Optimisation of the moulds cooling process

Key issues to cope with current market demands include production speed, flexibility and quality. In order to guarantee these issues, predictable and efficient cooling systems for the forming moulds are a necessity. Thomas Bewer* reports.

Mould cooling ensures the desired contact temperatures of mould and glass – a factor which influences final glass quality. Thus, predictable cooling offers more production flexibility, especially as far as specific shapes are concerned. However, a successful cooling system has to serve different needs on the blank and the blow side.

On the blank side, the cooling defines the temperature distribution on the mould cavity and influences the parison quality. This is one of the vital parameters of high quality glass containers. To achieve the desired temperature profile, the cooling needs to be adjustable.

On the blow side, the cooling leads to the stability of the container. This stability defines the production speed. The cooling capacity has to be predictable and high.

Blank side cooling

In order to achieve a predictable blank side cooling two things are required: clear operating conditions and a prediction tool. These requirements are met by two recent Emhart Glass developments. The clear operating conditions are guaranteed by the new blank side cooling system InVertiFlow, which guides the cooling air from the bottom to the top of the mould. Compared to the Emhart Glass blank side VertiFlow cooling, this corresponds to an ‘inverted’ cooling. On the other a new sophisticated simulation tool gives the ability to predict the blank and blow mould cooling in three dimensions.

For the InVertiFlow system the air inlet, on a plenum chamber, cools the blank mould from lower to upper side. The placement of the plenum chamber can be varied by spacers to accommodate the plenum at the desired height. Guiding the air from the bottom of the mould to its top makes the mould cooling and the neckring cooling individually adjustable, as they are not interfering. Additionally the hot air is removed from the section, reducing the mechanism temperatures.

Compared to VertiFlow cooling systems approximately one third less cooling time is required. The working environment is improved significantly as the hot air is carried away. No plenum chamber has to be removed, which drastically improves the mould change. Customers also report a very interesting potential for speed increase.

Availability

The InVertiFlow cooling system is currently available on the NIS and the AIS (see Fig 1). Furthermore, it is also available for IS machines with centre distances of 5 1/2” DG (see Fig 1), 5” DG and 4 1/4” DG. Current VertiFlow moulds can be used with minor modifications.

The AIS solution even allows running a VertiFlow and InVertiFlow cooling configuration. This very versatile equipment is in the Zero Batch phase. The experience is very encouraging. It verified the above mentioned advantages and allowed equilibrium to be reached faster after start up. Fewer seams were observed due to further improved clamping.

The new software tool TekPak significantly advances the process of mould cooling simulation giving the power to produce full 3D mould temperature profiles irrespective of

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the complexity of the container shape, for both blank or blow side using all forming processes (PB-BB-NPB). A CAD drawing package defines the geometry and a Finite Element Analysis (FEA) package does the calculation. The starting point of every calculation is the actual or planned design of the mould. Based on the design data, such as hole configuration, machine speed and timing, TekPak will then determine the specific mathematical boundary conditions needed to proceed. In the next step the customer’s 3D CAD model of the mould is transferred to the FEA solver. Once the geometrical model is available in the FEA solver, the boundary conditions generated by TekPak are entered. Once this has been completed the FEA solver calculates a predicted temperature distribution.

This advanced simulation tool is used by Emhart Glass to offer a temperature calculation service to customers.

**Blow side**

As mentioned above, on the blow side the cooling of the mould leads to the stability of the container. This demands a high cooling capacity. Two methods to increase the cooling capacity of VertiFlow systems are presented. Both possibilities were developed in the laboratory and successfully tested in the field.

The first possibility is to taper the end of the cooling bore. This is called a diffuser exit. The second approach is the use of additional cooling equipment called auxiliary cooling. Both possibilities are illustrated in **Fig 2**.

For the determination of the efficiency of these two approaches a test rig was built in the laboratory. Different specimens were prepared. A single cooling bore was drilled into a steel cylinder with 30mm diameter. For the measurement the specimen is heated up in a small furnace and cooled down by the cooling air passing through the bore. Based on the transient temperature change the cooling efficiency was calculated.

The results for different types of diffuser exits are summarised in **Fig 3**. The results show that the mass flow through the bores increased by 16-28%, depending on the design of the diffuser exit. The higher mass flow in turn results in a 13-19% higher cooling capacity, which can be used to reduce energy consumption, or in most cases increase machine speed.

**Field tests**

With the diffuser geometry identified in the laboratory, field tests were performed. Four mould halves were modified with the diffuser exits. The temperature of the modified moulds was compared to standard moulds using thermocouples mounted in the mould at different locations. The experiments gave an average reduction in temperature of 19°C for the tested container due to the diffuser exits. This reduction in temperature corresponds to 30% reduction in cooling pressure for the examined production.

However, the rate of cooling capacity improvement depends on the individual mould design. Therefore, further ways to improve the blow side cooling capacity were investigated. Gaining know how from the diffuser experiments led to the development of an auxiliary cooling for the blow side. The auxiliary cooling system is designed to work in addition to the existing blow side VertiFlow cooling system.

The system supplies air from the sides to the outer cooling bore row. The air supply is done via telescopic tubes, which allow supplying air during 360°, including mould travelling and in the open position. A pocket guarantees the even distribution of the air on the bores. The air supply is timed by one on/off per side. The system set-up is illustrated in **Fig 2**.

In order to supply the air from the pocket to the outer bore, row bores have to be drilled perpendicular to the cooling bores, as shown in **Fig 4**. These bores should have about the same diameter as the cooling bores. With this set-up it is possible to supply bores of the outermost row. It was verified that if the 360° auxiliary cooling is not used and not mounted, the moulds can be used on standard VertiFlow systems without any restrictions.

The auxiliary cooling principle was tested in the field. The results in **Fig 4** show a drastic improvement of the
cooling capacity. The mould temperature could be reduced by 100°C, when the auxiliary cooling was turned on for 360° cooling time. Furthermore, the results indicate that the vertical temperature profile can be influenced. Both findings demonstrate the speed increase potential of the auxiliary cooling.

Besides the cooling capacity improvements the auxiliary cooling equalises the mould temperatures during the forming cycle, resulting in a potentially longer mould life. At the inner cooling bores the cyclic temperature change is reduced by about 25%, on the outer bores even by 75%.

**Conclusion**

In the hollow glass forming process blank and blow mould cooling is an essential process step determining production flexibility, container quality and production speed. On the blank side the cooling needs to be predictable. Emhart Glass ensures the predictability by offering the flexible cooling system InVertiFlow and having a new service tool for mould temperatures called TekPak available. On the blow side a crucial need for the cooling system is its high performance. Experimental results showed that the existing VertiFlow cooling capacity can be increased by about 15% modifying the cooling bore exits. An even more significant cooling capacity increase, while additionally allowing to modify the vertical temperature profile is gained with the new 360° auxiliary cooling system.

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![Fig 4. Temperature measurements and mould modification for the auxiliary cooling system.](image)