Modern Food Packaging Technologies: Regulatory Aspects and Global Trends
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Welcome to the NPTEL online certification course on Modern Food Packaging Technologies Regulatory Aspects and Global Trends. In previous lectures we have seen what are the different types of glasses. In the present class we will be discussing the methods of forming process of the different glass materials. Let us discuss first what are the different types of glasses and what their mean and what is their application. The float glass that is clear flat glass produced by floating molten glass on a bed of molten metal typically tin and this is generally used for windows, mirrors, architectural applications.

The laminated glass this is also the same glass and prepared by the same way that is the clear flat glass is produced by floating molten glass on a bed of molten metal typically tin and this is generally used for windshields, skylights, bullet resistant glass Tinted glass. It contains additives to reduce transmitted light and heat controlling glare and heat absorption this is used in building windows and vehicle windows. Borosilicate glass this is known for high thermal resistance and durability and generally used in the laboratory glass wares, cookware and lighting. Fiber glass this consists of fine glass fibers woven into a fabric or mat and used generally for the insulation, reinforcements, composite materials etc.

The optical glasses they are highly transparent glass with low dispersion used in optical devices and are used for making lenses, prisms, optical instruments etc. Frosted glass this is treated to create a translucent appearance providing privacy while allowing light transmission and this is used primarily in partitions, doors, decorative windows. Now when how the glass is made the mixing and melting the raw materials are made, mixed and charged into a glass melting furnace which is maintained at a temperature of approximately 1500 degree Celsius. Here they are converted into molten glass that is chemically homogeneous and virtually free of gaseous inclusions that is the bubbles. The melting process consists of two phases first changing the solids into a liquid and fining or clearing up of the liquid.

During the refining process gases particularly carbon dioxide, sulphur dioxide and water vapor produced by the chemical reaction rise to the surface of the furnace and are removed. When the molten glass becomes free of gas that is in general terms it is known as seed free, it is then ready for forming into containers. It moves from the furnace into a working end of the furnace and mistakenly called the refiner where the thermal homogenization and cooling of the glass to the viscosity required for particular operation begin. At this point the temperature of melt has been lowered from 1250 to 1350 degree Celsius to approximately 1100 degree Celsius. The preferred energy source for glass making is natural gas although alternate fuels such as oil and propane are used in some plants.

The glass is carried from the working end of the furnace to the forming machine in a channel like structure called fore hearth which is fired by a number of small burners. The aim being to ensure uniform temperature distribution throughout the depth of the glass. At the end of the fore hearth is a gob forming mechanism consisting of a rotating sleeve and vertical plunger. The glass exists in a continuous viscous stream which is cut by rapidly moving horizontal steel blades to form what is known as a gob that is a mass or lump of molten glass. This control of temperature and shape during the formation of the gob is required for the high speed production of accurately formed glass containers.

Temperature in the vicinity of 1100 degree Celsius varying by no more than plus minus 1 degree are typical. Now, the process of converting a cylindrically shaped gob of glass into a bottle a jar is called forming and it is essentially a controlled cooling process. While various types of forming machines are used throughout the world the most predominant type is the IS machine that is the individual section. It performs two basic functions it shapes the gob into a hollow container and simultaneously removes heat from the gob to prevent it from deforming significantly under its own weight. The two basic types of processes are used to make containers for the IS machines the blow and blow that is popularly known as B and B and the press and blow that is P and B.

A closure size of approximately 35 millimeter is dividing line between narrow neck and B and B containers that is bottles and the white mouth that is P and B containers that is jars. The now let us discuss blow and blow type bottles are normally produced by a two step B and B process whereby a gob of glass accurately sheared in terms of weight and shape is delivered into an externally air cooled cast iron mold from above to shape a preform also known as a perision or body blank. Some of the glass flows over a plunger in the base of the mold which is used to mold the finish so called because in the early days the glass manufacturing it was part of the container to be fabricated last of the container by means of ring molds. Compressed air is applied to force the glass down onto the plunger to form the neck ring. Sometimes vacuum is applied from the bottom as the alternative or additional procedure.

