**Production Technology: Theory and Practice**
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**Lecture – 14**
**Machining Operations Performed on a Drilling Machine**

Hello and welcome back to the discussion sessions of production technology theory and practice. Let me remind you that in our last session, we discussed the practical machining operations that means, how processes are performed, I have shown it to you schematically how these processes are performed and how those tools look like. For example, in case of drilling, the drill has been shown. What are the geometries and all and after that we have discussed the reaming, then tapping. It was told that after the drilling operation the quality of the drill hole has to be made in a better way. In that case, we have to ream so that the already drilled hole surface finish can be enhanced and then if we have to cut the internal thread, we use the tapping as shown here.

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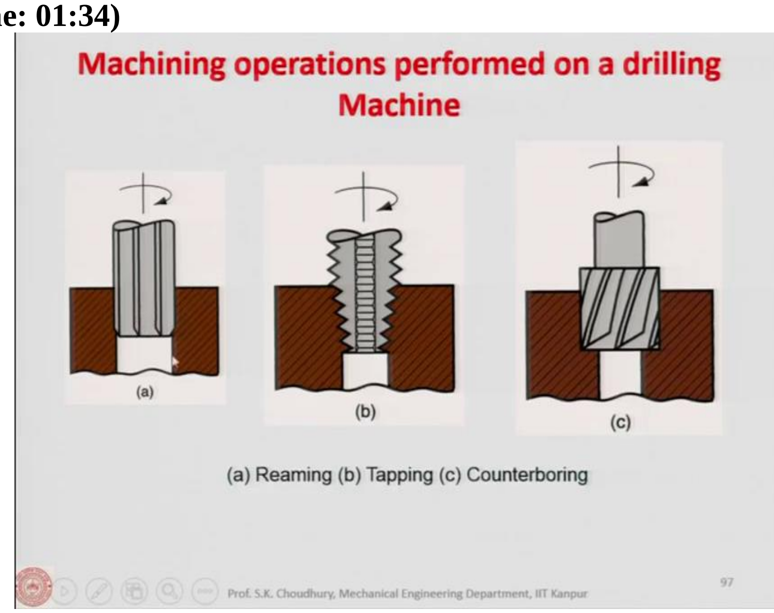


In this slide, here is the reamer. This has been already told that this process is the reaming process, where there is already a drilled hole and accuracy of the drill hole or the surface finish up the drill hole has to be enhanced. This is the process when the internal thread is being made, called as the tapping and this is the counterboring that means when you have two holes of two different diameters on the same axis.

After this is made, there will be a part with two holes. One hole is here and one hole is here and they have a common axis. This process is called the counterboring and I told you that counterboring is made so that a special kind of bolt can be inserted here so that the bolt head does not protrude out, it will be a sunk, so, that is why it is called a counterboring. There are also other purposes for which the counterboring is used and that we will see later and also some of the uses we will see in the laboratory.

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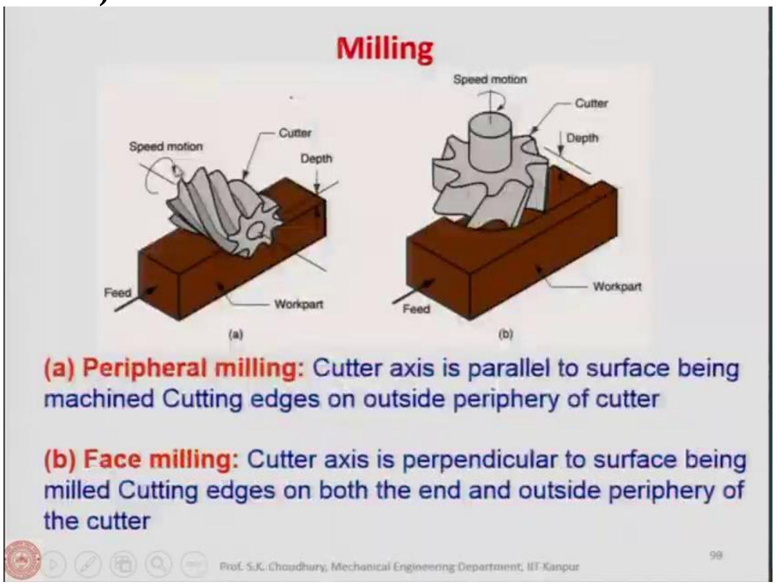


Here schematically we have shown the milling process, this one is the peripheral milling. Peripheral milling means that the cutter axis is parallel to the surface that is being milled and cutting edges on the outside periphery only. You can see that that this is the milling cutter, this is how it rotates and this is the axis of the milling cutter and this axis is parallel to the surface. Both are in the horizontal plane that is a surface that is being made and the cutter axis.

Another milling process is the face milling. In the face milling, the difference between the peripheral milling and the face milling is that the cutter axis is perpendicular to the surface that is being milled and cutting edges are at the face that is not visible and is at the $90^0$ angle with the axis and on the sides and outside periphery.

This is the outside periphery and here also we have the cutting edges in comparison to the peripheral milling. In case of peripheral milling, it is on the outside periphery but here the cutting edges will be here as well as on the outside periphery.

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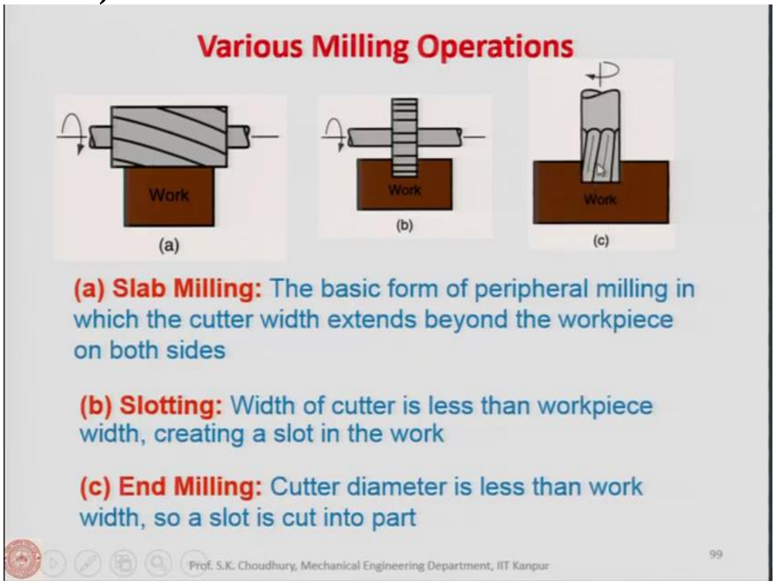


Various milling operations are categorized as the slab milling. This process is slab milling process which is the basic form of peripheral milling in which the cutter width extends beyond the workpiece on both sides. It means that the in the case of the slab milling in one go the entire width of the workpiece can be machined.

