Mathematical Modeling of Manufacturing Process
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Lecture -38
Principle of Glass and Ceramics Processing and their Shaping

Now, we will discuss about the glass welding process. In principle, actually glass is having range of temperature over which it becomes softer and becomes more flexible that is called the glass transition temperature. So when by heating we can bring in that situation at this point if we try to give some kind of shape to the glass then it will take the after that if you follow the cooling then glass actually takes a particular shape. So this is in general the processing of any kind of glass components.

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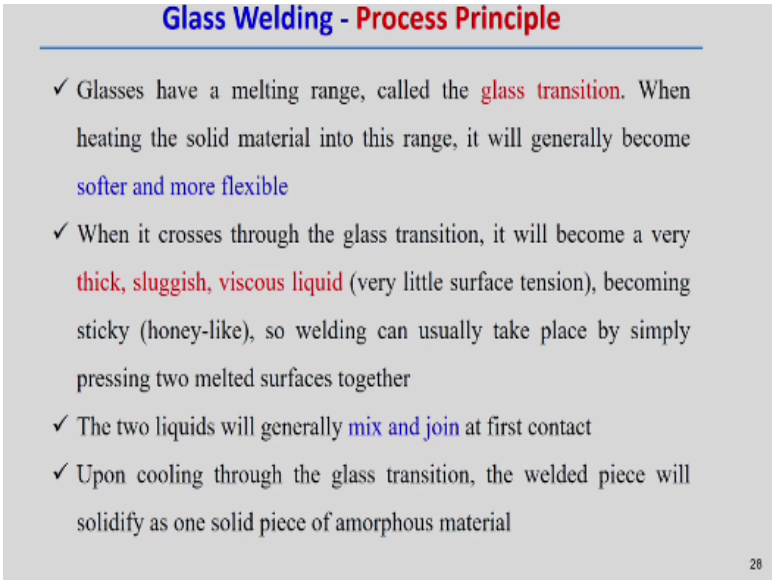

But when it crosses through the glass transition temperature then it will become a very thick sluggish and kind of viscous kind of liquid and when viscosity enhances and definitely the surface tension actually decreases so it becomes very sticky honey like structure. So welding can easily takes place by simply pressing two melted surface together. So in this cases what happens that we bring the by heating the glass.

It is a kind of improve the viscosity of this glass material and at this point and you are simply pressing the by pressing it the two different glass components can be joined and that is in principle the welding of the glass procedures, but two liquids will generally mix and join at

the first contact and then upon cooling therefore during the cooling phase glass transition within the glass transition phase.

The welded piece solidify and one solid piece of the it creates kind of the amorphous material. So we already discussed that it is if it is glass normally made of amorphous and normally the structure is amorphous structure such that the melting or maybe it becomes more flexible or soften its a wide range of temperature that is called the glass transition temperature.

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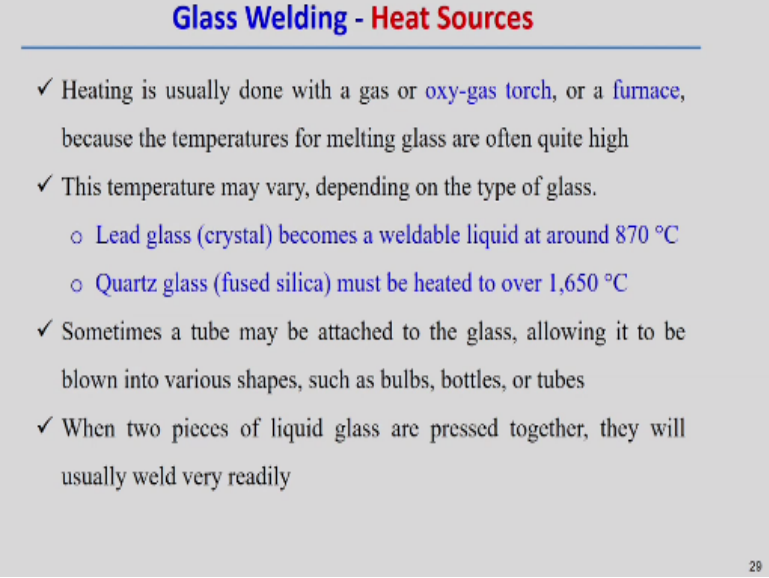

