Fundamentals of Manufacturing Processes
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Lecture – 43
Material Removal Processes: Grinding I

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. So, in the material removal processes as we have talked there are 3 broad categories; one is the conventional machining, another is grinding or abrasive based processes and third is the unconventional machining.

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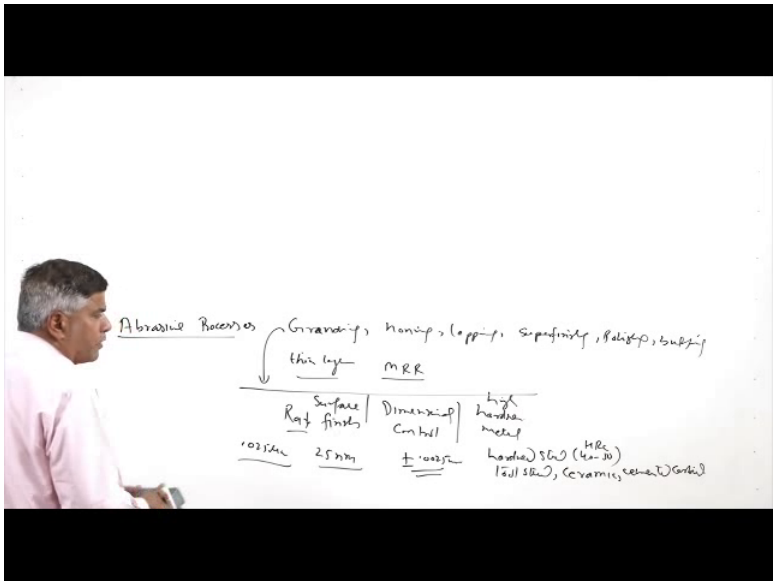

So, today we will be talking about the abrasive based processes where in material is removed to achieve the desired finish and the dimensions.

So, in abrasive based processes there are various processes, but the main process is the grinding, other processes like honing, lapping and super finishing, polishing and buffing all these are other abrasive based processes which help to remove although very little material a very thin layer of the material is removed. So, MRR is not basically in the target means the high MRR is not that important of course, it matters because we need to remove the material, but it is not a big a requirement. The main requirement is the surface finish, surface finish which can be achieved means Ra as low as possible and the

dimensional control or the dimensional control which we see in terms of the closeness of the tolerance.

So, this is the true 2 main aspects and third one is the ability to deal with the hard, high hardness metal systems. So, these are the 3 main advantageous features related with the abrasive based processes or the, we can say the grinding process because it is most commonly used. So, the in terms of the finish it can be used for achieving a means the abrasive based processes can help to realize very low surface finish which wherein ra can be as low as 25 nanometer. So, which corresponds to 0.025 micrometer and the very close dimensional control like 0.0025 mm can be achieved.

And high hardness materials like hardened steels, hardened steels like which are hardened for HRC 40, 50 tool steels and ceramics and cemented carbide all these also can be easily subjected for removal of the finer material so that the desired size and shape can be achieved. So, in light of these capabilities of the ah grinding abrasive based processes we need to see really what are the fundamental aspects related with the main abrasive based processes a process which is grinding.

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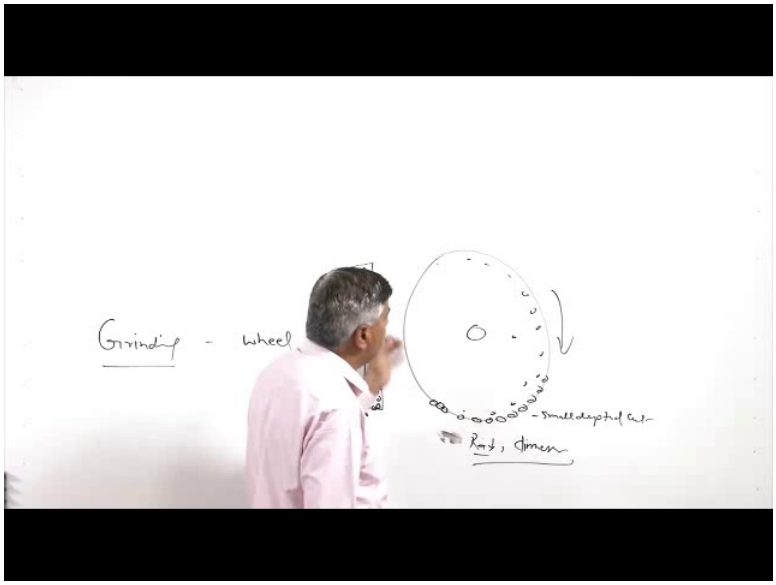