This the peripheral milling but in pictorial view. The milling cutter is the same and therefore, the slab milling is one of the types of a peripheral milling. Peripheral milling is a family of milling operations. Now, the second process is the slotting where a slot is made along the length of the workpiece.

This can be a milling cutter which is rotated and we have the straight milling cutter and width of cutter is less than the workpiece width. The width of the cutter is creating a slot in the work and this can be of a very long workpiece and along the length of the workpiece the slot can be made. It will rotate and then the shaft along with the arbor or along with the milling cutter will be given a feed along the length of the workpiece.

Another operation of the milling is the end milling where the cutter diameter is less than the work width. There is a cutter diameter because it is the cylindrical. A slot is cut into the part. The milling cutter is different than the one used here.

End milling cutters are very popularly used in practice for making grooves or making the contours for example and similarly in this slotting operation can also be made by the milling cutter, but the milling cutter is different here of course, it is the horizontal milling and this is the vertical milling.

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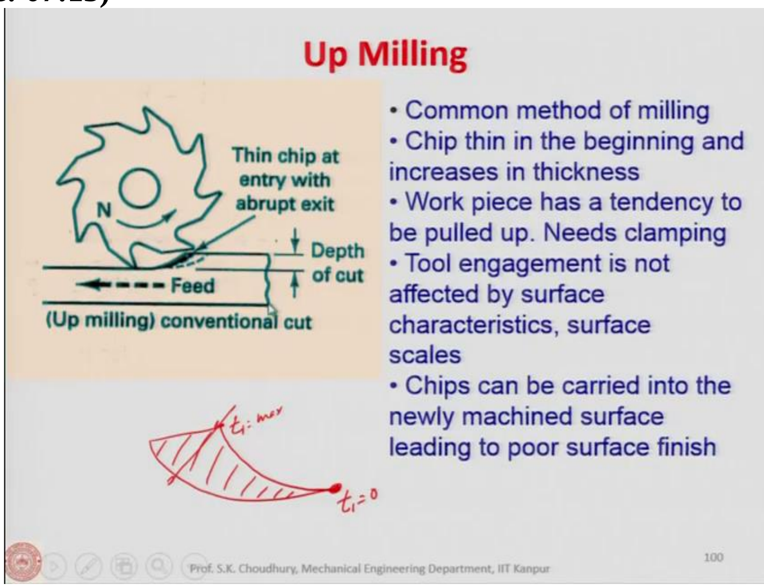


Here is the popular categorization of the milling. This is called the up milling. You must be familiar with that, this is the milling cutter and this is the workpiece. Up milling is when the direction rotation of the milling cutter and the feed movement given to the workpiece are different. This is a common method of milling mostly you will see in practice the up milling is used now.

In the beginning, from here when one of the teeth of the milling cutter grabs the workpiece material the chip thickness is 0 and the chip thickness becomes maximum as the tool is given feed. I have already shown it to you earlier also that this is a kind of chip that can be produced.

So, the $t_1 = 0$ and here the $t_1$ can be maximum. This we have shown in the case of milling process and we are again going to discuss this in case of grinding because that in grinding process also the $t_1$ becomes from 0 to maximum like in case of the milling. The workpiece has a tendency to be pulled up. Since these two directions of rotation of the milling cutter and the feed movement are different in that case when the milling cutter rotates, it will try to pull up the workpiece. Therefore, the clamping forces should be more. So, to secure the workpiece not to get pulled up and the tool engagement is not affected by surface characteristics or the surface scales. Scales means that when we have the hard particles like for example, after the metal forming process. You will see that there is a black layer and that black layer is strain hardened which is a very hard material.

That particular layer of material we always remove before the machining process starts. That is what it is said that it does not depend on whether the tool will be engaged properly or not, with the surface scales or the surface characteristics, chips can be carried into the newly machined surface. Another fear is that when the chip is formed, here these are the voids, in these voids the chips are accommodated.

So, when it is farther rotated this may rotate along with the chips located in the voids that is the space between the teeth and it may fall on the already machined surface because feed is given in this direction and the tool was moving in the anti-clockwise direction. The up milling is used in practice because of some reason that I will tell you when we will discuss the down milling.

But then some of those disadvantages are also there that means it has a tendency to getting pulled up and if the care is not taken then the chips can fall on this and it can spoil the surface.

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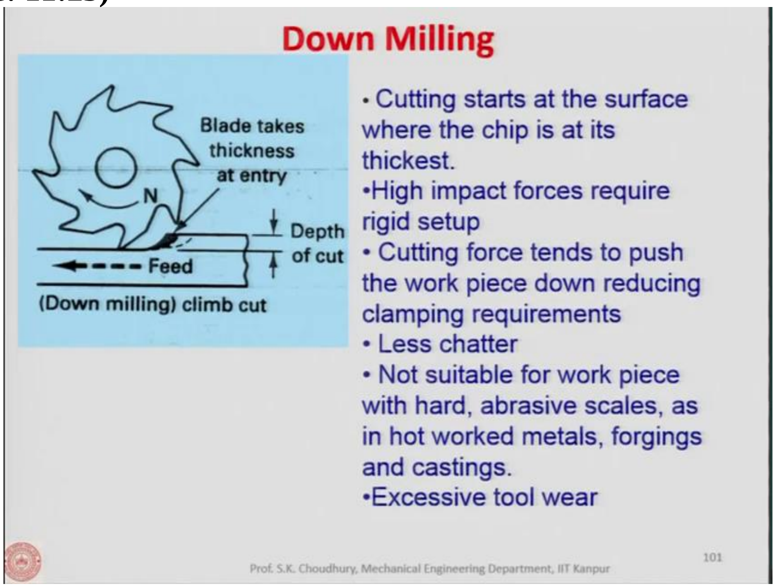


In down milling, the cutting starts from here. First of all, in down milling, the rotation of the milling cutter is in the same direction as in the feed given to the workpiece. Down milling is also called the climb cut. The cutting starts at the surface with the chip is at its thickness that means it starts from the maximum chip thickness it grabs and then it goes to the minimum.

Here since it grabs at once, the impact loading is very high. If you remember we talked about this in case of the orthogonal cutting and in the oblique cutting and I told you that in case of orthogonal cutting the tool grabs the material in one go at a time, but in case of the oblique cutting, it grabs the material gradually.

