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Conformal cooling efficiencies in stretch blow molding

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Analyzing different preform and mold temperatures helps optimize cooling channel design.

A number of key advancements in stretch blow molding processing machinery in the past decade have led to higher productivity and improved processing and quality of the blow-molded articles. A combination of factors including allowing resins to be reheated faster, molds to open and close in shorter time duration, lamps that emit more energy in a shorter wavelength, have made these advances possible. These technological innovations have benefitted brand owners and convertors who need to produce water bottles, hot-fill bottles, carbonated beverage containers, and custom-shaped oval and non-round containers at a faster rate.

Reduced mold contact time has frequently gone hand-in-hand with light weighting and new optimal weight packages. However, carbonated soft drinks, one of highest volume markets, has almost universally adopted the petaloid base design technology. Petaloid base performance is driven by a number of factors including geometry, material distribution, and the quenched temperature of the bottle's base portion after it has been extracted from the blow mold.

We therefore investigated enhancing cooling in the base mold to reduce stress cracking and improve shape retention at higher temperatures and pressures. We combined modeling and actual performance data to determine if conformal cooling can benefit such packages (see Figures 1 and 2).[4]

Over the last decade, the blow molding speed of PET containers has almost doubled. Throughputs topping 2200 bottles per cavity per hour are common. This has reduced the mold contact time to around 0.8 seconds compared to 2 seconds when the speed was closer to 1000 bottles per hour per mold.

The standard sidewall thickness of a PET carbonated beverage container is in the range of 0.25mm to 0.4mm. Room temperature is typically reached in less than 0.5 seconds, in contrast to the base and neck sections, which never cool all the way down to the mold temperature before bottle ejection. It is typically the base and the neck areas which are thicker and need longer cooling time. Cooling these areas is critical to prevent excessive gate relaxation (Figure 3), that, in extreme cases,

Figure 1. *Typical failure region on carbonated soft drink containers.*

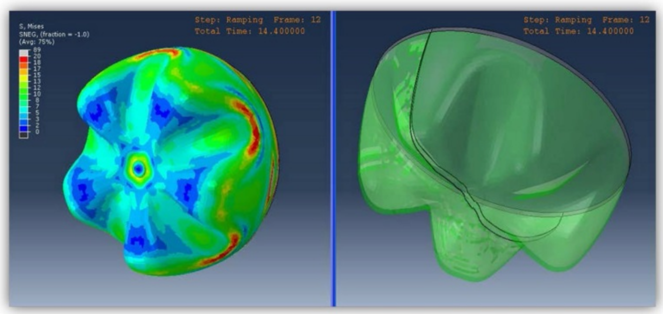
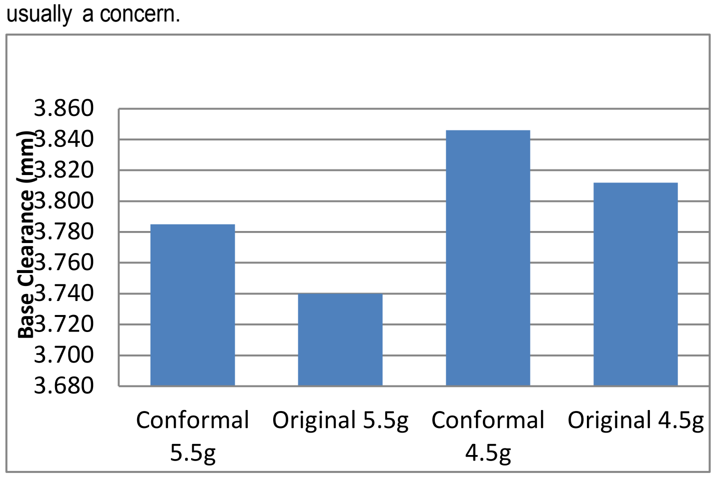


Figure 2. *Modeled stress and deformation in a petaloid base under internal pressure*

can cause bottles to lean and adversely affect stress crack performance. There is a thickness distribution gradient in the container base area (Figure 5), which is thicker near the gate (the melt inlet port for the injection molded preform) and rapidly tapers off near the sidewall. The thinner sidewall areas quench fast under normal mold cooling and are not usually a concern.



