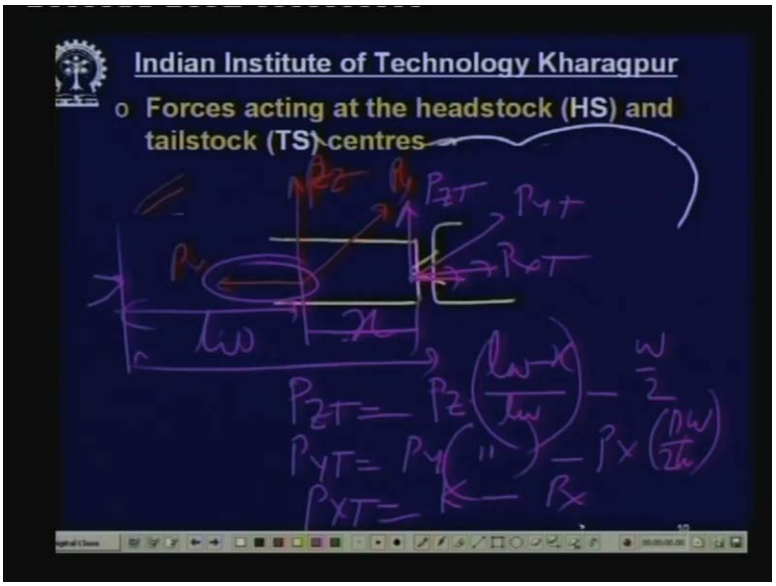

This is the job and this is the tailstock. Now these are the forces we showed. Suppose this is P z P z and this is P y and this is P x. We have to determine now the forces this P z T, P y T and Px T and this distance is x and the total length of the job is L w. Exactly the same way here, Pz T will be equal to take the moment about this headstock centre. So P z in to what is this? Distance L w minus x, this is L w minus x Lw minus x by L w again the half of the weight minus w by 2. Similarly P yT will be equal to P y same factor minus P x in to D w by 2 L w and but P xT will be equal to K minus P x because P x is acting in this direction. So this will be this K minus P x. So friend this is how these forces at the centres can be determined. Now come to forces acting on headstock and tailstock and bed:

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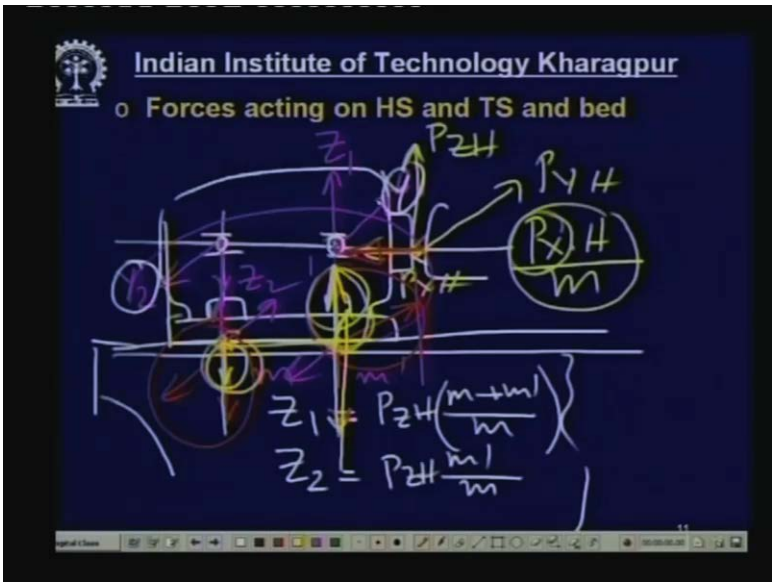

Now here, first you show suppose this is the headstock, this is the centre and this is the job and these are the bearings and there are two bolts by which this headstock is fitted or clamped on the bed. Now what we have to do now? What we have seen? That at this point, the forces act P zH then P yH and P xH. Now we have to determine the forces acting on the headstock body this headstock body what are the forces acting, now this force is to be transmitted to the spindle. Now the spindle will be loaded and the spindle from the spindle the force will be transmitted to the body through the housing. Now what was the distribution? Distribution will be one force here say Z 1 H 1. Let us point one consider one and at this point, this will be Z 2 and Y 2. These two are the forces acting. Now suppose this distance is m and this distance is m prime. Now you can determine all these forces Z 1 Z 2. For example, say Z 1 is how much. Z 1 you take the moment about this point. So this force P zH in to this distance m plus m prime divided by this distance this is Pz Z 1.

