Non - Metallic Materials
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Module - 11
Corrosion and degradation of non - metallic materials
Lecture - 59
Finishing of Ceramics

Welcome to my course Non-Metallic Materials and this is Module number 11, Corrosion and degradation of non metallic materials. And we are in lecture number 59 where today I will be talking on Finishing of Ceramics.

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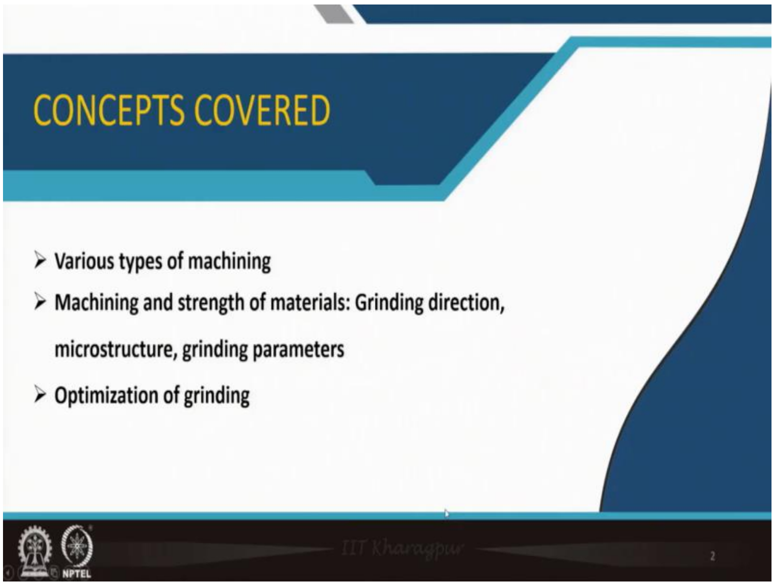

So, for ceramic, machining is relatively complicated. So, first I will introduce various types of machining in a complete a sintered ceramic article. And a machining suddenly affects the strength ultimate strength of the material.

So, what are the different factors, like grinding direction, microstructure of the material or several other grinding parameter. They influence their strength that will be discussed and finally, how to optimize the grinding in order to get reasonably good strength of the finished product that will be introduced.

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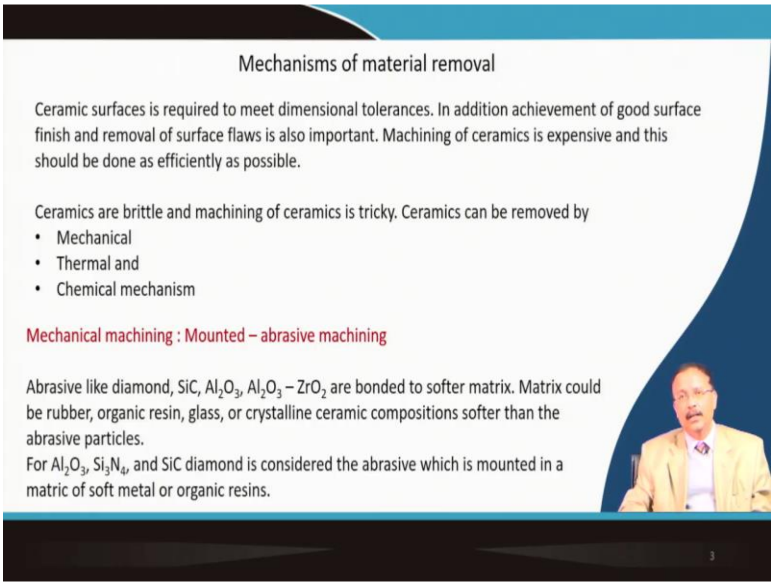

So, many of the ceramic surface that after you center it is required to meet certain dimensional tolerance. So, surface finish is also important and to maintain the tolerance, you need to machine it also. So, machining is not as easy as in case of metal because you know that ceramic is a brittle material. So, if you want to polish glass or you want to polish a turbine blade to make it more tolerant towards this dimension, it is really a tough job.

So, it is a tricky job; it is a tricky job to machine the sintered ceramic part. But broadly, there are three procedure that is followed. The first one is a mechanical type, second one is thermal type and also in some instances chemical mechanism is adopted to machine the ceramic part.

So, in the mechanical machining, abrasive usually they are mounted on a surface of some other material and then the ceramic article is forced on to the abrasive surface which sometimes they are mobile or sometimes you make the ceramic mobile depending on the type of the material we are talking about.

