Fundamentals of Manufacturing Processes
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Lecture – 45
Material Removal Processes: Grinding III

Hello, I welcome you all in this presentation related with the subject fundamentals of the manufacturing processes and we are talking about the grinding process. Today we will see some more basics related with the grinding process especially with regard to the wear off wheel which is used for grinding purpose or we can say grinding wheel wear.

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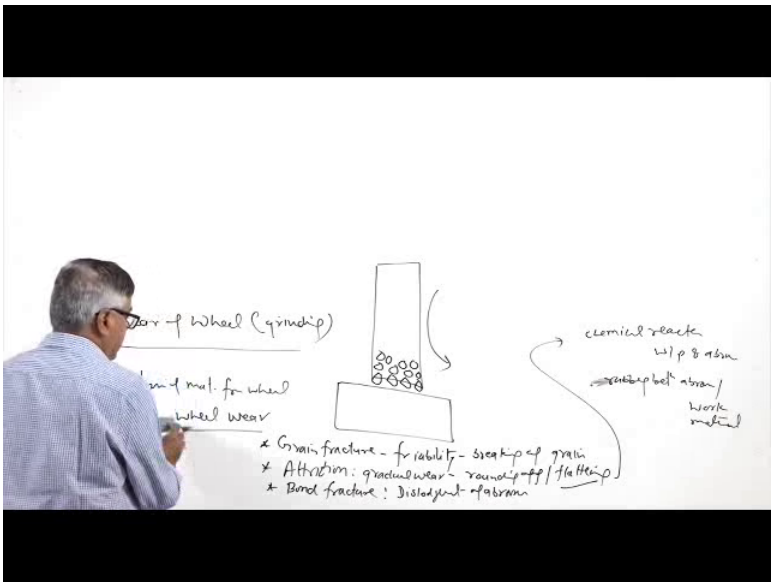

We know that the grinding wheel is made of the abrasives and the bonding material. So, abrasives are basically projecting beyond the surface. And these are also embedded or fitted within the grinding wheel in the bond material.

So, when the grinding wheel works or engages with the work piece material, over a period of time gradually the different types of the losses from the grinding wheel material takes place. So, that loss of material from grinding wheel is termed as grinding wheel wear. And the 3 primary mechanisms play in an important role in the material loss from the grinding wheel or in wheel wear. These are like grain fracture is one. This grain fracture is influenced by the friability property of the grains which are made like few

grains are more friable. So, they will be breaking easily. So, breaking friability means breaking or fracture of the abrasive grains under the cutting forces.

This is one mechanism and another operational mechanism is the attrition. Attrition is basically the gradual wear gradual wear of the abrasives as well as bond material. So, during these gradual wear or attrition the rounding off of the abrasive grains and flattening takes place. So, their cut ability is reduced. And the third one is the bond fracture. So, in case of the bond fracture basically the dislodgement of the abrasives from the wheel takes place.

So, here if we consider the grain fracture, in the wheel the grains are projecting like this. So, during the cutting the forces will be acting on to the grains when these forces become too high over a period of time the grain gets fractured. And this whether how easily it will fracture and during machining that is influenced by the friability. So, it is always good if when the cutting forces become high due to the dulling of the grains, then they should fracture. So, that the fresh cutting edges are generated in order to improve the grinding or material removal capability of the abrasives.

In attrition basically the grains which are sharp. So, gradually these get these wear out and get rounded off or they get flattened in this way. So, in both these cases whether rounding off is taking place or flattening is taking place the ability to cut ability to shear of the material from the work piece gets reduced. Third one is the bond fracture, where this is especially related with the grade property of the grinding wheel, which indicates the hardness or the softness of the wheel. So, hard wheel means the bonding between the bonding material and the abrasive is very good. In that case it the abrasive material will be held by the bonding material very firmly.

So, that the fracture of the bond will be less, fracture is reduced with the hard materials on the other hand if it is soft then the bond between the abrasive and the bond material will be poor. And in that case the abrasive will have a tendency to get dislodged due to the suppression from the bonding material because the bond between the abrasive and the at bonding material breaks.

