Fundamentals of Manufacturing Processes
Dr. D. K. Dwivedi
Department of Mechanical & Industrial Engineering
Indian Institute of Technology, Roorkee

Lecture – 44
Material Removal Processes: Grinding II

Hello, I welcome you all in this presentation related with the subject Fundamentals of the Manufacturing Processes and we are talking about the Material Removal Processes and in the material removal processes we are basically talking about the Grinding.

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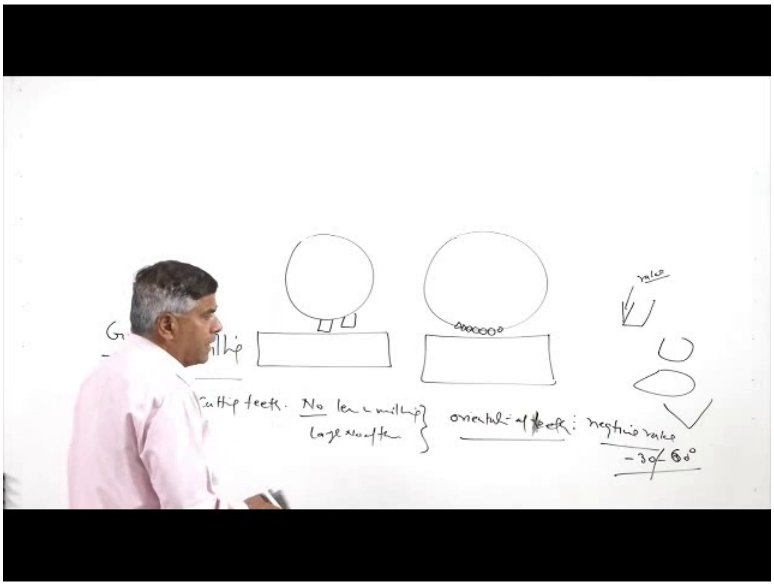

We know that the milling is a multi point milling uses the multi point cutting tool, it also uses like thus this disk shaped the cutting tool, which will be having the number of cutting edges, cutting piece, like this and it is engaged with the work piece for material removal and if we compare the grinding wheel we will be having the fine abrasives large in number and it also performs the cutting when rotating and you will interacts with the work piece.

If we compare the 2 processes, because in both the cases like the rotating tool engages with the work piece for removing the material and both are the multi point cutting, both uses the multi point cutting tool, but these 2 defer a significantly with respect to each other in terms of the number of aspects. One is the cutting teeth this is one so the cutting teeth numbers are less in the milling while in the grinding the these are very large number of teethes at any location.

So, number of cutting teethes are much more which will be performing cutting at a time in case of grinding wheel as compared to the case of milling; normally one cutting teethes performs cutting at a time in case of the milling, this is one factor. The second one in terms a with regard to the cutting teeth is the orientation of the teeth. So, if we see mostly in case of the milling uses mostly the positive rake angle.

This is how it is defined as a rake angle for the milling machine, while in case of the grinding will it uses the abrasives. So, abrasives are of the different orientations different sizes shapes and orientation. So, mostly the orientation of the grinding wheel, orientation of the abrasives in the grinding is such that it offers the negative rake angle during the grinding and which generally ranges from minus 30 to minus 60 degrees.

So, when we know that when the positive rake is used, it results in the higher shear angle, it lowers the cutting forces which will be acting on to the tool during the machining as compared to the case when the grinding is performed. The negative rake will be leading to the higher power requirement; power requirement more forces which will be acting on to the tooth means the on the abrasives as compared to that of the tooth in case of the milling.

