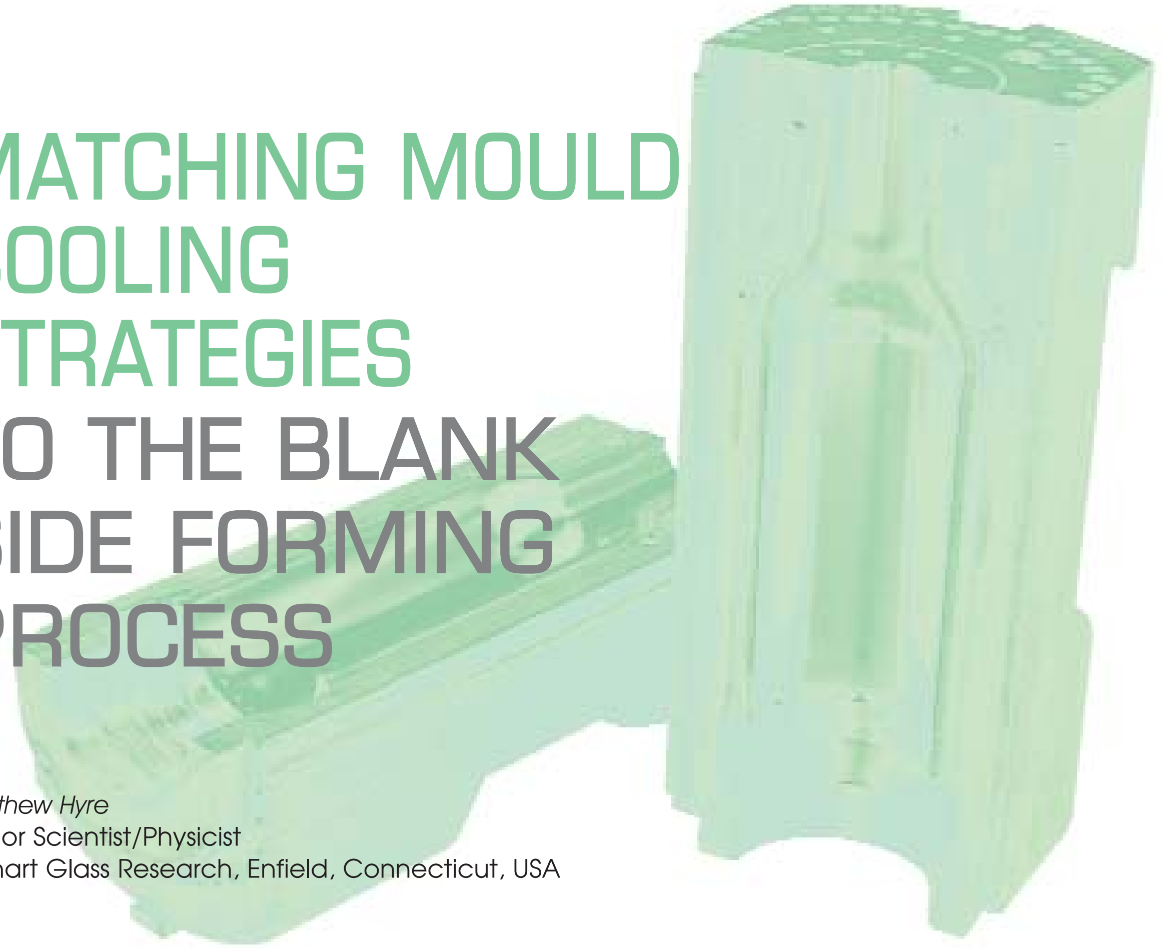

MATCHING MOULD COOLING STRATEGIES TO THE BLANK SIDE FORMING PROCESS

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In the glass container industry, two processes of forming small finished containers currently dominate: the Narrow Neck Press and Blow (NNPB) and the Blow and Blow (B&B) forming processes. In the NNPB process, pressing forms the glass container parison. Alternatively, in the B&B process the parison is blown. For most containers, the blank mould cooling strategy has been developed independent of the forming process. There are currently three primary blank cooling methodologies. In the most common system, the cooling air is blown horizontally across the blank moulds. Other cooling configurations use air flowing through vertically drilled holes in the mould. The direction of the air can either be from the top of the mould down, or from the bottom of the mould up. These cooling configurations can have a significant impact on the thermal profile of the parison. As a result, certain cooling configurations may be better suited for a given container type and forming process. Numerical modelling is becoming an important tool for the evaluation of the glass container forming cycle. In this study, computational techniques are used to virtually form the same container by both the B&B and NNPB forming processes. Heat removal requirements and IS machine timings were evaluated to determine the best cooling strategy.

