Fundamentals of Manufacturing Processes
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Lecture - 40
Material Removal Processes: Tool Failure & Tool Life

Hello, I welcome you all in the presentation related with the subject fundamentals of the manufacturing processes and we are talking about metal removal processes. In the previous lectures, we have seen that the cutting forces are generated during the machining and whatever is power consuming course of the machining that in turned converts into the heat, so heat is also generated because of the heat generation there is a rise in temperature of the tool.

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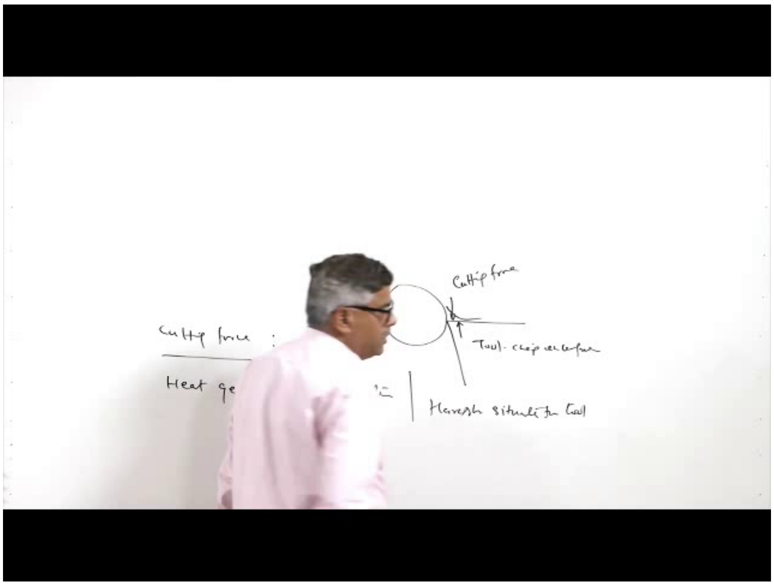

And when the cutting forces are generated there the due to the shearing at the tool chip interface, say this is the typical tool and during the machining the forces will be acting on to the tool.

So, the cutting force acting in downward direction and the heat is generated due to the flow of the chips over the chip tool interface and flow of the chip over the rake face and the heat generation leads to a rise in temperature of the tool chip interface. So, basically these are the 2 conditions which are generated normally during the machining this leads to the development of very harsh situation for the tool to survive, because the tool has to sustain the forces which are being generated during the machining as well as the heat; which is being generated; so, causing the rise in temperature of the tool. So, these 2 conditions under the abnormal conditions of the cutting forces and the rise in temperature this leads to the failure of the tool.

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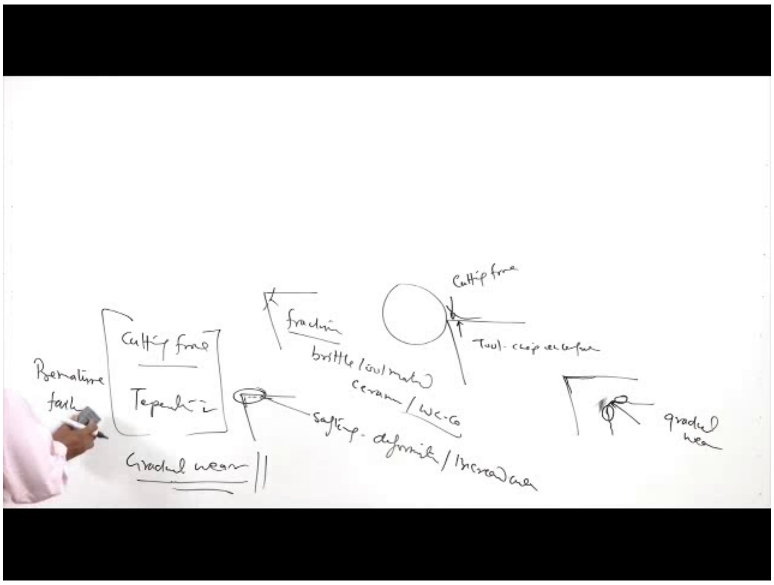

So, consider that when the cutting forces are too high then it leads to the fracture of the cutting edge. So, the fracture is one thing which mostly happens in case of the very harden brittle tool materials for example, like ceramics and tungsten carbide cobalt base tools on the other hand if the temperature is too high too rise in temperature of the cutting tools takes place then it leads to the softening of the cutting edge as well as accelerated wear mechanisms.

