Refining techniques and developments

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Abstract

The glass-forming liquid is melted industrially in large open tanks. The raw materials are added in granular form. Melting and chemical reactions between the grains produce a silicate liquid with a large amount of impurities, mainly bubbles. Since the rising velocity of a bubble is proportional to the square of the bubble radius and inversely proportional to the dynamic viscosity, the residence time of bubbles in the glass bath can be long. The classical method of bubble removal is to increase the melt temperature up to 1450C. This reduces the dynamic viscosity. The introduction of fining agents in the raw materials leads to the release of dissolved gases in the liquid, which inflate bubbles by mass transfer, especially if the temperature is high enough.

In such a process the mass transfer is crucial to analyse. The beginning of the lecture will be devoted to recalling the main characteristics of the mass transfer between the bubble and the glass-forming liquid. A list of the main gas species involved in the mass transfer will be given. It will be shown that while the fluid mechanics is in the creeping flow regime, the mass transfer is driven by advection. Some data on equilibrium constants of oxidation-reduction reactions and gas solubilities will be recalled. A description of oxidation-reduction reactions of fining agents is also given. Mass transfer between liquid and bubble will be presented with emphasis on the determination of Sherwood numbers, the dimensionless number of mass transfer coefficients. Emphasis will be placed on the chemical coupling between the liquid and the dispersed bubble phase.
A numerical model will be presented to study the mass transfer and bubble release, taking into account the coupling with oxidation-reduction. Some numerical examples will be used to show the main differences between the thermodynamic equilibrium and non-equilibrium states.

The innovative refining techniques will be presented in the last part of the talk. The removal of bubbles is controlled by the bubble size, the driving force is due to the concentration difference of the gas in the bulk and at the surface. Reducing the pressure increases the concentration difference, leading to an increase in the rate of bubble removal. Few numerical tests will show the effect of pressure reduction on bubble removal. The other possibility is to introduce a permeable gas species such as helium. The numerical model will be used to study the effect of helium. Finally, centrifugal fining will be presented in the last part of the talk.

Keywords: glass melting, bubble removal, oxidation, reduction reactions, mass transfer

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