Manufacturing Process - 1
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Module - 1
Lecture - 16
Machining – III

A warm welcome to all in this session on machining. We have been discussing the fundamental aspects of machining operation for the last two three lectures. In order to maintain the continuity in the subsequent of the lectures or to maintain the continuity of what we have covered and what we are going to cover in the next lectures, we will just like to review what we have covered till now.

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So, we started our discussion regarding the machining operations. We started with the discussion on the fundamentals of machining - what are the machining operations; where it is required. Then we went on to discuss the necessity of machining - why machining is required; why do we need to perform a machining operation; why we cannot make the product using any of the net or near net manufacturing processes like casting and forging.

Then, we went on to discuss that machining has certain advantages, but it also has certain disadvantages or the limitation. So, what was the major limitation? The major limitation was in terms of the wastage of the material in the form of chips. Then, we discussed what the different types of chips that are formed are, in which we discussed continuous chips, serrated chips or segmental chips, built-up edge chips, and then, we discussed the discontinuous chips. Under what conditions all these type of chips are going to form that was also discussed.

Then, we went on to discuss the problem areas with the continuous chips and the results - thereby that what are the results or what are the deteriorations or what are the limitations of the continuous chips, if continuous chips are going to form, how they are going to effect the surface finish or what are the problem areas with the continuous chips. Then, we discussed the chip breakers, that why do we need to break the chips.

Later on we discussed - what are the different types of measurement of cutting forces and we discussed the measurement of temperature. What is the influence of the cutting forces and what is the influence of the temperature that is raised or the heat that is generated in the cutting zone - that was discussed in the last lecture.

Then, we left in the last lecture while discussing the tool life, tool wear, tool failure. So, we start our discussion today with overview of tool life and tool wear. So, we have seen that whenever a tool is performing an operation, it undergoes a number of different conditions.

For example, it undergoes different types of stresses - highly localized stresses; then, very high level of temperatures are there, when the tool is in direct contact with the work piece. Moreover, when the chip is getting removed, it slides over the rack face of the tool; one surface or one edge of the tool, sometime rubs against the freshly generated machined surface. So, the tool undergoes different types of conditions or it has to sustain different types of condition. So, all these conditions that we have discussed lead to a tool wear, and the tool wear subsequently leads to the end of the tool life.

So, the tool has a particular life. Now, the life of the tool can be specified in a number of ways. For example, we can say this tool is suitable for 10 hours of operation under xyz condition. So, these conditions can be cutting tool, cutting speed, feed, depth of cut.

So, for a particular tool, we can say the total life of this tool is suppose 10 hours under these particular conditions or we can say that this tool is suitable for machining this particular material, for this much meters of length.

So, depending upon the specifications the tool has a life; but all these conditions - highly localized stresses, elevated temperature, rubbing action, abrading action leads to the tool wear, which further results into the failure of the tool. Moreover, the tool wear is not only going to affect the tool life, it is also going to affect the surface finish of the product that we are machining. Moreover, it is also going to affect the dimensional accuracy also.

So, we have seen that tool wear takes place because of certain conditions, which results into the lessening of the tool life; also it effects the quality of the product that we are producing. So, that was the summary of what we have covered in the last lecture regarding the tool life and failure. From there, we will now carry forward our discussion regarding the tool life, and wear rate, and failure.

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Now, the rate of tool wear depends on the tool and work piece materials. So, the first important point to note is the tool wear depends on the tool and the work pieces materials. Now, as a part of our lecture, we will discuss what the different types of tool materials are.

Similarly, there are different types of work pieces materials also. Work piece materials can be in the term of, suppose we take a example of some steels or it can be some grades of different cast alloys; it can be different types of all materials, like it can be titanium, it can be very high strength alloys. Now, depending upon what is the material that we are going to machine and what is the material of the tool which we are using to perform the machining operation, there is going to be, that is going to affect the wear rate or the rate of tool wear.

Moreover the tool chip, suppose one example we have taken under the conditions that lead to the tool wear, where the one edge or the one surface of the tool rubs against the freshly generated machined surface. If we are able to provide a proper relief angle or a proper clearance angle, so that this surface is not rubbing against the work piece surface. So, if we are able to avoid this rubbing action by providing a particular angle to the tool we are able to control the tool wear.

So, the rate of tool wear depends on two parameters, we have already seen - it depends upon the work piece material and the tool material. Moreover, it depends upon the shape of the tool.

Moreover, it depends upon the cutting fluids. Now, one important parameter that results into the tool wear is the temperature that is generated during the cutting operation or the heat that is generated during the cutting operation. So, in the cutting zone, where the tool is in direct contact with the work piece, and the temperature is getting raised, there if we are able to supply the cutting fluid the temperature will be lowered. Now the cutting fluid here will act as a cooling agent. It is important to note here that the cutting fluid has two important functions: the first one is to cool the cutting zone and the second one is to act as a lubricant. So, we will see as a part of this lecture, that where it should act as a coolant and where it should act as a lubricant.

So, here we are discussing the tool wear will depend on a number of parameters or the wear rate of the tool will depend on a number of parameters. So, first point we have already seen - it depends upon the tool material and the work material. Then it depends upon the tool shape; if we are not giving a proper geometry to the tool, then there are chances that the tool will rub against the work piece surface, and it will result into a tool wear.

Moreover, it depends upon the use of the cutting fluid. If we are using a cutting fluid and it is cooling, then the temperature that is generated in the cutting zone will not be too much and then tool wear maybe under the controlling limits.

Moreover, it will depend upon the process parameters also. Now what are the different process parameters? These are cutting speed, feed, and depth of cut. So, if we are machining at a very, very high speed, the chances are that the tool wear may be more. And if we are machining at a very small speed, then also there are chances; it depends on a number of parameters; its not that always this is going to be happen; but mostly if the speed is very, very high there are chances that the tool wear will be more.

Then such as different parameters, we have seen - cutting speed, feed, depth of cut, and the machine tool characteristics. So, the tool wear will also depend upon the machine tool characteristics. What are the important machine tool characteristics? If the machine tool is vibrating or the machine tool is having chatter, then the tool will also move, because the tool is mounted on a tool post, which is mounted on a machine. So, if the machine is vibrating, then the tool post will vibrate, and consequently the tool will vibrate, and there will be an excessive wear of the tool.

So, the tool wear is dependent upon a number of parameters and all those parameters are - the tool and the work piece material; the tool shape; the cutting fluids; the process parameters; and the machine tool characteristics. So, the tool wear will depend upon all these different parameters.

Then, there are two basic types of wear that has been reported; we are not going to go into the details of these types of wear or the wear mechanisms; we are just going to see that what are the different types of wear that takes place during the machining operation.

Now, corresponding to two regions in the cutting tool, one is the rag face, another is the flank face, two types of wear is reported. Now, what are these two important types of wear mechanisms or the wear types? This is the flank wear and the crater wear. Then there is a limitation on the flank and the crater wear. Now, depending upon that limiting factor, if the wear goes beyond that particular factor, then the tool has to be either rejected or it is has to be reground. So, there is a limitation on both the levels of flank wear as well as the crater wear. So, these are the two important types of wear that is generally reported in a cutting operation or they are generally reported on a particular cutting tool.

