Integrated approach to achieve optimum design of glass furnace.

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Abstract

A great challenge for glass manufacturers these days is to find an answer on how to reduce glass defects, to improve fuel efficiency, and to secure longer furnace campaign life. However, these elements are more likely to influence each other inversely. The long history of glass industries has contributed to decide on furnace configuration and its dimension and refractory selection. The accumulated knowledge should be passed on to the next generation to pave the way for a prosperous future for our industry.

We prove the key factors by scientific approach with elemental technologies, such as laboratory modeling, computer simulation on melting and refining behavior, defect analysis, fuel efficiency analysis, refractory analysis and so on. By being lined with those technologies, we assure to propose probably the optimum furnace design to reduce glass defects, especially bubble, seeds, and cat-scratch.

1. Introduction

"Furnace design" is one of the most important and interesting topic for every glass manufacture. In these days, trend of furnace campaign is toward extending over ten years even in the container glass field. Since furnace design significantly affects the quality of glass and the cost of production, failure on the design will not be tolerated. "Own experience" has strong power of persuasion on to the future design and we are not easily released from its influence even though we feel something necessary for innovation. For example, in order to reduce bubble and seeds, high temperature melting is an effective method. On the other hand, excessive high temperature gives damage to the refractory and results in short campaign life. This shows us clearly that a multiple factors should be integrated to realize well-balanced furnace as well as selection and application of refractory.

In this paper, firstly, we introduce elemental and essential technologies as a multiple factors to be integrated for evaluation of furnace design, such as glass tank simulation, laboratory observation of blister generating from refractory, corrosion speed, and refining characteristic of glass. Secondly, we lead you one of the design concept.

2. Essential technologies for optimum furnace design

2-1 Furnace simulation

2D and 3D mathematical model is a useful tool and extensively utilized for furnace design and trouble shooting. Fig.1 shows an example of 2D model.[1] This model enables us to understand macroscopic glass flow and temperature distribution of different kinds of design quickly. Fig.2 shows an example of 3D model. This result shows not only detail glass flow and temperature distribution but also refractory temperature, which gives the much influence to the corrosion of refractory and bubble generation from refractory.[2]

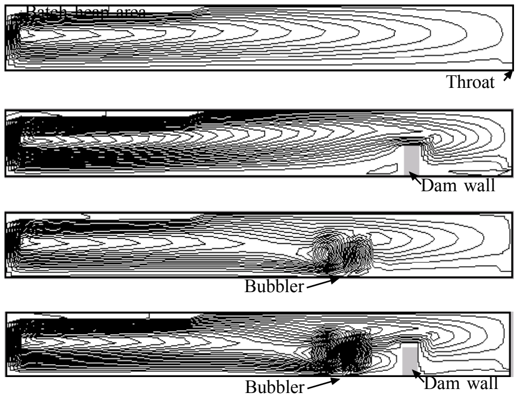


Fig.1 Glass flow line of 2D glass flow model results. (4 type design with flint glass)

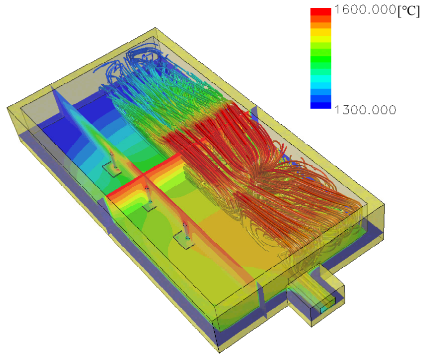


Fig.2 Sample result of 3D glass tank model.

2-2. Bubble generation from refractory

Bubble generation from refractory affects the quality of glass, and many kinds of evaluation methods are proposed.[3] Schematic diagram of our continuous blistering test equipment and the photo of bubble generation from refractory at 1200°C are shown in Fig.3.[4] This equipment enables the observation of blisters generated directly at high temperature area. Fig.4 shows the comparison of the blister generation rate between 41%-AZS(ZB-1711) and 95%-ZrO_2(ZB-X9510) for soda lime glass after 7 days. In the case of 41%-AZS, blister rate at 1450°C is about three times larger than that of 1350°C. Moreover, reduction of bubble generation can be seen through all temperature area in the case of 95%-ZrO_2.

