Introduction:

This project is concentrated on the failure analysis of a thin walled aluminum can (***Figure 1***) by axial compressive forces acting resulting in the crushing of the aluminum can. A thin-walled can that is included in this project is manufactured in the United States, which is an alloy containing 92.5% to 97% aluminum, <5.5% magnesium, <1.6% manganese, <0.15% chromium and some trace of iron, silicon and copper according to MSDS from aluminum producer Alcoa. Alloys used include 3004, 3105, or other 3xxx/5xxx series aluminum [1].

The body is made from a rectangular block that is rolled into a cylinder with a small overlap and then welded along the overlap by a high-speed resistance welding process. The two ends are mechanically joined to the body by a two-stage process known as double seaming. The design and manufacturing processes are highly efficient and very conservative of materials and energy.

The Failure of the aluminum can (***Figure 2***) is because of the axial compressive forces acting on the top of the can resulting in general buckling followed by wrinkling of facings of the can which we call a crushed can.

Figure 1: Aluminum Can

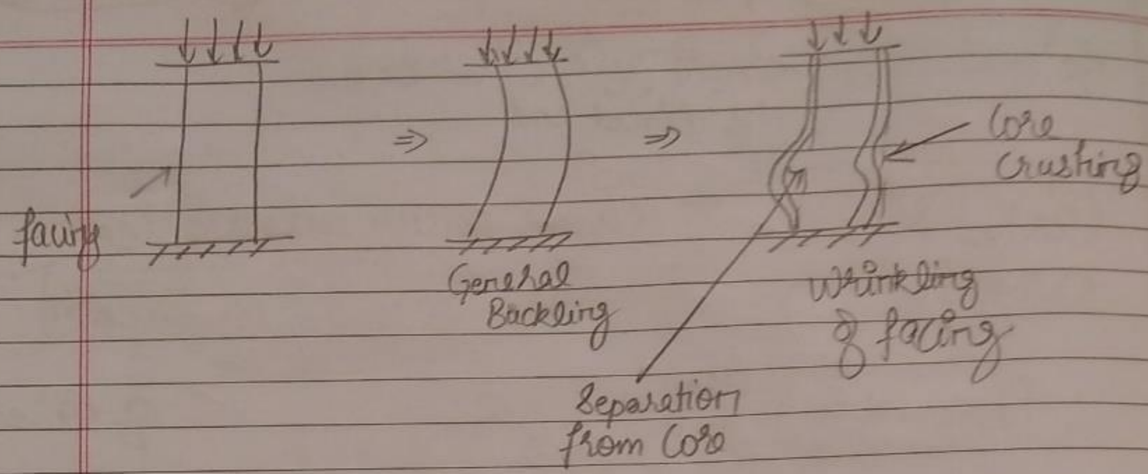
Figure 2: Crushed Aluminum Can

Analysis Section:

The buckling of the deformed can caves in around the indentation in the sidewall of the can pushing the sides adjacent to the dented face to deform outward. The side of the can then buckles along the line of the dent as well as the smaller areas on the opposite side of the dent dimples.

The axial compression is studied by moving down the upper plate (hand) while the lower plate is stationary. The force was calculated as we did the experiment while placing the aluminum can on a weighing machine. For theoretical Calculation, the gamma value was found using (***Figure 3)*** The calculation for force required to crush the aluminum can is shown in the appendix section which is found out to be 243 lbs.

Appendix:



Equation for Buckling Stress.

$$\sigma_x = \frac{\gamma E}{\sqrt{3(1-\mu^2)}} \frac{t}{r} \quad \text{—} (1)$$

where $r_i = 1.065\,in$
$r_o = 1.3\,in$
$t_l = 0.003\,in$
$t_u = 0.006\,in$

Taking Al properties from 3004 Aluminium Material property Data Sheet.