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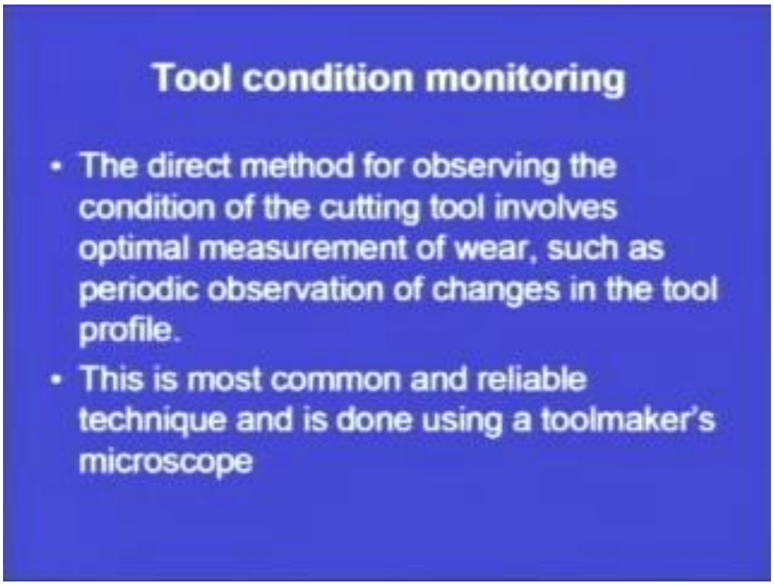

Now, we need to monitor the tool condition. We have seen that the tool is subjected to a number of testing conditions. Now, when the tool is under those conditions, under highly localized stresses, under high temperature, it is that the chip is rubbing against the tool, and the tool is rubbing against the work piece. So, under all these testing conditions, the tool wear is going to take place; the tool wear is going to depend upon a number of parameters.

Now, when in case of a… suppose we take an example of an automated machine tool. Now, in case of a automated machine tool, the operation is automatic; there is no man, there is no particular control that is being excised on the machining operation. So, whatever control is there, that control is excised by the program that has been fed into the controller. So, no man is there in order to check the quality of the tool. So, this particular control of the tool wear becomes extremely important in such circumstances.

So, we need to measure the tool wear or we need to monitor the condition of the tool, so that we know that the tool is performing its indented function particularly well or properly. If the tool is not performing its indented function properly, there are going to be a number of problem areas, which will become very difficult to address at a later stage.

So, there are two methods for monitoring the tool. So, the direct method for observing the condition of the cutting tool involves optimal measurement of wear such as, periodic observation of changes in the tool profile. Now this is one particular direct measurement technique. In direct measurement technique, we will observe the condition of the tool periodically after specified set of interval of time or specific set of time intervals.

We will stop the operation; take the tool out of the tool holder, and observer it under a toolmaker's microscope. The instrument that will be used will be the toolmaker's microscope and we will see the condition of the tool. So, we have a initial condition of the tool, and after a set of particular time, after a set of time interval, we will see that we have performed the machining operation using this tool for another 30 minutes. So, what was the condition or what was the profile of the tool before 30 minutes and after 30 minutes of the operation; means it is performing for 30 minutes, and then, we are taking it out and checking it. So, the direct method for observing the condition of the cutting tool involves optical measurement of wear such as periodic observation of changes in the tool profile, so that we will see after a specific set of time. And this is most common and reliable technique and then using a toolmaker's microscope. So, that already we have seen; I have discussed that toolmaker's microscope will be used to see the condition of the tool after a particular time of machining.

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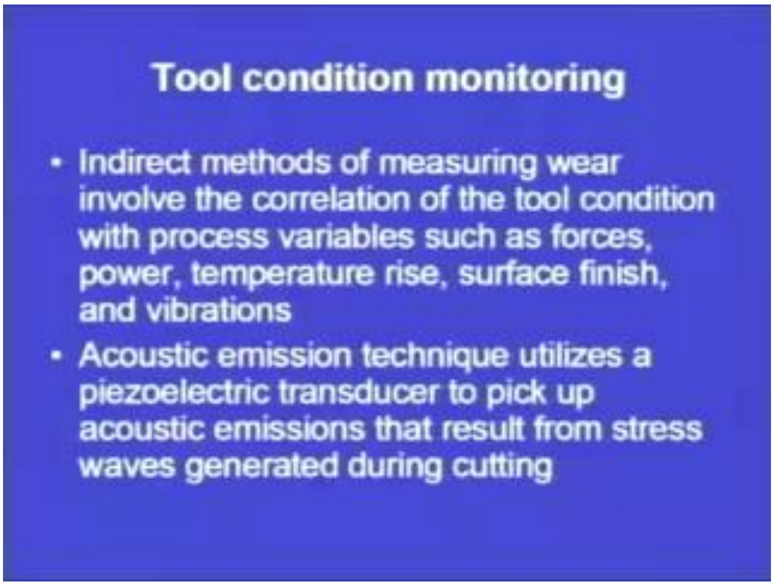

Then there is another indirect method. Now, we have taken an example of automatic machines, where in automatic machine it is very difficult to stop the operation in between. So, we need to have a indirect method of monitoring the tool as well as its condition, that how the tool is performing its indented operation.

Now, the indirect methods of measuring wear involve the correlation of the tool condition with process variables such as forces, power, temperature rise, surface finish, and vibrations. Now, we can correlate the present condition of the tool with a number of these process variables. So, how that is possible? That is possible by measuring all these variables when the tool is performing its operation or the tool is machining the work piece.

How we can measure this, already we have discussed that; we can measure the forces using the dynamometer; we can measure the power also; we can measure the temperature rise using a pyrometer or using the embedded thermocouples. Similarly, we can measure the surface finish of the part that is being manufactured. If there are number of techniques like Talysurf, Talyrond depending upon these, there are the instruments that can be used for measuring the surface finish. Then we can measure the vibrations also.

So, in here, in indirect method, we are not directly measuring the profile or measuring the tool wear using a toolmaker’s microscope; we are not stopping our operation. So, this is particularly relevant to a condition where we are using a automatic or automated machine tool. We do not want to stop the operation of the machine tool. We want that the operation should continue and indirectly we should be able to understand that whether the tool wear is taking place or not, and even if it is taking place at what rate it is taking place. So, if the tool is going to encounter an excessive wear rate, then it is going to have a influence on any of these process variables.

Suppose we take an example, whereby there is cutting tool which has been abraded or the tool has gone a substantial - has undergone - a substantial amount of wear. So, if the tool has undergone a substantial amount of wear, then there are chances that if we are recording the forces, there will be a sudden increase in the level or sudden increase in the magnitude of the forces that we are recording using a dynamometer. So, the indirect methods of measuring wear involve the correlation of tool condition with process variables such as forces, power, temperature rise, surface finish, and vibrations.

So, one example we have taken, whereby we have seen that if we see and we are recording the forces, and the rise in the forces or the magnitude of the force is substantial, we can conclude that there is some problem in the cutting zone, and the tool wear is substantial, it is not cutting; the edge has lost it its keenness; and the edge is not so keen to perform the machining operation; there is a rubbing action, and because of the rubbing action the force is showing a sudden increase.