So, the softening is the main issue due to rise in temperature of the tool. So, this softening causes the deformation of the cutting edge as well increased the wear of the tool. So, basically the blunting of the cutting edge due to the softening is the main way by which the failure of the tool occurs. So, if these, value of these 2 aspects like cutting forces or the temperature rise is too much, then it leads to the premature failure of the failure of the tool.

Like certain fracture the cutting edge or so blunting of the cutting is due to the softening. But there is a third condition when these 2 are not really very high then the tool will be wearing out gracefully. So, the gradual the wear of the tool delivers the enough life of the cutting tool, but in that case like initially the cutting edge is sharp then gradually there will be loss of the dimensions the face and the flank both will be wearing out as well as nose we will get modifies as we will find that the face has become rough or the cutting the flank is become rough and the cutting it also has been rounded off. So, it has blunted.

So, the face as well as flank and the nose these are the three zones which are affected in case of the gradual wear. So, we obviously, we will try to have the conditions in such a way that the premature failure of the tool does not take place, but it is mostly subjected to the wear and delivers the required tool life. So, with regard to the tool there are 2 aspects which are kept in focus while designing and developing a cutting tool. So, that it delivers the required tool life these 2 aspects include in light; these 2 aspects include the cutting tool technology.

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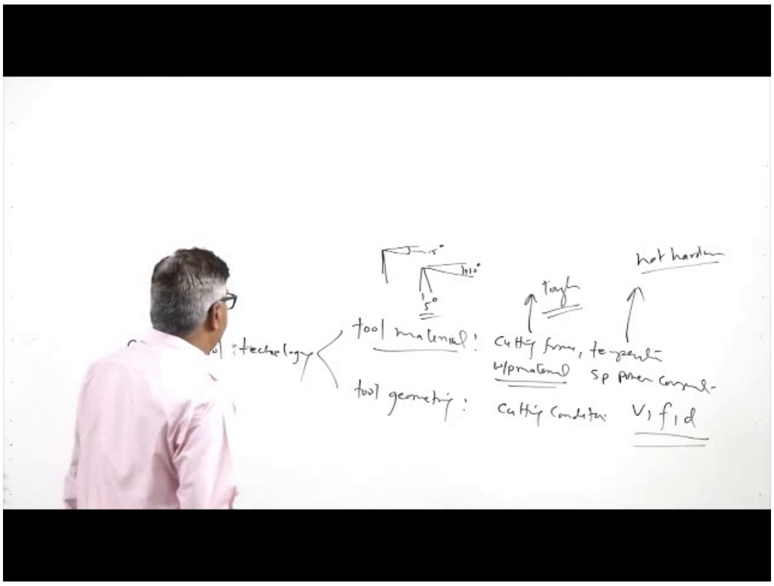

Basically, it involves the choice selection of the proper tool material and another is the choice of the tool geometry. So, the aspects like cutting forces generated temperature rise occurring during the machining and the specific power consumption; all these are kept in mind while or and the work piece material these are the factors which are kept in mind while selecting the suitable material. So, in light cutting forces, the cutting forces are too high, then we will be selecting the tough tool material; if the temperature is too high, then we will be selecting the hot high hot hardness tool materials so; obviously, high hot hardness tool materials will be having somewhat lower toughness.

And similarly, the work material is also kept in mind whether it is soft or hardens brittle. So, considering the aspects there are tool material is selected while that tool geometry is selected in light of the cutting conditions we used; which includes like the cutting speed feed and depth of cut to be given during the machining. So, that the tool can sustain the tool geometry can sustain tool geometry primarily involves like the kind of the rack angle which will be given whether it is positive or negative like say this is the this is the example of the negative rake negative rake maybe like say minus 5 degree or the positive rake in this way when it is sloping down.

