Polymer Assisted Abrasive Finishing Processes
(Grinding and Polymer based Grinding Wheels)

Dr. Mamilla Ravi Sankar
Department of Mechanical Engineering
Indian Institute of Technology, Guwahati

Lecture - 04

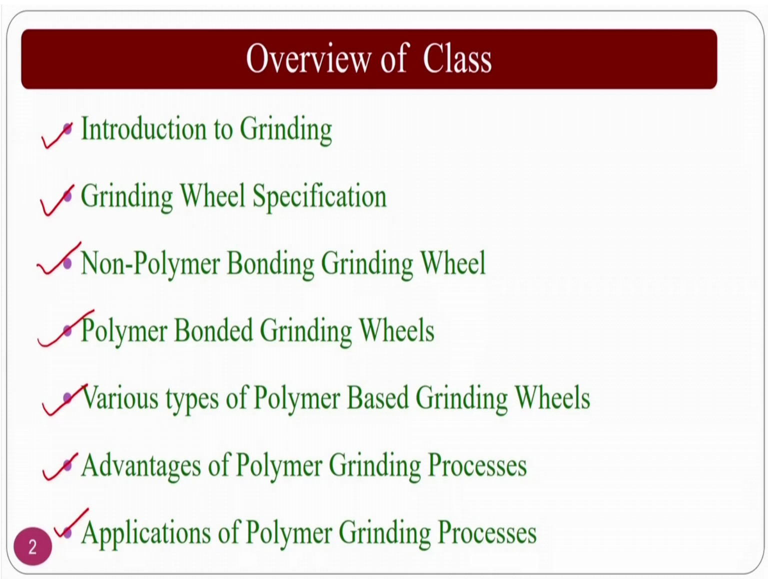
Introduction to Grinding and Polymer Assisted Grinding Wheels

In today class we are going to see about the Grinding and Polymer based Grinding Wheels. Since our particular course is about Polymer Assisted Abrasive Finishing Process, the first and foremost process that one can get the feel of this process is grinding basically ok.

So, the grinding wheels also made up of polymer bondings ok. There is one concept called bonding for that purpose we will see what is grinding? An introduction to the grinding and we will see what are the specifications of the grinding wheel, in that one we will get polymer based bond and polymer based grinding wheels. For going into the polymer based grinding wheels, we should understand the basics of the grinding process and grinding wheels specification.

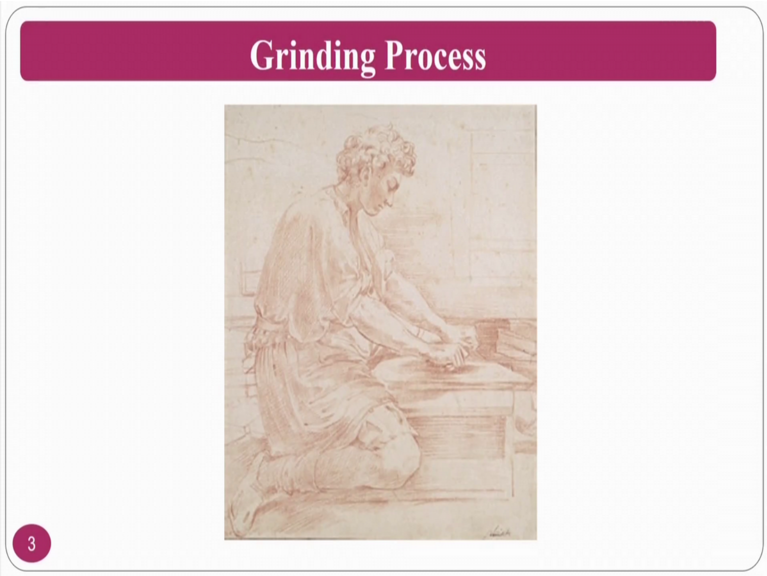
First we will see the overview of the class we will see about introduction to the grinding process.

(Refer Slide Time: 01:30)



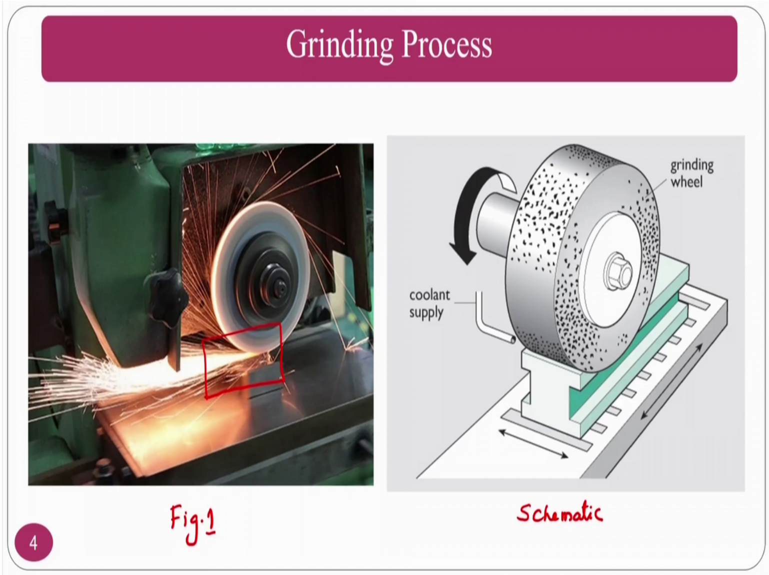
Then, we see about the grinding wheel specification, because grinding wheel specification leads to the polymer bonding and other things. Then, we will see the non-polymer based bonding grinding wheels and polymer bonded grinding wheels. In depth we will go into the polymer bonded grinding wheels what is meant by resinoid based, what is meant by rubber based grinding wheels and other things. Various types of polymer based grinding wheels as I said just now, that rubber based resin based and other things. And, advantages of the polymer grinding processes and applications where all these processes can be used compared to vitrified bond that is clay bond metallic bond and other things.

(Refer Slide Time: 02:24)



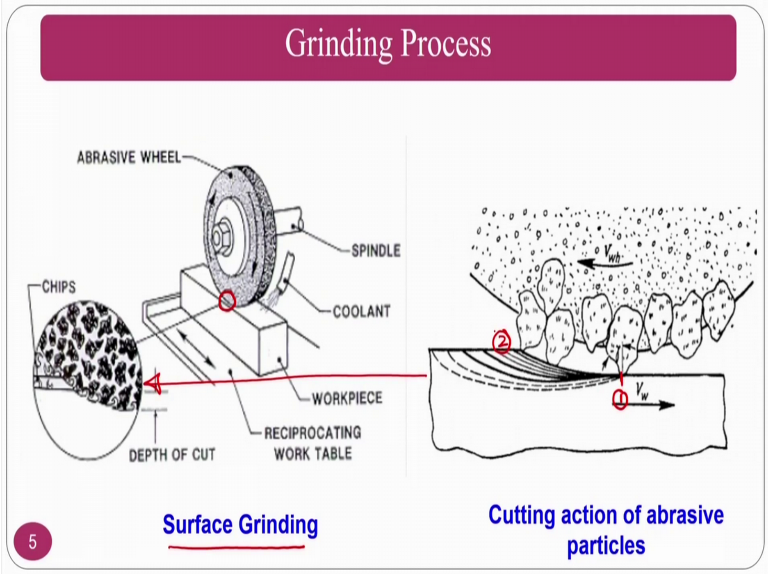
So, grinding process as you can see it is one of the primitive processes, which are used basically for medicine preparation and other things.

