Squeeze Performance of Oval Containers

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Overview

Household cleaning agents and many salad dressings, mayonnaise, ketchup and condiments are often packaged in oval-shaped containers that dispense their contents by being squeezed. These containers are frequently displayed at the sink or on a kitchen table. They have enough after-purchase visibility that brand owners still want them to look attractive and functional. Therefore, they should not look distorted or disheveled after a period of use.

Store shelves also present other challenges. Non-optimal stacking, coupled with excessively thin container corners, can create dents. Frequently, this is enough to deter the consumer from purchasing.

Typically, a wide-label panel area is preferred for boldly displaying the product's brand identity and its numerous marketing attributes but it does not necessarily imply the best dispensing or ergonomics. In reality, a wide, flat-paneled container is frequently the most challenging to blow, needing specialized equipment and is most prone to denting and buckling.

Having a well-defined grip area and one that does not crumple under finger indentation force, while dispensing controlled amounts of liquid, is the ideal goal to foster consumer satisfaction.

There is a great interplay between container grip region geometry, thickness distribution and squeeze performance. An optimal cross section and thickness distribution for each geometry envelope most likely exists that can maximize the performance of both top and squeeze load.

The Study Parameters

To help understand which container attributes make them easier or harder to dispense, PTI conducted a research study. The force needed to dispense, along with the amount dispensed per millimeter of indentation, were tracked for a variety of 20- to 25-ounce containers in different product categories. To make the comparisons fair, same size containers in a similar market segment were analyzed.

Product Categories

It was interesting to note that in the 20-ounce ketchup category almost all of the containers were rectangular or oval shaped with a very short flat shoulder. This compares to the 24-ounce shape where almost all of them had a long neck. The weights of the 24- and 20-ounce ketchup packages ranged between 35- and 41-grams with a good amount of overlap (the lightest weight 24-ounce package was lighter than the heaviest weight 20-ounce package).

All of the 20-ounce ketchup sizes investigated in this study had a large flip-top closure to provide inverted standup capability. This approach to improved functionality was introduced in the late nineties as a novel way to have viscous ketchup ready for dispensing the moment the cap was flipped open. These bottles had SP 400 33mm closures, which were twice as heavy and wide as those found on 24-ounce long-neck ketchup bottles with the same finish. In comparison, the 23- to 25-ounce dish soaps all had 28mm SP 400 finish.

Figure 1. 20 ounce ketchup bottles with inverted flip top SP 400 33mm closures.

In the long neck category, the 24-ounce ketchup bottle sizes shown in Figure 2 were researched. The weights for the 24-ounce size overlap quite a bit with the smaller 20-ounce size. However, on average they are 2- to 3-grams heavier.

Figure 2 . Long-neck ketchup containers in the 24 ounce category with SP 400 28mm closures.

Interestingly, the 23- to 25-ounce package sizes in the dish soap category weigh in at the same 36- to 40- gram range as the ketchup bottles, although the shape and geometry of these containers are significantly different. This is shown in Figure 3 below.

Figure 3 . Dish soap bottles in 24 to 25 ounces with 28mm SP 400 finish.

Procedure

The following data sets were collected from the various bottle samples:

- Material thickness distribution
- Weight distribution in package, closure and label
- Empty and filled top load and squeeze load

Material distribution of the various containers was measured with Torus equipment at different height and circumferential locations. Each packaging component (bottle, closure, label) were measured separately to get a clear idea of what each contributes to the final container. Finally, the package top load—which is important for filling, stacking and distribution—was measured along with the squeeze load using an MTS tensile tester at a speed of 2-inches per minute.

Results & Discussion

The empty vented top load results for the ketchup and dish soap categories are shown below in Chart 1 and they are in the 40- to 80-pounds of force range with one outlier at 140-pounds of force. However that can be perhaps explained as a result of its outlier weight being 10- to 15-grams heavier as shown in Chart 2.

Excluding that data set, the top load was highest for the long neck 24 ounce ketchup I Bottle with the F Bottle 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.