So, positive rake say of the 10 degree. So, depending upon the kind of the tool material we are using suitable tool geometry is selected similarly the relief angle or the clearance angle is usually given as low as. So, possible it is about the 5 degree so that the rubbing between the tool and the work piece can be avoided.

So, these are the 2 aspects related with the tools which will be governing the life of the tool and the failure tendency significantly. So, considering these aspects in mind that the there are three common modes of the failure of the tools.

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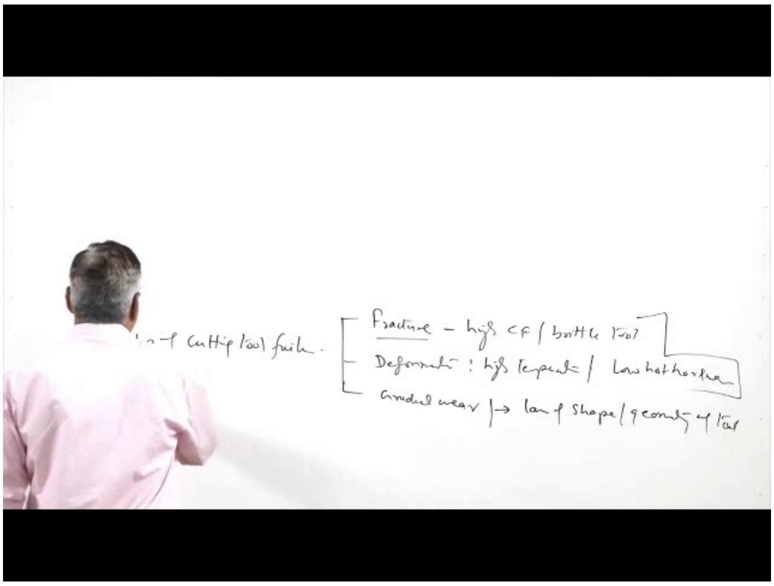

Which include like modes of the cutting tool failure. So, these modes include like the fracture and the second is the deformation and third is the gradual wear. So, the fracture happens when the high cutting forces are used in case of the brittle tool materials.

The deformation occurs when the high temperature is generated especially when the low hot hardness tool material is used and the gradual wear is the normal case; when the optimum conditions for the cutting position and temperature rise exit, but the gradual loss of the shape and the geometry of the tool takes place. So, basically the basically the tool material and tool geometry helps us in overcoming the issues or the modes of the first 2 modes of the failure like fracture and deformation and therefore, we need to see what are the factors that will be leading to the gradual wear and how do we decide that now.

The tool needs to be replaced or need to be re sharpened. So, that stage will be determining whether the tool is still usable or it has filled. So, the failure of the tool failure of the tool especially when the there is a gradual of the one failure is when in the cutting edge has fractured or the tool have cutting edge has blunted or when it is subjected to the gradual of wear beyond the limits.

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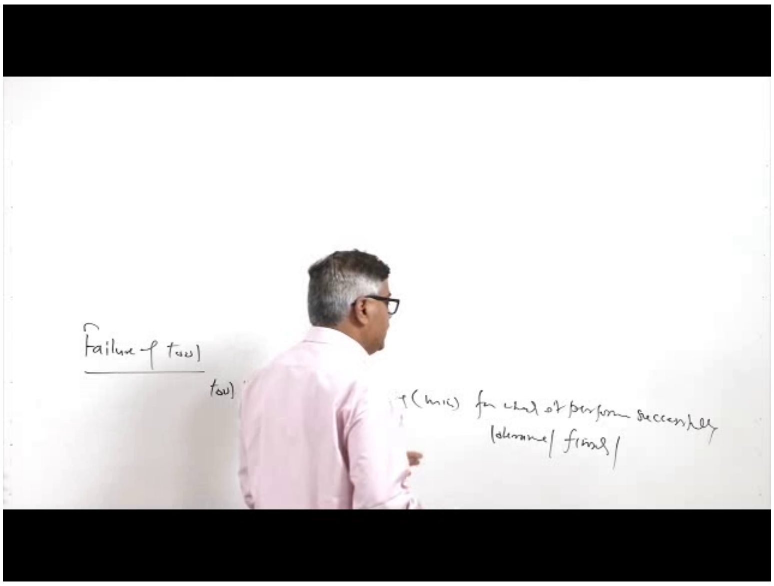