So, basically the mostly the grinding is performed with the help of a grinding wheel, which is nothing it is just a wheel which is comprises, basically which comprises the abrasive grains bonded with the suitable bonding material all along the body of the

wheel. So, this wheel basically comprises all these abrasives within its body and some of these of course, will be projecting on the surface of the periphery of the wheel.

So, with this wheel will be rotating at a very high speed and by giving very small depth of cut, very little layer of the material is removed in order to achieve the desired low surface finish and desired dimensions after removal of the material. So, this is how it works in the grinding is material removal processes where the material is removed by the abrasives bonded in a wheel which is rotated at a high speed.

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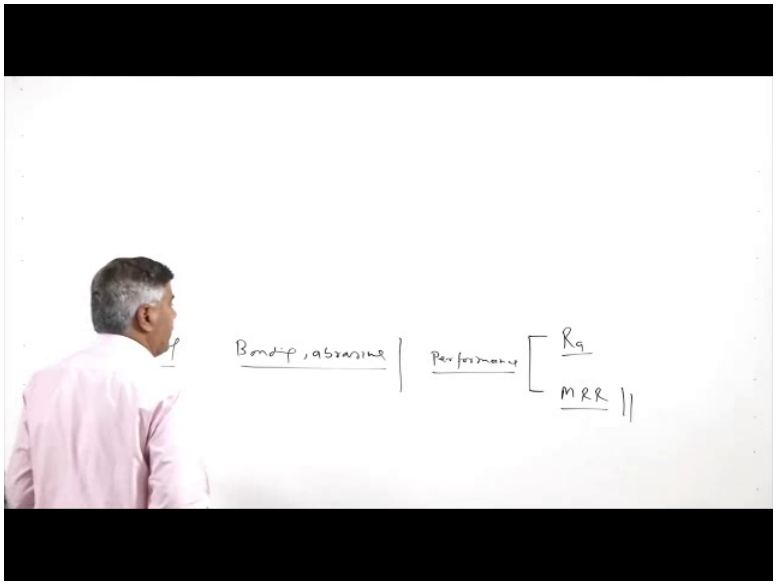

So, as we have seen the bonding material and the abrasives are the 2 main constituents of a abrasives are the 2 main constituents of the grinding wheel.

But there are many technical parameters related with these 2 with these 2 constituents which will be affecting the performance of the grinding process. So, the performance of the grinding process mainly checked in terms of the kind of the surface finish which will be achieved and the MRR or the metal removal rate which is realized. So, it will help us to see how faster that desired dimensions and surface finish can be achieved by removing the material or the thin layer from the surface of the work piece. So, the performance of the grinding is influenced by various characteristics and properties of the grinding wheel which mainly comprises the 2 constituents one is bond another is abrasives.

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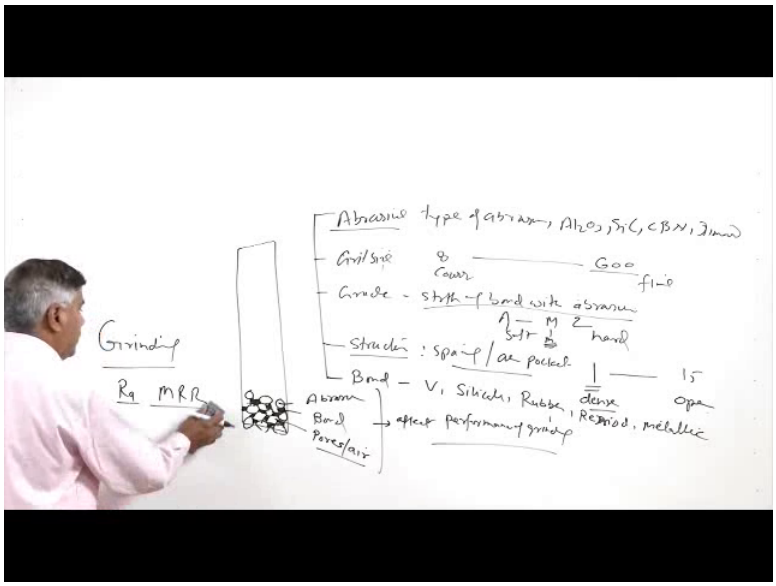

