Improving Consumer Experience with Squeezable Containers

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Abstract: *Packaging trends indicate that the consumer is demanding not only a visually appealing package but also one that has a functional benefit after purchase. Challenges to that outcome include adequate top load and dent resistance at the lightest possible weight. Products like ketchup, mayonnaise, salad dressing, dish and hand soap are a few types that need to meet these performance characteristics.*

It's important to understand various aspects of processing, material properties, package design, product characteristics and thickness distribution. Each of these factors can affect the ease of dispensing product. The goal is to do so without the package showing creasing and able to recover to its original shape.

This study examined existing commercial packages and analyzed the design features that can be modified to improve container squeezability. These geometric features involve structural components like ribs in the panel area and also the vertical and horizontal profile of the container design.

The study defines the relationship between the container aspect ratio, label panel area, thickness distribution and cross-section geometry. These relationships then define the optimum combination that can maximize the squeeze performance without compromising the other required specifications. The results show an effective way to arrive at a solution involving simulating the performance under realistic predictions of material distribution.

1. Introduction

The first step in this study was to determine the most commonly available packages in the 20-24 ounce category and determine their weight, thickness distribution and dispensing performance. We noticed that the packages could be separated into two distinct categories:

- 20 ounce ketchup containers
- 24 ounce long-neck ketchup containers

As can be seen from Figure 1, these ketchup containers have a similar hour glass-shaped label panel profile and a wide inverted flip-top closure. They have been labelled A through E and have different cross section profiles, weights and base standing geometry. The closures were identified as 33mm SP400 type and the bottles weighed between 35 and 37.4g. There were a number of other products like mayonnaise and salad dressing that were also packaged in similar shape and weight containers. For the purposes of this study, the packages selected are representative of those that need to be squeezed for dispensing.

A: 36g	B: 35.9g	C: 35g	D: 37.4g	E:37.4g

Figure 1: 20 oz Inverted Closure Ketchup bottles

In contrast, the 24 ounce ketchup bottles mainly long neck containers as shown in Figure 2. They also have the SP400 33mm finish but not the hour glass waistline and were meant to stand on their bases. The weights for these bottles labelled F through J were higher than the 20 ounce bottles in the range of 37-40.4g.

F: 38g	G: 36.9g	H: 40.4g	I::38.1g	J: 37.4g

Figure 2: 24oz Ketchup containers

Testing

The empty vented top load results for the ketchup bottles are shown below in Chart 1 and they are in the 40 to 80 pounds force range. The top load was highest for the long neck (Bottle I) 24 ounce ketchup bottle with the Bottle F a close second. This indicates that the long-neck 24 ounce ketchup bottles (with similar weight to the 20 ounce and higher volume capacity) have better top load compared to their flat neck counterparts. This is also intuitive from a structural perspective as a sharper shoulder would be less capable of supporting a vertical load. A higher thickness distribution would be necessary for such short neck containers to have a higher top load.