So, the life of the tool or the tool life is the cutting time; cutting time basically it is in given in minutes for which it performs successfully; performs successfully. So, what is that like; it should keep on giving us the required tolerance during machining desired surface finish and unnecessary rise in the specific power consumption or power consumption does not take place.

So, the tool should perform satisfactorily. So, as it gives us the derided tolerance which to be controlled desired surface finish. So, what is the time for which it can be used during the machining that decides the tool life it is normally expressed in terms of the minutes. So, to understand the wear of the tool aspects we do consider once typical tool geometry.

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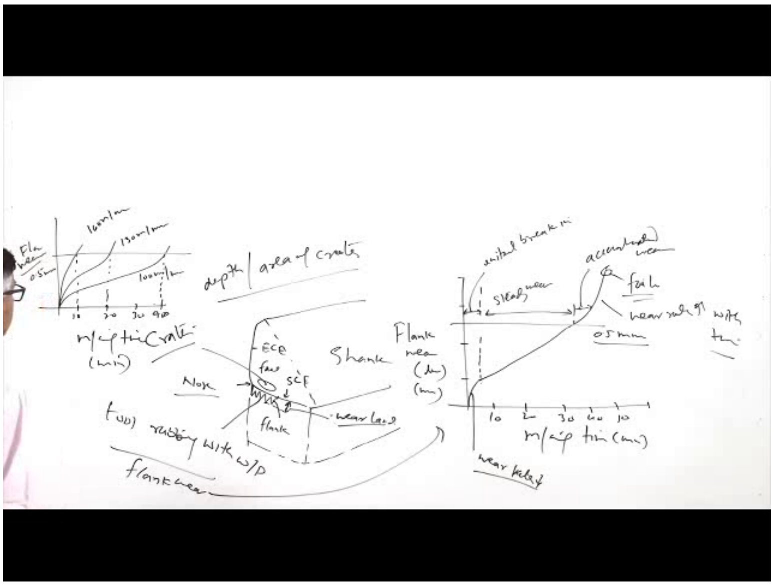

So, that we can look for the; what are the zones which are subjected to wear like say this is the end cutting edge; this is the side cutting edge and this is the shank of the tool like this. So, this is the edge which will be working with the work piece and this is the lower portion of the cutting tool this is the shank. So, this portion is shank. So, when this is the nose of the tool.

So, when that work piece interacts with the cutting edge this region. So, in this region basically this portion of the tool wears out due to the rubbing of the tool with the work piece. So, tool rubbing with the work pieces leads to the wear in this region which is called flank wear. So, this is the region of the flank and the band which is subjected to the wear is called wear land wear land or this is the way by which it is characterizes the flank wear and the width of the land is used as a major of the flank wear when chips. So, this is the edge which will be interacting with the work piece like this.

So, this portion or this portion is the flank and this is the portion where the wear land will be formed due to the rubbing between the work piece and the tool when the chips sliding over the face of the tool under the pressure after getting removed. So, the portion near the cutting edge portion of the face near the cutting edge is also subjected to the wear. So, this rake face wear; it is observed in this region of the face. So, this is the face of tool. So, this is the region where a small crater is formed which inside view we can see this is the normal new tool. So, the crater is formed and the craters formed it results formation the crater in this way this is crater near the cutting edge; it is formed due to the continuous rubbing.

Between the chips over and the face of the tool, so the crater near the cutting edge on the rake face is formed. So, the depth of the crater as well as area of the crater both are used to categorize the wear due to the crater or the size of the crater. So, mostly the work has been done to quantify the tool wear using the flank wear. So, if we mention, if we try to quantify the flank wear as a function of the time like this; this is the machining time machining time in minutes say 10, 20, 30, 40, 50. So, what is normally observe that initially the tool wear tool wears at very faster rate there after it wears at a slower rate and then at accelerating rate.