So, the characteristics that we need to see are like this, like the abrasives bonded or held firmly in the wheel. So, these are bonded by the bonding material like this. So, all these abrasives will be bonded by the bonding material in this way. So, what we will see here, there are 3 constituents in that way the one is the abrasive, second is bond and third is some spaces left between the abrasives and bond which we can say as pores where mainly the air is filled.

So, all these 3 features basically these; so although we make the wheel using the abrasives and bond, but some spaces are left between the bond and abrasives which are called pores. So, air pockets are left in and all these 3, 3 aspects affect the performance of a grinding. So, if you want to see that how in these 3 constituents and what are the properties or characteristics related with these 3 will be affecting the grinding performance.

So, there are basically the 4 or 5 important characteristics which includes the abrasives, which means the type of abrasive which is being used type of abrasive. So, basically ai 2 o 3 alumina is one of the most commonly used abrasive, silicon carbide is another and then cubic boron nitride is another and the diamond is 4th. These are the 4 common abrasives which are used then we have the size of the grit size, size of abrasive or it is also termed as grit size. So, a grit size can vary like say from 800 mesh size to the 600 this is extremely fine and this is very coarse.

So, depending upon the kind of a surface finish and the metal removal rate required the suitable grain, size or grit size is selected third aspect is the grade related with the grinding wheel, a grade is about the strength of bond with the abrasive. So, how formally the bond is holding the abrasives in its position that is what is identified by the grade and it is indicated by the letter A to Z, A is for the is very soft and it is for very hard M stands for the medium size, medium size the grade or the medium size hardness of the bond with the abrasive.

So, be grade basically strengths the shows the bonding or the firmness of the bonding of the abrasives with the bonding material, then we have the structure a structure indicates the kind of spacing between the abrasives air pockets which are there. So, it is indicated by the number 1 to 15, 1 is for very a dense and 15 is for open, 15 is for very open structure and a fifth is the kind of the bond which is being used.

So, various type of bonding materials like vitrified bond silicate bond, silicate bond, rubber bond, resinoid bond and metallic bond so these are the various bonding material. So, depending upon these characteristics of the wheel means the bond is made of the metal or silicate or rubber the structure open or close the grade the grit size and the abrasives which are being used for making the grinding wheel all these factors will be affecting the grinding performance in terms of the surface finish which will be achieved and the kind of a the metal removal rate which will be realized.

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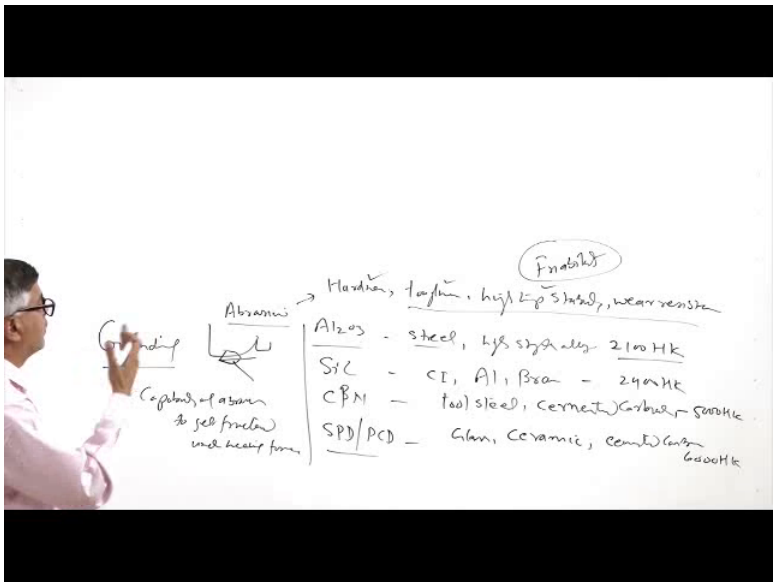