(Refer Slide Time: 02:33)



And later on the grinding process move for finishing applications in the early stages. Nowadays, this process is also called as one of the machining processes; because you would not only look for the surface finish, you also sometimes uses it for the material removal applications also. The basic problem that we have seen in introduction to this particular course thermal aspects in come into picture, because if you see the figure one the basic thing is there is a lot of spark generation and because of each not only the surface finish that you will get, but also thermally destroyed layers also will be form. So, for that purpose people will use some of the advancements like cutting fluid, green cutting fluid and other things. So, the normal schematic representation you can also see in figure 2 ok so, how the grinding wheel schematically represent and, how it is going to do the finishing process or the material removing process on a block of material.

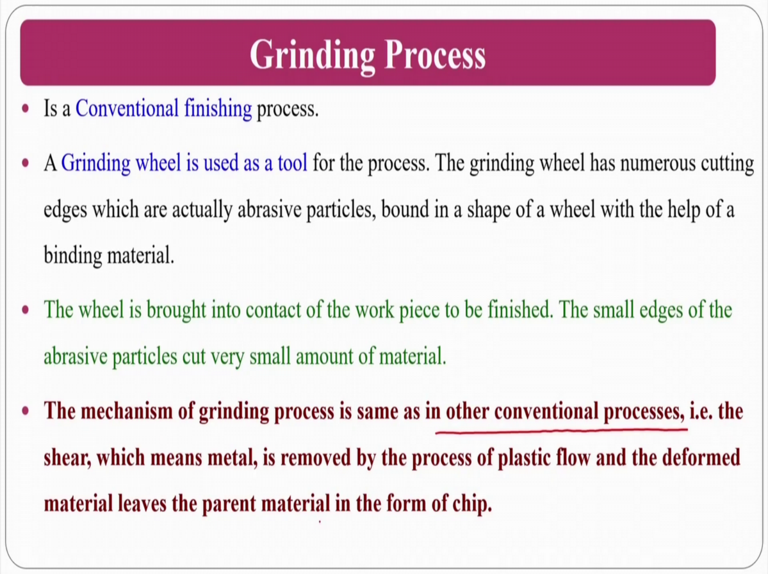
(Refer Slide Time: 03:44)



So, the grinding process, if you see the grinding process the basically it is a abrasion process where the material is removed by the action of micro cutting or sharing action. If you see the zoomed version of the grinding wheel in the surface grinding process, the abrasive particles are located on the periphery and this will try to remove the material. It starts from the 0.1 and it will move up to 0.2. So, that it will form a chip and shearing action will takes place.

Gradually these one by one abrasive particles will involve in the shearing action and the material removal will takes place nothing, but the shearing action of the material will takes place as we have seen in introduction that saviour plastic deformation will remove the material from the machining region.

(Refer Slide Time: 04:43)

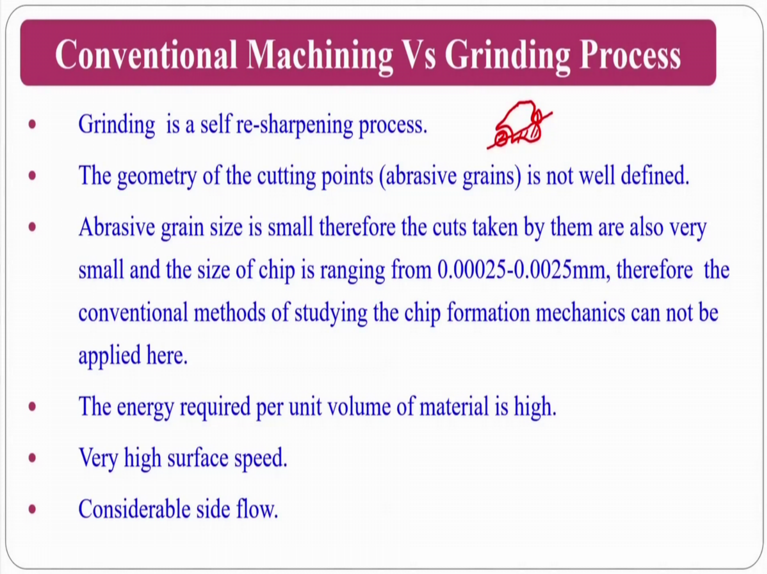


So, the grinding process it is one of the conventional finishing process in those days people uses it for the finishing process compared to turning milling and other thing. And, the grinding wheel used as a tool, which is a multipoint cutting tool. Since many abrasive particles are there on the periphery of the grinding wheel. So, it will be always treated as a multipoint cutting tool.

The wheel is brought in to the contact of the workpiece to be finished the small cutting edges will remove the material in small amounts, that is why the chips are very tiny in nature, that is why the energy required to remove the same amount of material compared to turning process it will be always high. There is one concept called size effect the people who want to know about the material removal versus energy requirement in the manufacturing process, you can just go through the size effect what is size effect and other things.

The mechanism of grinding process is the same in like other conventional process; like shearing and it is removed by the plastic flow and deformation of material leaves the parent material in the form of a microchip or a chip. This is what the basic material removal mechanism in a grinding process.

(Refer Slide Time: 05:58)



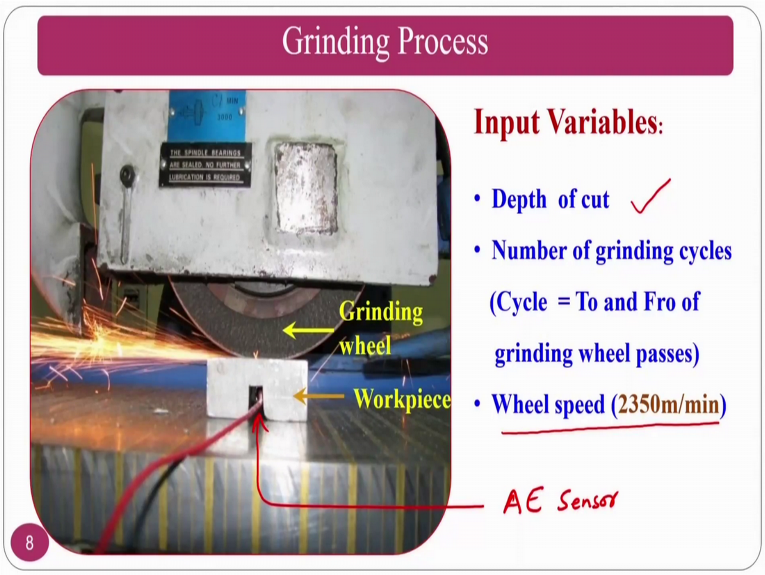
So, the conventional machining versus grinding; grinding is a self resharpening process; that means, that grinding wheel comprises of bonding material as well as the abrasive particles. The abrasive particles are on the surface of the grinding wheel. Once this dislodges a set of layer of the particles dislodges next set of layer will come into picture, or the abrasive particles basically they are random in shape that you can come across in upcoming slides and these are brittle materials. If you take silicon carbide or alumina these are brittle material assume that this is a brittle fracture. So, this is gone so; that means, that skin it has it is own cutting edges; that means, that it is giving the brittle fracture of the abrasive particle gives rise to a new cutting edges ok.

In this circumstances cutting edge 1, cutting edge 2, will come into picture and it is nothing, but the self resharpening. The geometry of cutting points is not well defined; that means, that the abrasive particles are randomly oriented and random cutting edges will be there on the abrasive particle.

So, normally this abrasive particles are very small in size, because of which what will happen the size of the chip that cut by this abrasive particles is also very very small, but whereas, in conventional machining like turning process and other process what will happen the chip sizes are much bigger. The energy required for unit volume of material removal is high compared to the conventional process and very high surface bits are required. Normally, grinding wheels rotate and an average in the range of 3000 rpm 4000 rpms and other thing. In a conventional machining process like turning process and other things the rpm of the workpiece will be around 1000 rpm or something ok; that means, that the grinding wheels operate at slightly higher rpm compared to the conventional turning process.

Considerable side flow, because normally in a single point cutting tool we assume whenever we have derived the equation, then it would not be any slide flow here. Here considerable amount of the slide flow will be there in the grinding process.