What is Z 2? Z 2 would be you take moment about this point P zH that is force in to this distance, m prime divided by this distance m. So in this way you can determine Y 1 this Y Y 1 and Y 2. Now the question is, now the force will be transmitted to the bed. How this will be transmitted, this force is going up. So through the bolt, the bed will receive a force acting in this direction. And in this side the force will be transmitted to the bed in this direction. So from this bolts or the junction on the headstock, this will receive force like this and also these forces will come to this and as a reaction these forces are acting on the bed.

Now on this headstock, the reaction force will be this reaction force this reaction force just opposite this reaction force and this reaction force. So the headstock will be subjected to these forces and the bed will be subjected to by the rate force this forces. Now beside this two forces which can be determined, another force will develop because of this P xH. This P xH will cause you know some force in this direction, additional force in this direction. So, the rate force plus this force together will be acting on the lathe bed in this direction and similarly one additional force will act in this direction. Now this force will be equal to how

much? This will be equal to P x in to the height divided by this distance m. So this additional force will come here and here. So you can see what are the forces that will be acting at the centre at these points on the lathe bed. One force in this direction due to Z 1, one force in this direction because of Z 2 and then this additional force this one, and this one because of P x all right. Now similar to forces acting on the tailstock in the tailstock side,

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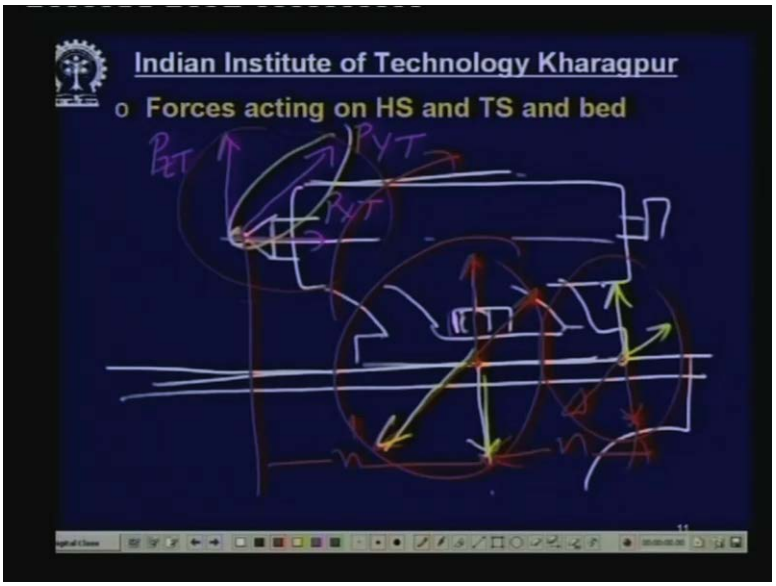

Suppose this is a tailstock centre and this tailstock is resting on the lathe bed okay and this is the centre. Here is a bolt by which it is clamped through here and at the centre, what are the forces acting we determined? These forces were P zT P yT for tailstock and P xT. Now this and suppose what are the forces that will be acting? This force will try to lift this lift this tailstock but this will be held tight by the bolt. So here the tailstock will receive a force downward and the lathe bed will receive a force upward. At this end, this will try to give a moment like this. So this end through this end the lathe bed will get a force in this direction and as a reaction on the tailstock the force will act in this direction.