So, the there are three zones with regard to the increasing flank wear rate this is the initial break in period this is just like a run in we are and the second is the a steady state wear and third is the accelerated wear zone accelerated wear zone. So, here wear rate wear rate actually decreases as a function of the machining time and here the wear rate increasing with the machining time with the time. So, thereafter here like say the failure of the tool will be occurring. So, here the tool fails.

So, depending upon the kind of the allowable wear land the allowable wear land gives us the time for which tool will be performing successfully. So, like say this is the flank wear like say in micrometer or in mm mostly the 0.5 mm wear land is used as a criteria for the life of the tool. So, as soon as the wear land is formed this wear land is formed one more than the 0.5 mm size we consider to consider the tool has failed. So, for this kind of situation if we walk with the different cutting conditions if we have the wear here we have the machining times machining time in minutes and then what we get like this for say 100 meter per minute cutting speed.

Somewhat like this for 130 meter per minute cutting speed and further higher for 160 meter per minute cutting speed. So, the like; say if this is the flank wear and if the cut off limit is this for acceptance when we decide that the now tool has failed which is say 0.5 mm, then the at 60 meter like say that tool life maybe 10 here, maybe 20 here, it may be 30 or 40 in x axis. So, at 160 the at so 160 meter per minute speed the tool life is just 10 minutes while at 130; it is 20 minute and for the 100 meter cutting speed; it is say 40 minute that is the machining time or the tool life or which it will be able to with stand for a land we wear up to 0.5 mm.

So, what it shows that the cutting speed has a significant effect on the tool life; cutting speed has the significant effect on the life or the tool wear. So, why it is happening? So, why the such great effect on the cutting speed has on the tool life for that we need look into the wear mechanisms of the mechanisms why which the tool wear will be taking place.

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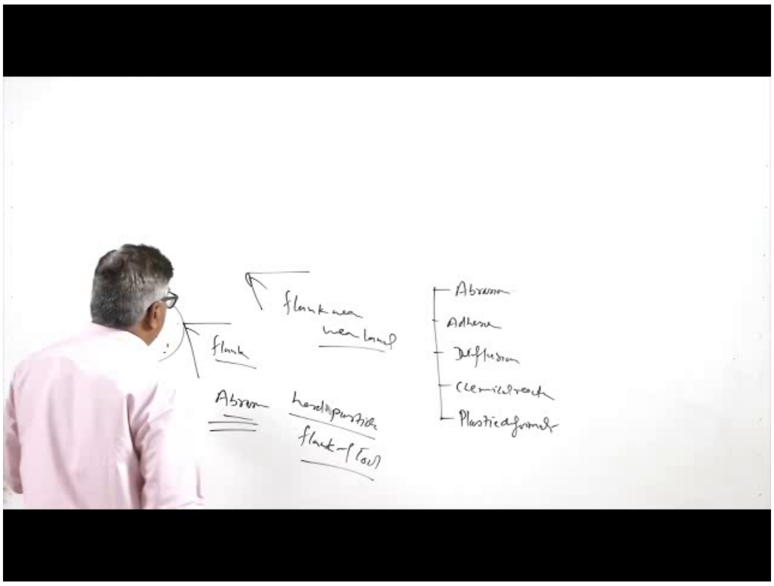

So, there are 4 or 5 mechanisms of the wear; these includes like a abrasion adhesion, then, diffusion and chemical reaction and plastic deformation these are the 5 mechanisms by which the last sort of material from the tool will be taking place. So, each mechanism plays a different role in the different area of the tool during the machining.

So, we need to consider that separately. So, in detail we will be talking about which area is affected by each of the mechanism related with the tool wear. So, considering the first abrasion; abrasion actually like if the work piece material is having a hard constituents in it. So, during machining these hard constituents will be rubbing with the flank of the tool. So, because this is a frequently these hard particles will be coming in contact with the tool flank and. So, the abrasion due to the rubbing of hard particles present hard particles or the constituents present in the work piece these rub with the flank of the tool and so, this causes the abrasion.