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10.2417/spepro.005905

Figure 3. *Comparison of actual bottle base clearance measurement data*

Our simulation takes into account variables such as mold coolant temperature, the preform temperature before blowing, the blown bottle thickness, and the thermal properties of the mold material, to predict the quenched-bottle temperature. As is commonly known, stress crack occurs only when container sidewalls are under internal loads. (Carbonated beverages are a good example.) A typical stress crack simulation would investigate the stress distribution in the container's base region. The mechanical properties are dependent on preform orientation along with the creep resistance of the container at elevated temperatures. The ability to minimize the stress distribution (Figure 2), through optimized geometry or maximized orientation, typically results in best performance. We used a 12oz container blow molded using a 23g preform designed for optimal material orientation for PET containers of a given i.v. or molecular weight. In trials with regular base cooling, the blow molded containers had poorer caustic stress crack resistance. Some containers failed in less than 2 minutes in 0.2% sodium hydroxide solution as stipulated under the ISBT (International Society of Beverage Technologists) protocol. The conformal cooled base containers at similar material distribution (base section weight) survived a minimum of 10 minutes indicating significant performance enhancement (Figure 4).

Stress Crack Results	5.5g base weight in Conformal Design	5.5g base weight in Original Design
Average	0:13:15	0:12:58
St. Dev	0:02:12	0:03:26
Min	0:10:53	0:01:27
Max	0:19:13	0:16:14

Figure 4. *ISBT Caustic Stress Crack performance results showing improvement in performance in conformal cooled geometry*

There are a variety of ways that conformal cooling can be effected. In the present study we had looked at improving the cooling water circulation in the base mold closer to the thicker material distribution. Other methods include the possibility of adding copper inserts in the critical thicker 'gate and strap' region of the base mold (Figure 7). Copper has twice the thermal conductivity of aluminum (210W/m·K), used to make conventional molds, and so we can predict the desired improvement in quenching by optimizing the extent of coverage of the inserts. We also plan to investigate gun drilling rather than laser sintering cooling lines so that they could be placed closer to the thicker sections of base. This might result in significantly better base cooling and performance. We measured the temperatures of blow-molded bottles (Figure 9) prepared using the conformal base-cooling technology and compared them with the control standard base cooling design where the cooling water lines go in a more simpler planar spiral path (see Figure 7).

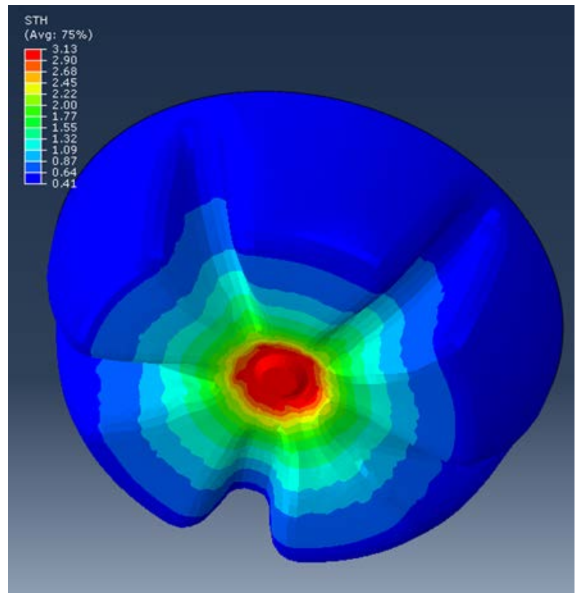

Figure 5. *Predicted Petaloid base thickness distribution plot*

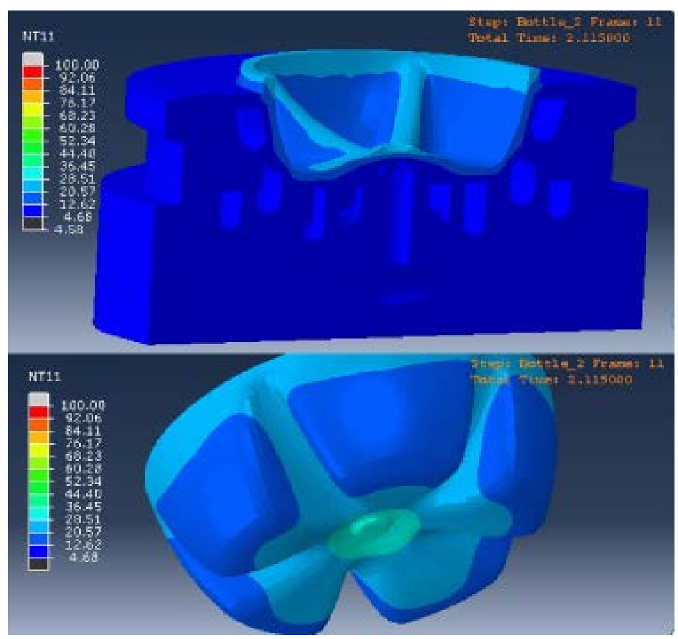

Figure 6. *Simulated Temperature distribution in the plastic part and the metal mold during a quenching cycle*