Similarly this Py will cause forces on the lathe bed this way lathe on the lathe bed in this way and on the tailstock on the tailstock this one at this point. On the tailstock this force and in the headstock sorry in the lathe bed in this direction. Since we know this distance suppose this n prime and this is n, we can determine all the forces. So to determine the forces at different points what we need? The magnitude of the force originated through cutting action and then the configuration and dimension of the machines and machine parts. Now forces acting on the bed under the saddle:

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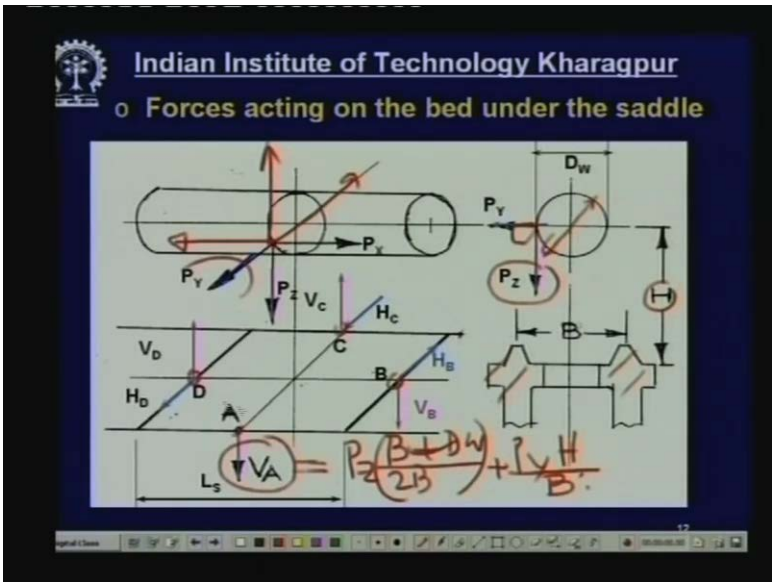

Now this is the work piece again come to the work piece. Now this is slightly you know isometric view shown and this is the cutting tool here. Now on the cutting tool as I told that the cutting tool is mounted on the tool post that is tool rest tool holder then tool post, then compound slide then cross slide and from cross slide to the saddle and from saddle, the force comes on the bed and so the bed receives forces that is imparted to the tool also. Now you remember that actually in way one the work piece the forces that where developed this was P z this was P y and this was P x on a work piece. What are the forces on the tool on the cutting tool? This is P z, this is P x and this is P y just in the opposite direction but magnitude and another way it is same. Now the saddle suppose the saddle is resting on this is the lathe bed okay. On the lathe bed, it is resting. This indicates the area of contact, the apparent area of contact between the saddle on the bed.

Now we assume that this contact is concentrated at 4 points A B C D. All the forces are concentrated on these 4 points, then what will happen? Now if you see from side, this is the work piece and this is the cutting tool here because of that P z will act like this P y and P x perpendicular to the plane. This is D w and this is the lathe bed okay of width B. This is the width of B and the diameter of the work piece D w and height of the centre is H okay. Now you have to determine the forces. How will you determine this? For example, the most important one is V a. How this must? This will be this will be created by the force P z and P y P y will create a moment that will induce a force V a in this direction on the bed. This will be equal to P z in to this B plus D w diameter of the work piece by 2 B plus P y. This P y multiplied by the H height the moment divided by the width of the saddle B or B prime say like this this is V a. Now V c will be similarly you can determine V c and next is this V D.

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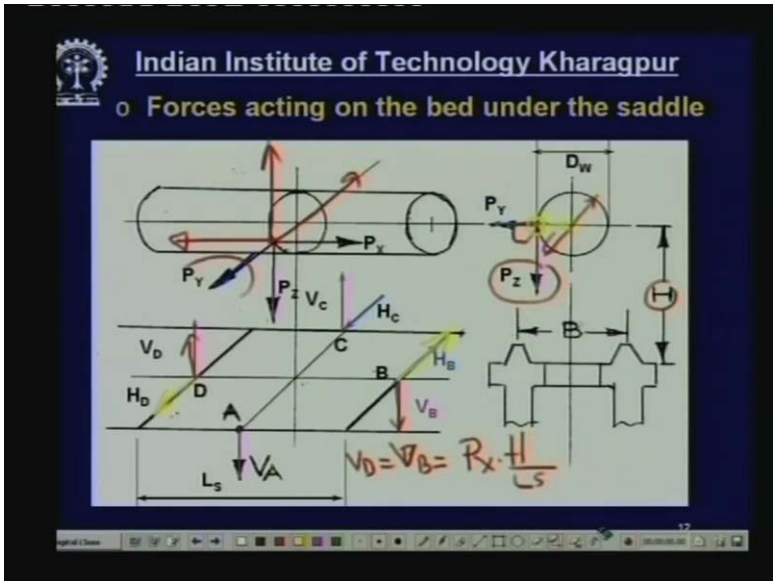