$E = 10{,}100{,}000\ psi$
$\mu = 0.35$

In order to use buckling eq^n we need to have single values of r & t

Weighted avg of $r = 0.7 r_o + 0.3 r_i$ (skewed toward body of can)

$\Rightarrow \boxed{r = 1.23\,in}$

& for $t = 0.7 t_l + .3 t_u \Rightarrow \boxed{t = 0.0039}$

$$\frac{r}{t} = 315$$

Date
Page

So from the Graph below, gamma = 0.41

Putting values in Eq (1)

$$\sigma_x = \frac{10,100,000 \times}{\sqrt{3(1-0.35^2)}} \frac{1}{315} \times 0.41$$

$$\Rightarrow \sigma = 8096\ psi \quad , \quad Area = 2\pi r t$$

$$A = 2\times \pi \times 1.23 \times 0.0039$$

$$\Rightarrow \boxed{A = 0.030\ in^2}$$

$$\sigma = \frac{F}{A}$$

$$\Rightarrow F = 8096 \times 0.030 \Rightarrow \boxed{F = 243\ lbs}$$

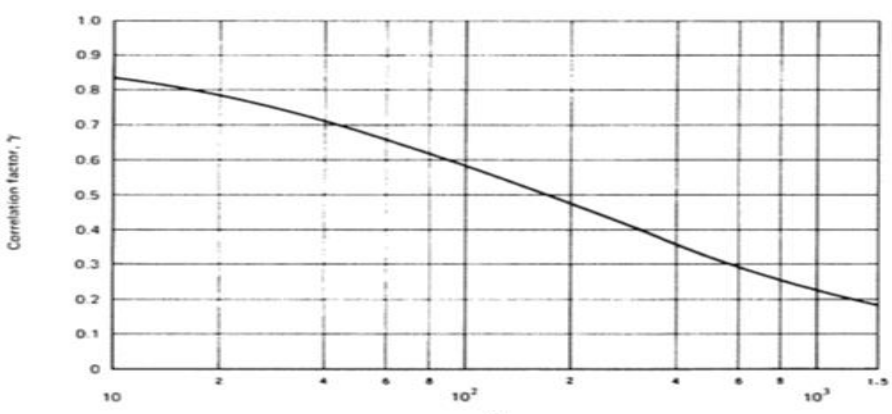


Figure 3: Correlation factors for isotropic circular cylinders subjected to axial compression

Discussion:

Applying our theory to the design of actual cylindrical shells becomes complicated because of the discrepancies between our experiment and the theory. In our case where we the longitudinal compression is predominant; the primary source of error is the dependence of the buckling load of cylindrical shells or small deviations from the nominal circular cylindrical shape of the structure. Because the unloaded shape of the aluminum can is usually not being stringently controlled. It is also said that the edge values of longitudinal and circumferential displacements of forces are not usually controlled and can cause an added error [3].

With our set boundary conditions of a static end and another is moving end causing compression it is found that it leads to better energy absorption because of asymmetric folds [2].

The other common cause of the buckling can be anything ranging from surface roughness, inclusions, transverse surface tears, initial off-flatness of sheet, presence of hard particles to circumferential direction of the can [4]

The velocity of impact and the location of the impact on the can, have the greatest effect on the indentation of the can. So, the initial velocity of the impact is directly proportional to the amount of can deflection and the max force. Also, the impact height along the length of the can caused greater deflection at the top as compared to bottom of the sidewall.

In order reduce the buckling, we can see to the force applied to the can causing it buckling where we come to conclusion of increasing the thickness of the walls, or a material with high “E” value.

Most of the changes are basically the way you approach the force interaction with the can, in case of increasing the thickness and a material in making for the can it might result in increased material usage over the time, causing the cost price of the product to go up, with less to no effect on the function but a greater customer satisfaction

Conclusion:

From the project findings, we can conclude that even though the buckling of the aluminum can is a result of multiple things like the amount of force, height of impact etc. But the thickness variation of the sidewall of the can is major cause of the buckling of the can, as it impacts the Amount of force required to cause buckling directly.

References:

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[2] Arxiv.org. (2017). [online]
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[4] Dynalook.com. (2017). [online]
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