Identifying breakage issues in crown closure bottles

Dr. Clarissa L. Justino de Lima and Peter W. de Haan report on findings obtained from using a medical CT scan in a novel manner to investigate how guide ring seam irregularities can result in breakage issues for both pry-off and twist-off finish bottles.

Common finish irregularities associated with the guide ring seam and neck rings [of crown closure glass bottles] are categorised as undermatch, overmatch, flange, or knockout. Examples of these four types of irregularities are shown in Figure 1. As shown in these cross-sectional views, a knockout has a similar physical appearance to a flange. However, a knockout is restricted to the junction of the vertical neck ring seam with the horizontal guide ring seam whereas a flange can occur at any position along the guide ring seam and typically extends around the circumference of the finish for some distance.

Overmatch and undermatch features are predominantly caused by misalignments or dimensional issues between the neck ring components of a finish mould. Flanges and knockouts are usually caused by improperly closed neck ring halves or damaged and/or misaligned mould parts. Flanges, overmatches and knockouts are normally regarded as more serious problems as they are susceptible to breakage upon contact. In addition, bottles with especially sharp flanges, knockouts or overmatch features can chip or fracture during capping and possibly lead to pieces of glass entering the filled bottle.[1] Undermatches are viewed as being more benign as they generally do not lead to breakage issues although in extreme circumstances, even undermatches can lead to problems.

The purpose of this paper is to discuss the manner in which guide ring seam irregularities can result in breakage issues for both pry-off and twist-off finishes.

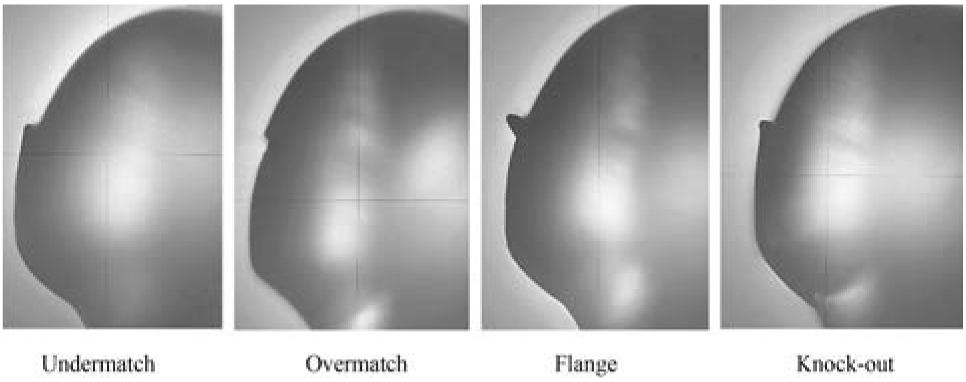

Figure 1: Guide ring seam irregularities.

Figure 2: Different finish types.

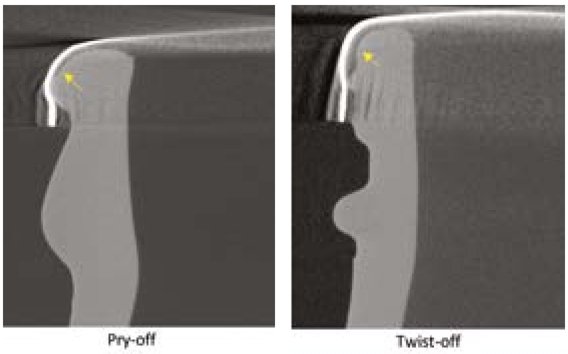

Figure 3: Examples of distances between the finish and the closure.

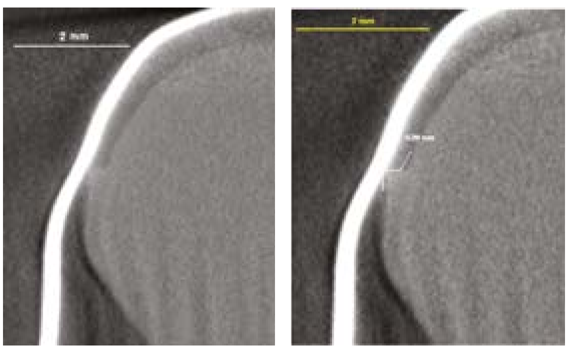
Figure 4: Undermatch with no space between the guide ring seam and the closure.