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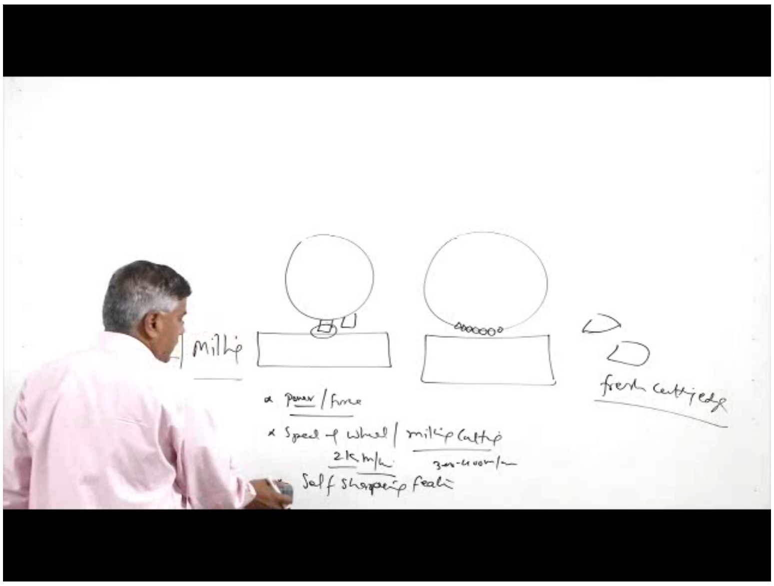

So, if we consider the unit unique volume of the material which is being removed, another one is the speed of the wheel or the milling cutter. So, the milling cutters rotate at much lower speed as compared to what at which the grinding wheels rotate. So, add up to 2000 meter per minute grinding wheel speeds are normally used, but for the milling like say 300 or 400 kind of the meter per minute speeds are even lower speeds are used and the third comparative aspect relate to the milling and grinding is the self sharpening feature of the grinding wheel. We know that the wear is an integral part of the any kind of the machining process.

So, the tool wears out in case of milling gradually and it needs to be either re sharpened or tool need to be tool is required to be replaced, but in case of the grinding after getting after becoming dull or after wearing out the 2 grinding abrasive break or abrasive fracture and the fracture of the abrasives after certain time of the grinding operation produces the fresh cutting edges. So, that in turn helps in improving the cutting or the grinding performance.

This feature is present means self sharpening feature is present with the grinding, but not with the milling. So, orientation of the teeth number of cutting teeth, the speed of the wheel or the milling cutter and the self sharpening feature these are the 3 aspects on the basis of which we can compare the grinding wheel grinding and the milling.

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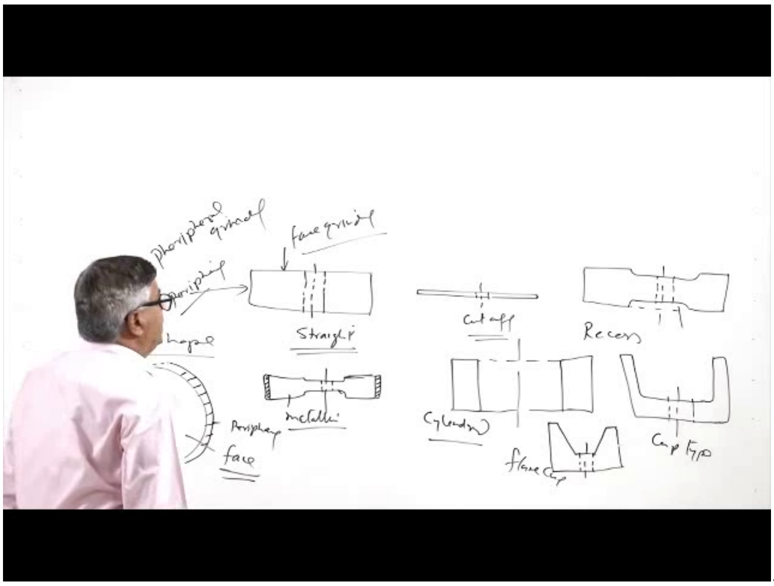.

If we see the wheels shapes which are used for the grinding purpose there variety of the shapes like the straight wheel wherein the there is a center hole, which will be used to for the mounting of the wheel, an entire wheel is made of a the abrasives, bonding material and the pores this kind of the wheel is termed as the a straight wheel, then we have the disc safe wheel where in very thin wheel having the one center hole which is used for mainly as a cut off wheel then recess wheel where in some kind of the gap is obtained in the middle portion of the wheel.