FIGURE 1
Machine timings for NNPB and B&B forming processes

	B&B CONTAINER	NNPB CONTAINER
Weight (gm)	188	192
Cycle Time (s)	4.1	4.3
Gob Temperature (°C)	1150	1150
Blank Contact Time (s)	1.82	1.4
Blank Mould Cooling (s)	2.8	1.6
Plunger Up (s)		1.0
Settle Blow Time (s)	0.46	
Counter Blow Time (s)	0.76	
Per cent Cycle Time in Blank Mould	46	33

Blank mould configuration

The bottle selected for analysis was a typical 12 ounce beer bottle. This bottle was selected because it has been formed by both the NNPB and B&B processes. The IS machine timings for the bottle are shown in Figure 1. These timings were used throughout the forming simulations to determine the effect of the blank mould cooling configuration. Figure 2 shows the blank mould configuration when the mould was configured for stack wind cooling. For top down and bottom up cooling, vertical holes were drilled in accordance with Emhart Glass blank side *Vertiflow* mould cooling guidelines.

Forming simulations

The forming simulations were started at blank mould gob loading and proceed through parison formation, invert, reheat/stretch, and final blow. The container was formed using both the NNPB and B&B forming processes with all three different mould cooling configurations (stack, top-down, bottom-up). The aim was to determine, for this particular container and each of the forming processes, if one cooling configuration was better suited than the others. These models have been describes elsewhere (see References).

The most critical aspect of the forming simulations is the determination of the heat transfer between the glass and the mould. This is also one of the most difficult aspects of the modelling effort. The problem is that the blank mould/plunger/final mould temperature distributions are not known so they must be determined as part of the simulation.

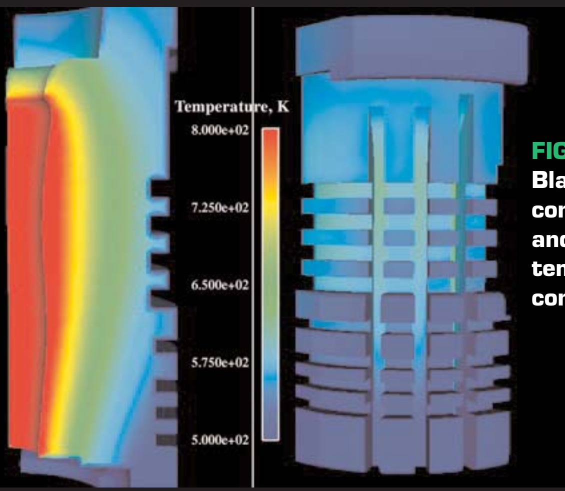

FIGURE 2
Blank mould configuration and temperature contours

To do this, an iterative procedure is used which is depicted in Figure 3. A similar approach was used on the blow side. To begin the forming simulations, arbitrary temperature profiles are used for all forming equipment. A forming simulation is then run which results in heat flux profiles between the glass and forming equipment. These flux profiles are imposed on the forming equipment iteratively until they do not change from cycle to cycle. At that point another forming simulation is run and the process begins again until the container thickness profile does not change. At this point in the process, all thermal profiles of the glass and forming equipment are known throughout the forming cycle.

