Manufacturing Processes - 1
Prof. Inderdeep Singh
Department of Mechanical & Industrial Engineering
Indian Institute of Technology Roorkee

Module - 1
Lecture - 14
Machining – 1

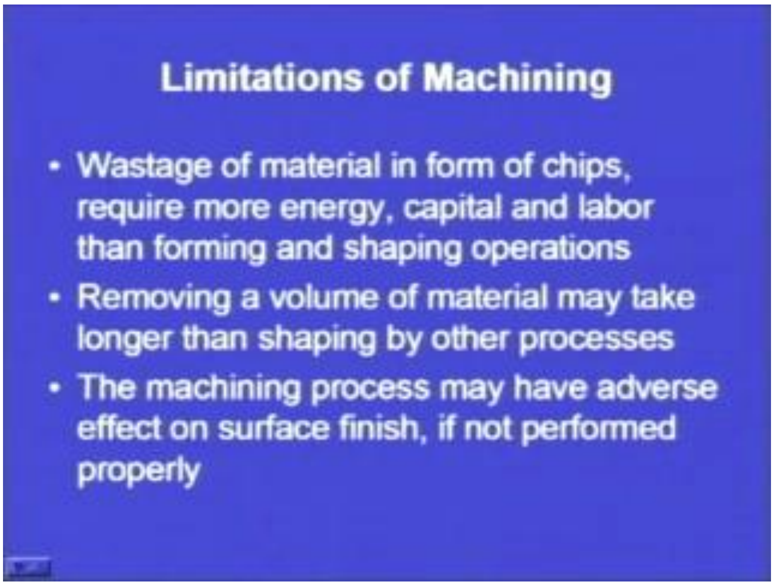
A warm welcome to all of you, in this second session on machining before we initiate our discussion on this particular aspect of machining, we will just like to review, what we have discussed in the previous lecture that was titled as machining fundamentals. In machining fundamentals, we saw that what is the basic operation of machining that we defined as a material removal process. Then what are the various types of processes, that are covered under the machining operation thereby we discussed that there, it can be a cutting process.

The cutting by a single point cutting tool or a multi point cutting tool, on the basis of single point or multi point cutting tool, the cutting process is can further be classified. Then we said that there can be abrasive process is also for example, grinding. And, there can be nontraditional machining operations also which use electrical energy or the energy of the lasers or chemical energy. So, depending upon the requirement, we have to choose a machining operation. Then we saw, what is the necessity of the machining operation?

So, in necessity we saw that if dimensional ((Refer Time: 01:37)) control is very stringent or dimensional stability has to be a certain or the tolerance levels are very, very stringent, then we have to go for a machining operation. We also saw that if the volume of production is not too large, then we can go for a machining operation. So, we tried to established machining, as an important manufacturing process for converting the raw material into a final product, which under goes various processes.

In the light of our discussion, we also discussed that how machining compares with the near net or net shape manufacturing technologies. We concluded last lecture with the limitations of the machining operation that what are the particular limitations areas, whereby we concluded that the material is wasted, in case of a machining operation in the form of chips or the material is removed in the form of chips, which are later discarded.

(Refer Slide Time: 02:39)



Another limitation of the machining that was noted was that the volume of material may take longer than shaping by other processes. So, whatever volume we have to remove, it may take longer as compare to the other manufacturing processes. So, we noted that with the help of example, if we take a case of a rod, and we want to reduce the diameter of that rod. Then there are number of operations that can be performed to accomplish this objective.

So, we have seen that if we go for a machining operation, it may take a longer time, as compare to other conventional metal forming or metal working operations. Then another limitation that was noted was that if we are not able to perform the operation or the machining operation properly. The surface finish, that we will get, will not be according to the desired specification or according to the desired quality levels.

So, we have seen that machining has certain limitations, what is the necessity of machining, that we have discussed in the last class. Just to take a thread, from wherever we left in the last lecture, we have just seen that we concluded there with the help of limitations, that is what we have started our lecture today with the limitations of machining. Now, an important aspect of machining is the machine ability. There are numbers of types or there are varieties of materials that are available with us. There may be some materials, which are very easily machinable, there may be other materials, which may be very difficult to machine.

So, how do we rate a material, that whether we will be able to machine it or we may not be able to machine it? So, the basic aspect or the basic mark or the basic gage is the machinability level or the machinability, it can be in the form of a number also. The machinability can be on a scale of 0 to 100. Now, depending upon, whether it is easily machinable or it is difficult to machine, any number will be got. So, the machinability aspects need to be studied in detail.

(Refer Slide Time: 04:48)

So, the machinability of a material is usually defined, in terms of four factors. Now, what are these four factors? These four factors are the surface finish and integrity of the machined part. The surface finish and integrity is the first important point that has to be taken care of, while we suggest or while we comply or while we say that this material is easily machinable. So, this is the first aspect, that has to be taken care of, that is the surface finish and integrity of the machined part. Second important aspect that has to be certain is the tool life that is obtained.

Now, in the previous lecture we have seen that machining operation can be considered as a system, and there are three important elements of the system, what were those three important elements of the system? Those three important elements of the system were the work piece material, the tool material as well as the machine or the machine tool.

Now, if we want to say that a particular material is machinable. We need to study the tool life that has been obtained, while machining that particular work piece.

The third important point to be taken care of is the force and power requirements. Now, we take examples, suppose there is a material, for which the force is required is much more or the power requirement is extremely high. There may be other material, for which the power requirement may be less. So, depending upon the force and the power requirement, we may somehow say that this particular material is easily machinable; this particular material is difficult to machine.

Then, the fourth important point is the chip controls that how we are controlling the chips that are getting formed. It is easier said than done, it is very difficult to classify the materials on the basis of their machinability. Because, we have to carry out of multi objective optimization here, because, there are number of objectives. For example, we take an example; we compare two different classes of materials, on basis of their machinability.

Now, these two classes of materials are entirely different, if we consider their mechanical, as well as their physical, and chemical properties. Now, these two materials are first one is suppose, we take a example of steel, and the second material that we are considering is a polymer matrix composite, which falls under the category of advanced materials. Now, we want to compare the machinability of these two materials. Now, there are four factors that have to be considered. Let us consider, factor number one that is surface finish, and integrity of the machined part.

Now, surface finish that we will get, while machining steel will be very, very good or the surface roughness will be less, and the surface characteristics will be very, very good, whereas if we machine a composite material, the surface finish may not be that good. The surface finish needs further finishing operations or we need the surface, we need to treat the surface for further or subsequent operations. So, surface finish is comparatively not good, in case of composite material, it is very good, in case of steel.