Similarly, in case of the down milling, when it grabs the tool with the maximum $t_1$ uncut thickness, the impact loading is very high. High impact forces required rigid setup. That needs a very rigid setup in the tool post that is where milling machine table or where the workpiece is clamped, now cutting force tends to push the workpiece down reducing the clamping requirement.

Here you can see that this is the other way round that this will try to push down. So, when it is pushing down that means the clamping requirement will be less. That means the clamping force that is required as in case of the up milling where there is a tendency for a tool to pull up the workpiece. In this case therefore, the clamping forces will be less but here there is one fear.

Since it is pulling and pushing down, there is a tendency for this workpiece to go towards the place where the operator is standing. So, one has to be very careful about the proper clamping of the job. In that case the tool may throw the workpiece towards the operator. Now chatter will be less because the $t_1$ starts from the maximum.

That is one point not suitable for workpiece with hard abrasive scales. If the scales are present on the workpiece surface obtained by metal forging or castings in that case, this grabbing of the tool material at a time of the $t_1$ maximum, then the tool wear will be more and even the tool may break.

It is not suitable for workpiece with hard abrasive scales as in hot worked metals forgings and castings. In that case the tool wear will be excessive and that is why it is not suggested that the down milling is performed immediately after the casting or immediately after the metal working process, because after the metal working process and the casting the layer at the top will be normally harder than the layer lying inside or the hardness of the top layer will be more.

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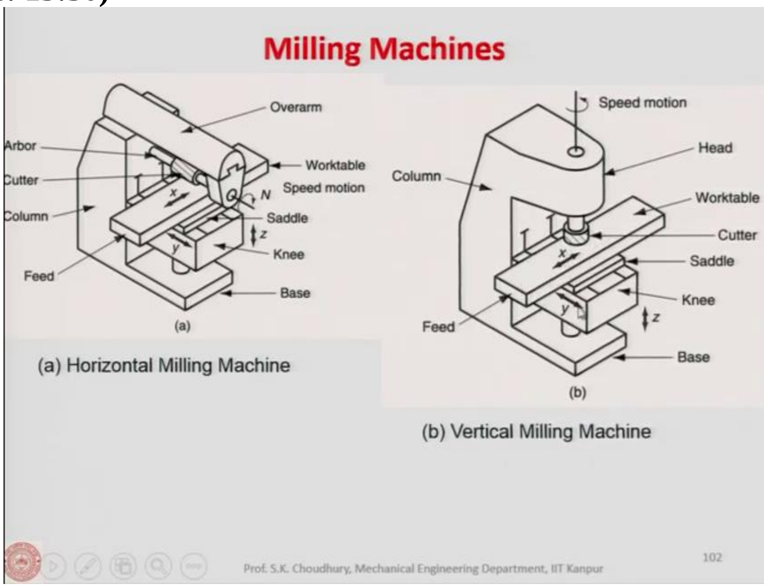


These are the milling machines, these machines we will see in the laboratory, this is the horizontal milling machine because the axis of the milling cutter is horizontal and here since the axis of the milling cutter is vertical, so, this is called a vertical milling machine. So, in the horizontal milling machine you will see that on the base the entire machine is located including the over arm on which we have the milling cutter.

Milling cutter is mounted on the arbor and the entire arbor is rotating and this is the support. This supports the arbor and one end of the arbor is in the spindle of the machine and this end is attached to the support. Now here we have the saddle this saddle moves in the y direction that is the cross direction and this is the feed direction. This is the work table, work table moves in this direction.

So, we will have the x and the y both in both directions the workpiece can be moved. Workpiece of course is mounted on the table; this is the column of the milling machine which is a part of the base of course this is called also the knee because if you see that here it is located in the middle. This is a base on this the saddle and worktable they move in the direction perpendicular to each other.

I repeat that this worktable moves along the x direction whereas the saddle moves in the feed in the y direction that means in perpendicular to x. Other components are almost the same in the vertical milling machine except that the axis of the milling cutter is vertical. This is the cutter here of course this cutter is horizontal and here also we have the base, the column, the head, the cutter and the table and this is given the feed. This is the x axis direction and on the knee we have the saddle which is given the y axis direction. So, other aspects are more or less the same.

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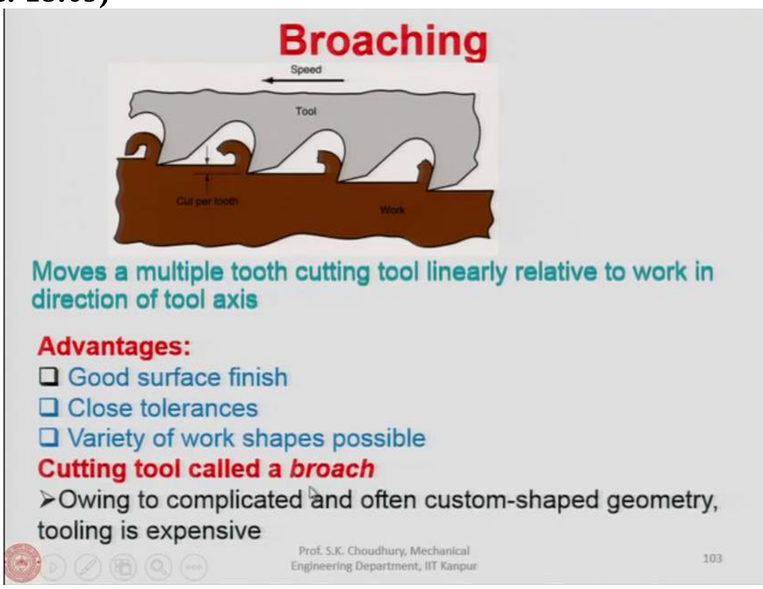


Next is the broaching operation and the broaching operation is very typical operation that we see it is somehow different than the other operations in the sense that here the feed is not given to the tool separately in the sense that for feeding like that concept which we had so far which we have seen in case of turning or milling, the feed in broaching is given by increasingly given the diameter of the teeth. Now, let me explain it to you.

This is given in the horizontal direction, that means, here, the cutter moves with multiple tooth, these are the multiple tooth cutting tool linearly relative to work in the direction of the tool axis. So, if you can see that the depth, of course, it is a 2 dimensional so that is why I am calling it as depth. So, this depth is less than this, this depth, is more this is less than this, this depth is less than the next one and this depth is the less.

This is called the broach. When the tool will be moving, it will be removing this much material and this tooth will be removing this much material. When it will go like this, finally it will be removing the total of this and this. The material which will be removed is the sum of the depth of cut of all the other teeth.