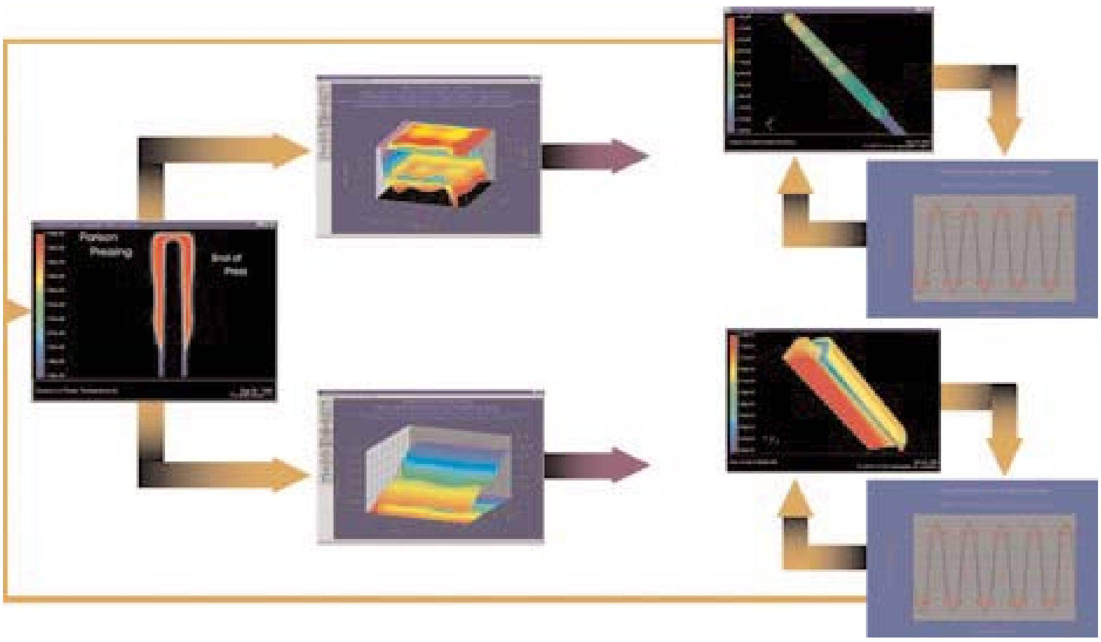

FIGURE 3
Mould/plunger temperature calculation methodology

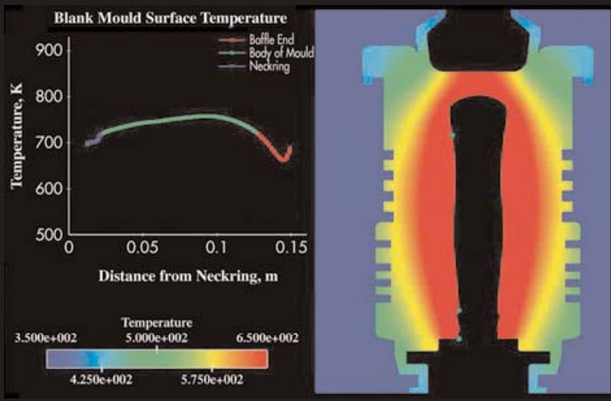

FIGURE 4
Blow and Blow with stack cooling

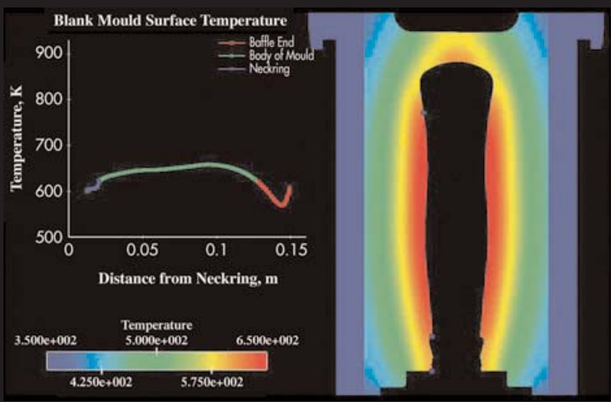

FIGURE 5
Blow and Blow with top down cooling

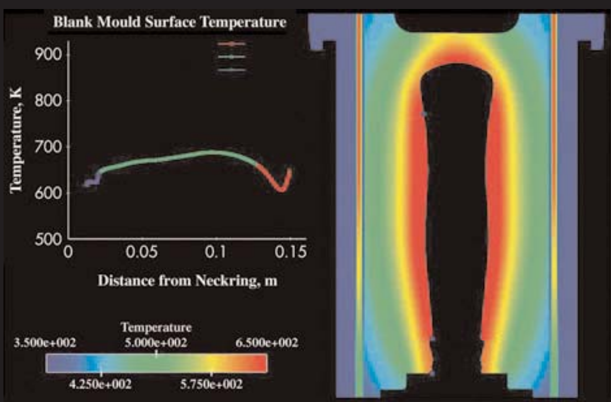

FIGURE 6
Blow and Blow with bottom up cooling

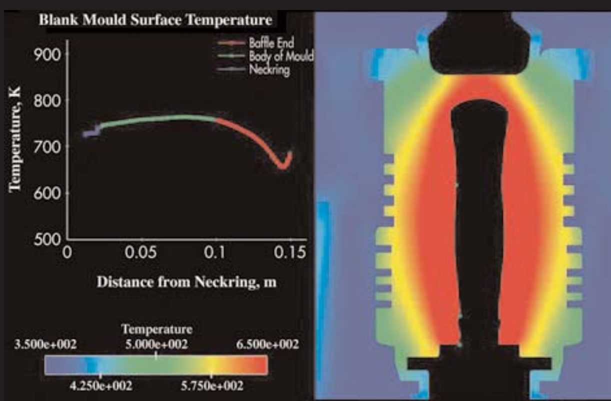

FIGURE 7
NNPB with stack cooling

Results

In order to determine how the cooling system affected different regions of the blank mould and parison, the blank mould was divided into three components: neckring, above the neckring to the loadline, and above the loadline to the baffle. In a Press and Blow process the glass first hits the region between the neckring and loadline, it is then pressed into the baffle, and then the neckring is filled. In a Blow/Blow process, the region first in contact with the glass is still the area between the neckring and loadline. However, the next region to see contact is the neckring during settle blow. The last region which is in contact with the glass is the baffle region.

Figures 4 through 9 show example cut planes through the blank mould with temperature contours immediately before the gob loads.

Figures 10 and 11 also show the blank mould wall temperature as a function of the vertical distance from the neckring immediately before the gob loads.

Since the contact time between the glass and mould changes with the different forming processes, it is advantageous to have certain areas of the mould colder or hotter than others. For example, in the Blow and Blow process, the contact time of the baffle is much less than that of the body of the mould since the glass hits there last. So to get a more even removal of total heat from the parison, the baffle end needs to be colder. For this forming process, the top down cooling configuration is better suited.