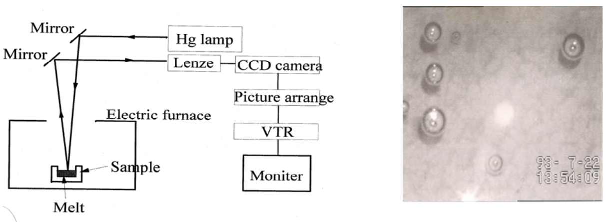


Fig.3 Schematic diagram of continuous blistering equipment and example of bubble generation from AZS

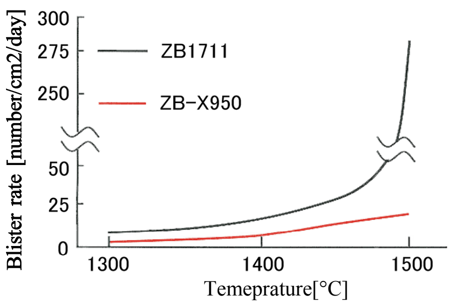


Fig.4 Blister rate in high temperature area with TV glass after 7 days

2-3. Corrosion speed of refractory

Corrosion speed affects the quality of glass such as stone and cat scratch. Furthermore refractory must secure a sufficient furnace campaign life. Fig.5 shows the corrosion rate of standard AZS refractory. Simple one-dimensional corrosion model which is combined the calculation of heat conductivity and thickness change, helps understanding of corrosion status in actual furnace. Fig.6 shows the thickness change of side tank block at various temperature, which is calculated by this model.[5] When the thickness of side wall is more than 100mm,

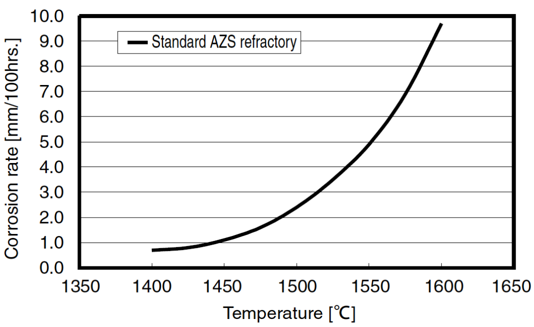


Fig.5 AZS corrosion rate

the corrosion speed of refractory is faster due to the higher boundary temperature between molten glass and refractory. However, it gets much slower if residual thickness becomes less than 50mm because the external cooling lowers the boundary temperature between the molten glass and refractory. Glass surface temperature of ordinary container glass is over 1500°C. Fig.6. shows that the thickness of side wall block become half within first one year. These corrosion phenomena affects to the furnace life and cat scratch caused by the contamination of ZrO_2.

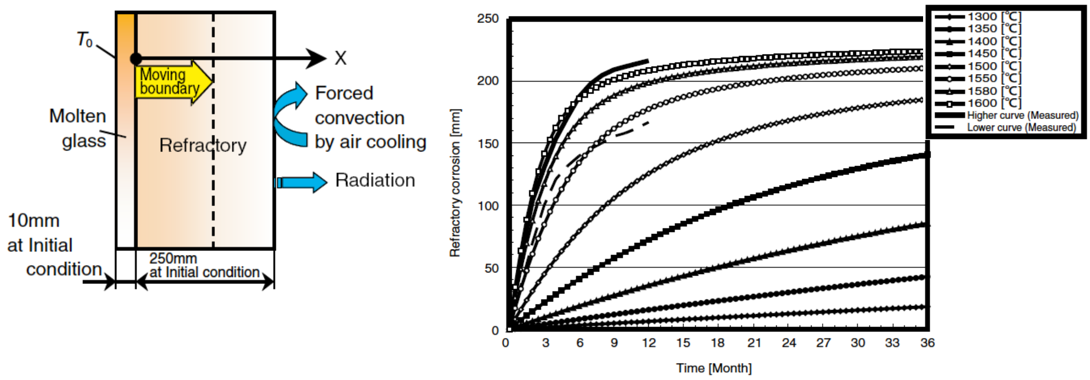
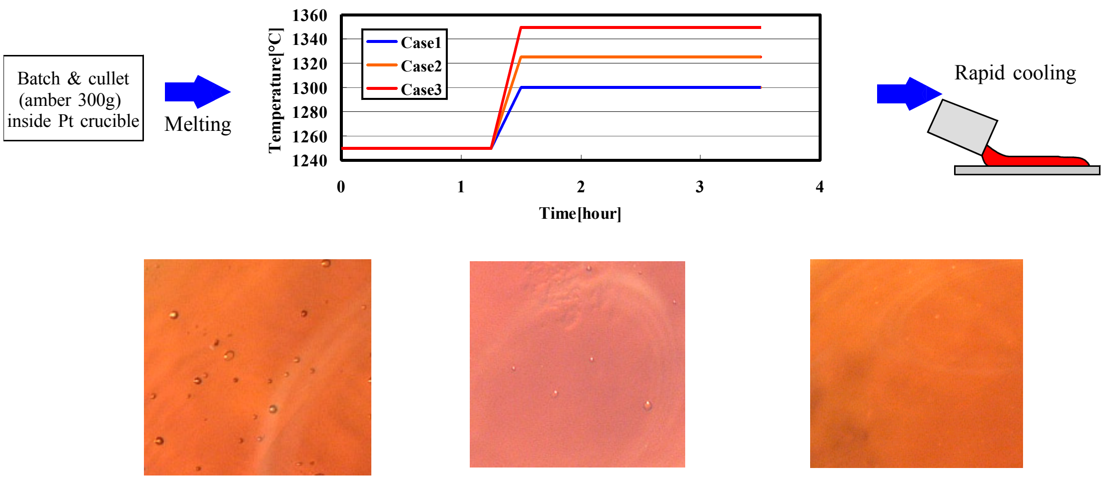


