Metal Cutting and Machine Tools
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Lecture - 01
Introduction

Welcome viewers to the starting course I mean starting lecture of the course metal cutting and machine tools. So, this will be a 10 hour course in which we will be discussing different aspects of metal cutting and different types of machine tools their applications etc. So, by way of introduction I will go through rough overview of the you know 2 ideas metal cutting and machine tools their relation ecetra, and then from the next lecture onwards we will be taking up all the aspects in more detail.

So, first of all metal cutting what do we exactly mean by that. Metal cutting in is you know concerned with removal of material, mind you metal cutting at this you know at this age does not necessarily involve only the removal of metals are only the cutting of metals, but it is referred to all materials in general. So, that if you consider it is correct to say material cutting or material removal, why are we removing material? Because we want to achieve a particular shape and size in a part by removal of material ok.

So, let us have a look; metal cutting in machine tools, my name is Ashimava Roy choudhury and I am professor in mechanical engineering department of IIT Kharagpur. So, let us have a look at this particular figure ok.

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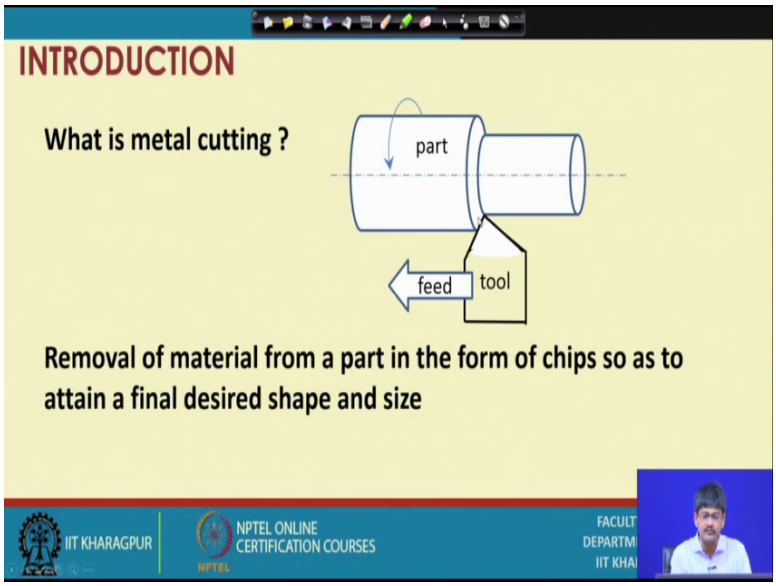

What do we have if you look at this particular figure, what do we have? We have just a moment, we have here you know work piece or part or job shown here rotating and there is something called a tool or a cutting tool, here how is it characterized? It is characterized by a sharp you know point and some sharp edges here, and it is moving past the rotating member that is removing material.

We will look at several other figures in which the removal of material is shown in more detail, what happens is when this part is coming here it gets into the path of the moving tool and this material comes out in the form of a chip a ribbon of material is removed here sorry just a moment, so removal of material from a part in the form of chips.

So, as to attain a desired shape and size, I want to attain a desired shape and size and for that I am removing material from the main body which is called the part or work piece or job etc I am removing part of it, so that at a particular shape is attained. So, naturally this particular exercise is carried out always on a part, where there is you know excess material is there, but why would we do that? We are doing that because there might be intricate geometries present on the surface of the part, which cannot be attained by other means.

So, immediately there is the identification of other methods of attaining a particular predetermined shape and size, and all these things you know together they are referred to as manufacturing. So, let us have a quick look what is manufacturing all about.