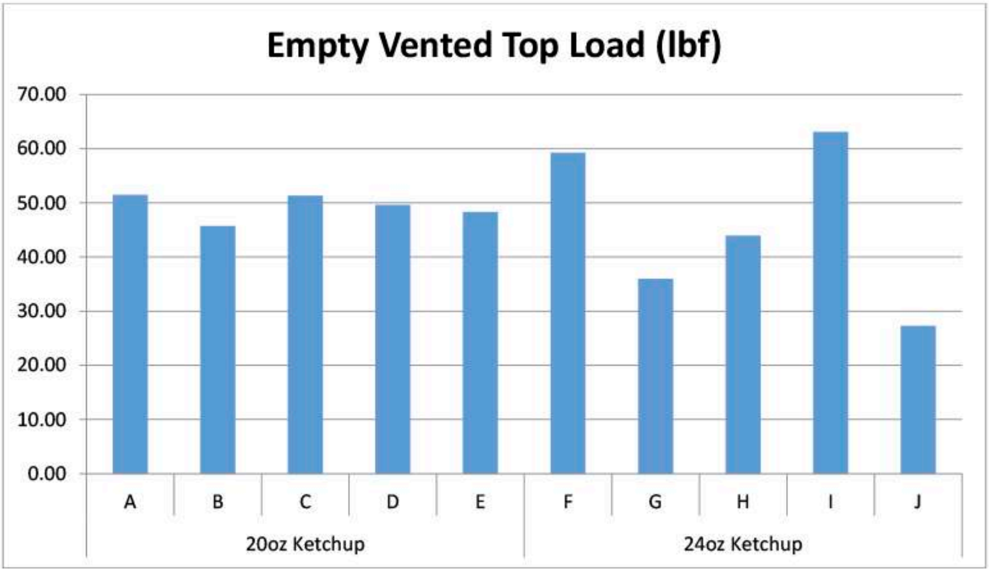

Chart 1. Empty Vented Top Load

The weight distribution of the various container sizes is shown below in Chart 2. It is evident that the 20-ounce ketchup bottles with inverted dispensing have a much heavier 33mm closure in the 9 to 11 gram range compared to a 24-ounce long neck bottle with a 3 to 4 gram closure. The overall material savings are much better for the narrow-neck closures. The labels typically account for less than 1 gram of the total package weight, no matter how extensive a surface they are applied over.