Moreover, if the power requirement increases or if the temperature in the cutting zone increases beyond a particular level, so one of the reasons for that particular rise in the temperature maybe the wear of the tool or the tool wear. Moreover, if we are getting a particular surface finish using a new machine - new cutting tool. Now, if we are using a old cutting tool, then the surface finish we will get will not be the same as the surface finish we are going to get with a new cutting tool. So, the old cutting tool means that it has worn out or a substantial wear has been taking place or substantial wear has taken place on that cutting tool. So, if we check the surface finish after certain intervals of time, we can see that tool wear has taken place or not, because the surface finish that we have - we will get - using a new tool and an old tool will be different.

So, we can see that if the surface finish has deteriorated beyond a particular level, we can very easily conclude that the tool wear has taken place; and if surface finish goes beyond a tolerance level, then we can say the tool has to be changed. If we are not going change the tool, the tool is directly going to replicate the same type of surface finish or the surface finish may even get worse after the certain time of operation.

So, one point is that we can directly measure the wear using toolmaker’s microscope or we can indirectly measure the wear - we can have a check on all these process variables and we can conclude whether tool wear has taken place or not.

Then, there is another technique that is called acoustic emission technique, that utilizes the piezoelectric transducer to pick up acoustic emissions that result from the stress waves generated during cutting. So, during cutting some stress waves are generated, and this acoustic emission transducers will pick up the stress waves, and send a feedback signal that this particular tool is wearing at this particular rate. So, it cannot - it may not - be able to predict that what rate the tool is getting worn, but it can only tell that the tool wear is reported; the tool wear is taking place. So, the acoustic emission technique utilizes a piezoelectric transducer to pick up the acoustic emissions that result from the stress wave generated during cutting.

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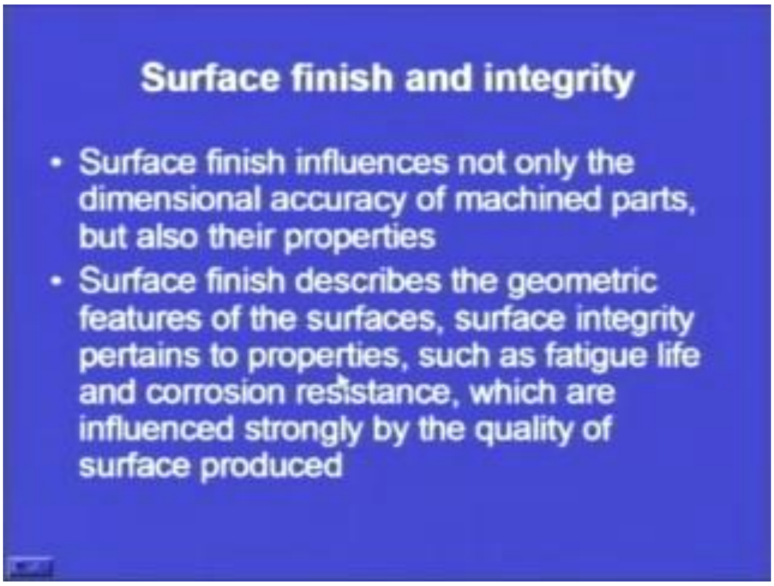

Then another important point in case of machining operations is surface finish and integrity. Surface finish influences not only the dimensional accuracy of the machined part, but also their properties. So, the kind of surface finish that we are going to get after the machining operation is not only going to affect the dimensional accuracy, but it will also affect the properties of the final product, and it will affect the in-service performance of the product when it is put into use. So, the surface finish is an important function or is an important criterion on the basis of which we can characterize whether the product has been machined properly or it has not been machined properly.

Now, surface finish describes the geometric features of the surfaces. So, surface finish describes the geometrical feature; whereas, the surface integrity pertains to the properties such as fatigue life and corrosion resistance. So, surface finish indicates the geometric features; whereas, the surface integrity pertains to the properties such as fatigue life and corrosion resistance, which are influenced strongly by the quality of surface produced.

So, already in the first point we have seen the surface quality or the quality of the surface that we have machined, depends upon a number of parameters, and the properties of the surface also depends upon the quality with which surface has been produced.

So, in order to just to summarize - surface finish describes the geometric features of the surfaces; surface integrity pertains to properties such as fatigue life and corrosion resistance which are influenced strongly by the quality of the surface produced. So, whatever quality we produce, these properties will depend if the quality is very, very poor, then these properties will be affected thereby.

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Now, surface finish and integrity, we will continue the factors affecting the surface integrity. So, what are the various factors that affect the surface integrity? These are the temperatures generated during processes or the temperatures generated during processing, these will depend on the residual stresses; these will also depend on the metallurgical transformations; moreover, they will depend upon the surface plastic deformation tearing and cracking.

Now, surface integrity incorporates an important point; that is the… we can just go back and see - this will depend, this will affect the fatigue life and corrosion resistance. We can take a lead from here - surface plastic deformation, tearing, and cracking. So, if cracking is taking place on a surface or the quality of the surface that we are generating is having certain cracks on it; now these cracks, however small these are, when we are going to use the surface for cyclic type of loading or we are going to use the component with this particular surface, which has some micro cracks for fatigue loading, then during the fatigue loading, these small micro cracks have the tendency to enlarge; some micro cracks may join together to form a bigger crack; and this crack may later on lead to the catastrophic failure of the product that has been machined with a surface that was having micro cracks.

So, when we are producing a surface, we need to establish that the surface integrity should be good. If the surface integrity is good, then there will not be any tearing or cracking on the surface. Moreover, the surface integrity will depend upon the temperatures generated during processing. So, these temperatures have to be controlled. If we are not controlling the temperatures, then the surface integrity that we will get, will not be good. So, all these parameters will influence a surface integrity as well as the surface finish of the product that we are producing.

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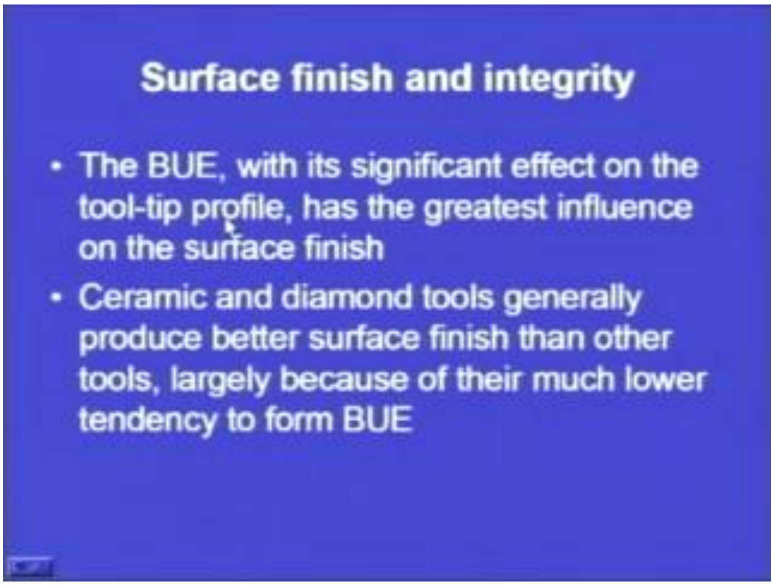

Then the built-up edge that was discussed when we discussed the different types of chips that are produced. The built-up edge with its significant effect on the tool-tip profile, we have seen what is a built-up edge just to summarize or just to review what was the built-up edge. The built-up edge is some material that is getting deposited on the tip of the tool in the layer wise fashion. So, if the built-up edge has a significance on the tool tip profile. So, this is some material that is deposited on the tip tool; if it has a significant effect on the tool tip or the profile of the tool tip, yesterday we have seen that if the angle is getting changed, then the complete machining behavior is going to change.