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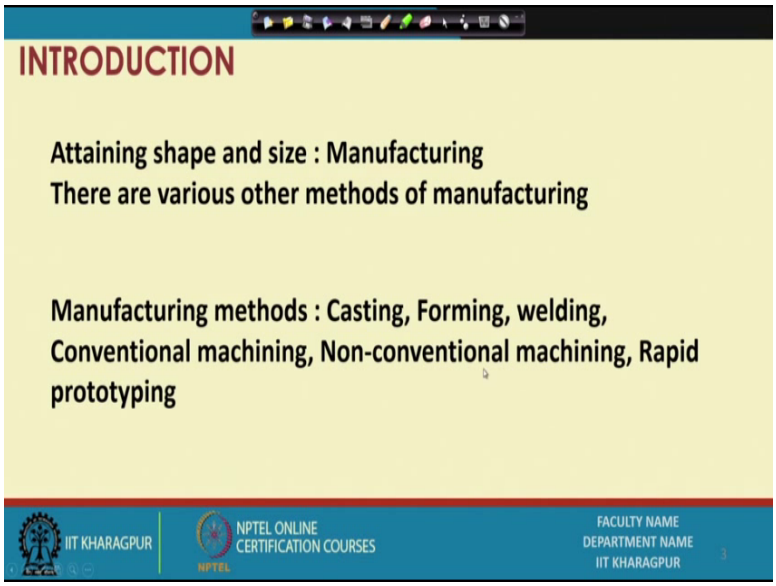

Attaining shape and size predetermined this is what manufacturing is all about. We can have different ways of manufacturing these shapes and sizes and metal cutting happens to be just one of them. So, let us have a look what are these methods by which we can manufacture shapes and I mean parts of different shapes and sizes.

We can have casting, we can have forming, we can have welding, we can have conventional machining, we can have non conventional machining and we can have rapid prototyping these are some of the you know main methods of attaining shapes and sizes; there can be other methods also there can be hybrid methods; that means, a mixture of 2 of the processes etc. Now in that case first of all where is metal cutting I cannot see metal cutting or material removal etc. Metal cutting belongs to this particular group; conventional machining, material removal, conventional machining, metal cutting, metal machining etc all these things are belonging to this particular group.

Why we calling it conventional? Because, we are going to you know apply certain practices there will be certain types of what I call it particular types of material removal, which can be categorized as a single under a single principle of material removal and that we can calling as conventional; what are these principles? It is something like this, if I you know if I remove material from a body by mechanical means by applying force and remove material that is generally referred to as conventional machining. We will see this in more detail of course, non conventional machining is that when we apply this

particular I mean when we remove material from a body, where some other principle of material removal is taking place; we refer to it as non conventional what is that where what are the process principles by which material removal can be carried out without mechanical means.

For example, electrochemical machining we can apply electrolysis and electrolytically dissolve a particular body, so that you know material is removed there we are not applying mechanical forces in order to remove material. So, non conventional machining can you know can be electrical discharges across a gap, so that these electrical discharges cause thermal damage to the material that means, simply it heats it up to such an extent etc, so that is called electrical discharge machining.

So, electrical discharge machining can be there, electrical sorry electrochemical machining can be there, laser machining can be there so many such non conventional machining methods are there. Generally we will only be having you know brief overview of these non conventional methods, in our lectures we will be mainly concentrating on the conventional machining principles rapid prototyping. Just like you are say removing material and attaining a particular shape; that means, you are moving by subtractive principles we are subtracting certain volumes from a main part main volume and attaining a definite shape and size, in the same way we might be adding on; that means, we might be going on additive manufacturing we might be adding different volumes together.

So, that they stick to each other and form our definite shape and size, in that case we call it the method of rapid prototyping or additive manufacturing. I will just you know in one or two lines I will just try to give you the idea of casting forming welding etc.

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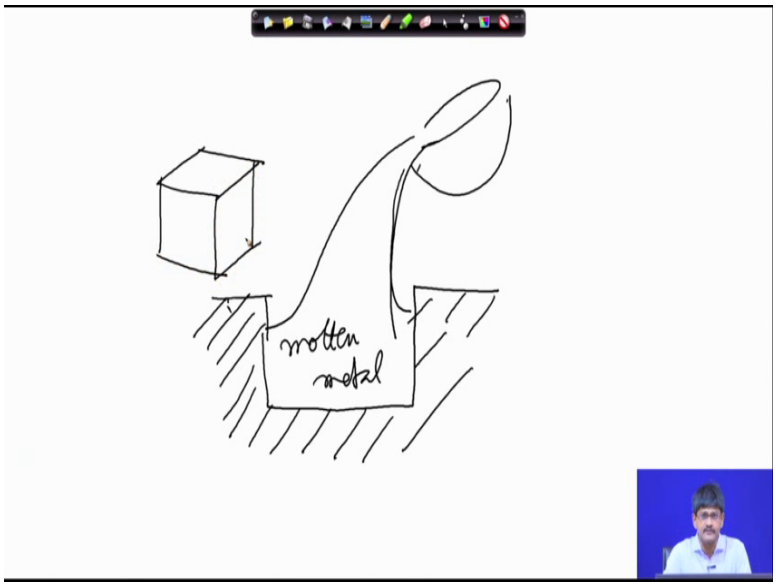

So, that we have a brief overview of the main methods of manufacturing, suppose I have a cavity, I am showing very simple principles. So, some methods some material is here. So, that a cavity is formed, inside this cavity I pour molten metal.