(Refer Slide Time: 08:18)

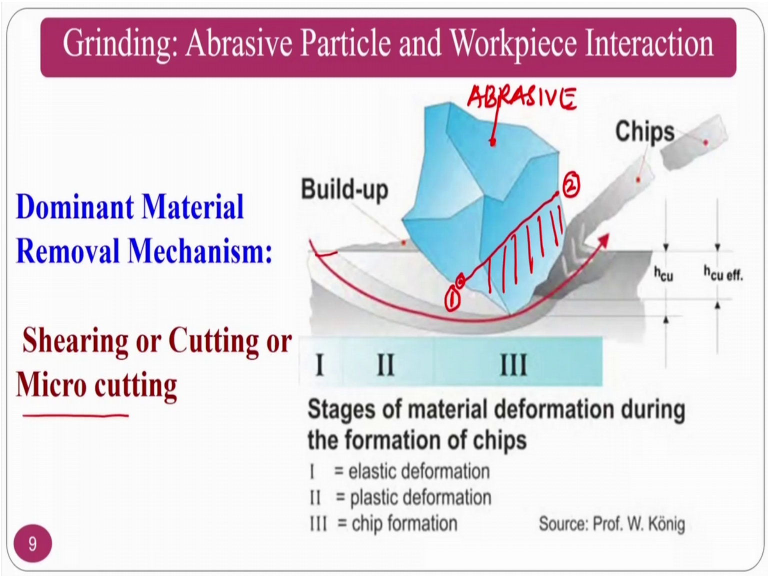


If, you see the grinding process normally the input variables that one can give is depth of cut how much you are going to give ; that means, that radial depth of cut that you are going to give. So, normally the radial depth of cut you will give in this terms like 5 microns, 2 microns, 10 microns, are something and the number of grinding cycles so, whether it is corresponding to and fro of the table and wheel speed. Normally, wheel speed some of the machines will have constant wheel speed; some of the machines will have variable speed and other things.

And, if you see in this picture what you can observe here is that online monitoring also you can do in the finishing process, or especially in the grinding process. In this one what you are observing here is acoustic emission sensor a AE sensor is placed ok. So, normally whenever there is a elastic waves that is generated because of the material removal action by the grinding process, that will assess in the form of the acoustic emission signal in the time domain, then you process it to the frequency domain. And, you can correlate what is the finished that you have achieved corresponding signals in the frequency domain and other things ok. This can help in online monitoring of this finishing process.

The main motto of telling this particular acoustic emission signal versus the surface finish, very less vapours are available against the grinding in acoustic emission. Especially the people who are interested they can look into the composites machining. In composites machining, you can check what is the signal that you are achieving, when you are machining the matrix material, what is the signal that you are getting in reinforcement, whenever the grinding wheel is machining at the reinforcement, whenever it is interacting at the interface. So, you will get more in depth details and those people who are doing masters and PhD, they can go ahead with online monitoring of surface finishing using grinding or any other finishing process with acoustic emission sensor or some other sensors that and you can correlate the surface finish versus the signal.

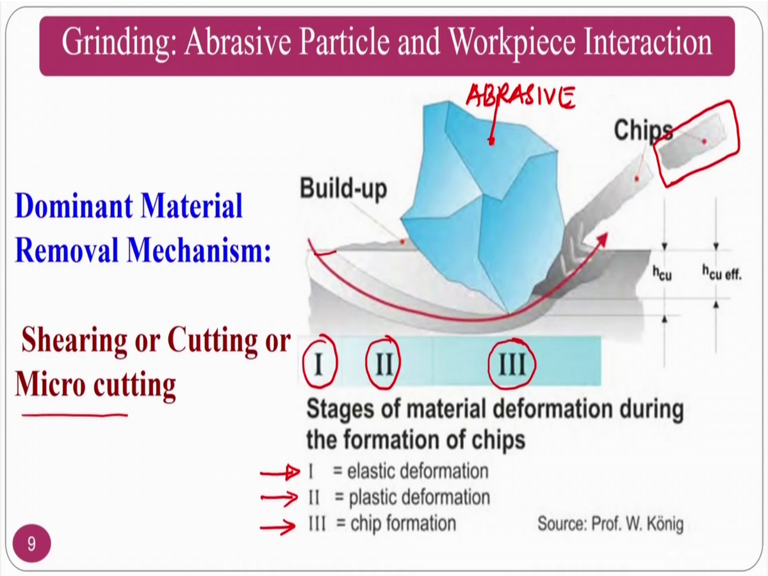
(Refer Slide Time: 10:47)



Normally, the dominant material removal mechanism here in the machining process is shearing or micro cutting, that you can clearly see that we have seen in the previous slide also; that this is a abrasive particle. As you can see the abrasive particle is random, the abrasive particle is random shape and the cutting edges also random.

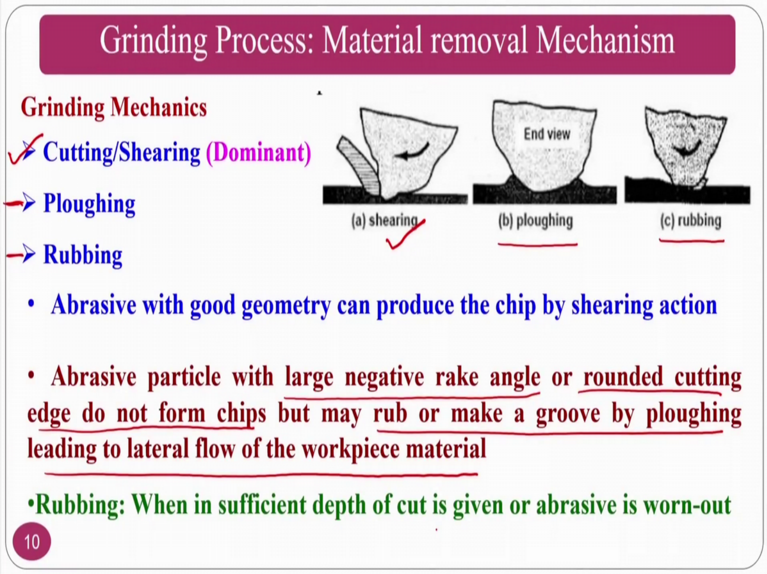
Assume that it is broken. As, in the previous slide self resharpening process assume that this is broken like this ok. This portion is gone the shaded portion is gone; that means, that this particular point 1 become another cutting edge point 2 will become another cutting edge. And, it will have multiple cutting edges based on the fracture and other things that is what self resharpening effect of the grinding process. And, if you see the finishing action here it will be done in 3 stages.

(Refer Slide Time: 11:54)



One stage one it is elastic deformation and stage 2 normally if you will have plastic deformation, and stage 3 the chip formation will be done, that you can see the bottom. So, that the material will remove in terms of microchip and goes off this is the microchip that is generated and goes off. This is not only a function of the finishing process or the grinding abrasive particle, but also it is the function or the chip sizes, it is also function of type of material, whether it is a ductile material, whether it is a brittle material or any other material ok.