Now, if suppose this is the tool tip, and there is some material that is getting deposited on the tool tip; then this angle with the vertical line which has been generated will get affected and this effect on the angle will affect on the machining behavior. So, the built-up edge, with its significant effect on the tool tip profile, has the greatest influence on the surface finish.

So, yesterday, or in the previous lecture, we have seen that there are certain conditions that how we can reduce the formation of the built-up edge. So, built-up edge, it was seen that sometimes it is advantages also, but those limitations that are coming with the advantages have to be removed. Then, if the built-edge has a significant effect on the tool tip profile, then it is directly going to influence the surface finish of the final product that we are going to produce. So the surface finish that we are getting may not be according to our desired levels.

Then the ceramic and diamond tools generally produce better surface finish then other tools. Why? Because of their much lower tendency to form built-up edge. So, this particular point summarizes that the built-up edge formation is going to result into the deterioration of the surface finish and the surface integrity. If we are going to choose ceramic and diamond tools, then these tools are going to generate a better surface, with a better surface quality, with a better surface finish, with a better surface integrity, as compared to the other cutting tools - why? Because in case of diamond as well as in case of ceramic the tendency of the built-up edge formation is minimum.

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Now, we come on to another important aspect of machining operations that is the cutting tool materials. We have, till now, seen that there is a cutting tool which is performing a machining operation. Now this tool is made up of a material. So, what are the requirements of the materials of the cutting tool that we will see.

The optimal selection of the cutting tool material is one of the most important factors in machining operations. So, it is worth mentioning, if we choose a particular material for a making a cutting tool and if it does not possess the adequate qualities, then this particular tool is not going to perform the intended function of performing the machining on a particular work piece. We want that the tool material should be such, that it should have some desired qualities; what are those desired qualities, that we see in the subsequent slide.

The cutting tool is subjected to high temperatures; this already we have seen that the cutting tool, when it is in the cutting zone, and it is performing the cutting operation, or it is performing the machining operation, it is in a zone, which is at a very high temperature or where the heat generation is taking place. So, the cutting tool is subjected to high temperatures; it is also subjected to contact stresses. Moreover, sliding along the tool chip interface - so the chip is sliding along the tool chip interface, and along the machined surface. So, sliding action is taking place along the tool chip interface as well as along the machined surface.

So, there are different testing conditions to which the cutting tool is subjected to. So, these particular conditions are going to result into a substantial amount of tool wear, which will further lead to the tool failure. But here we are discussing that what should be the material of the tool, so that if it is subjected to these particular conditions it is not going to fail or even if it is going to fail, it is going to serve for its designed life.

Now, we are designing a cutting tool, we will design it for a particular life. So, how the life will be set for a tool, that we have already seen; it can be in terms of some meters of length that it will machine or it can be in terms of its life. So, it depends that how the life - so life, already you have seen it can be in terms of the length it will machine or for the hours of operation. So, we can say this tool has been designed for 5 hours of operation under these conditions. Similarly, we can say this tool has been designed for machining 5 meters of length under these conditions.

So, the tool - if we are designing a tool, for a particular life, then the material of the tool should be such that it should be able to perform its function properly for its designed life. Then, the cutting tool when it is subjected to all these important conditions - that we have already discussed in the previous section also - the tool has to perform its operation. So, what are the requirements or the conditions or what are the characteristics that a material out of which we are going to make a cutting tool should possess, so that all these conditions do not have a deteriorating effect on the life of the tool - that we are going to discuss now.

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So, the cutting tool material should possess all these qualities or all these characteristics that we have listed here. So, the cutting tool must possess the following characteristics. What are those characteristics? These are hot hardness - hot hardness means that when the tool is performing the cutting operation, the temperature in the cutting zone is high; although the tool is substantially hard in its initial condition, but when it is subjected to elevated temperatures, then it should retain its hardness. So, hot hardness is a property of the material to maintain its hardness at an elevated temperature. So, the material out of which we are going to make a cutting tool or a cutting tool material should possess the quality of hot hardness.

Similarly, it should possess the quality of toughness also. Why toughness is required? Because sometimes, because of some vibrations or the work piece has not been clamped properly in the chuck, then because of some vibrations certain loading may come, so that the tool may break. So, in order to avoid that kind of tool failure, the tool material should be tough.

Similarly, the important characteristics is the wear resistance - the tool should have a wear resistance or the tool material should have the property of wear resistance. If it will have a property of wear resistance, then the tool wear will be less, and the tool life will be more.

Moreover, the tool material should also have chemical stability and inertness; it should not react with the cutting fluid or with the work piece material. Why? This point has been addressed here, because when we are using a cutting fluid, then cutting fluid is a, basically a, chemical material only or it is a form of a chemical. So, if the tool has a affinity to react with certain chemicals, then it may affect the tool life in the long run. So, the chemical stability and inertness is also important.

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Now, cutting tool materials with a wide range of mechanical physical and chemical properties are available. So, there are number of cutting tool materials available. What are these different types of cutting materials? These are in order of how they have found their significance.

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So, these are carbon and medium alloy steels, high speed steels, cast cobalt alloys, carbides, coated tools, alumina based ceramics, cubic boron nitride, silicon-nitride base ceramics, diamond, whisker-reinforced materials. So, we have seen that depending upon the physical, chemical, as well as the mechanical properties there is a wide range of materials that are available with us that can be used as cutting tool materials. But the important point to note is, that all these materials, whatever material we choose, to form or to make a cutting tool should possess the adequate characteristics that we have already discussed.

So, the important characteristics to note are the hot hardness, toughness, chemical inertness; then it should be inertness to the atmosphere at elevated temperatures. So, all these properties have to be ascertained for any of these materials. For example, now I will take an example of machining with the two different materials or two different cutting tool materials. If we take an example of a fiber reinforced plastic composite material, or to be more specific, if we take an example of the glass fiber reinforced plastic composite material; then, if we make a hole using a high speed steel drill, then the life of the high speed steel drill it maybe between 100 to 150 holes depending upon the type of fibers as well as the matrix that is being used to make a glass fiber reinforced plastic material.

But instead of using a chassis, if we are using a carbide material or a solid carbide drill to make a hole in the same material, it will be seen that the number of holes before the drill is going to fail may range from 200 to 250.

So, the important conclusion of this example that we can draw is, that fiber reinforced plastic material because of the abrasive nature of the fibers that have been incorporated into the matrix - that is the plastic matrix - these fibers will abrade the high speed steel tool at a faster rate and they will be able to abrade the ceramic or a carbide tool at slower rate. So, a carbide tool is a better candidate for making a hole in a composite material made of fiber - made up of fiber reinforced plastics - as compared to high speed steel.