Now, the second part, suppose we are machining it using a standard high speed steel tool. So, in case of isotropic material or in case of a material that we have chosen, suppose we take a simple grade of steel. The tool life that is obtained with high speed steel or carbide tool will be good, whereas, in case of a composite material, the tool life that we are going to get will be less. The third important point that we are going to consider the force and power requirement.

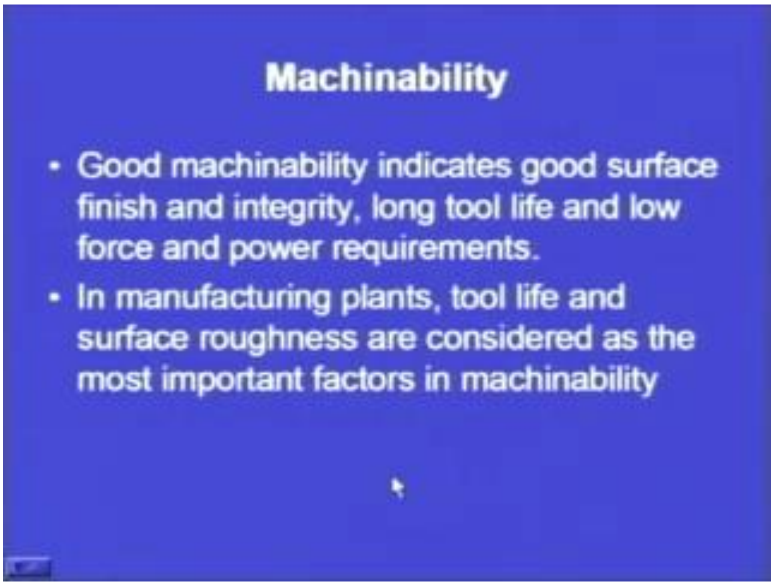
So, the power requirement, in case of a machining of steel or machining of any grade of steel will be very high, whereas the power requirement in machining of a composite or polymer matrix composite material will be extremely less. Now, depending upon the exact composition of the steel that we are using the chip control sometimes, the chip may form in a continuous manner or the continuous chips may be formed, whereas in case of a polymer matrix composite, the chip disposal is not a problem, because the chips will be formed in very, in the form of a powder or very small discontinuous chips will be formed, block let chips will be formed.

Now, we have seen that out of these four parameters, that are used to a certain the machinability of a material. There is the material, which is very good considering the first two parameters, that is the surface finish and integrity is very, very good, and the tool life that is obtained is also very good. But, there is another material, which is good in force and power requirement, because the force required is less, the power requirement is less, moreover the chips control is also better.

Now, how we can classify, how we can say that the machinability for this particular material is good, and machinability for this particular material is poor. So, it depends, then we have to optimize, depending upon all these parameters, and we have to see, what is our objective function? And, depending upon that objective function, we can finally classify or we can finally of same grade of materials or same classification of materials, we can grade them on a scale, from zero to hundred. And then we can say that this is machinable or more machinable as compare to this material or this is less machinable as compare to this material.

So, more and less on the basis of where the materials falls on the scale of zero to hundred can be done. But if the materials are substantially different, then the scales definitely will vary. So, it is not that easy, that we can very easily say, this is easily machinable or this is difficult to machine, it depends on a number of parameters, that we have seen here. Four parameters have been identified, that is the first one is the surface finish and integrity of the machined part, tool life obtained, force and power requirement, and the chip control.

(Refer Slide Time: 11:38)



Now, if we say, let us forget about the scale, on which we are going to classify or which we are going to rate the different materials, according to their machinability. Now, we are not going to that ((Refer Time: 11:52)) or that detail, but let us consider what is good machinability? Now, good machinability indicates good surface finish and integrity. So, the surface finish would be good and the integrity should also be good then, long tool life. So, the tool life should be long, may be certain particular hours of operation, and low force and power requirement.

So, if any material, if the power requirement or the force requirement is less, the tool life for machining that particular component of that particular material is long, and it indicates, and or, and the machining operation results in a very good surface finish. Then we can very easily conclude that this material is easily machinable or it has very good machinability. Also in manufacturing plants, I have said that it is different factors are there, and it is very difficult to optimize on all these factor, simultaneously. So, in manufacturing plants, tool life and surface roughness are considered as the most important factors in machinability.

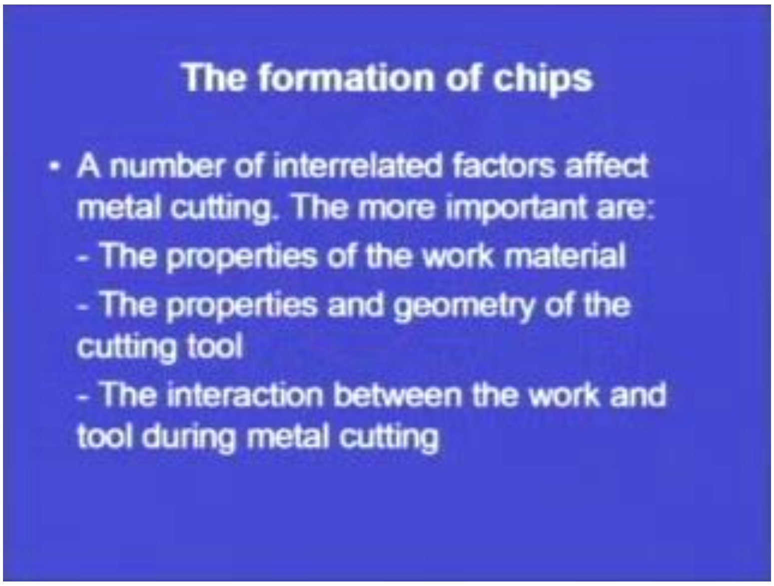
So, we have seen, although there are four factors that have to be considered for a certaining the machinability of a particular material. But, there are two factors, which are considerably important, as compare to the other two factors. So, what are these two factors, which are more important, those are the tool life and the surface roughness.

Now, for example, we take a material, we machine it, and the resulting tool life for machining that particular material is considerably large. Moreover, the surface finish that we are getting on our work piece is also according to the desired level or also according to the specifications, and the requirements.

Then, we can say, at this particular material is machinable, and its machinability is good, because we are getting a very good surface finish and the tool life is also considerably long. On the contrary, if we take an example of a material, for which. Suppose, we want to drill a hole, even after drilling five holes, the tools abrades. We are not able to make further holes using the same tool. So, the tool life is only five holes. So, we can very easily say that the tool life is very, very less in this particular case. So, the machinability of this particular material is not that good. And, this tool wear will also have an influence on the surface finish that we will get.

So, in order to conclude on this manufacturability aspect, there are four important points that have to be taken care of, while a certaining the machinability of a particular material, but there are two more important points. Those two more important points are the surface finish, as well as the tool life. Now, we come on to the formation of chips. So, basically, machining is a material removal process. In material removal process, some of the material will be removed from the surface, and that will result in the formation of the chips.

