A Paper Review on "Glass Processing"

M. Aadil Arshad[1] Muhammad Kashif[2] Nandkishor Suresh Kale[3] Prof. D. M. Ugle[4]
[1,2,3,4]Student
[1,2,3,4]Department of Mechanical Engineering
[1,2,3,4]STC, SERT, Shegaon, India

Abstract— Glass has change the world more than any other material. This seminar deals with the glass processing and some different types of glasses and their applications. As we know that glass is transparent silica product which may be amorphous or crystalline depending upon the heat treatment. To manufacture it, a mixture of silica and other oxides are melted and then cooled to a rigid condition. Glass does not change from a liquid to a solid at a fixed temperature but remains in a vitreous noncrystalline state. In this seminar we will look at the main methods used for processing of glass products glass processing could be said to be the most important processing method for glass. We will also look at processes that are used to modify glasses for specific applications .Glass production starts with a mixture of raw materials which for glass manufacture often contain a high proportion of naturally occurring minerals.(e.g. sand and lime stone) to the final packaging. The major steps involve in the processing of glass are batch preparation, melting and refining, forming and shaping, thermal conditioning, annealing, finishing, cutting and inspection etc. Glass processing deals with the different stages of glass manufacturing such which type of raw materials are required for batch preparation then how melting takes place and also which type of forming process are carried out. After these whole process glass is drawn off for further cutting and inspection process after all these processes glass is obtained in required size and shape.

Key words: Glass Melting Furnace, Glass Strength, Cutting

I. Introduction

The word glass is derived from the. Latin term glaesum. Glaesum is used to refer to a transparent material. The first glass object used by man originated from obsidian, a natural volcanic glass. First man-made glass was found in Egypt around 3500 years ago. Generally, glass can be defined as an inorganic product of fusion that has been cooled to a rigid condition without crystallization. Glass is therefore, by definition, an amorphous or non-crystalline solid. The behavior of glass is similar to amorphous polymers because glass has no distinct melting and freezing point. Today, there are around 750 different types of commercial glasses available. The commercial glass that is majorly manufactured around the world is soda-lime glass (sand 63-74%, soda ash 12-16%and limestone 7-14%). The different uses of glass ranges from windows (flat glass) container sand cookware to glass with special mechanical, electrical and optical characteristics. Depending upon the manufacturing process and end use of the product, different constituents can be used. For example, boron oxide (B2O3) is added to improve heat durability in glass which is used for cookware, automobile headlamps and laboratory glassware. Similarly silver (Ag) is added in sunglasses and strontium is added in television screens to absorb radiation. The commercial glasses mainly used are categorized by following types:

1) Soda-lime glass (high density, low strength, low cost, e.g. beverage containers, window glass).
2) Lead-alkali glass (low strength, high electrical resistivity, e.g. microelectronics).
3) Borosilicate glass (good chemical and impact resistance, e.g. laboratory glassware, automobile headlamps, utensils).
4) 96% silica glass (good thermal and chemical resistance).
5) Fused silica (high impact resistance).
6) Aluminosilicate glass (e.g. high-efficiency lamps).

Handling of glass is a critical issue. Glass breakage may take place due to stress concentration, scratches, impurities present in glass, thermal stresses etc. Depending upon the application, glass is manufactured using different processes. For example, toughened glass is manufactured by rapid cooling, which is used in making bullet proof windows. Similarly, wired glass is manufactured by meshing steel wire into molten glass by rolling process. It is used for making low cost fire resistant glass which automatically breaks at high temperatures. The transformation phases of crystalline and amorphous Oxygen atom Silicon atom Sodium atom solids can be understand by examining silica (SiO2) which can exist in either state. When silica is in crystal form and is heated at a temperature Tm (freezing or melting point), it becomes liquid. It is observed that at melting point the specific volume of crystalline solids changes abruptly which causes sharp changes in physical properties. Whereas the amorphous structure of silica softens gradually (start softening at temperature Tg) when those are heated because there is a wide temperature range between the solid and liquid state. The temperature Tg is the glass transition temperature of the solids.

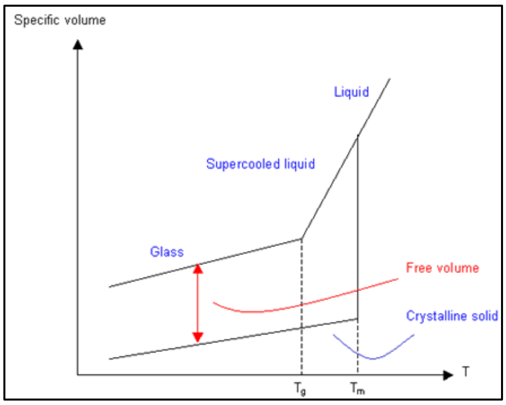

Fig. 1: Phase transformation of crystalline and amorphous solids on heating.