For the NNPB forming process, the glass hits the baffle before the finish mould is filled. Therefore, it would be advantageous for the surface of the neckring to be cooled as much as possible compared to the baffle end in order to remove the same amount of heat from each area of the parison. For this forming process, the bottom up cooling configuration is better suited.

The curves for each of these regions were integrated to determine the total heat removed from the glass in each sector. Figure 12 shows the deviation of heat removed from each sector from the average surface heat removal for the two different forming processes.

For this particular bottle, if it is formed using the Blow and Blow process, top down cooling removes heat most evenly from all areas of the parison. For the NNPB process, the bottom up cooling provides a more even heat removal from the parison.

Conclusions

Several blank side mould cooling technologies and configurations currently exist. Different cooling configurations may be better suited for specific forming processes, bottle types and cooling technologies. Modelling mould cooling strategies combined with forming process simulations can provide valuable insight into which cooling configuration optimizes heat removal. These models are now being combined with finite element models which evaluate burst pressure limits, impact strength, and axial loads to determine the blank side cooling effect on final container strength.

References

Hyre, M.R., "Effect of Glass to Mould Heat Transfer on Glass Container Forming," 2004, in Advances in Fusion and Processing of Glass, Varner, J.R., Seward, T.P., and Schaeffer, H.A., eds., ACS press, pp. 271-281.

Hyre, M.R., "Dynamic Computational Modeling of the Glass Forming Process," 2004, in Computer Aided Process Engineering, Barbosa-Pavoa, A., and Matos, H., eds., Elsevier Press, pp. 205-211.