(Refer Slide Time: 12:35)



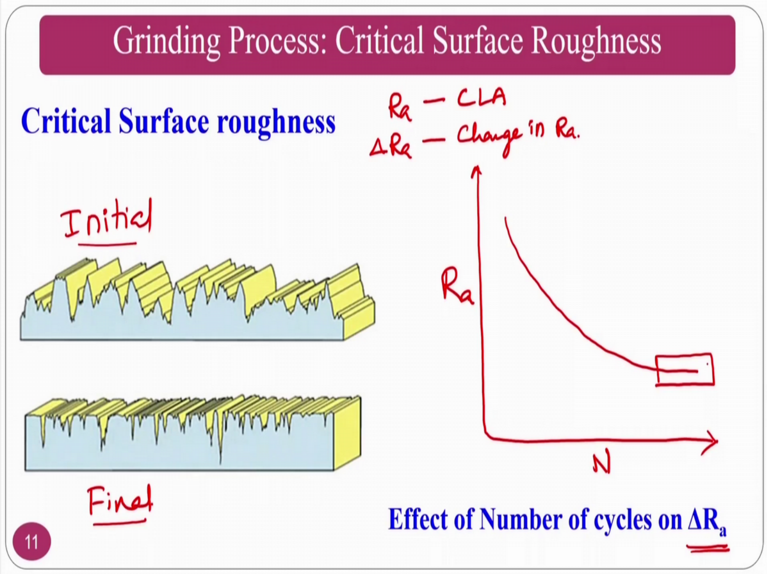
So, the material removal mechanism as I said the dominant mechanism is micro cutting or cutting with respect to the workpiece material. And, other 2 mechanisms also is there in the textbooks that is nothing, but the ploughing and you can also see the rubbing if you are giving sufficient amount of depth of cut then the shearing action will be dominating or micro cutting will be dominating.

If you are not going to give the sufficient cut or if you are going to give less depth of cut and very soft materials, in that circumstances what will happen ploughing takes place. Ploughing is taken from how do the farmers plough and other thing ok. Whenever you are removing this material this remove material will fall into the next sector, whenever the abrasive particle will go there again it has to interact with the same material.

Rubbing action is another common phenomena, whenever you are going to give very very minimal depth of cut like less than on micron or something. If there is no sufficient depth of cut in that circumstance just it will slightly move by rubbing on the surface because of which there will be a burning action of the surface will takes place. So, abrasive particles with large negative rake angle or round cutting edge do not form chips this may rub and make groove by the ploughing leading to lateral flow of the workpiece material. This is called ploughing.

So, in sufficient depth of cut at the same time if you are abrasive particle is not sharp enough in that circumstances ploughing action will be dominated. And, rubbing when the insufficient depth of cut is given to abrasive or and this will create the rubbing action.

(Refer Slide Time: 14:28)

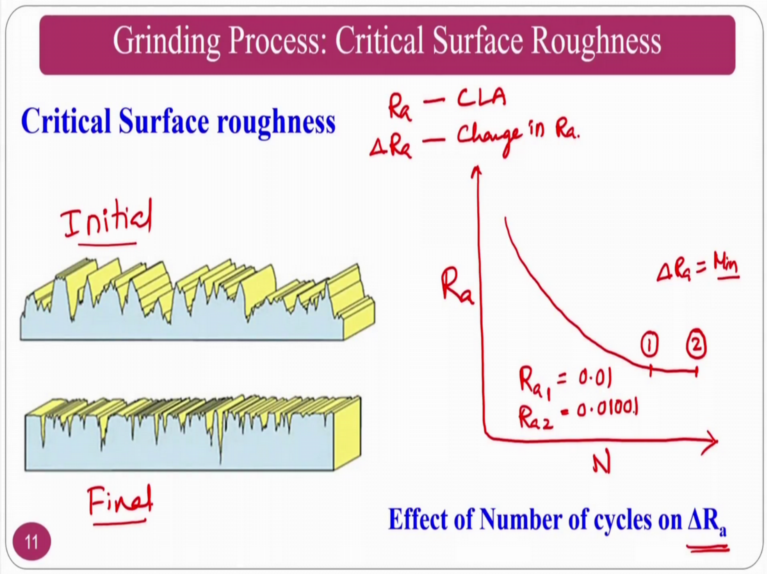


Normally, the basic problem with the rubbing action is it will burn out the surface. So, whenever you see the surface, it surface look like it blackish and other thing. So, the critical surface roughness, because we are talking about the finishing process that is why we look into the grinding process as the finishing process or as the conventional finishing process. Critical surface roughness is the roughness beyond which the change in roughness is very very minimal. This is my initial surface and this is my final surface or pre final you can say. So, whenever you plot the effect of number of cycles on delta R a R ok. So, this is number of cycles assume that you are going to plot with surface roughness only ok. Change in R a delta R a is nothing, but change in surface roughness; that means, the initial minus final.

So, you should always understand what are the parameters that I am writing on the y axis? If, I am writing R a ; that means, this is CLA value, that is centreline average value delta R a if I am writing; that means, that it is change in R a change in surface roughness value ok.

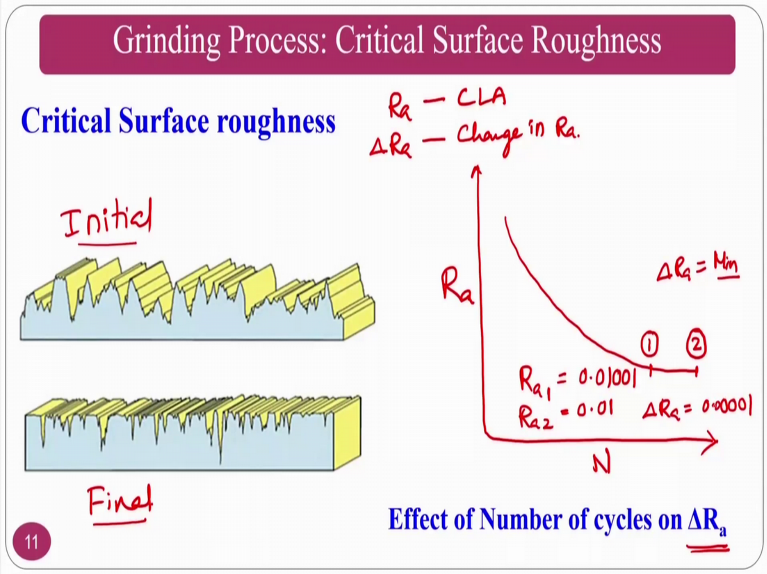
Assume that if I am writing R a, the surface roughness value. The surface roughness value in a grinding process, if I see initial and if I see the final the final is less than initial; that means, that; obviously, it will be go in this direction ok. So, the change in R a here is approximately minimal that is nothing, but the critical surface roughness; that means, assume that if I am going to take 0.1 and 0.2.

(Refer Slide Time: 16:31)



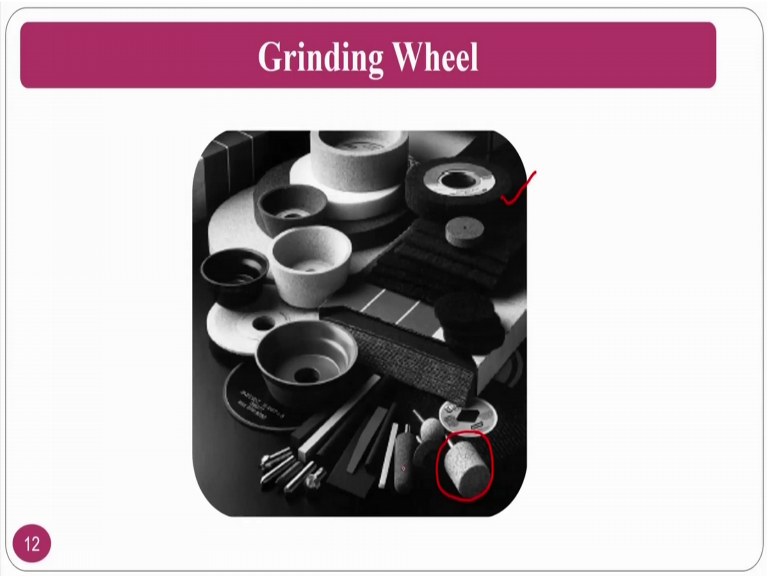
Assume that if I am taking point 1 and if I am taking point 2 the change in R a delta R a is approximately minimal, then if I am going to increase the machining time or if I am going to increase number of cycles also there would not be much change in the surface roughness. So, it is mere waste of the energy that I am going to give to the machine. So, you can stop the machine there and you can say that this is the critical surface roughness. The critical surface roughness is nothing, but the change in R a or the change in surface roughness will be very minimal. As per example if I tell in the other way, R a at point 1 is 0.01. R a at point 2 is 0.01001. Then there is no much change, but here in this range it may slightly fluctuate are like that it may go or it may go down. Normally, it may not go up you can say it go down only. Sometimes, it may be error in calculations also or you can for better understanding you can say in R a 1 it is 0.001 and in the case point 2 it will be 01 ok.