So, we need to see these characteristics in detail. So, starting with the abrasives, abrasives as I have said the alumina Al2o3 which is used for mainly for the steels ductile materials and there are high strength alloys because it is very tough, but and the hardness is low which is of about 2100 knoop hardness, another one is the silicon carbide which is mainly used for like the cast iron and other cemented carbide and the ceramic a kind of ah like cast iron the aluminum brass kind of the metals and its hardness is 2400 HK the knoop hardness.

Then we have this cubic boron nitride, cubic boron nitride is used for ah grinding of the like tool steels hardened steels and the cemented carbides. Cemented carbide tools and aerospace alloys and its hardness is found much higher like 5000 HK and then we have the diamond like a synthetic diamond or a sintered polycrystalline diamond also known as poly crystalline diamond. So, both these are these are used for like the grinding of the glasses or a ceramic and the cemented carbide tools and these are of as we have said 6000 HK the knoop hardness.

So, depending upon the abrasives their hardness very source because a hardness is one of the important parameter, but apart from the hardness other properties which are desired just like any other tool material the properties that we need to look for the abrasives because these will be performing the actually the grinding process like the hardness is needed, toughness is needed high temperature stability is required then wear resistance is required and the 4th one which is a important is friability.

So, all other things we have already explained and their importance we know from the properties required any another in any other tool material. So, these are the similar properties like hardness, toughness, high temperature, stability and the wear resistance, but the friability is unique for the abrasives. So, it is about the, it is about that the way by which ah the its about the capability of the abrasives to get fractured under the heavy forces or cutting forces which will be acting like the, this is the wheel and this is the abrasive projecting once it gets rounded off. So, its cut ability will be reduced and so under the reduced cut ability the heavy forces will be acting during the grinding.

So, under those heavy forces if it gets fractured it will be producing the fresh cutting edges. So, fresh a fracture of the abrasives will be leading to the formation of the fresh cutting edges. So, the formation of the fresh cutting edges due to the fracture of the

abrasives is governed by the friability of the abrasive. So, for the grinding wheel it is important that the friability of the abrasives is good. So, that it can maintain it is a cutability.

If we compare like alumina and the silicon carbide alumina is considered to be tougher than the silicon carbide that is why the alumina is normally used for the high strength and the tough materials as compared to the silicon carbide which is mainly used for the hardened brittle materials as well as where the impact forces chances for the action of the impact forces is a less.

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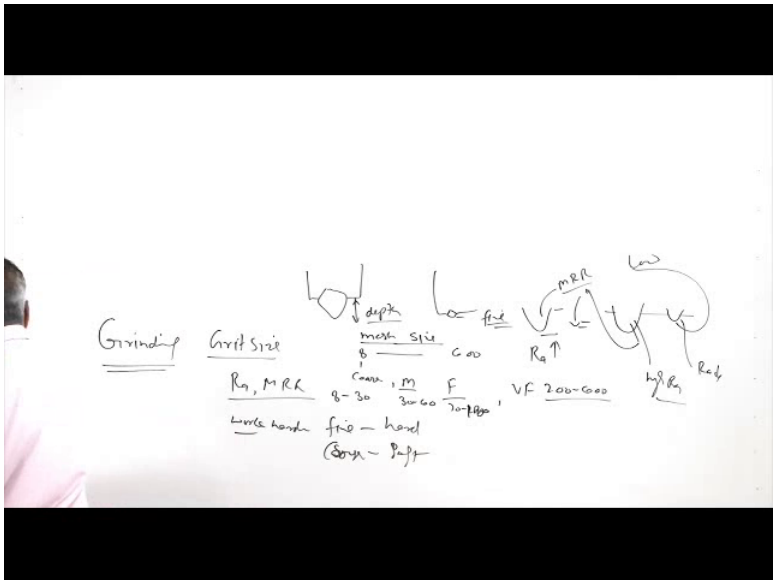

So, apart from the abrasive the next important characteristic is the grit size, grit size is about the size of the abrasive whether it is fine or sorry where it is very coarse or it is very fine.

