Manufacturing processes - 1
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Module - 1
Lecture - 15
Machining – II

A warm welcome to all of you, in this session on machining, so in the last lecture, we have started the discussion, regarding the basic machining operation like, how machining is performed. We have seen that, what is the necessity of machining, why do we require to go for an operation like machining, when we have already net and near net type of manufacturing technologies or manufacturing processes like, casting, forming that are already available with us. So, what is the application spectrum of machining, where machining is required, all that was discussed in the last lecture.

So, today we will start our discussion, regarding the different other aspects of machining. But, before we start a discussion, regarding the other aspects of machining operations, we will just like to review, what we have discussed in the last lecture. So, that a continuity in the lecture is maintained. So, yesterday we discussed the basics of machining operation, that first lecture was titled as machining fundamentals.

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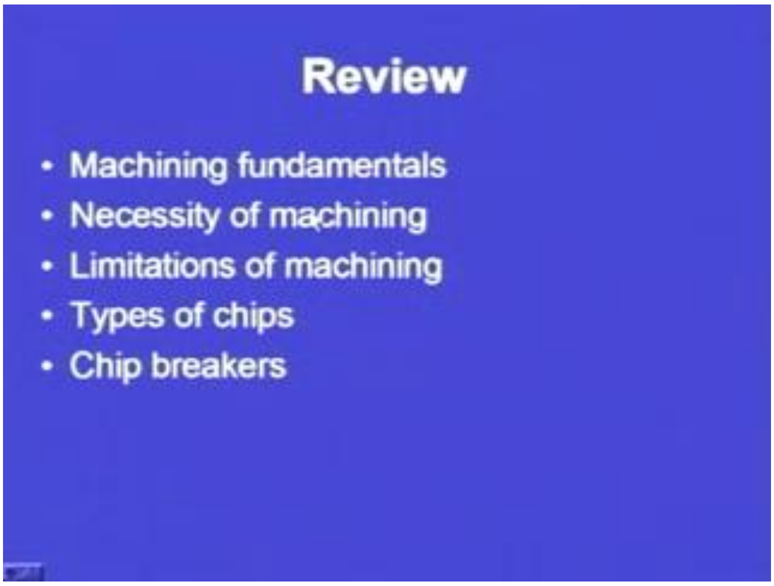

So, we have discussed that what are the machining fundamentals, why machining is required, how does it compare with the other manufacturing processes like casting, forging or other metal working operations, where does the application spectrum of machining lie. Then, we discuss what is the necessity of machining, in which we discuss a number of points were machining has been shown that, it is imperative, it is necessary, and it is I can go to the extent of saying that it is inevitable for certain products.

So, there is certain category of products, if we are not going to machining them, we are not going to utilize the complete capability or the complete functions of those particular products. So, machining thereby becomes imperative or I can say it, becomes inevitable. Then, what were the limitation of machining we have seen the first important and the most important limitations of machining was that most of the material here or I can say that if you are cutting than major part of the material, if you are finishing than smaller material is waste.

So, wastage of material is one of the most devastating or we can say, one of the most economically process, economically not, we are not able to justify that the machining operation as compared to the normal or the conventional manufacturing processes. In conventional manufacturing process, there is no loss of material, but here in case machining, always there is a loss of material in the form of chips. Then, we discussed, what are the different types of chips that are formed, so different types of chips that were discussed, were continuous chips, build up edge chips. Then, we discussed the serrated and segmental chips and finally the, discontinuous chips.

So, we have also seeing that under what condition, and for what type of material, these type of chips will be formed. Then, we discussed towards the end of the lecture, what are the chip breakers, why are the chip breakers required, why do we need to break the chip, why, what are the problem areas with the continuous chips. So, all those important aspects, regarding the fundamentals of machining operation, were studied in the last lecture. Now, today we start, we carry forward our discussion, regarding the fundamentals of machining operation.

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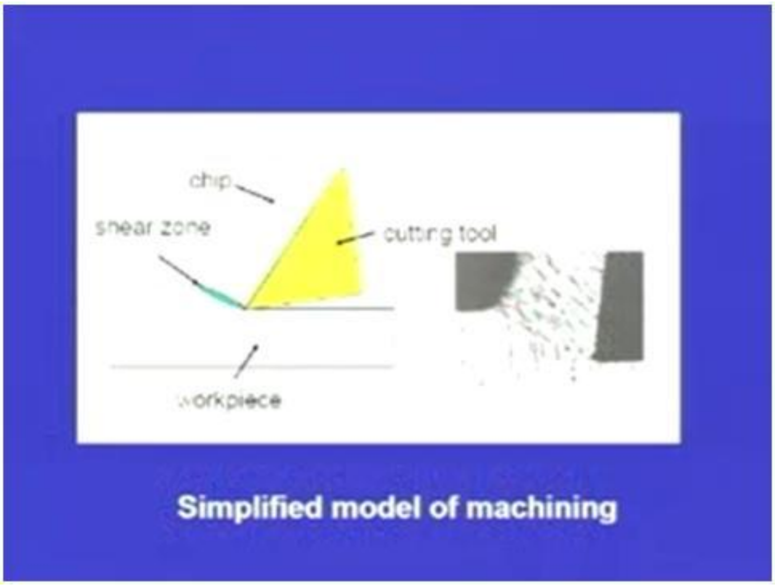

Now, this is a very basic diagram of a or a very basic model of a machining operation. Since, yesterday we have been talking about the rake face. So, this diagram has been incorporated, in order to explain the different elements of the machining operation. So, we can see here, that this is the work piece, which is getting machined. So, we can see this geometrical entity, we can call it thickness. So, thickness here is more as compared the thickness at this section, why, because some part of the material has been removed from this surface.

So, this is the, this line is the machined surface, this yellow colored portion, give as the, this is the cutting tool, then a chip has been formed. So, in our previous lecture we have seen, what are the different types of chips that formed? So, that depends upon the work piece material, this is the work piece. So, the material of the work piece, suppose it is a ductile material. So, that chip that we will get, will be a continuous chip, whereas, if this work piece is a brittle material, then there are chances, that the chip will be a brittle chip or we can say, the chip will be a discontinuous type of a chip or a powdered form of a chip.