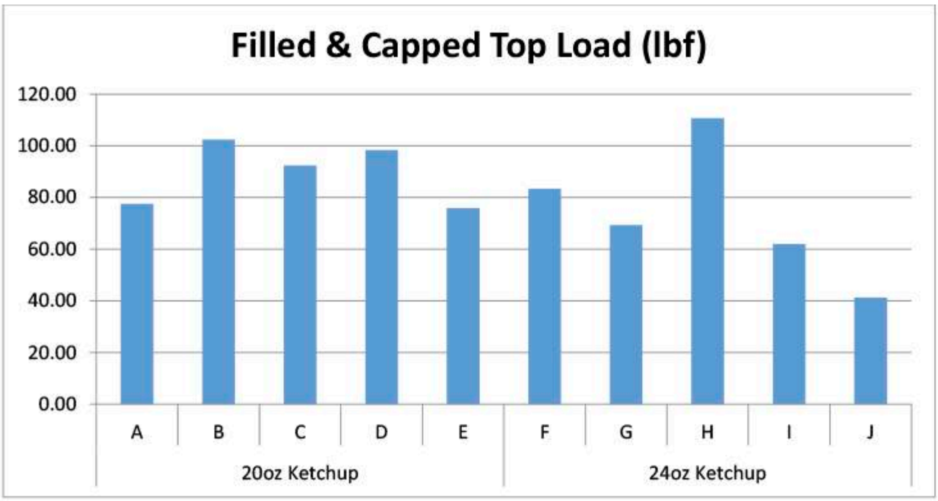

Chart 2. Filled Top Load Performance

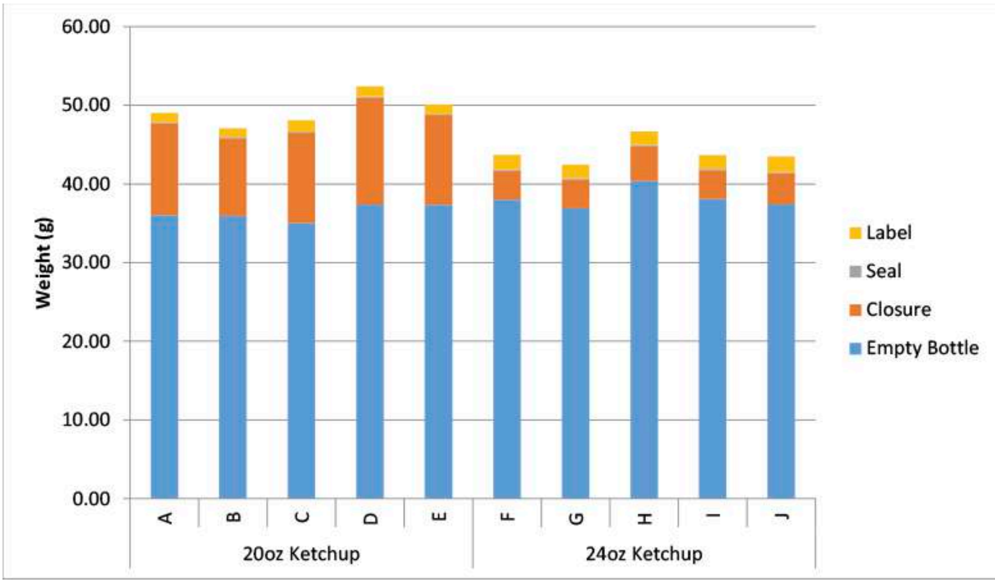

Chart 3. Package Weight Distribution

The major and minor wall thickness distribution for the 20 ounce ketchup sizes are shown below in Chart 3. As expected, the minor axis is significantly thicker compared to the major axis even though a number of these packages with high-aspect ratio are probably blow molded using preferential heating.

This is supposed to even out the difference between major and minor axes. The shoulder and heel areas of the bottles are thinnest at 0.4 to 0.6mm both along the major and minor profiles while the grip area is the thickest at close to 0.5 to 0.8mm.

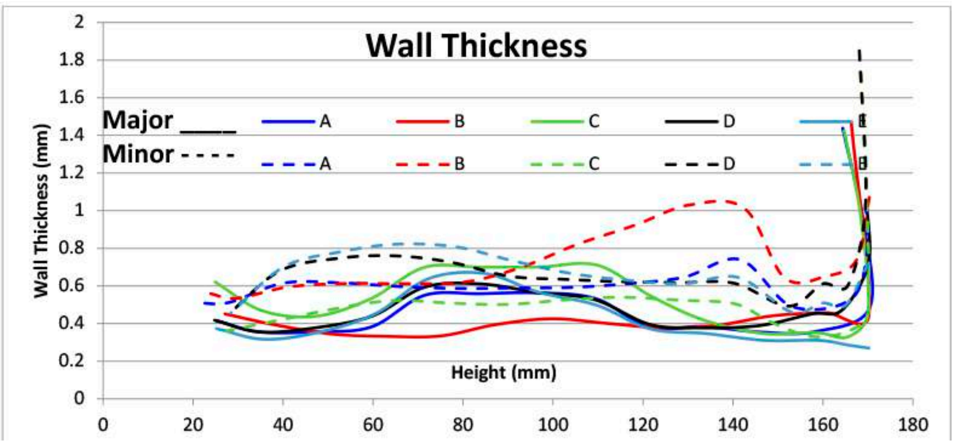

Chart 4. Material Distribution of 20oz Ketchup containers along major and minor axis profiles