So, usually a abrasive like diamond, silicon carbide, aluminum oxide, alumina, zirconia composite. They are bonded to the softer matrix and this matrix could be rubber or organic resin, glass, crystalline ceramic compositions which are softer than the abrasive particle.

So, for harder material like aluminium oxide, silicon nitride or silicon carbide diamond is the only abrasive which is mounted again on a matrix of soft metal or organic resin.

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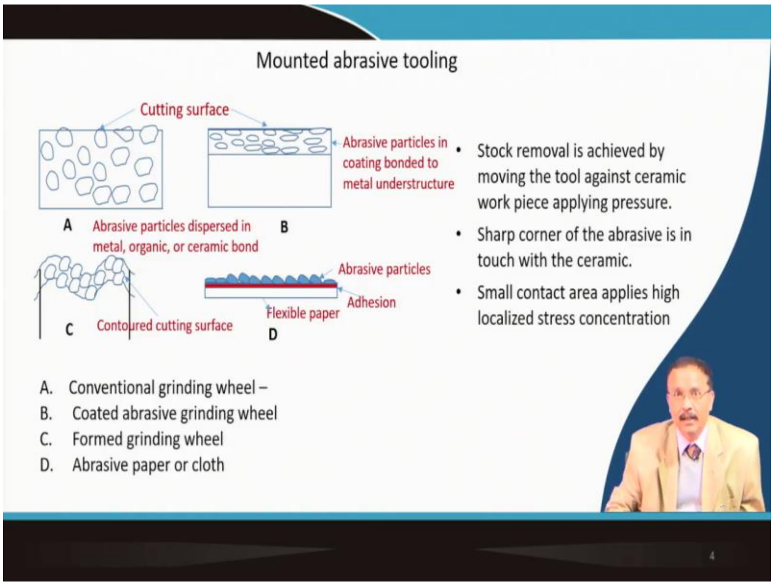

So, basically this four types of grinding is adapted for mounted abrasive tooling. The first one is a conventional grinding wheel which all of you are familiar with. Second one is again it is a coated abrasive on a grinding well.

And third one is having some kind of contoured surface and this is the abrasive part. And fourth one is usually a paper or cloth is there and with a glue you put this abrasive part. So, this is the common example of emery papers; so, called emery paper.

So, the removal of the ceramic article that is achieved by moving the tool against the ceramic work piece by applying pressure. So, the sharp corner of the abrasive that is in touch with the ceramic and it is having a very small contact area and that applies a very localized stress concentration to remove the extra part of the material.

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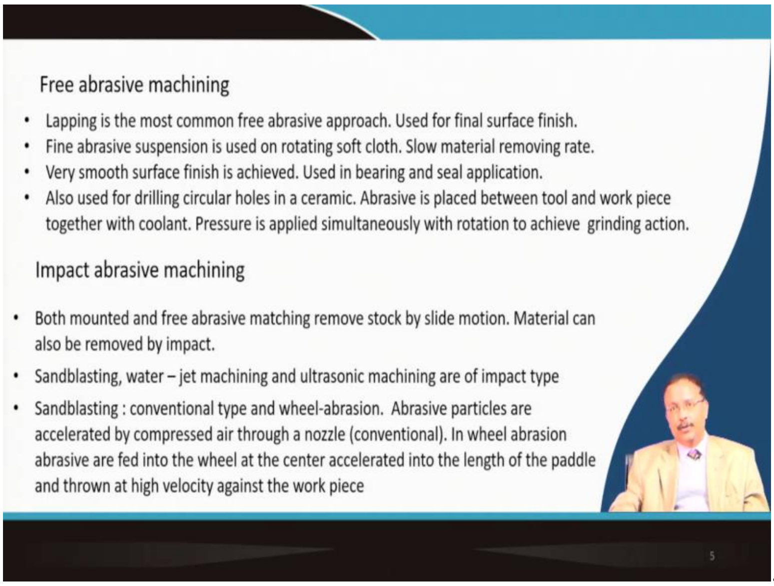

Second we have free abrasive machining and lapping is one example that is most common. So, the abrasive you take in a suspended form and then put this abrasive on a moving cloth to polish the ceramic article. And usually this type of free abrasive machining is done when you need a final surface finish almost optical finish; if it is required then lapping is usually done.

So, a soft cloth like velvet is used, but the removal rate of the material is relatively slow. For sudden bearing or seal ceramic seal, usually a very fine surface finishes required. So, there a free surface abrasive machining is required. Sometimes this fine abrasive is also used to drill circular hole in a ceramic material.

So, in that case abrasive is placed in between tool and work piece together with a coolant and pressure is applied simultaneously with the rotation. So, there is a grinding action to make this hole insight the sintered ceramic.

