Forehearth colouring – a technology update

Richard Sims
Nikolaus Sorg GmbH & Co KG

The concept of changing the glass colour in a forehearth is not new, and has been around for at least 30 years. The basic idea is very attractive, as it offers much better production flexibility than changing the glass colour in a furnace. Nevertheless, the technology has not found widespread use, partially because of the costs involved, but also as a result of the quality limitations from which the traditional systems suffer.

A forehearth colouring system consists of two main components – a colourant material and a mixing system. This paper is concerned with the second of these – the hardware used to mix the base glass and colourant material to give a homogenous coloured glass. However, it should be noted that successful operation will only be achieved when both components perform correctly.

Mixing

The success of a colourant forehearth depends on the complete mixing of the base glass and the colourant. However, there are many misconceptions about what is actually involved in this process.

The so-called mixing actually takes place by diffusion of the colourant oxides and other components of the colourant material into the network of the base glass. The diffusion only takes place at the contact surfaces between the two materials.
There are three factors which influence the extent and speed of the diffusion process :

- The surface area of contact between the colourant and the base glass
- The time available for diffusion
- The concentration differences of the various components between the colourant and the base glass

The process can be accelerated if the contact surface area can be increased, and this is the first aim of the mechanical mixing process of the stirrers. To achieve an increase in the surface area the colourant must be pulled into long, thin streams, which is achieved by the application of a shearing effect.

The time available for diffusion must be maximised. This means that the faster central glass flow must be slowed down and the slower moving side flows speeded up to give a general increase in residence time.

The concentration differences cannot be easily influenced, but continuous movement within the glass bath will tend to prevent the early development of a stable, low diffusion rate.

Stirring in glass

On the basis of the description of mixing it is clear that a stirring system must be designed to influence at least the first two of the three factors which affect the rate of diffusion :

- To provide an increase in the contact surface area between the colourant and the basic glass
- To increase the time available for diffusion by reducing the differences in the velocity of the various parts of the glass bath cross section at any location.

There are a number of designs of stirrers available from refractory manufacturers, and these can be split into two general types :

- Spiral type, also known as blenders. A typical spiral type stirrer is shown in figure 1.
- Paddle type. A range of paddle stirrers are shown in figures 2 – 4.

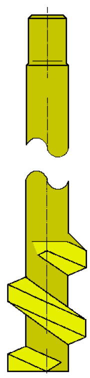


figure 1

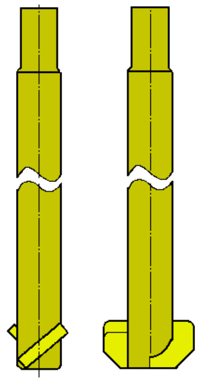


figure 2

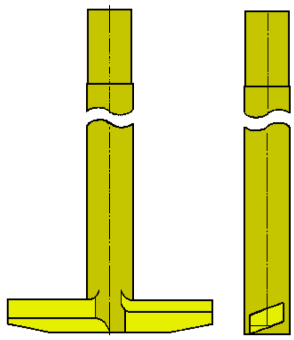


figure 3

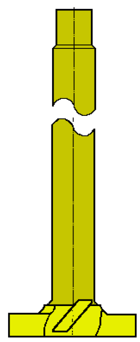


figure 4

As would be expected, both types have advantages and disadvantages.

Spiral type stirrers

These stirrers are essentially transporters, which are capable of moving bulk glass vertically upwards or downwards, depending on the direction of rotation. They only exert a limited shear effect on the glass.

These stirrers are normally used in a group, installed across the channel. The number of stirrers actually used depends on the width of the channel, but they are placed close to one another, so that there are only narrow gaps between the individual stirrers.

It is therefore necessary to consider the effect produced by a number of such stirrers working together, rather than that of a single stirrer.

Model tests have shown that the main advantage of this type of arrangement lies in its effect on the glass flow patterns. A typical flow pattern exists in a forehearth channel, with a velocity gradient from the channel centre to the sides, and from the surface to the bottom. The combination of the mechanical barrier produced by the refractory material of the stirrers, and the transport effect of their rotation, can be used to modify the flow pattern, so that differences between the fastest and slowest velocities are reduced, and, as a consequence, the average residence time increased.

Therefore, this type of stirrer, correctly applied, is used to increase the time available for the diffusion process.

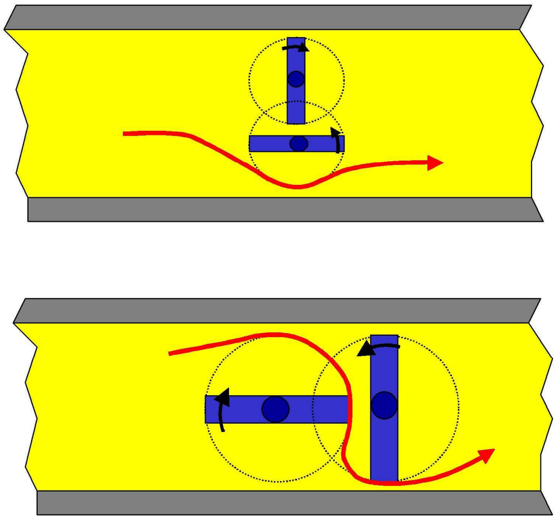
Paddle stirrers

Paddle stirrers can provide the important shearing effect that is necessary to increase the surface area available for diffusion.

