Modern Food Packaging Technologies: Regulatory Aspects and Global Trends

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Welcome to NPTEL online certification course on Modern Food Packaging Technologies, Regulatory Aspects and Global Trends. We were different physical properties of the glass material. In the last lectures we were discussing different physical properties of the glass material. Now the mechanical properties of glass because of its amorphous structure glass is brittle and usually breaks because of an applied tensile stress. It is now generally accepted that fracture of glass originates at small imperfections or flaws.

The large majority of which are found at the surface. A bruise or contact with any hard body will produce on the glass surface very small cracks or checks that may be invisible to the naked eyes. However, because of their extreme narrowness they cause a concentration of stress that may be many times greater than the nominal stress at the section containing them. Because of their ductility metals yield at such points and equalize stress before failure occurs.

Since glass cannot yield the applied stress when it is high enough causes these flaws to propagate. Thus it is the ultimate tensile strength of a glass surface which determines when a container will break. The fracture formula is thus tensile stress plus stress concentrator is equal to fracture. In practice a stress concentrator may be a small crack or check induced in the manufacturing process or a scratch resulting from careless container handling. Therefore, the major step taken to make glass more break resistance involves the elimination of surface flash for example, micro cracks by careful handling during and after forming and annealing since the condition of the surface has a great deal to do with its tensile properties.

The mechanical strength of a glass container is a measure of its ability to resist breaking when forces or impacts are applied. Glass deforms specially until it breaks in direct proportion to the applied stress. The proportionality constant between the applied stress and the resulting strain being Young's modulus that is e it is about 70 giga Pascal for typical glass. The following four aspects are important internal pressure resistance this is important for bottles produced for carbonated beverages and when the glass container is likely to be processed in boiling water or in pasteurized hot water. In boiling water or in pressurized hot water internal pressure produces bending stresses at various points on the outer surface of the container.

The next point is resistance to impact two forms of impacts are important a moving container contacting a stationary object as when a bottle is dropped and a moving object contacting a stationary bottle as in the filling line and a moving object contacting a stationary bottle as in a filling line. In the latter situation design features are incorporated into the side wall to strengthen contact points. The development of surface treatments including energy absorbing coatings to lessen the feasibility of glass when it contacts a stationary object has been very successful. A cross section of a round bottle illustrating the ways in which tensile stresses on the inside and outside surfaces vary at various points around the bottle circumference is shown in this figure. You can see the inside the bottle the product is hot and outside the atmosphere is cold.

So when the hot product containing bottle is subject to cold environment then stresses are developed and this will break and the vice versa the reverse is also true when a cold product containing container is subjected to high temperature like pressurized steam or the pressurized boiling water then the stresses are developed and the bottle will crack. And likewise if the bottle is dropped from a height to a stationary object that is the ground are reverse when the product is poured into a necessary bottle then product is in moving condition. So, again impact is developed and the bottle cracks. The vertical load strength while glass can resist severe compression the design of the solder is important in minimizing breakage during high speed filling and sealing operations. Resistance to scratches and abrasions the overall strength of glass can be significantly impaired by surface damage such as scratches and abrasions.

This is especially important in the case of reduced wall thickness bottles such as one trip bottles. The surface treatments involving tin compounds in conjunction with other treatments provide scuff resistance thereby overcoming susceptibility to early failure during bottle life. Density the density of glass is 2.5 which gives flat glass a mass of 2.5 kg per meter square per meter cube per millimeter of thickness or 2500 kilometer per millimeter cube.

Compressive strength the compressive strength of glass is extremely high about 1000 Newton per millimeter square or 1000 mega Pascal. This means that to shatter a 1 centimeter cube of glass it requires a load of some 10 tons tensile strength. When glass is deflected it has one phase under compression and the other in tension. Whilst the resistance of glass to compressive strength is extremely high its resistance to tensile stress is significantly lower. The resistance to breakage on deflection is in the order of 40 mega Pascal or Newton per meter millimeter square for annealed glass and it is as high as 120 to 200 mega Pascal for toughened glass.

The increased strength of sand gobain glass securit toughened glass is the result of the toughening process putting both phases under the high compression. The sand gobain glass can advice on appropriate working stresses for different glass types and can calculate suitable thickness for any architectural applications. Now, elasticity the glass is a perfectly elastic material it does not exhibit permanent deformation until breakage. However, it is fragile and will break without warning if subjected to excessive stress. Young's modulus this modulus expresses the tensile force that would theoretically have to be applied to a glass sample to stretch it by an amount equal to its original length.

It is expressed as a force per unit area for glass in accordance with European standards E that is Young's modulus is equal to 7 into 10 to the power 10 Pascal that is 70 giga Pascal. Now, the Poisson's ratio that is mu that is lateral contraction coefficient when a sample is stretched under mechanical stress a decrease in the cross section is cross section is observed. Poisson's ratio is the relation between the unit decrease in the direction perpendicular to the axis of the effort and the unit strain in the direction of the effort. For glass in buildings the value of coefficient is 0.22. Now, let us discuss the thermal properties of glass. The thermal strength of a glass container is a measure of its ability to withstand sudden temperature change. In the food industry the behavior of glass with respect to temperature is the major significance because relative to other forms of food packaging glass has the least resistance to temperature changes. The resistance to thermal failure depends on the types of glass employed the shape of the container and the wall thickness. When a glass container is suddenly cooled for example, on removal from a hot oven.