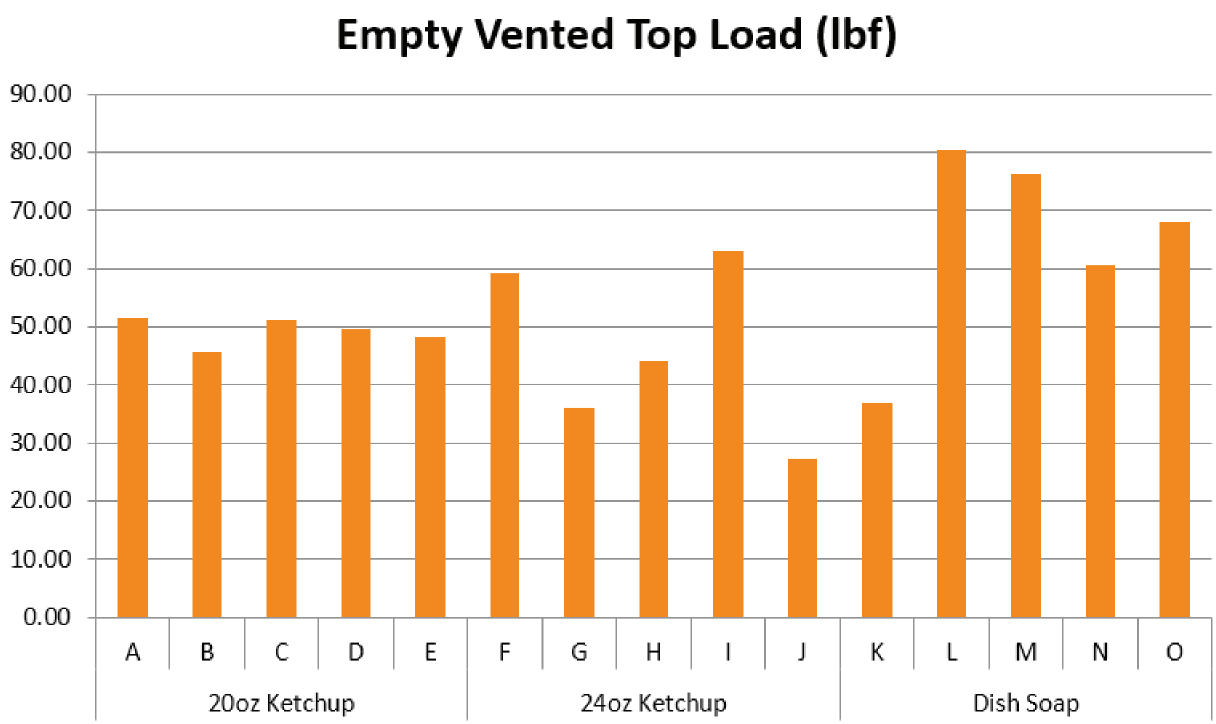


Chart 1 . Empty Vented Top Load.

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 or dish soap 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.

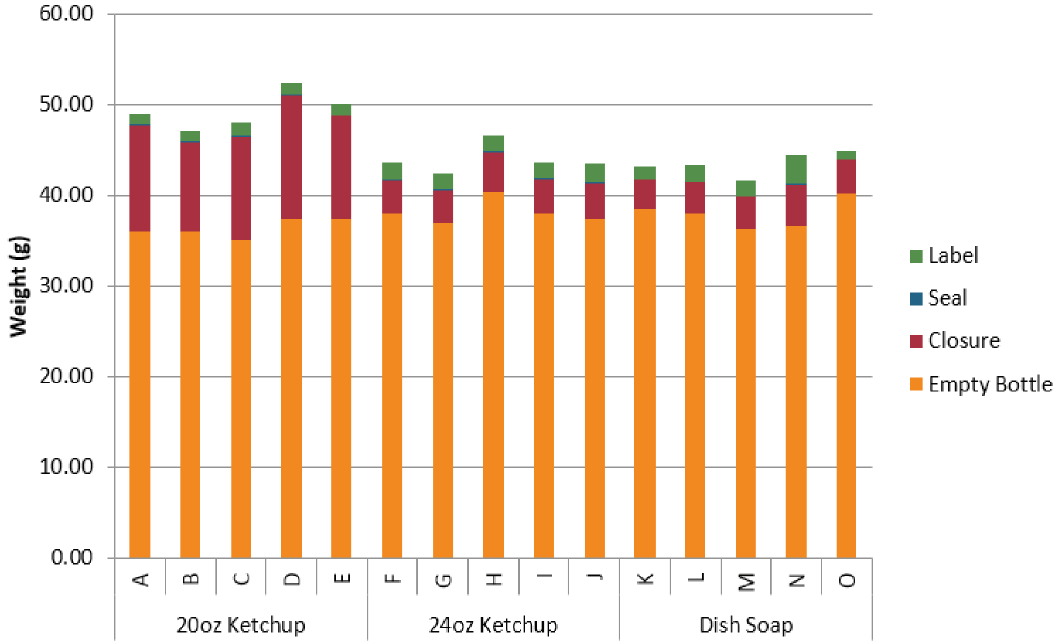


Chart 2 . Package Weight Distributon.