So this is in principle following the joining of the glass, but what way we can heat the sample the normal heating source for example simply we can use the oxy gas torch or furnace also can be used to heat the glass samples and because the temperature for melting are often quite high in this cases. So sometimes we need kind of oxy-gas torch or furnace to heat the glass samples.

But of course the glass the temperature can vary depending upon what type of the glass we are handling. For example, lead glass and the crystal then in these cases becomes a weldable liquid at around 870 degree centigrade even we can see that around weldable at around 870 degree centigrade which is quite more even for in case of aluminum also this temperature and if we handle the quartz glass.

In this cases there can be heated necessary to heat it around 1650 degree centigrade which is much more and of course even I can say I can tell that it is near above the melting of the in

case of steel or iron. So therefore sometimes a tube may be attached to the glass allowing it to blown into the various shape. So when you try to soften it then at this point we try to give the different kind of the shape for glass.

For example, if you use a tube under then such as bubbles bottles, tubes formation can be drawn can a can be made during the processing of the glass, but when two pieces of the liquid glass are pressed together they will actually usually weld very rapidly during this process.

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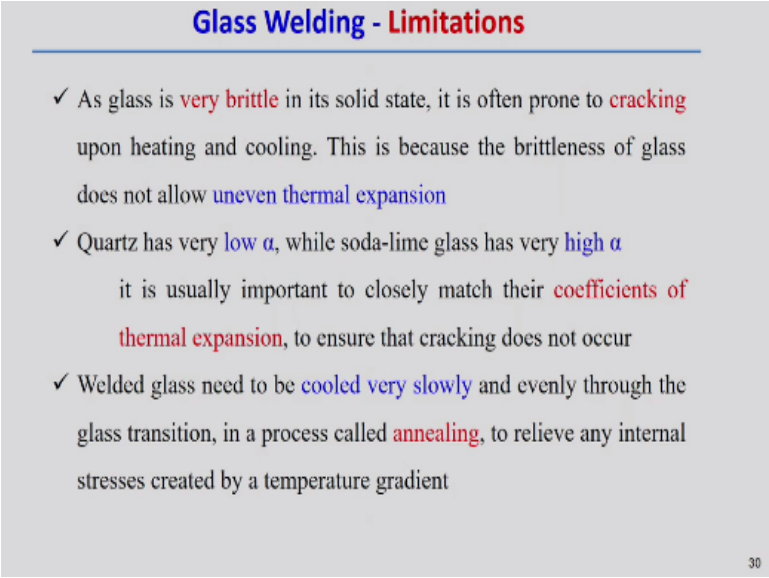

But limitation as glass is very brittle in its solid state so therefore it is never possible to welding or joining or processing of the glass at the solid state normally in other cases welding also we sometimes do the solid state processing or solid state joining of the two different components, but it is not possible in case of the glass and of course since it is a very brittle so there is a chances of formation of the crack.

If we do not handle the rate of the cooling during the formation. So because uneven heating and cooling actually induces some amount of the crack during the position of the glass so that is the main difficulties to handling the glass and this is definitely because of the brittleness of the glass and it does not allow uneven thermal expansion that kind of situation condition we have to create to handle or joining of the glass components.

But in case of quartz actually is very low thermal expansion coefficient. So where soda-lime glasses having very high thermal coefficient, high value of alpha. So therefore it is usually important to closely match the thermal expansion coefficients such that we can join

successfully of the two different components and of course to ensure not to happen any kind of the crack.