So, when a course abrasive is used a big sized abrasive will be projecting behind the, a beyond the surface of the wheel while in case of the fine abrasive very small portion will be projecting. So, this effects this governs basically the depth by which the cut will be made during the grinding by the abrasive while in case of the fine abrasives the depth of a cut which will be made will be fine. So, the thickness of the chip which will be removed will you find in case of the fine abrasives as compared to the case when the coarse grit is used.

So, the grit size varies is measured in using the mesh screening using the seeps of the different mesh sizes. So, mesh size can vary mesh size which is commonly used for the mesh size of the abrasives which are used for the grinding wheel can vary from like say 8 to a 600, 8 is extremely coarse. So, ranges for like 8 to 30 for coarse, medium it is 30 to 60, fine it is like 70 to 200, 70 to a 180, very fine is from 200 to a 600 mesh size.

So, a finer is the abrasive smaller will be the scratch size or if the cursor is the abrasive courser deeper will be the scratch size. So, accordingly the MRR will be more for the course abrasives as compared to the fine abrasives while the Ra will be high for the course abrasive because of the greater depth of the scratches which will be formed during the grinding while the depth of this scratches will be fine in case of a the fine abrasives.

So, if this is a surface course abrasive will be forming the deeper scratch as compared to the fine abrasives. So, this will be leading to the high MRR and this will be leading to the low MRR, this will be causing the very low Ra, this will be causing the high Ra. So, this is how the effect of the grit size can be understood, apart from the m, apart from the effect of the grit size on Ra or the surface roughness which will be produced or the metal removal rate, it also grits a grit size selection is also influenced by the work material hardness.

So, normally a fine grit is used for the hard materials and a coarse grit is used for the soft materials because the coarse grade course abrasives have will have the tendency to get fractured when they are used for the grinding of the hard materials due to the action of the heavy cutting forces or a forces which will be acting during the grinding.

Another important feature is the grade the grade indicates the bond strength bit between the abrasive and the bonding material.

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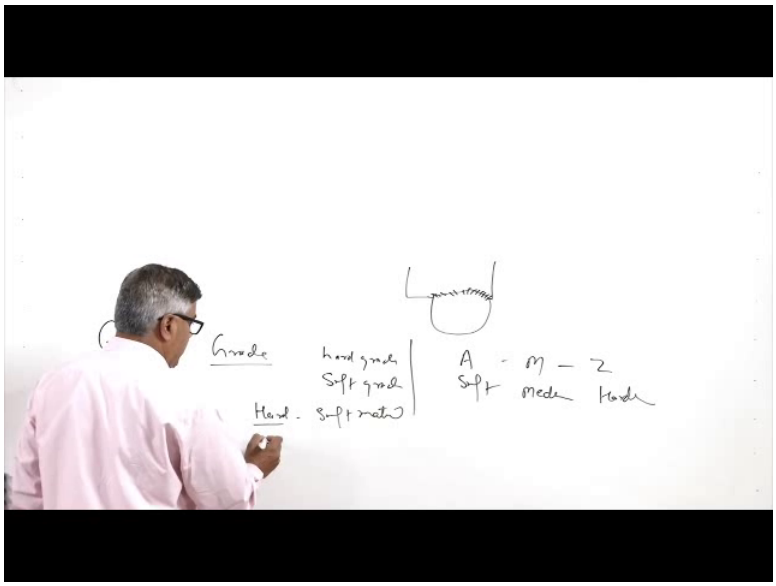

So, if the bond strength is very good then we will say the hard grade or if the bond strength between the abrasive and the like this is the abrasive held by the bonding material. So, the this a bonded strength of the bonding material with the abrasive is termed as the grade and hard grade when the bonding is very good or when the bond is weak then we will say soft grade.