This is the shear zone, if you draw straight line here, we will get the shear angle; this is the cutting tool. So, these are the important elements in the machining operation. So, wherever we perform a machining operation, these three or four elements will always come into picture, always there will be a work piece, on which the machining has to be performed, there will be a cutting tool. Now, the cutting tool will depend upon the type of the machining operation that we are performing. If we are performing the operation of drilling or we are going to make a hole in a particular material or in our work piece.

Then, the tool that we will use will be a twist drill or any other form of a drill. If we want to plan a surface, then the planning tool will be used, if we want to shape a surface or on a shaper, then we will do the shaping tool. If we are going to machining a surface or we want to end mill a surface, then end milling type of cutter will be used. So, depending upon the requirement, this tool will vary. I have only discussed regarding the geometry of the tool.

Now, there will be end, there can be end mill cutter, there can be twister tool, there can be single point cutting tool, there can be multi point cutting tool. Now, depending upon the geometry, depending upon the requirement, we will choose the geometry. Then, this tool can be of any material, we will see as a subsequent part of this lecture that what are the different types of tool materials, what are the requirements from the different types of tool materials like, it should be, it should have hot hardness or what type of property it should have that will be discussed as the part of this lecture.

Then, these work piece properties also influence the machining operation, moreover the types of chips, we have already discussed. So, here we see this black portion is the tool, and this is the chip that is getting formed, this is the very simplified model of a machining operation.

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Now, if we discuss this was, this is what we are going to continue from the last lecture, we were discussing the chip formation in metals. Now, chip formation in non- metallic material also takes place in the similar fashion only or in the similar manner only. So, just I read it out, chip formation mechanisms for metals that we have already discussed that, how the chip formation takes place, what are the various elements that influence the chip formation? The chip formation mechanisms for metals are generally applicable to non- metallic materials also.

So, the mechanism of chip formation will remain same, in case of non- metallic materials also. A variety of chips are obtained in cutting thermoplastics. Now, the thermoplastic is one non- metallic material that has been chosen, depending upon the type of polymer, as well as the process parameters, such as depth of cut, tool geometry and cutting speed. Now, one example has been given of thermoplastics. So, if we are cutting thermoplastics, then the basic mechanism of chip removal or the chip formation will be same, but it will depend upon the type of the polymer.

The type of polymer says that, here also it will depend upon the type of the work piece material that we are machining, as was in the case of metals. If it is a ductile material, the chip formation will be different; if it is a brittle material, the chip formation will be different, similarly, in case of thermoplastics also, if it will depend upon the type of the polymer that has been chosen for machining operation. So, a variety of chips are obtained in cutting thermoplastics, depending upon the type of the polymer. So, work piece material will define what types of chips are going to form.

As well as the process parameters, process parameters what are the different process parameters, that is depth of cut or it can be the cutting speed or it can be the feed rate. So, depending upon the process parameters also, it will dictate that, what type of the chip formation will take place. Moreover, the tool geometry will also dictate that, what type of the chip formation is going to take place. For example, yesterday we have seen, that rack angle will influence, whether it will be a continuous type of chip formation or it will be discontinuous type of chip formation.

So, rack angle how can, what is rack angle, rack angle basically, defines the geometry of a cutting tool. So, the tool geometry will also define that, what type of chip formation will take place or it will dictate that, what type of chip formation should take place, while machining a thermoplastic material. Similarly, the cutting speed will also enforce, already that we have discussed. Thereby being brittle, we have discussed the thermoplastics, what are the various factors that will influence the chip formation in a thermoplastic.

Similarly, being brittle thermosetting plastics. So, initially we have considered only the thermoplastics, now we are considering another category of plastic that is the thermosetting plastics. So, being brittle, thermosetting plastics and ceramics produce discontinuous chips. So, here also, the thermosetting plastics are brittle in nature, whereas, thermoplastics has some kind of, they will undergo some kind of deformation, and some continuous form of chips may be form.

Now, if we take an example of chip formation in non metallic material. If we take an example of fiber reinforce plastics, whereby these plastics, it can be thermosetting also, it can be thermoplastics also, when these plastics have been reinforce with fibers. The fibers may be of carbon, these fibers may be of graphite, these fibers can be ((Refer Time: 10:59)) fibers or these fibers can be glass fibers are depending upon the type of the fiber that has been chosen, as well as the metric that has been chosen to form a composite material.

The chip formation will depend upon the number of parameters that we have already discussed. So, first important parameter is the material, out of which it has been formed, if we take a case, whereby we consider that, it is a thermoplastic. Thermoplastic means, the metric is made up of a plastic, which is the thermoplastic and the fiber are suppose glass fibers, when we machined it, then the type of chip formation that will take place, will be entirely different, if the metrics material is thermosetting plastic, in instead of a thermoplastic.

So, it depends upon the basic ingredients of the raw material or of the product, that we are designing or of the component, that we are machining, that what type of chip formation will take place. But, the basic mechanisms of chip formation will remain same; it will not vary too much, as in the metals as well as in the non metallic material.

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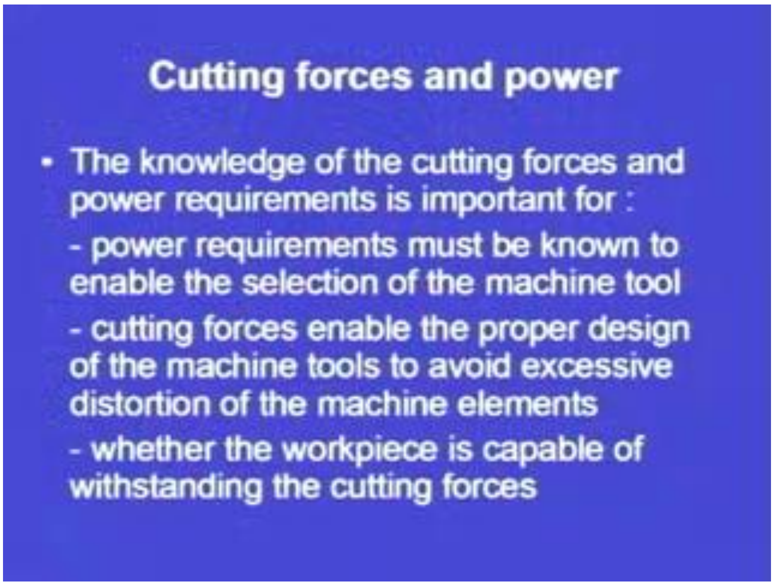

Now, we come on to another important aspect of machining that is the cutting forces and power. We need to study the cutting forces and the power requirement, why? Because, as we have already seen that, when that tool is going to cut the work piece, there will be a number of stresses that will be developed that there will induced certain forces on the tool, as well as on the machine tool. The cutting tool will undergo some forces or it has to undergo certain forces, as well as the some forces will also be exerted on the machine tool.