(Refer Slide Time: 15:29)



Now, a number of interrelated factors affect the metal cutting. The more important are, although, there are number of factors that will affect the machinable cutting operations. But, there are certain important parameters or certain important factors that influence this. So, what are those, that is the properties of the work material. Already, we know that if we are machining aluminum, which has fair degree of ductility, it will behave in a different manner, whereas if we are machining a ceramic material, it will behave in a different manner.

So, there are number of interrelated factors that will affect the metal cutting. So, the properties of the work material, is one of the important factor that has to be considered, while we are doing any study on the machining aspects. Then the properties and geometry of the cutting tool, already till now, we have discussed that the cutting tool is made up of different materials. So, there are different materials that are used as the cutting tools. For example, we can use diamond as a cutting tool, we can use high speed steel as a cutting tool; we can use ((Refer Time: 16:40)) as a cutting tool; we can use solid carbide as a cutting tool.

So, different types of materials are there for the cutting tool. Similarly, there are different types of geometry is also. For example, in turning operation, we may use the single point cutting tool. For example, in a drilling operation, we may use a twisted drill, in case of a milling operation; we may use different types of milling cutters. So, the geometry of the cutting tool, as well as, the material of the cutting tool is also an important factor, then the interaction between the work and the tool during the metal cutting.

So, the tool is going to be in direct contact of the work piece, when we are talking about the conventional machining operations. If we go beyond this discussion, and we talk regarding the unconventional machining operations, some of the operations, the tool may not be in direct contact with the work piece. But, this discussion is focusing the attention on a conventional machining operation, where the tool is in direct contact with the work piece.

So, when the tool is in direct contact with the work piece, the interaction between the tools has to be studied in detail. So, we have seen that the properties of the work material is the most important factor, then the properties of properties and geometry of the cutting tool is another important parameter. And, the interaction between the tool and the work piece is the third important parameter.

(Refer Slide Time: 18:10)

Now, chip formation basically is a mechanism of localized shear deformation. So, deformation is taking place here also, and it is the localized shear deformation. So, chip formation basically is a mechanism of localized shear deformation, resulting in the failure of the work material immediately ahead of the cutting edge of the tool. So, suppose, this is the material that we want to machine, this is suppose the cutting tool, our localized area just ahead of the cutting tool.

So, this is the cutting tool, the area that is just ahead of the cutting tool will fail, and will be removed in the form of chips. So, just to summarize, chip formation basically is a mechanism of localized shear deformation, why this material will be removed, because of the localized shear deformation, resulting in the failure of the work material immediately ahead of the cutting edge of the tool.

Now, the relative motion between the tool and the work piece, compresses the work material near the tool, and induces shear type deformation within it. So, there is a relative motion between the tool and the work piece. Now, depending upon the different types of machining operations, sometimes the tool may be moving, and the work piece may be stationary. In another machining operation, the tool may be stationary and the work piece may be moving.

So, depending upon the operation, but the important point to note is the relative motion between the tool and the work piece. Always, the tool and the work piece will be in motion, one may be stationary, other may be moving, but there will always be a relative motion. So, the relative motion between the tool and the work piece compresses the work material near the tool, and induces shear type deformation within it. So, shear type of deformation will be induced in the work piece material.

(Refer Slide Time: 20:21)

During cutting, shear and compression stress levels exist within the material ahead of the tool, sufficient to cause plastic strain, throughout the shear zone, and to exceed the material strength locally. So, why, suppose the stresses are getting developed, All right. There are stresses that are being developed, just ahead of the tool tip, but why the material is getting removed.

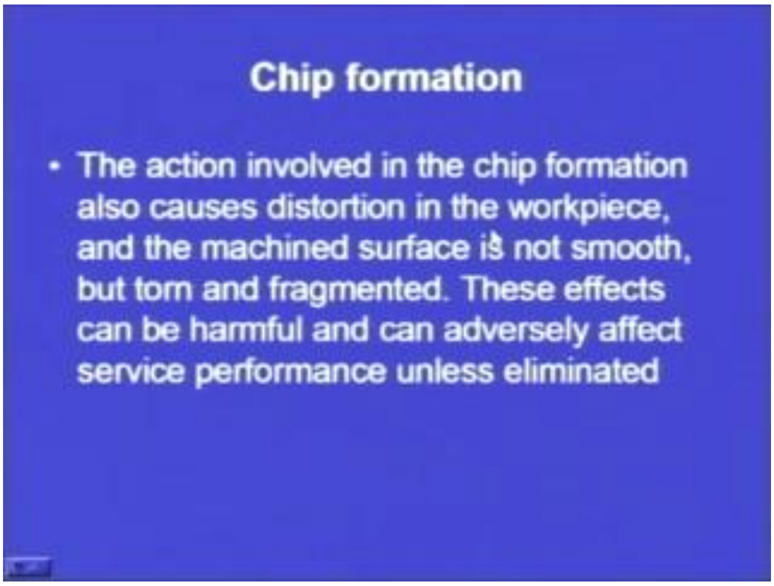
The material is getting removed, because of this particular point. Because, sufficient to cause plastic strain, throughout the shear zone and to exceed the material strength locally. So, material also has its own strength. So, locally in that particular zone, the plastic strain that is being caused will exceed the material strength locally, near the cutting edge. Such stress is associated with extreme pressure and with forces, which can be large, acting on the work piece and the tool.

So, the major point to study here or to discuss here is the generation of the forces that act on the tool, as well as on the work piece. So, just we can see the last two, three points here, such stress is associated with extreme pressure and with forces. So, extreme pressure will be developed, and forces will be developed, which can be large. So, this will be large in magnitude, acting on the work piece and the tool. So, these forces will act on the work piece, as well as on the tool.

So, important point to note here is that initially we have seen, if we are not performing the function or the machining operation properly, there are bound to be certain problem areas. And, out of which, one was that we are not going to get the adequate surface finish, for which, we are going or which we are aiming yet. Now, if these forces and the pressure that are generated, because of this particular phenomenon or this particular mechanism that is happening.

Then, it will have certain adverse effect on the component dimensional accuracy or the component surface finish that we are producing. So, here we see that forces and pressures are generated, and we have to control this forces and pressures. So, important point is that when we are holding a tool in a tool holder, we need to clamp it properly. So, that this particular tool should not fly away or this particular tool should not break. So, this forces and pressures that are generated should be controlled.

(Refer Slide Time: 23:07)



The action involved in the chip formation also causes distortion in the work piece. Now, the work piece may also get distorted and the machined surface is not smooth, already I have told, the smooth surface finish may not be achieved. But, torn and fragmented, the surface will be torn and fragmented. These effects can be harmful and can adversely affect the service performance until eliminated. Now, what are the problems areas, this problems area are that the action involved in the chip formation also causes distortion in the work piece.