So, in that case when the this abrasive is pulled out this leaves behind the it is space in the in in the location where it was held. So, this kind of this space is left where from the abrasive is dislodged. So, these are the 3 ways by which more material loss from the

grinding wheel takes place. With regard to the attrition there are certain mechanisms which work in like their may be kind of chemical reaction between the between the work material and the abrasives is one. And the second is the rubbing action between the rubbing between the abrasives and the work material taking place causing the loss of the material and which will be leading to the rounding off or the flattening of the abrasive abrasives. So, which in turn will be reducing the cut ability.

So, from here it is clear that during the grinding process the material loss from the grinding wheel also takes place while the material is removed from the work piece for a controlling the dimensions or for achieving the desired size and shape. So, in order to now quantify the wear of the grinding wheel, some parameters have been developed and these are like one of them is like grinding ratio.

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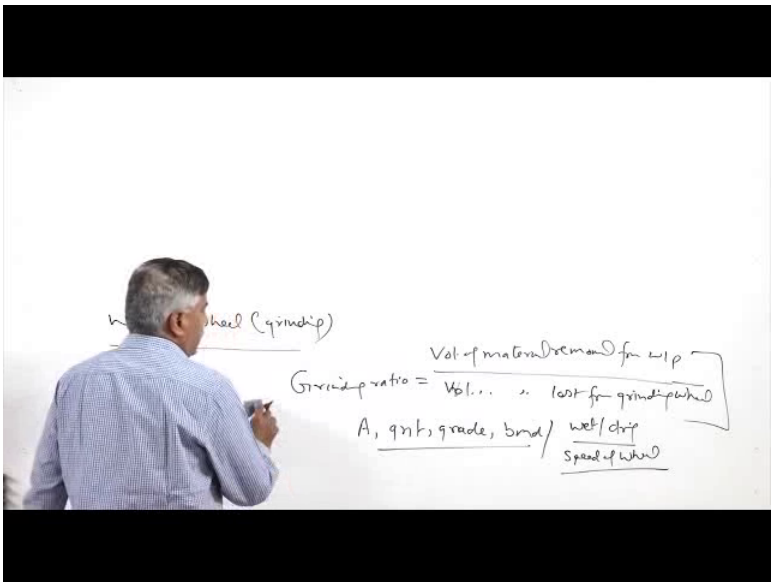

Grinding ratio is the ratio of the volume of the material removed from work piece divided by the volume of the material which is lost from the grinding wheel volume of the material lost from the grinding wheel.

So, it is always desired that there is no loss of the material from the grinding wheel when the grinding is taking place, but they still do to these operational mechanisms like attrition or bond fracture or the fracture of the grains, that the some loss of the material from the grinding wheel always takes place; however, they said to a great extent influenced by the kind of materials work the kind of characteristics of the grinding wheel

has in which includes like the abrasives the size of the grate the grade as well as the kind of bonding. So, these are some of the conditions, apart characteristics of the grinding wheel which will be affecting the their way by which material loss from the grinding wheel will be taking place. Apart from that the material loss from the grinding wheel is also affected by whether it is being done under the wet or the dry conditions. So, that will be affecting the temperature of the grinding wheel surface then speed of the wheel at which it is being used as speed of the grinding wheel at which it is being used.

So, now we will see there is a kind of relationship has been established between the wear the grinding ratio and the kind of surface of finish which is achieved as a function of the speed of the grinding wheel.

