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Mathematical modelling of the mixing and flow inside a float glass furnace towards reducing the colour change time

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Abstract

The transition between two different glass colours in a float furnace is a costly manufacturing procedure as the glass properties are out of specification during this period. This transition period is determined by the control and understanding of the mixing characteristics for the specific float glass furnace. Initiatives to reduce costs and waste production have led to increased focus on reducing the colour change time. Published research on the mixing characteristics in a glass tank gave reasonable approximations of the response curve. However, the actual response curves of modern float glass furnaces deviate from these systems. Therefore, the aim of this investigation was to create a mathematical mixing model that can approximate the residence time inside the furnace based on the glass flows. This mathematical mixing model was used to reduce the duration of the colour change, with respect to the iron concentration.

The first step was to create a validated CFD model that would provide in depth knowledge and understanding of the flow cells in the furnace. Subsequently a mathematical one or two parameter mixing model was developed for the furnace.

The results from this study indicate that the colour change can be separated into four parts. A one parameter mixing model with five to eight perfect mixers in series can describe the first stage of the colour change, where the inlet iron concentration is set at a certain percentage higher than the final required iron concentration. The number of perfect mixers in series depends on the barrier depth with five mixers used for 0.41 m barrier depth and eight mixers in series for 0.56 m barrier depth. The second stage of the colour change when the barrier is removed causes a change in the furnace mixing characteristics and a sudden

increase of iron concentration at the outlet of more than 0.1 mass % Fe_2O_3 within 4 hours. The third stage follows this short period by an increase in the iron outlet concentration that can be modelled by three perfect mixers in series when the barrier is out and the inlet iron concentration is reduced to the required outlet iron concentration. The fourth stage of the colour change is when the barrier is inserted again. This stage can be modelled by a four mixer in series model for the 0.3 m barrier depth.

The colour change time was reduced by 10 hours, with respect to the iron concentration, through adjusting key variables during the colour change. These were the overdope rate, overdope duration and the time when the barrier is removed. Multiple methods were tested with the mathematic mixing model of which two methods reduced the colour change time by 10 hours. One method was increasing the overdope rate to 180 % from the standard 130 % for a duration of 31 hours and also removing the barrier at 31 hours. Another method was to remove the barrier at 52 hours instead of 33 hours at an over dope rate of 130 % for a duration of 37 hours.

These methods will decrease the colour change time with respect to iron concentration, but may increase the time that the optical distortion is out of specification; as the glass may not homogenise within the required time in the furnace. It is also noteworthy to mention that this model was created for a specific furnace design and bubbling rate and will vary from furnace to furnace; but the perfect mixers in series model could be applied to other furnaces by using the response curve from that furnace.