So, soft grade will we will be leading to the suppression of the abrasives from the wheel or bonding material easily as compared to the hard grade and alphabetically these are designated means the grade is indicated with using the alphabetical, alphabetically the letter A is used for very soft grade, M is used for the medium grade hardness and the Z is used for the very hard grade. So, a grade is a selection of the grade is influenced by the kind of the work material which is to be used for example, the hard grade is used for the soft work piece or soft work piece material and the soft blades are used for the hard material.

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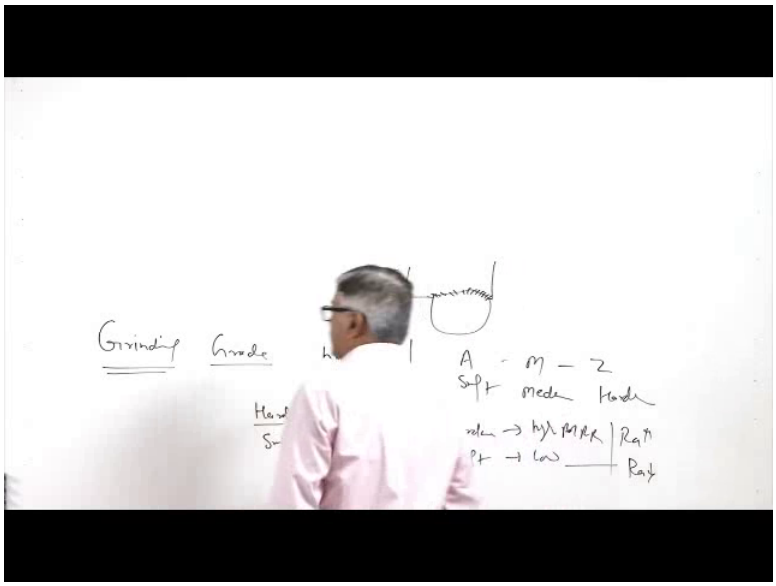

Similarly, the purpose wise hard grades are used for the high MRR and soft grades are used for the low MRR. So, this will be leading to the greater Ra and this will be leading to the lower Ra, apart from the grade we have now the structure. Structure indicates how closely the abrasives are packed in a grinding wheel or how what kind of the inter particle spacing between the grinding wheel.

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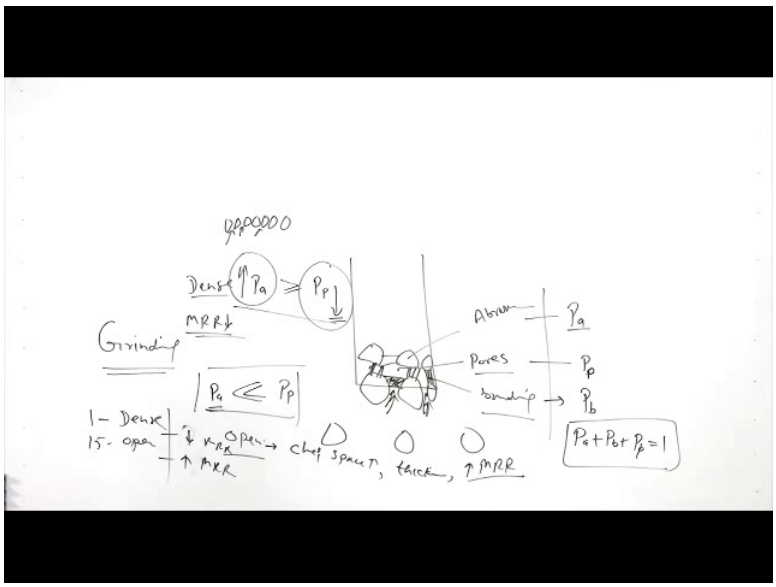

So, if we if we see any grinding wheel as I have mentioned earlier there are abrasives and abrasives are bonded by the a bonding material like this, but there are a lot of spaces

between the this is the bonding material, but there are lot of spaces between the abrasives and the abrasives and the bonding material which is termed as pores. So, we have 3 constituents like abrasives pores and the bonding material. So, proportions of all these 3 like if the abrasives are indicated by Pa, proportion of the abrasive in a wheel is Pa proportion of the pores or air pockets in the wheel is the Pp and the proportion of the bonding material is Pb, then sum of all these 3 like Pa plus Pb plus Pp will be leading to the equal to 1.