Because of difference in the thermal expansion coefficient between the two components so that is the most critical part for handling of the glass welding processes. In general, welded glass in principle has to be cooled down very slowly and evenly through the glass transition temperature and this process is called also annealing that we have already described what is the annealing with one of the phase and the glass processing.

So therefore (()) (06:08) any material stresses two internal stresses created by the temperature gradient that kind of situation we have to avoid and that is why it needs to follow the annealing process and for handling of the glass. In general, the cooling can be done very carefully and very slowly that is the main principle of welding of the glass components.

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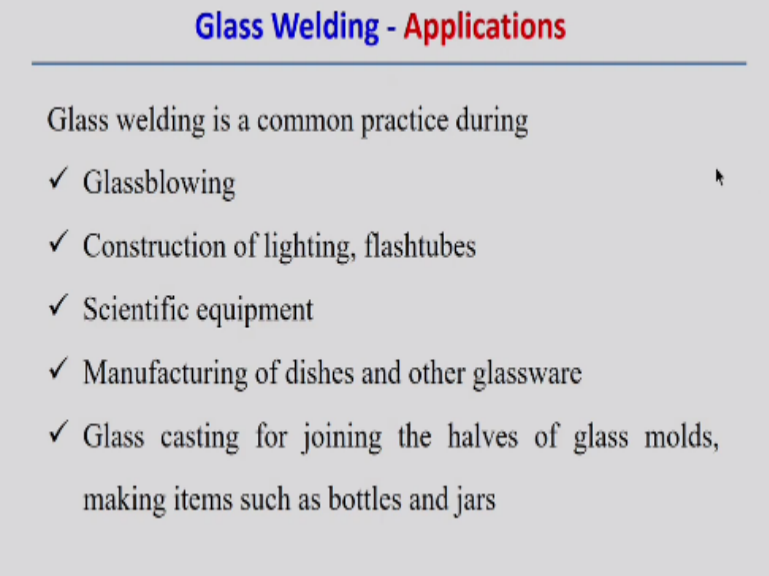

Glass welding is a common practice during the glassblowing process, construction of the lighting flashtubes there you can see that formation of the glass is necessary, scientific equipment also we can we can find out the application of the glass manufacturing of dishes and other glassware also and glass casting for joining the halves of the glass molds, making items.

Such as bottles and jars also there we can follow the glass casting process to get the desire shape. So these are the typical application of the glass welding process how we can find out at the joining of the two glass components or as well as taking the different shape of the

glass. Now we come to that ceramic welding process of course we know that ceramic is one another type of material with huge applications, but (()) (07:26) having the also similar kind of behavior is also very brittle.

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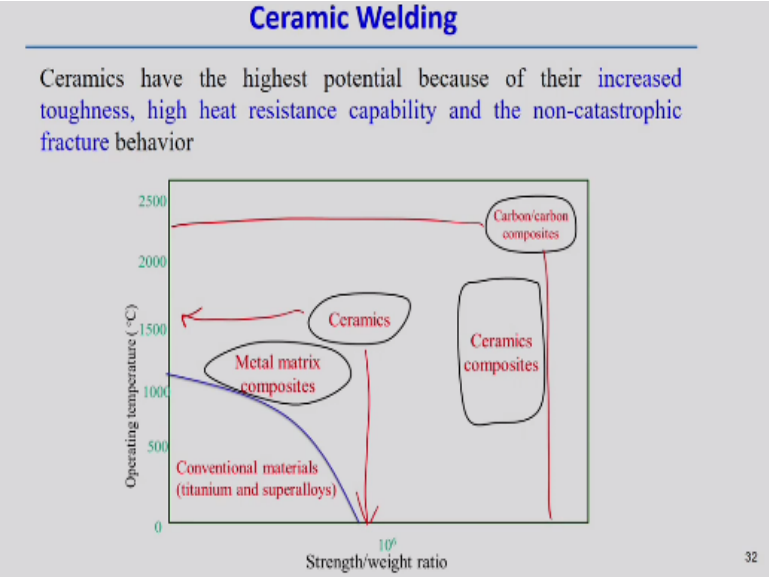

This is having the highest potential because of the increased toughness high heat resistant capabilities and of course and the non catastrophic failure fracture behavior. So therefore all these typical characteristics makes the (()) (07:46) of the ceramics is very difficult and most important thing is the ceramic is also very brittle if we look into that operating temperature and strength weight ratio.

