Introduction to Machining and Machining Fluids
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Lecture - 23
Introduction to Abrasive Processes – Grinding

Today, we are going to see about the Abrasive Processes, we completed some of the machining processes as well as the machining fluids. So, we are in the area of one of the multipoint cutting tool processes, you can say it is millions of cutting edges will be there in this process.

So, the surface roughness are the surface that you are going to get is completely random in nature because, the orientation of the abrasive particle as well as the shape and size of the abrasive particles will vary for process to process.

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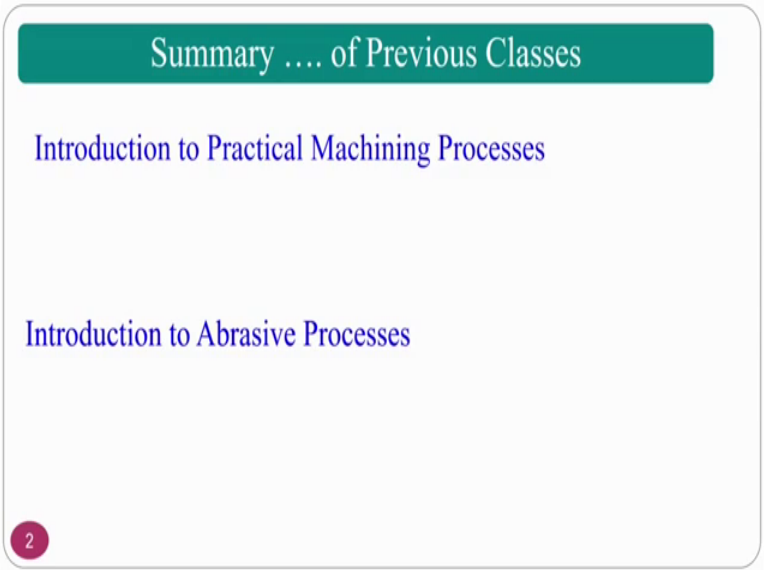

So, let me enter into the process, till now we have seen the practical machining processes such as milling drilling other processes, at the same time this is also one of the practical machining process, as per the present scenario is concerned the grinding, or the conventional type of grinding is considered to be one of the machining process only, but if you see as such it is one of the finishing processes in a olden age, or nowadays also some of the industries they follow it as the finishing process, how you are looking at that perspective decides, whether it is a machining process, or a finishing process.

If you are looking for this process lie material removal process, you can say that it is a machining process, if you are looking like a if this process as a surface finish process are the final finishing process. So, it is as a finishing process, how you are looking that perspective decides whether today's lecture you are going to take or you are going to grasp as a machining process are the finishing process.

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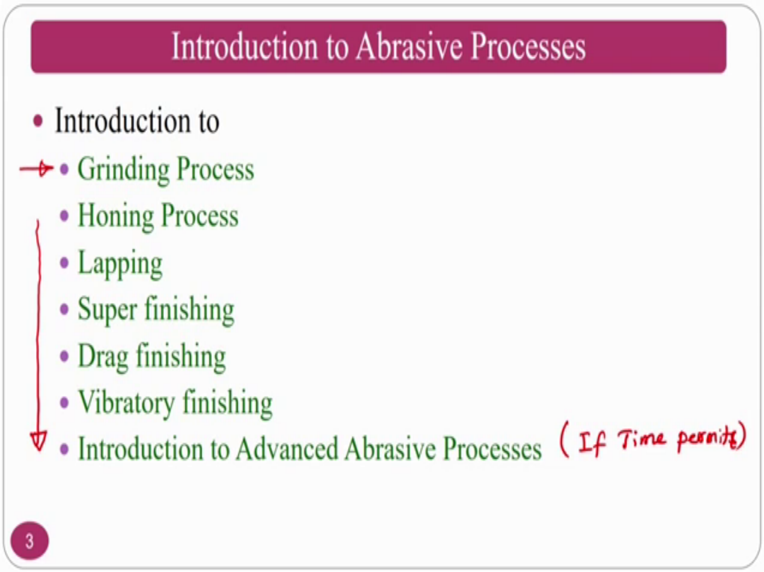

We will see now about the introduction to abrasive processes various abrasive processes we deal in which mostly the common physics are the common example of the abrasive finishing process is the grinding process, that is why we talk in (Refer Time: 02:38) of the varieties or the advantages types and all those things grinding process and when, we go on to the honing process, lapping process, super finishing, drag finishing, vibratory finishing and all other processes, which are also considered to be one of the conventional finishing processes will see a little bit little bit of this processes ok.

In particular about this particular class, we deal with the grinding process only. If time permits we will also see advanced finishing process, if time is there because number of hours also has a constraint. So, if time permits we will also see the glimpse just how and what are these process and all those things.

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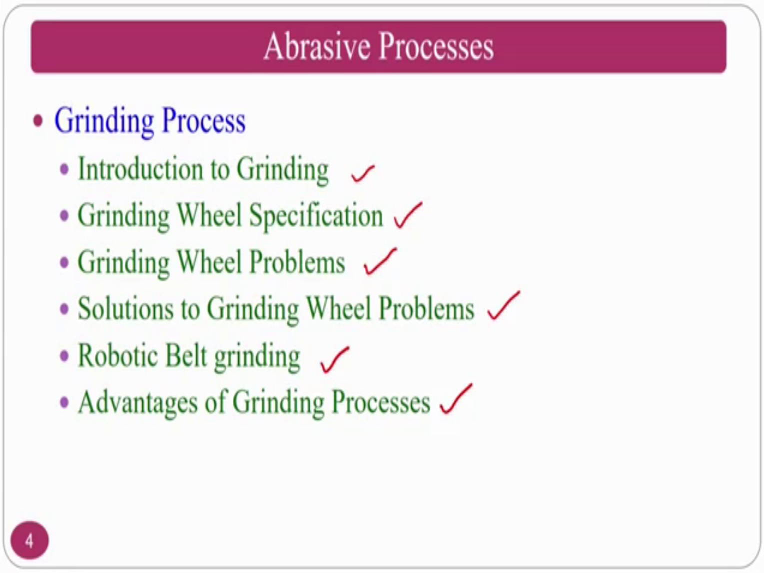

So, in the grinding process today we are going to deal with introduction to the grinding, in grinding wheel specification and the what are the problems and the solutions to the problems what is robotic belt grinding process, at the same time we will see what are the advantages as well as applications of grinding processes.

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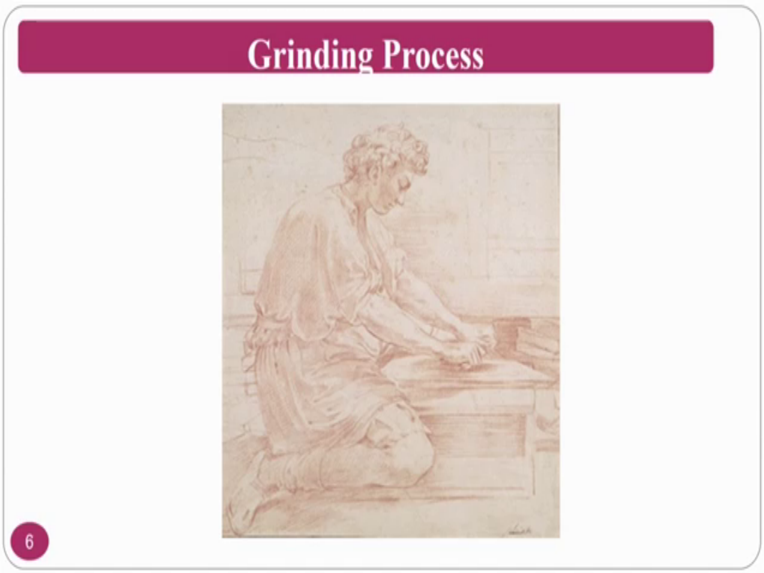

So, the grinding process the grinding process is one of the ancient process, where people used to make it the grind the materials to make medicine. So, on if you go to the villages also, mothers normally they, do the chutney and all those things using rock as well as one of the woods.

So, they also grind that because so, that you can swallow it easily rather than swallowing complete leaf, just they do it the chutneys the red chillies and all those things, they will just that is the conventional way of the grinding into the powder particles, or grounding into the semi solid where the particle size is very less that is also called as a grinding process.

One of the example is ball milling is one of the grinding process, where you can crush the bigger particles into smaller particles. So, not only the particles reducing we also uses this process for finishing application or the machining application.

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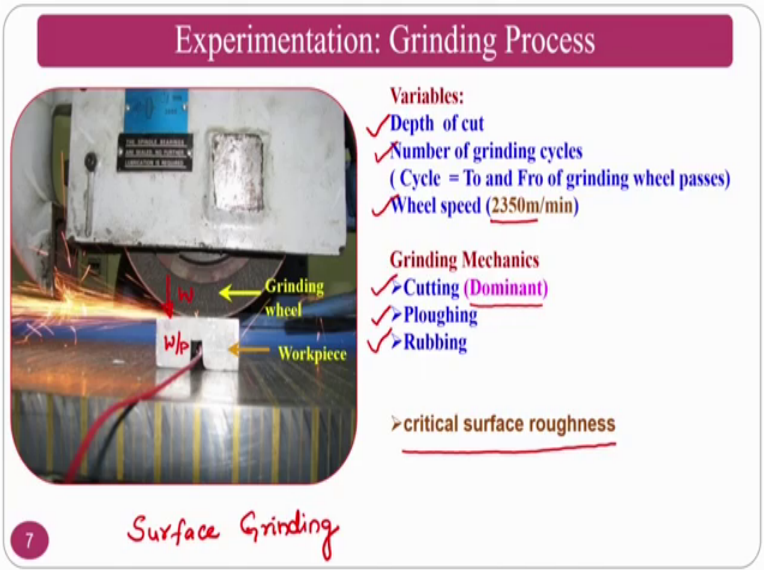

If you see this particular process, where the shown is surface grinding, what is surface grinding and other things you will come across so, the surface grinding just there is a work piece, this is the work piece and, this is a wheel the wheel is rotating at certain speed 2350 per RPM, it is rotating it is taken from the laboratory or laboratory only. So, various variables that you can give and you can generate, or you can get the output responses.

So, the variables that normally you can give is depth of cut that is nothing, but how much depth you are going to give so, that on the work piece. The second thing is number of grindings cycles that is complete rotation is 1 cycle. So, number of cycles you can give 1000 cycles 2000 cycles and all those things you can. So, another important parameter is wheel speed how much speed you can rotate, if you want higher speed you can give the wheel speed higher.

If you want lower speed all those things this are the some of the common variables, apart from the wheel designations like, you can also vary the abrasive particles size and abrasive particle type and all those things also you can vary at the same time you can use the flood cooling, since you have the knowledge of flood cooling NQL and all those things. You can also vary their volume flow rate as well as the pressure and all those things also can be variable ok, those are apart from the basic machining process of grinding ok.