So, ultimately the molten metal will solidify, so if it solidifies, it will attain the inside or internal a shape and be of a definite size. So, this is casting, melt the material pour it into a cavity of predetermined shape and size and when it solidifies, we can take it out I mean we can remove the I mean this particular sand mould which is shown here, that can be destroyed and we can take it out and we will get a solidified body, say it might be something like this and if this is exactly the shape that you wanted and you are satisfied with the rough surface roughness and you know whatever imperfections might be there that is it in a single process you will be achieving what you wanted.

If however, there are you know some surface imperfections which you have to do away with or the surface is too rough for sand particles are sticking to it, so many other sort of defects can be there in that case what we do is, we go for secondary processes.

Secondary procecess in order to make the job or the part or the work piece or the or the casting acceptable. So, this is what is casting all about; we basically go for melting and re solidification in a cavity of predetermined shape and size. There are so many other details about casting, which I am not touching here because, we just want to have the basic idea by which this particular processes work. Second so if we once again look at

this, so let me quickly go for another page. So, here welding what are we doing? We are fabricating, we are say connecting up these 2 pieces need to be you know joined.

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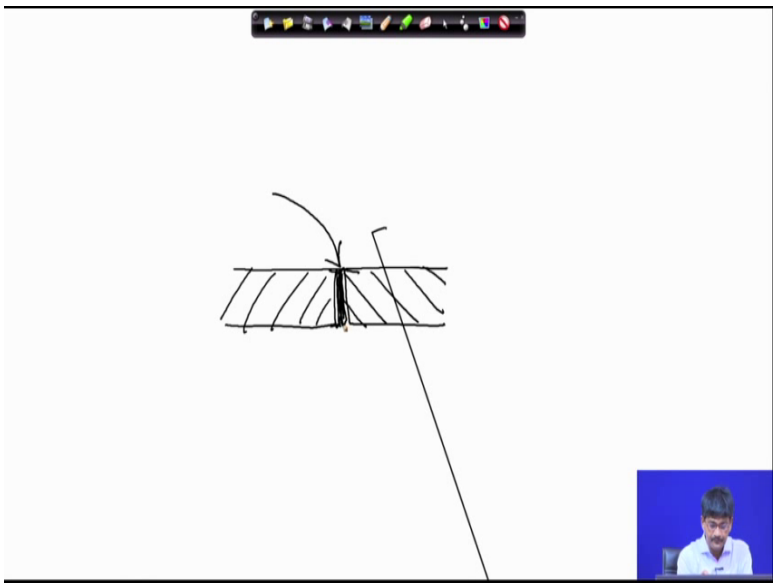

So, welding is a joining process, we can build up ships with that. So, some material in between or make them very close together and heat them.

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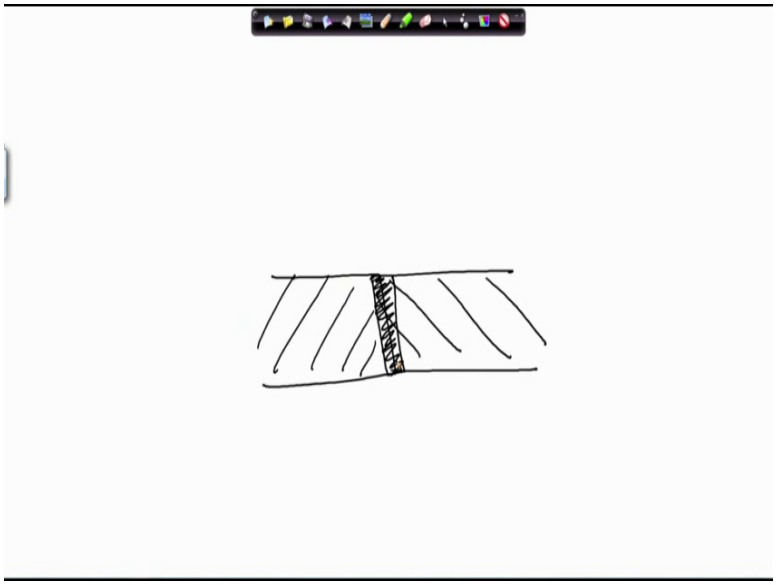