So, one important problem area is the distortion in the work piece, and the machined surface is not smooth, so surface finish is not good. So, these effects may be harmful and may affect the in service performance of the product that has been machined. So, surface finish is not good, if we are going to assemble one particular rod or one particular shop, which has been machined, and we are going to assemble it into another particular hole.

So, if the surface finish is not good, the fit may not be proper, and during the service operation, this may come out, and we may not be able to assess the loss that may take place, because of this particular joint failure. So, we have to ascertain that the quality, that we are producing, should be according to our desired level. So, important point to note here is that surface finish that we are getting should be good, and there should be no distortion in the work piece.

If the work piece will distort, the surface finish will automatically get affected, moreover the tool wear will also be excessive. So, when the tool wear will more, that will be seen on the surface finish of the work piece. If the tool wears out very fast, then the tool edge becomes blend, and when it is rubbing against the work piece, the surface finish that we will get, will be very, very poor.

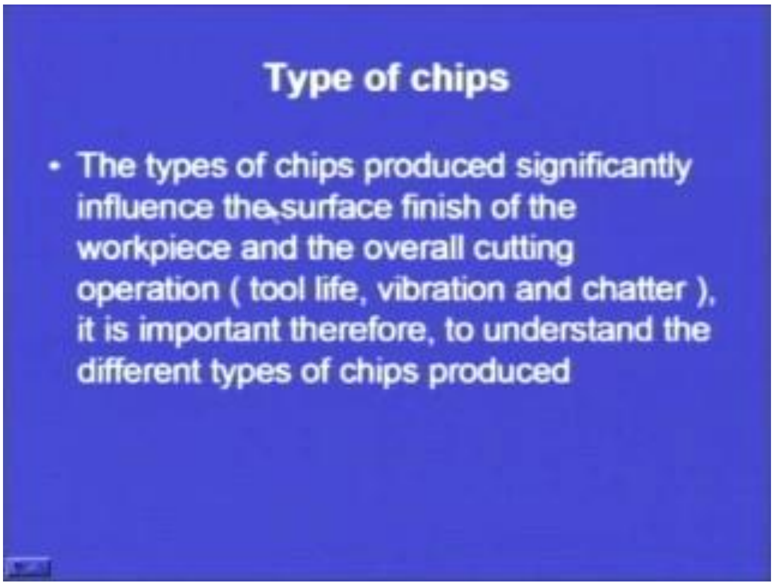
(Refer Slide Time: 25:04)

Now, another important point to note, in case of chip formation is the considerable heat, that is generated in the cutting zone. So, we have seen that forces and pressures are generated; there is a distortion to the work piece that may result. It may affect the surface finish of the work piece; it may also result in the excessive tool view. Similarly, there is a large amount of heat that is generated. Now, considerable heat is generated in the cutting zone, the heat generation results in elevated temperatures. Now, when the heat, when the tool is in continuous contact with the work piece, then the, because of the friction, because of the rubbing, some heat will be generated.

So, heat generation results in the elevated temperatures in the cutting zone, especially in the chips and the cutting tool, which is in direct contact with the work piece during machining. Now, the tool as we have already seen is in direct contact with the work piece. Now, there is a study or there has been number of studies, which have shown that what is the distribution of this particular heat, that how much heat will be carried away by the chips, how much heat will going to the work piece, how much heat will going to the tool.

But, the important point to note is that while machining, the temperature is definitely going to increase. And, at an elevated temperature, we have to study the behavior of the tool, the behavior of the work piece, and we have to see that when the chips are getting removed. They should be removed properly, because of the high temperature of the chips, some kind of accident or some kind of health hazard may result or some kind of accident may take place.

(Refer Slide Time: 27:06)



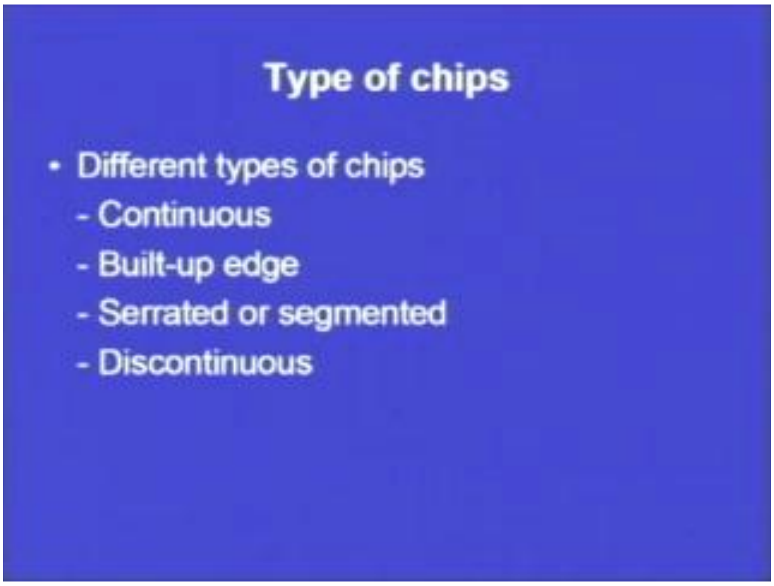
Now, types of chips, the types of chips produced significantly influence the surface finish of the work piece. Now, previous lecture also we have seen now also we have seen in the limitations also of the machining operation that the type of chip has certain bearing on the surface finish of the final product that we will get. So, how is that influencing, that is influencing, when the chips that are formed are continuous in nature.

So, when they are, when the chips are in continuous nature, then these chips, when they are forming may entangle with the tool holder, they may get entangle with the work piece or they may even get entangle with the ways disposal system. And, thereby they may influence the surface finish or they may the deteriorated the surface finish of the work piece that we are intending to achieve. So, the types of chips produced significantly influence the surface finish of the work piece, and the overall cutting operation.

So, how they influence the overall cutting operation, they may influence the tool life, they may influence the vibration and chatter. So, it is important therefore, to understand the different types of chips that are produced. So, there are different types of chips that are produced, that we will see in the subsequent slides. That these may be continuous in nature, these may be the chips with the buildup edge, then they may be, these may be discontinuous chips or these may be segmented or serrated chips. So, there are different types of chips that are produced, and this formation depends upon a number of parameters.

Now, these parameters are the factors that influence the type of chip that will be formed by machining a particular material, depends upon a number of parameters. So, these parameters are the type of the work piece or the material of the work piece. The operating variables may be in terms of the cutting speed, the feed rate or the depth of cut. Then it also influenced by the cutting condition, whether we are using a cutting fluid or we are performing an operation without the use any cutting fluid. So, there are number of parameters on the basis of which the formation or the different types of chip formation will depend.