So, if you see the 3 mechanisms of material removal, one is cutting or shearing of the material that is dominating here, the cutting of the material is nothing, but if you have sufficient depth of cut what will happen the abrasive particles, will shear the surface and takes the chip that is nothing, but the cutting or shearing operation normally this is the dominant mechanism of material removal in the grinding process, there is a ploughing action also ploughing means, if you see the farmers whenever they do with hull what will happen though material will come and it will fall in the previous one. So, there material will be not completely removed that is material will go into the previously existing surface this is called the ploughing.

Another one is rubbing if you do not give sufficient amount of depth of cut and all those things what will happen, the rubbing will takes place, you might have seen the mechanism of ball burnishing and all those things, that is what is happening and the chips will again mere on the surfaces and it will destroy the surfaces. So, you also if some people are working in the area of grinding, or abrasive grinding process, or abrasive processes you come across the critical surface roughness and all those things.

Since, the roughness which I have told, in the previous lectures has some relevance here, turning, boring these are the processes where you may not get good surface finish if at all you want to get good surface finish normally you can go for this particular process, but the critical surface roughness is the surface roughness beyond which even though you change the input parameter, you may not improve the surface finish assume that if I am going to increase the wheel speed beyond. Assume that I am not going to get the surface roughness the delta change in the surface roughness is very negligible; that means, that that is what my critical input parameter.

So, if my output parameter change is very negligible, then I do not want to move beyond that one, why should I give more load to the machine. So, that is nothing, but the critical surface roughness ok.

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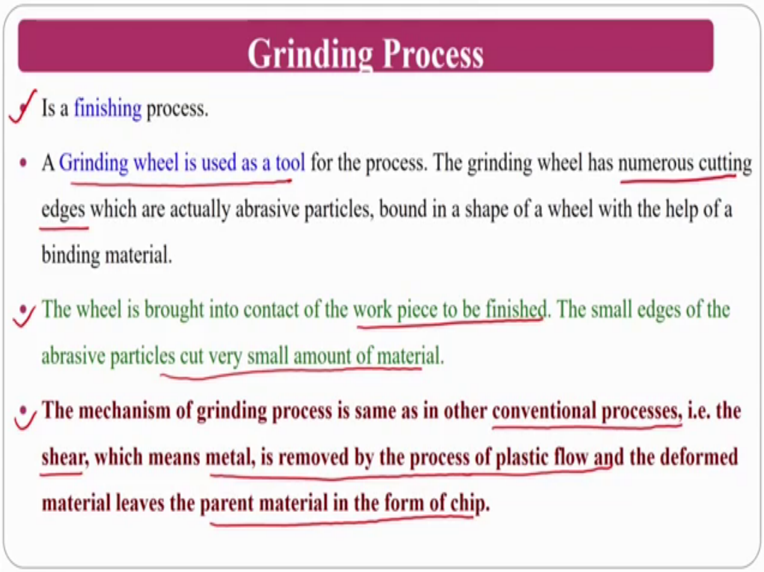

So, grinding introduction if you see the introduction it is a finishing process, normally it is used as a tool where you will have a numerous cutting edges, that is millions and millions of cutting edges which are called as the abrasive particles which are bound by the shape of the grinding wheel, with the help of binding material normally the binding material will hold the abrasive particles, intact there are finishing processes unbounded finishing processes, this comes under the bounded finishing processes.

The wheel if you see the wheel is brought into the contact of the work piece to be finished or the machine, the small edges of the abrasive particles cut very small amount of the material. So, it shears the very small amount of the work piece material which is given as a depth of cut.

The mechanism of the grinding process is same as conventional finishing process, that is the shearing which means material removal by the process of plastic flow and, the deformation material leaves the parent material from the in the form of a tiny chip are depend on your input conditions it may also the micro chips also.

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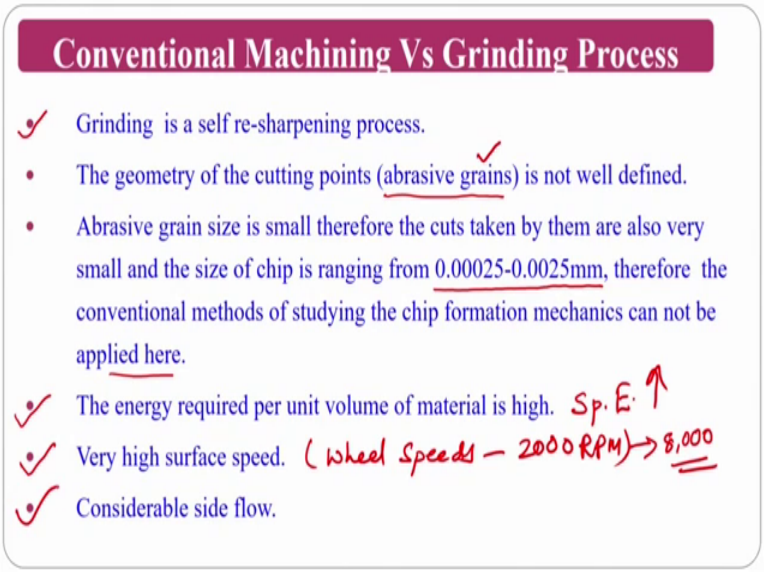

Thus it that is about the grinding. So, the conventional machining versus grinding process if you see the grinding is a self sharpening process, self sharpening process means if the abrasive are gone. So, new abrasives will come into picture that is nothing, but the grinding wheel is a brittle material basically, if a set of particles are assume that I have a grinding wheel like this.

So, if the abrasive particles are here, if this abrasive particles are gone what will happen, next set of abrasive particles which are there will come into action and, it will do the machining operation, or the finishing operation that is nothing, but the self sharpening process. But where as if you see the single point cutting tool like turning process, your tool where gone means you have to change the tool.

The geometry of cutting points that is the abrasive grains are sometimes may be some textbooks says that it is abrasive grains some papers are, some of the textbooks say they say that abrasive particles also is not well defined; that means, that the shape and size. Size normally you can get in a range assume that my size is 220 you can convert this into the abrasive particle size, I will tell you what is the mess size what is the abrasive size what is the difference between how whether they are linearly proportional or inversely proportional all those things I will tell you. So, these are all not defined.

Some of the abrasive particle may look like this, some of the abrasive particles may look like this, some of the abrasive particles may look like this. So, there is no particular shape, but if your specifying certain mess size; that means, that approximately some are in the range of some of plus or minus within the range size may be ok, but the shape may not be consistent in the abrasive particles.

Abrasive grains are very small therefore; cut takes them also very small and the size of ranges from this range. So, that is very very small for the normal applications therefore, the conventional methods studying the chip formation mechanics cannot be applicable here ok. So, that is the difference there the chip size is very high the size affect will come into picture the size affect is energy increases if the chip thickness goes down. So, that is itself is a very big theory which I am not going to explain here.

So, in the conventional machining like turning process here the chip mechanics is slightly different, the energy required per unit volume is very high at means specific energy will be very high grinding process for the same material removal very high surface speeds because, normally the wheel speeds will be in the range of above 1000 normally 2000 3000 will be here.

But in lathe and other processes normally, if you see the conventional machining process the RPM of work piece you may not go more than 2000, or something here normally it also go approximately 5000 to 8000 or something also. So, considerable size flow will be there because, varying action will be taking place.

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Now, we are moving into the grinding wheel, which is most important part of our grinding process is grinding wheel, there is a variety of grinding wheel tool and cutter grinder surface grinder grinding wheel, tooler cuter grinder grinding wheel, there are some other cylindrical grinding wheels many many more, the if you see the depend on your requirement there are variety of grinding wheels are there.

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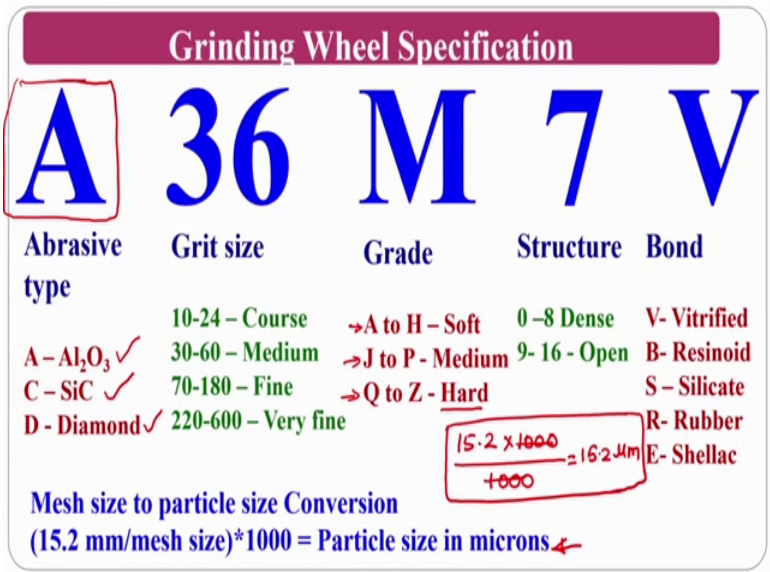

So, wheel specification, the wheel specification in a common terminology like goes like this, but it may be prefixed or super fixed by some other things like company name company they have their own codes. So, this that may be possible in of the some of the cases; however, we do not bother about company or something. So, we bother about what is the basic specification of a grinding wheel ok. So, if you see A 36 M 7 I am taking a example and I will explain ok. So, A stands for abrasive type, 36 stands for your grit size, or particle size and M stands for the grade, 7 stands for the structure, and V stands for the bond type.

So, if you see the abrasive type there are varieties of abrasives, if there is A here that means, it is Al 2 O 3 that is alumina type of abrasive particle, if C is there it is silicon carbide, if D was there in that place of a it was diamond so; that means, I mean to say that type of abrasives, which are going to use in that particular grinding wheel which I am specifying as A 36 M 7 V.

So, next goes the grit size that is nothing, but if the grit size is 10 to 24 course means very big or rough, normally course size of grits are normally used whenever you are going to machine the material; that means, that where your material removal is a criteria not the surface roughness is the criteria. So, if you go 30 to 60 it will be medium, 70 to 8 will be fine and 220 to this 1 will be super fine. If your particle size goes seventy and above normally you can go for the finishing process, these two you can go for finishing processes, these two normally you can go for machining processes.

So, grit size course means very big, if it is big the material removal will be also big the surface roughness will be too high; that means, that surface finish will be very bad. So, if you see the M, M stands for the grade, I tell what is the grade and all those things in the upcoming slides.