Third one is an impact abrasive machining. So, here both mounted and free abrasive matching remove stock by slide motion, material also can be removed by impact. So, sandblasting is one example of it. Water jet machining that is also adopted or sometimes ultrasonic machining, they are also of impact type.

So, in sandblasting conventional type or wheel abrasion both are used. So, abrasive particles, they are accelerated by air and they passed through a nozzle which is a conventional type. In case of the wheel abrasion abrasive are fed into the wheel at the center and accelerated into the length of the paddle and they are thrown at high velocity against the work piece.

So, this is sandblasting. They are basically used to clean the ceramic surface maybe the temple and the old ceramic article which is having its own stain over the period of time there. Sandblasting is usually used to clean the surface part.

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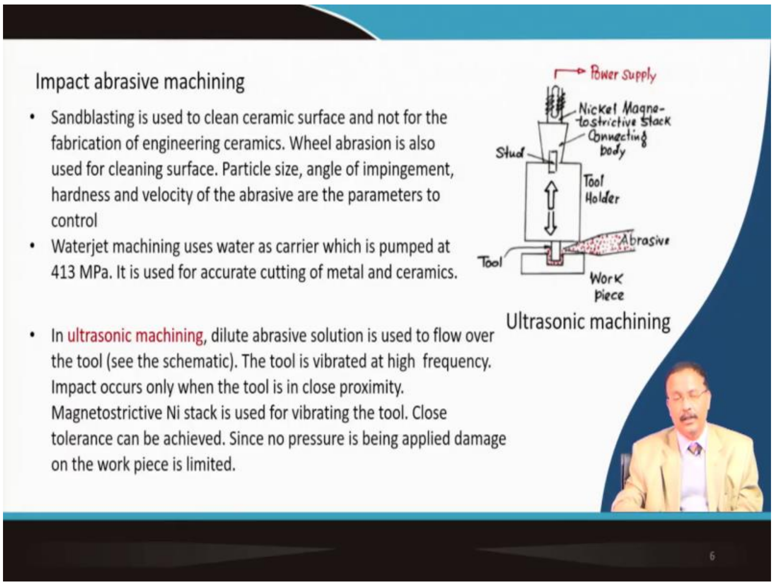

So, for fabrication of the ceramic engineering ceramic usually sandblasting they are not done.

Wheel abrasion that is also used for cleaning the surface, the size of the particle, angle of impingement, hardness, velocity of the abrasive these are the parameter to be controlled so, that you can have effective cleaning action.

Water jet machining that basically uses water as a carrier. They are pumped at reasonable high pressure and this can be used to cut both metal and ceramic along with the abrasive part.

So, here in a schematic, ultrasonic machining example has been cited. So, this is the ceramic article and you would like to make a hole maybe a through hole a very precise through hole although this ultrasonic machining a very precise dimension of this hole making is very difficult.

But this is one of the one of the good tools to make the a small hole inside is standard ceramic a center sample. So, tool is kept as a very close proximity and then abrasive which is a dilute suspension that is thrown here and then there is a nickel magnetostrictive stack that is there which vibrates at ultrasonic frequency.

And you have the abrasion abrasive particle, they are continuously flowing through this nozzle and there is no pressure between the tool and the work piece. And by the simple impact of this abrasive particle along with this sound by ultrasonic web, the fine hole one can make which is reasonably good defect free article.

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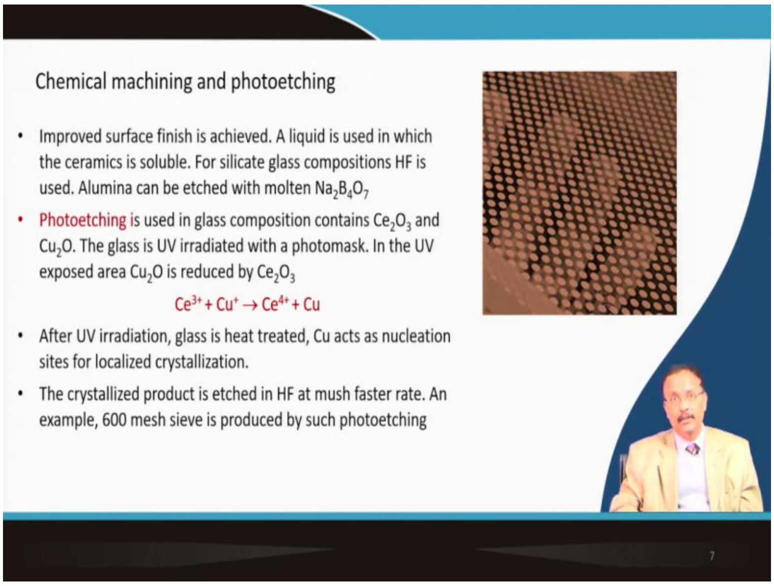

Chemical machining that is also done for the final finish. So, a very good surface finishes achieved, liquid is used in which the ceramic is basically soluble. For silicate glass you know that hydrofluoric acid can be used or in case of alumina, sodium Na 2 B 4 O 7 this molten solution can be used for the surface finish.