So, the tool, as well as the machine tool or we can say very simple, in the very simple language, the tool, the cutting tool or the machine, both have to be study, both have to be rigid. So that, these forces that are generated, because of the cutting action, do not cause any form of distortion to the tool or to the machine. So, we need to understand, what type of forces will be generated, what will be the direction of these forces, how these forces should be controlled. So, all these parameters have to be studied.

Moreover, when we select a particular machine for a particular operation, we have to specify it, and the power is one of the important specifications that has to be provided. If we have to machine a very, very hard material or a material with a very high strength, then the forces, that may be encountered in machining, that high strength material may be extremely high. So, when the force requirement is very, very high, so power requirement may also be high.

So, we need to select a machine tool or we need to select a machine, which can sustain, which can provide that kind of power, and which can sustain, that kind of forces. So, there is an important discussion, that is regarding the cutting forces and power that should be done or important knowledge base should be develop, regarding the cutting forces and the power, before selecting a particular machine. Now, just to see, what we have been discussing for cutting forces and power. The knowledge of the cutting forces and the power requirement is important, already we have discussed, all these things.

Power requirements must be known to enable the selection of the machine tool, already we have discussed that, when we are faced with the problem to select a particular machine tool for machining certain materials. We have to have knowledge of the power requirements, if we are not knowing, the power requirement, if we take a machine, just without considering the power requirements for that particular machining operation. The machine may not operate properly or there may be too much of vibration and chatter.

So, already we have seen in previous lecture that, this vibration and chatter will cause a lot of problems in the proper machining operation. And, if the machining operation is not proper, what are the different types of problems that will be encountered. These problems may range from the degradation of the surface finish to the excessive tool wear or sometimes, the tool failure also. So, we need to control these cutting forces, we need to control these, we need to avoid the deterioration of the surface finish, and we need to avoid the tool breakage also.

So, in order to control all these parameters, we can only say that, there should be no vibration and chatter, when the machining operation is being done. So, in order to avoid vibration and chatter, we should select a particular machine tool or a specific machine tool, which can sustain or which can control the forces, that are been generated. So, that the machine tool should be, such that, it should be, it should have sufficient rigidity, it should have sufficient stiffness.

So, the power requirement must be known to enable the selection of the machine tool. The power requirements must be known, to enable the selection of a machine tool. Similarly, the cutting forces enable the proper design of the machine tools to avoid excessive distortion of the machine elements. So, we have been discussing the same point from the last slide also that the cutting forces, enable the proper design of the machine tool.

If we are not knowing the cutting forces, then the machine tool may not work properly or the design may not be, according to the requirements of that particular machining operation. So, excessive distortion to the machine elements should be avoided, what are the different problems of excessive distortion that we already discussed in the previous point. So, excessive distortions, vibration, chatter, all these things have to be avoided, and how it will be avoided, if we have a prior knowledge that, what are going to be the forces, that will be encountered during this machining operation, what are the power requirements for this machining operation.

If we are knowing, what is going to be the forces, and what is going to the power requirement, we can very easily control, different type of problems, that may later on result, if this consideration is not given at the onset only or at the beginning. If we are not going to give this consideration regarding the cutting forces and the power requirement. Then, all these problems of distortion of the machine element or vibration or chatter or deterioration of the surface finish or excessive tool wear or the breakage of the tool may take place after some time.

Now, whether the work piece is capable of withstanding the cutting forces, this also is important point. The work piece material will define that, whether it will be able to sustain that kind of cutting forces or not. We may take a material, which is not able to withstand, those kind of cutting forces that are generated, because of that operation, then the material will fail, and will not be able it for it is, will not be able to use it for it, it is intended function.

So, knowledge regarding the cutting forces, as well as the power is important for the smooth, as well as the proper in performance or the proper operation of the machine. Now, coming on to, measuring the cutting forces. Now, we have been discuss in that, the cutting forces are important, the power requirement is important, we should have prior knowledge regarding the cutting forces, we should have prior knowledge regarding power requirement, but how to measure the cutting forces.

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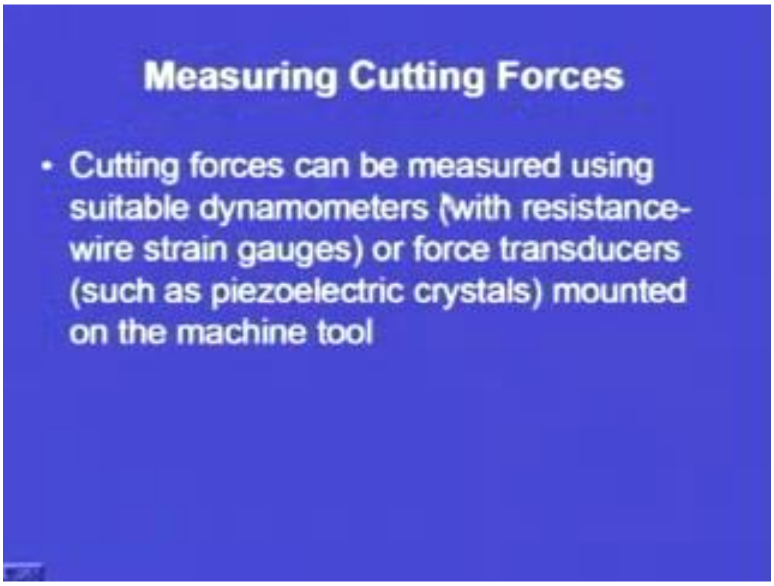

Now, the cutting forces can be measured using suitable dynamometers with resistance wire strain gauges or force transducers, such as piezoelectric crystals, mounted on the machine tool. Now, we can measure the cutting forces, it is not too difficult. We can also estimate or we can also analytically calculate, the different elements of the forces, different types of forces that are generated. So, there are ((Refer Time: 19:28)) that have been developed for machining of materials, in which we see that we can analytically estimate or analytically calculate, what are the forces that are going to be generated or this operation.