A. Glass Properties

The behavior of glass is linearly elastic and brittle. The stress-strain curve for the glass is shown in Figure. In compression, the glass is very strong and its compressive strength can reach up to10,000MPa. But in tension, when stress level exceeds 100 MPa, glass fails easily. The failure of glass is due to the stress concentration at surface flaws as no plastic flow is

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possible in glass. For the most commercial glasses, Young's modulus of elasticity (E) ranges from 55-90 GPa and the Poisson's ratio (μ) ranges from 0.16-0.28. The fiberglass which is drawn from the molten glass has tensile strength ranges from 0.2-7 GPa. The glass fiber is stronger than the steel and most of the time used as a reinforcing material to form reinforced plastics. The other important properties of glass are low thermal conductivity, high dielectric strength, resistance to corrosion on attack by water and acid.

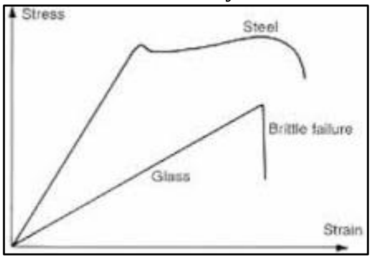

Fig. 2: stress strain curve of glass and steel

B. *Processes*

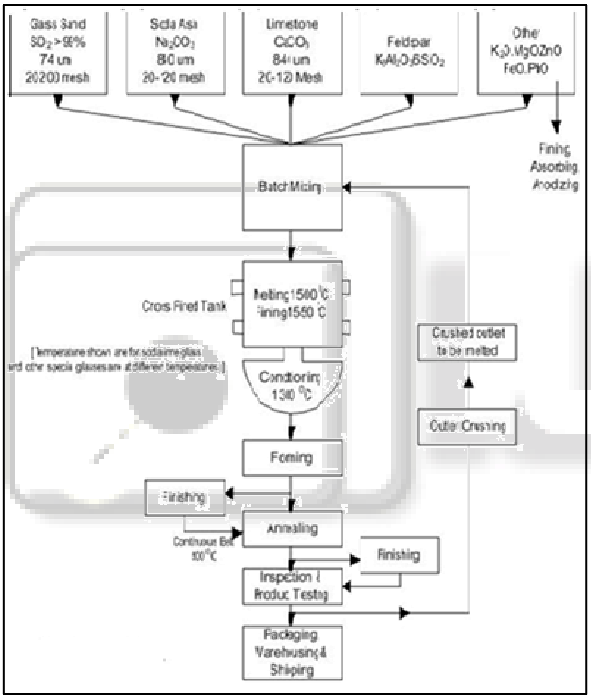

Fig. 3: Glass Processing

1) *Batch Preparation*

Is the step where the raw materials for glass are blended to achieve the desired final glass product. While the main components in glass are high-quality sand (silica), limestone, and soda ash, there are many other components that can be added. The glass batch contains formers, fluxes, stabilizers, and sometimes colorants.

2) *Formers*

Glass formers are one of the most important components present in any glass. Silica (SiO2), boric oxide (B2O3) and phosphoric oxide (P2O5) are the most common type of glass formers present in oxide glass.

3) *Fluxes*

Fluxes are added to lower the temperature at which the batch melts. Soda ash (sodium carbonate, or Na2CO3) and potash (potassium carbonate, or K2O), are commonly used alkali fluxes (present as oxides). About one-third of the soda ash produced in the United States is used by the glass industry.

4) *Stabilizers*

Stabilizers are used to make glass more chemically stable, and to keep the finished glass from dissolving, crumbling or falling apart .Common stabilizers include limestone, alumina, magnesia and barium carbonate.

5) *Colorants*

Colorants are used to control the color in the final glass. The amount of iron oxides (impurities) present in the glass results in unintentional change in color of glass. It include iron, chromium, cerium, cobalt and nickel.

C. *The Melting Process*

The melting process is a complex combination of chemical reactions and physical processes. This section only represents a brief summary of some of the important aspects of the process.

1) *Regenerative Furnaces*

The term 'regenerative' refers to a form of heat-recovery system used in glass making. Burners firing fossil fuels are usually positioned in or below combustion air/waste gas ports. The heat in the waste gases is used to preheat air prior to combustion. This is achieved by passing the waste gases through a chamber containing refractory material, which absorbs the heat. The furnace fires on only one of two sets of burners at any one time. After a predetermined period, usually 20 minutes, the firing cycle of the furnace is reversed and the combustion air is passed through the chamber previously heated by the waste gases. A regenerative furnace has two regenerator chambers; while one chamber is being heated by waste gas from the combustion process, the other is preheating incoming combustion air. Typical air preheat temperatures (depending on the number of ports) are normally in the range of 1200 – 1350 ºC, sometimes up to 1400 ºC. In the cross-fired regenerative furnace, combustion ports and burners are positioned along the sides of the furnace, regenerator chambers are located on either side of the furnace and are connected to the furnace via the port necks. The flame passes above the molten material and directly into the opposite ports. The number of ports used (up to eight) is a function of the size and capacity of the furnace and its particular design. Some larger furnaces may have there generator chambers divided for each burner port. This type of design effectively using a multiplicity of burners is particularly suited to larger installations, facilitating the differentiation of the temperature along the furnace length necessary to stimulate the required convection currents in the glass melt.