(Refer Slide Time: 17:54)



In this case the delta R a is approximately 0.011. What is the delta R a? In this condition it is 0.0001. So, it is approximately very less value. So, you can stop that is nothing, but the critical roughness value.

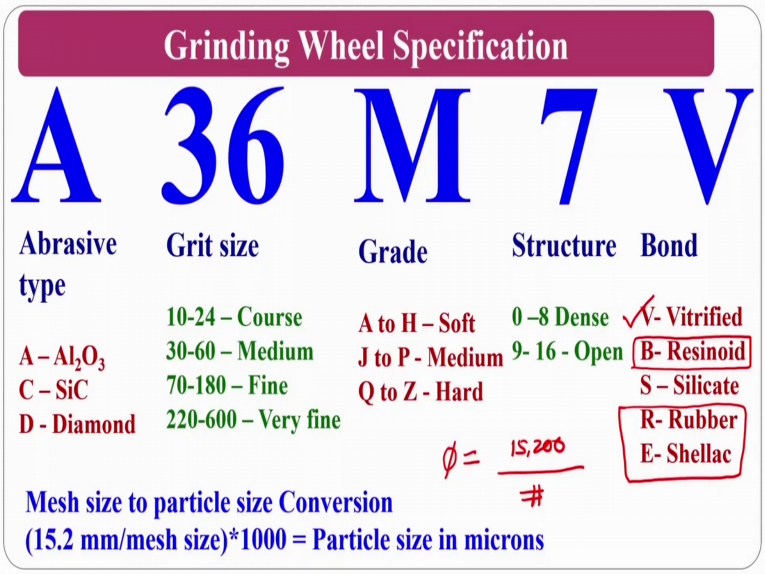
(Refer Slide Time: 18:25)



Now, our intention in this particular course is to understand about polymer grinding wheels. If, at all I want to understand the polymer grinding wheels, as a part of polymer assisted abrasive finishing processes, we should know how the wheel is fabricated, how the wheel is specified and other things. For that purpose, we are going into the wheel how it is specified and other things. If, you can see the wheels many types of grinding wheels are there, like surface grinding wheels are there cup shape tool and cutter grinders are there, many many varieties of cylindrical grinding wheels are there, and you can see as per your requirement like form grinding and other things ok.

So, we will see how the grinding wheel is specified. Normally, the grinding wheel specified in terms of many variables. For example, let me explain with the example.

(Refer Slide Time: 19:26)



That is a 36 M 7 V this is one specification of a grinding this specification a stands for abrasive type. Abrasive type means, whether it is aluminium oxide, whether it is silicon carbide, whether it is diamond, whether it is CBN or any other abrasive particle 36 stands for grit size ok.

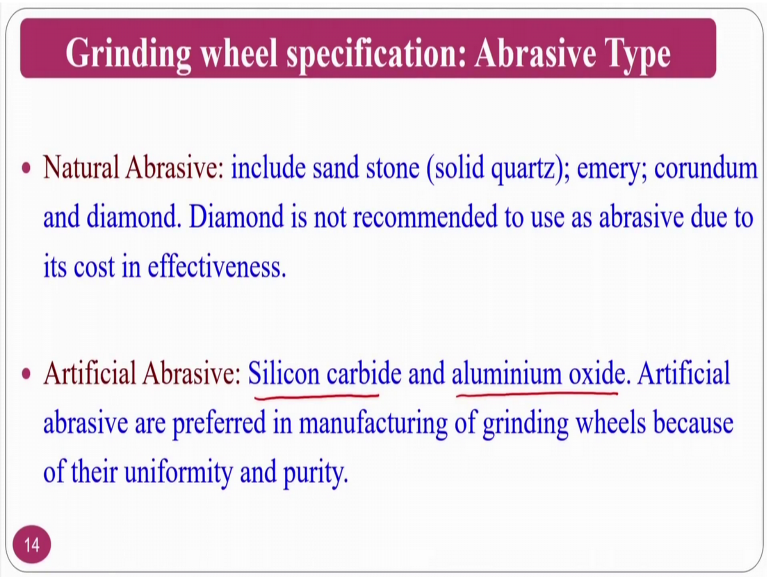
So, if the grit I will explain these things in upcoming slides also the grit stands for particle, if the grit size stands for the mesh. So, if the mesh is number and the abrasive particle or inversely proportional. If my grit size is less or you can say that this is mesh size also. The normally mesh size and abrasive particle size are inversely relevant ok. If your mesh size is low in number; that means, that my particle size is big.

And, details will come in the upcoming slides M stands for grade is nothing, but how the bonding material is holding the abrasive particle? Whether it is holding firmly or whether it is holding loosely that tells the grade. 7 stands for structure; structure means how many abrasive particles are placed in a unit space? If, the abrasive particles density in that area is very high that is nothing, but the dense structure. If, it is low in number then it is called open structure, V stands for bonding, here the V specifies vitrified bond.

But, as for the course is concern we are going to study mostly about the polymer based abrasive grinding wheels such as Resinoid bonding, rubber bonding, and shellac bonding. These are comes under the polymer, but silicate normally it is one type of glass. So, it would not come under polymer. So, we will study about resinoid bonding, we will study about rubber bonding, we study about shellac bonding where all these abrasive wheels are used for what applications and other things we will see.

So, mesh size to particle size conversion normally assume that particle size diameter equal to 15.2 mm you can convert into microns by mesh size ok. So, if at all you want to convert into microns, then you can go 15,200 you can convert into micron size.

(Refer Slide Time: 22:14)

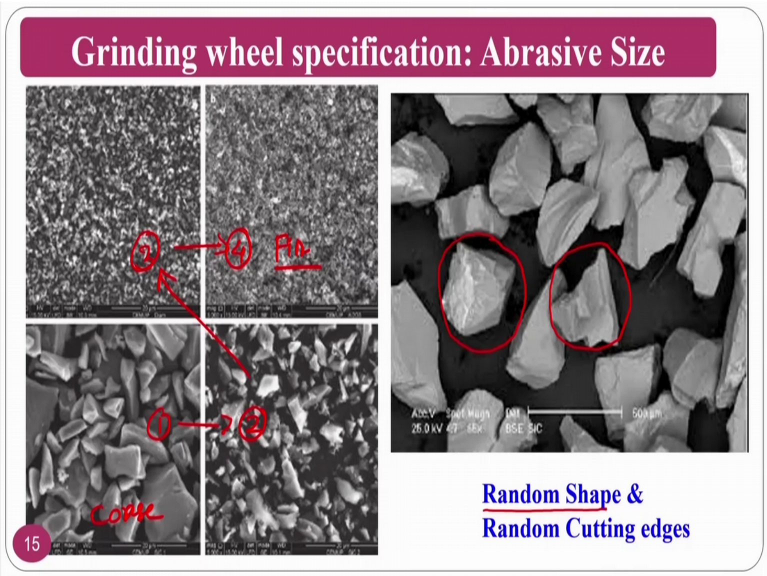


So, the abrasive type there are multiple varieties of abrasives one is natural type of abrasives; like diamond, quartz and other things. Normally use one in the natural case is diamond particles, artificial abrasive particles are enormously there in the market. Those are economic and you can use that mostly and abundantly and economically available abrasive particles are 2. As for the Indian market is concerned silicon carbide as well as aluminium oxide ok. You can also get cerium oxide and other things may be these are slightly costlier than the silicon carbide and aluminium oxide.