So, here as the part of this lecture, we are not going to consider the analytical aspect, because this is the general discussion, regarding the machining operation. But, we can experimentally also measure that, what are going to be the forces, that has been going to be generated by the machining, this particular or that particular material. So, two important measuring instruments or measuring devices has been given in this point. This is the resistance wire strain gauges or the piezoelectric crystals; these can be used to measure the forces. So, how this is incorporated, if we are going, suppose we take an example of a drilling operation.

Now, the drill is given a motion, suppose this is the z direction. So, the drill is given a motion in the z direction, and the work piece is in the x y plane. Now, when the drill is coming, and it is make going to make a hole, inside the work piece that is in this plane.

Then, below this work piece, we can mount a dynamometer. So, this dynamometer can work on any of the principles, as shown on your screen. There are two principles that have been shown, the first one is the resistance wire strain gauges, and the second one is the piezoelectric crystals.

So, any of these two can be used and we will mount, thus the dynamometer that we have selected, below this work piece. So, when the drilling operation is taking place, this four component drill dynamometer can be connected to the charge amplifier, and to the display. Now, this display can be a digital display or the display can go directly into a computer system, where we can see that, how the forces are varying with the time, and how the, what is the going to be the magnitude of the forces.

Now, magnitude of the forces that have been generated can be seen on the y axis, with the time on the x axis. So, we will be able to see that, how the forces are varying, whereas if we have a digital display, we can have a maximum value of the forces that have been generated in this drilling operation. So, it depends that, for what purpose we are regarding the forces, if we are only regarding the forces to know that, what is going to be the maximum force for drilling a hole in this particular material. We can have a digital display, on which we will know that, this is going to be the maximum force or we can say, this is going to be the maximum torque.

There will be different types of forces that will be generated, during the drilling operation. But if we want to go in for further analysis that, how the forces varying, when the drill point touches that work piece, what is the force, when it is doing the drilling operation, when the clips are completely in engagement with the work piece, what are forces that are generated, what are forces generated, when the drill has come out of the hole or has started to come out of the hole. So, that particular behavior of the force with the time, during the drilling operation can be seen on a x y plot.

And, try to understand that, how the force is varying with time, when a drill is making a hole inside a work piece. So, using any of these instruments, we can, we are able to measure the forces. So, these forces can later on be used for a number of usages, as we have seen. If we know that, for this particular material, this is going to be the force requirement; this is going to be power requirement or these will be the forces that will be generated, and this will be the power that will be required.

Very easily, we can select a particular machine tool for the z operation, but if we are not knowing the forces, if we are not knowing the power requirement. Then, if we, you do the guess work, the machine tool that we may buy, may not be able to perform the intended function of making a hole or for end milling or for shaping or for whatever purpose. We have selected a particular machine tool, may not serve the intended function of, for which it has been bought or for which it has been selected.

Now, coming on to the temperature in cutting, so we have seen, the different types of chips are formed. Then, there are cutting forces and power requirement, that is important to understand, then the important point is the temperature in cutting. Now, we have seen that, when a tool is in direct contact with the work piece, the heat is generated. And, the temperature elevates or there is an elevated temperature or elevated heat zone that is prevalent between the tool and the work piece. Suppose, this is the work piece and this is the tool, when the tool is in direct contact with the work piece in this zone, the heat is going to be moved.

Now, some part of this heat, we have discussed earlier, also will be taken away by the chips. Then, a substantial amount of this heat will go to the work piece, and some amount of heat will also go to the tool. But, the maximum amount of heat will be carried away by the chips, but that temperature raise is not only going to affect the chips, because the chips are getting removed anyway. But, it is going to have an effect on the tool, as well as on the work piece.

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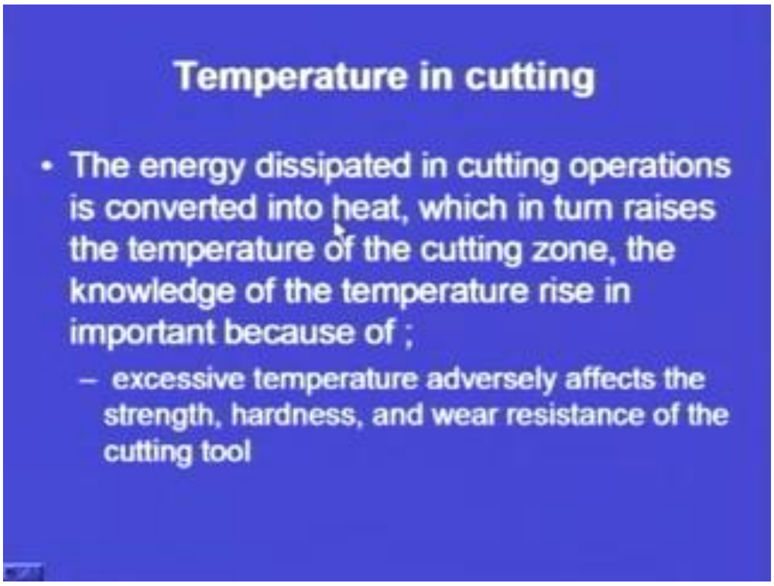

So, the energy dissipated in cutting operations is converted into heat. So, when the tool is in direct contact with the work piece. So, the energy that is dissipated is converted into heat, which in turn raises the temperature of the cutting zone. So, the cutting zone is the zone, where the tool is in contact with the work piece. So, the raises the temperature of the cutting zone, the knowledge of the temperature rise is important. Now, this temperature rise that is taking place, because of the heat generation in the cutting zone, we need to understand, the knowledge is important for number of factors that will be, we will be considering now.