(Refer Slide Time: 29:37)



Now, already we have discussed, what are the different types of chips, just I will briefly summarize, the different types of chips that are formed are continuous chips, chips with built up edge, serrated or segmented chip, and discontinuous chips. So, now we will discuss each one of these types under what conditions this types of chips are formed, and what is the influence on the surface finish etcetera?

(Refer Slide Time: 30:10)

Now, first type of chips that we are going to consider, in case of machining operation are the continuous chips. So, continuous chips are formed, under specific set of conditions. So, what are these specific set of conditions, these specific set of conditions are, with ductile materials, if the material that we are machining using a standard tool is a ductile materials, then there are every chances that we are going to get continuous chips. Moreover, if the operation is being performed at relatively higher cutting speeds, then there are chances that continuous chips will be formed, moreover, if the rake angles are also higher.

So, till now we have not discussed, what is the rake angle, that we will be discussed, when we discuss the geometry of a single point cutting tool. But, here we can only try to understand that if the rake angle is higher, we are going to get the continuous chips. So, there are three conditions that have been mentioned. So, we can for our self see that these are again taking into the account those three elements, that we have discussed in the start of our series of lectures on machining. Those three elements work, the work piece material, the tool, as well as, the machine tool.

So, the machine tool comes into picture, when we talk about the high cutting speed. The material comes into picture, when we talk about the ductile material and the tool comes into picture, when we talk about the rake angle. So, continuous chips will be formed under these three important conditions with ductile material at higher cutting speeds and at higher rake angles.

(Refer Slide Time: 32:02)

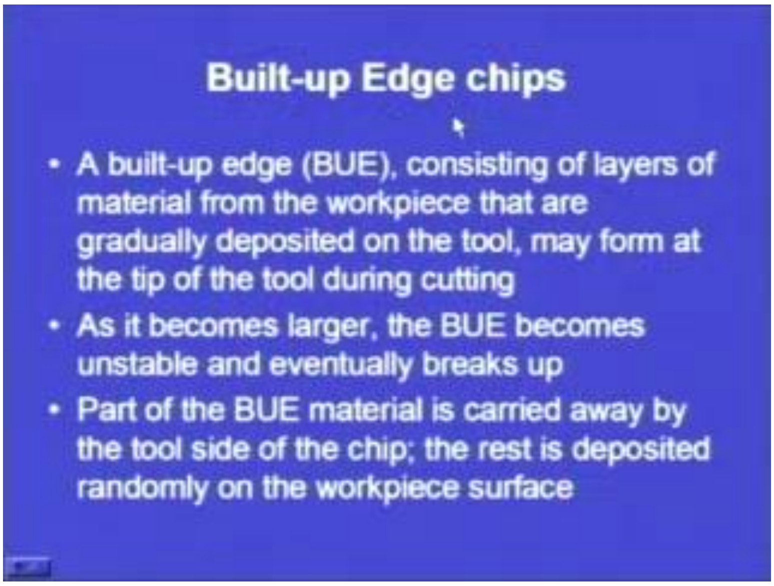
Now, continuous chips generally produce good surface finish. So, surface finish that we will get, if we are going to produce or if we are going to get continuous chips will be good. So, generally produce good surface finish, continuous chips are not always desirable. Although, when the material is getting removed continuously, and we are going to get continuous chips, the surface finish will be good, but particularly in certain cases, the continuous chips are not desirable.

Particularly in the computer controlled machine tools widely used today. Why this particular type of chips, we do not want to get or we do not want to get that this type of chips are found, we do not desire that these types of chips are formed, because they tend to become entangled around the tool holder, the fixturing, the work piece and the chip disposal system. Now, these are all the parts of the machine tool or the work piece also has been considered here. But, the tool holder we can see, the tool holder, the fixturing and the chip disposal system, all these are parts of the machine and we are considering the work piece also.

Now, these continuous chips that are forming as a result of the machining operation have the tendency to get entangled around all these four different points of the machine that have been considered here. Now, they may get entangled around the tool holder, they may get entangled around the work folding fixtures or they may get entangled around the work piece itself or they may get entangle around the chip disposal system. So, this entangling once it happens has to be removed. Then the process has to be intermittently stopped in between.

And, after stopping the process, we have to remove this entangle chips, that have got entangle or that have got like fixed with the tool holder or they got fixed with the work piece material. Moreover, when they are in contact with the work piece material, there are chances that they may abrade the surface of the work piece, and thus affecting its final surface finish. So, although when, while machining, we get a very good surface finish with continuous chips, but if we get entangled with the different parts of the machine, then it is not particularly desirable. Moreover, these may also affect the surface finish of the final product.

(Refer Slide Time: 34:43)



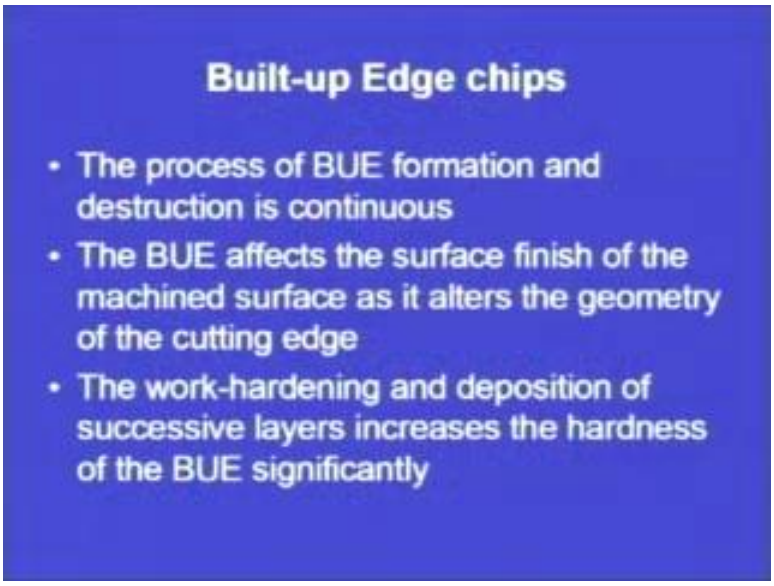
Now, the second important category is the built-up edge chips. Now, first of all we will try to understand, what is this built-up edge? A built-up edge or we will call it as BUE, consisting of layers of material from the work piece that are gradually deposited on the tool. So, till now, we have read that there will be layers of material from the work piece. So, whatever material we are removing or whatever is our work piece, some of the part of it, very small in size will get deposited, gradually it will happen; gradually it will get deposited on the tool.

