Master's Thesis Engineering Technology

2022-2023

The optimization of the durability of returnable glass bottles after repeatedly filling

Bielen Marthe

Master of Chemical Engineering Technology

Introduction

Sustainability is an important driver for AB InBev, the world's largest brewery, which is why they want to stimulate the use of circular packaging. Refillable glass bottles are collected after use, sterilized, and refilled before they are put back on the market. Most of the refillable bottles can be used up to fifteen times, while some can even be used up to one hundred times. [1]

Problem definition

The number of cycles the bottles can be refilled depends on the strength of the glass bottle. The strength of glass shows its resistance to fracture when exposed to external loads. The loads to which refillable bottles are subjected during the life cycle can be both static, such as internal pressure, topload pressure, and impact, and dynamic, such as friction.

Research objectives

The main objective of this study is to quantify the relationship between the individual and combined effects of friction, pressure, and impact on the strength of selected types of glass bottles to predict the quality of reusability in a simulation process. First, different test methods to exert friction, pressure, and impact are optimized, and the effect of the test settings is analysed.

Internal pressure

The internal pressure resistance (IPR) of a bottle can be measured by filling it with water and increasing the hydrostatic pressure inside the bottle at a uniform rate, with a test limit of 60.0 bar. Once the IPR that a bottle can withstand is exceeded, the bottle breaks, and the maximal IPR value is displayed.

The tested bottles have an average IPR value of 38.0 bar, with a standard deviation of 10.0 bar. A high standard deviation is expected as the strength is a result of the flaw severity, which will be different for each produced bottle. The bottles meet the quality requirements that demand an average IPR value of above 25 bar. For carbonation levels between 3 g/L and 6 g/L, the minimum pressure per individual bottle lies at 12 bar, which means all bottles fall within specifications. The results are normally distributed (Figure 1), with both ends of the bell curve truncated. The truncation is a consequence of the test limit and the pre-sorting of the bottles by the supplier.

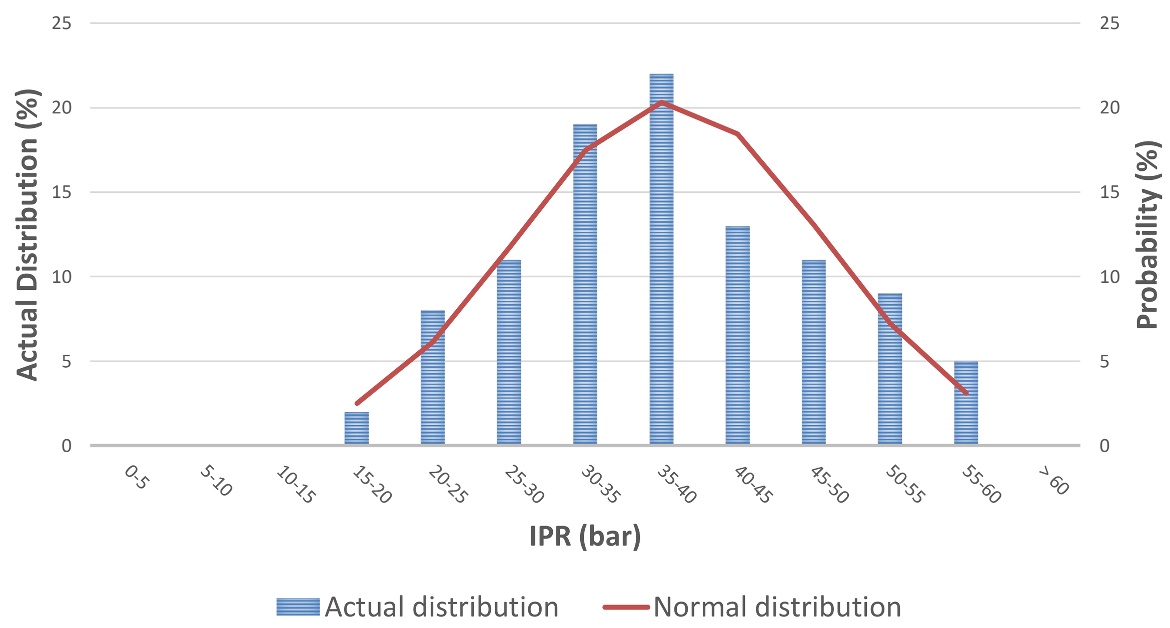

Figure 1: Normal distribution of IPR (bar) of neat bottles

Impact

A pendulum was released from a specific height impacting the glass bottle at the shoulder (Figure 2).

Settings:

- 100 strokes, with the force varying between 50 CPS and 150 CPS
- 100 CPS, with the number of strokes varying between 50 strokes and 150 strokes

Only the series of 100 strokes of impacts of 100 CPS shows a significant difference. While analysing the bottles that had their fracture origin located at the impact site, a reduction in strength of over 35% is shown. Since some of the fractures started at the impact site, these bottles were plastically deformed and the damage that was caused is permanent.