So, in certain cases photoetching is also done that is used basically a glass composition which contains cerium oxide where cerium is in plus 3 valence state and copper oxide where copper is plus 1 valence state. So, the glass can be UV radiated with some kind of photo mask which is shown here. So, it is e radiated with UV radiation so, where it is exposed to UV radiation.

Then copper oxide is reduced by cerium oxide. So, it is plus 3 valent copper is the plus 1 valent. So, cerium is oxidized and copper is reduced to metallic state. So after this UV radiation, the glass is heat treated so, then copper acts as a heterogeneous nucleation site and it yields to local crystallization.

You way like to dissolve this crystallized product by treating with HF. So, HF will eat this crystallized product as a much faster rate. So, you can get a mesh of as small as 600 mesh sieve very fine whole you can make by this chemical machining followed by photoetch; photoetching followed by chemical machining, you can make a very glass very very fine 600 mesh glass block.

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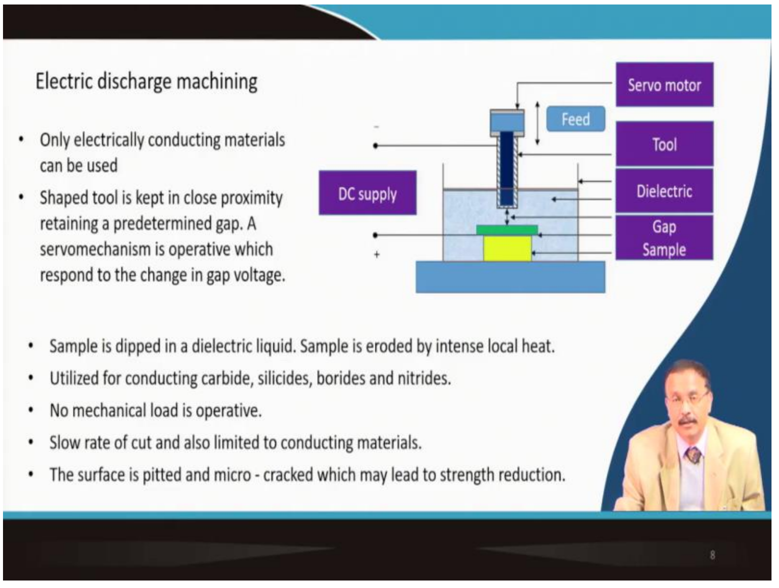

Electric discharge machining that is applicable to only conducting ceramic material or at least if they are semiconducting in nature. So, this shape tool escaped a very close proximity through an electrode which is this distance is maintained and there is a servo mechanism is operative which basically respond to this gap voltage.

So, the whole sample is dipped in a dielectric liquid and basically the samples are eroded by local heat. This is one of the method to make the bulk ceramic sample for the observation under transmission electron microscope.

So, initial thinning of the sample just after cutting typically a 3 millimeter diameters. After initial cutting, this is electric discharged machine to make it more and thinner and then final chemical polishing is done to have the region which is thin enough for transmission electron microscopy examination.

So, this idiom is used for conducting carbide silicide which are relatively conducting borides, nitrides. So, here as you can see no mechanical load is operative, but the rate of material removal is extremely small and the surface is not very smooth, it is pitted with some kind of micro crack which may lead to strength reduction for final use.

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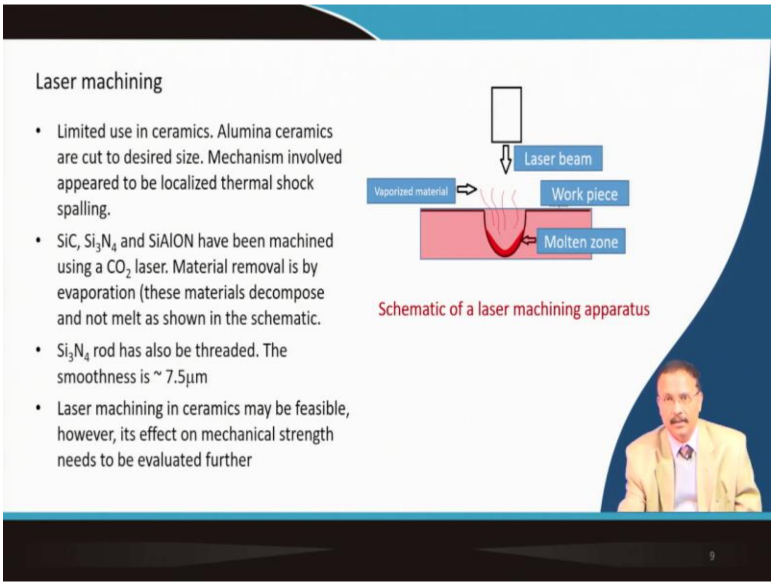