So, if I have 2 such materials this is one, this is the other and I heat them at this point, so that this part melts when it solidifies this will be a single piece. So, that we can join parts and make up shapes, our main concern is to make shapes of predetermined shape and

size. So, many times you might have seen even in a civil activities, gates, grilles, window grilles etc these are made very elegantly by welding. So, just imagine if welding had not been there how would you have done these things.

So, it is a very important manufacturing process, so we come to know of casting we come to know of welding. Now welding can be of different, I mean different welding methods can be there, but that is not our concern today's lecture, our concern is to get to know to have an overview of the different manufacturing processes; so that we one we understand where exactly machining or metal cutting or material removal process stands.

Next we come to forming. So, let us have a quick look at forming, forming method essentially involves you know deformation, I deform a particular body into a definite shape let us have an example.

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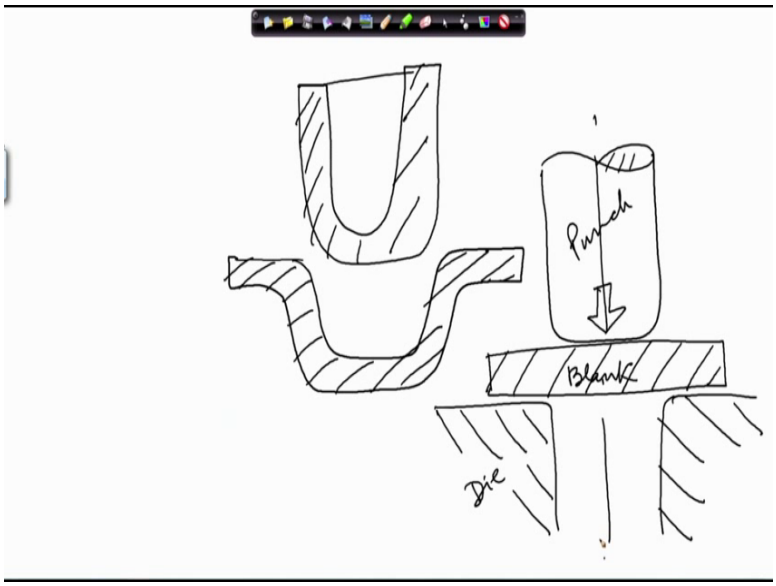

This is a very simple and explanatory example, someone shows you this part it is a sheet metal and we are seeing it only from the side a sort of sectional view, how was this done? and that particular person says that it was done by say deep drawing, what is deep drawing? So, initially there must have been a body of this type, a sheet metal piece, may be circular this way and there was a punch and there was die.

Now what are these punctuation of dies? They must be you know materials which are made of hard and tough materials so that they do not deform, but this deforms this is our

length. Length refers to the shape of a part before machining or before metal forming or before any such formative or manufacturing process the blank.

So, this we call the punch, this we call the blank, and this we are calling the die, so if this goes down we will have gradual deformation and this is one intermediate step, when it is fully through this will be drawn in the form of a cup. So, at that time that the shape the internal shape will correspond to that of the punch outside shape, it will be a conjugate of that surface outside diameter will be corresponding to the inside diameter of the die ok.

So, this is one example of metal forming, you can deform a body into shape you are not having removal of material in the form of chips, you are not having melting, you are not having joining, but you are basically deforming by plastic deformation. Please note that had it been elastic deformation it would have sprung back into shape. So, it is definitely plastic deformation, which means that once it is deformed it cannot come back to the original shape. So, is what is this is called? Is called deep drawing and there can be other methods also for example, there can be rolling, there can be forging, there can be extrusion, there can be back extrusion so, many methods are there.