Hyre, M.R., "Numerical Simulation of Glass Forming and Conditioning," 2002, J. Am. Cer. Soc., 85, pp. 1-10.

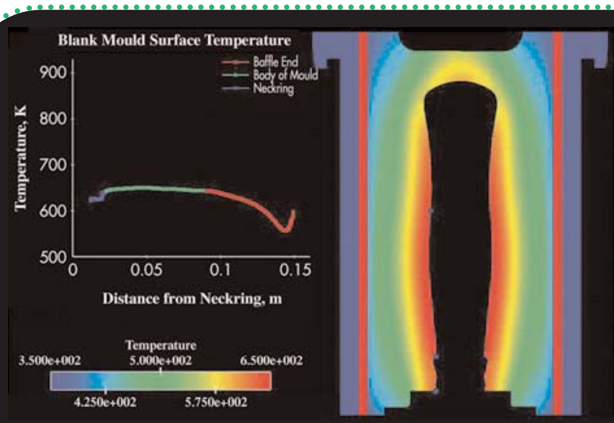

FIGURE 8
NNPB with top down cooling

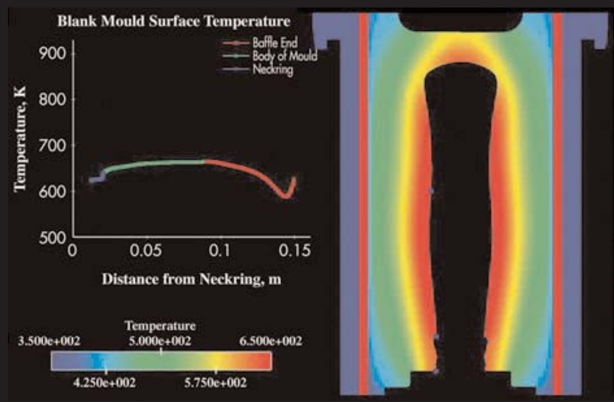

FIGURE 9
NNPB with bottom up cooling

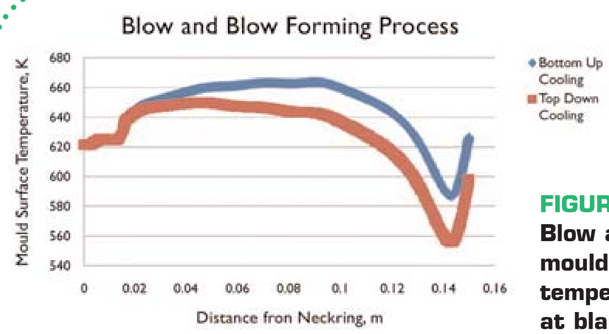

FIGURE 10
Blow and Blow mould surface temperatures at blanks open

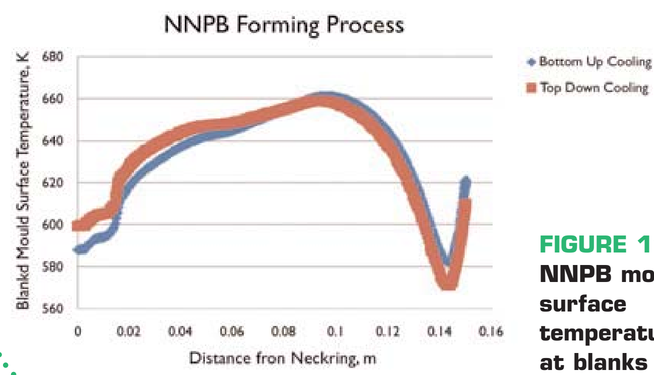

FIGURE 11
NNPB mould surface temperatures at blanks open

FIGURE 12
Per cent deviation from average heat removal from parison

	BAFFLE	BODY	NECKRING	MAX BODY/ BAFFLE DEVIATION
B&B Bottom Up	-5	5	0	10
B&B Top Down	-2	2	0	4
B&B Stack Cooling	-4	4	0	8
NNPB Bottom Up	2	2	-5	4
NNPB Top Down	1	7	-7	6
NNPB Stack	0	9	-9	9