So, similarly, depending upon the requirements, depending upon the work piece material, depending upon the different variables - different control variable - we have to make a selection that which particular tool material should be selected for performing the machining operation.

We have taken example; we have compared two different tool materials - that is, high speed steel and carbide. So, carbide in our case - that is in case or fiber reinforced plastics drilling - will perform better as compared to the high speed steel; whereas, under certain circumstances a chassis in for some other material may perform better than a carbide tool. So, depending upon the requirement, depending upon the conditions, we have to make a judicious selection that which particular tool material should be selected for which particular application.

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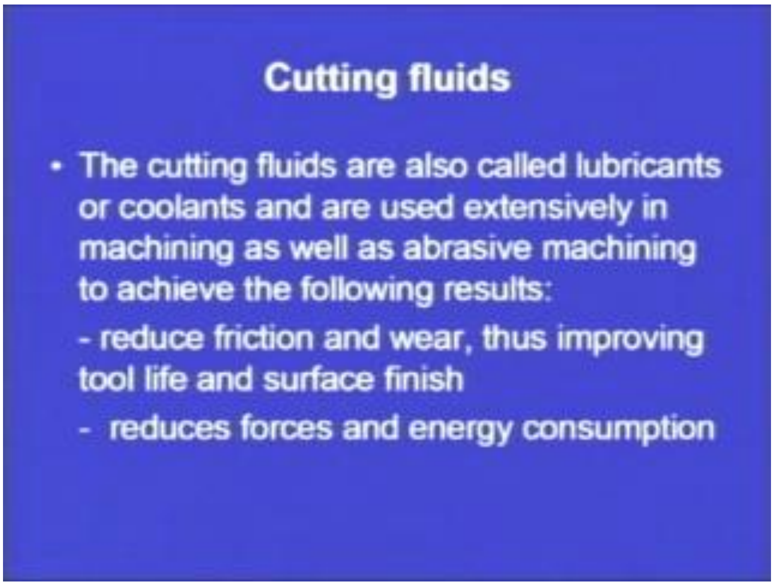

Now, coming on to the cutting fluids, we have seen that there are different types of cutting tool materials that are available and depending upon the requirement we have to choose that which particular material we are going to use. Now, coming on to another important aspect that is the cutting fluids. Now cutting fluids are also called lubricants or coolants. So, basically we have seen the cutting fluid has two different operations; it has two different functions - one is that it will act as a coolant and the another is it will act as a lubricant. Now, this cooling and lubricant - lubrication mechanism - will differ depending upon the composition of the cutting fluid that we have chosen for our indented application. So, the cutting fluid also called lubricants or coolants and are used extensively in machining as well as abrasive machining to achieve the following results.

So, why we are going to use a cutting fluid? Either it with be acting as a lubricant or it will be acting as a coolant. So, why cutting fluid is a required? It reduces the friction and wear, thus improving the tool life and surface finish. So, when the wear will be reduced the tool life will increase. So, cutting fluid will reduce the friction and the wear, and it will improve the tool life and the surface finish. It reduces the force and energy consumption.

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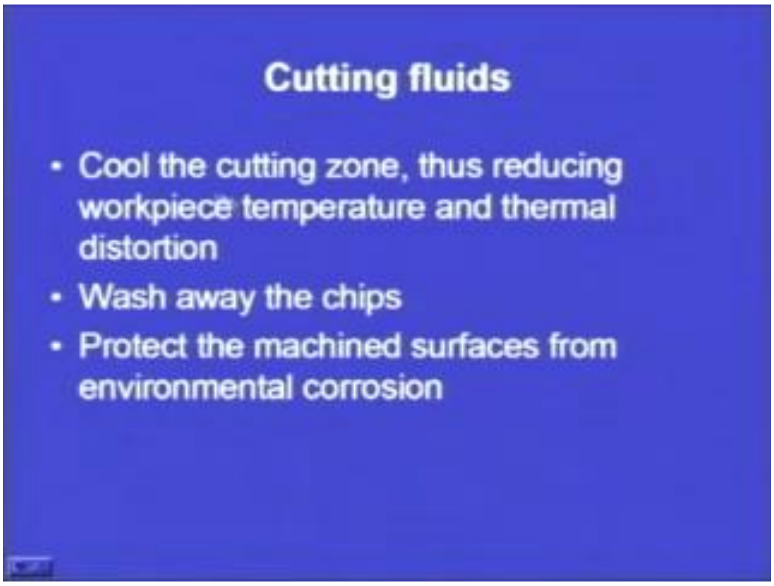

Moreover, it will cool the cutting zone. We have seen that the temperature rises to a substantial level in the cutting zone; so, it will cool the cutting zone, thus reducing the work piece temperature and thermal distortion. So, thermal distortion results into a number of deteriorating results. So, the cutting fluid will cool the cutting zone, thus reducing the work piece temperature and thermal distortion. So, the work piece distortion will be affected.

Then it washes away the chips. The cutting fluid can be used to carry away the chips. Also it protects the machined surfaces from the environment corrosion. Now, if we see that some part of the heat that is getting generated at the tool work interface goes with the chips, some of it will go to the work piece, some of it will go to the tool. So, the work piece is at an elevated temperature. Moreover, if we are not using a cutting fluid, then the work piece at an elevated temperature may react with the atmosphere and some kind of surface deterioration of the work piece may take place.

If we are using a cutting fluid, the cutting fluid will always form a film around the work piece that we are machining or it will form a film around the newly machined surface, so that the machine surface is not in direct contact with the environment. And any oxide formation or any type of layer formation on the surface of the work piece will be avoided, if we are using a cutting fluid.

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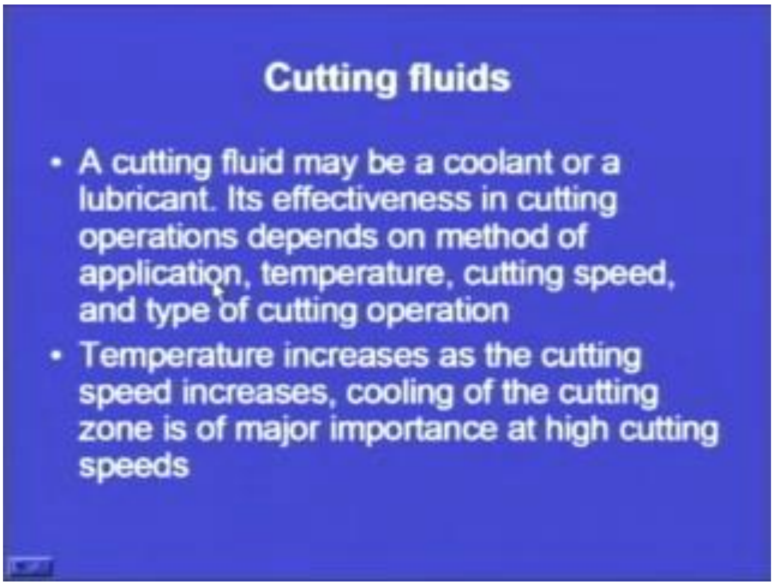

So, we have seen that cutting fluids are used for a number of different reasons. So, a cutting fluid may be a coolant or a lubricant. Its effectiveness in cutting operations depends on the method of its application. We will see that there are number of methods in which a cutting fluid can be applied. Then it also depends on the temperature that we are aiming at, so that this is the temperature that has been raised; we want to bring it lower to this temperature. So, how it is going to behave that will depend upon the temperature that we are aiming at. Then it will depend on the cutting speed also, and the type of cutting operation - how the cutting operation is being carried out, it will depend on that also.