So, this may form at the tip of the tool during the cutting operation. So, first point says that some material of the work piece may get deposited on the tool or the tip of the tool gradually. So, it is called the built up edge. As it becomes larger, the built up edge becomes unstable and eventually breaks up. So, what we have seen till now, some material of the work piece will get deposited layer wise on the tip of the tool, and it will grow eventually, and after sometime, it will become unstable, and it will part of.

Now, some part of the built up edge material is carried away by the tool side of the chip. The tool side of the chip means that if this is the face of the tool, and this the chip, that is flowing or going on to the rough face of the tool. Then this side of the face is a tool side of the face, and the other side is free to the atmosphere or free to the ambient conditions. So, this tool side of the face will carry some part or some material of this built up edge. And, the rest of the material that is left around will be randomly spotted or randomly distributed over the work piece surface.

So, basically what we have seen, in case of the built up chips that the built up edge is formed on the tip of the tool with the material, that is coming from the work piece. So, some of the work piece material will get deposited on the tip of the tool to form a built-up edge. And, it will be a gradual process, and the material will be developed layer wise. It will grow up, up to a certain level, then it will become unstable, and later on it will break up. So, when it breaks up, some part of the built-up edge will be taken by the tool face of the chip. And, some part will be deposited randomly on the work surface.

(Refer Slide Time: 37:40)



Now, the process of built up edge formation and its conditions. So, these two sides of the face will carry some part or some material of this built up edge. And, the rest of the material that is left around will be randomly spotted or randomly distributed over the work piece surface. So, basically what we have seen in case of the built up chips, that the built up edge is formed on the tip of the tool with the material that is coming from the work piece.

So, some of the work piece material will get deposited on the tip of the tool, to form a built up edge, and it will be a gradual process, and the material will be developed layer wise. It will grow up, up to a certain level, then it will become unstable, and later on, it will break up. So, when it breaks up, some part of the built up edge will be taken by the tool face of the chip, and some part will be deposited randomly on the work surface. So, the process of built up edge formation and destruction is continues.

So, once ((Refer Time: 38:48)) the tool is continuously performing the operation, it will eventually become unstable, and then it will break, some part will be removed with the chips, some will be deposited on the work piece. Again, after sometime, the built up edge formation will start, then some part will be taken, and when it breaks, some part will be taken with the chips, some will be deposited on the work piece, this will be the continuous operation. So, after sometime, it will form and it will break, then forms, then break, form, break, so this will be a continuous process.

Now, built up edge affects, the surface finish of the machined surface, as it alters the geometry of the cutting edge. Now, the surface finish of the work piece or the job, that we are machining, is affected by the formation of the built up edge. As we will see in our discussion, regarding the geometry of a single point or the multi point cutting tool, we will see that the tool is always given certain standard angles. It can be back rake angle; it can be side rake angle, and cutting edge angle side cutting.

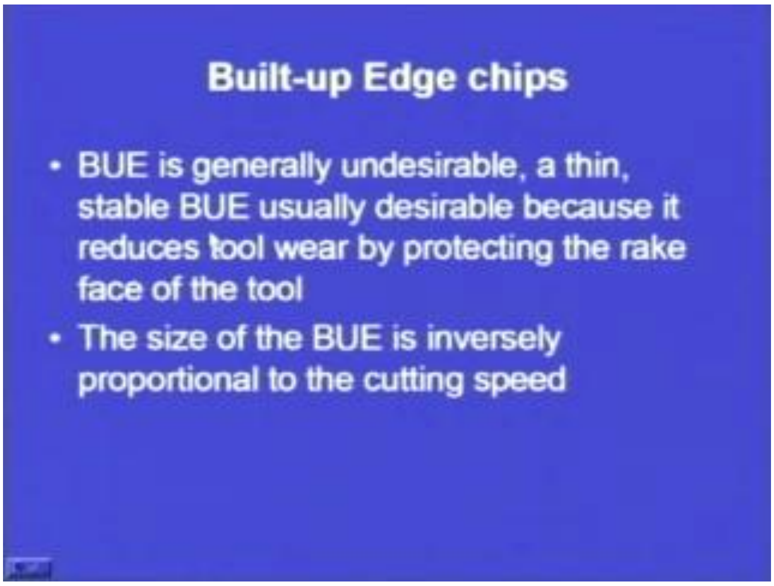
So, different angles will be given to the tool point, so that it performs the cutting operations satisfactorily, relief will be provided. So, that it should not rough against the work piece. But, when according to our specified geometry, there is certain mechanism that is happening during the cutting operations, so that some material from the work piece is getting deposited on the tip of the tool. Then the geometry that we have designed for that particular operation will be altered.

We have designed suppose, the back rake angle should be x level. After the formation of this built up edge, that x may change to x plus two or it may reduce to x minus two. So, depending upon the built up edge formation, the geometry of the tool that we have designed will be altered. And, if the geometry of the design, geometry of the tool is not according to our design, is not according to our specifications. Then the quality of the surface will get deteriorated or the final product, that we are going to get, will not be according to the desired specification levels.

So, the built up edge affects the surface finish of the machined surface, as it alters the geometry of the cutting edge. So, that we have already seen, there is a standard geometry, if this formation takes place, the geometry will get changed. Then the work - hardening and deposition of successive layers, increases the hardness of the built up edge significantly.

Now, the work hardening is also taking place, because the operation is also taking place at an elevated temperatures, some form of work hardening may take place. And, the deposition of successively as we have seen that this built up edge will be formed successively, it is gradual process. And, in that gradual process, number of layers will be deposited. Thus, the hardness of built up edge will improve or will increase significantly.

(Refer Slide Time: 42:20)



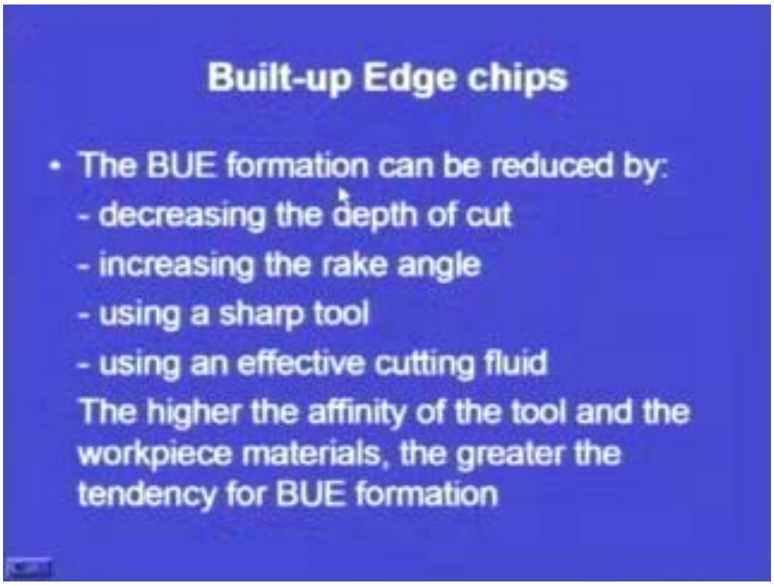
Now, as we have seen the built up edge alters the geometry of the tool and may result in rubbing action or may affects the surface finish of the final product. But, built up edge therefore, is generally undesirable. But, a thin stable built up edge means, a thin, it should not be very thick, and a stable, it should not be unstable, it should be stable. We have seen that after sometime, it will become unstable, and it will eventually break and some part will be carried away by the chip, some part will be deposited on the work piece surface randomly.