But as we just need to have an overview, I am sure that you will get the basic idea of metal forming from this example; next when we when we are talking about sorry. So, this part we have already discussed overview of casting forming welding conventional machining we are going to discuss that is actually our topic and non conventional machining let me give you a quick idea about some of the processes. Non conventional machining say I will start with laser.

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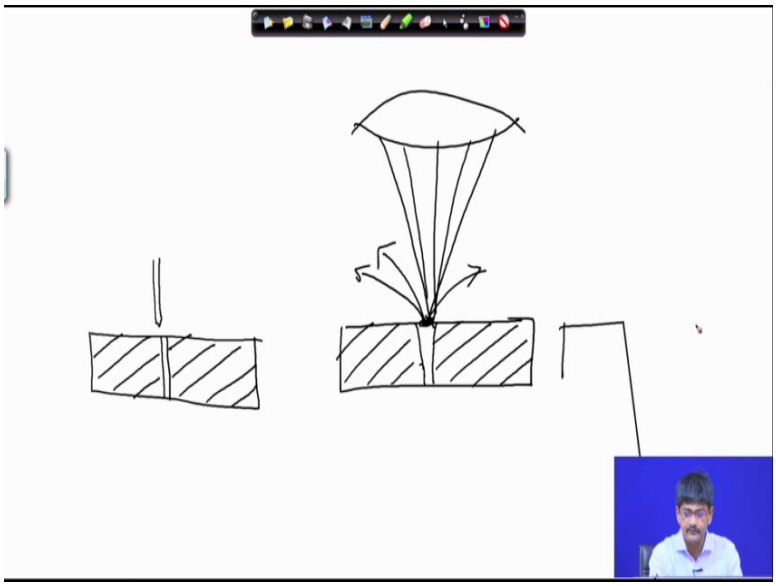

I need to make us very you know narrow hole here, what kind of dimensions am I talking about? I am talking about say dimension of say 250 microns; if it is 250 microns it means it is 0.25 millimetres. Now is it possible to drill a hole of 0.25 millimetres by conventional means; that means, by mechanical means having a tool which can you know push away material and cut it off and produce this hole maybe it is possible. But the case that as the size goes on in getting reduced, it becomes increasingly difficult to do it, why? Because a thin very small diameter drill will have to sustain I mean it has to withstand the stresses which will be induced during a cutting, and it might not be able to sustain.

So, as the drill is becoming narrower and narrower, I mean smaller and smaller diameters are being cut we have the possibility of drill snapping or it might even buckle if the L by D ratio is very high what defines the L by D ratio? If you are having the drill coming here; if you have a look at this if you have the drill coming here conventional drill sorry, this has to get inside and therefore, it has it is length has to be at least larger than this length. So, if this length is very high compared to the diameter you have a high L by D ratio drill that is a problem, why because it might be buckling. Even if it does not snap under the stresses it might buckle.

So, it is indeed there is a degree high degree of difficulty in drilling such a hole by conventional means. Let us now think of the laser how can the laser solve the problem?

You can have this job under the laser beam and a lens is focusing it here, the laser beam is basically a light beam electromagnetic radiation, if it is focused here since the laser has you know coherence there will be phase coherence here. So, that they will be build up of intensity, and this energy will be converted to heat energy, most of it will be converted to heat energy if it is not reflected or by some other means lost, and there will be tremendous temperature rise at this particular position.

This temperature rise will give rise to melting evaporation and ultimate removal of the material in the form of vapour, in the form of liquid ejection and we will find that hole is initiated which hopefully will be you know propagated right through; so that we have a hole. So, instead of using conventional means of applying mechanical forces and having a sharp edge etcetera we can remove material, this way also this is one non conventional method other methods as I mentioned can be you have the part here just a moment.