So, the mesh sizes commonly available in the market you can get is 80 mesh size 220 mesh size 180 mesh size 400 600 800 1200. This is the commonly available mesh sizes that in the Indian market. And, those people who want to procure this material these are not costly. Silicon carbide particles 2 20 mesh size assume that if you want to purchase 1 kg. As per the current cost is concerned it may be less than 500 rupees ok.

So, you can get this particular material for your application and you can use it also for your finishing applications or if you want to fabricate a grinding wheel, using polymers as a bound binding material and other thing you can generate. And, some people if you want to make a small grinding wheels or using polymer bonding or vitrified bonding and other things you can procure the silicon carbide particles or alumina particles and you can prepare easily, but only thing is that you should know the standard processor of making the grinding wheels.

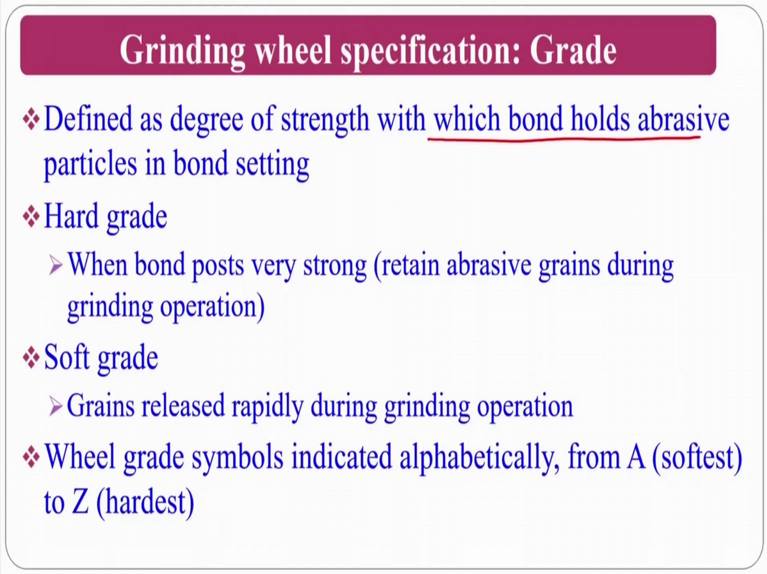
(Refer Slide Time: 24:07)



Abrasive sizes as I said coarse these are coarse and these are the fine or you can say super fine or something ok. So, the abrasive particle is big that mean that it is coarse as, if at all you want to make it Nano particle size, then what you have to do is you have to go for the ball milling operation. And, you can convert from 1 to 2, and 2 to 3 you can convert, and 3 to 4 you can convert using ball milling action ok.

So, what you have to note in abrasive particles is that the shape is random. You can see any particular abrasive particle all the abrasive particles are different. At the same time their cutting edges also different. For example, if you see this is the cutting edge and for other material this is the cutting edge. So, these cutting edges are completely different and these are randomly oriented. As, I said that this is a self resharpening process; for example, this abrasive particle breaks here. So, it will generate again a new cutting edge. So, that is how this process work and it has it is own importance in the arena of manufacturing.

(Refer Slide Time: 25:33)

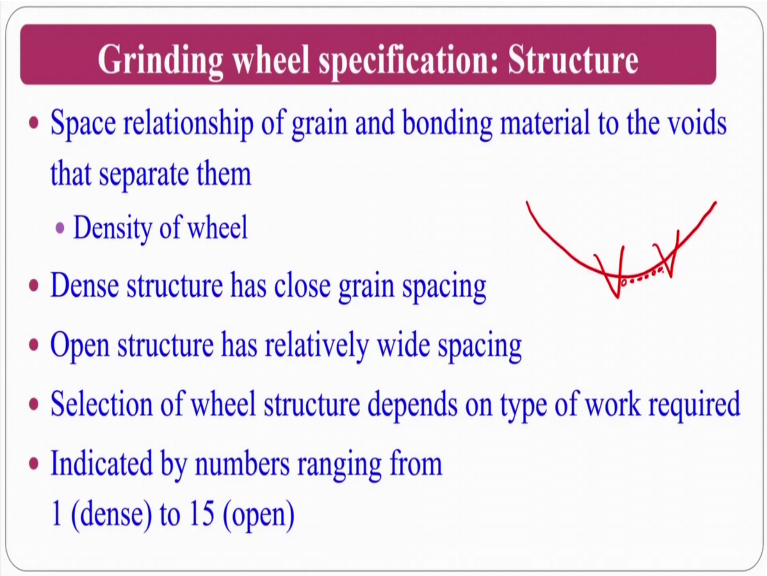


As, I said the grade define degree of the strength with which the bond holds abrasive particles that mean that I am going to have a rubber bond, where my matrix material is rubber. And, how the rubber is holding the abrasive particle, whether it is holding firmly, or whether it is holding loosely that will decide the grade.

Hard grade when the bond post very strong; that means, that the holding ability of rubber which is a matrix material of abrasive particle is very strong; that means, that it is hard grade. Normally, hard grades is used for softer materials and the soft grade means these are held the abrasive particles are held softly; that means, that this can dislodge from the grinding wheel easily these are normally used for hard work pieces.

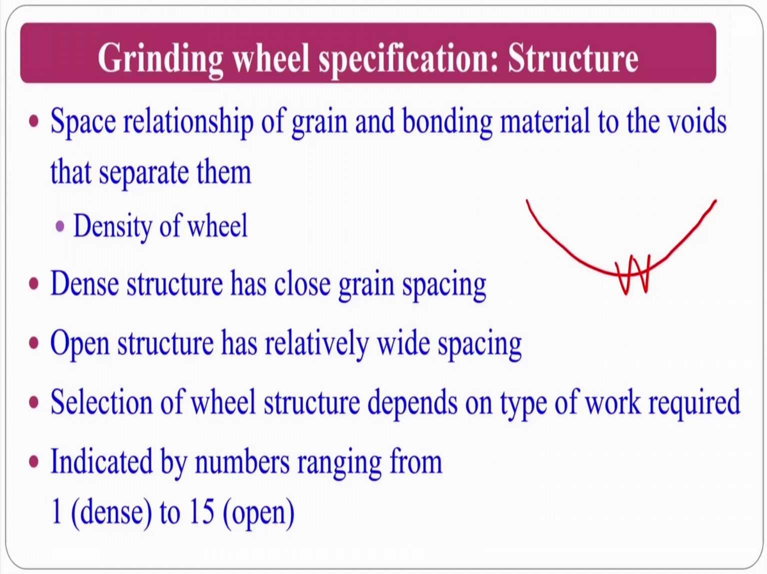
Wheel grade symbols indicate alphabetically from A to Z, why I am saying is if you have a hard grinding wheel versus hard work piece, it cannot dislodge at the same time it cannot remove the material. Because of which wheel problems will come, I am not going to discuss about wheel problems like wheel loading, glazing and other things. If at all you want some details about this there is another course that is called abrasive based machining and finishing processes, that you can go through where you can see what is the circumstances that causes the wheel loading, what is glazing, how these problems can be solved like truing and dressing and other things, you can see in that course that course name you can type in YouTube, that is called abrasive based machining and finishing process.

(Refer Slide Time: 27:25)



Next comes the structure the structure, if you see the space relationship between grain and the bonding material to the voids and separate them. This is nothing, but the density of the wheel. Basically this tells the how the abrasive particles are placed in a grinding wheel. As, I said if you are using a rubber bonded abrasive wheel, if abrasive particles are nearer assume that this is my grinding wheel if my abrasive particle is like this is called open structure.