But, if it is a thin built up edge, and it is according to the geometry of the tool or it confirms to the geometry of the tool. So, if it is thin, and it is stable, and it is confirming to the geometry of the tool, built up edge usually is sometimes become desirable, because it reduces the tool wear by protecting the rake face of the tool. So, if the formation is taking place in such a way, in such a manner that the exact geometry of the tool geometry of the tool that we have designed is not getting affected.

First point, the built up edge is not very thick, second point, and the built up edge is a stable built up edge. Then if these three conditions are satisfied, then sometimes the built up edges is desirable, why it is desirable, because it protects the rake face of the tool against wear. So, the excessive wear of the tool, tool point geometry will not take place. This built up edge will cut the work piece, and the surface finish that we will get under these limiting conditions will also be comparable or it also will also be good.

Now, the size of the built up edge is inversely proportional to the cutting speed. So, inversely proportional means that if built up edge, the size is very, very large; it will result, because of the slow cutting speed. If the cutting speed is very, very large, then the built up edge size will be less. Now, the size of the built up edge is inversely proportional to the cutting speed. So, speed more, size less, speed less, size more.

(Refer Slide Time: 44:35)



Now, the built up edge formation can be reduced by, already in our discussion we have seen that usually or generally speaking built up edge formation is not desirable. But, under certain limiting conditions is it avoids the excessive tool wear by forming a layer, gradual thin layer on top of the tool tip. But, if we leave a part all those limiting conditions, we want that no built up edge formation should take place. So, how can we reduce the formation of a built up edge. So, the built up edge formation can be reduced by decreasing the depth of cut, so the depth of cut that we give, while the machining operation should not be too high.

So, if at a particular level or a particular level of the depth of cut, built up edge formation is taking place. Then we do not want a formation to take place; we should decrease the depth of cut. Then increasing the rake angle, so at higher rake angles, the built up edge formation can be reduced, then using a sharp tool. Sometimes, if we are using a blend tool, the chances of formation of built up edge or more. So, it is desirable that we use a very, very sharp tool, so that the built up edge formation is avoided.

Then, using an effective cutting fluid, so if we are using the cutting fluid, there are every chances, that the built up edge, may not take place or they may not form, moreover it can be reduced. The chances of formation of built up edge can be reduced by using an effective cutting fluid. So, another important point to note is the higher the affinity of the tool and the work piece material. So, we are using a particular tool, then there is a particular work piece, the tool is going to go and the machine in the work piece.

So, these two are made up of different materials, if these two materials have a very strong affinity among each other. Then there are greater tendency for the formation of the built up edge. So, the higher the affinity of the tool and the work piece materials, the greater the tendency for built up edge formation. Now, it depends, if the affinity is too high, then there are every chances that built up edge formation is bound or is going to take place.

(Refer Slide Time: 47:13)

Then, the third category of chips is the serrated chips. So, serrated chips also called segmented or non-homogeneous chips are semi-continuous chips. So, these are in between the continuous and the discontinuous chips with zones of low and high shear strain. So, if we see the chips, there will be zone of high and low shear strains. Now, which type of metals will result into serrated chips? So, metals with low thermal conductivity, and strength that decreases sharply with temperature. So, with increase in temperature, if the strength is decreasing, such as one example has been given, for example, titanium, this type of behavior is observe, the chip have a saw tooth like appearance.

So, the even the appearance or the shape of the chip has been even, it will be saw tooth like. So, metals with low thermal conductivity and strength that decreases sharply with temperature, such as titanium, exhibit this behavior, the chips have saw tooth like appearance. So, serrated chips will be formed in between the continuous and the discontinuous chips. And, these are particularly relevant, when we are machining certain particular category of materials, what are the properties of the materials, which has already been mentioned here.

(Refer Slide Time: 48:42)

Now, we come on to another category of chips or another types of chips, those are the discontinuous chips. So, discontinuous chips usually form under the following conditions. So, there are conditions for the formation of continuous chips, there are certain conditions for the formation of built up edge. There are certain conditions for the formation of serrated or segmental chips. Similarly, there are certain conditions. So, these conditions can be in terms of operating variables. These conditions can be in term of the material of the work piece or the tool material or any other parameter for example, the cutting fluid.

So, discontinuous chips will also form under a particular set of conditions. So, what are those conditions? So, these conditions are the brittle work piece materials. So, if the material is brittle, then there is every chance that the formation of chips will be a discontinuous chip. Then another important case is the materials that contain hard inclusions and impurities. So, while the initial stage, in the initial stage, when the material has been formed, may be it has been formed by casting operation. So, this cast product, if it has too many inclusions and impurities. There are chances that when we machine this particular cast product, we are going to get the discontinuous type of chips.

Then, if the very low or very high cutting speeds are used, at very low cutting speeds also, we are going to get discontinuous chips, and at very high cutting speeds also, we are going to get discontinuous chips. Then if the depth of cut is also very, very large, we are going to get discontinuous chips. Moreover, rake angles, if are less will result in the discontinuous chips. So, there are certain parameters like, if the material is brittle; rake angle is less; depth of cut is also large. Then if the cutting speed is very, very large or if it is very, very small, we are going to get discontinuous type of chips.