The differential linear velocities found at different locations along the paddle arm ensure that a shearing effect is achieved.

When two-blade paddles are used these can also be arranged so that the circular path of one intersects that of the adjacent one. This provides a change of movement direction, which can increase the shear effect.

However, paddle stirrers also have one major disadvantage. The pushing effect of the paddle creates a fast path for glass on one side, and this glass quickly leaves the area of influence of the stirrer. The combination of two or more paddles, either alongside one another or one after another, does not change this problem. This situation is shown in figure 5 below.



Other examples of stirring in the glass industry

Stirring is commonplace in some parts of the glass industry, such as in the manufacture of optical glass, where extremely high levels of homogeneity are required. Here it is normal to stir in a platinum-lined container using a platinum stirrer, and with the glass flowing is a vertical direction.

There is only a very narrow gap between the stirrer and the container wall, and the paddles consist of relatively thin rods as, which can be rotated at quite high speeds.

The fact that the glass flows vertically through the stirring cell means that all of the glass has to pass through the plane of rotation of the paddles, and thus must be subjected to the intensive shearing action which the combination of thin rod paddles and high rotational velocity produce.

Colouring forehearths – the traditional system

Forehearth colouring is not a new idea, and it has been practised for at least 30 years. The traditional stirring system comprises a number of groups of spiral stirrers installed one after the other along the channel. Each group or bank consists of between 3 and 5 such stirrers placed across the channel, the number used depending on the channel width.

The number of banks depends on the maximum pull required, but is usually between 3 and 5.

As described above, the spiral type stirrers provide an important increase in the effective residence time, but they provide very little shearing effect to increase the surface area available for diffusion.

Therefore, this system makes positive use of only one of the two major factory which influence the mixing process.

Colouring forehearths – the SORG® system

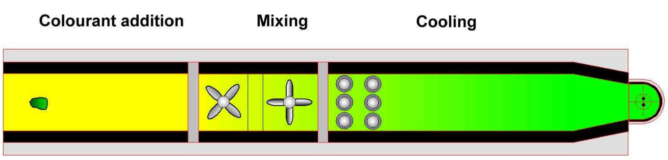
The SORG® colouring forehearth utilises the basic design principle employed in the optical industry, in that refractory barriers are used to give the glass flow a vertical component in the stirring area.

In practical terms this is achieved in the following way. At the beginning of the stirring area a skimmer block is immersed in the glass from above. This is followed by a low barrier wall protruding from the channel bottom, and a further skimmer installed from above. This combination produces two chambers in the channel, in the first of which the glass must flow upwards whilst in the second the glass must flow downwards.

A single refractory paddle stirrer with 4 blades is installed in each of these chambers, and this arrangement provides the conditions necessary for the important first part of the diffusion process in which the colourant is stretched out into long thin streams. This arrangement is followed by banks of spiral stirrers. These act as brakes to reduce the speed of the fastest forward current, whilst providing a mixing effect by moving the glass from the bottom to the top of the glass bath, or vice versa.

The combination of paddle and spiral stirrers allows the advantages of each type to be used, and provides influence of both of the important factors which affect the rate of diffusion.

A typical arrangement of a SORG® colouring forehearth is shown in figure 6 below.



One particular characteristic of all colouring forehearths which sometimes causes problems is the channel length which is required. Additional room must be found for the melting and mixing areas, and so colouring installations are normally longer than conventional forehearths for the same maximum pull.

The SORG® colouring forehearth design is easily able to accommodate corners and so, for instance part of the colouring system can be installed in place of the working end, with the remainder placed in the first part of the forehearth after the 90° corner.

A further increase in the effectiveness of the stirring can be obtained if an additional bank of spiral stirrers is provided before the actual mixing area.

Once again, this type of stirrer is used to slow the main glass current and, in this case, increase the residence time of the colourant in the melting zone.

The SORG® colourant forehearth system was originally developed on the basis of physical modelling techniques, and comparative tests showed a much better mixing capacity than the conventional system. In practise the system has achieved very good results, and is currently used for normal containers, high quality flacons and perfume containers, stemware and glass bricks. A range of products already manufactured on SORG colourant forehearth systems is shown in figure 7.

Conclusion

Traditional colourant mixing systems utilise some form of stirrers installed in the forehearth channel, in which the glass flows horizontally.

The SORG® colouring forehearth was developed on the basis of stirring technologies used in the optical industry which uses mixing cells in which the glass flow is vertical. The SORG® system features refractory barriers in the channel which give the glass flow a vertical component in the stirring area. This provides a significant improvement in the effectiveness of the mixing.

The new system offers additional advantages. The SORG® experience of forehearth design, which itself goes back more than 25 years, has been applied to provide a complete product which includes optimised gas heating system in the colourant melting area, including oxygen control if required, and a powerful glass cooling system which can be applied after the colour mixing has taken place to reduce glass temperatures to values suitable for the forming process.