As a result, the last tooth which will be cutting and that that tooth will be taking the finished cut because that is the final cut. That tooth will give the finishing of the workpiece surface. All other teeth will have the rough cutting. This is the advantage of the broaching that here you will get the machining process without giving the feed to the tool and with high precision.

Here specifically the feed motion does not have to be provided and broaching is done for making the slots or making the key holes and for many other purposes where you need really the very high quality and the surface roughness of the flat when it is made or the groove where it is made internal slots. In case of broaching the surface finish is normally better than in other cases.

Advantages are the good surface finish and close tolerances meaning that if we have the tolerance of the hole to be made very rigid, let us say, $\pm 0.01$or $\pm 0.02$, this kind of tolerance can be achieved by means of broaching; variety of work shapes are possible to fabricate.

Owing to complicated and often custom-shaped geometry, tooling is expensive because here the entire brooch is very heavy, which is very big which can be very bulky and entire broach has to be made with the same material and once again I will repeat that the tool material is very expensive,. When instead of making the chips where cutting process will take place, the entire broach tool has to be made with that same material. So, that becomes very expensive. That is why the broaching process becomes sometimes more expensive than other processes.

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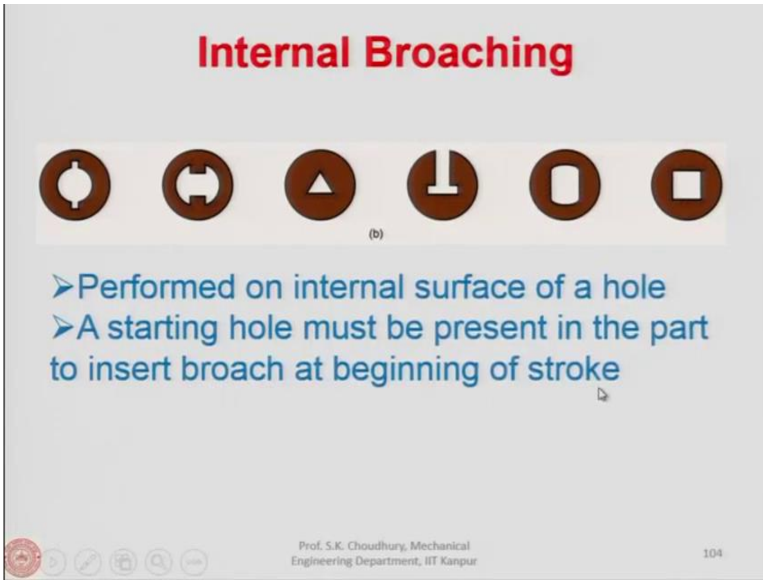


These are the internal broaching shapes. This is the hole with the slots. It may be used for the key holes, this hole is for different types, different types holes can be made here like triangular shape of the internal hole, this is a slot. This is a T-slot, this is another slot with the semi-circular shape and this is the square hole. If you see here that this is a cylindrical surface and this hole is the square hole and that the making an internal square hole is very difficult.

Otherwise, drill will always make you a cylindrical internal hole. If you have to make a square cross section internal hold then the broaching is one of the very few options. Performed on internal surface of a hole, a starting hole must be present in the part because otherwise the broach cannot be operated like a drill. Drill is made on the surface where no hole is made so far. But after a hole is made by drilling, we do the reaming; broaching process is performed to insert the broach at the beginning of stroke.

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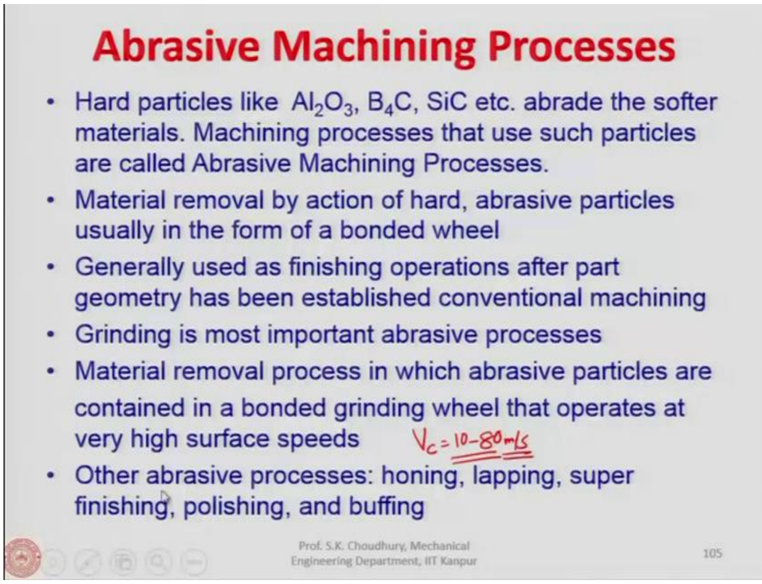


Next topic is the abrasive machining processes. Let us first give you a preamble that why these abrasive processes are used and why these processes are called the abrasive processes. Now, the tool material as we keep telling that these have to be harder than the workpiece material and that percentage is quite high that is from 35 to 58%.

The metallurgists are coming up with the newer and newer materials with the harder property and with the better properties with much more hardness, but those materials have to be machined and has to be shaped and therefore, the tool material that you will be using for machining those hard components they have to be harder than that component. So, there comes the problem.

Of course, there are hard particles like aluminum oxide, boron carbide, silicon carbide those hard particles can be used to machine those, kind of hard materials. But in the nature those hard particles come in the form of grains only like sand, this is aluminum oxide, similarly the silicon carbide, and the diamond. Diamond comes in the crystal form and so on.

To make a tool out of that like grind like cutting tool, they have to be combined together all these grains have to be bonded. That is how the cutting tool is obtained like grinding wheels, that or the lapping or the honing and so on Those hard particles abrade the softer material that is why the process using the grains like aluminum oxide, boron carbide, silicon carbide, they are called the abrasive processes.

If you see here hard particles like aluminum oxide, boron carbide, silicon carbide etcetera they abrade the softer materials as I said machining processes that use such particles are called the abrasive machining processes. The material removal by action of hard abrasive particles usually in the form of a bonded wheel. I said that those grains have to be given a shape of a tool. So very popular is the bonded wheel and that is called the grinding wheel.

All those hard particles, abrasive grains, they are bound together with the help of some kind of glue or resins we will come to that. They are bonded overall and used as finishing operations after part geometry has been established by conventional machining.

Grinding is most important abrasive processes. There are abrasive processes like grinding, lapping, honing and superfinishing. Out of that the grinding is one of the most popular material removal processes in which abrasive particles are contained in a bonded grinding wheel that operates at very high surface speeds.