We see the for operating temperature for welding of the ceramics somehow in between. Here you can see that around this temperature and the strength of weight ratio is almost at the middle position and of course which is completely different from the carbon composite. This are the where we can see the operating temperature of the ceramic such that we can do the welding of the ceramics.

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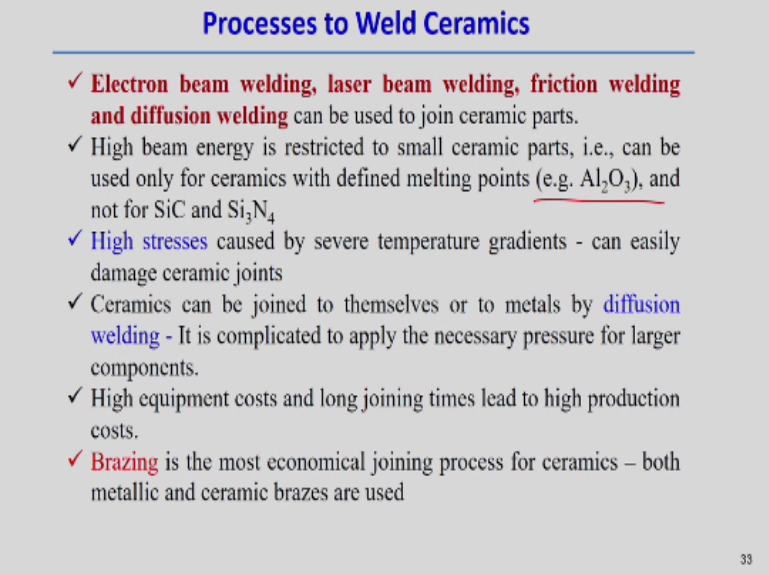

Processes to weld a joining of the ceramics is like that electron beam welding can be done, laser beam welding can be done, friction welding and diffusion welding normally all these processes are normally applied for the joining of the ceramic components. High beam energy is restricted to small ceramic parts for example can be used only for the ceramics with the different melting point.

For example, aluminum oxide Al2O3 and not for silicon carbide and Si3N4 cannot be handled by using the high energy beam. So therefore electron beam or laser beam welding for joining of the ceramic components is limited to particular ceramic component one example is for example Al2O3. High stresses caused by severe temperature gradient can easily damage ceramic joints.

So that is the one point because ceramics the it cannot absorb the deformation therefore high stresses can be created if their existence of any kind of the temperature gradient. So that can easily generate that can easily damage the ceramic joints. So ceramic can also be joined by themselves or using the metals by diffusion welding processes, but it is very complicated and large pressure amount of pressure is required specifically for larger component.

And which is in principle which is the principle of the diffusion welding processes also and high equipment cost long joining times normally leads to the high production cost if we follow the diffusion welding processes. So most feasible and economical process is brazing for joining of the commercial ceramics components both metallic as well as the ceramic braze can be used for joining of the ceramic components.