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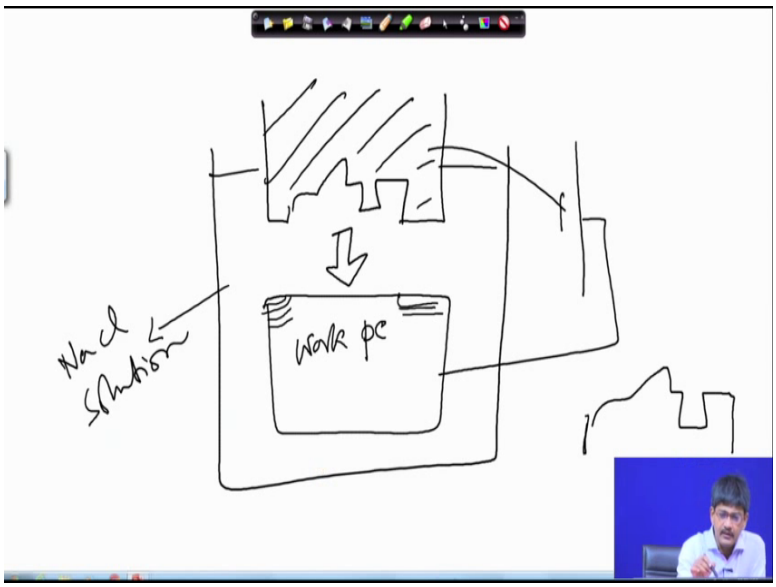

You have the part here and you are suppose having a job of this type, and you bring it towards the job you give it electrical connection all right sorry just a moment, you give it electrical connection, you submerge the whole thing in electrolyte solution.

Say NaCl solution; this is your once again your work piece at this moment it is the blank. So, the conjugate of this surface will be produced because other parts like this protruding part it will be dissolving electrolytically this will be dissolving, this will be dissolving

etcetera what will remain is the conjugate of this so, that you will find that this part has been produced.

Of course you know there are some mistakes in this drawing these surfaces will be creating some issue for us. So, please consider that actually straight or tapering surfaces only will be produced. So, this will produce a re-entrant side here at this mode. So, that is a mistake it is very difficult to produce this surfaces.

So, we can dissolve material instead of mechanically you know stressing them, so these are some non conventional methods. Let us come back to our original discussion. So in our original discussion, so now we come to the discussion of metal cutting.

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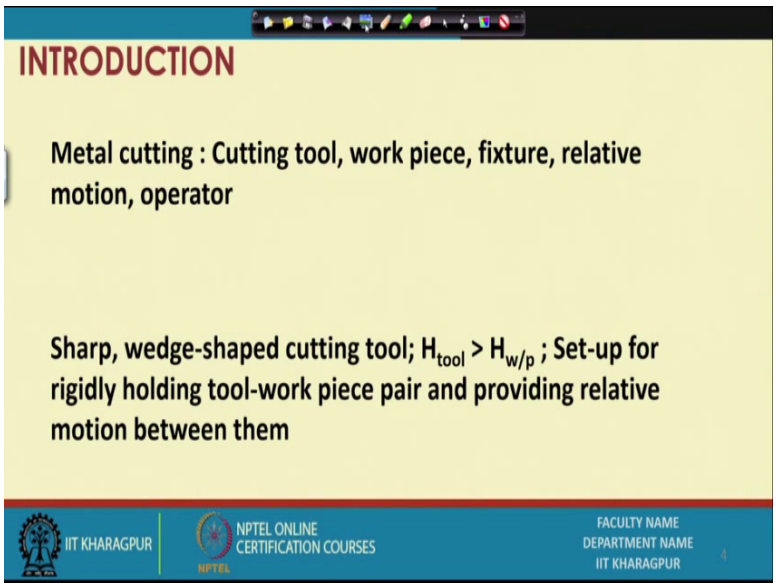

So, if you have a look here, metal cutting involves cutting tool work piece, fixture, relative motion and in most many cases operator what will be exactly mean by this? we mean that just like we were having some active member which was removing material from the work piece or the blank, in case of metal cutting we have something called the cutting element or cutting tool which actually removes material by dint of it is higher hardness, by a presence of a sharp edge at least 1 or 2 sharp edges on it, and of course by it is shape by it is wedge like shape.

So, a cutting tool is required for removing material, the work piece has to be there; that means, naturally if you are giving shape to a particular body, that has to be present and it

is important that the blank has higher dimensions, than that of the final job and that is called machining allowance.

We allow or we put some extra material which can be removed, so that the final shape can be attained. If you do not give machining allowance, then you cannot machine because there is no material left; I mean there is no material on the basic shape which can be removed and this and the final job can be produced.