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.

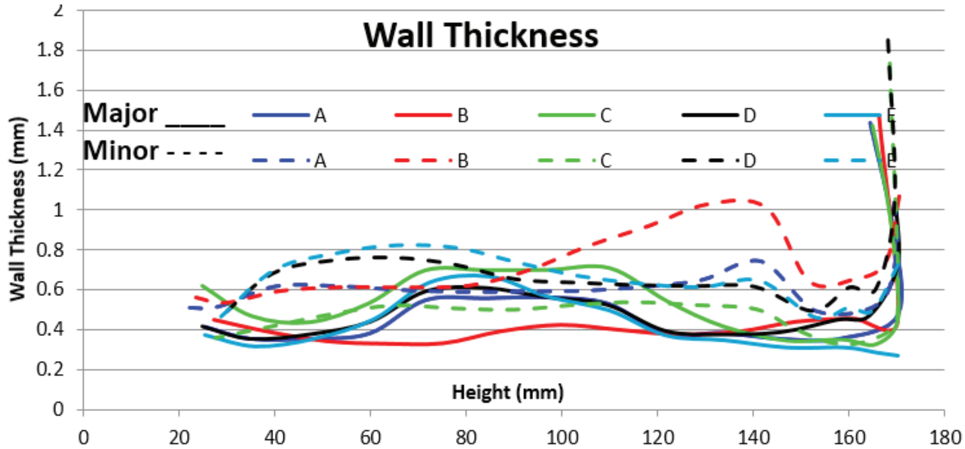


Chart 3 . Material Distribution.

Across different product categories, it is interesting to note that this label area where most of the package handling and dispensing interactions take place have a thickness distribution in the 0.4 to 0.6mm range. This is shown in Chart 4.

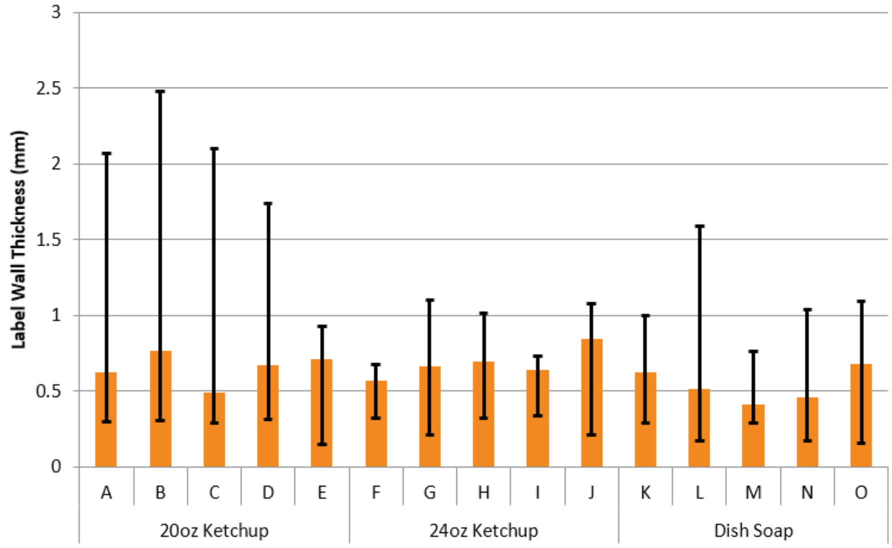


Chart 4 . Label Thickness Distribution.