So, that is what we in totally will be making the grinding wheel. So, in the case when the probe fraction of the abrasives is less and the fraction of the abrasive a air pockets is more. Pp is more and a fraction of the abrasives is less in that case we get very widely spaced abrasives and this kind of structure is called open and in this case the lot of gaps will be there between the abrasives and between a lot of the gaps will be present between the abrasives. So, this will provide lot of chip space.

So, after getting remove the chip will be accommodated in these spaces in case of the open structure. So, when the structure is open like so the chip space is more and which makes it suitable for removal of a thicker layer and this leads to the a means greater thickness of the chip can be removed when the chip space is more by the coarse abrasives and. So, this will be leading to the higher MRR. So, when the higher MRR is to be used, open structure is used while the dense or the closest structure is used when the abrasives are more and the air pockets or the, a fraction of the fraction of the pores is less.

So, for the less percentage of the pores and more percentage of the abrasives will be leading to the very closed packed abrasives. So, in this case very less chip space will be present between the abrasives which will make the removal of the larger amount of the material during the grinding. So, in case of the densest structure when the abrasives are more and the pores fraction of the pores is less. So, very closely packed abrasives will be leading to the reduced chip space which will be leading to the reduced MRR.

So, these are the 2 situations regarding the structure. So, very open structure is indicated by. So, means letter 1 to 15 is used to indicate the structure of the wheel which is like 1 to 15 is used. So, one is used for the dense structure and 15 is used for the open structure

this leads to the high MRR and this results in the sorry a low MRR and this results in the high MRR.

So, as per the case as per the requirement suitable kind of the structure is selected for a developing the grinding wheel, next and the fifth ah factor is the bond of the bonding material the bonding material will be holding the abrasives firmly that.

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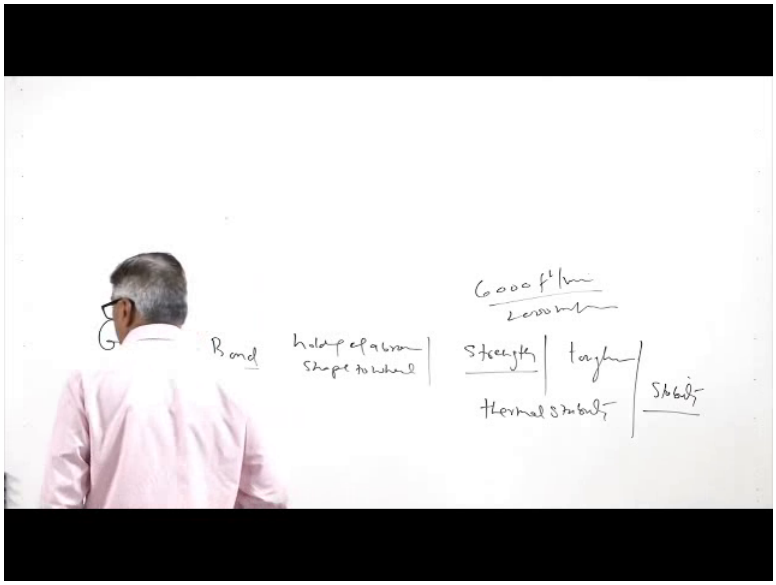

So, the holding of the abrasive is one job which is done by the bonding material and it gives the shape to the wheel. So, shaping of the wheel is also facilitated by the grinding material, but the since the wheel rotates at much a higher speed which may be as high as like 6000 feet per minute.

So, a rotation at a too high speed like 2000 meter per minute surface speed of the wheel, wheel is rotating too high. So, it is required to sustain heavy forces for that heavy centrifugal forces which reacting on to the wheel. So, it is important that the strength is good then toughness is another important requirement the thermal stability of the wheel means that a high temperature resistance because lot of a heat is generated during the grinding. So, that there is a rise in temperature so wheel should not get destabilized due to the rise in temperature so this is the another one.