So, the effectiveness of the cutting fluid depends upon a number of parameters. So, the effectiveness will depend upon - how we are going to apply; at what temperature we are going to apply; what is the cutting speed; and what is the type of cutting operation. So, depending upon all these parameters, we can gauge the effectiveness of a cutting fluid. Now, the temperature increases as the cutting speed increases. It is a general phenomenon that if we are increasing the cutting speed, then the temperature that is being produced or the temperature that is being elevated will be increased. So, the temperature increases as the cutting speed increases. So, the cooling of the cutting zone is of major importance at high cutting speeds.

So, if we are performing the machining operation at a high cutting speed, then the cooling of the cutting zone is more important as compared to machining at a lower cutting speed. Why? Because the temperature rise in case of high cutting speeds will be more as compared to the temperature rise in the low cutting speeds.

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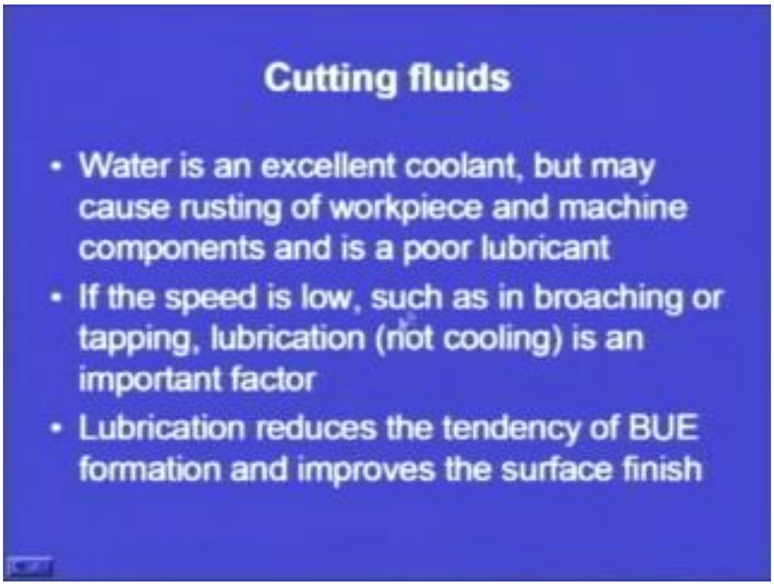

Now - what type of coolants or the lubricant should be used? Now, water is an excellent coolant. If we do not find any other material, we can use directly water as a coolant; but it will only perform the cooling action. We have seen the two important functions are there for the cutting fluid, we can use water as the cutting fluid no doubt, but it has only one function - that is the cooling action only.

If we want to have a lubrication action also, then we need to add certain oils to water. So, that to form emulsion, which will serve both our purposes; it will act as a coolant also, it will act as a lubricant also. So, water is an excellent coolant, but may cause rusting of work piece and machine components and is a poor lubricant. So, already I have told we can directly choose water as a coolant, but it depends that whether we want lubrication also or not. If we do not want lubrication, we can directly use water as a coolant.

But another limitation while using water as a coolant is that it may sometimes result into rusting; the rust may be on the work piece as well as on the machine components also, because in a machine tool, this particular system - the coolant system or the lubricant system - will be incorporated and it has to be recycled again and again. So, water will be in direct contact with different elements. So, if proper care is not taken, then water may result into the rusting of the certain machine elements, and sometimes, it may result into the rusting of the work piece also. So, we can use water as a coolant, but under certain limiting conditions.

If the speed is low, such as in broaching or tapping operation, lubrication is an important factor. Now, suppose we want that water, we want to use water there, in case of these operations like broaching and tapping, which is being performed at a very low speed, then we want that lubrication should take place; water may not be an appropriate cutting fluid in these cases.

So, if speeds are low, such as in broaching or tapping, lubrication is an important factor. So, water is a poor lubricant. So, we cannot use water here in case of broaching and tapping; here we will have to use a particular oil, depending upon the work piece material and the tool material that we are using for performing broaching and tapping. So, here the main requirement is lubrication, it is not cooling; if it would have been cooling, we would have directly used water.

Then lubrication reduces the tendency of built-up edge formation. So, if we are using a particular lubricant or if we are using a cutting fluid which has the lubrication facility, then it will reduce the formation of or the tendency to form a built-up edge, and thus it will result into the improvement in the surface finish. So, if we are using a particular cutting fluid, the chances of built-up edge formation are also minimized, and the problem areas associated with the built-up edge formation can also be countered.

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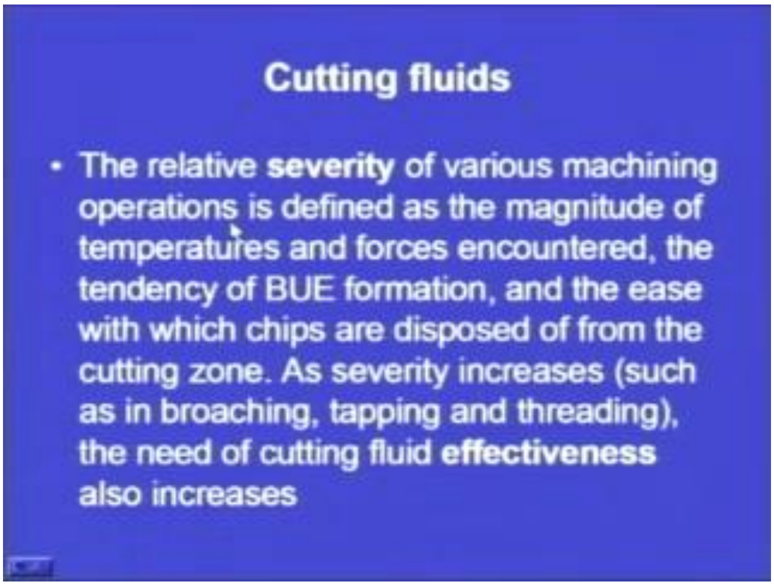

Now, the relative severity of the various machining operations. Now the severity is shown in bold. So, the relative severity of the various machining operations is defined as the magnitude of temperatures and the forces encountered. So, now we have come to another important term, that is severity of a machining operation - how it is defined? It depends on the magnitude of the temperatures and the forces encountered, what is the level of the temperatures that are getting generated, because of the machining operation; what are the different types of forces that are getting encountered or the forces encountered during that operation; the tendency of built-up edge formation; and the ease with which chips are disposed off from the cutting zone.

So, we will call a process as more severe or less severe. So, how we will define this degree of severity? This degree of severity will depend on these four important parameters that have been listed in the first point. So, these important parameters are the rise in the temperature, the forces encountered, the tendency of BUE formation, and the ease with which the chips are disposed of. So, depending upon these four important factors, we will say that this process is more severe, this process is less severe.