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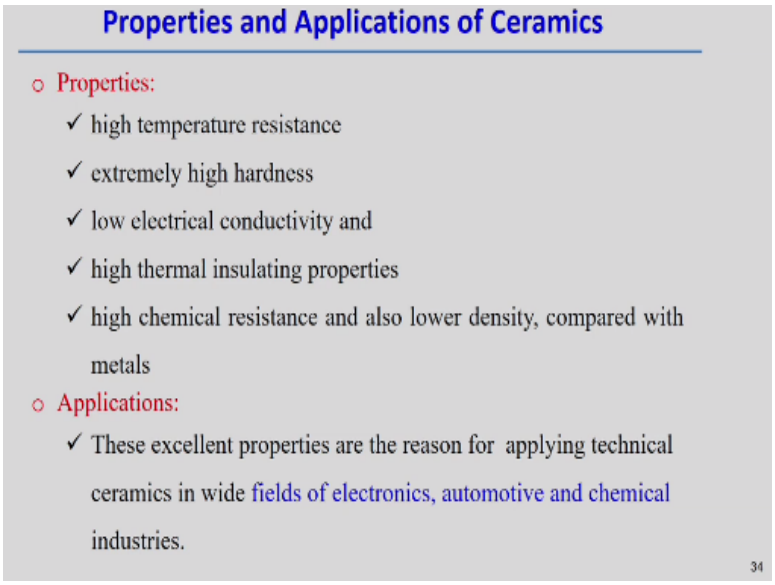

Properties and applications of ceramics I can see the properties it is a high temperature resistance that is the main properties and we can based on that several application is possible or ceramic components. Extremely high hardness, low electrical conductivity and therefore this can be used some insulating material, high chemical resistance as well as the lower density compared with the metals these are the typical advantages of the ceramics.

And that is why with this attractive properties a lot of application you can find out using the ceramics. So therefore excellent properties reason for applying technical ceramics in the field of electronics, automobile and the chemical industries also and maybe electronics ceramics normally used for the act as insulator there.

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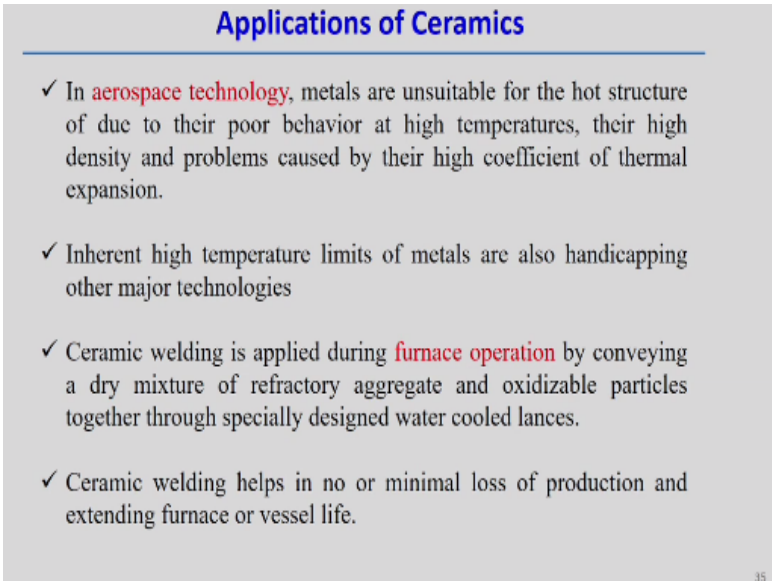

In aerospace technology also we can find out the application of ceramics the metals and metals are unsuitable for the hot structure of due to their poor behavior. So therefore at high temperature application is ceramics more suitable as compared to the metallic component and of course other point is important there the density is low in case of certain ceramic component as compared to the metallic component.

But only the problem is the high thermal expansion and coefficients is also very low in case of ceramics. So any kind of temperature gradient some create problem processing of the ceramic components which may not be the case in case of the metallic material. So inherent temperature high temperature limits the metals are also handicapping other major technologies.

So high temperature application that is the advantage of the ceramics as compared to the metal and even ceramic welding is applied during the furnace operation also by conveying the dry mixture of the refractory aggregates and the oxides particles together through specially designed water cooled lances there we can finding out the welding of the ceramics even in case of furnace operation.

And ceramic welding helps in no or minimum loss of production and extending furnace or the vessel life that is also another advantage of using the ceramics.