Laser machining is actually limited in case of ceramic, but in alumina ceramic the laser machining has been done. So, the mechanism is a localized thermal shock and resultants poling for a material removal. So, usually silicon carbide, silicon nitride, silicon aluminium nitride SiAION, they are machined by carbon dioxide laser.

So, material removal is by evaporation. So, as you know that this material will decompose and not melt as shown in this view graph. So, it will just decomposed. So, silicon nitride rod, they are traded, but the smoothness is quite good about point 7.5micron by using this laser machining.

So, laser machining in ceramics may be feasible, but its effect on the mechanical strength that is not a very well known at this stage because not many different types of ceramics have been used for lesser machining to test their effect on mechanical property. But this is one of the way to machine the sintered ceramic part.

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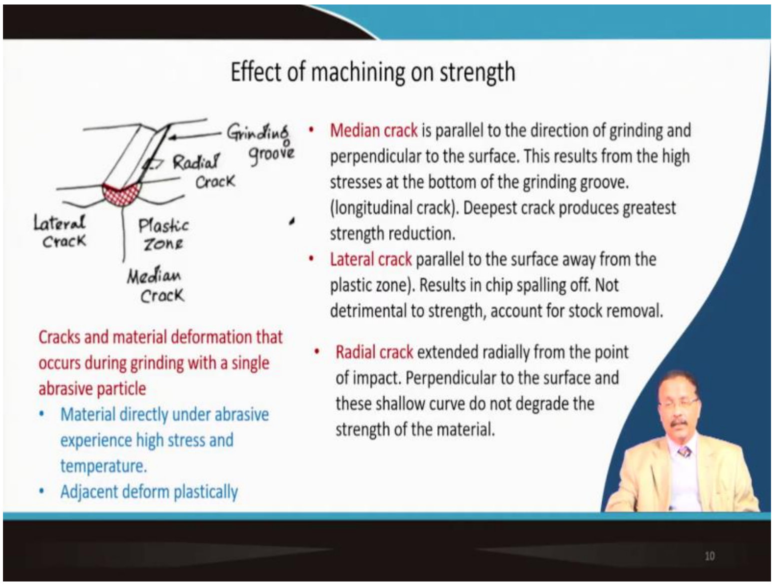

Now, once a particle abrasive particle that is getting polishing in the surface and remove this material. So, there are different types of crack that comes out. So, material which are directly under abrasive experience, a very high stress and temperature and the adjacent part, they will deform plastically something like this.

So, median crack that is parallel to the direction of the grinding. So, the grinding is taking place in the z direction. So, that is parallel to the direction of the grinding and it is perpendicular to the surface as you can see it. So, this results from high stresses at the bottom of this grinding grove which is being made by this abrasive particle.

So, these are known as longitudinal crack and this kind of crack actually, they affects more as far as the strength of the ceramic is concerned the presence of this kind of crack. Lateral crack as you can see that is parallel to the surface which is being a machined and this actually result the chip spalling off.

It is not very detrimental for the strength of the ceramic article, but this is required for the removal of the material. Apart from this two, you have a radial crack that is extended radially from the point of impact and it is also perpendicular to the surface. And this curves are this kind of a cracks are not very deep. So, they are shallow and they do not really degrade the strength of the material.