So, if the wheel a bonding material is having the required properties, then it will be a leading to the stability of the wheel during the rotation and it will not be shattering or the fracturing under the severe grinding conditions.

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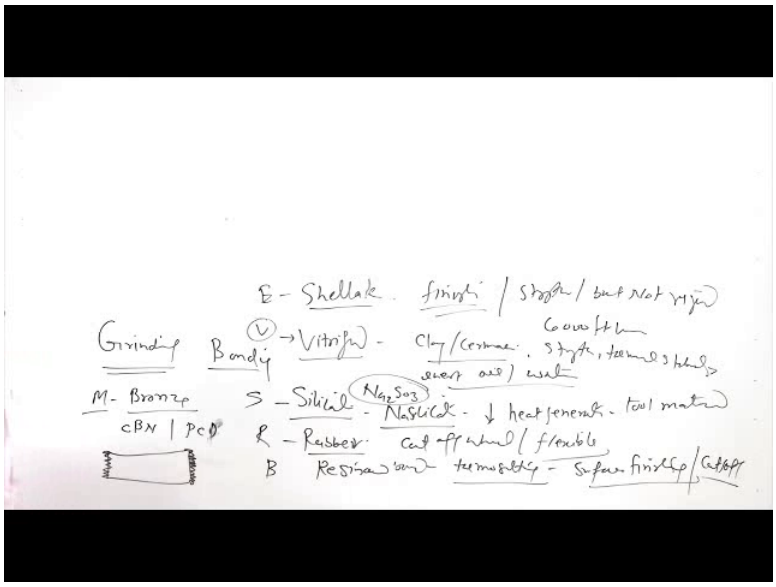

So, the there are few common types of the materials which are used as a grinding wheel for the different purposes and, but one of the a most common bonding material is the vitrified which is a combination of basically clay and the ceramics it becomes very good in terms of a strength and the offers good thermal stability and that is why it is used for most of the common purposes and can run effectively up to 6000 feet per minute or 2000 meter per minute speed without much difficulty and this is commonly used for this also shows the inertness to the oil and the water.

So, it is equally good for the wet conditions also apart from this then we have the silicate, silicate bond it is basically the sodium silicate which is a used for making this type of the wheel and this is this type of wheel is used when the requirement is that less heat generation, especially during the grinding of the tool materials because high temperature can lead to the deterioration or modification in the properties of the tool material. So, silicate bond is a, another one like Na2So3 is the formula for the silicate bond, rubber bond is the another one which is mainly used for the making of cut off wheels it is basically flexible because it is made of the rubber.

Then we have the resinoid bond resinoid bond basically phenol formaldehyde is a thermosetting resins which is used for this purpose and it offers its mainly used for the finishing surface finishing purpose this kind of the bonding material is used. Apart from that we have the shellac, shellac is another a bond. So, super finishing as well as this is also used for the cut off wheels shellac bond is used for the finishing purpose and it is and it is good in terms of the strength, but not rigid.

The last one is the metallic bond indicated by the letter M. So, there are a number of different ways by which it can be designators letter V is used for vitrified silicate is used C then we have, then see a rubber is E resonate shellac, shellac is E then rubber is R vitrified VM is this silicate is S and a resinoid or our is r and a resinoid is b. So, these how these are shown m is used for the metallic bonding material and mainly bronze is used as a metallic the bond bonding material, it is used for bonding the abrasives like cubic boron nitride and the PCD and or sintered polycrystalline diamond.

So, basically these are made like this where entire wheel is made of the metal and at the surface the abrasives are applied for the grinding purpose. So, these are the kind of the 5 important characteristics related with the grinding wheel and which will be significantly affecting the grinding performance as has been described for the different characteristics.

So, here I will summarize this presentation, in this presentation I have talked about the importance of the grinding wheel and what are the important characteristics related with the grinding wheel which will be affecting the performance of the grinding or the parameters which are used to indicate the grinding performance like metal removal rate and the surface finish also I have tried to talk about the are that the things which we need to keep in mind while going for a particular kind of feature present in the grinding wheel.

Thank you for your attention.