So, the grade specifies the bond strength, how firmly you are holding the abrasive particle that is nothing, but the grade ok. So, there is A to H stands for soft grade, then J to P stands for medium grade and, Q to Z stands for hard grade; that means, the soft grade means the abrasive particle is held very lightly. So, it can be loosely delaminates from the bot. So, if the hard means it is firmly hold the abrasive particle is firmly hold by the bond material.

Next structure there are two varieties of structures one is open structure, another one is a dense structure, if it is 0 to 8 normally, it is dense structure 9 to 16 it Si a open structure open. Structure means structure means what the particles distribution, abrasive particles how the abrasive particles are distributed on the grinding wheel, if it is too nearer to the consecutive particles; that means, dense if it is there is a gap then; that means, it is open structure.

Next comes the bond, V stands for vitrified bond and type of bond, normally the bond material is there clay is there, the metal is there, this type of things are there. So, if the vitrified bond is there that is one type of bond, if V here it is representing the V that means, that it is going to be vitrified bond and, if in case of V it will it is D resinoid bond, if it is S silicate bond, R is rubber bond and E is a shellac bond ok. So, what are these bonds and all those things will see in the upcoming slides.

So, mesh size there is slightly confusion for the basic people who are looking at the presentation that, there will be a difference between mesh size and grit size, or the particle size.

Assume that I want to convert the mesh size, mesh means you know our mothers normally whenever you have a wheat flour or some flour, they will you to sieve this one that is nothing, but the mesh the square holes which are there on the net where the mothers used to sieve is nothing, but the mesh for a unit area how many that square holes are there that is decides the mesh number.

If your mesh number is very high for a square for a same area; that means, that the particles passes through that mess will be very small; that means, your abrasive particle size is inversely proportional to your mesh size, assume that if I want to calculate normally there is a formula that is called 15.2 mm by mesh size normally represented by hash multiplied by 1000 gives your abrasive particle size in terms of micro meters ok.

So, assume for example, I have a thousand mesh size let me take a 1000 mesh size. So, it is there already I am given here. So, 15.2 multiply by 1000, why I am multiplying is to convert into microns divided by 1000 mesh size, if it goes what will happen you will get 15.23 micro meters; that means, my abrasive particles size if I take the mesh size is 1000. So, my abrasive particle size is 15.2 microns. In this way one can calculate the abrasive particle size.

So, that is a relation if I am increasing my denominator; that means, my particle size if I go assume that 1000 particle size what will happen, it will be 1.52 micro meters so; that means, that if I am going to increase mesh size that the particle size is gradually decreasing, that is the relation between the mesh size as well as particle size.

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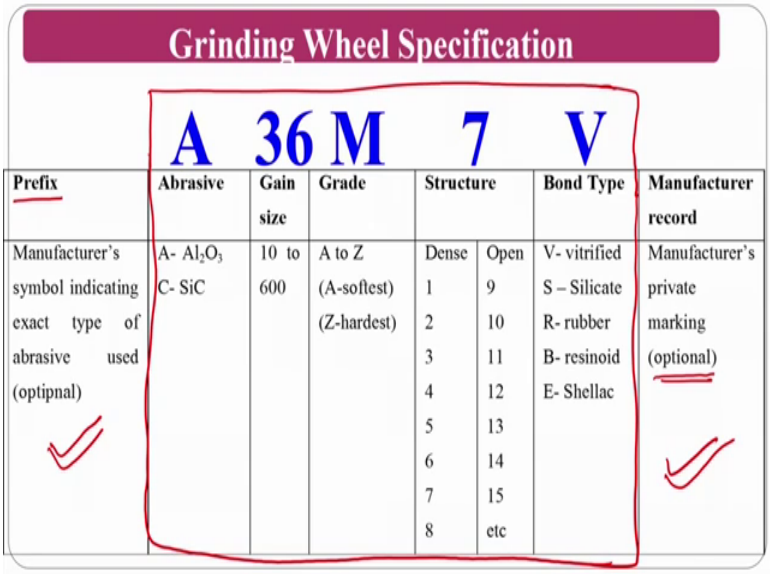

Again the same thing just to show you the prefix and suffix just I took this one match normally the some of the companies, they will show the symbols indicating exact type of abrasive used which is in optional basically, at the same time at the end also some of the manufacturers they will give, their private marking which is also a optional.

So, that is why I telt in this particular thing about this particular portion, which is a constant for all of the manufacturers, but this one and this one is optional for the manufacturers. So, you do not worry, but this is what the commonly followed grinding wheel specification for any type of grinding wheels.

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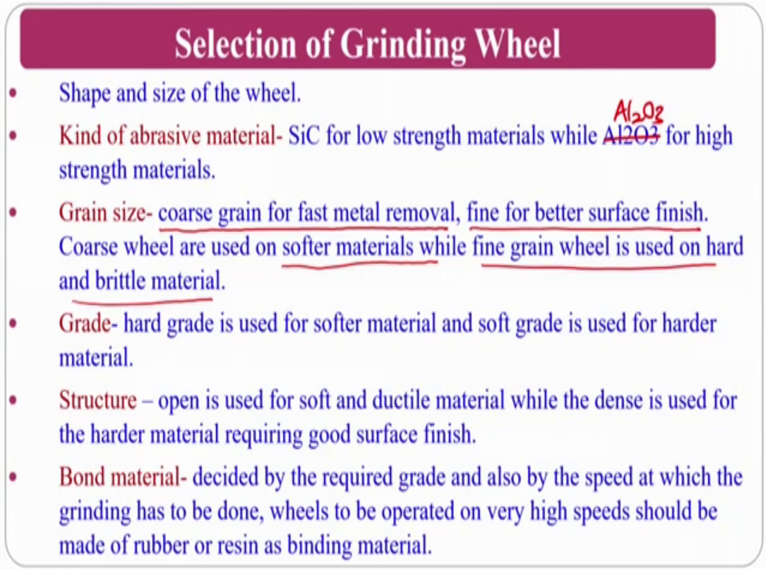

So, the selection of grinding wheel if you see the shape and size of the grinding wheel is important, the kind of abrasive material which is whether it is a silicon carbide or Al 2 O 3, or for the high material strength grain size, whether it is a coarse grain size these are the particle size 1 has to know, if at all I want to machine it or material removal normally the grain size should be coarse and finer are better for the surface finish applications.

So, if you also see that the coarse are wheels are normally used in the softer material and, fine grains normally used in the hard and brittle materials, this is a common concept followed by the grinding process grade, hard grade normally uses for the soft wheel soft materials machining and softer grades are used for the machining of the harder work piece materials, structure open structure any how bond material these are all things will come.

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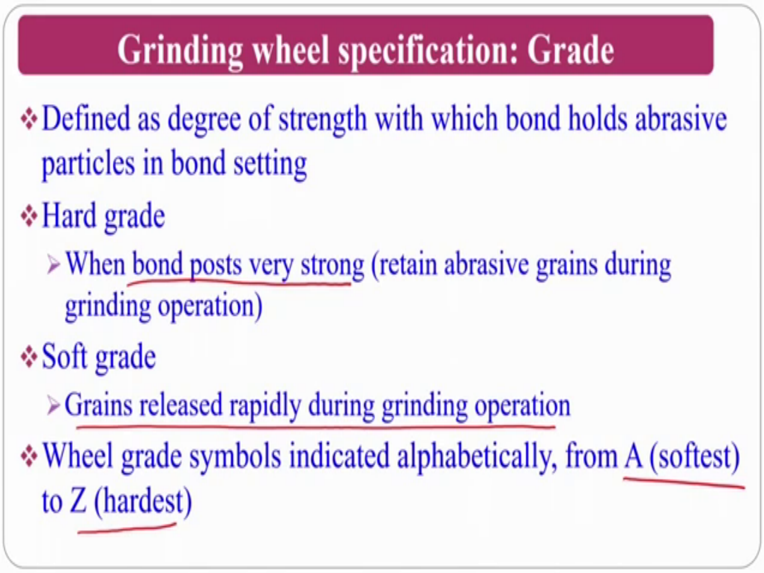

So, among the wheel specification normally A 36, whatever we have seen grades as well as the structure the two things if you see here, you are there is no much problem about anything here, if you see abrasive type there is no confusion because, you are saying what are the abrasive type of abrasive particle, if you see the grid size; that means, that you are talking about the particle size. If you see the grade I will explain if you see the structure ok; that means, that A and 36 do not have any confusion, let me go into directly into the grade structure and bond ok.

So, I will explain you grade structure and bond. So, what is the grade define the degree of strength at which the bond holds the abrasive particles so; that means, that how firmly the abrasive particle is held by the bond material, whether it is a vitrified bond, or any bond hard grade means it is held very hardly; that means, tightly.

It bond posts very strong strength, if it is a soft grade grains are released rapidly during the grinding process. So, wheels grade symbols indicate alphabetically from A to Z that is softer to the hardest; that means, if you see the grade what is happening is, if I want A to machine softer material assume that I want to machine a softer material, I should always go for a harder wheel because abrasive particle should be firmly hold. So, that the material whole takes place.

Assume that if I am going to use softer wheel there, even though I machining a softer material my abrasive particles are dislodging. So, which I do not want for that purpose;

obviously, the person has to go for harder wheels. In case a harder materials assume that I want to machine a very hard material in that circumstances I should go for softer grade wheels. So, if I enable to machine what will happen this will dislodge the new cutting edge will come by the self shortening effect of the grinding wheel and it will try to remove the material.

So, if I am using harder grade what will happen, neither it can remove the material, nor it cannot dislodge the abrasive particle from the wheel in that circumstances what will happen, the abrasive particle will break and the surface will become glare glares is nothing, but one of the problems of the grinding wheel, I will come across that 1 in the upcoming slide that is why always keep in mind that you have to use the softer wheels for harder work piece material, harder wheels for softer work piece material

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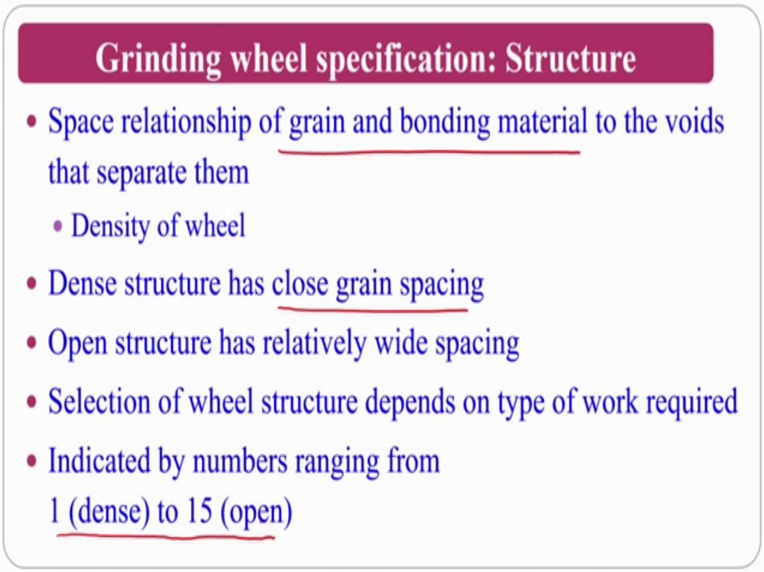

Already I told you that this defines the particle location. So, space relationship of the grain and bond material which is tells the grinding wheel, density dense structure means closer grain spacing close it is close grain spacing and open structure is relatively wider spacing selection of the grinding wheel structure depend on type of work required indicated by numbers, in range of 1 to 15, normally if I have less value; that means, the density, if I have more value it is the open structure.