Now, as the severity increases - so if we are performing the machining operation and the machining operation is very severe - then this is a case… in case of broaching, tapping and threading, if we are performing the operations of broaching, tapping, and threading, then the severity will be more; the need of cutting fluid effectiveness also increases.

So, if the process severity is more - more means the temperature rise is more, the forces encountered are high or to a larger level - then this forces temperature and chips disposal is very, very difficult. Then, in these particular types of conditions, the effectiveness of the cutting fluids becomes very, very important. Whereas, if there is a condition where the process is not so severe, then - not so severe, means the temperature that are getting raised is not so high - in that particular case the effectiveness of cutting fluid is not all that important; but if the process is really, really severe then the effectiveness of the cutting fluid is very, very important.

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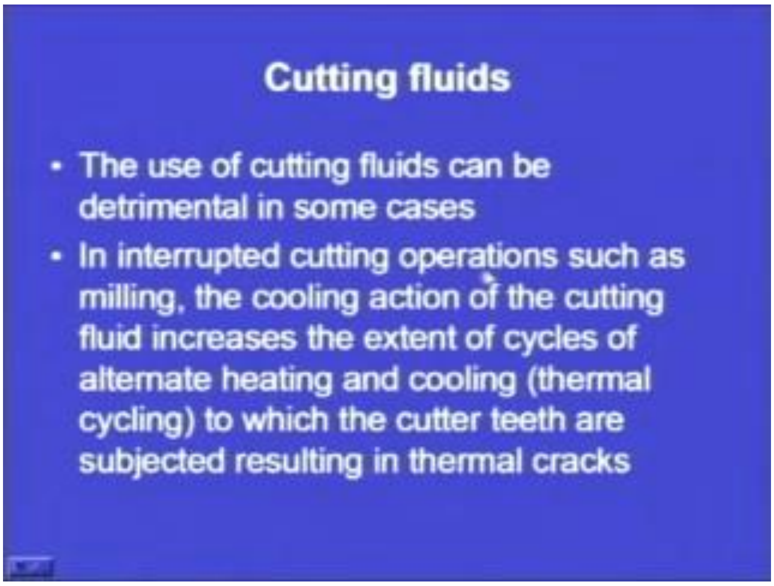

Now, the use of cutting fluids can be detrimental in some cases. We have seen that the cutting fluid should be very, very effective, but the use can be detrimental under certain limiting conditions. So, the use of cutting fluids can be detrimental in some cases. What are those cases? For example, in interrupted cutting operations such as milling - so, milling is a interrupted cutting operation - the cooling action of the cutting fluid increases the extent of cycles of alternate heating and cooling.

Now, the tool is cutting - when it is performing the machining operation - it is a multipoint tool. So, when it is performing the machining operation, it is at a elevated temperature, when it comes out the cutting fluid is given to the or it is applied to the whole of the cutter.

So, when the cutting fluid is applied to the whole of the cutter, then some teeth which are not doing the cutting operation are at a relatively lesser temperature, but when they perform the cutting operation the temperature is higher. So, in interrupted cutting operations such as milling, the cooling action of the cutting fluid increases the extent of cycles of alternate heating and cooling. So, one particular cutting tool is going alternate cycles of heating and cooling - so that we call as thermal cycling - to which the cutter teeth are subjected, resulting in thermal cracks. So, this thermal cycling to which the cutter teeth are subjected may result into the thermal cracks, and may finally, lead to the tool failure. So, under such circumstances we can avoid the use of cutting fluid also.

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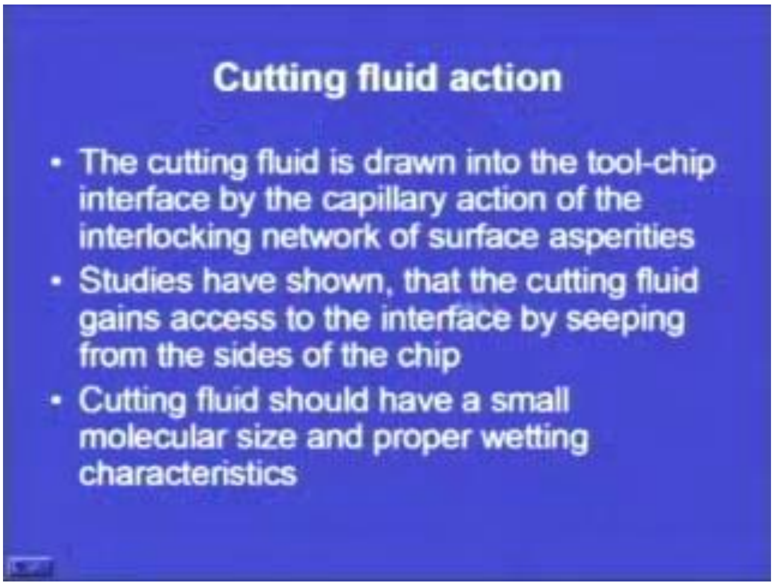

Now, how the cutting fluid acts or the cutting fluid action - the cutting fluid is drawn into the tool chip interface. There is a tool chip interface, already we have seen, by the capillary action of the interlocking network of surface asperities. So, there are some surface asperities in this meeting part, and in the surface asperities by the capillary action the cutting fluid is drawn into.

And studies have shown, that the cutting fluid gains access to the interface by seeping from the sides for chip. So when the chip is forming, from the sides of the chip the cutting fluid will seep into the zone. Then the cutting fluid should have a small molecular size and proper wetting characteristics. Now, whatever surface asperities we are talking about or whatever zone where the cutting fluid has to go the size is relatively small. So, for that particular action to take place, for the small size, the molecular size should be small for the cutting fluid and it should have proper wetting characteristics.

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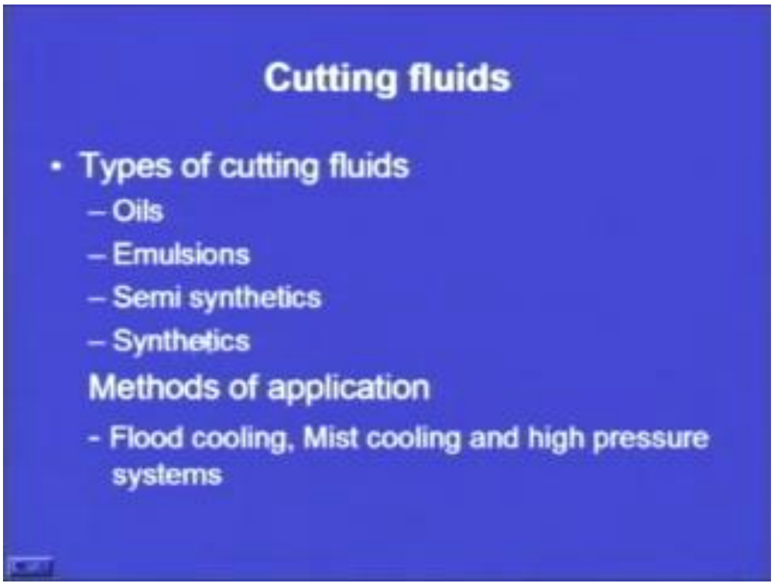

Now, what are different types of cutting fluids? Now, different types of cutting fluids can be oils, these can be emulsions, these can be semi-synthetics, these can be synthetics. So, depending upon the different types of requirements, we have to choose among different types of cutting fluid. So, we have a wide variety of cutting fluids that are available and depending upon our requirement we will choose any of these.