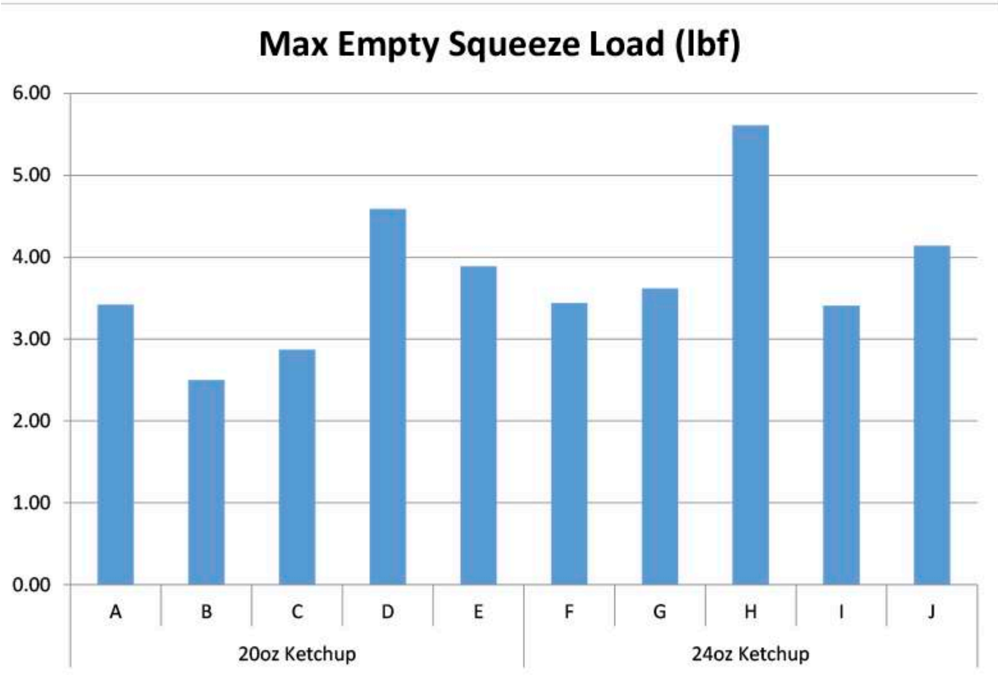

Chart 5. Squeeze Load Performance

A different way to characterize the bottle is to also look at their filled top-load performance. This is significant because bottles are subjected to similar loads during transportation and distribution. Chart 2 shows filled 20 ounce ketchup bottles supporting a load between 68 and 110 pounds of force. Compare these results with the empty top load data shown in Chart 1 for the same empty ketchup bottles withstanding a vertical load between 42 and 50 pounds of force. The same weight bottle has between 1.8 to 2 times higher top load performance.

Design & Simulation

A second objective of this study was to determine how through simulation one can optimize the performance of these containers. A hypothetical container geometry was sketched up and the waist and grip profiles were redesigned to have a linear and arced grip profile compared with a container having no grip. The three hypothetical shapes are shown below in Figure 3. Between Design 1 and Design 3 the shape and extent of the grip profile was modified.

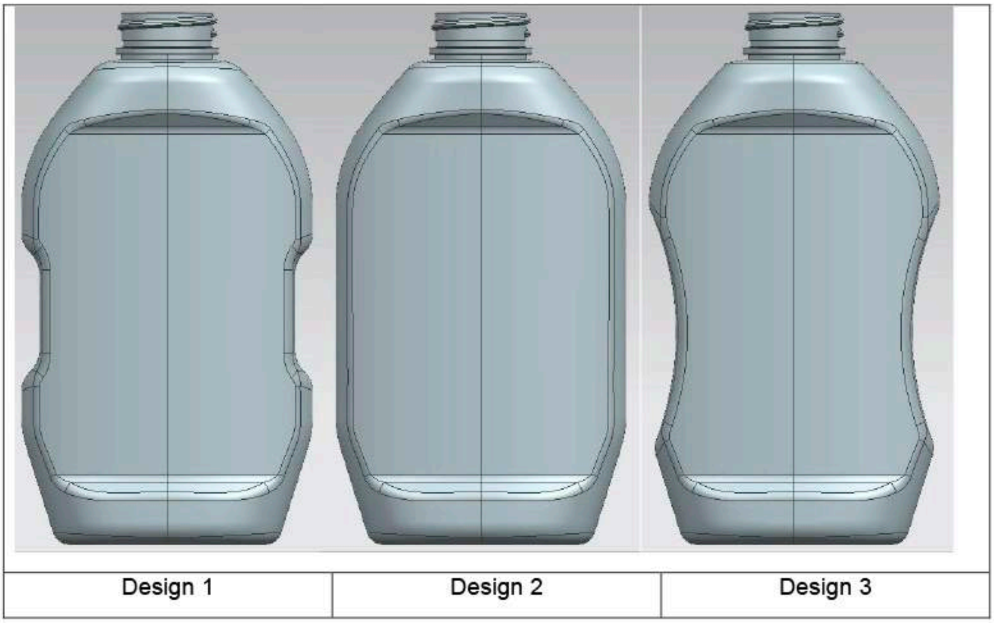

Figure 3. Different Grip Geometry for Squeeze and Top Load evaluation

The containers were blown using a 30g preform using PTI's Virtual Prototyping Software. As the containers exceeded the 1.5 aspect ratio, preferential heating was used. The resulting thickness distribution is shown in Figure 4. The minimum thickness was along the corner of the bottle which is the farthest away from the center of the bottle and was about 0.37mm. It should be noted that the container performance depends not only on the thickness but also on the geometry.