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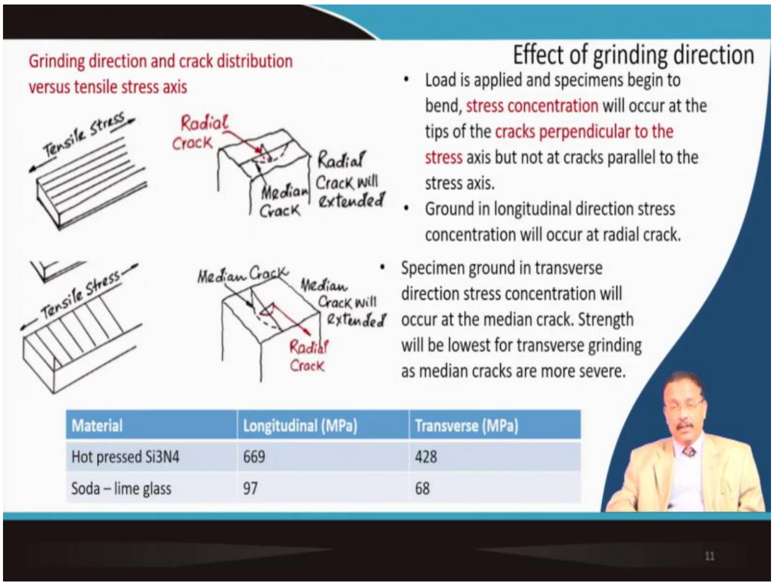

Now, the grinding direction and the crack distribution that actually affect the mechanical property of the material. So, as the load is applied during the machining, the specimen is begin to bend.

So, the stress concentration that will occur at the tip of the crack which is perpendicular to the stress axis, but it will not affect much to the crack which is parallel to the stress axis. So, here it is the stress axis.

So, you can see the median crack here, this crack will not be affected right. But the radial crack this crack will extend because stress concentration will occur at the tip of the crack and crack that is perpendicular to the stress axis that will actually lead to more stress concentration.

Now, if the specimen is ground in the transverse direction which is the second case. So, stress concentration will occur at the median crack. So, here the median crack is this one. So, all the stress concentration will be there along with the median crack. So, the strength will be affected, it will be lowest for the transverse grinding as median crack they are more severe as compared to this radial crack.

So, experimentally this is also verified in case of hot pressed silicon nitride, longitudinal it is 669, the strength of the material after machining in transverse direction if you do the machining, it is 428. Same thing applies for solar lime glass also. In case of longitudinal, it is 97; in case of transverse, it is 68. So, the direction it affects the mechanical strength.

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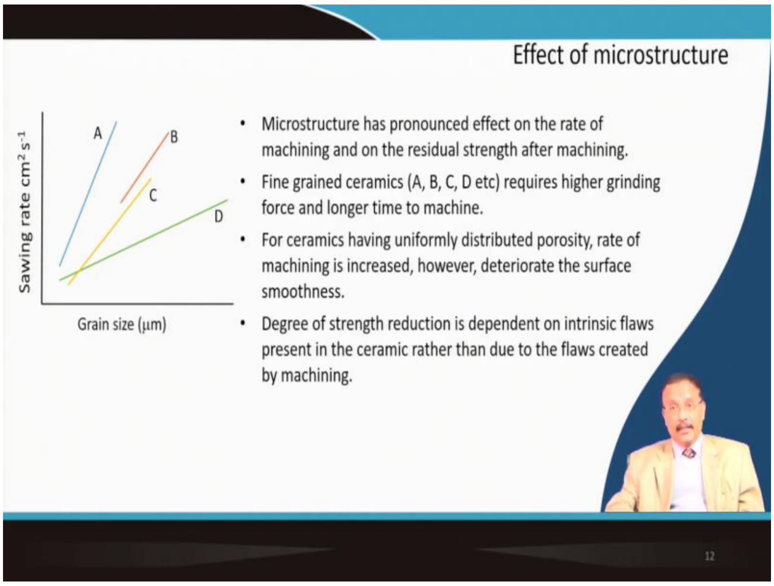

Microstructure also plays a major role on the rate of machining. So, I have considered fine grained ceramics four different types A, B, C, D. So, the finer requires more grinding force and it takes long time to get machined. So, the ceramic which are having a very uniformly distributed porosity, the rate of machining is increased; however, deteriorate the surface smoothness.

So, if you have porosity left in the material of course, your machining will be expedite. The rate of machining will be expedite, but due to the pore there when the surface is exposed it will be rough and you need to re polish it and it will have its effect on strength as well.

So, degree of strength reduction is dependent on intrinsic flaw present in the ceramic. So, that is more affects more as compared to the surface flow that is created by the machining. So, again it is of at most importance to center the ceramic material to the full extent. So, that the internal porosity presents of crack (Refer Time: 21:30) are grossly minimized.

