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Radiotracer investigation in a glass production unit

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HIGHLIGHTS

- Radiotracer investigations were carried out in a glass production unit.
- Lanthanum-140 was used as radiotracer.
- Flow parameters were measured in different sections of the unit.
- Performance of the glass production unit was evaluated.

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ABSTRACT

A radiotracer investigation was carried out in a glass production unit in a glass industry. Lanthanum-140 as lanthanium oxide mixed with silica was used as a radiotracer to trace the molten glass in various sections of the unit. Residence time distributions of molten glass were measured and analyzed to identify the flow abnormities. The flow parameters such as breakthrough time, mean residence time, homogenization time, dead volume and flow patterns in different sections of the unit were obtained from the measured RTD data. The results of the investigation were used to improve and optimize the operation of the glass production unit.

1. Introduction

Glass has been a part of human life for centuries and is used for various purposes in day to day life. It is produced from cheap and abundantly available raw materials such as silica (SiO_2), sodium carbonate (Na_2CO_3), calcium carbonate ($CaCO_3$) and cullet together with small quantities of various other minor ingredients. The glass manufacturing process primarily involves two steps i.e. batch mixing and batch melting. In batch mixing, the various raw materials and ingredients are crushed and mixed in a rotary mixer to ensure a homogeneous mix of the ingredients. In the second step i.e. batch melting, the homogeneous mixture is continuously fed to a furnace and heated to a temperature of 1500 – 1550 °C, where it is melted. The glass production process actually involves four processes i.e. melting, fining, homogenizing and conditioning. The melting implies physical transformation of the batch materials from solid to liquid phase. This stage includes several chemical reactions in addition to the heat transfer process. Gases are evolved from the batch and from the fining agents, and bubble to the surface, promoting mixing and homogenization of the melt. The fining process continues until all of the gas bubbles have escaped from the surface. Each of these processes occurs in a near sequential but overlapping order (Cable, 1969, 1998; Doremus, 1973; Ducharme, 1991; Khun, 1999; Kawaguchi et al., 2008; Philip et al., 2010; Ruud, 2008).

Fuels are burnt to create a high temperature inside the furnace, where the batch is reacted, vitrified, degassed, homogenized, and shaped into different products. The products are subsequently annealed and baked. All these processes consume a significant amount of energy and incurring substantial cost in glass production. It is imperative for the industrialist to understand that the energy conversation is one of the most important policies for the

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industry, the nation and the world. Fossil fuels such as coal, petroleum and natural gas are used as the source of heat in the glass production process. During the combustion of fossil fuels in the melting process, various chemical reactions take place and various gases such as CO, CO_2, NO_X and SO_X are produced and discharged into the atmosphere leading to serious environmental hazards. Therefore, the glass industry is subjected to stringent control, and is facing a great challenge with the ever increasing regulations like the Kyoto Protocol.

The production of glass is a very complicated process and glass technologists have been making great efforts to develop new technologies for improving the glass quality and process efficiency. These two parameters primarily depend upon flow dynamics and heat transfer behavior of the molten glass in the furnace and forehearth of a glass production unit. The heat transfer behavior also depends upon the flow dynamics of the molten glass. The flow dynamics include parameters such as mean residence time (MRT), minimum residence time, maximum residence time, flow patterns, homogenization time, dead volume, glass stream velocity, bypass flow and stream circulation. These parameters have to be known to the plant engineers to evaluate glass quality and process efficiency, to control the process, for troubleshooting, to optimize operating parameters, to improve design of the existing furnace and design a new furnace. Numerical models such as computational fluid dynamics models are often used to investigate flow dynamics in glass production units, but have many limitations to obtain accurate and reliable information (Cozzi et al., 1983; Beerkens, 2002; Yen and Hwang, 2008, 2010; Carvalho and Nogueira, 1993; Morris, 2007; Soubeih et al., 2015).