The knowledge of cutting forces and power requirement is important that we have already seen, if you are not knowing then there may be some problems at the later stage, when we have bought a machine tool, and it is not satisfying the intended function. Similarly, the knowledge regarding the temperature generation or regarding the heat generation, during the cutting operation is equally important. So, we need to understand it, for the following reasons. The excessive temperature adversely affects the strength, excessive temperature means temperature beyond a certain limit, adversely affect the strength, hardness, and wear resistance of the cutting tool.

So, there are three, four points that have been addressed here, excessive temperature adversely affects the strength. So, first important point is the strength will be affected by the increase in the temperature, the hardness will also be affected; moreover, the wear resistance will also be affected. So, three important parameters of the cutting tool are getting affected by the increase in the temperature in the cutting zone, strength, hardness and wear resistance.

Now, the cutting tool is an important element of the machining system. If our cutting tool is not performing its function properly, then whatever is the intended function, whatever is on surface finish requirement or whatever is our desired quality that will not be attainable. So, it is important that the temperature in the cutting zone has to be controlled. For example, here we take, only we take only one important aspect that is hardness. Now, machining we have already discussed, it is the machine, it is a operation where we have we use or we employ the aspect of relative hardness.

There is a work piece; there is a tool, the tool comes and performs its operation on the work piece. The tool has to be harder than the work piece, but because of this operation, the heat is getting generated and it is losing, the tool is losing it is hardness. If the tool loses it is hardness, it is not going to perform the intended operation or the machining operation, for which it has been used, and if it is not going to perform the operation. Then, there are chances that the surface finish that we will get, will not be good or sometimes it may so happen that, no machining itself is taking place. So, the temperature control is also very, very important.

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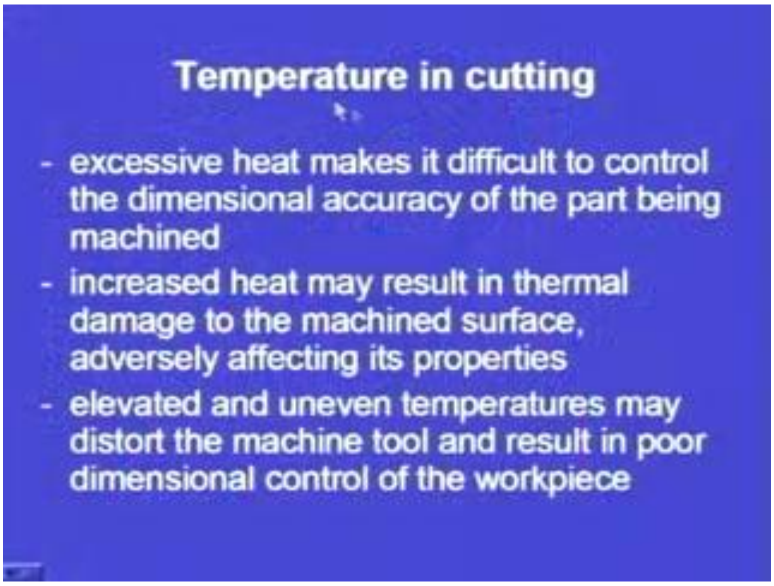

Now, excessive heat makes it difficult to control the dimensional accuracy of the part being machined. So, initially we have seen in the first point that, the heat that is being produced or a temperature that is being raised in the cutting zone is going to affect our cutting tool. Here, we see that, the excessive heat will also affect the work piece. So, the excessive heat makes it difficult to control the dimensional accuracy of the part being machined.

So, the dimensional accuracy of the part, in the very beginning, when we started our discussion, regarding the machining operation or the machining fundamentals, we have seen that, all these products can also be made. I should not say all, but most of the products that we are machining or made initially by the near net or net shape manufacturing technologies like, costing, forging or metal working operation. But, later on, in order to improve the dimensional accuracy of the part, we perform the machining operation.

But, if there is an elevated temperature, there is heat generation in the cutting zone, then the dimensional accuracy of the part will machined is suffering or is getting deteriorated. So, the dimensional accuracy that for the purpose for which, we are performing the machining operation is getting defeated. So, the important point to note is that, we have to control the temperature in the cutting zone. Now, third important point to understand, regarding the heat that is generated in the cutting zone is that increased heat may result in thermal damage to the machined surface, adversely affecting its properties.

So, increased heat may also result in thermal damage to the machined surface. So, it will affect the properties of the surface that we are generating. So, basically, we are performing a machining operation to improve the surface finish, as well as the surface integrity of the surface. But, if we are raising the heat or the we are not raising the heat in fact, the heat is getting raised, heat is getting generated, because of this particular machining operation, when the tool is in direct contact with the work piece, the heat is getting generated. So, it is a phenomenon that is inevitable.

So, when heat is generated, we have to avoid this heat why, because we have seen that the, this elevated temperatures or not only going to affect the cutting tool. But, these are also going to affect the machined surface, and they are going to impair the surface quality, as well as the surface integrity. Moreover, elevated and uneven temperatures may distort the machine tool and result in poor dimensional control of the work piece.

So, till now we have seen, the heat is generated, All right, agreed, when the heat is getting generated, it is going to affect the cutting tool, it is going to affect its hardness, it is going to affect its strength. Similarly, the elevated temperatures are going to affect the work piece also, the dimensional accuracy will be deteriorated or the dimensional accuracy will be affected. Moreover, the surface quality or the surface finish will be affected; the surface integrity will be affected.

Although, two important elements have been addressed, we discussed in our last lecture that, there are three important elements of machining operation or three important elements of machining, what are those three important elements. Those three important elements work; the work piece material, the tool material, as well as the machine. So, when the heat is getting generated in the cutting zone, the tool is also getting affected, the work piece is also getting affected, as well as the machine tools is also getting affected.