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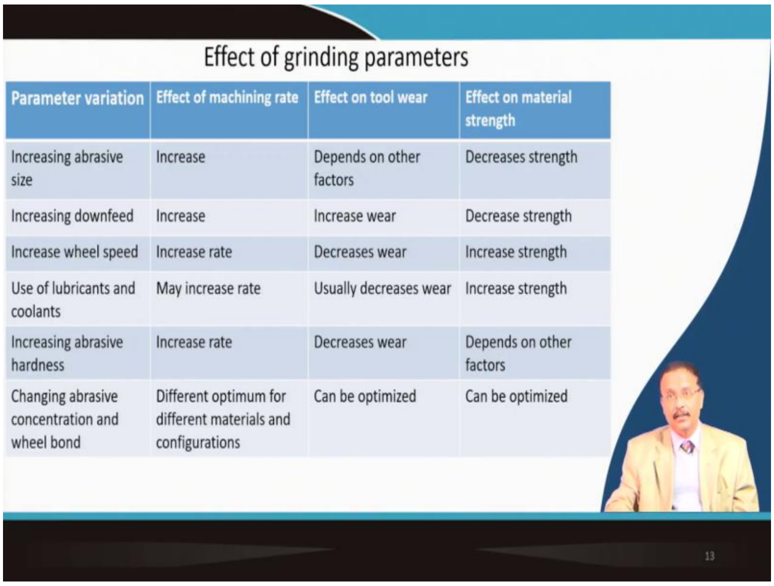

So, the grinding parameters it is tabulated here. So, these are the parametric variation. So, it is you can just think of it and you will be able to understand their effect. For example, increasing abrasive size, then suddenly if you have large size of abrasive then machining rate will increase. Tool will also wear the grinding tool will also wear more and material strength will get reduced because of this larger surface flaw.

Likewise the increase of the feed material, increase of the wheel speed use of lubricant or coolant while you are machining the ceramic, increase of the abrasive hardness or changing the abrasive concentration in the wheel bond. They will all have their own effect and you can use your judgment to see.

For example, if you use lubricant, then suddenly the heat will be dissipated more. So, that may increase the machining rate. If you increase the abrasive hardness, then it will be easier for you to remove the material. So, likewise this grinding parameter their effect on the machining rate and effect on the wear of the tool, the erosion of the tool and finally, on the strength of the material can easily be understood.

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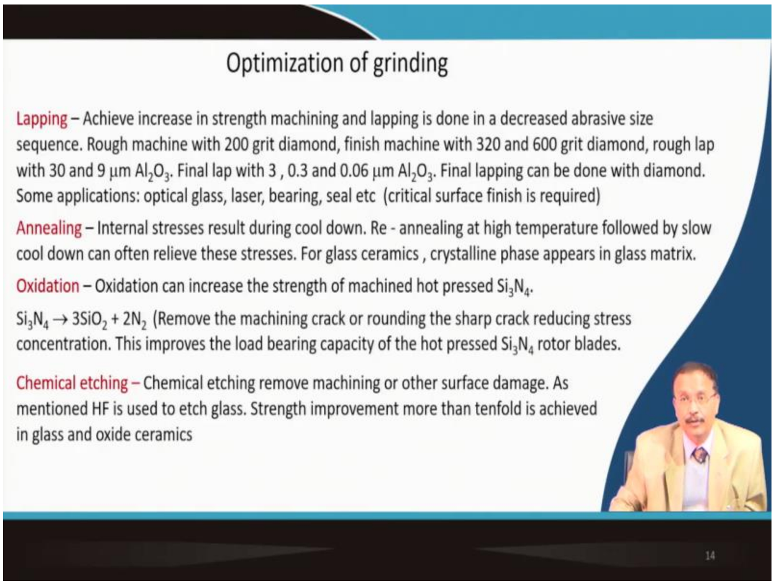

So, finally, you will have to optimize the grinding. So, lapping is one. So, in case of lapping, progressively you use higher to a lower size of abrasive. So, rough machining is usually done by 200 grit diamond and then as the number increases. So, it becomes finer and finer.

So, 320 and 600 grit of diamond, then with 30 and 9 micrometer of aluminum oxide and finally, very fine size of aluminum oxide 3.3 and 0.06 micrometer. So, this final lapping once you done progressively from higher to lower particle size of the abrasive, the surface finish is quite good almost optical quality polish shining finish, you will get in the ceramic as well if it is sintered well.

Annealing also is done to remove the internal stress uh. So, that already i have explained that in case of glass, the tempering is done to remove the internal stress to make it stronger. So, annealing is having its own effect after grinding operation. Then oxidation sometimes it is very useful in case of the silicon nitride kind of thing. So, the surface is getting oxidized to form silicon dioxide.

So, once this is oxidized, the machining crack is almost filled up or at least a sharp crack, they are rounded off. So, that reduces the stress concentration. So, that improve the load bearing capacity and as you know the silicon nitride is used for rotator blades.