Figure 2: Pendulum striking a bottle at shoulder height [2]

Figure 4: Pair of scuffed bottles with visual damage
Detail : Fracture origin after friction was applied

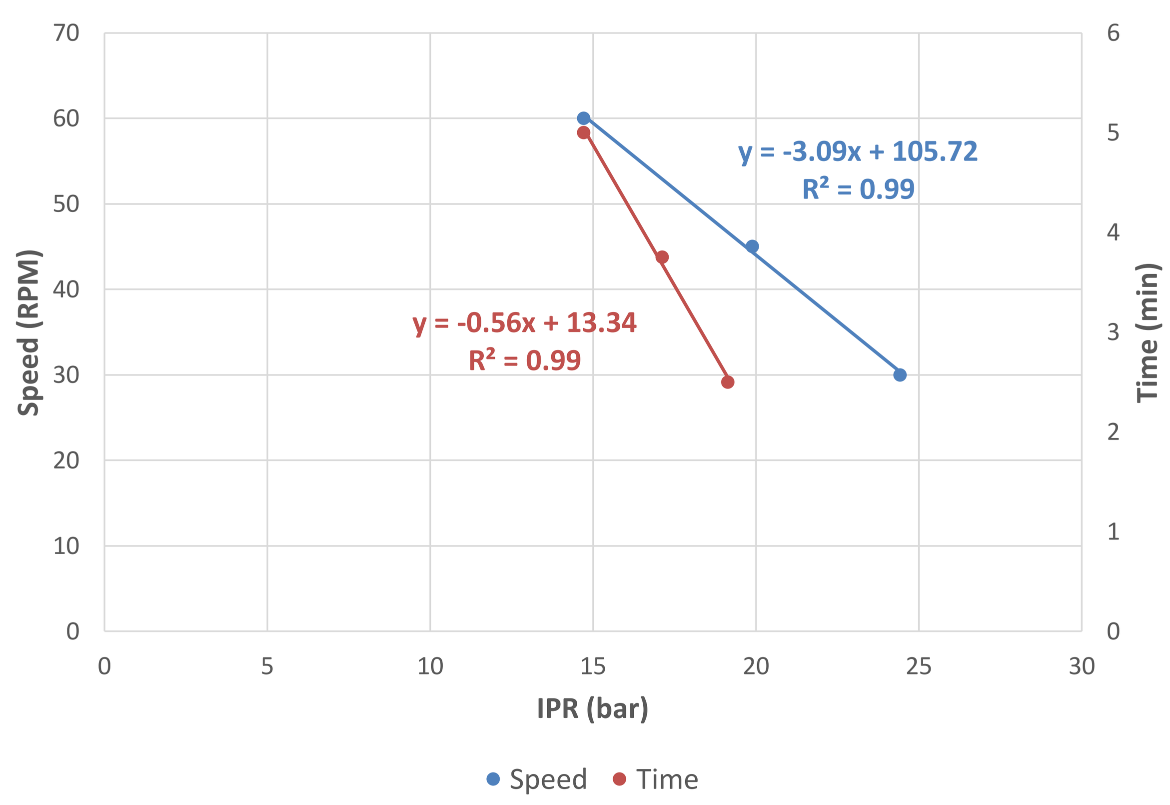

Figure 3: Influence of speed and time during line simulation

Friction

Line simulation

The simulation of a conveyor belt causes both impact and friction on the bottles.

Settings:

	5.0 min	3.75 min	2.5 min
60 RPM	X	X	X
45 RPM	X		
30 RPM	X		

Both the time and the rotational speed (Figure 3) of the line simulation have a linear effect on the strength of the bottles. A line simulation with a rotation speed of 60 RPM and a duration time of 5.0 minutes causes a reduction in IPR of more than 60%.

Scuffing simulation

Two bottles rotate in opposite directions causing friction.

Settings:

- 10 min, 40 RPM slip, 2 bar, 45° between samples

On some bottles the friction causes scuffing. On some, the damage is only slightly visible, on others it shows white lines (Figure 4). The tested bottles only show a reduction in strength when the friction causes scuffing. A 10-minute scuffing simulation caused visible damage and reduces the strength of the bottles by no more than 45%. The 45° bottles show a less significant drop in strength than the 0° bottles. The 45° bottle damage is spread over a bigger surface.

Whenever glass bottles have been subjected to friction, the circumference where friction was applied becomes the greatest flaw and thus the weakest spot of the bottle. Applying a load to the bottles after friction will increase the stress and cause the bottle to break. The fracture origin will be located at the scuffing circumference (Figure 6).

Conclusion

The tested bottles meet the standard of 25 bar for internal pressure resistance set for refillable bottles. The distribution in measured IPR values shows a bell curve with truncated ends. The analysis shows that friction, from the moment it causes visible damage, causes the greatest reduction in IPR values and thus has the greatest influence on the strength of the bottle. In addition to friction, impact also causes a significant difference in measured IPR values.

Supervisors / Co-supervisors / Advisors: Prof. dr. ir. Buntinx Mieke, Ing. Vandecruys Jonas

References:

[1] "Circular packaging – Driving Sustainable Packaging," AB InBev, 2021. [Online]. Available: https://www.ab-inbev.com/sustainability/circular-packaging/. [Accessed 7 April 2023]

[2] AGR International, Inc., "Impact Tester - Tests the Impact, Dent, and Puncture Resistance of Containers," 2016. [Online]. Available: https://www.agrintl.com/wp-content/uploads/2016/03/IT_2_redesign.pdf. [Accessed 14 April 2023].

ABInBev — To a Future With More Cheers

De opleiding industrieel ingenieur is een gezamenlijke opleiding van UHasselt en KU Leuven

UHASSELT

KU LEUVEN