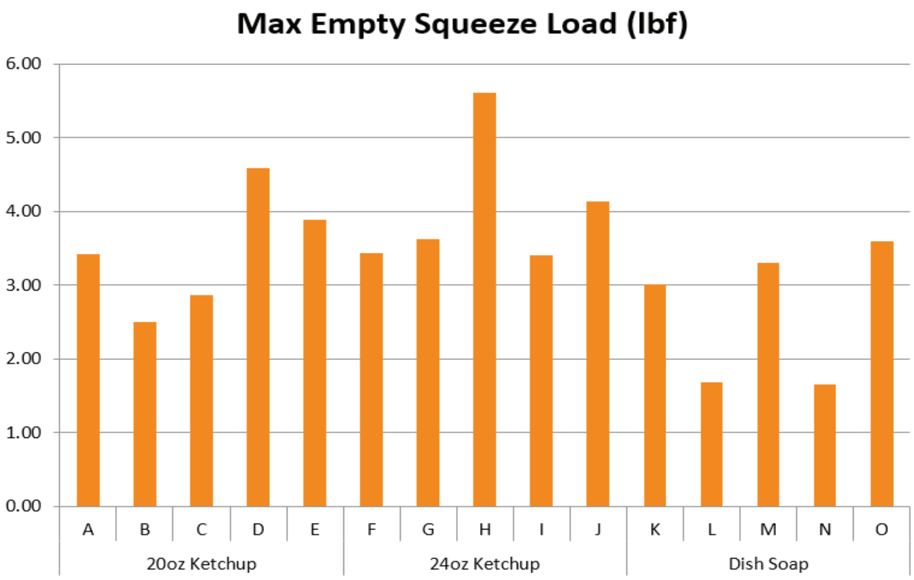


Chart 5. Squeeze Load Performance.

A different way to characterize the bottles is to also look at their filled top-load performance. This is significant because of what bottles are subjected to during transportation and distribution. (See Chart 6 showing 20-ounce ketchup bottles subjected to between 75- and 102-pounds of force.) Compare these results with the empty top load data shown in Chart 1 for the same size ketchup bottles subjected to between 42- and 50-pounds of force. The same weight bottle has between 1.8- to 2-times higher top load performance.

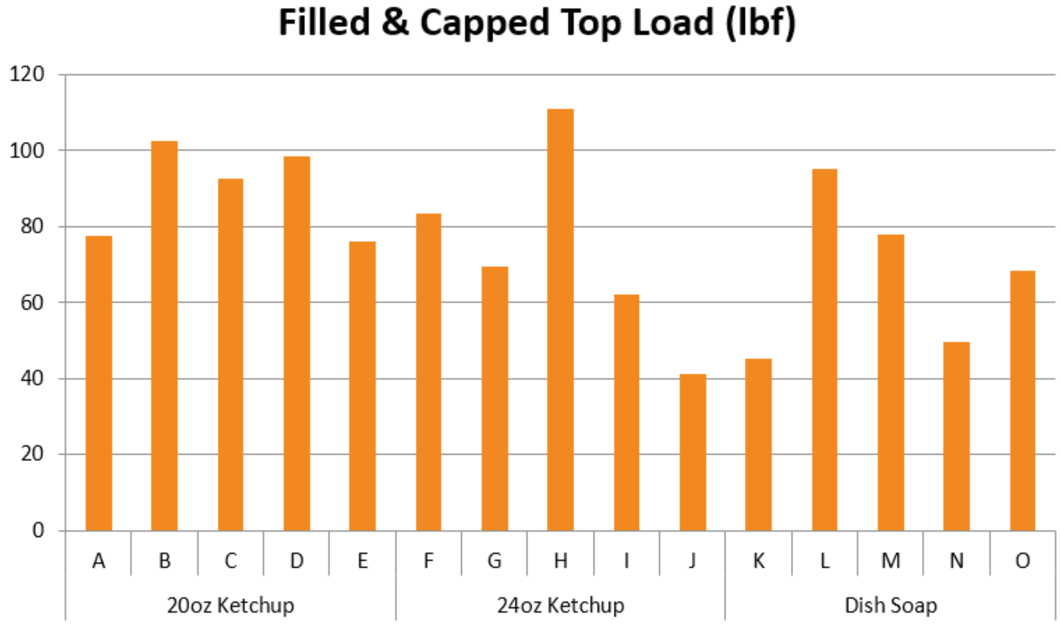
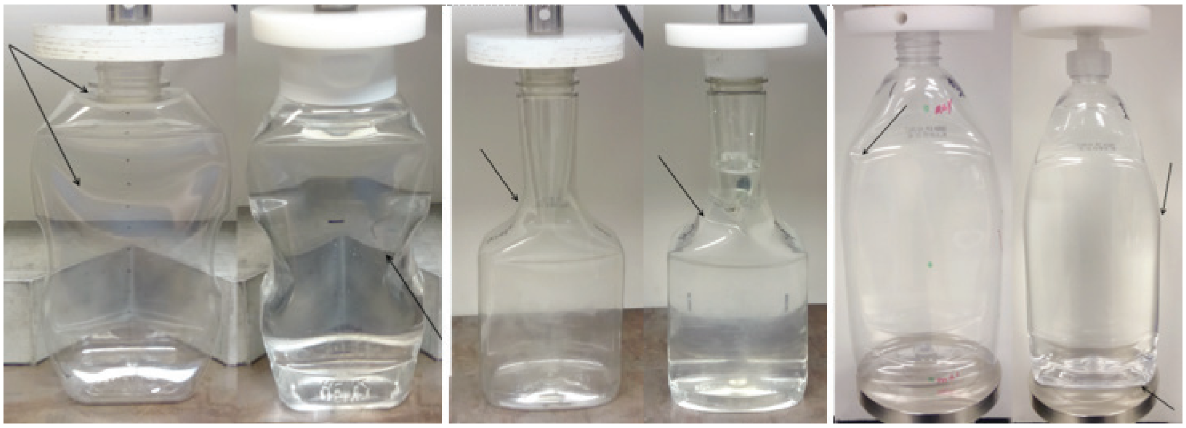