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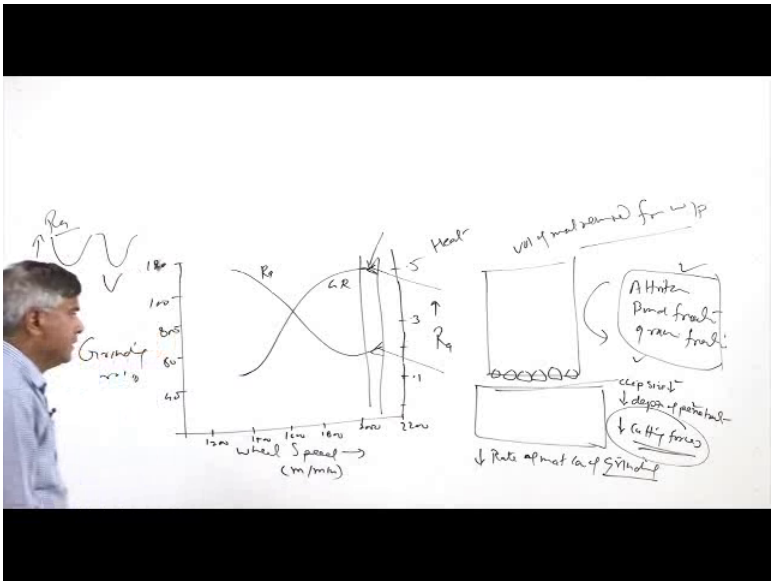

So, like in the; we will see one plot where in x axis is having like wheel speed of the wheel, like normally say it may be like 1200, 1400, 1600, 1800, 2000 or 2200 like this, the speed of the wheel surface in meter per minute. And if we see the in the y axis if we have the 2 side accesses like this. So, the surface roughness in this side in terms of the Ra which is increasing lick like say from 0.05, to 0.1 to point 0.15. Likewise, we can say for a much larger scale we mentioned it like 0.1, 0.3, 0.5.

On the other hand, the grinding ratio like 40, 60, 80, 100, 120. It is common to have the grinding ratio in the range of like say 90 to 125, but further it will be influenced by the number of other parameters which related with the grinding.

So, here in y axis, we are showing the grinding ratio. So, what happens when the when we work at the lower speed. So, the grinding ratio basically increases with the increase of the wheel speed. So, here what we have this is the grinding ratio, how it will be changing. So, increasing the speed of the wheel the grinding ratio improves because. So, here it is indicating that for a unit volume of the work material removed the loss of the material from the grinding wheel is less.

Similarly, on the other hand so here it may starts to fall also at much higher speed on the other hand the surface roughness goes in like this. So, this is showing the Ra and this is showing the RG value. So, what we can see here at the lowest speed the grinding ratio is low at the high speed the grinding ratio increases. So, how can we relate this? We know that like say this is the grinding wheel of a particular type, having the abrasives projecting beyond the surface and this is the surface with which it will be integrating interacting.

So, when the wheel is rotated at a high speed. So, the at high speed the depth the chip size is reduced because of the reduced depth of penetration at a high speed. So, when the chip size is reduced due to the reduction in depth of the chip. So, basically it reduces the cutting forces which will be acting on to the abrasives during the machining.

So, the since the reduction in cutting forces will be leading to the reduced rate of the material loss rate of material loss from the grinding wheel in terms of like say the grain fracture or attrition or the bond fracture. So, reduction in cutting forces basically reduces all those reduces the severity of all those operational mechanisms were responsible for the loss of material from the grinding wheel and which were like attrition the bond fracture and the grain fracture.

So, severity of all these 3 modes is reduced with the reduction in the cutting forces, when we work at a higher speed due to the reduction in depth of penetration reduction in chip size which in turn reduces the cutting forces. So, reduction in cutting force reduces the rate of the rate at which the material loss from the wheel will be taking place.

So, this is what we can see here trend that increase in the wheel speed basically increases the grinding ratio, there is another reason also behind the increase in the behind the increase in the grinding ratio due to the increase in speed that with the increase in speed. The volume of the material removed also increases. So, volume of the material from the

removed from the work piece also increases. Since the grinding ratio is the ratio of the volume of the material of work piece removed divided by the volume of the grinding wheel material removed.

So, with the increase of the wheel speed this volume of the material loss from the grinding wheel is decreasing while the volume of the material being removed due to the grinding action from the work piece is increasing. So, increasing volume of the material removed from the work piece and a decrease in the volume of material removed from the grinding wheel, these 2 leads to the increase in the grinding ratio. So, this is the one thing and the second also can be easily understood with regard to the roughness with the increase of the wheel speed under that integral conditions over the surface or surface roughness decreases.