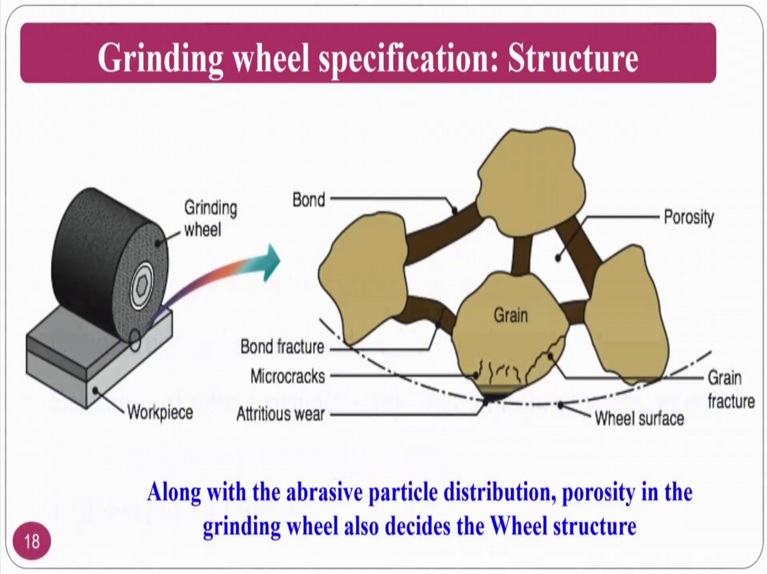
(Refer Slide Time: 28:06)



Instead of that one if my grinding wheel abrasive particles are placed very closely that; that means, that it is called closed structure ok.

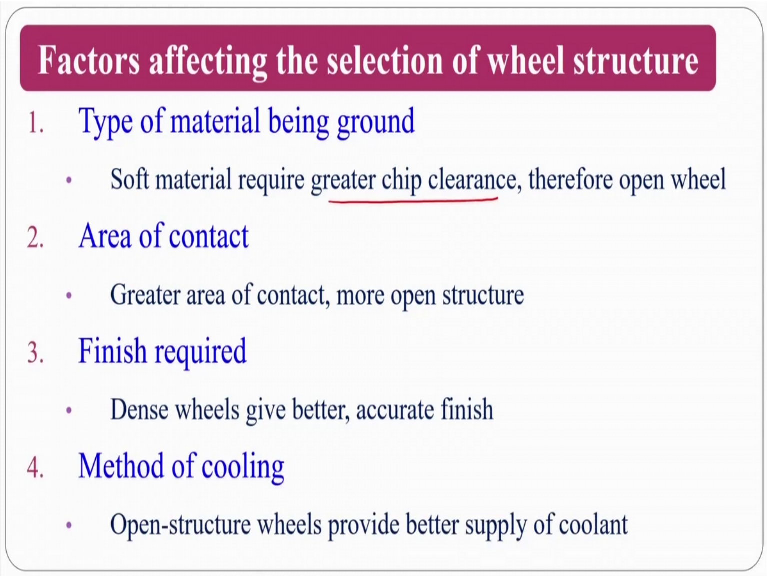
So, when you will use closed structure, when you will use the open structure, this also depend on which type of material that you are going to finish. If, you are going to finish soft material that mean that material removal will be high. So, you need open structure. So, that the material that is coming out can be accommodated here, assume that this is open structure is there I have little big gap where I, it can accumulate the material for the soft. If it is hard material in that circumstances you need closed or dense structure. In dense structure the material number of abrasive particles will be more and this will counter the work piece material to be removed.

(Refer Slide Time: 29:00)



As, you can see not only the abrasive particles spacing, but also voids that are generated between the bonding material and abrasive particles will also decide the structure ok. So, the spacing between abrasive particles and the voids also generated are nothing, but the force. So, some of the grinding wheels deliberately they may be giving this porogens and they fabricate the grinding wheel. So, that there will be some pores generated in the grinding wheel, this is nothing, but the structure.

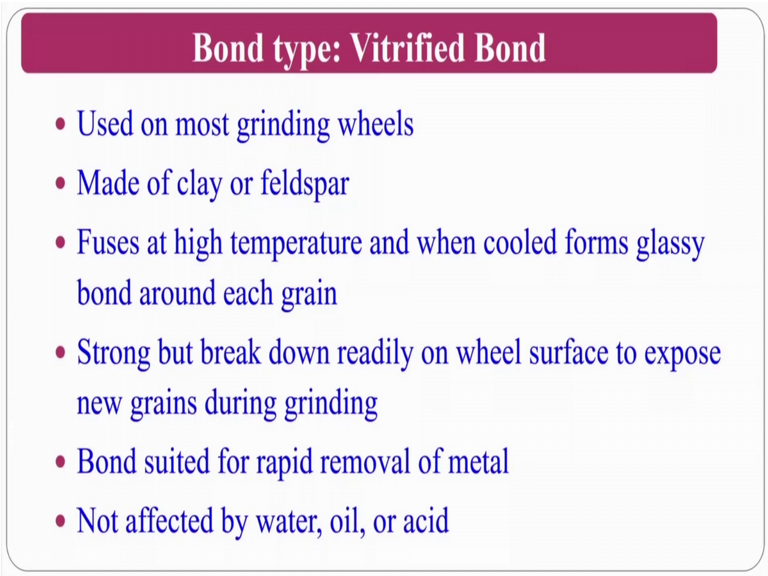
(Refer Slide Time: 29:39)



Factors affecting the selection of wheel structure so, the structure how and what will be my structure? The type of material being ground, if it is soft material require chip clearance for that purpose; obviously, you need a open structure, area of contact, greater area of contact more open structure is required.

How much finish I want? That dense wheel give the better surface finish and accurate surface finish method of cooling; normally if at all I want to go for the proper cooling open structure wheels provide better cooling, because the abrasive to abrasive distance is more. So, the cutting fluid can penetrate into the space and it can penetrate into the surface force that is there on the grinding wheel also.

(Refer Slide Time: 30:26)

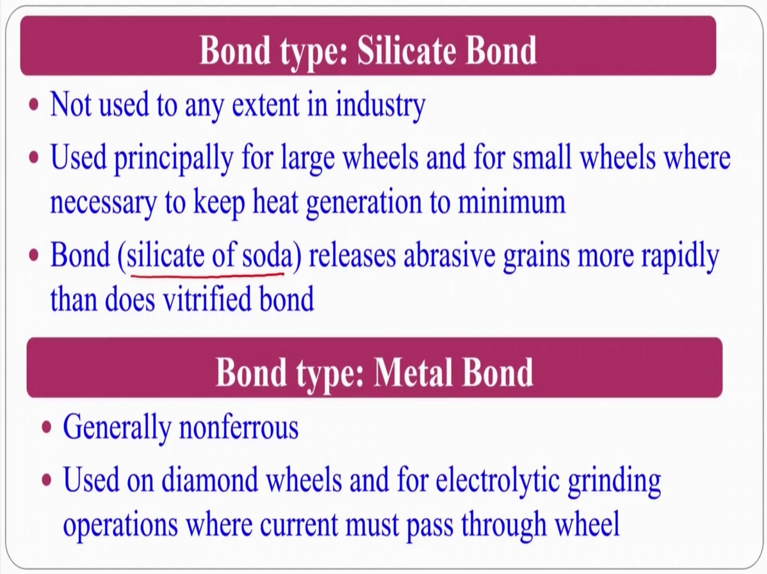


Now, we are moving towards what is our objective is polymer bonded abrasive wheels for that purpose, we are making a connection or we are making a laddering between the grinding process, and polymer grinding wheels. In the process of this one we are come across this wheel specification and we came to the final specification that is called bonding. So, non-polymeric bonding materials the first and foremost an most important and in the grinding arena is vitrified bond, where you can see the clay is used as a grinding.