This is the kind of recess which is given to the wheel this is the center hole which will be used for mounting of the wheel and so this is the recess type of the grinding wheel, a straight wheel, and cut off wheel, then there are metallic wheels where in the most of the wheel is made of the metal like this or here we have center hole for mounting of the wheel and near the outer periphery, basically abrasives are attached or fitted in case of the metallic wheels. Then we have based on the other shapes like cylindrical wheel; a cylindrical wheel will have the geometry of this kind this is the central hole and this is the wheel and then cup shape wheel will be off like this where in there is a central hole for mounting and the shape of the wheel is of the cup type, then another wheel is the flare cup shape flare cup shape is like this where in the center hole at the center.

So, this is cylindrical grinding wheel, this is a cup type, and this is flare cup type of the grinding wheel. If we see these grinding wheels like say this is the top view. So, any grinding wheel say like this will have certain, thickness, this manner and there will be one hole at the center for mounting purpose, this is the periphery of the wheel and this is face of the wheel.

So, both periphery as well as the face can be used for the grinding purpose like in this case this periphery of the wheel can be used for the grinding purpose and when the periphery of the wheel is used it is called peripheral grinding, pheral grinding and when the face is it is called face grinding similar to that of the milling. If you have to obtain the conditions under which the grinding is been performed or we have to consider the rotationally speed and the way by which the wheel engages with the work piece.

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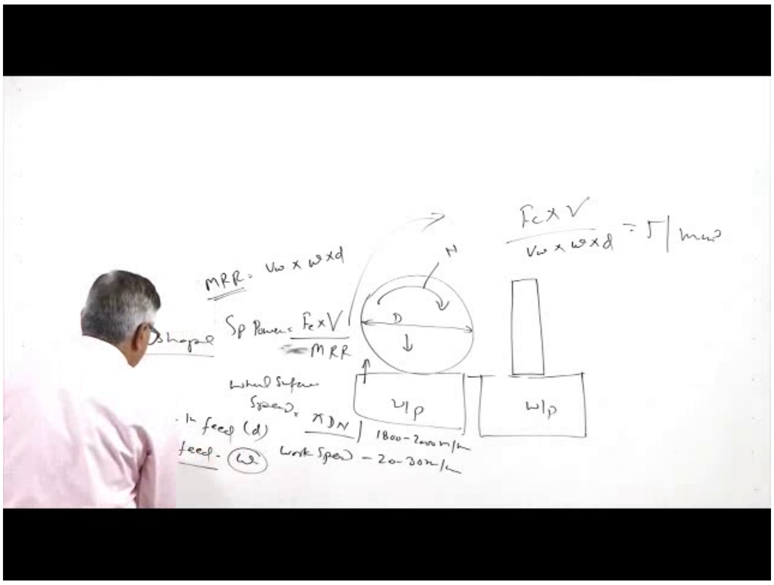

Say this is the grinding wheel rotating at certain speed and in the side view if we see the wheel is like this and it is working on to the surface of the work piece like this is the work piece and this is the work piece.

The rotational movement is given to the grinding wheel say it is rotated rotating at the N RPM Rotational Revolutions per Minute and this is the diameter of the grinding wheel, then the wheel surface speed is given using the pi D N, D is the diameter of the wheel n is the revolution per minute. Against the rotating grinding wheel work piece is fed past the grinding wheel at a certain speed that is what is termed as the work speed. So, wheel speed is say like 1800 to 2000 meter per minute, while the work speed is limited like 20 to 30 meter per minute. The way by which it will be engaging with the work piece and the cut is facilitated by moving the work piece either upward or moving the ground grinding wheel downward.

So, the Depth of cut in case of the grinding is termed as in feed and in order to cover the entire surface area basically the cross feed is given so that this will be determining the width of cut. So, width of cut is determined by the w and the width or in feed or depth of cut is indicated by the letter d. If you have to obtain the metal removal rate, then metal removal rate is obtained in terms of the like the speed of the work piece V w and w is the width of cut and d is the depth of cut.

So, the speed at which the work piece is engaged with the work with the grinding wheel w is the width of cut and d is the depth of cut so this what will be giving us the metal removal rate.