This V D this one V D and V B. These two forces will be caused by the force P x. This force P x that is acting in this direction that will create a moment because of that moment caused by P x the V D and V B V D will be equal to V B and this will be equal to P x in to height divided by the length of the saddle tats all simply. Now these two forces how about what about these two forces horizontal forces H D and this one H B. These forces will be caused by the moment because the P x is acting in this point. At this point with this point, within momentum this much. So this will also cause a torque or moment and then this will be this will be how much.

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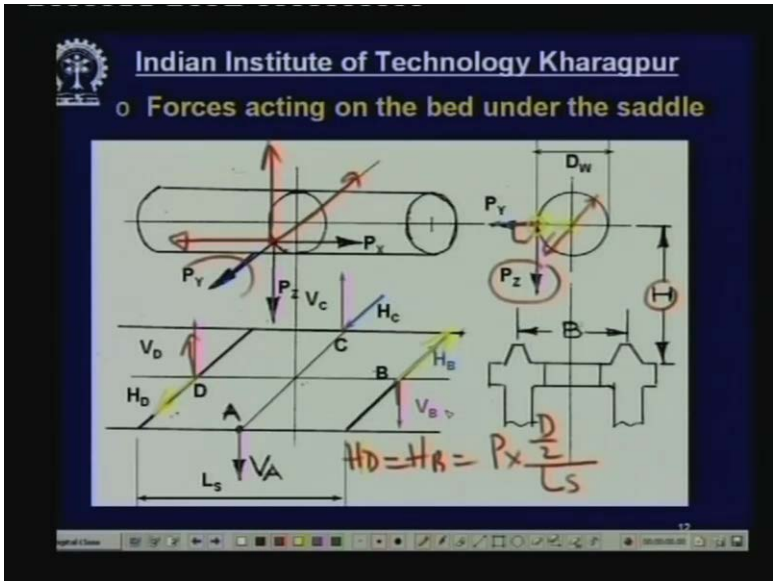

H D the horizontal force H D is equal to H B that will be equal to P x in to the momentum D by 2 divided by L s. So this is how, all the forces now this forces I have shown these are acting on the lathe bed. What are the forces acting on the saddle? The same force but in the opposite direction tats all. So this way we could find that how the forces are originated in the machine tool like centre lathe and how they are distributed over the different parts of the machine tool. Now, this will help design of the machine tool and fulfill the other purposes as I already mentioned. Now come to drilling machine, the forces acting in drilling machine.

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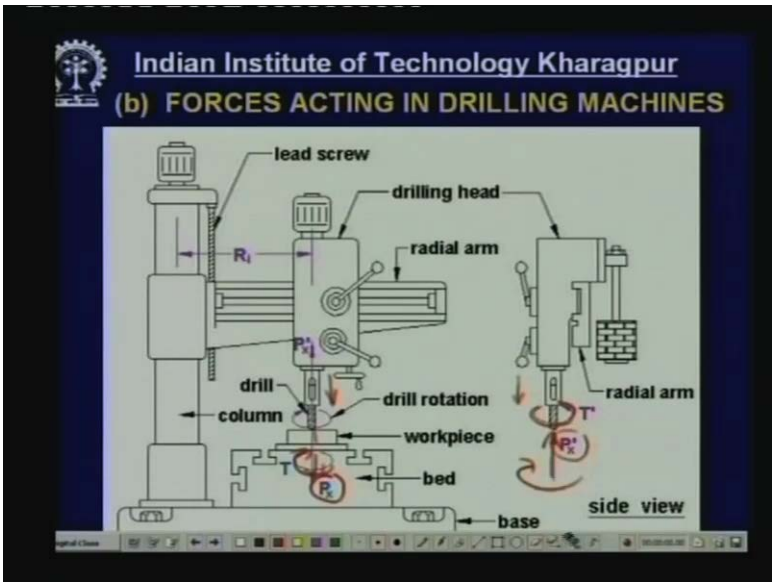