When we say that the grinding wheel or the grinding process operates at a very high speed that very high speed is normally 10 to 80 meter per second. So, just imagine that this is meter per second and this is a very high speed and therefore if you see the grinding machines, bigger grinding machines particularly, we will see that the grinding wheel is always shielded by a shield which is called the apron.

It is because during the grinding process when it is rotating particularly and it is not balanced properly or a particular part of the grinding wheel breaks in that case that broken piece can act as a bullet literally because it is coming at a very high speed and if that particle or that part of the grinding wheel hits person, the operator for example, then it can be very fatal. Then other abrasive processes like honing, lapping, superfinishing, polishing and buffing are the other processes which are also called the abrasive processes apart from the grinding process.

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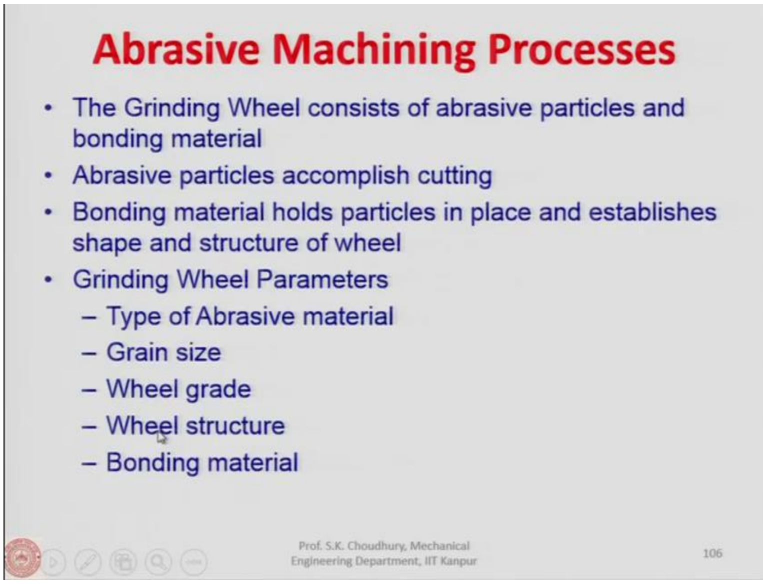


The grinding wheel consists of the abrasive particles and the bonding material because the materials have to be properly bound inside the grinding wheel. So the binding material is important because how strong the grinding wheel will depend on the binding material. Bonding material holds particles in place and establishes shape and structure of wheel

There are 5 grinding parameters: type of abrasive material, grain size, wheel grade, wheel structure and the bonding material. On these 5 parameters the grinding wheel performance will depend like how the grinding wheel is performing depending on the type of the abrasive particles. It depends on the size of the abrasive particles. It depends on the what kind of grade the abrasive wheel has or what kind of structure the abrasive wheel has or what is the strength of the binding material or what is the bonding material is used to fabricate the grinding wheel. All these 5 factors including the bonding material we will have the performance of the grinding wheel defined.

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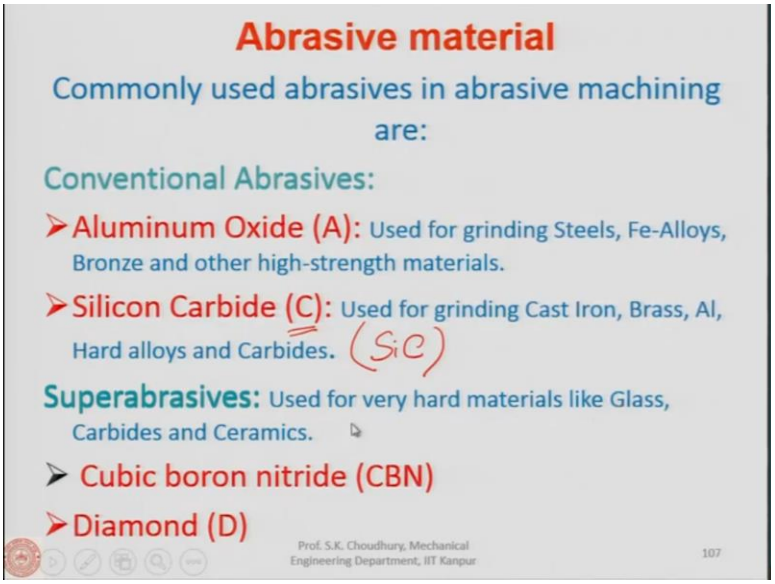


Commonly used abrasives making the grinding wheel or the honing or the lapping are of three types. Basically, we have three types of abrasives which are used: aluminum oxide which is designated by A, silicon carbide which is designated by C and rarely used are the cubic boron nitride CBN or the diamond.

CBN and diamond are for very hard work piece materials. When the work piece material is brittle and hard these are the super abrasives used for very hard materials like glass and they are also very brittle and it cannot be ground without the CBN or the diamond grinding wheel. So most popular is aluminum oxide $Al_2O_3$ used for grinding steels, ferrous alloys, bronze and other high-strength materials.

Whenever there are high strength materials to be ground, the aluminum oxide has to be selected that is the $Al_2O_3$. Silicon carbide is given as a SiC and that is designated as the C and what is the designation I am coming to that will specify the performance of the grinding wheel. Silicon carbide is used for grinding cast iron, brass, aluminum hard alloys and the carbides. Silicon carbide is normally more expensive than the aluminum oxide. They are used for grinding the hard materials. Hard materials normally are also the brittle materials. Now, the cubic boron niride, diamond are used for grinding very hard materials glass, carbide, ceramics etcetera.

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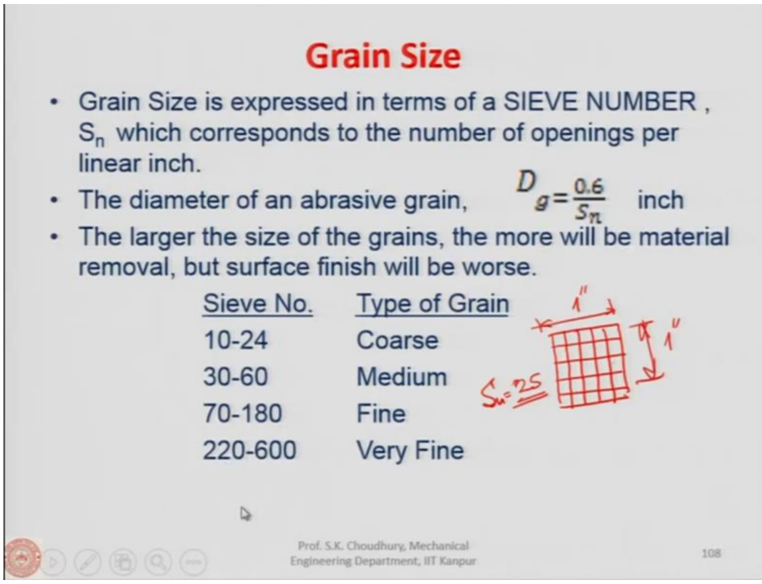


Regarding the grain size that means how we are defining the performance of the grinding wheel depending on the grain size. Grain size is expressed in terms of the sieve number. Sieve number is a $S_n$ suppose, which corresponds to the number of openings per linear inch. What does it mean is the following that just imagine that if you have an opening which is 1 inch by 1 inch, let us say this is the square, this is 1 inch and this is 1 inch.