Table I

Flange	Total distance at flange
0.14	0.34
0.22	0.32
0.18	0.36
0.13	0.38
0.11	0.35
0.09	0.49

Table II

Undermatch	Total distance at undermatch
0.22	0.46
0.09	0.54
0.13	0.44
0.29	0.29

Table III

Knockout	Total distance at knockout
0.25	0.40
0.21	0.39

Also: one overmatch flaw (0.05 mm and a total distance of 0.33 mm)

Pry-off finish: Guide ring seam measurements (mm).

Table IV

Flange	Total distance at flange
0.10	0.45
0.09	0.51
0.06	0.47

Table V

Undermatch	Total distance at undermatch
0.09	0.54
0.09	0.59
0.15	0.62
0.14	0.53

Twist-off finish: Guide rig seam measurements (mm).

Figure 5: Representative fracture pattern.

Experiment

The samples used in this study consisted of empty 330ml and 600 ml bottles with a pry-off finish and 250 ml bottles with a twist-off finish; these latter bottles had been previously filled and capped in a commercial filling line (the finish types are shown in Figure 2). The empty bottles were manually capped with crimp values that are typical for these types of finishes.

The interactions between the applied metal closures and bottle finishes were analysed with a Phoenix Nanotom 180NF CT-scanner; 1440 images were obtained for each sample around the entire circumference of the finish. The images were analysed with Volume Graphics software and dimensional measurements were performed using an ImageJ program.

Two approaches were used for the measurement of the height of the most severe guide ring seam irregularity. For overmatch and undermatch features, the distance was measured between the tangent of the irregularity and the tangent of the finish surface. For ▸

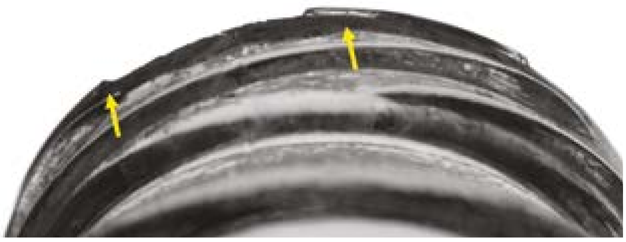

Figure 6: Overmatch defect measuring 0.26mm.

Figure 7: Percussion cone.

Figure 8: Flange measuring 0.12mm.

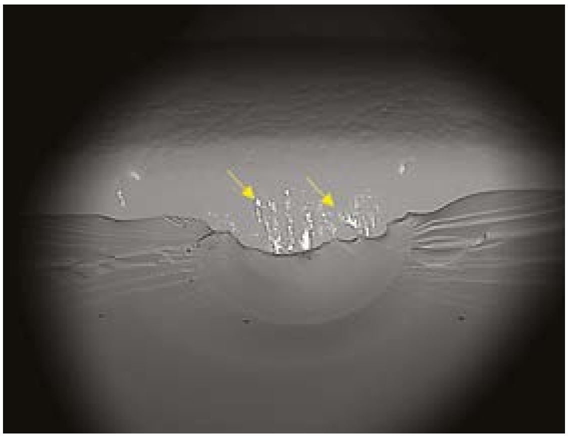

Figure 9: Metal to glass frictive damage.

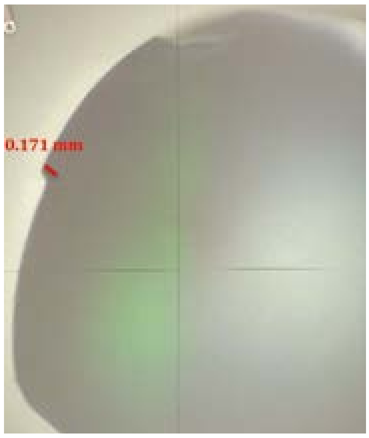

Figure 10: Overmatch measuring 0.17mm.

flanges and knockouts, the height was measured between the tangent of the finish surface and the tip of the irregularity.