Now this diagram shows a radial drilling machine which is largest and most complex amongst all the drilling machines. So we have chosen a radial drilling machine, a radial drilling machine as you can see here, that there is a cutting tool drill. This is the drill okay and this is the work piece which makes hole okay through or blind hole. So this is the basic purpose. Now then what happens because of the cutting action, the drill rotates. Here this shows that the drill is rotating and moving downward that the feed motion is also there. So one is cutting motion and one is feed motion, one is feed motion. The drill down moves downward like this.

So there is a feed motion and there is a rotation like this. Inside the job, now what happens? Within the job, a thrust force P x will develop which will be acting vertically downward, axially another torque as action on the tool drill the reaction a torque T and a vertical axial force P x. Now these two forces are the original cutting force. These forces will now be transmitted to all other members throughout the drilling machine and accordingly you have to utilize them. Now let us have a look. How these are distributed? I shall not show you all the force, but tell you really how it is transmitted and one by one. First let us consider that the force coming to the job so this is the job.

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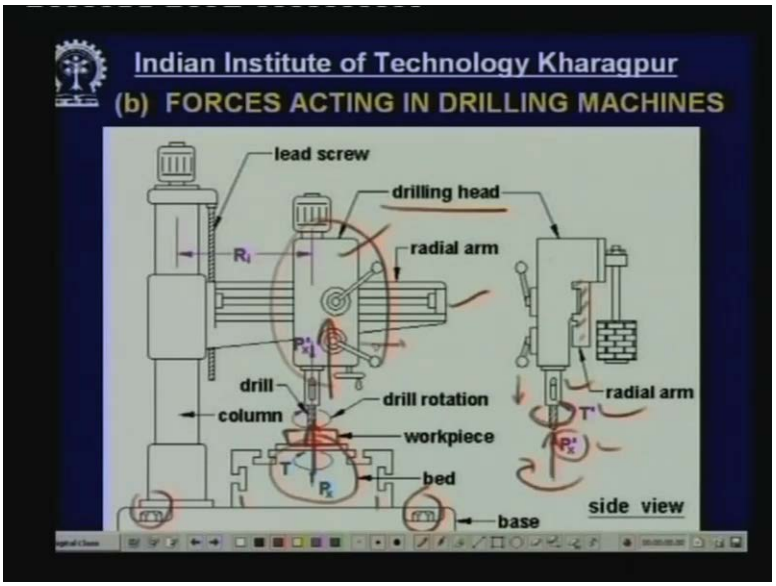

From this job the forces, torque and thrust comes on to the bed okay. The bed is grouted on the base. So all the forces come on to the base and the base is fitted in to the foundation. So this torque and this thrust force are transmitted through the cut job up to the foundation in equal magnitude and direction, these are the forces. Now what about the ? Now suppose now then you understand that when you design the foundation, you have to consider these two forces and there distribution through the bolts. Now come to the other part the force, torque and thrust that is transmitted from the cutting tool drill to the spindle, from spindle to the drilling head. This is called drilling head drilling head and from drilling head to the arm on which the drilling hear drilling head is mounted and slides and the arm is mounted on the column.

This column and how the column is loaded by forces let us examine. This torque and thrust will be transmitted to the spindle which is rotating. Now the torque multiplied by the speed angular speed will give you the power. So power consumption can be determined from torque. Now this force P x and torque you can design the spindle. Next is this force P x which is very large I told you earlier if you remember that the thrust force in drilling machine is unusually very large because of unfavorable drilling action, cutting action of the drill point may be say half turn to few turns. Now drill force that acts here what will happen. This will come through the spindle in to this drilling head. The drilling head is resting on the saddle. This is, if you take the section of this this is radial arm radial, this is section of the radial arm this is a radial arm. So this force will act on the radial arm. Let us clean it and now see that this force P x will act on this arm.