So how many openings are there. That is given by the sieve number. Let us say these many openings here in this. So, this is 1 2 3 4 5 and 1 2 3 4 5 so, there are 25 openings and the sieve number $S_n$ will be equal to 25 for this. It means that if you have this kind of a sieve and if you put let us say sand on that sieve and then you vibrate it and you will see the particles which are coming.

That will be up to a sieve number of 25 and which will be remaining will be more or different from the 25. Whatever sieve number will be given that signifies the number of openings in 1 square inch that is why it is called the sieve number. Now, the diameter of an abrasive grain $D_g$ let us say will be given by 0.6 by this sieve number.

This is inversely proportional to the sieve number. that more the sieve number less will be the diameter and vice versa, but this is given in inch because this formula is taken from the American source and therefore, in India we have to convert it into millimeter or micron when we are defining the diameter of a grain. This is a mean diameter because it is not really a very round shape to say that this diameter so it can be of different shapes and we take the mean diameter of the abrasive grain therefore, finally you will find out from *(0.6 / $S_n$)* and $S_n$ will be given, $S_n$ number is given in different grades. Like for example 10 to 24 grains are supposed to be the coarse grains.

Because the diameter will be bigger, 24 will be here so it will be bigger diameter then the other like 30 to 60 sieve number will be called as the medium type of grain they are not very coarse but they are little finer 70 to 180 these are the finer grains and 220 to 600 they are very fine grains. So, these sizes are standard international standard and everywhere in the world, we use this kind of a standard to define the diameter of an abrasive grain.

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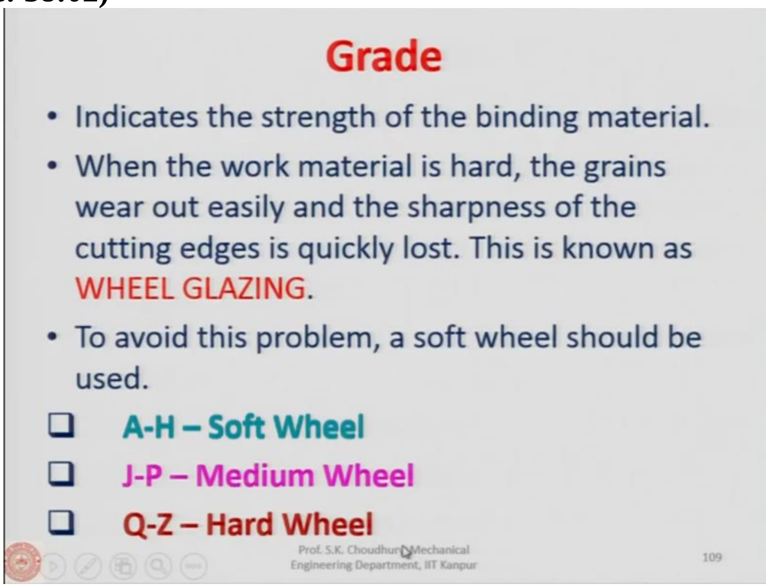


Next is the grade, the grade indicates the strength of the binding material. When the work piece material is hard, the grains wear out very easily and the sharpness of the cutting edges is quickly lost. This is known as the wheel glazing. I will explain to you why it is important. First of all the phenomena is that when the work piece material is hard and the grinding wheel is hard then the grinding wheel will be worn out because the surface is very hard or work material is hard.

But now since the grinding wheel is hard that means the binding material is very hard and it is holding the grain very tightly then that grain will not be dislodged easily and on the surface of the grinding wheel these worn out grains will stay and that is called the glazing because in that case the entire wheel surface will be glazed and will look like it is illuminating the light. So, it is glazed wheel and the glazed wheel not cut efficiently because it will cut less and it will rub more it will consume more power and the more force.

Therefore, it is not effective and we want those worn-out grains to come out of the wheel surface because behind those worn-out grains, we will always have the sharp grains. So, the sharp grains will remove the material more and it will consume less power it will consume less cutting force as well. So, it is always beneficial that on the wheel surface we have the sharp grains and if the sharp grains are worn-out, we have to take them out.

It is desirable that those worn-out grains come out of the surface because otherwise we will not get the sharp grains which are located behind those worn-out grains. To avoid this problem the soft wheel should be used because if the work piece is hard and the grinding wheel is soft then after getting worn out those grains will be dislodged quickly and then the sharp grains will be coming out behind the worn-out grains.

The international standard is that A to H are the soft wheels and the wheels designated from J to P are the medium wheels and those who is designated as Q to Z are the hard wheels. All the 26 letters of English alphabet except the O and I because the O looks like 0 and I looks like 1 so except O and I all the other 24 alphabets are used to designate the grade of the grinding wheel. So once again A to H is the soft wheel and similarly J to P and Q to Z is the hardest. Next to grade is the structure.

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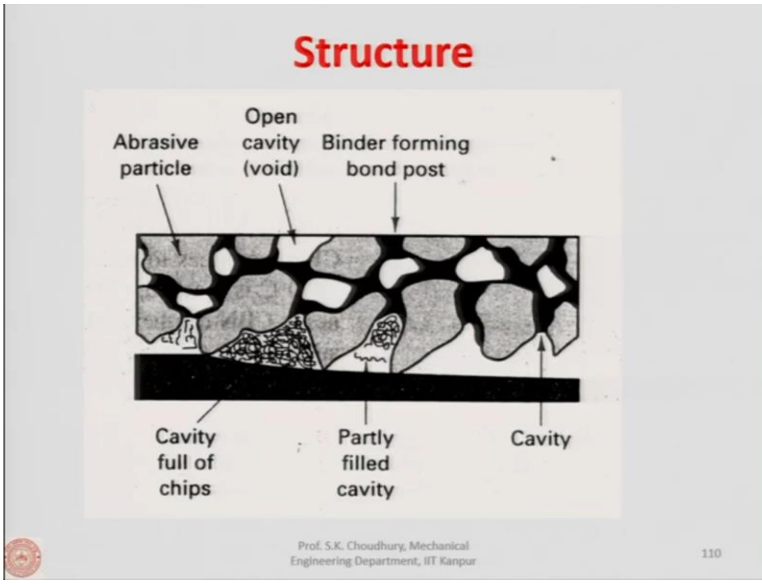


A very enlarged view of the surface of a grinding wheel is shown and you can see that in between the grains there is a void. Void is the space to accommodate the chips like in case of the milling cutters. In milling cutter, I have shown it to you when we were discussing the up milling, down milling that between the teeth there is a space that is called the void and that in those voids the chip is accommodated.