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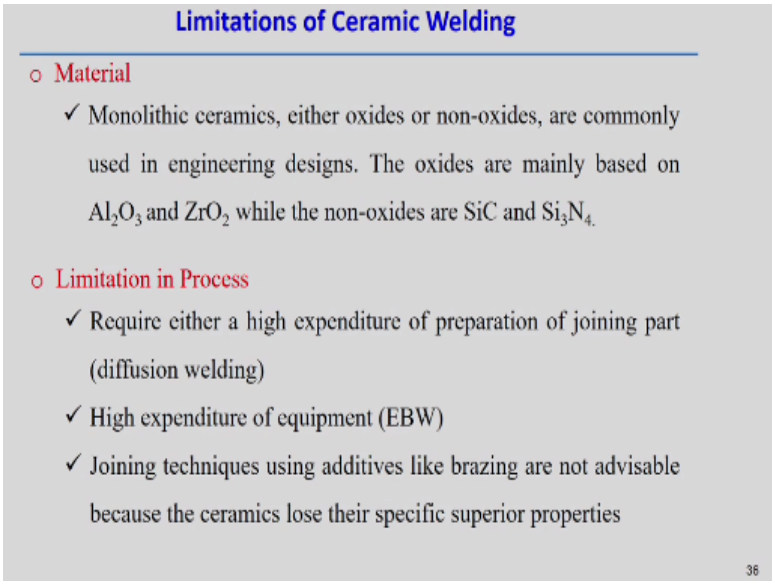

Limitation of the ceramic welding, the monolithic ceramics either oxides or non oxides are commonly used in the engineering design. The oxides are mainly based on the Al2O3, ZrO2

and with the non oxide silicon carbon and Si3N4. These are the typical most components we use the ceramics made of all these components, but limitation in the process we can find out either a high expenditure of preparation of the joining part.

Maybe if we look in to join the two components, ceramic components then it Is the diffusion welding one is the reliable process, but diffusion welding takes a equipment cost is very high as well as the time requirement also very in case of handling the ceramic components. High expenditure equipment even if we follow the electron beam welding process for a particular specific ceramic components in this cases the machine cost is also very high in this case.

Joining techniques using the additives like brazing are not advisable because the ceramics lose their specific superior properties when you try to braze using the braze joint, but other since the brazing is the one of the economical process to simply joining the two ceramic components, but joint strength may not be as high as if we follow the diffusion welding or may be high energy beam oiling process.

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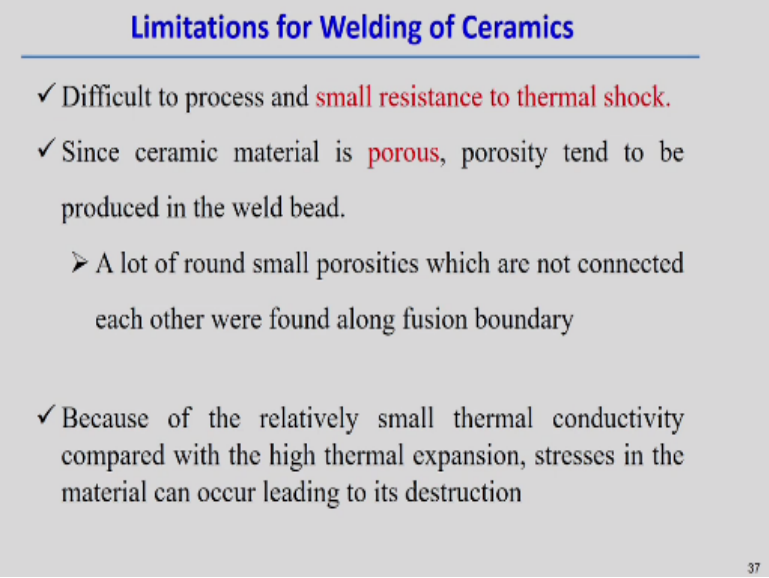

Limitation other limitation for welding of the ceramic components like difficult to process because of the small resistance to the thermal shock. So any temperature gradient or thermal shock is normally not absorbed by the ceramic components therefore that is the one of the difficulties or when you are processing the ceramics. Since ceramics material is porous material so porosity tend to be produced in the weld bead.