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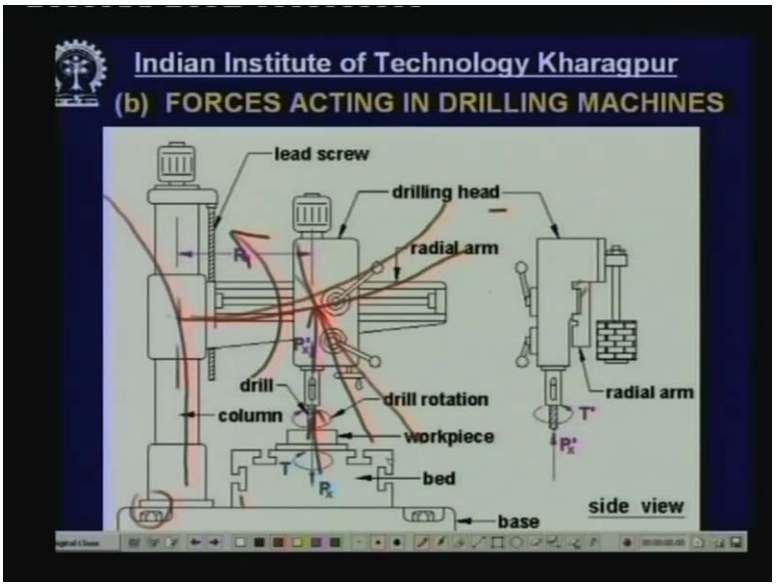

So the arm will be subjected to a moment like this all right and this will undergo a deflection because of this torque and bending bending moment and then because of that spindle may be inclined and this will cause error in this drill hole. Because of this moment, the column will also deflect and this radial will deflect further and the spindle will deflect further. This will cause lot of error or inaccuracy in the hole, in the axis, in the angle and the diameter. So, all these problems will arise. Therefore, if we know the force and the deflection we can estimate the amount of dimensional inaccuracy or estimate this process capability and we can design accordingly.

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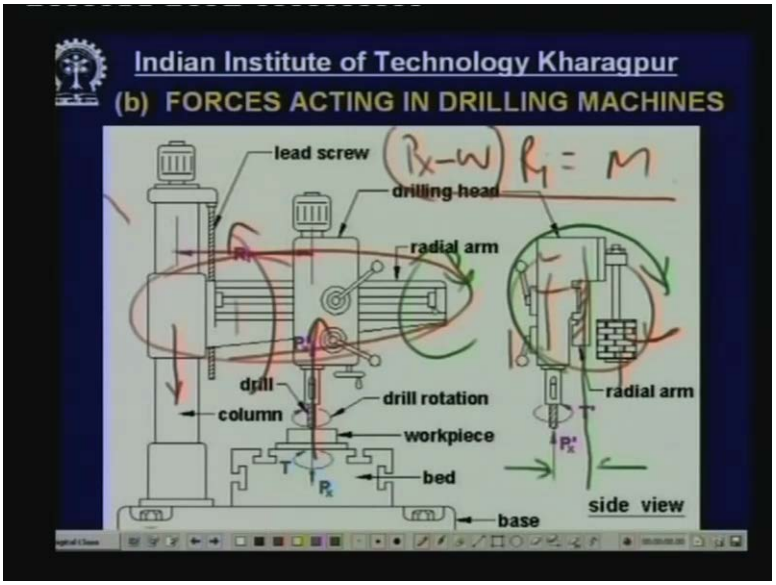

Now remember here the saddle, this arm this radial arm okay. So this the radial arm on one side, this is the drilling head hanging which is very heavy to balance it another dead weight is mounted. So this dead weight and the self weight balance but the entire load is coming on to the bed on to the sorry on to this cantilever beam. Therefore when you consider the moment which is equal to the force, P x multiplied by the radial arm then, and since the force gravitational force act downward. So what we have to do? We have to deduct this dead weight like this dead weights that multiplied by R i is the moment. But, there will be lot of bending moment no doubt. This is the torque on this but this will be the bending moment this much okay and the same will come on to the column.