Chart 6. Filled Top Load Performance.

This trend is not borne out in the long neck 24-ounce ketchup category where the empty top load values were between 36- and 63-pounds of force and the filled ones were between 40- and 110-pounds of force. The geometry of the design and the fill height plays a significant role in such situations.

Figure 3 below shows a contrast between a flared out, almost flat shoulder and a long-neck, vertical shoulder ketchup bottle. The dish soap shoulder geometry is less flat and more conical representing an in between shape compared to the other two. The long neck bottle with low fill point will see virtually no difference between the filled and empty top load performance with similar buckling load and failure mechanism. The flat shoulder bottle with a waist has buckling occurring in totally different regions of the container with different magnitude resistance. The oval dish soap containers also show another set of trends with buckling in the grip area of empty top load and a more roundness of the container and base pushup rolling in.

We are excluding from this hypothesis some extremely heavy bottles which had a high 143 pounds of force empty top load that only marginally increased to 152 pounds of force under filled top load. Therefore, the dynamics of headspace compression and container geometry along with thickness distribution plays a big role in the top load performance.



Empty & Filled Top Load buckling failure across categories.

Just as there is a difference between filled and empty top load performance, there seems to be differences between empty and filled squeeze performance. The containers were squeezed in the mid label area and the max squeeze load is shown below in Chart 7.

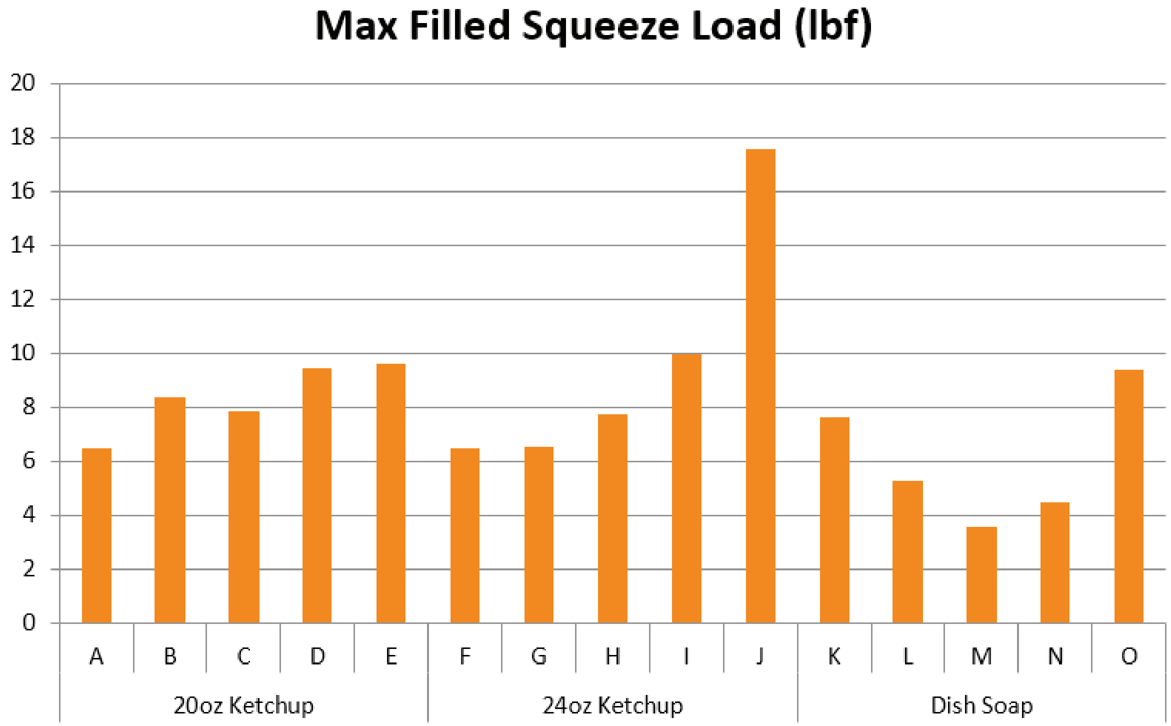


Chart 7. Filled Squeeze Load Performance.