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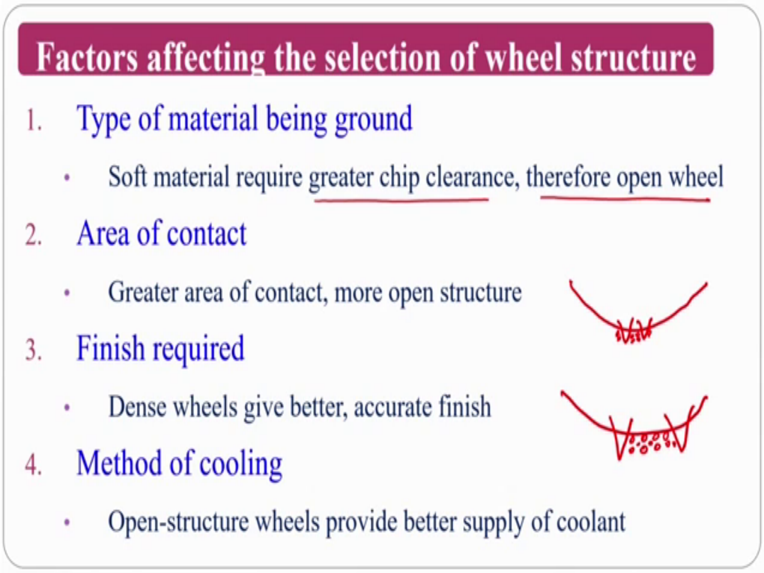

Now, there is a analogy that if at all I want to go for the machining of a harder material, machining of a softer material, which type of things that I want. So, type of material being round softer materials require greater chip clearance therefore, you need a open wheel; that means, if I have a wheel like this I have 2 abrasive particles here, if I am going for a softer material; that means, that my material removal is very high; that means, that my material will come and accumulate here, for that reason you should always have a open structure.

So, that your grinding wheel will have 2 abrasive particles like this the greater amount of material can be accommodated before it will become dull that is why one has to go for the open structure.

Finish required normally dense will give that finish structure method of cooling open structure wheels provide better structure of coolant. So, if you see here, if I want to do the hard work piece material there, normally you should go for dense structure dense structure means. So, that the abrasive particles number of abrasive particles will take part and it will ok, you just there the loading problem is not a problem wheel loading, the wheel loading is also one of the problem that I will discuss wheel loading is not a problem in the hard machine materials. So, you can go for a dense structure ok.

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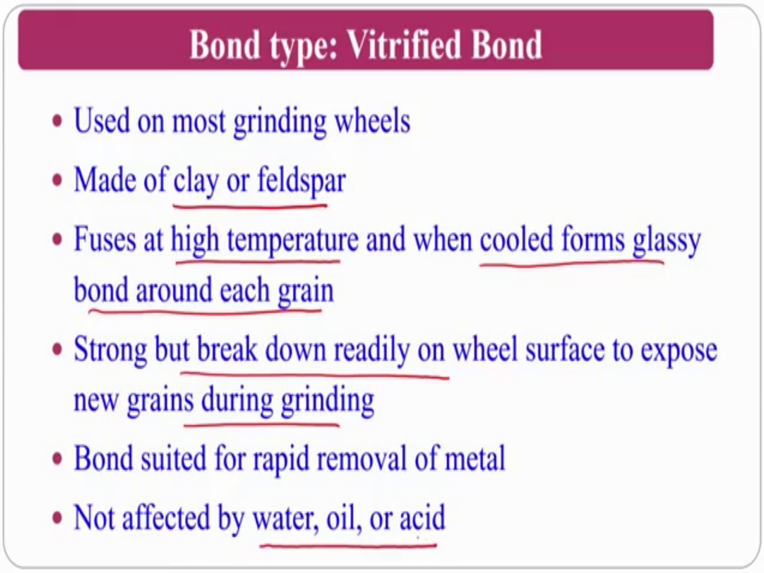

Bond type vitrified, bond vitrified bond is nothing, but this is the clay, normally how the bricks are manufactured and all those things. It is the clay, or feldspar the fuses with the high temperature when the cool forms a glassy bonding between each grains that are there ok. Normally the brick is formed assume that you are having a grinding wheel shape thing, just you embed the abrasive particles in the clay just you just go and do it like heating. So, you will get a grinding wheel that is nothing, but vitrified bond.

Strong bond, but break down readily because the surface exposed to new grains that is called self shortening effect will be there and, bond suits for rapid removal of metal and not affected by the water, or oil, or acid ok. These types of bonds are do not have much affect because, it is heated with the high temperature and it forms it firmly bond a vitrified bond from the clay plus additives abrasive particles.

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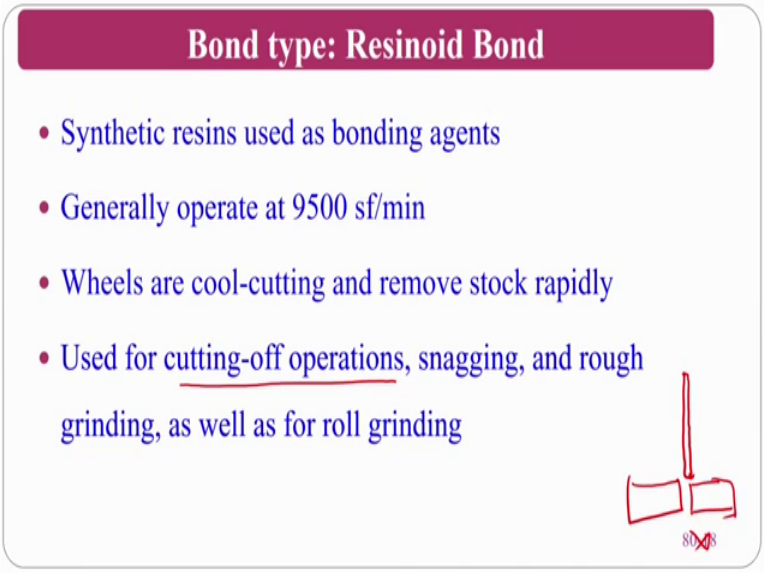

If you see the second variety that is called resin bond resin is a synthetic resins are used, generally operates at very high speed that is 9500 speeds wheels are cool cutting and remove stock rapidly, if at all I want to go for the material removal processes normally, you can go for resinoid bond the cutting off operations also because, wherever if you can make a very thin grinding wheels, you can make and you can use it for the cutting off operations of the work pieces ok.

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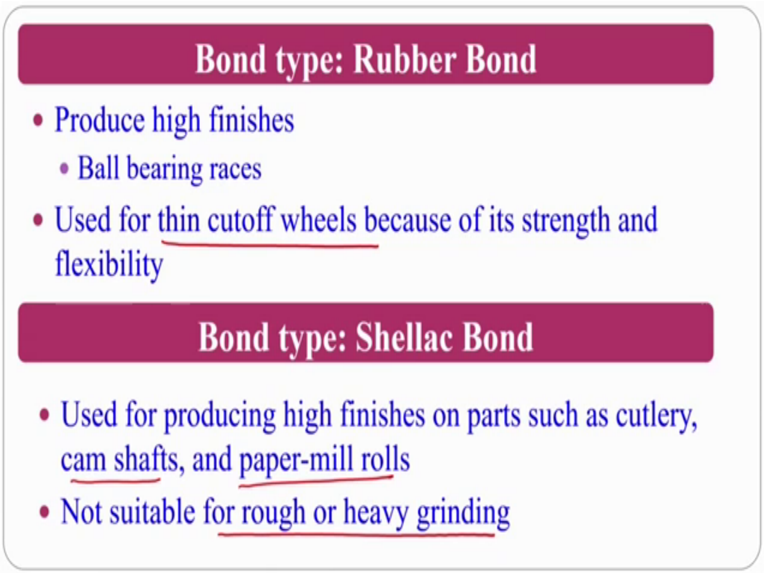

So, Like that so, now we will go for the rubber type of bonding where the rubber bonding produces finishing on normally these type of bondings are used for the finishing operations because, the rubber are dominated by elastic characteristics and, they also possess the viscous nature, these are also used for thin cutting wheels, because of its strength and flexibility used for also for regulating wheels in centerless grinding process.

Centerless grinding process we will come up in upcoming slides, there is a bond type, if you see the bond type then shellac bond normally the shellac bonds are used for the cam shafts paper mill rollers and all those things, not suitable for rough and heavy grinding these are very sophisticated grinding wheels for the simple small small works like finish, or cutting off something these type of things will be used.

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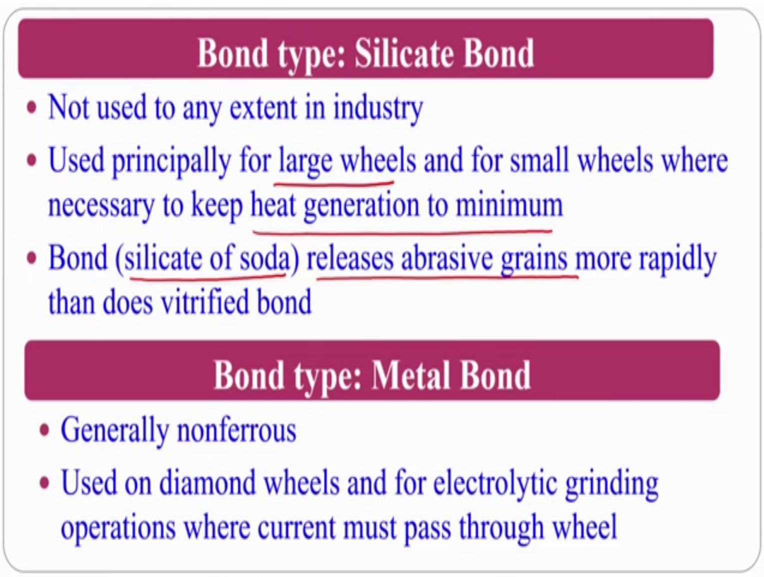

And silicate bonds these are all not used any extent in industry because, it is used principally for the large wheels and for the small wheels there is necessary to heat generation to the minimum normally, these are all used very very big in size. So, otherwise there will be heat generation in problem will come into picture, silicate of soda silicate will be used releases abrasive grains more rapidly; that means, that the abrasive grains are released very fast; that means, that it is held abrasive particles loosely ok, the grade is softer grade.