So, when the machine tool is getting affected, it results in poor dimensional control of the work piece. So, the work piece is getting affected, because of the distortion in the tool, the machine, when the machine is getting affected, machine is getting affected because of the temperature. This may be a rarest of rare phenomenon, because the cutting zone is far, far at a large distance from the machine tool. It is may be a machine tool bed or a machine tool head or a machine tool tailstock. So, the distance is there, the temperature raise will take place only in the cutting zone.

So, cutting zone will be at a substantial difference from all other elements of the machine, but sometimes, because of uneven heating or because of some high elevated temperature, this problem may arise. It is not always going to arise, but under certain circumstance, certain special circumstances, these kinds of problems may arise that, there is a distortion that is taking place in the machine tool, which is subsequently going to affect the dimensional control of the work piece.

If the machine elements are distorted, the surface finish or the dimensional control of the work piece, that we are machining, will not be according to our desired levels or will not be according to the proper quality characteristics or quality specifications, for which we are going to perform the machining operation. Now, we have seen that, forces are generated, power requirement is there, we can measure the power also we can measure the cutting forces that are generated also we have already seen the dynamometers are used to measure the cutting forces.

Similarly, the measurement of temperature is also important, why measurement is important, when we know that, what is going to be the temperature that is going to be generated. Then only we can exercise some control, we can see that, how this temperature has to be load or how this temperature generation has to be avoided. If we are not knowing that, what is going to be temperature that is going to be generated, during a particular machining operation, it is too difficult for us to exercise a control.

So, the measurement of temperature is also equally important. So, we can control the temperature, we can, we will see that, we can use to cutting fluids; cutting fluids can be used as a coolant, as well as the lubricant. So, these cutting fluids can control or will control the substantial temperature rise in the cutting zone. But, initially we should know that, what is going to be the temperature rise, in this particular application or this particular machining operation, so that we can properly select a cutting fluid.

If we are not knowing that, what is going to be the temperature rise, we will not be able to select the specific cutting fluid for that is applicable, for that particular temperature rise. And, the very purpose of using a cutting fluid will be lost. And, if we are going to add another functionality into the machine tool, that we are using the cutting fluid also, then node out, we are also adding to the cost of the product, because the cutting fluid will itself, cost something, and moreover the system for bringing the cutting fluid into the cutting zone, will be costing something.

Moreover, the recycling will also be an important issue that has to be taken care of. So, we are adding another system into our machining operation at some cost. So, the use of the cutting fluid is only useful, when we know that, what is going to be temperature rise in our cutting zone are during the machining operation. So, how we can measure this cutting, measure this temperature rise that we will see.

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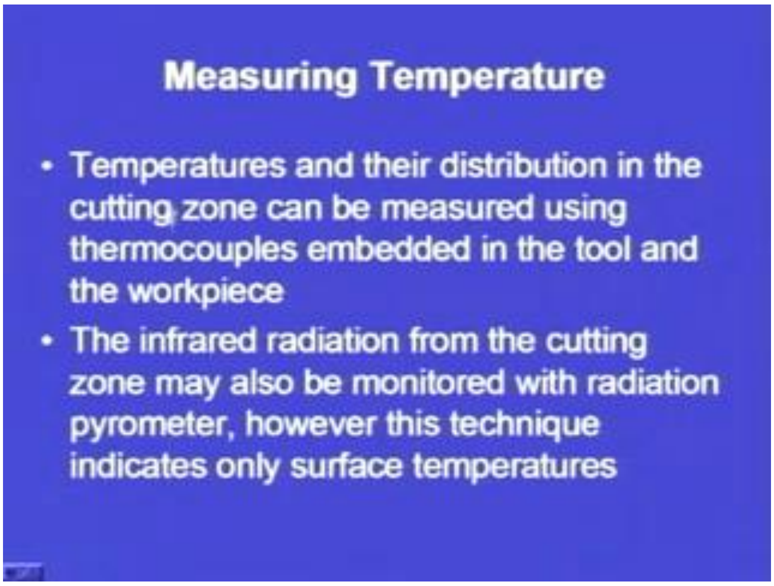

Now, temperatures and their distribution in the cutting zone can be measured using thermocouples, embedded in the tool and the work piece. So, we need to understand the increasing the temperature that we have already seen, now temperatures and the distribution in the cutting zone. So, in the cutting zone, there is going to be an increase a temperature. Moreover, there will be a distribution of the temperature; it is not that at one particular section or at one particular point, if there is one thousand degree centigrade.

Suppose we take an example, then at other particular point also, the temperature will be one thousand degree only, at one section it will be x, at other section it will be y, at another section it can be z. So, there will be distribution of the temperature. So, the exact measurement, as well as the distribution, so we need to know the magnitude, as well as how that magnitude or how that temperature is distributed, along the tool and the work piece that can be measured using the thermocouples.

And, these thermocouples can be embedded and the tool and the work, in the tool and the work piece, but it is easier said than done. It is a very sophisticated procedure, how to embed our thermocouple into a tool, as well as into a work piece. So, it depends that, at what particular location, we want to measure the temperature, and according to identification of that location, we will put the thermocouple there. Then, this is not the only technique for measuring the temperature, there are number of other techniques for measuring the temperature in the cutting zone.

So, another technique is the infrared radiation from the cutting zone, there will be a production of infrared radiation. So, the infrared radiation from the cutting zone may also be monitored. So, we can monitor infrared radiation that is getting generated in the cutting zone with radiation pyrometer. So, there is another device, another instrument that we are calling as radiation pyrometer. So, the infrared radiation from the cutting zone may also be monitored using radiation pyrometer; however, this technique indicates only surface temperatures.

In, when we are embedding a thermocouple into a tool, and a work piece, we are going to get the temperature at that particular location, whereas if we are going to use a radiation pyrometer. We are only going to get the temperatures at the surface of the material or the surface of the work piece being machined. So, the limitation is that, we are only going to get the surface temperatures. If we want to know that, what is going to be the temperature in the bulk of the material? That is getting machined, that is not possible using this technique.

Moreover, the emissivity of the surface that, how emissive the surface is, will affect that, how our, how sensitive our instrument is, and how emissive the surface is. If the emissivity is good, it may so happened that, the pyrometer may be give us the exact reading of the temperature, but if it is not so emissive, if the machine is less. So, it may so happen that, we are not able to exactly record the temperature of the surface. So, we can see that, it is very easy to record the temperature, if we are using the thermocouple, it is relatively difficult.