Fig.6 One dimensional refractory corrosion model result.
Left : Schematic view of modeling. Right: The result of corrosion model in the temperature area from 1300[C] to 1600[C]. Measured curves show the actual measurement at glass surface part in a number of furnace in several decades ago.

2-4. Refining of bubble

The refining of gas bubbles from molten glass is an important process. At the ordinary soda lime glass, SO_2 and O_2 evolved from the dissolved Na_2SO_4 help to carry out gases generated inside the molten glass through the surface. The mechanism is affected very much by the temperature history of glass melt inside the furnace. Fig.7 shows crucible test result of amber batch glass, which is melted in three kinds of temperature history. The residual bubble is drastically reduced when temperature is increased by 50°C.



Case1（Many bubble） **Case2（Few bubble）** **Case3（No bubble）**

Fig.7 Resudial bubble inspection of amber glass, melted with 3 kind of temperature curves.

3. Typical furnace study and discussion

Computer simulation result for typical furnace (amber, pull=180t/d) is shown in Fig.8. Case1 is without bubbler and dam, and case2 is with dam and bubbler. Both cases have the same condition such as pull rate, the amount of oil, booster power, and so on besides bubbler and dam equipment. Regarding paving temperature near the bubbler, case2 is about 70°C higher than case1 because amber glass has low effective heat conductivity and thus temperature difference between surface and pave is larger in the case1.

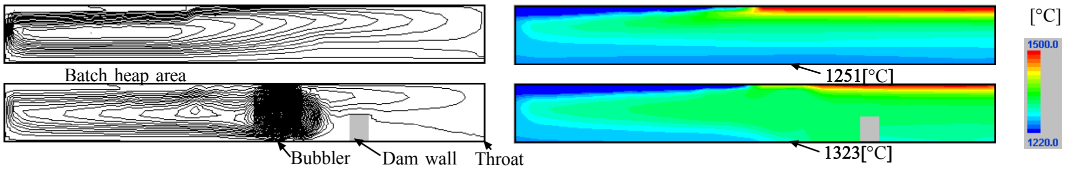


Fig.8 Flow line and temperature distribution (2D mathematical model)

(1) Case1 is without bubbler and dam wall.

(2) Case2 is with bubbler and dam wall. (Total bubbler air flow rate is 13[Nm^3/min])

Temperature history curve of typical glass path with minimum residence time by particle tracking analysis is shown in Fig.9. Maximum temperature in case2 is about 70°C higher than in case1. This temperature increase gives much effect to refining reaction, and this effect can be evaluated by the refining test described above.

Regarding energy efficiency, these results also show energy-saving potential with bubbler and dam wall, because the paving temperature of case2 is higher than that of case1 in spite of the same energy consumption (oil rate and electric booster power).

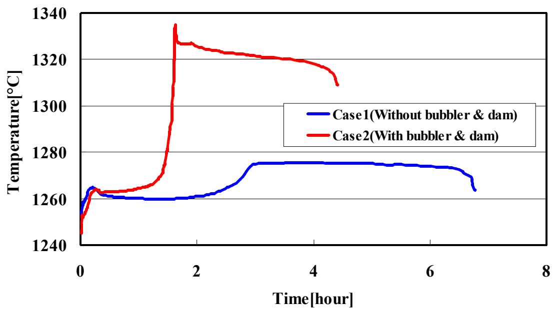


Fig.9 Temperature history curves of typical glass path which has minimum residence time.

4. Conclusions

Elemental technique for furnace evaluation is introduced, and the discuss is given about the effect of bubbler and dam wall in a typical furnace which produce amber glass. Bubbler and dam wall improve the temperature profile, which gives the remarkable influence to the glass quality and saving energy. On the other hand, bubbler sometimes causes the trouble such as glass leakage, increase of bubble generation in some furnace. Therefore, it is very important for us to determine suitable design and operation method through integrated approach based on past actual performance, simulation, evaluation of refractory and bubble characterization, and engineering.

5. References

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