So, abrasion basically occurs in the causes the wear in the flank in form of the flying wear or the wear land. So, this happens primarily due to the presence of the hard particle or hard constituents in the work piece materials will be rubbing with the flank during machining and this will be causing the frank wear then adhesion. Adhesion primarily occurs in the rake face of the tool since the chips are sliding under the pressure over the face of the tool.

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So, under the pressure the cold bond between the chip material and the tool face tool face takes place and this cold bonding; cold bonds break through the relative motion between that tool and the chip and this braking of the tool bond causes the loss of the material from the rake face of the tool.

Like say this is the face and the chips; if they are sliding under the heavy pressure over device of the tool. So, these be funding; these will be forming the cold bonds and duo the relive motion conclude motion of the face of the chip over face of the tool a small piece of the material from the rake face also be lost. So, the metal to metal contact exist between the tool and the chip at a tool chip interface and because of this metal to metal contact under the relative movement conditions due to the movement of the chip over the rake face the loss of the material takes place; primarily due to the breaking of the bonds at the tool chip interface; this is the kind of cold bond which is form.

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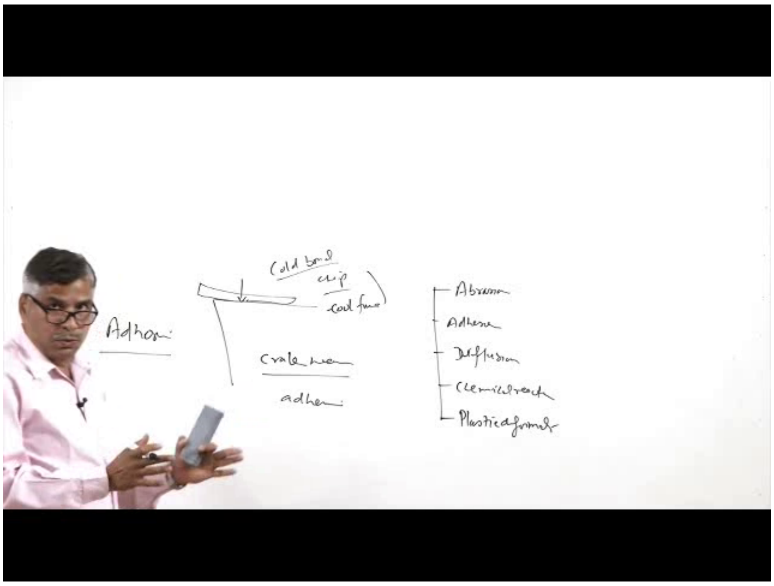

So, the crater wear is primarily caused by the adhesion which is occurring between the tool and the tip at the tool chip interface. So, higher is the temperature lower with be the hardness and this in turn be increasing the adhesion between the chip and the tool rake face which in turn will be increasing and adhesion there is archer law also which says that the wear rate is the wear volume is inversely proportional to hardness of material size the rise in temperature reduces the hardness. So, which in turn will be creasing the wear of the material diffusion is another approach wherein since the high temperature is generated and the tool chip interface and the material.