Another one is metal bond. Normally, metal bonds are used in the electrical discharge grinding electrical discharge diamond grinding there are two processes are many other processes, where you need the conductivity; that means, electrical conductivity in the wheel also there normally the metal type of bondings were used. So, what I mean to say is metal bonding are commonly used in electrical discharge grinding electrical discharge diamond grinding, electro chemical grinding these are many many advanced grinding processes are there they will use this.

So, wheel problems the everybody will have problems in the life. So, fortunately, or unfortunately the grinding wheel also have its own problems. If you see the first problem before seeing the problem normally how the grinding wheel look like, if you see the grinding wheel look like and how it faces the problem.

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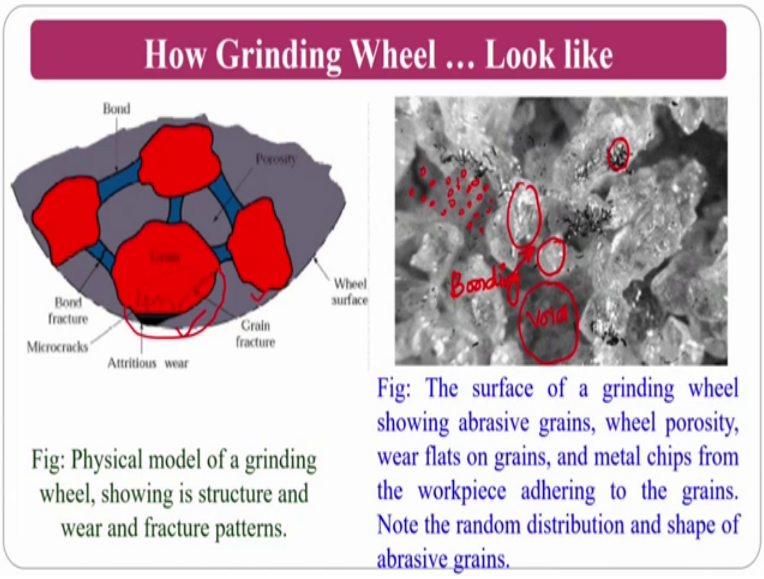

Fig: Physical model of a grinding wheel, showing is structure and wear and fracture patterns.

Fig: The surface of a grinding wheel showing abrasive grains, wheel porosity, wear flats on grains, and metal chips from the workpiece adhering to the grains. Note the random distribution and shape of abrasive grains.

These are the grinding abrasive particles these are the abrasive particles and, this is the bonding and in between there is a porosity and all those things this is a schematic diagram, this is the physical model or how you can represent that one under you can also see attritious wear and all those things here. So, if you see practically how it look like these are the voids, this is the bonding this is the abrasive particle this is the abrasive particle in between you have a bonding.

So, this abrasive particles will get assistance from the bonding and it will try to remove the material, if it is a softer wheel the machined material will go and sit in the this gaps, this is called normally structure open structure of this one the abrasive, this material will go and sit here for that purpose it will be, this abrasive particles try to shear the work piece material, that is how the abrasive wheel look like now the problems.

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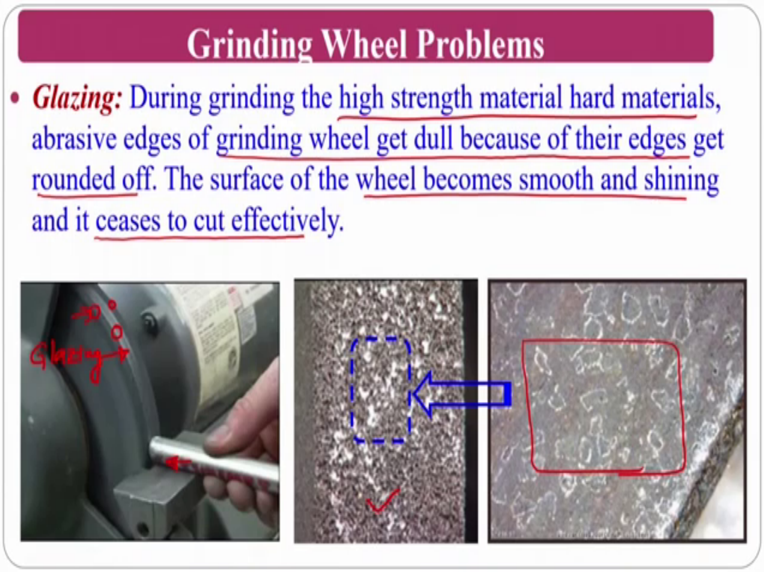

The first problem is glazing; glazing is nothing, but normally whenever if you see the hard work piece material versus hard wheel that hard grade, normally you will get a glazing problem what is the glazing high strength material hard metals abrasive wheels get dull because of their edges get rounded off; that means, if I have a hard wheel; that means, my abrasive particles are firmly bonded, if you are using against the hard work piece in that circumstances my abrasive particles are unable to remove the material and they brake, because these abrasive particles are ceramic particles, they will have a brittle fracture and it loses it cutting edges and become dull.

Then the surface will become smooth and shining and creates it will become less effective, that is if you see in this particular picture, there the difference you can clearly see here where ever the work piece is attacking, or where they are contacting, there the surface is completely shining other area, if you see here the other area is not shining; that means, that this shining portion is glaze you can say glazing. This also have good abrasive particles, this particular portion is good this particular portion is good, but this particular portion is glazed ok, that is about the glazing.

If you can also see the practically how it look like, because of the hard grade versus hard work pieces the surface become smooth, I mean not the work piece surface become smooth the surface of the grinding wheel become smooth, that is what you can clearly see in this wheel as well as same thing, if you can exaggerate can see here how the abrasive particles are become dull and inefficient this is called the Glazing.

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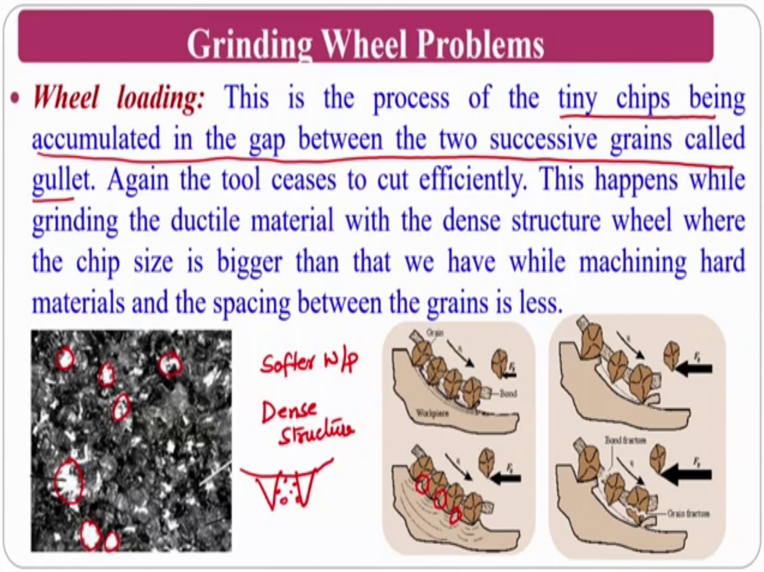

The second problem is wheel loading, if this is the process where the tiny chips are being accumulated in the gap between two successive grains that is called gullet, two abrasive particles are there in between there is a gap that is called gullet, if the abrasive particles are too near and, if you are going for the machining of softer materials; that means, whenever you are machining a softer material with dense structure, then this problem will comes. If you see this one what will happen this white 1 is nothing, but the material is occupied that means nothing, but material is loaded inside the grinding wheel.

Whenever you have a softer work piece and dense structure, then you do not have sufficient space between two abrasive particles to accommodate the chips. So, I mean to say there is no I am not saying, there is a gap very minimal gap in that circumstances very less time the wheel loading takes place because, the material removal of the softer work piece is very high, that is what you can also see here how the material is occupying between two abrasive particles ok. So, this is about the wheel loading

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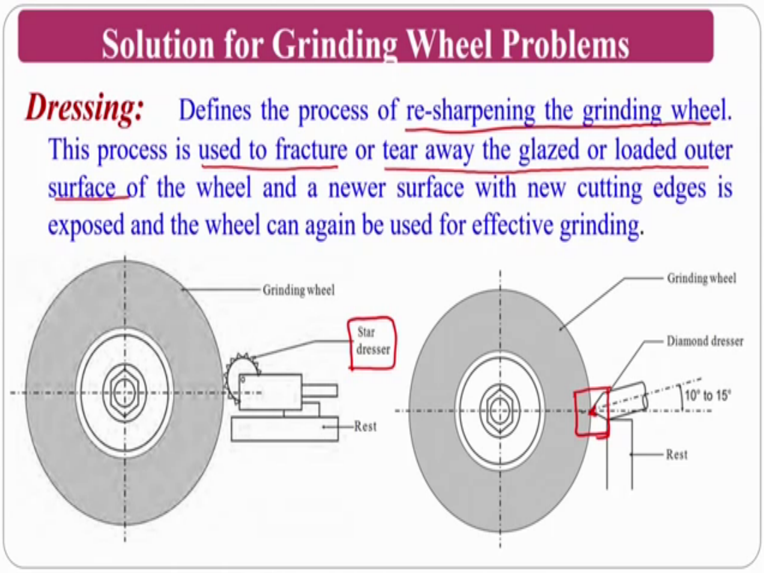

Now, how to resolve this problems these are the common problems of the grinding wheel and, the solutions if you see here one is dressing. So, dressing defines the process of re sharpening of the grinding wheel this process used to fracture or tear away, the glazed or loaded outer surface that means, that it is applicable for both the problems that is the glazing, if you see the glazing that mean that the sharp edges are gone and it becomes smooth on the wheel.

So, I have to remove that layer and I have to get a new layer that is what intension is in other case if abrasive particles are loaded or; that means, that gap between two abrasive particles are consecutive abrasive particles are loaded by the work piece material, then also you have to remove because in a both cases wheel loading as well as wheel glazing the wheel become inefficient. So, you have to find some suitable solution that is what you will do is you just put a star dresser there is one type of dresser and, you just drawn the grinding wheel process.

If you do the just you have to run the grinding wheel, then outer surface of the grinding wheel will remove by the star dresser, you can also use some of the diamond dresser, where it will be a like a point, this will particular grinding one will remove the outer layer and, you will get a new surface which is having abrasive particles ready to go for the grinding process, these are the two varieties of dressers, when is a star dresser is there another one is a diamond dresser will be there both will remove the glazer layer, or the loaded surface and gives the fresh surface for the grinding operation that is how you can come up.