Chemical etching is done to remove the machining or surface damage. So, HF is the chemical that is used for glass. So, that is the rubbed glass and usually in this kind of glass, the strength improvement is almost tenfold in as compared to the normal glass or for certain oxide also, this chemical etching is found to be quite good.

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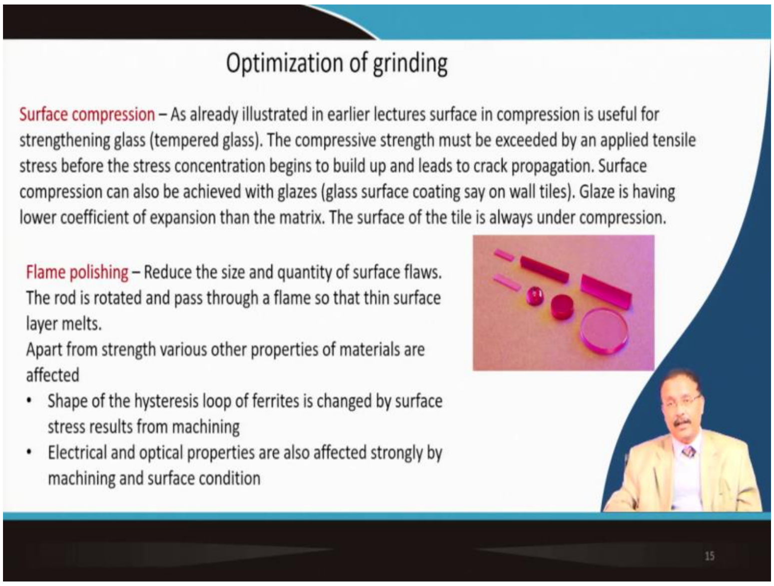

Surface compression that is also used for a glass either by use of chemical or by heat treatment that is actually yield a compressed layer on the surface. And if you are applying a tensile load, it will have to overcome this compressive stress before it fracture the material. So, that is found to be useful.

So, in case of ceramic tile, sometimes a glaze is applied on top of it. So, that glaze is having a lower coefficient of expansion than the matrix and always the surface is under compression in case of laser usually flame polishing is done. And in case of flame polishing it size it reduces the size and quantity of the surface flaws and the rod is basically rotated and pass through a flame so, that the thin surface layer that basically melts.

And apart from the strength various other properties of the material is also affected. So, for example, shape of the hysteresis slope of the ferrite that is changed by surface stress results from this kind of machining, certain electrical and optical properties are also affected by machining and surface conditioning techniques.

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So, the reference for this part of the lecture is a book by Richerson, Chapter-12 Final Machining. So, you can use it as a study material.

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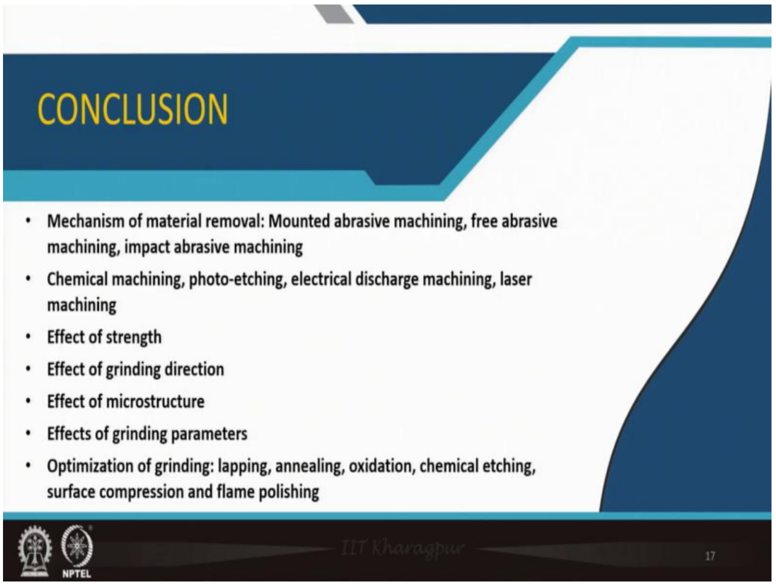

So, mechanism of material removal is explained, mounted abrasive machining, free abrasive machining, and impact abrasive machining has been discussed. Chemical machining, photo etching chain, electric discharge machining, laser machining; this concepts have been introduced.

Then how machining affects the strength the grinding direction effects the strength, microstructure plays a major role to control, the strength of ceramic after machining. Then several grinding parameters we have introduced and finally, optimization of the grinding in way of lapping, annealing oxidation, chemical etching, surface compression and finally, flame polishing; this concepts where just write.

Thank you for your attention.