A number of different correlations were studied between the squeeze resistance and the label wall thickness, bottle weight and label panel curvature radius. The highest correlation was seen between squeeze resistance and label thickness as shown in Chart 8. The one outlier was the 37.4 gram Bottle J ketchup that had the highest squeeze load of 17.5 pounds of force but also had the lowest empty top load of 27 pounds of force in the category studied.

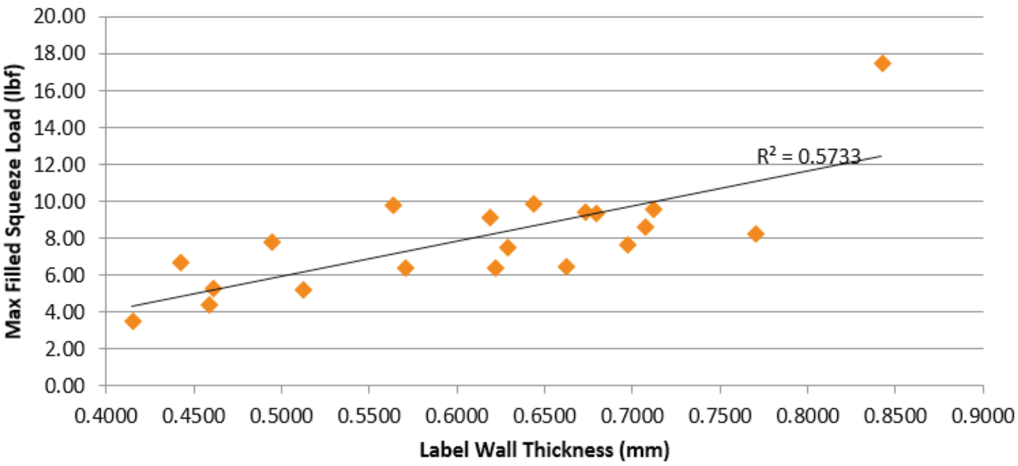


Chart 8. Correlation between Squeeze Load and Label Wall Thickness.

One of the critical aspects of squeeze performance is the resistance to indentation. This is measured as a load vs. deflection curve and is commonly used to understand the relative stiffness of different panel geometry. Simulation studies often try to replicate this load vs deflection curve and while the max load is one single point, the entire curve depicts the response of the label to different levels of indentation.

A commonly accepted standard is a resistance of 2.25 pounds of force at an indentation of 0.4 inch. Chart 9 below indicates that almost every package in this study meets that performance requirement. The high resistance package is Bottle J. One word of caution is that high stiffness is not necessarily a desired performance attribute in many circumstances. If it takes a tremendous amount of force to dispense the contents of a package, it is not necessarily suitable for the younger and aged section of the consumer base.

Hence this load vs. deflection curve is very important to calibrate with consumer feedback. Ideally the container should not dent very easily and at the same time dispensing the contents should not require extreme effort. A number of these curves seem to have a linear response throughout while some of them have dual slope where they stiffen after some initial indentation.