If you have to obtain the a specific energy or a specific power consumption for grinding purpose, then the grinding force Fc multiplied by the wheel speed divided by the speed of the work piece that is the metal removal it basically we have to divide the MRR. So, which under the simplified conditions becomes Fc into V V is basically the pi dn, the rotational speed and the wheel diameter and V is the w that is speed at which work piece engages with the wheel and w is the width of cut and d is the depth of cut, this is what will be given as the Joule per mm cube?

If we calculate the specific energy for the grinding comes out to be extremely high higher than the conventional machining like milling process. So, will try to look for what are the reasons behind the high specific energy for the grinding wheel as compared to that of the conventional milling or the machining processes. As I have said a specific energy for grinding becomes much higher about 10 times than the conventional machining like milling process.

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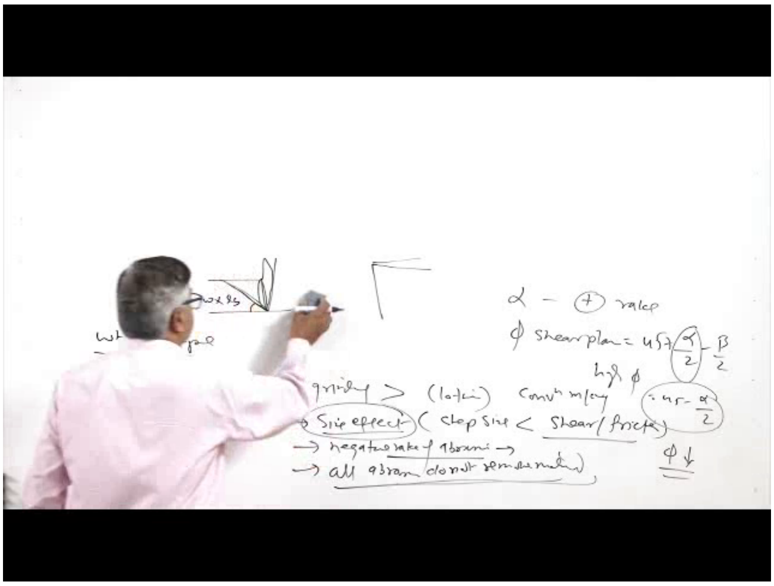

So, the reason for this there are 3 important regions one is the size effect, a second is the negative rake of the abrasives which engage with the work piece for the removal of the material and third one that all the wheel is rotating, but all abrasives do not remove material, but only few abrasives participate in the material removal process.

We know that the size effect means what if the thick chip is removed then the specific energy is less as compared to the case, when the thin chip is removed this is what we have already learned from the a conventional machining itself, because number of in this case shearing it needs to be done number of times and in this case for the same volume shearing needs to be done just once as well as the number of times the frictional effect, which will be experienced will be more in case of the thin chip as compared to the case when thick chip is used.

In any case when the chip size effect means the chip size is less then it increases the shearing and the energy required for overcoming the friction in general for given volume of the material. So, the size effect means since the chip size is very fine, in case of the grinding as compared to that the that of the conventional machining, that is why it leads to the much higher energy consumption per unit volume as compared to that of the conventional milling.

Another effect is the rake negative rake; conventional milling basically uses the positive rake, which helps in increasing the value of the alpha so means negative rake means, in conventional milling we use the positive rake alpha is positive rake. So, this as per the merchants theory the phi that is the shear plane angle, when the positive rake is used it increases the 45 plus alpha by 2 minus beta by 2. So, a positive rake means it will be giving as the high phi value and higher value of the shear plane angle results in the smaller shear plane area. So, the lesser forces will which will required as compared to the case when the lower shear plane angle is used this will be leading to the greater shear plane length and shear plane length multiplied by the width of cut will be in deciding the shear area.

When negative rake is used negative rake is used means the 45 minus alpha; alpha is negative. So, this will be reducing the basically the phi value will be reducing, which will be requiring more work to be done for the shearing and that is why this will be leading to the increased power requirement for the grinding purpose and all abrasives do not perform cutting this a very important aspect relate to the grinding and this is an integral feature of the grinding process itself, which leads to the somewhat reduced removal of the material as all abrasives do not participate in the grinding process.