When the finish molding is complete the plunger is retracted and air blown in from the bottom of the mold enlarging the size of the bubble until the glass is pressed out against the blank mold to form a hollow thick wall perform or perision. This is then inverted and transferred to the blow mold where it elongates under its own weight until it nearly touches the base of the mold. Air at 200 kilo Pascal is applied so that the glass is pressed against the metal surface of the blow mold which is air cooled to ensure rapid removal of heat. The mold is then opened and the fully blown perision now at temperature 650 degree Celsius is removed and briefly held over a dead plate to allow air to flow up through the dead plate and around the container to further cool it. It is then transported to the annealing layer.

This figure depicts how the gob is made and after that it enters through the blank and there if the neck is formed and after that it is inverted back and then air is blown and then the bottle is ejected and it transferred to the annealing layer. Now, wide mouth press and blow type in the case of jars a two step wide mouth press and blow process is used. The body blank or perision is formed by pressing the gop of molten glass against the mold walls with a large plunger. When the cavity is filled glass is then pushed down into the neck ring and then finish is formed. No baffle or counter blow air is used in the formation of the perision with the operation relying on the mechanical introduction of the plunger into the glass.

The rest of the steps in the wide mouth press and blow process are identical to those of the blow and blow process. Narrow leg press and blow is a more recent process for lightweight bottles in which the gob is delivered into the blank mold and pressed by a metal plunger. The plunger and gob together have the same volume as the blank mold cavity. This enables the glass maker to decide exactly how the glass is distributed in the perision and hence to be able to more accurately control the uniformity of glass distribution in the finished container. Indeed weight savings of up to 30 percent can be made.

The second stage is the similar to the B and B process. Now, narrow neck press and blow the perision is blown to a finished container having a more uniform wall thickness and as a result higher strength. The mechanical performance of lightweight glass bottles produced by the narrow neck press and blow process has been compared with the same glass bottles regular weight that is 20 percent heavier produced by the conventional B and B process. The lightweight glass bottles had a more homogeneous thickness distribution in comparison with the regular weight bottles and a better performance about 33 percent improvement in relation to the impact strength especially in the heel. The vertical load strength of the lightweight glass bottle also indicated a superior performance to the regular weight bottle.

Due to the better thickness distribution of lightweight glass bottles they withstood a maximum temperature difference progressive thermal shock of 5 to 10 degree higher than the regular weight bottles. Now, the annealing the term annealing generally refers to the removal of a stress and the annealing temperature or the point is defined ASTM C 336 as the temperature at which the stress in the glass are relieved in a few minutes. The containers are transferred from the dead plate to a large oven known as a lehr which is equipped with a belt conveyor. The function of the annealing lehr is to produce a stable product by removing any residual stresses resulting from on non uniform cooling rates during forming and handling. This is achieved by raising the temperature of the container to approximately 540 degree Celsius almost the softening point of the glass holding it there for a few minutes and then cooling at a rate which is consistent with the removal of a stress from a predetermined wall thickness.

The critical area of temperature is between the upper annealing point that is the softening point and the lower annealing point after which they may be cooled at a rate which enables them to be handled as they emerge from the lehr. During cooling the inside surface is hotter than the outside this results in compression on the outer surface, but tension at the inner surface. As mentioned earlier the glass fractures only in tension and usually at the surface sudden cooling introduces tensile stresses into the outer surfaces and compensating compressional stress in the interior. Poorly unyield containers may be subject to breakage if the tension is high or the inner surface is bruised. The finishing the strength of a newly made glass container can be rapidly reduced by moisture or abrasion and some from surface treatment to increase the strength is essential since glass is non lubricious.