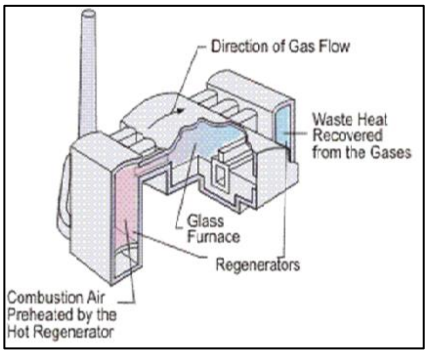

Fig. 4: Regenerative furnaces

2) *Refining*

During refining (often referred to as fining), gas bubbles are eliminated from the batch and molten glass. Refining occurs

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throughout the melting chamber, beginning with the batch charge to the furnace and continuing until the complete dissolution of crystalline materials. Imperfections (referred to as stones or cords) may be introduced into the glass during melting when the grains of dry raw material are too large to completely react by the time the flux has melted, or if the batch has not been adequately mixed. During refining these glass inclusions are eliminated or reduced. As the temperature of the glass decreases, some of the gases are reabsorbed into the melt. As these dissolve, gaseous seeds or bubbles may form containing constituents such as oxygen, sulphur dioxide, water, nitrogen, or carbon dioxide, depending on the type of glass. Refining helps to remove these seeds.

3) Homogenization

Homogenizing occurs throughout the melting chamber, and is finished when the properties of the glass meet the desired specifications. Perfect homogeneity exists when the glass melt exhibits no variations in the desired properties. Variations might include local differences in refractive index, density or coefficient of expansion, all of which will affect the mechanical and optical properties of the glass.

4) Thermal Conditioning

During thermal conditioning, glass is stabilized and brought to a uniform temperature. When thermal conditioning begins is a matter of interpretation, and depends on furnace type and operating conditions. In general, thermal conditioning is assumed to begin immediately after the glass melt reaches its highest average temperature in the furnace, since after this time it will begin cooling to the working temperature for forming. Thermal conditioning is occurring in the melting and refining sections of the furnace, and in the for hearth. In container furnaces, the refining is used primarily for temperature conditioning .Physical mixing in the feeder, bubblers, and stabilization of gases are all used to help achieve proper thermal conditioning. Stirring is usually accomplished with a water-cooled stainless steel or un cooled platinum paddle operating at the glass melt temperature. Bubblers are water cooled, high-carbon steel nozzles located on the furnace floor.

5) Annealing

Glass products sometimes have induced residual stress unlike metal products if cooling is not done at a sufficiently low rate. In order to release the internal stresses, the temperature of glass melt is held steady over a long period time. This process is known as annealing. Annealing is a process of controlled cooling and heating of a material to remove residual stresses. The process may be carried out in a thermally insulated chamber known as a lehr. Annealing removes thermal stresses from the glass caused by quenching process and hence increase the overall strength. . In annealing process, the glass is heated unit the temperature reaches a stress-relief point, i.e. annealing temperature (also known as annealing point) at a viscosity (η) of 1013 Poise. At the annealing temperature, the glass is still in a hard state but at the same time it is soft enough to relieve thermal stresses. The glass is then allowed to remain at the annealing point for some period of time until the temperature is even throughout. Annealing time may range from a few minutes to few months.

D. Forming Process

Forming is the stage where the molten glass begins its transformation into a final shape. As it moves from the melting tank to the forming machine, the molten glass looks like a thick, red-orange syrup. Forming processes must mold the molten glass quickly, because it becomes rigid as it cools. There are a wide range of forming processes, even within some glass segments. Molten glass can be molded, drawn, rolled, cast, blown, pressed, or spun into fibers.

E. Press Forming

Some table and kitchen ware are manufactured using press-forming machines. Press-forming utilizes a mould, plunger and ring to form the finish area. Press-forming moulds are mostly made of cast iron, and in some cases, stainless steels or other materials .Simple glassware (bowls, plates) is often made using press-forming. Machine pressing is done using around, single table machine in a one-step process where the same plunger can be used on several moulds. . Production speeds for pressed ware are variable, ranging from 10-60pieces per minutes. Production speeds are dependent on the time required for cooling the glass and allowing it to set up in the press. Formed pieces are removed either manually or automatically. Methods include removal by air jets.