What is the problem with that? If you produce the exact shape by some other means like if you produce it by casting or welding or by metal forming etc; there is a chance that the surface characteristics which are present it might not be suitable for the final application that we are planning, it for; like suppose you say that I am going to produce the exact dimensions by casting, what is the guarantee that the surface will be acceptable? If the surface is not acceptable you have to do some you know machining on the surface and there you have no machining allowance left if you plan it that way.

So, some machining allowance has to be there just before you start machining. So, by the work piece we understand a blank. Next fixture what is the meaning of the fixture, here has specific meaning in case of metal cutting for, but for the time being we are referring to fixture as you know some sort of fixing or holding steadfast the work piece and the cutting tool rigidly, you want to hold the cutting tool on the work piece rigidly, so that when they are in contact with each other and they are having relative motion they do not get displaced or deflected or they do not slip out of their holding positions.

That means hundreds of Newton's might be acting between them they should not lose their rigid position at that time, if they lose it then machining will not be possible; unless you hold the work piece and the tool very rigidly you cannot have machining possible in those cases but you might say, but the cutter is moving cutter may be rotating or the work piece might be rotating in that case how come you are still claiming that you are holding them rigidly; they might rotate they might move, but they cannot get displaced from their positions by the application of the cutting forces which arise during machining, we will have an expansion of this thing when we discuss those aspects.

Now comes the question of relative motion unless we have relative motion between the tool and the work piece, we cannot have the production of surfaces we cannot generate surfaces unless we have relative motion; now these relative motions can be categorised at

this moment we would not go to it, but basically if you are having a primary you know generating motion it is generally called cutting speed; which basically means that the cutting tool moves very fast pass the work piece and on it is way it removes material from the work piece and if it is successfully this strip of material if it is removed, then we will be shifting the cutting tool from time to time.

So, that this cutting action is extended to different parts of the job surface or the blank surface that is called feed motion and sometimes it is called directrix motion; operator operate is a very important part of this whole system in manually operated machines, you know manually operated machines are still there we cannot deny their presence, just because we are having automated machines automation just because we are having CNC etc; special purpose machines cam control machines all sorts of automation we cannot deny that a sizable part of the production is also done by operators. So, if the operator does something wrong machining would not be possible.

So, that is why more on the negative side the operator is very important, if he does his work correctly we have no issues next just a moment. So, now we come to this particular aspect that is sharp wedge shaped cutting tool. Now we are giving more details about the cutting tool the cutting tool has to be sharp, the cutting tool has to be wedge shaped it is hardness has to be more than that of the work piece, generally it should be at least 1.3 times the hardness of the tool and there has to be a setup for rigidly holding the work piece and the tool pair and relative motion has to be provided between them ok.

Why does the cutting tool have to be wedge shape it and why does it have to be sharp what is the necessity of such particular shape ok.

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Let us have a quick, look see if we are having a body of this type these are 2 bodies say they are extremely hard and they are totally rigid, there is no question of deformation and just beneath them I am having a blank piece of material this is our blank and I am having tool 1, I am having tool 2; among these 2 tools I am asked to operate them and remove material. So, what are we supposed to do we are going to first do one indentation that is we will be penetrating this inside this one also inside and then we will be producing relative motion; obviously, in this case you know if you if this particular definite shape is not a basic requirement, that is suppose someone says that this is the shape that I want to be reproduced here.

If that is not an issue then what is generally done is suppose you want to remove material up to this point, I want to remove this material in that case this comes down I apply forces. So, that this comes down right up to this point and then for example suppose you move it this way, so this whole thing peels off when it comes here the whole thing you will find it peels off in the form of a ribbon like material called chip, move this remove this; here also if you move it up to this point and remove this.

So, it is basically case of indentation or pressing and creating a sort of indentation and then moving this way here also the same thing will happen. So, what is the difference between them the difference that here there will be a tremendous force that you have to apply, unnecessarily because I had you had this 1 how is it this characterized it has a

wedge shape by wedge shape, I mean something like this it has a wedge shaped with a sharp point, with this it can easily penetrate while this cannot.

So, that is why generally the tools have to have this particular shape because, it is easier for indentation. So, when it indents and it starts moving towards 1 side and if these 2 bodies are rigidly held we can have removal of material. So, sharp point wedge shape and we will also learn that if we have sharp edges it will also always help us to remove material. So, this is understood we have character and we have identified what should be the desired shape of the tool, so that it can remove material; you might say why not this shape say a knife introduce it this way and then scrape off cut it here so that this comes out.