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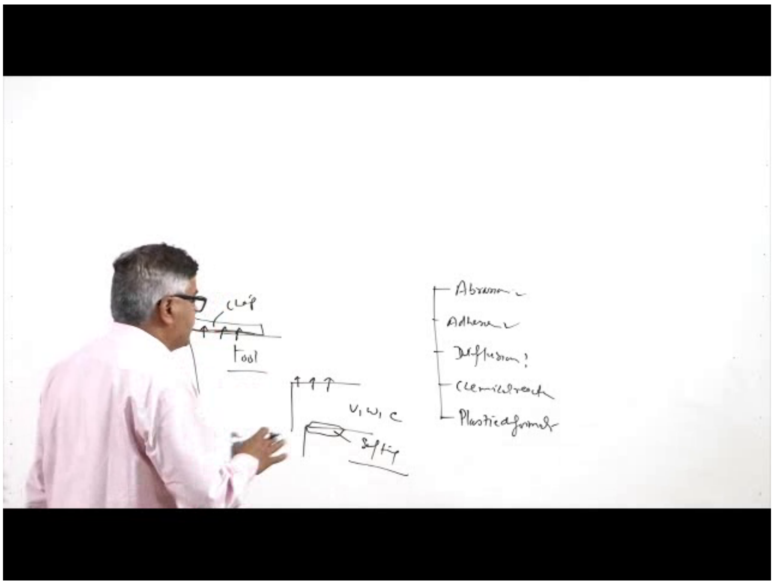

And the chips are in contact with face of the tool. So, this is because of the difference in composition between the chip and the tool tools tool material has a lot of alloying elements and their special consequents so, which are not generally there with the chip. So, the alloying elements starts getting diffused into the chips and over a period of time elements like vanadium tungsten carbon etcetera get diffuse into the into the chip.

So, this leads to the depletion of the certain alloying elements nearly rake face of the tool and the loss of alloying elements leads the softening of the rake face surface and this softening ultimately causes the increased wear due to adhesion and abrasion. And therefore, rise in temperature basically facilitates the diffusion of the alloying elements from the rake face which will be leading to the loss of alloying elements or depletion or deficiency of the alloying elements near the rake face which in turned reduces the hardness and increases the wear by abrasion and the adhesion.

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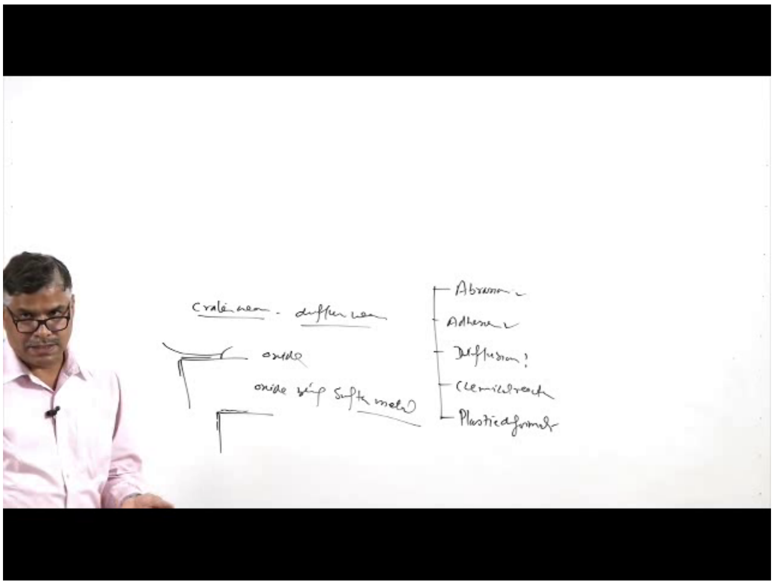

So, crater wear occurs due to the diffusive wear or due to the diffusion chemical attack a chemical attack is the simple form where rise in temperature of the rake face of the tool will be causing the oxidation. So, one oxide layer is formed at the fly face and the flank of the tool since the oxides some of the oxides being oxides being softer than the base metal.

Then the base metal of the tool, then it will be leading to the easy removal during the machining during machining or due to the movement of the chips over the face of the tool or rubbing of the flank with the work piece. So, the removal of the oxides is easier because they are of the lower hardness. So, these metals those cutting tool materials which gets oxidized due during the machining at high temperature these oxides get removed and their removal leads to exposes the again the fresh material of the tool exposure of the fresh material of the tool to the high temperature as well as to the environmental conditions. So, that again will be causing the oxidation and their removal. So, the formation oxides and their removal continuously leads to the continuously leads to the wear of the material.

So, oxidation is also another mechanism and both flank as well as crater wear will be contributed by the chemical reactions especially in form of the oxides the deformation is the case when the rise in temperature near the cutting edge if it is too high.