So, we know that the like this is the grinding wheel having the abrasives projecting. So, at low speed there is a lot of time to interact lot of time for interaction between the abrasives and the work piece. So, this causes the much deeper penetration into the work piece. So, it will be producing the much deeper scratches while removing the material from the surface. On the other hand, when the work piece is wheel speed is increased at that times there is the depth of penetration gets reduced. So, under the identical conditions the depth by which the abrasives are able to penetrate into the work piece that is gets that gets reduced. And which in turn leads to the removal of the material due to higher removal of the material due to the increased speed, at the same time reduce the depth of the scratches and the grooves which will be formed on the surface of the work piece.

So, if we compare these grooves which will be formed as a result of the grinding in one case it is deeper another case it is less. So, this will be simply indicating the this will be of the higher Ra and this will be of the lower Ra value. So, this is how we can understand that increase in speed actually reduces increases the grinding ratio and reduces the surface roughness.

Another important thing is at much higher speeds that is this zone. If we see this zone the trend is like a increase in speed is further increasing the roughness and decreasing the grinding ratio because at too high wheel speed the heat generation becomes. So, severe that it adversely affects the surface roughness as well as it adversely affects the it starts

accelerating the loss of material, from the surface of the grinding wheel and severity of all these 3 factors starts increasing due to the increasing surface temperature of the wheel, as well as work piece. So, that in turn will be leading to the increase in surface roughness beyond a certain limit of the wheel speed will and that decrease in the RG ratio.

Now, we will see the another important factor related with the grinding is the selection of the grinding wheel for the different kind of the working conditions. So, we need to see the factors that we need to consider for selection of particular kind of wheel. Because there are a variety of the wheels in terms of the abrasives grit size grades structure bond material. So, we need to select the suitable kind of the grinding wheel which can serve the purpose.

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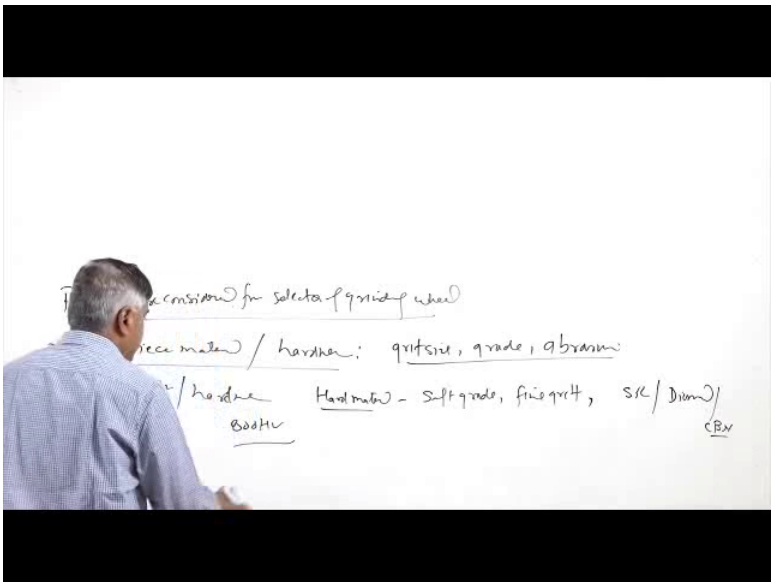

So, the factors to be considered for selection of the grinding wheel.

So, one by one I will take up and I will try to explain these factors, like the first one is the work piece material, work piece material which is to be processed by the grinding or it is hardness or hardness of the work piece material which is to be processed. With regard to this one material would of the work piece may be soft it may be hard or of the different categories. So, the factors that we need to consider to take care of this aspect, is like we need to see the grit size grade of the wheel and the abrasives. These are the 3 factors that need to be considered in light of the work piece material to be processed.