Now, if the void is small, the small chips of the grinding wheel will be entering and would not be able to come out in that case the entire wheel surface will be clogged by the small chips in these voids of the grinding wheel and that is also a bad like in case of wheel glazing In that case since the sharp grains will not be able to be in contact with the work piece and these chips which are clogged in or which are trapped inside these voids they will rub and consume more power.

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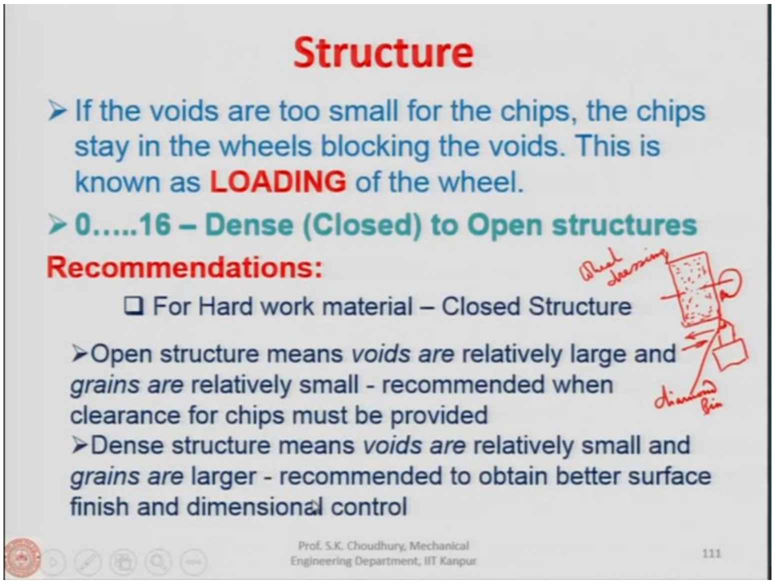

Ff the voids are too small for the chips to stay in the wheel blocking the voids and this is known as the loading of the wheel. So, wheel loading is also not desirable like the wheel glazing. So, in wheel loading case it is the layer of the clogged chips and in case of wheel glazing it is the layer of the board grains. Both of these have to be removed.

That means that layer have to has to be removed and that is done by the following way:
Suppose we have the grinding wheel like this and the glazed wheel or glazed layer or the loaded layer will be on the top. This is the grinding wheel and this is rotating and these are the grains. This is the diamond pin and that diamond pin is used to remove the surface layer from the grinding wheel. It is given the feed to reciprocate.

This process is called wheel dressing. Wheel dressing is done to remove the layer from the wheel surface where either the worn-out grains are there or the clogged chips are there. After this thin layer is removed we will find that the wheel will be with the sharp grains on the surface. That will cut more and will consume less power and so on.

According to the International standard there are 17 grades of structure of the grinding wheels. These are from 0 to 16 like 0 1 2 3 etcetera. These are the dense wheels or the closed structure. Close structure means the voids between them is very small and starting from probably 10, 12 and after that these are the open structures relatively let us say in comparison to 0, the 16 is the most open structure.

That means if the structure is designated by 16 that means the voids are very big and probably there will be a possibility of the chips getting clogged there when the chips are small in case of the grinding. The recommendations are that for hard work material, we need the closed structure and we should select the closed structure as 0 1 2 3 4 5.

Open structure means voids are relatively large and grains are relatively small, recommended when clearance for chips must be provided. These are the wheels with the open structure, where the voids are relatively large that should be recommended when the clearance for the chip is to be provided. Now, the dense structure means the voids are relatively small, opposite to this open structure and grains are therefore larger and that is recommended to obtain better surface finish and dimensional control. This is a dense structure.

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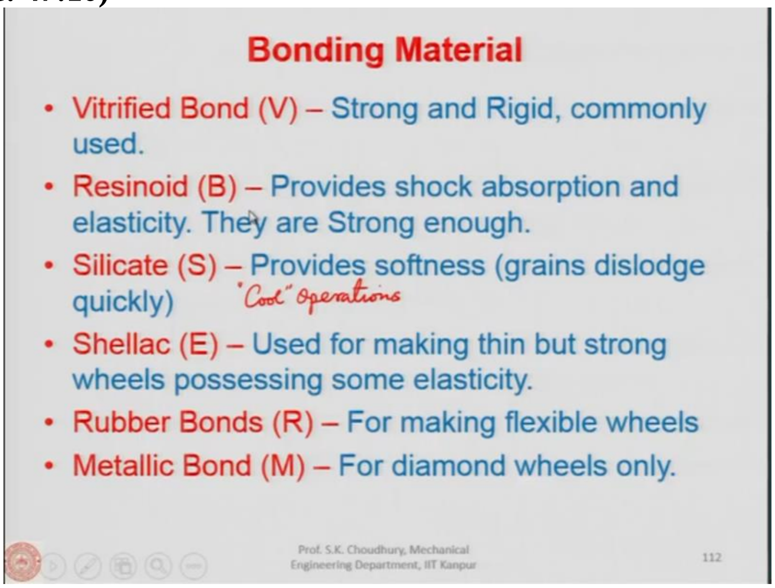


Next to that and finally is the bonding material. There are various bonding materials particularly these 6 bonding materials I have noted down. These bonding materials are vitrified bond, resinoid, silicate, shellac, rubber bonds and the metallic bond. So, these are the most important bonds which are used as binding materials used in case of the grinding wheel. The vitrified bond it is designated as a letter V, capital letter V. These are very strong, rigid, they are commonly used and are available abundantly in the nature, and they are not very expensive. Next bonding material is the resinoid and the resinoid is designated by B. Resinoid provides the shock absorption and elasticity. They are strong enough they are probably as strong as the vitrified bond.