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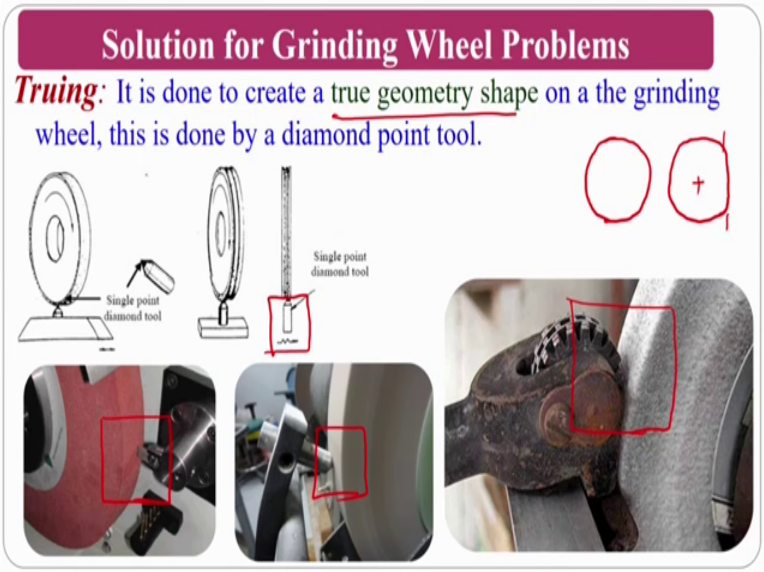

Next one is truing basically truing means because of the sudden jerks, or something what will happen the grinding wheel will loses its true geometry that means, that if I want a geometry circular geometry certain parts of circular T will goes off assume that I want a grinding wheel like this. Because of the sudden shock or something if I the grinding wheel will become like this what will happen, this particular portion, this particular portion become a straight, I want to do the truing operation; that means, that I want to make into a true geometrically circle shape.

So, for that purpose I will use here also diamond indenter and, I will since I am giving you constant depth of cut, this particular portion which already were warn out those portions would not come in contact, but the other regions will come and contact and you will get a original circular surface that is about the truing. Truing means, you are going to get a true geometry of the grinding wheel ok. If you can see here the how the truing is done the dresser, this also you can use for the purpose of the dressing also.

So, because these are all can be use dressing as well as you can use also for the truing purpose also. If you can see this surface how the surface is activated are surface is getting back to the original true circular shape, this is going to help in getting the height geometry. So, that there would not be much shocks on the work piece and all those things in this way it will help.

So, type of grinding process we since we are talking about introduction of particularly to the machining and machining fluid, I am not talking about any mechanics, or something because I already told many times that particular chlores is floated, or may be floated in the next semester. So, people can take up that one that is why I am not talking about any mechanics like any mathematical equation or something ok.

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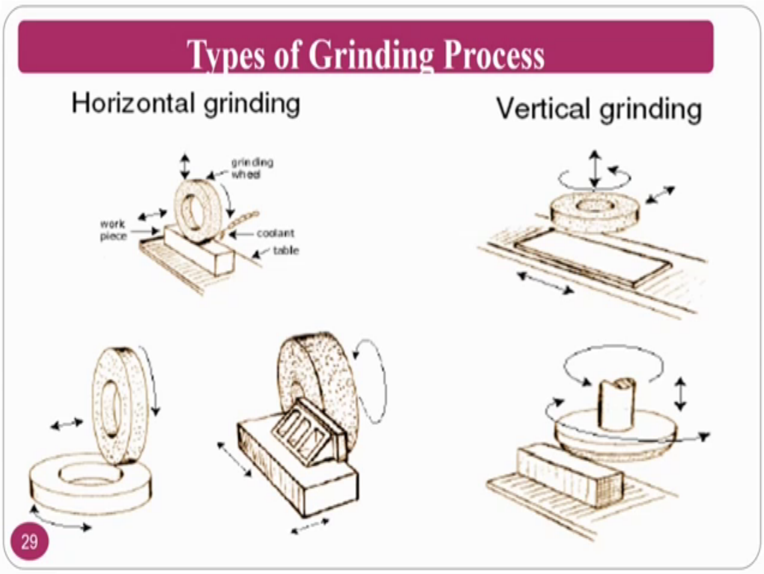

So, types of grinding if you see horizontal grinding vertical grinding in as you see, in the milling process also you will have the horizontal grinding and vertical grinding where the your Arber axis where you will mount, if it is parallel to your work piece that is called horizontal, if it is perpendicular then it is called vertical.

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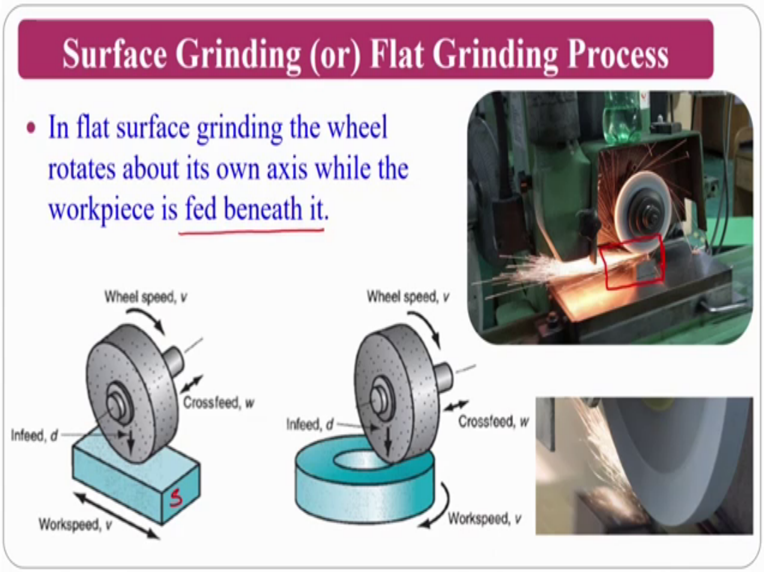

So, the first one is flat grinding process are the surface grinding process, if you see this the surface is there and the wheel is there just the flat surface grinding wheel, if you see here it will rotate about its own axis while the work piece is fed beneath it normally; that means, that it is fed beneath the grinding wheel and it will do only on the surface you can clearly see here how the surface because of the high speed the surface is getting machined and, we will get a very perfect flat surfaces for the perfect flat surfaces normally you can go for surface grinding operations ok.

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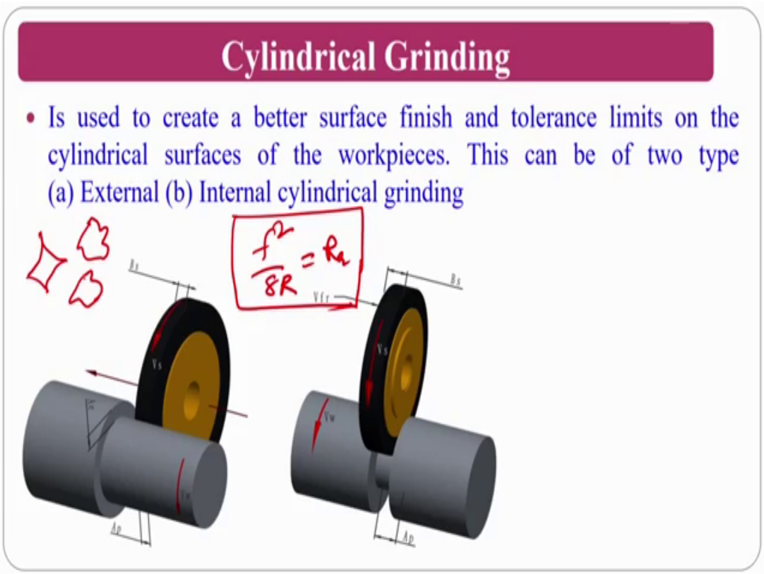

Cylindrical grinding is another one where you can see here, if at all I want the good geometry you can get even by turning the operation also, but the problem with the turning process is your surface roughness that is f square by 8 R equal to your R a will be; that means, that it is will be a function of your feed as well as nose areas here, there is nothing because your abrasive particle is too tiny and it will remove the material.

But only one point you should clearly notice in the grinding process is the abrasive particles all will poses the negative rake angles, no abrasive particles will be like concave surface like that all the abrasive particles mostly it will be like abrasive convex particle; that means, that you will have the negative rake angles, but the size of abrasive particle is too small compared to your nose radius the surface roughness which you are going to get is very fine, as the particle size goes down you will get very very good surface finish.

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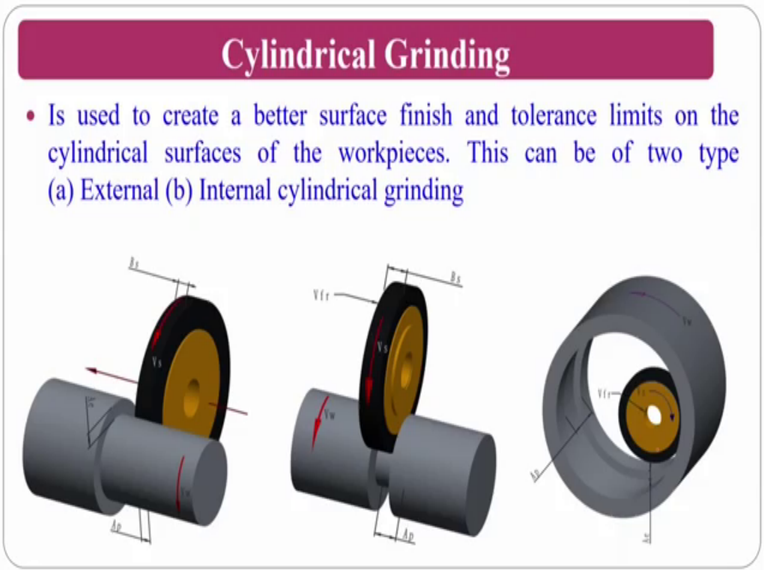

If you see there is another cylindrical process that is called internal cylindrical process, if you are working on outside surface it is external cylindrical grinding process, if you are working inside that is called inner cylindrical grinding process.

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So, external and internal just if you see that is a schematic diagram, these are the practical diagram, that is the schematic diagrams and this is the practically visible diagrams that we have taken. So, if you see cylindrical grinding process there are 4 motions which are involved in the cylindrical grinding process.

Rapid motion of the grinding wheel will be 1, this is the grinding wheel ok, normally the RPM will be about 2000 slow rotation of the work piece against the grinding wheel. So, the work piece also will be rotated against the grinding wheel. So, that machining will takes place and finishing will takes place horizontal traverse of the work bench and which is back and forth of the grinding wheel.