So a lot of round or small porosities which are not connected each other were found along the fusion boundary so that is one of the difficulties of joining of the ceramic components, welding of the ceramic components. Relatively small thermal conductivity compared with the other thermal expansion, stresses in the material can leading to its destruction. So small thermal conductivities expansion is very low.

So small temperature gradient can creates a high stress rise here and that can lead to the destruction of the components that is a most serious problem of handling the ceramic components.

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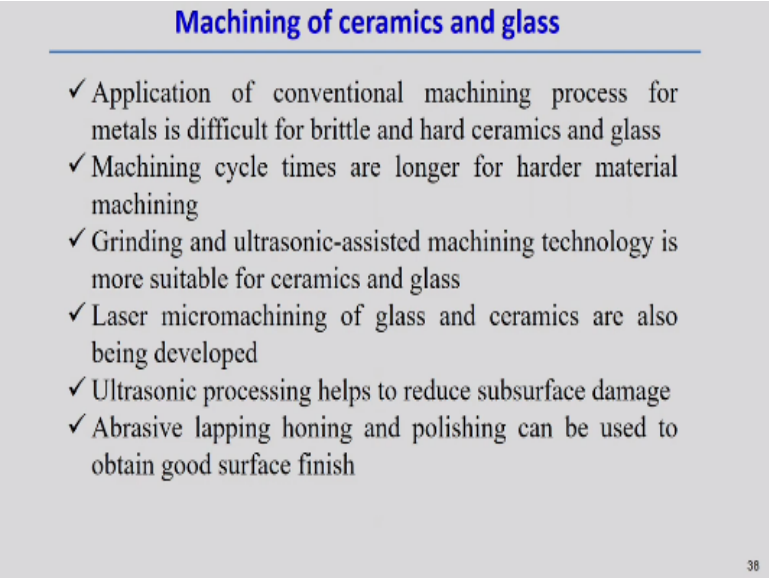

Now we can do the machining of the ceramics and glass process like apart from the joining of the ceramic and the glass components, but here highlighted the typical significance points for the machining of the ceramics and glasses. It is also required sometimes so application of the conventional machining process for metals is actually difficult or brittle because of the for brittle, hard brittle and hard ceramics and glass components.

So therefore machining cycle times are longer for hardened material machining definitely that it is in general that is a general comments on that high time, cycle time, (()) (15:23) required if the metal becomes very hard. So therefore the most of the cases we follow the processing of the ceramics and the glass components simply the grinding is the one of the process and apart from that ultrasonic-assisted machining technology has been developed to process (()) (15:42) or the metal removal in case of the ceramics and glass.

But of course if we compare the grinding and the ultrasonic assisted machining in ultrasonic assisted machining the material removal rate is very low as compared to the grinding process. So that is the one limitation the time requirement becomes very high for the machining of the ceramics and the glass components in general. Laser micromachining of the glass and ceramics are also being developed and using the laser as a source.

But ultrasonic processing helps to reduce the subsurface damage because the affected zone using the ultrasonic assisted machining process is very small. So therefore since the affected zone is very small and it is confined the machining or the change in the properties whatever temperature gradient thermal gradient or any other kind of changes that actually happen its very localized small zone.

So that is why ultrasonic processing we can very precisely control the finishing operation in case of the glass and ceramic. So in that sense ultrasonic machining is more is the more suitable for machining of the ceramics and glass if we want to get very high surface finish. Even abrasive lapping, honing and other finishing processes, polishing can be used to obtain the good surface finish in general.

So these are the typical points which is associated with the machining of the ceramics and glass components.