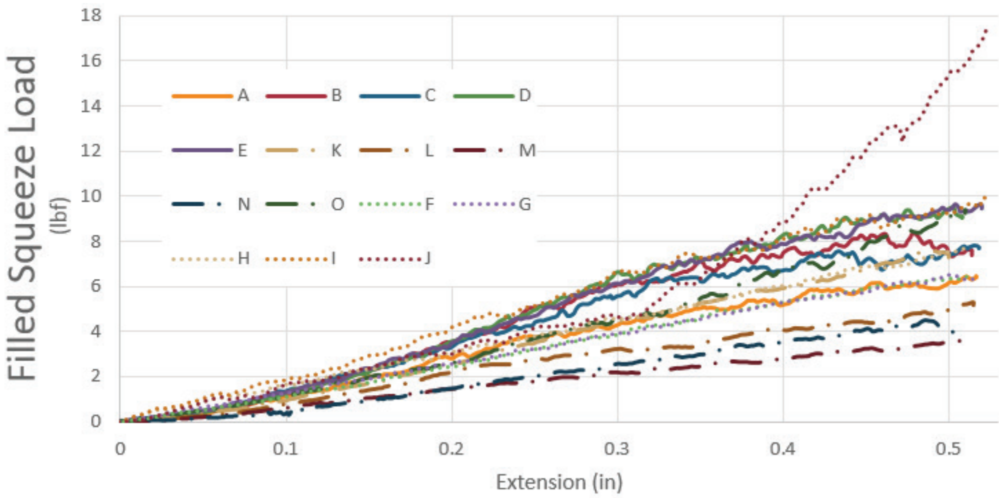


Chart 9. Load vs indentation curve for filled squeeze load.

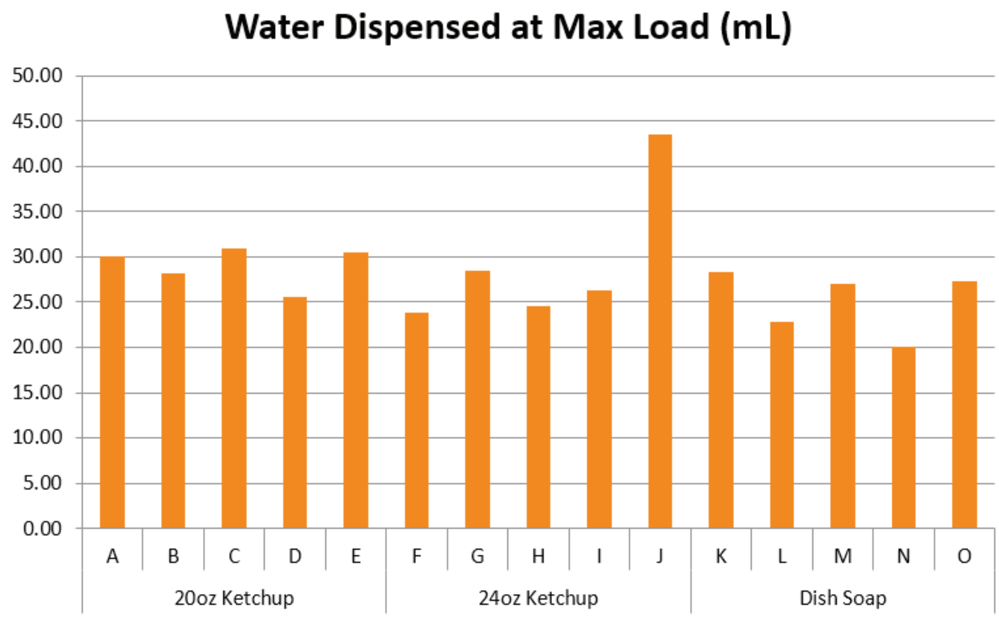


Chart 10. Dispensed volume at maximum squeeze load.

Squeeze is also defined as ease of dispensing and at the same time how much liquid is dispensed and that is displayed in Chart 10. On an average the dispensed volume is about 20- to 32-cubic cm for these 20- to 25-ounce containers. The deflection at max squeeze load ranged from 0.46- to 0.52-inches.

As squeeze performance is being analyzed, one important characteristic is the ovality of the containers. Containers with flatter walls are easier to squeeze as there is larger panel area to indent. However the resultant impact of such a flat panel design is that the depth of the container can get minimized resulting in poor stability. The containers' stability was also investigated as shown below in Chart 11. The minimum angle ranged from 8- to 15.5-degrees, which is quite a wide range. Typically, accepted industry stability values are in excess of 11.5 degrees. A majority of the containers fall in that range.

It should be noted that once the containers are filled, their tilt angle changes since the center of gravity moves up or down depending on the shape of the container. Chart 12 shows that a majority of the long neck ketchup containers had a positive effect on stability when they were filled. This intuitively makes sense since the bulk of the filled liquid is below the slender long neck. Some of the containers showed increases as high as 3 degrees which is substantial from a stability perspective.