Results and discussion

Results from the CT scan measurements are summarised in Tables I through V. The heights of the individual flaws are shown along with the total distances from the glass surfaces to the closures where the flaws were located.

The average total distance between the guide ring seam and the closure for pry-off and twist-off finishes were 0.39mm and 0.53mm, respectively, a statistically significant difference at a confidence level of 95%. As shown in Figure 3, these differences are due to the configuration of these two types of finishes and the manner in which the closure interacts with the finish. The presence of threads combined with a right angle between the finish E wall and the sealing surface of twist-off finishes results in a relatively large distance between the finish and the closure skirt. The obtuse angle between the crimp bead and the sealing surface of a pry-off finish led to a relatively small distance between the finish and the closure skirt.

As a consequence, finish irregularities of the same dimension would be more concerning when located on a pry-off bottle as they would be located closer to the closure, which increases the risk of becoming damaged during the crowning operation. For example, the maximum irregularity height for the pry-off bottles was 0.29mm which was the same as the minimum 'total distance' (0.29mm). For twist-off finishes, the minimum 'total distance' was 0.45mm, which would provide ample space to accommodate the largest irregularity height measured in this study.

Failure mechanism

Flanges, overmatch features, and knockouts are classified as serious irregularities if they are unusually large. High tensile stresses will be developed if these irregularities are contacted by the closure during the crowning operation in a filling line or if they are contacted by an opener during removal of the closure by a consumer. These high stresses can create a cone crack which could fracture the glass completely or could act as a stress concentrator. When the bottle is opened, either shear forces (closure twisting) or leverage forces (bottle opener) could act on the cone crack partial fracture causing it to develop into a complete fracture.

Figure 4 shows an unusual situation in which an undermatch can also act as a focal point of contact stresses leading to breakage under abnormal situations. In this example, the edge of the undermatch feature is in direct contact with the closure and high contact stresses will be generated. These stresses could lead to the development of a cone crack and ultimately the potential for complete failure of the finish.

Case Studies

The following are examples in which guide ring seam irregularities led to problems in commercial practice.

#1: Twist-off closure: A beverage filler received a series of consumer complaints regarding fractures of twist-off finishes as shown in Figure 5. The fractures originated at percussion cones which coincided with an overmatch of the outer guide ring seam (0.26mm), as shown in Figure 6. The overmatch acted as a focal point for the crimp forces during application of the crown closure leading to the formation of a cone crack. Extension of the cone crack into a complete failure occurred by either a leverage force generated by the use of a bottle opener or a shear force from the twisting motion of the closure. In either case, the overmatch was the cause of the problem.

#2: Pry-off closure: A beverage company received a consumer complaint related to a fractured finish as shown in Figure 7. The fracture initiated at the outer-guide ring seam, which exhibited a flange (0.12mm), as shown in Figure 8. The force applied to the flange during closure application created high contact stresses in the glass which resulted in chippage of the finish.

#3: Bottle opener: A filler received a consumer complaint related to the fractured finish of a beer bottle that originated at a cone crack. Metal-to-glass damage was also detected at the fracture origin, as shown in Figure 9. Analysis of the metal composition indicated that it was deposited from a device used to remove the closure. Furthermore, the bottle exhibited an overmatch (0.17mm), as shown in Figure 10. High contact stresses were generated upon contact of the overmatch during closure removal which caused the breakage.

Conclusions

Analyses of bottle finishes indicated that the distance between the guide ring seam and the closure in pry-off bottles was smaller compared to twist-off bottles. This smaller distance enhances the potential that guide ring seam irregularities of the same height may lead to more problems with pry-off finishes compared to twist-off finishes.

It is recognised that other parameters can affect the gap between finishes and closures. Parameters such as crimp gauge, closure material, crowner head wear, crowner settings, verticality in the crowner, ovality of the finish, and capping force, among others are the subject of further investigations. ●

1 B.S. Aldinger, P.W. de Haan. 'Color Atlas of Glass Container Defects'. American Glass Research, Butler, 2019.

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