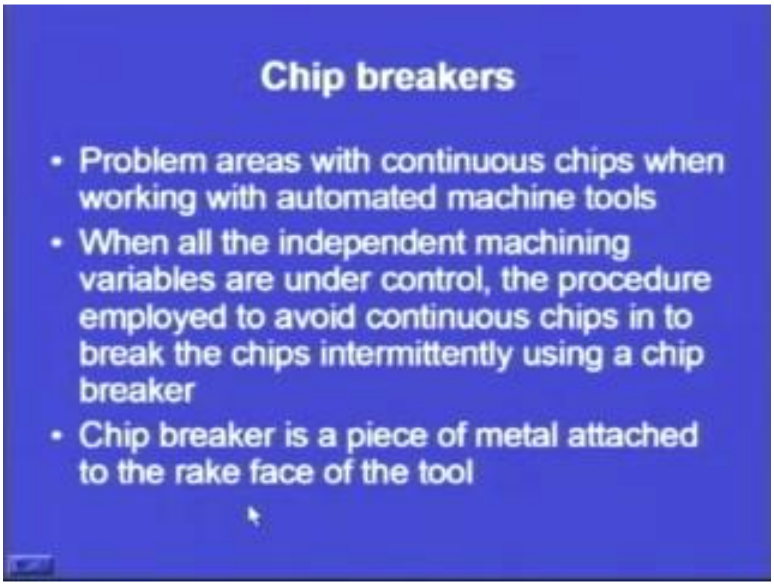
(Refer Slide Time: 50:49)

Then, other parameters or other factors that result into the discontinuous chips are lake of an effective cutting fluid. If we are not using a cutting fluid, we are going to get discontinuous chips, then low stiffness of the machine tool. So, stiffness point, we are going to address in detail. So, if there is a lake of effective cutting fluid, discontinuous chips will be formed, and if the stiffness of the machine tool is less, we are going to get discontinuous chips. So, the forces vary, because of the discontinuous nature of the chip formation, when the discontinuous natures of chip formation or discontinuous chips are forming, the tool is not in direct contact with the work piece.

So, the forces may vary. The rigidity of the tool holder first point, work holding device second point, and the machine tool is important. So, the rigidity of the tool holder, as well as the work holding device, as well as of the machine tool, thus becomes important. Otherwise, vibration and chatter may be noted, adversely affecting the surface finish and the cutting tool. So, when discontinuous chips are forming, the forces vary, there is a variation in the forces, and this variation may result in the excessive chatter or it may result in the excessive tool wear.

But, this can be controlled, if we have proper rigidity in our tool holder, even the work holding device is rigid and the machine tool that we are using is also rigid. So, just to summarize, the forces vary, because of the discontinuous nature of chip formation, the rigidity of the tool holder, work holding device, and the machine tool is important, otherwise vibration and chatter may be noted, adversely affecting the surface finish and the cutting tool. So, it result in excessive tool wear, and it will result in the surface finish deterioration.

(Refer Slide Time: 52:49)



Now, we have seen that there are different types of chips that are formed, while we machine a particular material. So, depending upon the type of the material, depending upon the operating variables, depending upon the number of other parameters, we will get different types of chips. So, we have seen, we have observed that will continuous type of chips, there are certain problem. So, we can see now, we are going to address the aspect of chip breakers. So, problem areas with continuous chips, when working with automated machine tools.

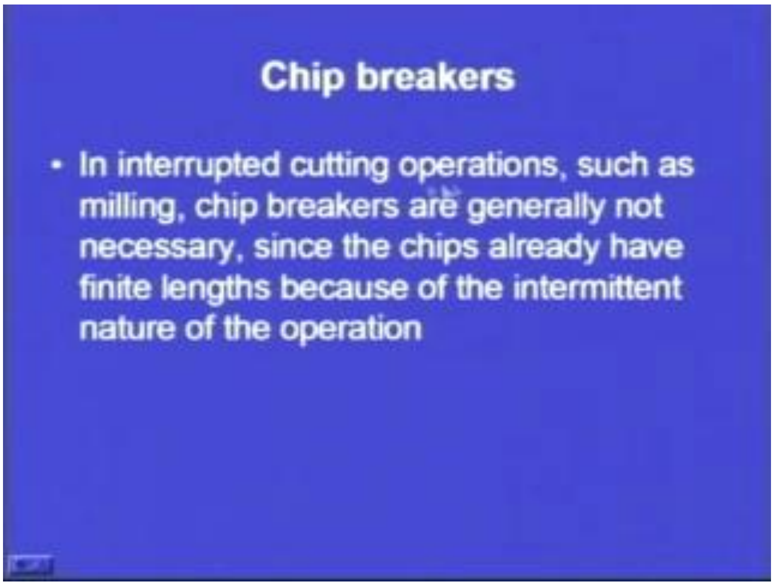
So, when the automatic operation of machining is taking place and we are getting continuous chips. These chips may get entangles with the tool holder; these may get entangled with the work piece or the waste disposal system. So, this entangling may result into a number of failures, and if it is automatic process, then we have to stop the process in between, again we have to start the process. So, there will be a break in the process. In order to overcome, this kind of problem, in order to avoid the formation of continuous chips, we use chip breakers, which are nothing, but it is a piece of metal, that is attached to the tool.

So, problem areas are there, when continuous chips are formed, and these problem areas are particularly relevant, when we are having an automatic machining or automated machine tools. When all the independent machining variables are under control, when all the other variables are under controls speed, feed, depth of cut, and all these parameters are under control. The procedure employed to avoid continuous chips in to break, the chips intermittently using a chip breaker. So, the procedure employed to avoid continuous chips is that we can break the chips intermittently using a chip breaker. The chip breaker is nothing as I have already told; it is a piece of metal, that is attached to the rake face of the tool.

(Refer Slide Time: 54:53)

Now, most cutting tools and inserts are equipped with built-in chip breakers. So, initially we use to apply a piece of metal at the rake face of the tool, but presently, most cutting tools and inserts are equipped with the built-in chip breakers. Now, chip breakers increase the effective rake angle of the tool and consequently increase the shear angle. So, this is what we will discuss, when we study the mechanisms or the mechanics of cutting. The chips can also be broken by changing the tool geometry, thereby controlling the chip flow as in the turning operations. So, chips can also be broken, while modifying the tool geometry. So, tool geometry can also be modified, so that the chip breaks, when it slides over the rake face of the tool.

(Refer Slide Time: 55:48)



Moreover, in case of interrupted cutting operations, what are these interrupted cutting operations, these interrupted cutting operations are for example, milling. So, in interrupted cutting operations, such as milling, chip breakers are generally not necessary, we are not requiring the chip breakers. Since, the chips already have finite length. The chips that are form in milling operations have finite lengths, because of the intermittent nature of the operation. So, the operation is not a continuous operation, it is an intermittent type of operation. So, while we use milling operation, we need not provide a chip break up.

So, we have seen that if continuous chips are forming, there are certain problem areas with the formation of continuous chips. And these, if all other independent variables means, we have controlled all the other parameters, which can be controlled like speed, feed, depth of cut. And may be other parameter like, use of cutting fluid, whatever all parameters, that influences the formation of the chips have been controlled. Then we can go for another important technique that is; we can break the chips using the chip breaker.

So, with this we come to the end of this lecture on machining. We have discussed in today's lecture, the basic fundamental principles of chip formation we have seen, what are the different types of chips are formed? What are the various conditions under which different types of chips will be formed? And later on we concluded that if all the parameters are controlled, even then we can break the chips, using the concept of chip breaker, which are provided with the designs of the tools or the insert, so that the chip curves over the chip breaker and breaks. In the subsequent lectures, we will discuss the other details, regarding the machining operations.

Thank you.