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Then under the cutting forces cutting edge tends to get blunt or get deformed. So, the under the cutting forces acting during the machining rise in temperature will be causing the softening of the cutting edge softening will lead to the blunting of the cutting edge and blunting will lead to the increase in radius of the cutting edge and means a loss of loss of the sharpness of the cutting edge as well as the change in the tool geometry.

So, all these will be increasing the cutting process; increasing the surface roughness and thus there will be adversely effecting the surface finish and that kind of the control over the dimensions which is needed will not be achieved. So, basically the tool will be performing adversity and this will be leading to the failure of the tool. So, this is what is they are related with the wear mechanisms, which are observed in the tools and that the temperature is basically the main factor in governing these wear mechanisms and the temperature is significantly is affected by the cutting speed.

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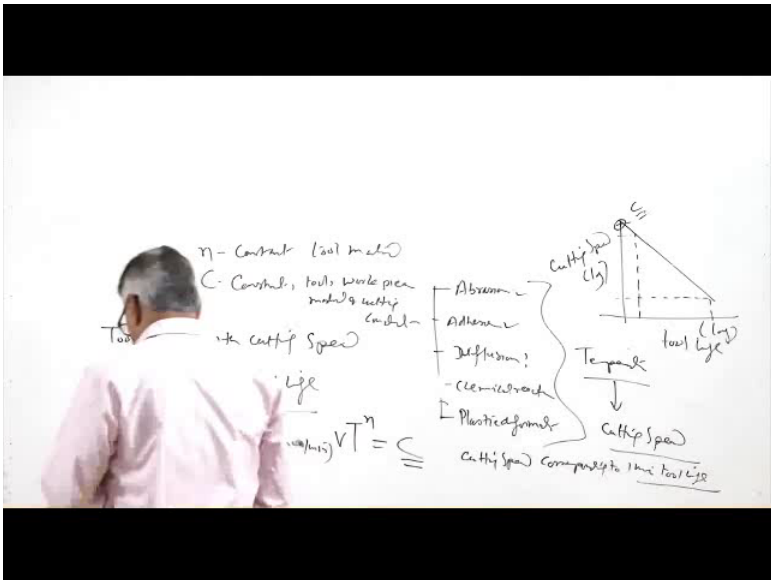

Because it increases the localization; increase in cutting speed increases the localization of the heat which in turn increases the temperature at the tool chip interface. So, therefore, the tool life attempts have been made to relate the tool life with the cutting speed since the cutting speed increases the temperature. So, the efforts have been made in order to relate the tool life with the cutting speed and one of the very famous Taylor’s tool life equation is a very commonly used for showing the effect of the cutting speed on the tool life and this is expressed like V is the cutting speed and T is the temperature raised to the power n; T is the tool life and equal to C. So, V this is the cutting speed, T is the tool life in minutes.

Normally it is meter per minute meter per minute while the other 2 factors are like n is the constant which it is it depends upon the tool material while the C is the another constant which depends upon the tool material work piece material work piece material and the cutting conditions which are being used. So, if we see that if we want to understand the value of C; what the C is. So, for this purpose we draw one cutting speed plot here this is the cutting speed and the tool life in the log scale both are in the log scale. So, the relation is found to be one linear one, wherein if we mention here the cutting speed increase in cutting speed basically reduces the tool life. So, when you work with the low cutting speed tool life is more and the cut high cutting speed tool life reduces. So, C is basically the condition corresponding to the C is basically the cutting speed cutting speed corresponding to one minute tool life while n is it depends upon the tool material.

So, this is simply obtained by an extrapolation of this the cutting speed tool life curve. So, where it cuts corresponding to the one minute tool life that speed gives us the value of C. So, this is one of the very commonly used the relationship which is used for expressing the effect of the cutting speed on the tool life. Now, I will summarize this presentation in this presentation I have talked about the different modes of that failure of the tool and the tool failure mechanisms and apart from that also I have talked about the Taylor's tool life equation which is used to express the effect of the cutting speed on the tool life.

Thank you for your attention.