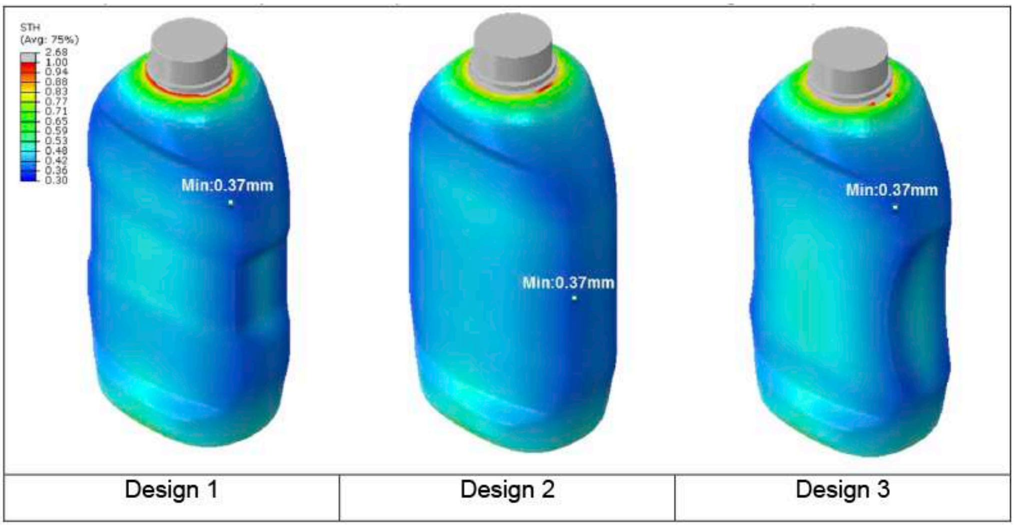

Figure 4. Predicted Wall Thickness Distribution of the design variables considered

One of the first performance attributes investigated is the squeeze load of the container and this is simulated by having a mechanical finger squeeze the middle label area. Figure 5 shows the stress and deformation pattern of the three designs when indented to the same extent. The simulations were run using Abaqus Explicit product from SIMULIA.

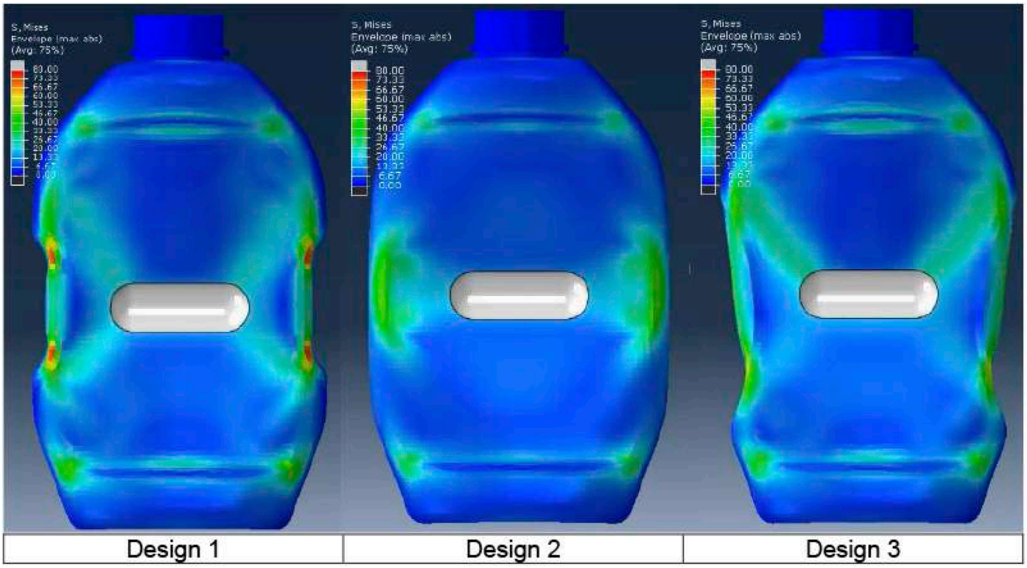

Figure 5. Deformation validation captured with high-speed camera during drop testing