It is mostly used in grinding wheels made up of clay or feldspar, fuses at high temperature when cooled form glassy and strong breakdown readily, and suited for high and rapid removal of material not affected by water oil and other. Is just how it is fabricated you just take the clay and some other ingredients, that is company specific, then you add with the abrasive particles and you mould it as per your requirement, then you just heat by electric heating and other things you got the grinding wheel ok.

So, the only thing here is you are using the clay and feldspar; this is the one of the raw material to make the vitrified bond. And, the second non polymeric is silicate bonding as I said.

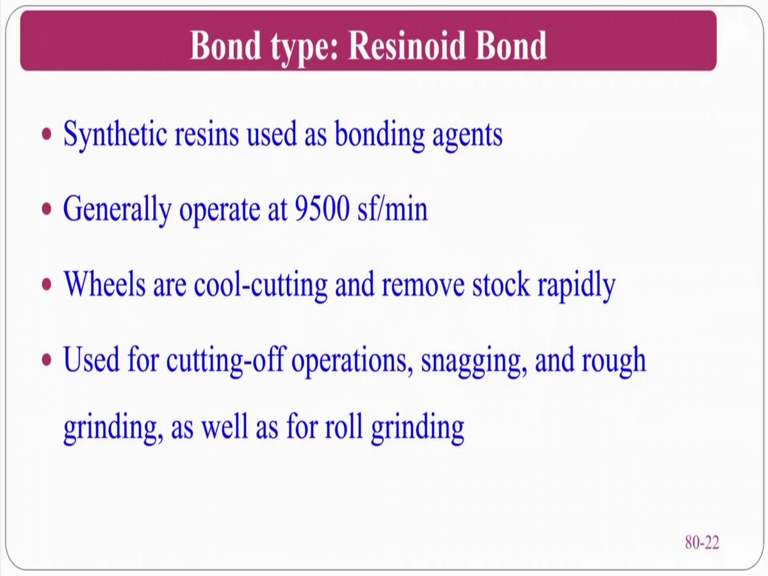
(Refer Slide Time: 32:01)



This is not much used in the industry used principally large wheels and for small wheels where necessary for keeping heat generation to be minimum, and bonds normally use a silicate of soda. So, the problem with this one is it is a brittle material and the abrasive grains which are there will be readily or rapidly can be released; that means, that this abrasive wheels are soft in grade.

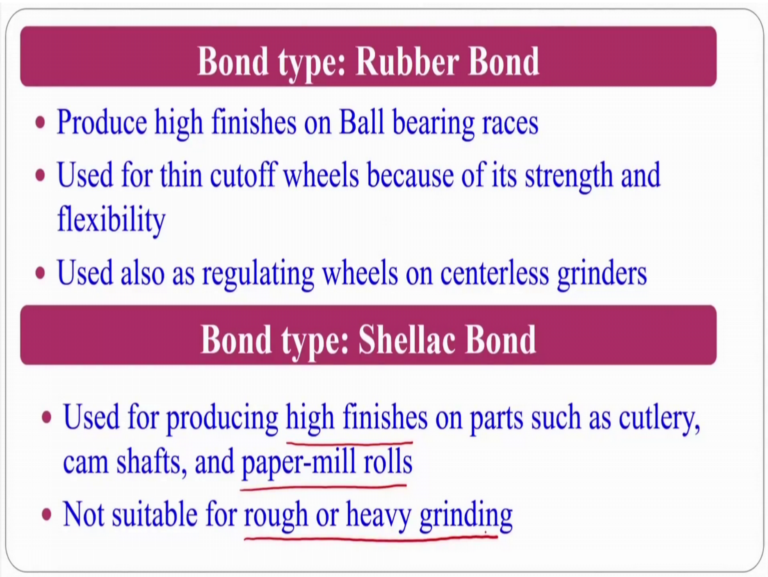
Another, non polymeric is metal bonded. These are all normally used for diamond wheels. For example, electric discharge diamond grinding, electrochemical grinding, and other purposes this will be used because, you need the electrical conductivity to act in the electric discharge diamond grinding or electrochemical grinding process ok. There the conductivity is required for workpiece as well as tool, in these 2 conditions that is electric discharge diamond grinding and electrochemical grinding process you require conductivity, for that purpose you need to go for metallic bond.

(Refer Slide Time: 33:11)



Now, we move on to our own that is called the polymer type of bonding just a glimpse I will give you initially, that is nothing, but synthetic resins are used for the bonding agent. Generally operate at very high speeds, wheels are cool cutting and remove stock rapidly and used for cutting off operations, snagging, rough grinding, as well as roll grinding applications you will use for Resinoid bonding.

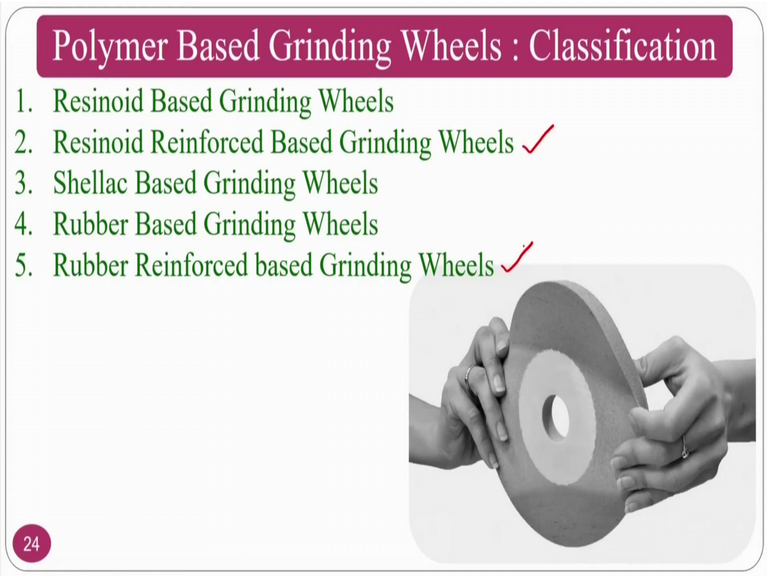
(Refer Slide Time: 33:39)



Then, we go for rubber bonding and this produces high finishes; that means that these grinding wheels are normally used for finishing applications. Thin wheels also can be used for cutting off applications and used also for regulating wheels in centerless grinding wheel. Centerless grinding wheel, you will have one grinding wheel another one you will have a regulating grinding wheel, there also you can use the rubber bonded grinding wheel. And, the third variety of polymer bonded rubber wheels, polymer bonded grinding wheels is shellac bonded. It is used for producing high finishes on part such as cutlery, camshaft, and paper-mill rolls and other things. Not suitable for rough or heavy grinding; that means, that these are all good for finishing applications.

So, this is about the polymer grinding wheels there are 3 varieties of polymer grinding wheels; one is resinoid bonding where resins are used, rubber bonding, where rubber is the bonding material and the shellac bonding, shellac is as a bonding material along with the abrasive particles ok.

(Refer Slide Time: 34:57)



Not only this there are some other varieties, where you can use the reinforcement such as resinoid reinforce based grinding wheels this is another variety people are using it ok. Another one is rubber reinforced grinding wheels also are the another variety ok. So, these are the 5 varieties are there, but commonly available the grinding wheels, which are polymer based, and which we are going to look in the class is resinoid based, shellac based, and rubber based, and we will also see some of things about resinoid reinforcement and rubber reinforcement. And, you can see how the grinding wheel is deforming with a hand. This is called polymer flexibility is there and that is why this wheels are used that is why, we have studied in previous slide this wheels are commonly used for regulating wheels in centerless grinding wheel, and high finishing. Because elastic deformation of this grinding wheels is high compared to vitrified bonding or metallic bonding and other bonding. This the elasticity of this grinding wheels is high compared to metallic and vitrified bond that is why these are all commonly used for finishing applications.

Thank you.