So, the work piece material may be very soft or it may be very hard. So, which we can see like 140 hv for aluminium alloys maybe 800 hv hardness for the hardened steel. So, there is can be lot of variation in terms of the hardness and in terms with the and also with the change of the work piece material there is a lot of change especially with regard to the hardness which is important from the grinding point of view.

So, what we need to see here the grit size, when we work with the hard materials we normally go for the soft grades, fine grit size. And with the hard materials we prefer to go for like silicon carbide, diamond and CBN. For example, so, here we will start with the concept of the grit size, why need to we go for a particular kind of the grit sizes with the change of the work piece material.

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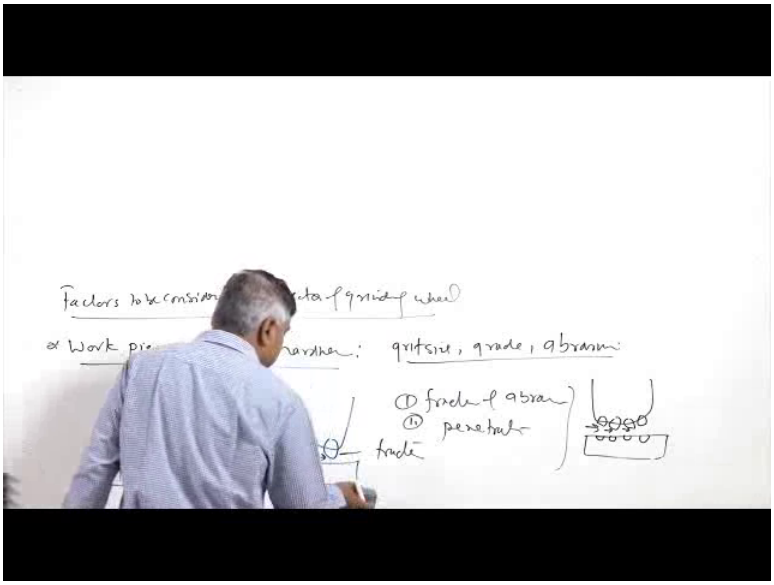

So, when we work with the soft material like this. Soft material of the work piece, the abrasives even if they are course they will be able to penetrate deep into the work piece. And so they will be able to remove the material effectively without getting fracture. So, no fracture in case of the coarse abrasives and the soft material, but if the coarse abrasives are used with the hard materials, then with the hard materials penetration will be difficult one there and the 2 the cutting forces acting on to the abrasives during the grinding will be so high that the abrasives will be fractured easily. So, there are 2 aspects one is the fracture of the abrasives. And the second one is the penetration, penetration

with the coarse abrasives in the hard material is not possible is difficult, while the coarse abrasives when deal when are used with the hard materials they get fractured easily.

So, it is better that if the fine abrasives are used they will be able to penetrate little bit onto the surface of the hard work piece material may be little bit. But the under the cutting forces which are acting during the grinding due to the o over hank portion limited overhang portion of the abrasives the fracture will be difficult.

So, the fine grit size abrasives will be able to survive more effectively when working with the hard materials as compared to the soft materials. Now coming to the another grade which is another characteristic which is need to which is to be considered while selecting the grinding wheel as per the work piece material is the grade.

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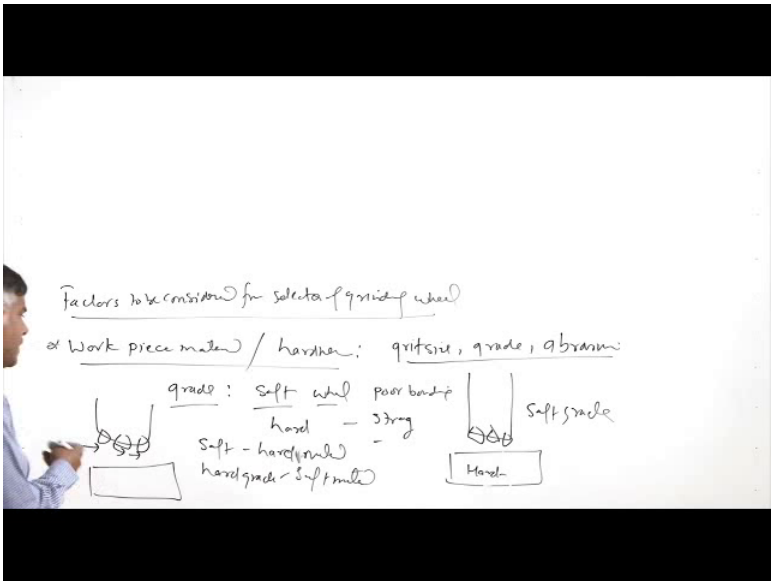