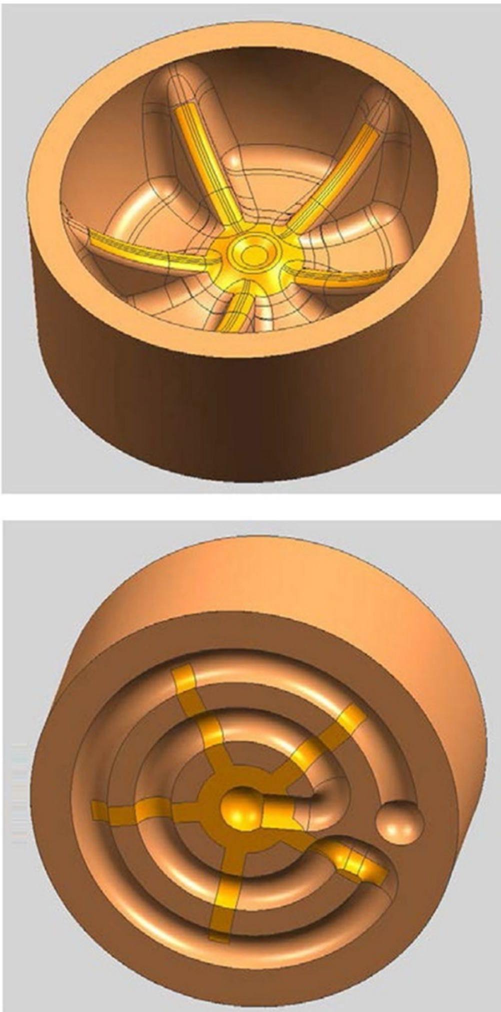

Figure 7. *Base cooling option with copper insert*

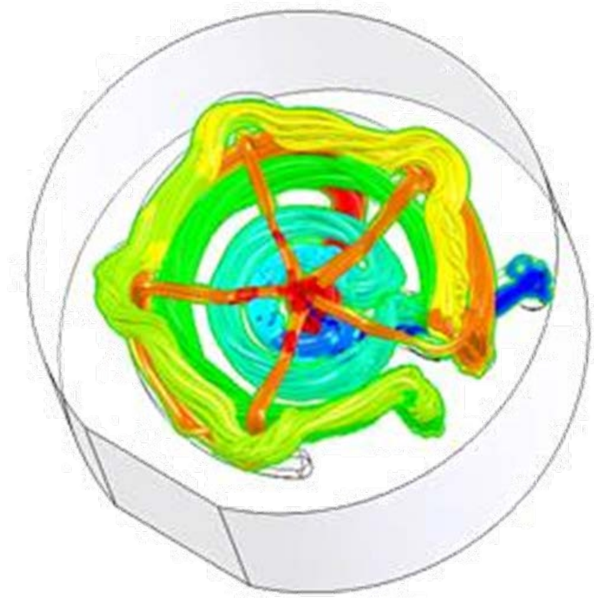

Figure 8. *Base cooling option with conformal cooling*

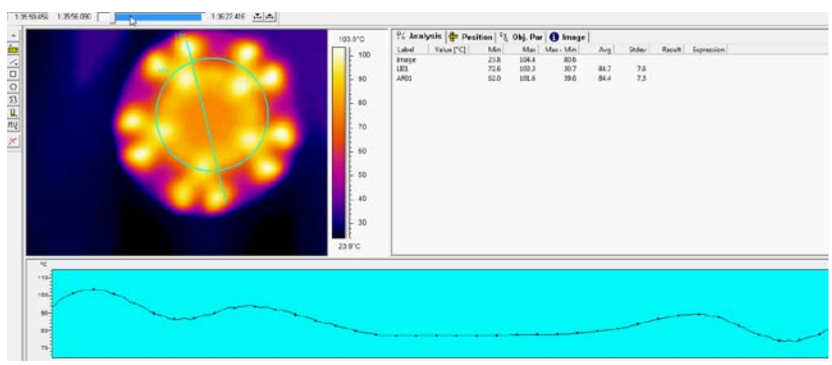

Figure 9. Petaloid b*ottle base temperature monitored with a Thermal Imaging camera*

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