It is interesting to observe the stress pattern differences between the various designs, which is an indication of the distribution of the load evenly over the label panel surface. Design 1 had a diagonal distribution of the load which is ideal while Design 2 had a horizontal localized indentation that typically leads to creasing and locking. Design 3 had a wider stress distribution region but it was confined to the upper diagonal region only with a somewhat lower effect along the lower diagonal. This analysis compares well with the reaction force on the mechanical fingers that is plotted below in Figure 6. The horizontal stress pattern for Design 2 performed the worst with minimum resistance past 10mm of indentation. Design 1 and 3 were similar for the first 8.5mm of indentation after which the response curves diverge with later stiffening by Design 1 compared to Design 3.

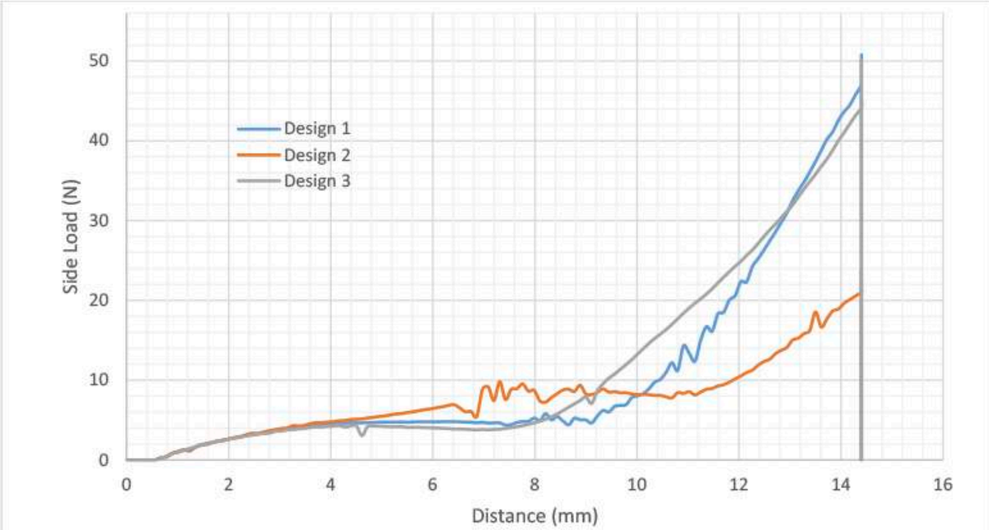

Figure 6. Squeeze resistance data for the 3 designs considered

It has been argued that a good squeeze experience is where the container is easy to squeeze for small controlled amounts of dispensing followed by a larger resistance to deformation that quickly builds up to higher resistance levels that prevents permanent deformation and denting.

Design 3 with a larger grip arc has the potential to have a better squeeze performance if the stress distribution of Figure 5 can be balanced uniformly along the upper and lower diagonal. This would enable a smaller deformation to be distributed over a larger area and result in better dispensing.

To determine the effect of the label geometry change on the empty top load performance, the three designs were subjected to vertical loading and the stress and deformation pattern is shown below in Figure 7. The flat shoulder and the upper and lower label corners are the regions with maximum stress and deformation. It was interesting to see that Design 2 had the same failure region for Top Load as Side Load and that is often the case for oval containers when they are squeezed or top loaded or under vacuum.