Tensile stresses are set up on the outer surface which compensating compressional stresses on the inner surface and the conversely sudden heating leads to surface compression and internal tension. In both situations the stresses are temporary and disappear when the equilibrium temperature has been reached. This phenomena we have discussed in the last slide in the picture because glass containers fracture only in tension the temporary stresses from sudden cooling are much more damaging than those resulting from sudden heating. Since the potentially damaged outside surface is in tension it is found in practice that the amount of tension produced in one surface of a bottle by suddenly chilling it is about twice as great as the tension produced by suddenly heating the outside surface. Assuming the same temperature change in both cases the thermal shock resistance cannot be calculated directly because the strength of glass containers is greater under momentary stress than under prolonged load.

Therefore empirical testing procedures are used ASTM C 149 covers the determination of the relative resistance of commercial glass containers that is bottles and jars to thermal shock and is intended to apply to all types of glass containers that are required to withstand sudden temperature changes that is the thermal shock in service. Such as in washing pasteurization or hot fill processes or in being transferred from a warmer to a colder medium or vice versa. Resistance to breaking is determined by transferring glass containers which have been totally emerged in a hot water bath typically at 63 degree Celsius for 5 minutes to a cold water bath typically at 21 degree Celsius and observing the number of breakages. The thermal properties includes linear expansion. Linear expansion is expressed by a coefficient measuring the stretch per unit length for a variation of 1 degree Celsius.

This coefficient generally given for a temperature range of 20 to 300 degree Celsius. The coefficient of linear expansion of glass is 9 into 10 to the power minus 6 meter and sometimes the temperature factor is also added in the unit. Thermal stress due to the law of thermal conductivity of glass partially heating or cooling a sheet of glass creates stresses which may cause thermal breakage. The glasses and other transparent materials tend to darken. Now let us discuss the optical properties of the glass.

Glasses and other transparent materials tend to darken and lose much of their ability to transmit light when bombarded by high energy radiations such as those used in food radiations. There are two principle causes of this coloration of glass. First the impact of the radiations may displace electrons which can become lost in holes in the structure forming color centers. The second changes produced in the valence of in bivalent or multivalent metal oxides which may result in increase absorption of light in the visible range. This second effect forms the basis of the process to protect glass from this coloration where a metal oxide which will change its valence under bombardment more radially than the electrons are displaced is included in the composition of the glass.

The addition of cerium 4 oxide is reduced to cerium 3 oxide by the radiations. In glasses an amount up to 1.5 percent has proved an effective means of reducing coloration. Unfortunately it is a very expensive oxide. So glass containers treated this way are significantly more costly than standard conditions.

The different wavelength of the colors different lights are presented in this graph because glass has no crystalline structure when it is homogeneous and free from any stress. It is optically isotropic. The optical properties of glass relate to the degree of penetration of light and subsequent effect of that transmission, transmission being a function of wavelength. The spectral transmission of glass is determined by reflection at the glass surface and the optical absorption within the glass. Transmission may be controlled by addition of coloring additives such as metallic oxides, sulphides or selenides and the compounds that are frequently used listed in this table.

Most of the transition metals oxide for example, cobalt, nickel, chromium, iron etc will give rise to absorption bands not only in the visible, but also in the ultraviolet and infrared regions of the spectrum. The three main colors of glass used to produce containers are flint or clear, amber or brown and green. Now let us discuss the glass forming processes. Raw materials for glass manufacturing. The typical composition of a soda lime glass is given in table 1.

The largest constituent is silica that is about 68 to 73 percent. The second largest constituent is cullet that is 15 to 50 percent. Originally both are glass scar from the factory and recycled glass from consumers so called post consumer glass. Basically there are five types of raw materials needed for glass manufacturing. Each raw material gives different material properties for glass.

The silica sand, soda ice that is sodium carbonate, soda lime, cullet that is the recycled glass, oxides and additives. The silica sand that is responsible for transparency and strength. The soda ice that is a sodium carbonate that acts as a flux lowering the melting point of silica and adding glass formation. Limestone that helps in enhancing the glass durability and stability. The cullet that is the recycled glass that is used to reduce energy consumption and promote sustainability by incorporating.

And the oxides and additives mostly used to modify glass properties such as colorants for example, iron oxide for green glass. Flint glass is the most color sensitive with the tolerance of 1 percent green or 5 percent amber cullet in the batch mix. Amber glass can tolerate 10 percent green cullet while up to 50 percent mixture of amber and flint cullet can be used in production of green glass. The use of cullet can cause problems with the production of some types of glass unless there is good separation of colored glass and removal of associated materials such as labels. In addition to the problem of color mixing, ceramic and metal contamination especially aluminum bottle caps can also limit the use of cullet in glass manufacturing.

However, use of cullet is economically desirable since less energy is required to melt cullet than the new raw materials. Cullet also reduces the amount of dust and other particulate matter that often accompanies a batch made exclusively from new raw materials. Although the total primary energy use decreases as the percent of cullet rises, the maximum energy saved is only about 13 percent. Thank you very much.