Measurement and analysis of residence time distribution (RTD), a characteristic parameter of continuous flow systems, provides qualitative as well as quantitative information about the flow dynamics of continuous flow systems. Radiotracers have been widely used for measurement of RTD of process material and homogenization time in an industrial process system because of their many advantages over conventional tracers. The main advantages include physico-chemical compatibility, high detection sensitivity, in-situ detection, availability of a number of radiotracers for different phases, limited memory effects, they do not degrade in the harsh industrial environment and often do not have any alternative in most of the industrial situations (Charlton, 1986; IAEA, 1990, 2001; Thyn et al., 2000; Pant et al., 2001). It is not easy to conduct radiotracer investigations in glass production units because of the high temperature involved, and relatively higher amounts of radiotracer activities are required due to thick glass shielding and cooling requirements needed for the radiation detectors. Only a very few investigations have been reported worldwide on use of radiotracers in glass production units (Bondarev et al., 1970; Palige et al., 1995; Michalik and Kruszewski, 1986).

At the request of M/s Gujrat Borosil Limited, Bharuch, Gujarat, a radiotracer investigation was carried out to measure residence time distribution of molten glass in a glass melting furnace, forehearth and annealing section of a glass production unit. The main objectives of the investigation were to identify flow abnormalities, flow parameters of molten glass and to investigate homogeneity/uniformity of produced glass, and flow patterns.

2. Glass production unit

The schematic diagram of the glass production unit used for production of glass is shown in Fig. 1. The unit consists of a batch mixing equipment (rotary mixer) for mixing of various ingredients of the raw material, continuous or intermittent feeding system, heating system, a tank furnace (volume:136 m^3, mass capacity 336 t), forehearth, roller for shaping, and cooling and cutting sections. The mixture of raw materials is fed into the tank furnace at a rate of 185 t/d (74.8 m^3/d) through the two independent feeders connected to right and left side of the furnace. A dam wall across the width of the furnace divides the tank into two parts and provides the desired residence time and homogeneity in the molten glass. An end fired heating mechanism is used for heating the raw material inside the tank furnace. Natural gas and air are fed through the burners mounted on the back end of the tank furnace that combust inside the tank furnace and provide necessary heat for melting of the raw feed. The feed in the tank melts, reacts, homogenizes and attains a temperature of about 1500 °C. After melting, the molten glass (density: 2.475 g/cm^3) flows into the forehearth through a throat, where it is further homogenizes, annealed and attains necessary strength. During the annealing process, the temperature of the molten glass is brought down from 1500 °C to 1000 °C. After residing inside the forehearth for sufficiently long time, the molten glass is passed through rollers and converted into continuous sheet of desired thickness (0.003 m). The glass sheet is subsequently passed through a long cooling section, where it is cooled to a temperature of about 40 °C. At the end of the cooling section, glass sheet is cut into pieces of desired size, (2.1 m × 2.4 m) packed in wooden cases and transported to different users and distributors.

3. Radiotracer experiment

The radiotracer investigation was carried out to measure RTD in a tank furnace and forehearth; and the homogenization time of

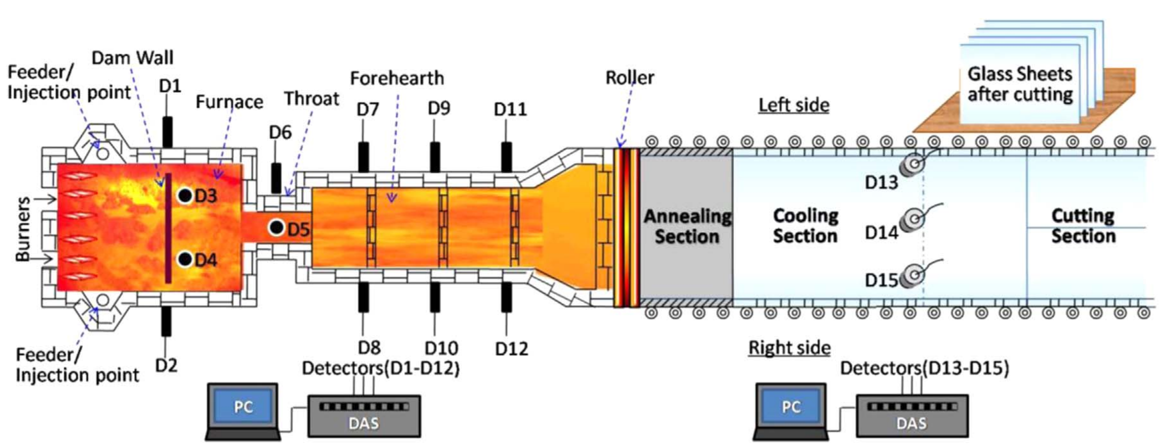

Fig. 1. Schematic diagram of the glass production unit and experimental setup.