And another one is in feed wheel control this is nothing, but depth of cut; that means, that you will give depth of cut like this. This will also move in this direction. So, that is this are the 4 motions for the this is external and this is internal grinding ok, you can see the grinding wheel here the grinding wheel is fed in this direction the grinding wheel is rotated inside the work pieces. So, this is how practically the internal cylindrical grinding and external cylindrical grinding look like.

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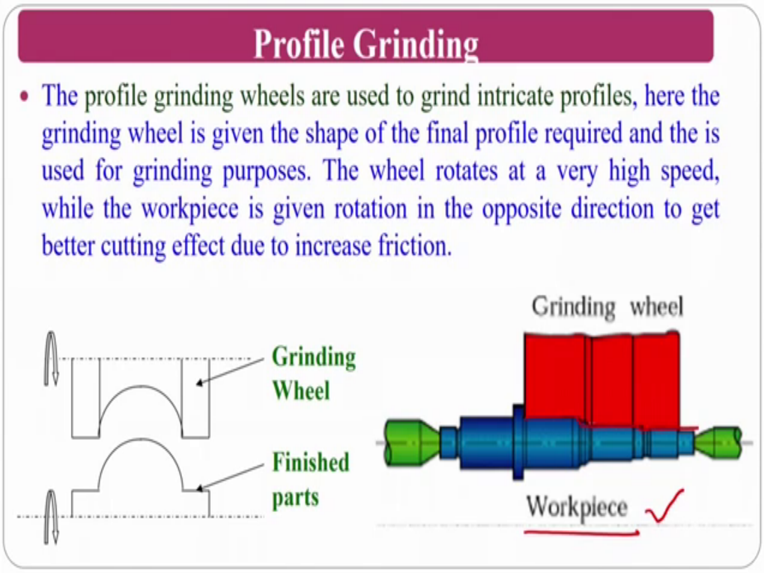

The profile grinding, if you see the profile grinding, normally this are used to grind intricate profile; that means, that if I want to machine or if I want to finish a profile assume that I want to machine this particular profile, what I want is I need to generate a profile which is converse to that surface ok. So, if you can generate a wheel which is converse to my surface normally, if it comes in contact with uniform surface of the cylindrical rod what will happen it will generate your specified form.

These wheels rotate at very high speed while the work piece is given rotation in the opposite direction to get because, since we have seen the cylindrical grinding operation this also work in the similar lines, but only thing is that there the surface of the grinding wheel is same here, the surface of the grinding wheel will be converse of what you want product that is what the profile grinding.

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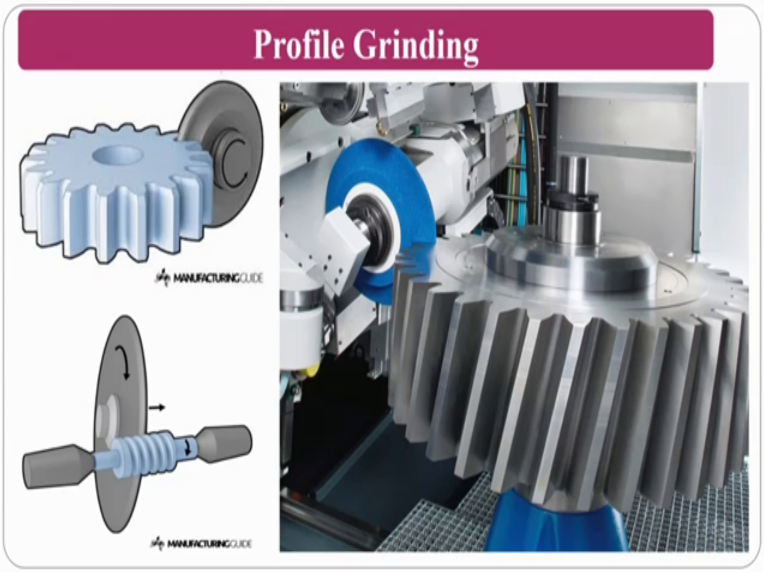

If you see some of the examples, you can go by like this also this also and, this also like this you can this one of the profiles, if you have a grinding wheel you have to take into convership and just you have to give so, that you get a proper profile.

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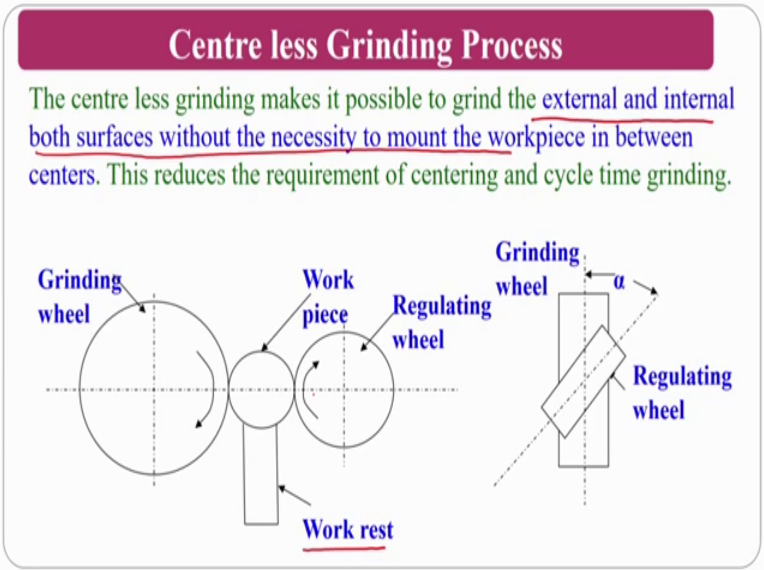

Centre less grinding is another variety of grinding process, where there are two varieties one is given here, this is a external and internal both surfaces you can do by this centre less grinding process; that means, that there is no center if at all I want to do the machining process and turning process, you have to hold the work piece between the centers that is nothing, but normally the centered process.

If there is no centers then; that means, if at all I want to finish the machine the irregular surfaces normally you go for the centre less grinding process, if you see this is the grinding wheel and, this is the regulating wheel and work piece will be there and work rest will be there. So, it will work piece will be kept on a work rest and grinding wheel will be removing the material and the regulating wheel will be assisting the process.

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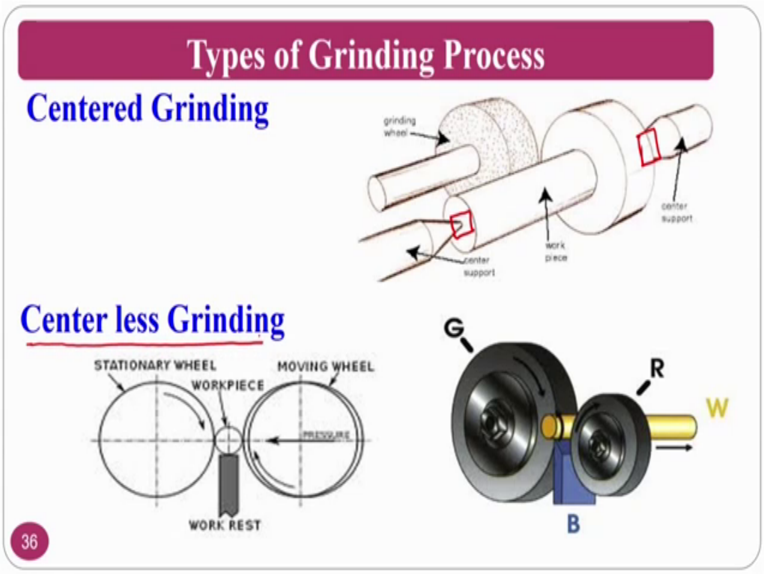

So, two things are there one is centered grinding as well as centre less grinding, if you see here in the centered grinding there it is the work piece held between the centers. So, perfectly only I can do it for the normal regular shape, if at all I have a irregular surface, then I have to go for center less grinding process that I have told in the previous slide also.

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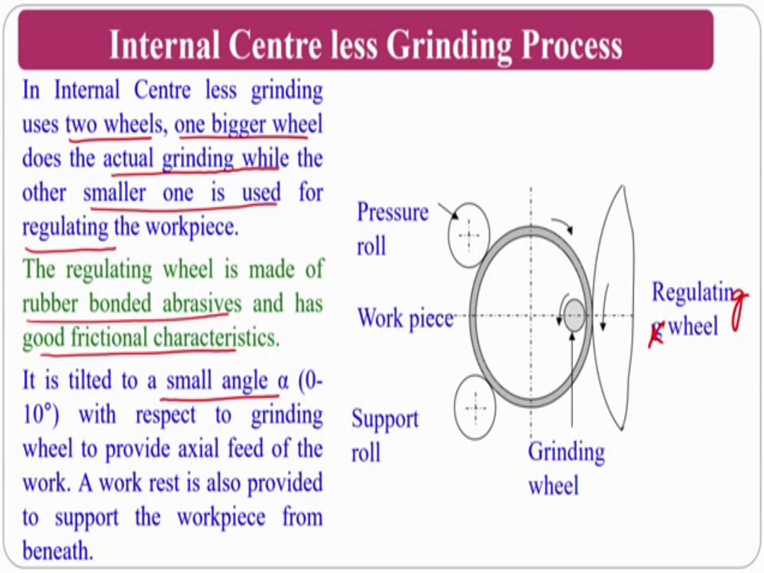

There is called another one is internal center less grinding also is available, where if you see internal center less grinding there are 2 wheels, one is bigger wheel, another which is actually is the grinding wheel, while the smaller one is used to as a regulating wheel. So, this is regulating wheel actually the and the pressure rolls are there supporting rolls are there and all those things, in that regulating wheel is made up of rubber bond abrasives and has good frictional characteristics. So, that it will be intact.

Normally if you see here the angles are not given any how this is about the simple center less grinding wheel process, where you can do the internally if there is a irregular surface also. So, normally tilted angles also there some of the things are there, in the mechanics which for the basic introduction you may not required.

So, what I mean to say is that if at all I have a irregular shapes like camps for example, I want to grind normally you will go for external center less grinding process, if you have similarly hollow things you can go for internal center less grinding process.