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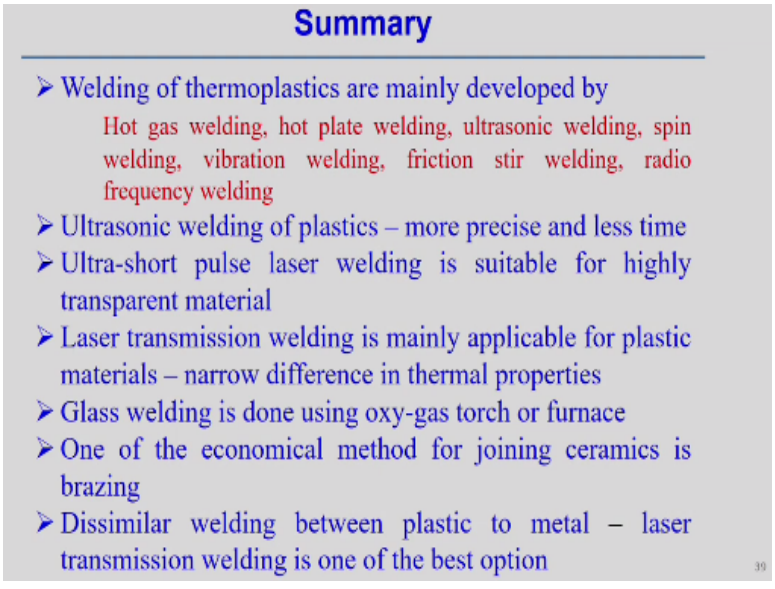

In summary for the processing of the non-metallic materials we can say that welding or joining of the thermoplastics are mainly developed. The different processes such as the hot

gas welding, hot plate welding, ultrasonic welding, spin welding, vibration welding, friction stir welding even radio frequency welding. These are the different types of the technology has been developed for the processing of the thermoplastic.

But ultrasonic welding of the plastics and normally more precise and the less time as compared to the handle of the metallic material or may be ceramics and glasses, but ultra-short pulse laser welding is suitable for the highly transparent material we observe that in case of transparent material if we if we want to join the two transparent material by using the ultra-short pulse laser processes.

In this case at the interface the laser actually release the amount of the energy and two transparent material can be joined by using the ultra-short pulse, but which may not be possible using the conventional because that laser (()) (18:22) is transparent to this particular material. So in that sense ultrasonic laser pulse is having some advantage specifically for joining of the transparent material.

Laser transmission welding is one of the process has been developed which is mainly applicable for the plastic materials, but of course this laser transversal can also be applicable for the joining of the metal to the plastic and we can see the different (()) (18:45) application there may be some requirement of the joining of the metal to the plastic in that cases we normally follow the laser transmission welding process.

And laser transmission welding is mainly applicable plastic material because it is a narrow difference in the thermal properties actually exist so that so it is more suitable there and glass welding we can see the glass welding is done we can some heat source simply by using the oxy-gas torch and or maybe furnace heating is required for handling the glass components or maybe joining of the glass components.

But only limitation of the glass components is that the cooling rate becomes very, very slow such that uneven heating and distribution can be avoided. So one of the economical method for joining of the ceramic components is the brazing process although the joint state may not be as high as compared to the other process, but it is more economical process. Dissimilar welding between plastics to the metal.

The laser transmission welding is one of the best option that we have already discussed here. So in this module actually we have tried to look into the different non metallic materials and normally we focused on the analysis of the or different manufacturing technology applicable for the plastics mainly and that thermoplastics within the plastic we can make that two different group thermoplastic and thermosetting plastic.

And apart from that what way we can handle the ceramics and the glass components. So in this cases normally we discuss that different joining processes mostly focused on this module, but apart from that the different machining processes also applicable for the plastic components as well as the ceramics and glass and also we have discussed that joining of the components biomechanical components it is often require to joining of the two components.

For example, metals and the plastics may be specific applications and that we tried to explore what are the different techniques just try to give overall view of the different manufacturing technology which is relevant to the nonmetallic materials. So thank you very much for your kind attention.