But they can provide a little bit of shock absorption. When particularly there is an interrupted cutting for example, in case of interrupted cutting, each time the tool is entering the work piece and exiting from the work piece there will be a shock of a shocking load or impact loading. Load has to be withstood by the grinding wheel and the grinding wheel may be brittle. Therefore the resinoid is used as a bonding material to overcome that kind of shock load or the impact loading. The resinoid overall provides the shock absorption to some extent but not very high elasticityand they are strong. Silicate is a very important bonding material and very widely used in case of the grinding wheel particularly when we need to have the softness. Softness means the grinding wheel grains will be dislodged quickly. In that case you understand that when the grinding wheel grains will dislodge quickly that means the sharp grains will always be there and once the sharp grains are there on the surface, I already told you that the power consumption and the force will be less. So, the temperature occurring will be less. These kind of bonding materials like silicate are used in further cool operation and the cool operation means those operations where we do not bond the high cutting temperature or the high heat generated. For example, when we have the turning tool with the cutting insert. I have already shown it to you that there are inserts which are used in the milling cutter, the inserts which are used in the turning tool. and inserts which are used also in the drilling or the drill. When those inserts have to be reground, we do not want the temperature to be raised in the vicinity or in that in the vicinity of that edge, because otherwise the vicinity of that edge maybe thermally deformed. In that case the silicate is very popularly used because, it always allows the dislodging of the grains quickly and always the sharp grains will be available on the surface.

So to say there is a cool operation and that cool operation can be performed by the silicate bonding material where the heat generation will be relatively less. Next bonding material is shellac and is designated by E that is used for making thin but strong wheels possessing some elasticity. You can you have seen the elasticity is provided by the resinoid as well to some extent the shellac also can provide the elasticity.

But basically, this is made for the thin but strong wheels. Those thin and the strong wheels are made for parting of the material. Like for example there may be some cylindrical jobs which are very large in diameter and that has to be cut off. When it has to be cut off we want the surface to be of very high quality.
That surface has to be exactly perpendicular to the axis of the cylindrical job. In that case this kind of thin wheels are used. But they have to be strong because that since the diameter is more as it is going inside towards the center, it can vibrate and if it is not very strong it will not withstand and it has to possess some elasticity to withstand that vibration in case it happens in the work piece. Next to that there is another bonding material which popularly used for making the flexible wheels. These are the rubber bonds and the rubber bonds are designated by capital R and finally we have the metallic bond. Metallic bonds are designated by M and the metallic bonds are exclusively used for the diamond wheels.

When the grains are diamond grains, they are bound by the binding material of some kind of metal. Now, if you see starting from the very beginning, we have the abrasive material first they are designated by a letter of the alphabet next is the grain size they are designated by a number, next is the grade again by a letter structure by a number and finally the bonding material as the by the alphabet again the letter again.

These are in sequence first it is by a letter of the alphabet then a number then a letter and so on. The performance of the abrasive of the grinding wheel is given by this number. When we are purchasing the grinding wheel, we have to mention this sequence of the parameters.

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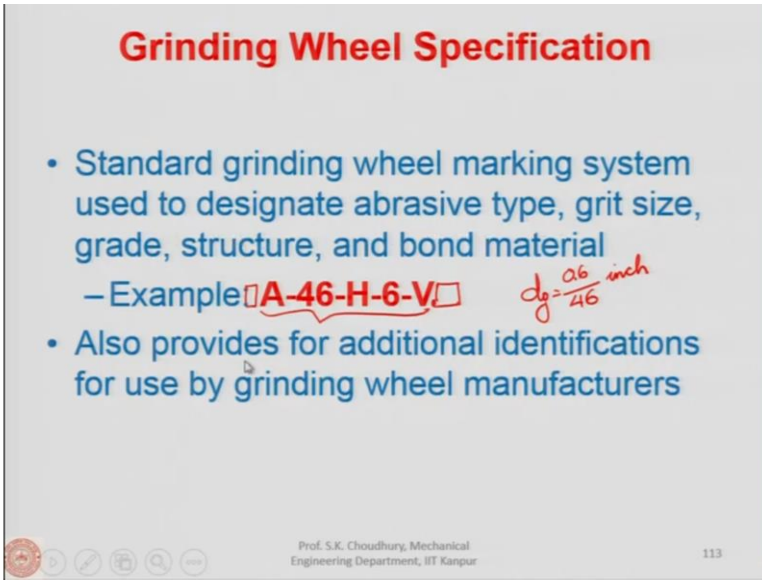


For example, we can say that this is A-46-H-6-V. That means the abrasive material used is aluminum oxide. The size of the abrasive grain is 46 and the diameter of the grain we can find out, that $0.6/S_n$. So, we can find out that this diameter will be 0.6 / 46 it is in inch that you can convert to micron. Next is the grade. In the grade I will show it to you that this grade is for the soft wheel A to H then 6 is the structure and we have said that 0 is the dense structure that is a closed structure. This will be the relatively close structure and V is the vitrified bond this is the vitrified bond which is strong and rigid and commonly used.

So if you tell that you need this kind of grinding wheel or if you have a grinding wheel with this performance, you will be knowing that these grinding will be used where. For example, this grinding wheel cannot be used for grinding cast iron, why? Because we have this limitation that aluminum oxide used for grinding wheels or grinding steel material ferrous alloys bronze and for cast iron which is the brittle material and hard material.

For that you need to have the silicon carbide. Second thing for example here is the size so you cannot use that for very finishing operation because this is the coarse grain not very fine grain because it is inversely proportional to this number. This grinding wheel is not for the finish operation and so on. So, suppose you need to have a particular surface roughness, a particular material that is being ground, a particular condition that is given to you of the work piece material and the parameters, in that case you have to judiciously select that. What should be the grinding wheel and you have to tell only in this way. There could be a manufacturers code here and at the end. So, the manufacturer of the grinding wheel may have their, own code here in the beginning and at the end.

But these are the five parameters by which the performance of the grinding wheel will be defined. It is written that standard grinding wheel marking system used to designate the abrasive type, grit size, grade structure and bond material. By this also provides for additional identification for use by the grinding wheel manufacturers in the beginning and or at the end. So, this is the complete signature of a grinding wheel like.

You must remember that we have discussed the tool nomenclature. Let us say turning tool nomenclature there we had the 6 angles and the tool nose radius by 7 parameters we were defining the type of the tool that we are designating or we are using similarly in case of abrasive wheel. We designate the abrasive wheel performance by this and while purchasing the grinding wheel, you have to mention this kind of 5 parameters. So once again these 5 parameters are the abrasive materials.

These are the aluminum oxide, silicon carbide and so on, grain size grade structure 0 to 16 and the bonding material. Rest of the material I will discuss in our next discussion session. Thank you for your attention.