Now, what will be the requirement? The requirement will be in terms of either we want only cooling or we want only lubrication or we want a combination of these. Now, how these can be applied? These can be applied by flood cooling in which we will directly flood the zone like the cutting zone as we as is the case with the floods or the flash floods that we see during the rainy season; the cutting fluid will be flooded in a large quantity at the cutting zone.

Then the mist cooling and high pressure systems also. In present day scenario where we are using automated machines, using a nozzle type of arrangement, we can use this high pressure systems. Now, these methods of application will also depend upon the requirements of cooling that are there at the cutting zone.

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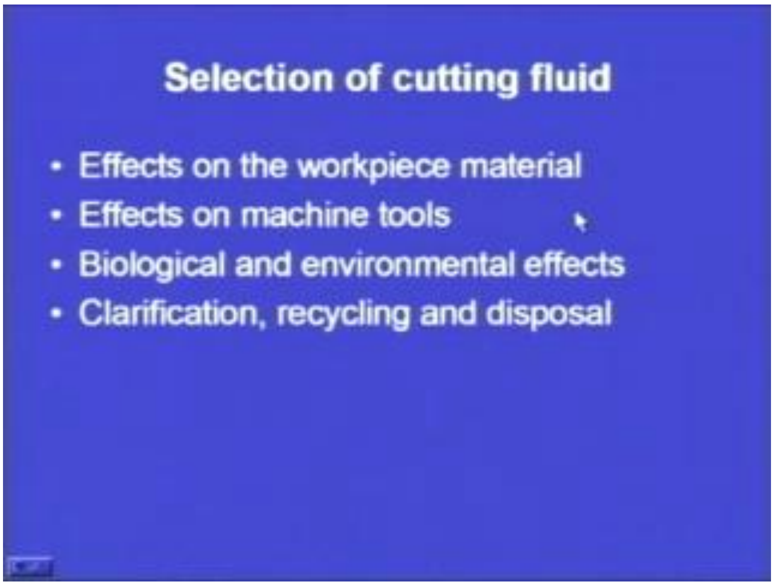

Now, coming on to the selection of the cutting fluid. Now, the cutting fluid selection depends upon a number of parameters. Now these are parameters are - how it is going to effect the work piece material? How the cutting fluid is going to effect the work piece material? Because we want that the environment attack should not take place on the work piece material; ; it should form a thin layer around the work piece when it is in the heated condition. Then there are number of other requirements that are there. So, how the cutting fluid is going to affect the work piece material - that is one important factor.

Then how it is going to effect the machine tool? So, how it is going to effect the machine tool means, that as we have seen the water may cause a rusting action on the different elements of the machine tool. So, one example can be coated as of water; it should be treated in such a way that it does not cause any action or any rusting action on the machine element.

Similarly, if we choose any particular oil, how that oil is going to behave with the machine element, if it is going to react then what is going to be the effect of that reaction - all those aspects have to be seen while we select a particular cutting fluid.

Then, what are going to be the biological and environmental effects of using the cutting fluid? If at an elevated temperature, if the cutting fluid reacts with the tool material or with the work material or if some fumes are formed, those fumes may be poisonous in nature. So, all those aspects like the biological and environmental effects have to be taken into account.

Similarly, how we are going the carry out the clarification, how we are going to carry out the recycling, and how we are going to dispose of the used cutting fluid has also to be considered before we select a particular category of cutting fluid for performing the intended function of cooling and lubrication in the machining operation.

So with this, we come to the end of this particular session on machining. Just to have a brief overview of what we have covered in these 16 lectures on Manufacturing processes. We have covered 3 lectures on Powder Metallurgy; then we went on to discuss the Metal Working Principles - cold working, hot working, warm working, and then, different metal working processes, different sheet forming operations or sheet working techniques we have seen. Then, we have seen High Energy Rate Forming processes, and thereby we discussed the Basic Fundamentals of Machining.

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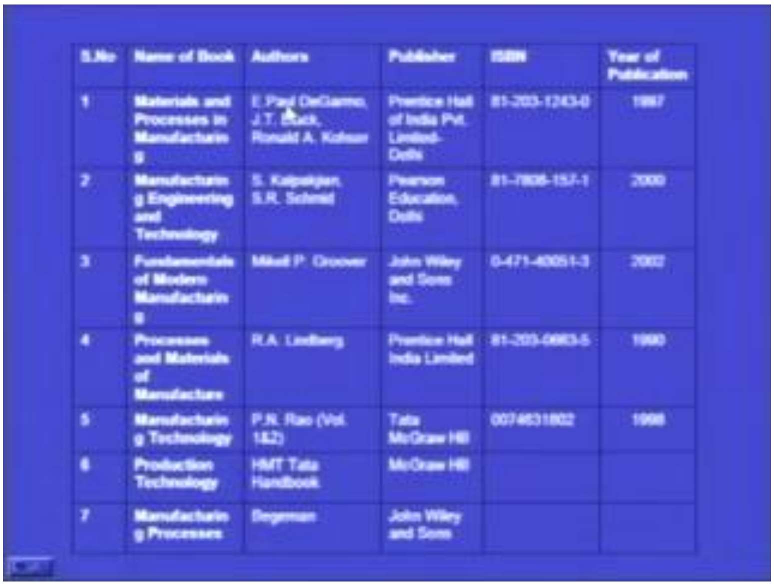

S.No	Name of Book	Authors	Publisher	ISBN	Year of Publication
1	Materials and Processes in Manufacturing	E.Paul DeGarmo, J.T. Black, Ronald A. Kohser	Prentice Hall of India Pvt. Limited-Delhi	81-203-1243-0	1997
2	Manufacturing Engineering and Technology	S. Kalpakjian, S.R. Schmid	Pearson Education, Delhi	81-7808-157-1	2000
3	Fundamentals of Modern Manufacturing	Mikell P. Groover	John Wiley and Sons Inc.	0-471-40051-3	2002
4	Processes and Materials of Manufacture	R.A. Lindberg	Prentice Hall India Limited	81-203-0663-5	1990
5	Manufacturing Technology	P.N. Rao (Vol. 1&2)	Tata McGraw Hill	0074631802	1998
6	Production Technology	HMT Tata Handbook	McGraw Hill		
7	Manufacturing Processes	Degarmo	John Wiley and Sons		

So, in order to give you the references, these are some of the books, may not be too clear on your screen. So, I will just read out the name of the book and the authors; if any reference is required, the references can be taken from these books.

So, the name of the book: first one - Materials and Processes in Manufacturing. So, this is by Paul DeGarmo; Manufacturing and Engineering Technology by Kalpakjian and

Schmid; Fundaments of Modern Manufacturing by M.P.Groover; Processes and Materials of Manufacture by R.A. Lindberg; Manufacturing Technology by P.N.Rao; Production Technology by HMT Tata Handbook; and Manufacturing Processes by Begeman. So, the these are some of the important books on this important aspect of manufacturing processes.

Thank you.