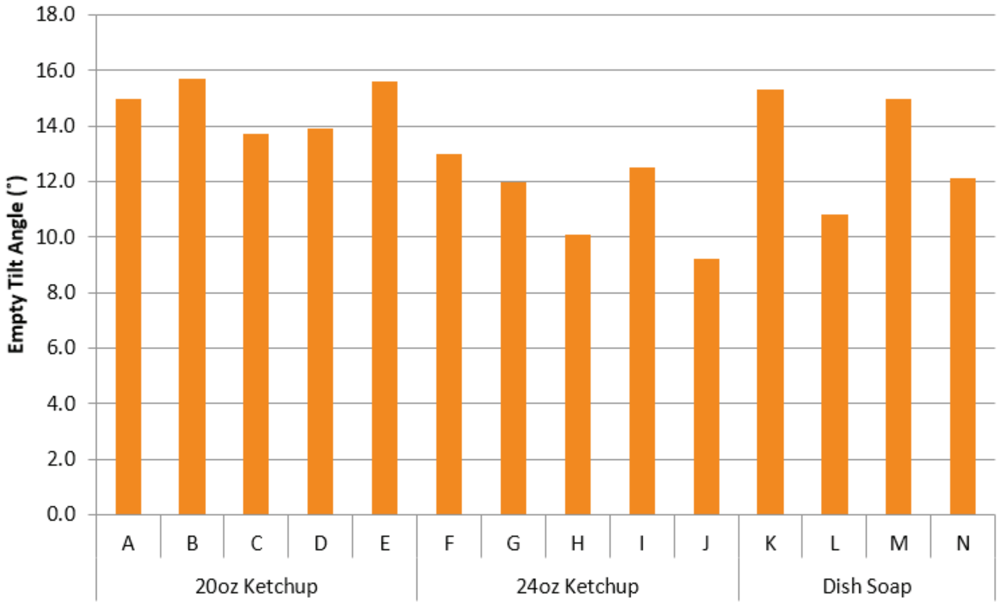


Chart 11. Tilt Angle measured on the minor axis of the containers.

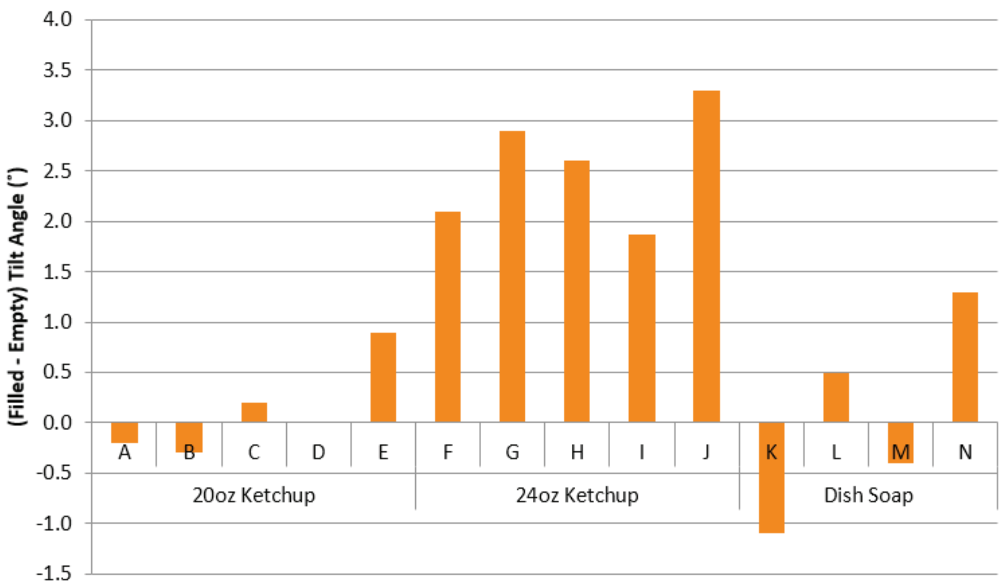


Chart 12. Tilt Angle difference between filled and empty containers.

Conclusion

This study shows that most of the containers in the same size range with widely differing geometry have similar weights, barring a few outliers. However, there is a great interplay between container grip region geometry, thickness distribution and squeeze performance. There likely exists an optimal cross section and thickness distribution for each geometry envelope that can maximize the performance of both top load and squeeze load.

Furthermore, there is the possibility of light weighting the container by changing shoulder angle, container aspect ratio and grip geometry. This is evident in how the long neck containers of higher volume and similar weight have higher top load strength.

Today's computer simulations can drive each of these performance criteria to an optimized value using iterations in the virtual design engineering space. There is a great potential to identify other critical parameters that drive consumer satisfaction such as ergonomics, easy pouring and bottle stability.

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