You know that the grade is about the hardness or the bond strength by which the bonding material is holding the abrasives. So, soft wheel means the poor bonding. Poor bonding and hard wheel means very strong bonding between the abrasives and the bond material.

So, when we are working with the hard material, more work piece material is hard. So, in case of the hard materials the cutting forces will be high. So, the bonds will be dislodged easily. So, what is done basically the when the when we are working with the soft material, the when we are working with the hard material normally soft grade is preferred.

So, that under the cutting during the cutting the abrasives are removed in course of the removal and the fresh abrasives are exposed to the surface. So, the cutting a continues effectively while in case of the soft work piece material the abrasives remain intact. And they will be able to withstand against the little bit cutting forces which are acting which will be acting on to the abrasives during the grinding of the soft material.

So, that is why soft material for, soft grade for hard metals and hard grade for the soft metal is preferred. Because whatever little bit for whatever little forces are acting on to the abrasives under those forces the hard grade will be able to withstand effectively.

Now, tough like the tough abrasives are used with the tough materials and hard abrasives are used with the hard material. So, if we consider the relationship like the alumina Al2O3, is hard as well as of very good toughness. That is why it is used for the tough materials like the steels which will be producing the ductile chips and other tough metals.

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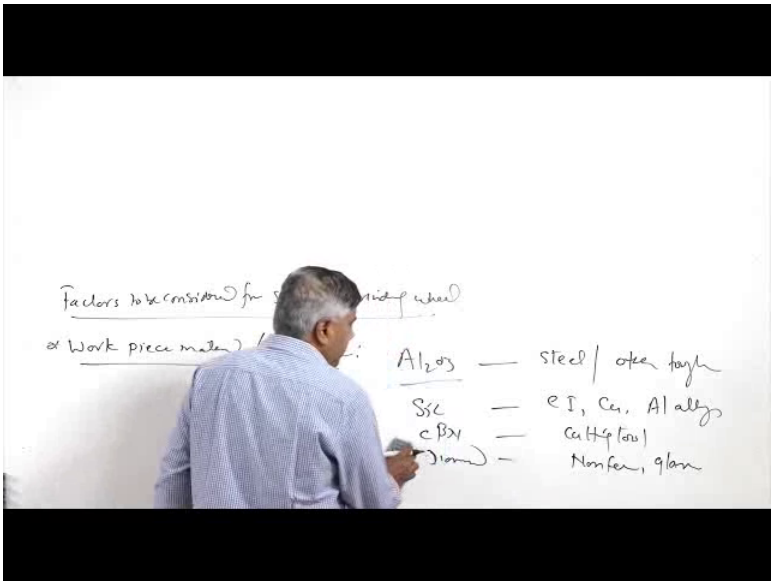

On the other hand, silicon carbide is used for cast iron and other like copper or other aluminium alloys like CBN, Cubic Boron Nitride is used for grinding of the cutting tools and the diamond is used for like the nonferrous metals as well as nonferrous metals as well as these are used for grinding of the glasses.

So, depending upon the kind of the work piece material we need to select the suitable characteristics of the grinding wheel especially grit size grade and abrasives apart from

the work piece material. There are other characteristics also like the stock to be removed stock to be removed.