If it is, if we are using a pyrometer, it is relatively easy, but depending upon the application areas, each of this process has its application; it each of this process or each of this instruments or each of this device has its advantages, as well as its limitations. So, depending upon the requirement, depending upon the type of the machining operation that we are performing, we can particularly select anyone of this technique. There will be other techniques also for measuring the temperature in the cutting zone, but that, because of the time constraints, we are not going to go into detail of all the techniques, regarding the measuring temperature.

We have seen that, these are two important techniques, with which we can establish that, what is going to be temperature that is going to be generated at the cutting zone. So, once we are able to establish the temperature, as well as the distribution of the temperature in the cutting zone. We can then go forward and select that, what is the type of cutting fluid, how we should inject the cutting fluid, what should be the application technique of the cutting fluid, for controlling the temperature in the cutting zone, what should be the properties of the cutting fluid, for controlling this much temperature raise inside the cutting zone.

Now, we have seen, cutting forces, temperature in the machining operation. Now, we come on to another important aspect, which is directly related to the economics of metal cutting. We have to justify a process, economically, so that, it competes with the competitive processes. Now, two life, why two life is important, wherever we go, this is a regular cost, that is incurred by any plant, that is based on the machining as a important manufacturing process.

Once, if we acquire a machine tool, that machine tool is a permanent asset, but these tools regularly add to the cost. So, it is regular cost that is associated with the tools. Moreover, if we are not properly operating or if we are not performing the machining operation properly, this tool life will adverse will be adversely affected, and we are not going to, we will not be able to economically justify the operation.

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Now, tool life has two important points that is wear and the failure. So, wear is anyhow going to take place, whenever suppose, one particular example that comes to my mind of, if wear or friction is that, when we use a pencil, we write with the lead pencil I am talking about not with pen, a lead pencil; that is used by children, when the pencil is used to write something or to scramble something on a piece of paper, so the lead wears out. So, that is one advantage of wear, we can say. Although, as an engineer, as a scientist one can say that, wear is always ((Refer Time: 44:04)), but sometimes the wear is also useful.

For example, the pencil when we rub a pencil on a piece of paper, a line is created or some words are written. So, there also, the lead is varying out, but here coming on to other discussion to life, which incorporates wear and failure, the wear has to be avoided. We want that the tool material or the tool, that we have selected, should not wear out very fast. If in case, it wears out very fast, then we have to replace the tool, either or we have to regrind the tool or redress the tool. Now, regrinding will also add to the cost.

So, then we select a particular tool material, we have to make this thing or we have to wear this thing in our mind, that its wear rate or the wear should be minimum. So, the tool life will depend upon the wear that how the tool is getting warm with the time. Now, the cutting tools are subjected to why this, why we are giving so much of importance to this tool life or and wear and failure. Because, the cutting tools, that we are using, they are subjecting to high localized stresses.

So, we have already seen when the tool is in direct contact with the work piece, highly localized stresses are developed. And because of which the plastic deformation or the failure takes place or some of the part of the work piece is removed or detached from the work piece in the form of chips and gets removed. So, that highly localized stresses are generated. So, first point is that, the tool undergo highly localized stresses, the second is high temperature we have already seen, while machining operation, a cutting zone, high temperatures are generated or it is a zone, where heat is more or heat is generated in the cutting zone.

So, because of that heat, there are elevated temperatures, and at elevated temperature, the hardness, the strength, as well as the wear resistance of the tool is going to be affected. So, highly localized, it has to, it is subjected to highly localized stresses, that cutting tools are subjected to high pressures, then the sliding of the chip along the rack face. So, in the very first diagram that, we have seen today in our lecture that, there is a cutting tool and the chip goes at the face of the tool like this.

So, this basically is the rack face of the tool, suppose this is the tool, this is the rack face of the tool, and the chip goes over the rack of the tool like this. So, this rubbing action between the chip, the chip is a, for harden materials sometimes. So, when it, this hard material is rubbing against the tool rack face, there is always going to be some effect on both of these. But, the chip is not going to be used for any other purpose, it is a waste material only, but the tool rack face has to be used again and again, this tool has to be used again and again.

So, when the chip is crossing the abrading action or wear, on this particular rack face, then there is going to be certain failure of the tool after some time. It is not that once the chip has rub, the tool is going to break, but gradually, when the chip is continuously rubbing against the tool, after some hours of service may be I say, that the tool after ten hours of service, there may be some kind of wear that will be noted, on the face of the tool. So, that has to be avoided. So, the cutting tools are subjected to high stresses, it gives can be compressive or tensile, depending upon the type of application.

So, high localized stresses, high temperatures, sliding of the chip along the rack face, and sliding of the tool along the freshly cut surface. Now, when the tool is doing the machining operation like this, if the tool also has two faces, suppose, this is the tool, that is going like this. So, this face and the machined face, suppose this is the machined face, when this is moving, if we are not providing a proper relief angle or we are not providing the proper tool geometry, one face of the tool may rub against the machined surface. And subsequently, we will note, some kind of wear on the surface of the tool that is rubbing against the freshly generated machine surface.

So, it is important for us to understand, all these phenomenon, which a tool undergo or a cutting tool undergoes, in order to a certain a tool life of the material. If the tool is subjected to highly localized stresses, it is subjected to high temperature, it is subjected to rubbing action of the chip along the rack face of the tool or one face of the tool rubbing against the freshly generated machine surface. So, how, why all these things are, what all these things are going to result into this, all these things are going to result into the tool wear, and that will later on result into the tool failure. So, the tool life will depend on, all these parameters that we have just discussed.