So the column will also get the entire load of this one will work downward on to the column. So the column has to be very rigid and strong. So this is how all the forces beside that here you see that this force and this dead weight. They balance but what about this? This is the axis neutral axis of the arm and this is the force P x. So there is a gap momentum. So this will cause a twist on this will cause a twist on the arm. This has also to be taken in to account while designing or say when determining the overall system compliance extra rigidity and so on. Now forces acting in shaping machine and planing machine:

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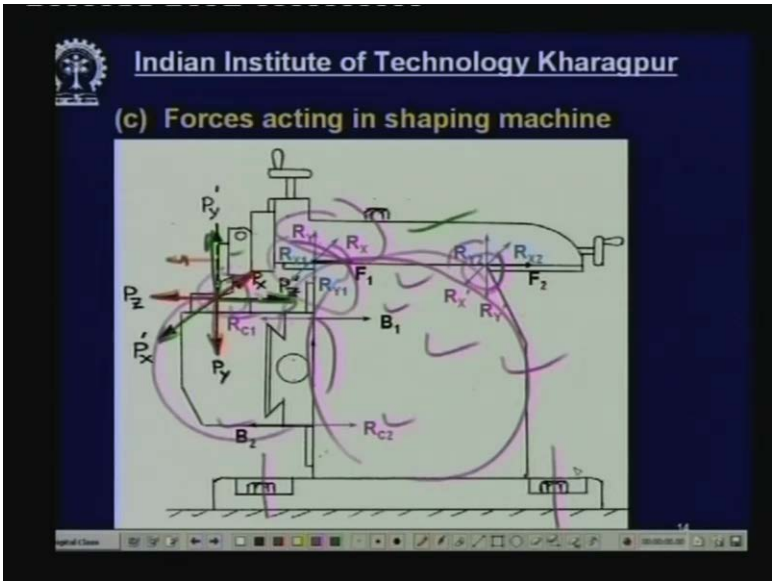

Planning machine and shaping machines are more or less same. So let us consider only shaping machine. The shaping machine is very simple. Here we can see that this is the job and this is the cutting tool. Cutting tool moves forward in the cutting stroke, then what happens? This is the cutting force P z acting on the job. This is P y acting downward on the job and P x acting on the job. Actually there is only one force like single point cutting that is resolved in to P x P y P z as shown acting on the job and job is mounted on the table. So the table will also receive the same forces. But as reaction, what you get as a reaction? This is a reaction force P z P y and P y and P x on the tool. Now this tool is mounted on this clapper box on this ram. So, all the forces will be transmitted to the ram.

Now these pink forces shown here; these are the forces acting on the ram. Through this two points and at this point, these forces shown here in blue. These are the forces acting on... This is acting on the ram as well as reaction on this column because the forces shown over here that will be acting on the ram will create reaction of same forces on the column. This is the column main body. Now the forces acting B 1 and B 2 Rc 1 reaction forces, all these forces will be acting on the bed and the reaction on the column. So the column receives force through the ram and through the bed coming from the cutting point and this way and now you can say that from this all these forces are transmitted to the foundation, through this foundation bolts. Now planing machine:

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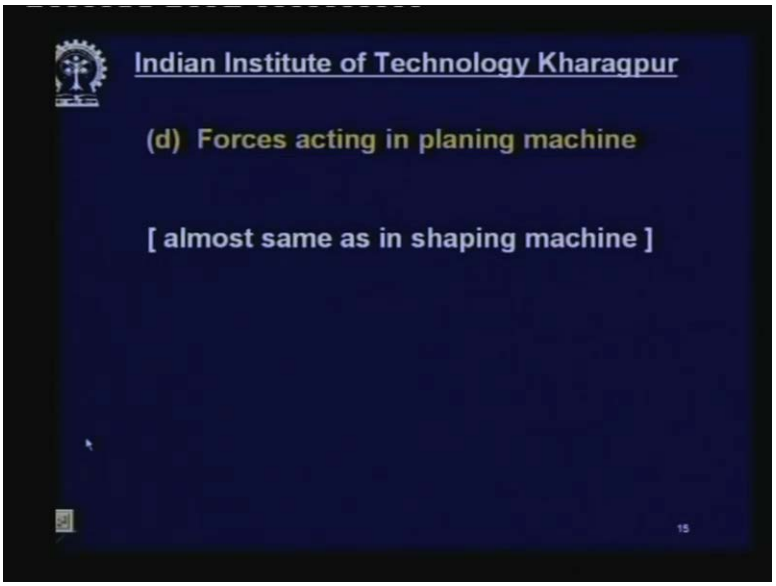

Planing machine and shaping machines are more or less same as I told you that the magnitude, location and this direction of the forces acting on the different parts will depend upon the pattern of the source forces and then the configuration and dimension of the machine tool. Now the shaping machine and planing machine are same in respect of machining principle. So P x P y P z will be exactly same. Only the forces distributed at the different points will be different because the planing machines are large, the dimensions are different. Otherwise the basic principles are all same. Last the planning, the milling machine;

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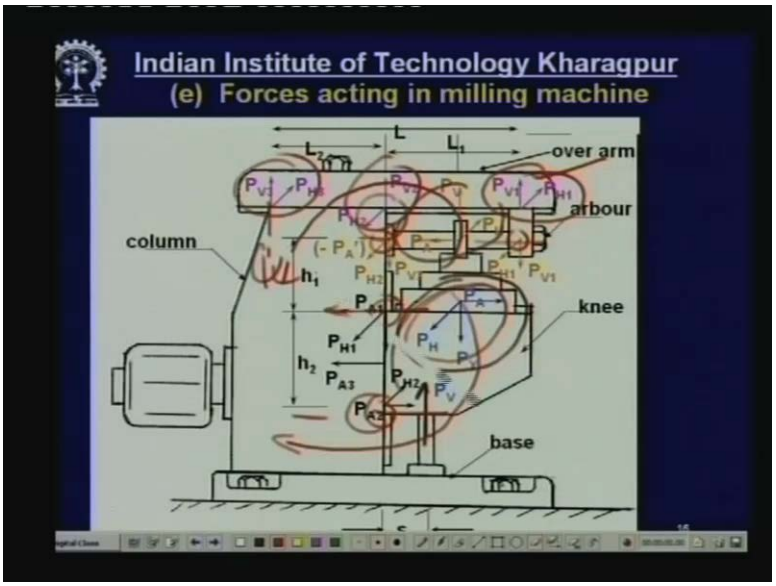

What do we see in milling machine? This is the tool and this is the job. From the job, they are transmitted to this parts. This is the job holder vice, this is the cross like, this is the bed and this is knee and this is the base and foundation. So these are the forces which act on the job from this job to the bed and so bed receives and the reaction force comes to this. So the blue forces are coming on to the bed. Now the forces that are shown over here by red are acting on the arbour. Now the reaction forces will develop here at the arbour and this force will transmitted to the over arm. So these are the forces acting on the over arm at three locations and these will be again transmitted to this column from here and here.

From the bed, the forces will also be acting from these two points, in this direction and in this direction and in this direction. Similarly this will be having some reaction forces on to the blank. So from the forces P A P H P Y on one side, you come to this side and come in to this column and from this side also come in to the column. So you get the forces acting on all parts of the body and you can get the forces acting on all the parts of the milling machine. Now similarly, this is how you have shown milling machine. Now again I remind you that we have considered only the cutting forces. But there are other forces also like dead weight, inertia than friction and so on. The basic principle of the force distribution, analysis were more or less same in all machine tools. So you can do this work onward for any conventional as well as CNC machine tools. Please practice it and you will do it and you can see books also, number of books are there.

Thank you.