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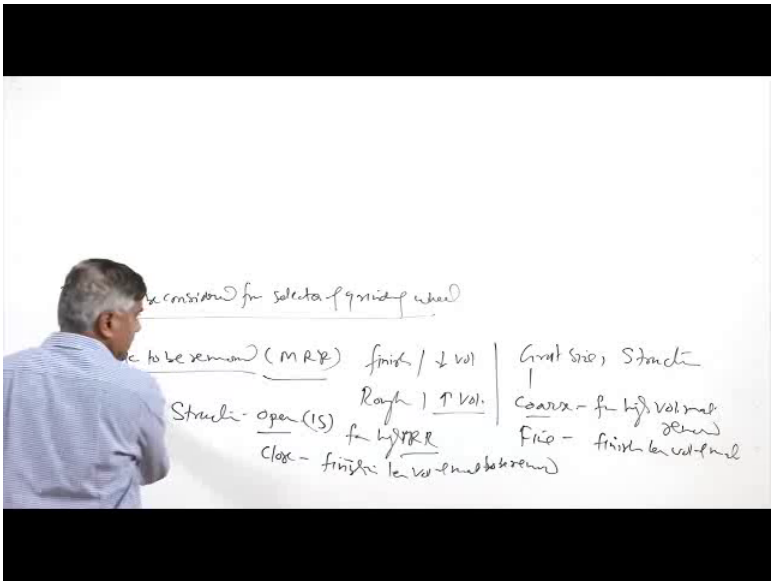

This is about metal removal rate or the volume of the material which is to be removed from the work piece. So, if just finishing is to be done then very less volume of the material will be removed. And if the roughing is done then, the volume of the material to be removed will be high. So, as per the case, there are 2 characteristics which are considered one is the grit size another is the structure.

So, coarse grits are used for coarse grit coarse size abrasives for the high volume material removal when the MRR needs to be high. On the other hand, the fine grits size is used for fine grits are used for finishing purpose where less volume of the material to be removed. Similarly, the structure open structure is used like having the 15 as num number wise, it is indicated open structure is used for the high metal MRR metal removal rate or a large volume of the stock to be removed and closed structure is used for finishing purpose where less volume of the material to be removed.

So, this is a another important characteristics, with regard to the factors another factor which needs to be considered for selection of the grinding wheel. I will write the other factors quickly.

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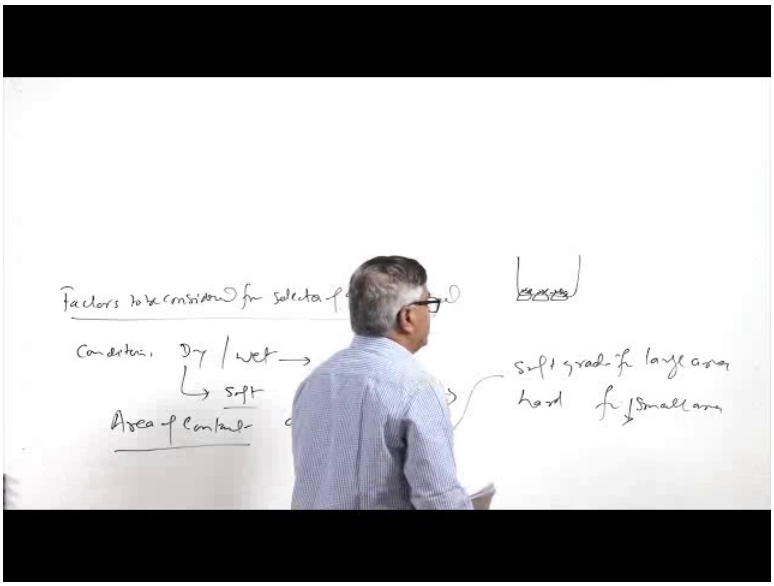

So, that I can compile all of them, and these are like. The conditions under which grinding is to be done maybe it is with dry or the wet. If the dry grinding is to be done means the dry grinding means work piece is adversely affected with the use of the cutting fluids in that case, we need to do the dry grinding. And if the grinding is to be performed and normally prefer the soft grade. And if the grinding can be done under the wet conditions then normally hard grade is selected because hard grade will be generating lot of heat. So, with the use of the cutting fluid we can we can take off the heat being generated during the grinding.