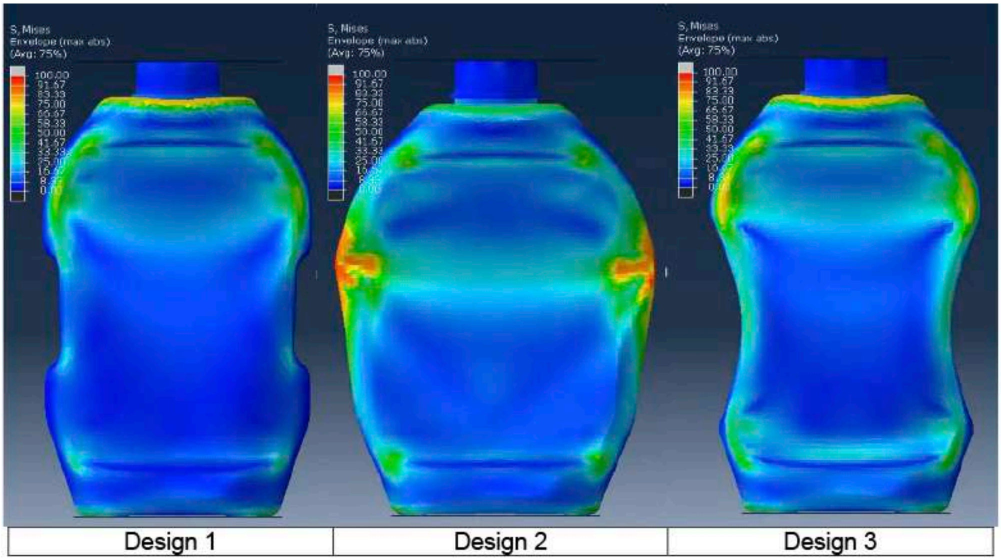

Figure 7. Top Load stress and deformation characteristic of the designs evaluated

The stress distribution in Design 3 was distributed the most uniformly along the upper and lower portions of the container and this is reflected in the highest top load as shown in Figure 8. Design 2 with a straight vertical panel and non-hour glass shaped label panel section did better than Design 1. The Top Load analysis was also run using SIMULIA's Aabqus Explicit product.

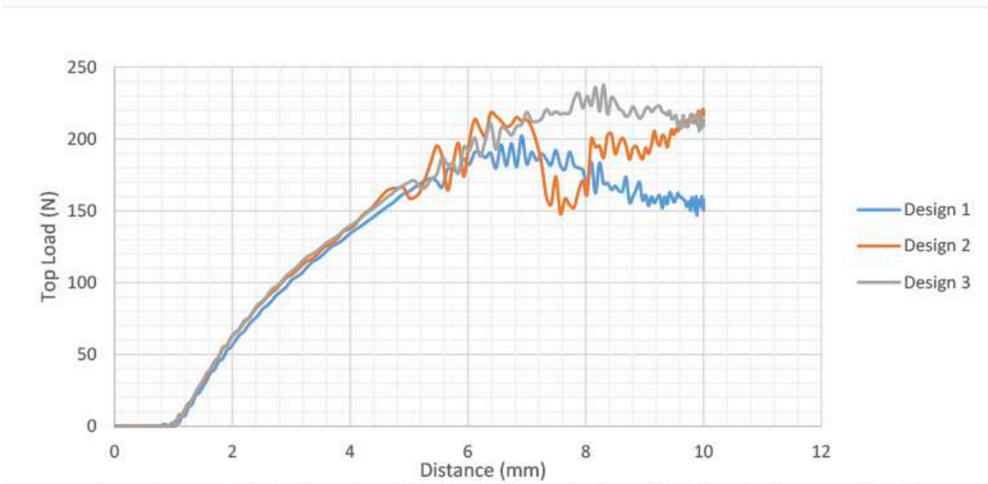

Figure 8. Empty Top Load performance data simulated for the designs evaluated

The difference between peak top load strength of 240N for Design 3 and 200N for Design 1 is substantial to conclude that the geometry needs to be optimized for the best top load and squeeze performance. This is an ideal optimization solution that can be attempted through an Isight workflow, an optimization and automation product available from SIMULIA. The variables could be the container geometry, thickness distribution and container weight. The benefit to the consumer and the brand owner would be lightest sustainable container meeting the performance specifications for both Top Load and Squeeze.

In conclusion, the use of modeling allows package modification and optimization that results in lighter weight, robust ergonomic designs. These are not only economical from material savings point of view, but also from reduced processing time.

Reference

1. Application of Abaqus for Practical Postbuckling Analyses of Cylindrocal Shells under Axial Compression – Kobayashi, T and Mihara, Y., Mechanical Design & Analysis Corporation, Simulia Customer Conference, Providence, Rhode Island, May 2010

Acknowledgment

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