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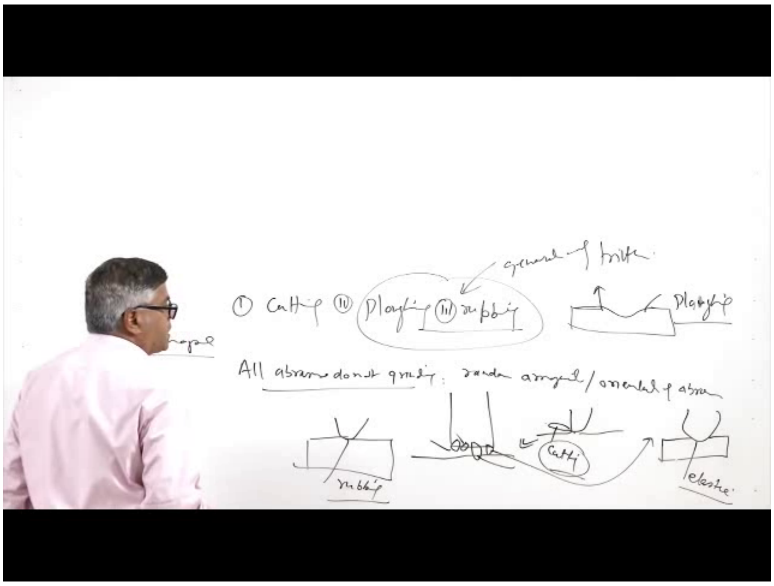

This third aspect that all abrasives do not perform grinding to and the main reason for this is the random arrangement and orientation arrangement and orientation of the abrasives in the grinding wheel. If we see the grinding wheel like this so the few abrasives are projected more than the other abrasives and they are oriented in different manner. Say if we see this scenario maybe 3 abrasives 2 abrasives will be performing cutting and these 2 will not be performing cutting.

So, all the abrasives actually here the cut will be performed how abrasives will get inside the work piece and it will be forming the chip in this form. So, cutting is being performed in this case. For the second case here abrasive is just penetrating, but not performing so this will be leading to the elastic deformation of the material not the plastic deformation and when it happens or even if the plastic deformation shearing is not facilitated.

So, in this case when material is getting deformed, but it is not sheared off due to the rounding of the abrasives then we find an impression on the surface of the work piece of this kind where in the groove is formed, but material is not removed by displacement of the material. So, plastic deformation at the location of the abrasive where it has passed through the surface of the work piece will be deforming the material displacing the material sidewise this is known as Ploughing Plough ing ploughing.

So, ploughing is kind of the plastic deformation by displacing the material sidewise, but not removing it. So, the grinding is basically performed in the case when there is a cutting in ploughing there is no cutting just displacement of the material and third stage where abrasive just touches to the surface of the work piece. So, it is performing just rubbing. So, depending upon the extent of projection of the abrasives from the surface from the surface of the grinding wheel that determines how the abrasives will be interacting with the work piece.

So, based on these 3 approaches the abrasives work in 3 ways, one is cutting where material is removed, second is Ploughing where material is displaced sidewise, and third one is just rubbing of the abrasives with the surface of the work piece. So, the ploughing and rubbing basically contributes to generation of the lot of generation of frictional heat. So, this frictional heat actually affects the surface of the work piece as well as the grinding wheel.

Because of the rubbing and the ploughing as we have seen where few abrasives will performing the cutting while other abrasives will be just causing the ploughing and the rubbing.