Then we have the area of contact area of contact, normally area of contact affects the like grit size and the grade like the coarse grit size is used for large area. So, that the unit pressure are acting on the abrasives is less. While because in the coarse abrasives will be having the in when coarse abrasives are used number of abrasives are less as compared to the case, when the fine abrasives are used this is when the fine abrasives are used there are large number of the grains to take up the pressure during the grinding. So, if the large area is to be used, then maybe we prefer for the coarse abrasives when the area of contact is small area of contact between the wheel and the work piece then fine grit size is selected.

So, that the fine grains can sustain the pressure high unit pressure which will be acting during the grinding under the conditions of the smaller contact area. Then the grade wise

the soft grade is selected soft grade for a large area of contact and hard grade hard for a small area of contact. The reason for this when the area of the contact between the grinding wheel in work piece is less. So, unit pressure will be high abrasives must be able to sustain that high unit pressure. So, the bonding between the abrasives and the bond material must be good and that is why hard grade is preferred, but when the large area of contact existing lesser unit pressure. Under those conditions even soft grade will be able to survive effectively. There is one more factor related with the selection of the grinding wheel and which is the wheel speed and the third the second one is the severity of the operation.

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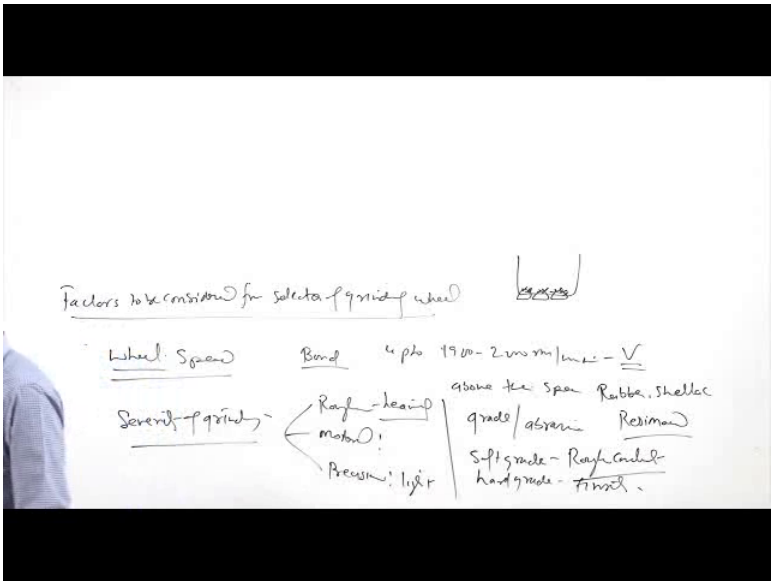

So, wheel speed basically affects the selection of the bond material. Normally up to up to like say 900, 1900 to 2000 meter per minute speed like vitrified bond is in generally selected. While for much higher speeds above this speed and normally if and normally than rubber, shellac and resinoid bonds are resinoid bonds are used. The next factor is the severity of the operation, severity of the grinding operation with regard to the severity we can divide in the 2 categories like maybe 3 like moderate or like precision and the roughing.

So, roughing the heavy conditions of the cutting forces exist in moderate and the precision very light cutting conditions exist. In so for and so this basically these cutting

conditions or severity operation affects the grade as well as the abrasives. So, grade and the abrasive selection is influenced by the severity of the operation.

So, normally the soft grade soft grade is selected for the roughing conditions. So, that the abrasives will keep on breaking and producing the fresh cutting edges in order to have the good in cut ability and good grinding action. While the hard grade is used for the for finishing and precision work, hard grade is used for the precision work.

So, here now we will summarize this presentation. In this presentation I have talked about the factors that lead to the loss of the material from the grinding wheel the how the wheel speed affects the grinding ratio. And what are the factors that we need to consider for the selection of the grinding wheel.

Thank you for your attention.