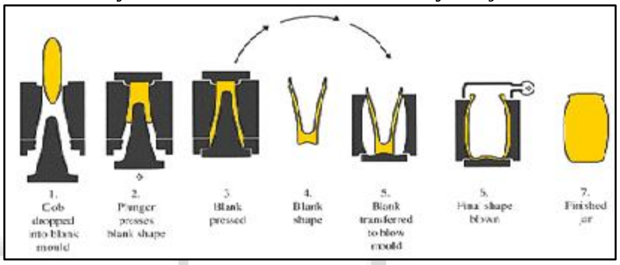

Fig. 5: Press Forming

F. Spinning process

The spinning process is sometimes used to produce circular articles such as plates and shallow bowls. A hot glass gobies dropped into the mould, and is then rotated to form the article by centrifugal force .Paste moulds are often used to produce both medium- and high-grade tumblers. The parison in this case is created by using a plunger and a cast iron mould. As the cast iron mould pulls away, a two-section water-cooled paste mould folds into place around the parison. The paste mould is then rotated during final air blowing to attain a smooth, high-finish.

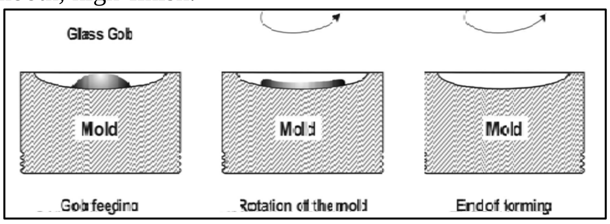

Fig. 6: Spinning Process

G. Glass Cutting Process

Conventionally, the plate glass cutting is usually done by using a diamond point tool. The step follow are: (a) marking and scribing (shallow cutting) on the plate glass surface as per the desired profile using a diamond point tool, and (b) application of an external force on the glass with extreme skill so that the glass breaks along the scribing. The cut surface obtained by the above methods is always irregular, wavy and with poor surface finish, in spite of the amount of skill used and the care taken. Hence grinding and polishing are required to bring the glass to required size, shape and surface finish.

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But this increase the fabrication cost and is highly time consuming. The glass damages are more likely during cutting. Also it is impossible to cut complex profiles (shapes other than a straight line).

Fig. 7: Diamond point cutting tool

H. Abrasive Jet Machining

To overcome the disadvantages of glass cutting Abrasive jet machine is used. This method is relatively simple one and has several comparable advantages. It makes use of low cost, simple x-y table for glass movement for its operation. The process is safe and does not involve very high temperature. This process is clean and does not generate glass powder. Any complex shape is easy to cut to very close tolerance. The surface finish is smoother than the one obtained by diamond tool For an easy initiation of cutting, a shallow cut or scratch (of approx. 2mm length) on the glass surface at the starting edge is required. The scratch can be made using diamond point tool or a hacksaw. A rotary table can be used for circular cutting.

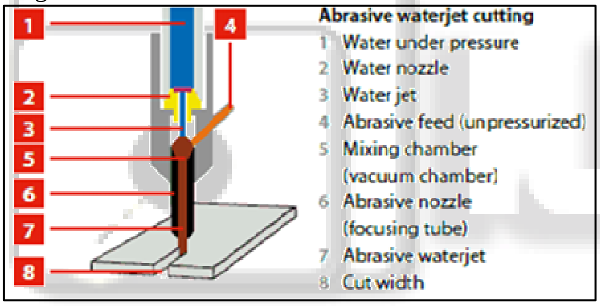

Fig. 8: Abrasive jet machine

II. CONCLUSION

Experiments shows that the physical and elastic properties of glasses were found slightly affected by the changes in the glass composition. At the starting of the process all the raw materials are mixed together in a proper proportion to achieve the desired quality of glass. Melting of the raw material is carried out in furnace the type of the furnace depends upon quantity and type of glass being produced. The batch materials to manufacture glass can be divided into following five categories according to their role in the process: glass former, flux, modifier, colorant and fining agent. After that refining process is carried out and gas bubbles are eliminated from the batch and molten glass. Compounds such as sodium sulphate, barium oxide, boric acid, sodium chloride and calcium fluoride are used as refining agents. To meet the desired specifications of glass the glass is then passed through the homogenization process. Forming is the stage where the molten glass begins its transformation into a final shape. As it moves from the melting tank to the forming machine, the molten glass looks like a thick, red-orange syrup. Forming processes must mold the molten glass quickly, because it becomes rigid as it cools.In forming process press forming, spinning and rolling are done. After the forming the glass goes through cutting and inspection process. And finally glass is produced in required form, size, and properties.

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