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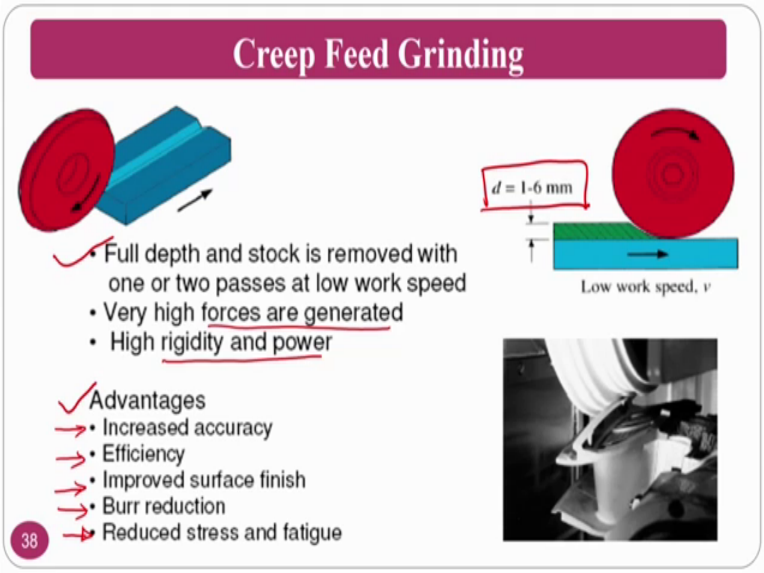

There is another variety which is called creep feed grinding where the depth of cut is so, high. Normally so, if the full depth of cutter stock is removed in one or two process, normally it is called as a creep feed grinding and very high forces are generated and very high rigidity and power is required in the grinding wheel for this one.

Advantages of this process is increases, accuracy, efficiency as well as surface finish burr reduction will be there and reduced stress and fatigue will be there most important advantage of this particular process is that you can remove the material in less time; that means, that you are going to give the depth of cut in a huge amount that is if you are going to give normal grinding 10 microns 20 microns and all those things in creep feed grinding will give more than 1 mm, or something that single go; that means, that it is purely a material removal process.

That means, it is the process that you if you want to get certain shape, or size in less time you can go for the creep feed grinding normally, if you see here the depth of cut is 1.6 mm in a 1 go in normal grinding wheels it may not sustain. For this purpose you need to have a specially high strength grinding wheels for this particular purpose.

So, we are going to another variety of grinding purpose which are conventionally advanced ok, these are the old techniques, but there is some of the advancements are there in this particular processes. So, that is why it is called which are the conventionally, but this used for the adventional.

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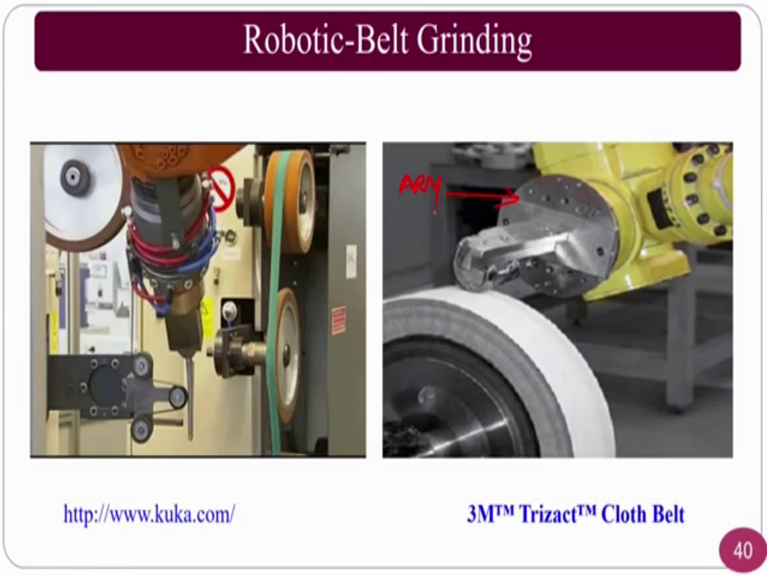

So, here you are use the robotic arm to against the built grinding process, if you see here it is a hip implant basically machined against the built grinding process ok. These are the belt, if you see this is also belt and this is also a belt continuously flowing belt is there which is moving and.

So, that the finishing of the implant will takes place if you see here, can you see now the belt is continuously rotating and the robotic arm is putting some pressure on the metal, if at all I have a complicated surface to be finished. Till now what we have seen, if have a irregular shape up to some extent like convex concave and all those things, internal surfaces, cylindrical surfaces, as well as most importantly flat surfaces.

If at all I have still more complex surfaces, then we can go for robotic arm assisting belt grinding processes, these are one of the advanced techniques, but using the conventional mechanisms like belt grinding and all those things, you can see here it is polished against the cloth belt.

So, there is called buffing there is called polishing of this complex surfaces and all those things there also, they will this particular portion is a robotic arm this is a robotic this is a arm, which can give the motion as per the requirement, this is one variety.

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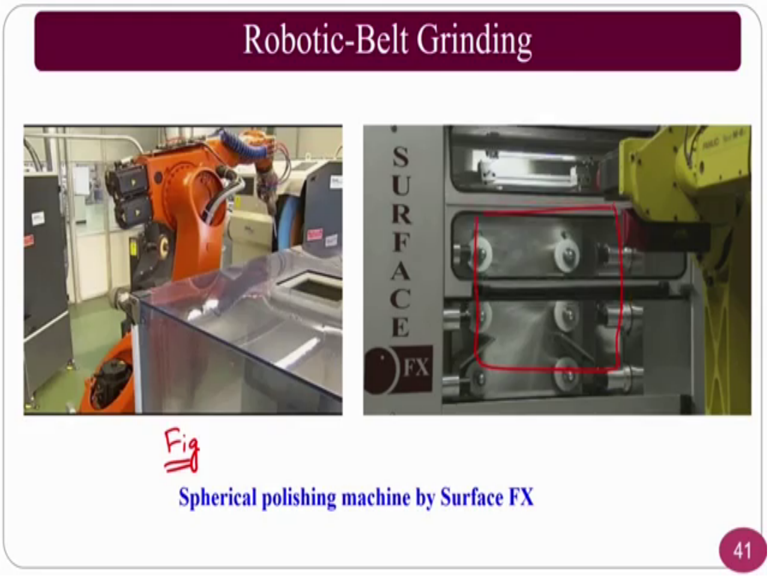

If you see there is second variety there is also grinding wheels, which where you can put the complex surfaces using the robotic arm, here also not only the belts you can also use the grinding wheels itself that is what I want to show, if you see here the second picture this is the figure 1, where hip implant stem is fabricating, or finishing is going on.

In another case hip implant head is going to finish here, if you can see here the finishing action is taking place on the head ok, that is how the normally bio implants of for example, I am taking in this one as a bio implant is a hip joint because, you need a good surface finish on the hip, if it is not there normally the motion of particular person will be very less ok. So, you need very good surface finish on that one.

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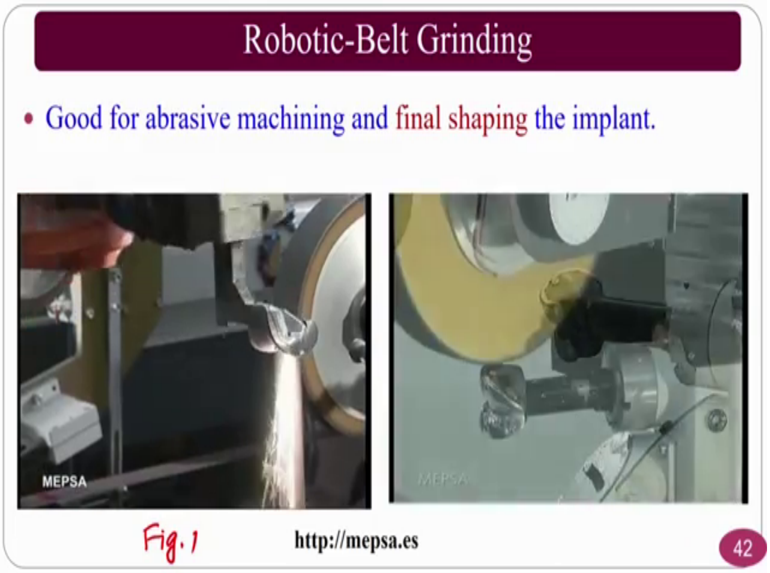

If you see the knee implant; knee implant also can be machined in two ways, or the finished in two ways that is called belt grinding, if you see here the belt grinding operation and knee implant. In the figure 1 how the knee implant getting different different complex motions from the robotic arm and, it is fed against the belt ok. And it is getting super finished, or it is get finished. In another case if you see the knee implant is fed against the grinding wheel itself.

So, in this way the complex surface is finished. So, grinding process has ability to do simple to complex shapes and, it also can give very good surface finish, depend always please note that the surface finish, if you want then you have to give very low input conditions; So, that the interacting forces between wheel as well as the work piece will be less ok.

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These are the advantages and applications, if you see the advantages dimensional accuracy good surface finish form locational accuracy normally this is applicable for hardened, or unhardened work piece materials applications, huge amount of applications are there like surface, finishing, slitting, parting, descaling stock removal finishing of flat and cutting, as well as what we have seen last is it can also useful for the finishing of the complex surfaces.

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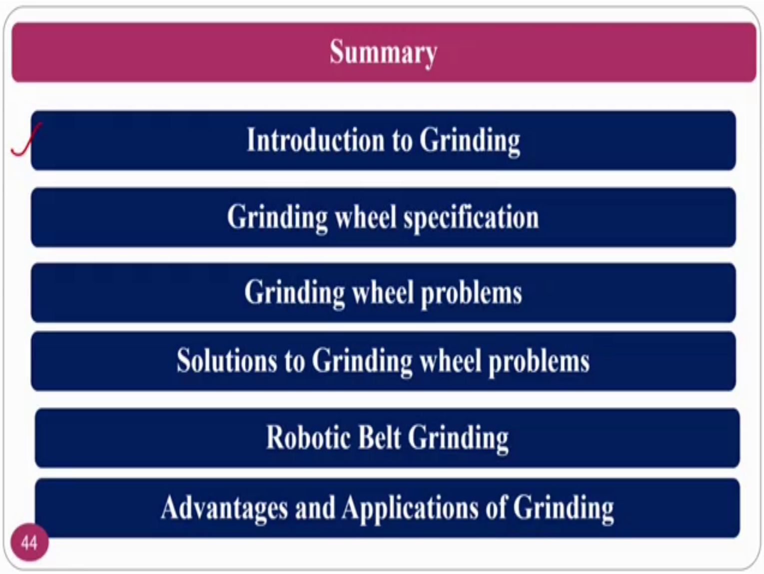

Summary of this particular class if you see, the summary goes like this introduction to the grinding we have seen, followed by the grinding wheel specification wheel problems, as well as that is solutions, and at last we have seen the one of the applications of the basic physics in terms of the robotic arm belt grinding and all those things followed by the advantages and applications.

So, this is one of the conventional fascinating process, where you can take up if you are a masters and PHD student, you have a lot of scope to do the research. It is a evergreen process and if you can find lot of papers still, you can do lot more research in it and thank you for this lecture, as well as for your kind patience hope you enjoyed the course from the advance from the basic of the grinding to the advanced version one of the version that I have shown as a glimpse hope you enjoyed the class.

Thank you.