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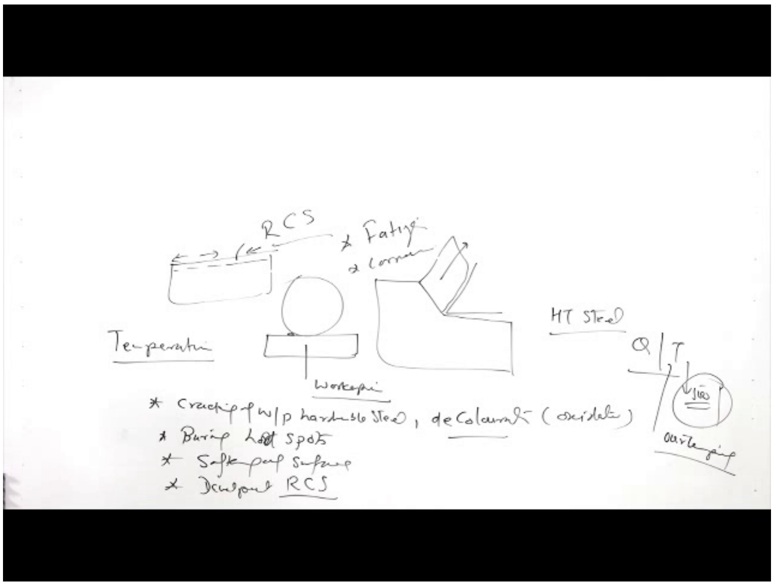

So, that leads to the rise in temperature a during the grinding. So, rise in temperature during the grinding especially of the work piece if there is a rise in temperature. If we see the scenario as compared to the conventional machining, in case of the conventional machining the chips carry away lot of heat being generated in the primary shear deformation zone and the secondary shear deformation zone.

So, the chips carry most of the heat while in case of the grinding the chip size is very small and they are very fragmented. So, the heat generated mostly carried by the work piece. Since most of the heat is retained by the work piece as well as part of that will also be retained by the wheel, that is why the work piece is very badly affected by the heat generated during the grinding and this effects appear basically in the different forms which may be in terms of like the cracking of the work piece like hardenable, steels experience this kind of effect.

Apart from this there can be oxidation, which can lead to the de colorization of the surface of the wheel due to the basically oxidation of the heated metal and there is one more which is called burning of the material like formation of the hard spots and third one it can lead to the softening of the surfaces like the grinding is performed on the heat treated steels say it is a quenched and then tempered if tempering has been done at 500 degree centigrade and for after final heat treatment and processing if it is subjected to the grinding.

So, rise in temperature of the material during the grinding if it goes beyond 500 degree centigrade then metal gets over tempered. So, over tempering will be simply leading to the softening of the material or softening of the quenched and tempered steels or even quenched steels also get softened due to the heat generated during the grinding and then we have another, but there is one favorable effect of the temperature rise during the machining during the grinding is the development of the Residual Compressive Stresses.

Since only the surface layers are heated and when they are heated they will expand, but when they contract during the cooling this contraction is not permitted because it is metallurgically related even the if the surface is hardened it occurs why the martensitic transformation. So, both these conditions lead to the development of the residual compressive stresses and these stresses actually favorable with regard to the improvement in the fatigue life as well as corrosion resistance of the material.

So, one favorable effect is observed with regard to the development of the residual compressive stresses and so that was the effect of the temperature rise on the work piece.

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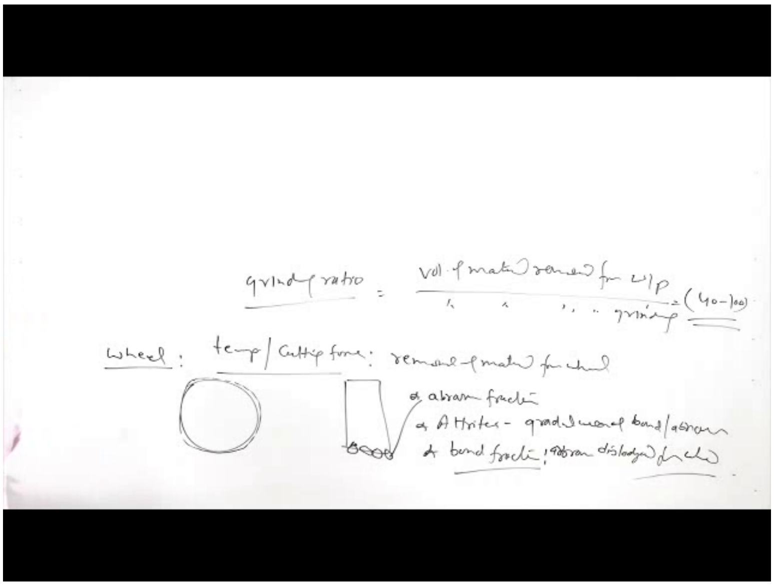

Similar to that the wheel grinding wheel is also affected by the temperature rise as well as the forces so like the temperature and the cutting forces acting on during the grinding they also affect the are the wheel, mainly in terms of the removal of material from the wheel and this happens a basically in 3 ways like the wheel is like this having the abrasives.