Problem is now we are talking of removal of metal not removal of soft materials for example, say a bread or butter or worry called chocolate no, I mean slightly soft chocolate no or ice cream, no knife will be able to sustain the heavy forces which will be coming when you are trying to cut metal; if you are trying to cut metal these have to be you know sizably robust, that is why whenever you are seeing cutting tools you must have seen cutting tools used on the lathe on the milling machine they are the size is quite robust.

You might be having a cutting tool, which is of this shape and it might have always may do very curious. Why do we use a shape of this type why not a knife if you have a knife it would not be able to withstand the heavy huge forces which are coming. So, so we have understood these things metal cutting what it is all about.

Now comes the next aspect the setup for rigidly holding tool work piece pair and providing relative motion between them this is what the machine tool is all about. So, cutting tool is that particular small piece which removes material by dint of it is hardness and what it call it and sharp point and wedge shape and the machine tool is the one which is the body which holds the work piece and tool rigidly.

So, that they cannot deflect and also it provides the relative motion between them that is the machine tool. So, cutting tool and machine tool they are absolute you know necessities in the metal cutting system. Now let us go to the next slide and our last one possibly in this particular first lecture just a moment.

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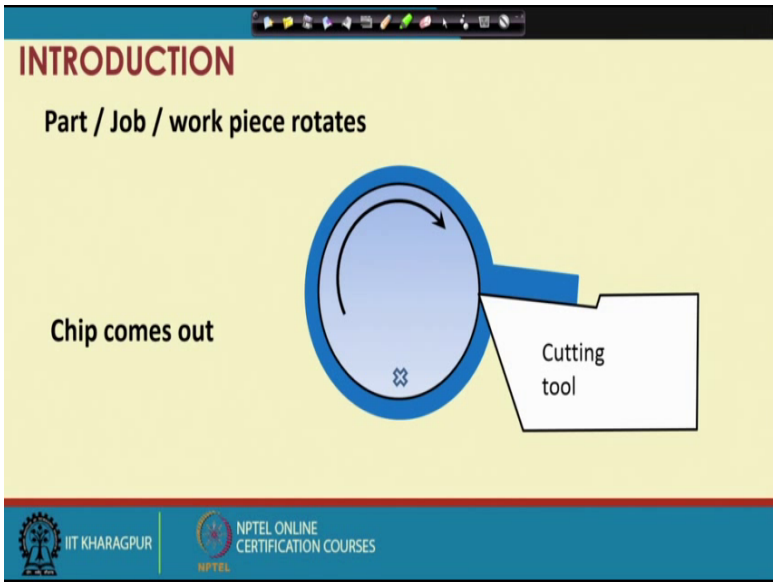

So, let us have a look at how this whole thing can be done on the lathe, the lathe is the most common machine tool on that surfaces of revolutions are produced; surfaces of revolution mean that about an axis the body will have a symmetric shape axis symmetric bodies are produced. What is this body for example, just one moment this body is the cylindrical body seen from the end. So, this is the axis of rotation it is rotating this way and this is the cutting tool that wedge shape which has you know indented or gone inside or pressed inside by a certain amount, this is the depth up to which it has moved in and after that relative motion will be produced by rotation of the cylinder, cylinder is rotating while cutting tool is not there for relative motion is produced.

If this relative motion is produced if they are held rigidly then material will be removed in the form of the chip that is the material which is coming out. So, on the tool material comes out it might be you know slightly curling up all also depending upon the cutting conditions. So, we understand that part or the job of the work piece rotates and the chip comes out; this is this is the basic model of material removal specifically we have taken up this example on the lathe and now that we have identified all those things; we can find them all here wedge shape sharp point chip coming out relative motion being provided to the blank.

So, that this material is getting removed in the form of the chip and you are going to get a smaller cylinder. So, now that we have identified the basic requirements say in the

process of metal cutting; now that we have identified it is exact position in the you know family of manufacturing processes, we can next in the next lecture we can take up more detail about first you know what is a cutting tool and what is a machine tool cutting tool as such can be characterized by different geometry elements and we will take that up in more detail in the next lecture, after a description of the cutting tool is completed we will take up description of different types of machine tools, so that is the end of the first lecture.

Thank you very much.