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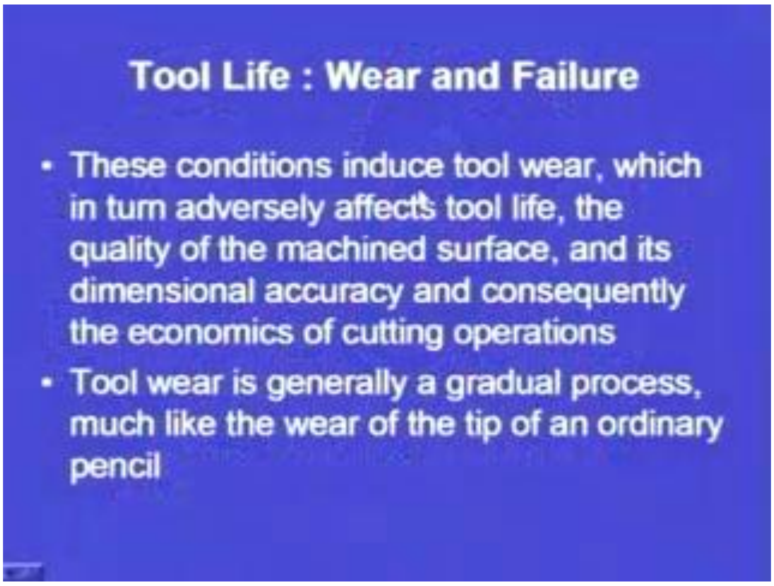

Now, these conditions include tool wear, which in turn adversely affect the tool life. So, we have already seen, this point I have already addressed, in the previous slide or the previous transparency we have seen that, there are different condition, that the tool has to undergo, what was those conditions. Those conditions were stresses, temperatures, high temperatures, then rubbing action, abrading action. So, what all these conditions are finally, going to lead into. If all these conditions, the tool has to undergo, this will result in tool wear, all these parameters that we have just discussed.

All these parameters will lead to tool wear. And, this will adversely affect the tool life, if the wear is move, because if we would have discussed in detail. There are two different types of wear that we will see as a subsequent part of this lecture. So, different types of wear mechanisms are there, different types of wear are recorded. Now, the wear that we will see has certain particular critical levels. If the wear takes place beyond a particular level that has been set, then the tool has to be either discarded or has to be reground.

So, till now we have seen that, there are number of parameters that affect or that induces a tool wear, and tool wear adversely affects the tool life. So, this tool wear has the particular limiting factors, and if this tool wear recorded, this recorded beyond this particular level, then the tool life is zero means, the tool life has to be start at that particular time only. It will be set, there is a tool has already undergone its service life, and now, either it has to be reground or a new tool has to be bought. So, this is the limiting factor on the life of the tool and that is the tool wear.

So, these conditions that we have already discussed, will not go again to those conditions, induce tool wear, which in turn adversely affects the tool life. So, tool life gets affected by the tool wear, the quality of the machined surface, and its dimensional accuracy, and subsequently the economics of the cutting operations. So, we can say that, all these conditions that we have already considered, they will affect the tool wear. Tool wear is going to affect tool life we have seen that, tool life will be reduced, if too much of wear has been reported.

So, we can say that tool is dead now; it is not going to perform any function further. But, it is not that, it is only going to affect the tool life. The tool wear is not only going to affect the tool life, it is going to have an effect on a number of other parameters also. So, that induces the tool wear, which in turn adversely affects the tool life, All right, till now we have discussed, the quality of the machined surface. So, if the tool wear takes place. Now, suppose if we take an example of a single point cutting tool.

Single point cutting tool has an important nomenclature element that, we can say as the nose radius, while machining, if we say that the nose radius, increases beyond a particular limit or the nose becomes too blend. Then, during the machining operation, it will be resulting into a very poor surface finish. If the cleanliness of the cutting edge is lost, and the cutting edge become blend, then it is going to affect the surface finish or it is going to affect the machining surface. So, if the tool wear goes beyond a particular level, it is not only going to affect the tool life, it is also going to affect the quality of the machining surface and its dimensional accuracy.

So, if the tool wear is taking place, because of the conditions that we have discussed earlier, this particular tool wear is going to affect the tool life. It is even going to affect the quality of the machined surface, that we are going to generate or that we are going to get, as well as its dimensional accuracy. So, the work piece of the product that we are going to get, after machining with the tool, which has been warned out, will not be according to our desired quality, as well as according to our desired standards.

Then, all these will result into the economics of cutting operation. So, economic, economy is definitely going to get affected, why economy is going to get affected. Suppose, we have a particular dimension of a work piece that we want to produce, the tool has been worn out. We are using the same tool to produce that particular dimension. So, using the tool, we have produced the dimension, but the surface quality that we have got is not according to the desired specification, that is going to happen.

We cannot further do the machining operation, because there is a limitation on the size of the product that we are producing, this is a material removal process, if we say no. Then, now we can use another tool and give another cut. Then, during the next cut, some amount of material will be removed, and the dimension that we are going to get will be less, as compared to the required dimension that is there in the design. So, if that particular situation arises, that particular work piece on which, the surface finish is not good, because of the tool wear, that particular work piece has to be rejected.

So, if numbers of work pieces are rejected like this. Then, this is certainly going to have, and bearing on the economics of the operation that we are performing. Similarly, if tool wear is reported at a very fast phase or at a very fast rate, tool wear is very fast. Then, the tool has to be reground again and again. And then the tool regrinding fast will add to the cost of the product. So, the economy is thereby going to get affected. So, the tool wear is going to result into a number of problem areas, but certainly, the tool wear will take place. But, it should be in a control manner, it should not be beyond a critical limit.

Then, tool wear is generally a gradual process that I have already told that, it is going to take place, but it should be in a controlled manner, much like the wear of the tip of an ordinary pencil, I have already quoted the example of a pencil. So, it is like a pencil, when we keep on writing, some wear is going to take place. Similarly, when we are using the cutting tools, some wear is bound to happen. But, it should not go beyond the particular level, otherwise the tool life will be ending there, and the tool has to, either reground or it has to be discarded or it has to be replaced.

So, with this, we come to the end of this session on machining. So, we have discussed today, some of the basic fundamentals, regarding the machining operation. In which, we have seen that, what tool wear takes place, there are different types of forces, how we can measure the forces, what is the important of controlling the temperature in the machining operation. So, subsequently we will discuss, try to discuss, what are the different types of machining operation, and we will carry forward our discussion, that we are leaving now, into the next lecture.

Thank you.