The two general types of surface treatment are applied to glass containers to modify mechanical properties hot end treatment. In hot end treatment typically carried out while the glass container is at 550 degree Celsius. Vapor containing tin or titanium generally in the form of a tetrachloride is brought into the contact with the outside of the container forming a thin unimolecular film of metal oxide. This treatment prevents surface damage while the container is still hot strengthens the surface and improves the adhesion of the subsequent cold end coating. The cold end treatment cold end treatment typically carried out while the glass container is at less than 100 degree Celsius is designed to protect the container surface and assist its flow through the filling line.

Typically it involves spraying of an organic material in an aqueous base containing either waxes, steroids, silicones, oleic acid or polyethylene onto the out outside of the container to increase its lubricity by providing a surface with a low coefficient of friction. It is important to check the compatibility of the cold end treatment with any adhesives used to attach levels sometimes only the cold end treatment is applied. One of the major advantages of glass as a packaging material is its capability to be formed into a wide range of shapes related to specific end uses, customer requirements and aesthetic appeal. The commercialization of computer aided design and computer aided manufacture has made the task of designing and manufacturing new glass containers considerably easier and more rapid. This has led to greater flexibility and resulted in a considerable efficiencies through a more thorough analysis of stresses and strength or weight factors and calculation of likely mechanical performance.

In particular the application of finite element analysis has resulted in light weighting of glass containers with improved mechanical performance. For example, the forming processes has been modeled as a coupled thermodynamic or mechanical problem with corresponding interaction between glass, air and equipment and correctly represented the flow of the glass and the energy exchange during the process. As well simulations have helped optimize cooling conditions and increased production speeds. The basic nomenclature used for glass containers are shown in the figure. In the different parts has been with their name has been shown in this figure which is evident from the figure.

Generally the shape of the container is determined by the nature of the product each product group having a characteristic shape. Thus liquid products generally have a small diameter finishes for easier pouring solid products require large finishes for filling and removing the contents. As well as filling and emptying requirements considerations must also be given to the nature and manner of labeling the container and is compatibility with the packaging and shipping systems. The container finish is the part of the container that holds the cap or closure that is the glass surrounding the opening of the container. It must be compatible with the cap or closure and can be broadly classified by size that is the diameter, sealing method for example, twist cap cork etc and special features for example, snap cap pour out etcetera.

The finish has several specific areas including the sealing surface which may be on the top or side of the finish or a combination of the two. The glass lug which is one of the several horizontal tapering and protruding ridges of glass around the periphery of the finish on which the closure can be secured by twisting. The continuous thread which is a spiral projecting glass ridge on the finish intended to mess with the thread of a screw type closure. A transfer bead which is a continuous horizontal ridge near the bottom of the finish used in transferring the container from one part of the manufacturing operation to another. A vertical neck ring seam resulting from the joining of the two parts of the neck ring and a neck ring parting line which is a horizontal mark on the glass surface at the bottom of the neck ring to finish ring.

Resulting from the matching of the neck ring parts with the body mold parts. Although there are literally hundreds of different finishes used on glass containers a series of voluntary standards containing specific dimensions, specifications and tolerances has been established for every finish designation by the standard authorities in other parts of the world. These voluntary standards are intended to provide a basis for achieving compatibility and interchangeability between manufacturers and users of glass containers and closures. Once a design has been accepted the molds used in the manufacturing process must be made. They are usually constructed of cast iron and consist of three parts a bottom plate, a body mold divided vertically into two halves and a neck or finish mold which is also usually split into two parts.

Because of the high cost of mold manufacture changes to container size and shape are usually made only if large quantities of the container are required. Generally customers select their containers from the standard range provided by glass manufacturers unless they are extremely large users in which case the extra expense of customized designs is justified. The glass packaging institute has established limits which are generally accepted as reasonable tolerance by most manufacturers. Tolerance have been made for increases in container size as a consequence of mold wear as well as expected process capabilities of the manufacturer. Although closure tolerances can be met this often incurs a higher cost since molds must be replaced more frequently. Thank you very much.