So, there are 3 possibilities one is the abrasives fracture this is one, attrition is the another where the gradual wear of the bond as well as abrasives takes place and third one is the bond fracture, where in the bond when bond gets fractured then abrasives dislodged from the from the wheel.

So, all these 3 means a removal of the material from the wheel through these 3 approaches through these mechanisms lead to the loss of the material from the grinding wheel. The grinding wheel loss of the material from the grinding wheel is also termed as the wheel wear. So, to quantify this people have developed one ratio which is called grinding ratio; grinding ratio is basically about the volume of the material removed from work piece to the volume of the material removed from the grinding while grinding wheel.

And this indicates that how much material of the work piece is removed before the wheel as compared to the loss of the material from the grinding wheel and this may be like the 40 to 100 or 100 20 ratio is a common depending upon the kind of work material and the grinding wheel which is being used. If you have to see the way by which grinding wheel wears out during the grinding there are different stages for that and different mechanisms work in the different stages and these stages are like.

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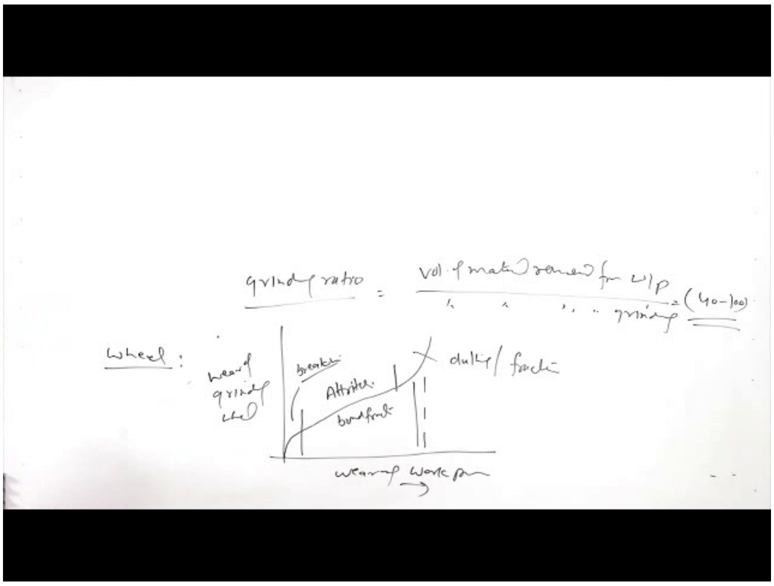

So, here what we have the wear of grinding wheel and wear of the work piece material or it is basically the volume of the material which is being removed. So, initially when the grinding wheel is placed in use, the initially it wears out faster rate than the wear rate becomes constant and then it occurs at accelerating rate. This one is called break in period where in initially fresh abrasives fracture and this is the steady state rate where primarily attrition, bond, fracture takes place and third one where the abrasives become dull so the fracture of the abrasives and the fracture of the bonds takes place.

So, here the cut ability in the third face is reduced significantly. So, without removal of the much of the material from the work piece, the greater removal of the material from the grinding wheel takes place. So, these are the 3 stages by which the way by these are 3 stages by the way material lost from the grinding wheel will be taking place.

So, here now will summarize this presentation in this presentation I have talked about the specific power consumption related with the grinding and the factors affecting the specific power consumption in the grinding process and thereafter I have also talked about the way by which the grinding wheel wears out and how in which way the different phases are experienced by the grinding wheel during it is life. In terms of the brake in braking in stage or is attrition stage and the accelerating wear of the grinding wheel.

Thank you for your attention.