

Aerosol cans under pressure and buckling loads

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Abstract This study focuses on the computational modelling of an aerosol can by predicting the level of pop-up and burst pressure levels as the can is subjected to increased pressure loading, along with the determination to top load force causing can wall buckling. Numerical findings are assessed against European Packaging Standard and experimental trials for reliability of such a design. The challenge of the present study is the use of in situ data to mimic the can predictive behaviour within the Ansys Software suite. This data includes the can material, which is non-linear strain hardening aluminium allowing for yielding at high strain, can wall variable thickness and loading characteristics. The methodology is then applied to reduce the can weight by optimal distribution of the can wall thickness and redesign the base section whilst revealing an innovative design that fulfils the qualification needs, impacting directly on the material cost, in addition to cost of transport and energy. The authors are awaiting IP clearance to disseminate the optimum design. Meanwhile, analysis on the initial design is permitted.

1- Aims

The aim of this work is to ensure that the can fulfils two major packaging requirements (EU standards) related to a) pressure loading enabling a hold up pressure of 12 bar without bursting under 20% excess of holding pressure, and b) sustaining a compressing top loading on the bead up to 981 N. Simulation is performed on Ansys software, and benchmarked against experimental data. Due to the commercial impact of such work, few publications have been disseminated discussing details of the methodology used. One might cite the work carried by Hardy and Abduslam [3] and Patten [4] on extrusion and forming process of aerosol can and optimisation. Similarly Fox [5] carry out a stress analysis of self-pressurized aerosol container using Ansys. The authors failed to identify similar work (with similar can design) to that presented here for comparison purposes. The paper is organised as follows: Each of the two EU packaging requirements are tested (in turn) experimentally, followed by the equivalent numerical analysis.

2- Experimental data - Pressure loading

The can is manufactured by extrusion of the aluminium slug during which the base and the cylindrical wall are formed of which a variable thickness is obtained from these can parts. The thickness data is paramount for a realistic simulation.

Can material: Tensile tests were carried out on samples cut from manufactured cans, in the longitudinal and circumferential directions. The stress-strain curves across locations are illustrated in Figure 1.

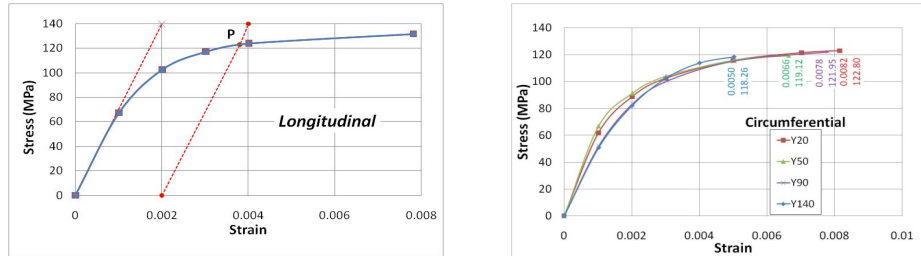


Figure 1: Stress-strain curve for longitudinal and circumferential direction

Pressure loading: For these tests fulfilling the packaging requirements (EU standards), the can was fixed from the bead (ring) and internal pressure was applied to the inner can walls as shown in Figure 2 (left). In this case, the fluctuation in the curve at around 43 s indicates the occurrence of the pop-up at around 22 bar, and a burst pressure at end time of 50 s of around 24 bar.

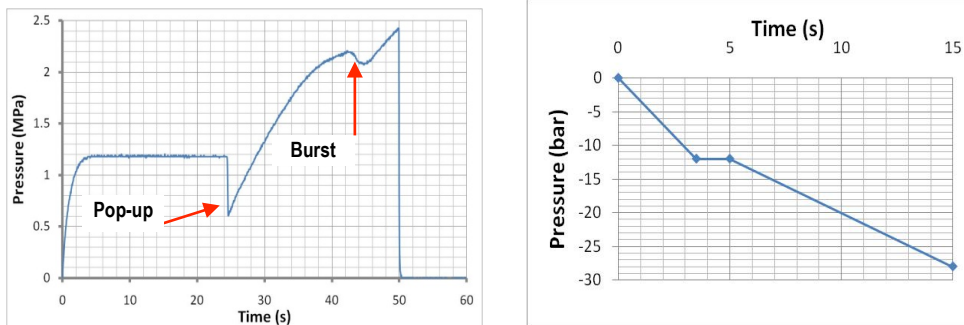


Figure 2: (left) Temporal pressure loading, (right) Numerical pressure loading history

3- Numerical Modelling - Pressure loading

A 3D variable thickness shell modelling is appropriate for such structures, in contrast to 3D solid elements. The time for pressure holding up at 12 bar is set for 2 s and the continuous pressure increase beyond 12 bar to 28 bar occurs over 10 s (see Figure 2-right). The can should burst before the pressure attains 28 bar set.

Pop-up pressure: The analysis of the deformation history at the de-dome centre and the response of the reaction force on the bead, shown in Figure 3, revealed the occurrence of the pop-up (large increase within a very short period of time). The pop-up pressure is determined as 22.13 bar, matching to that measured experimentally (22.25 bar).

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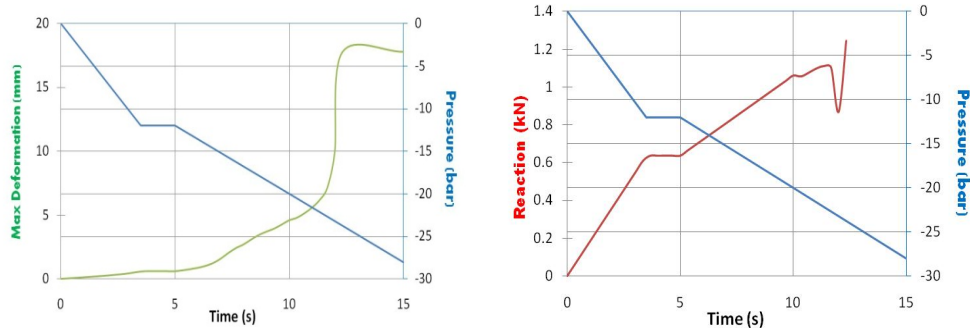


Figure 3: Maximum deformation (left) and force reaction (right) history

Burst pressure: As the pressure continues to increase, the can reaches the bursting pressure level. Here, burst results in numerical divergence at 12.482 s, thus the burst pressure is 23.97 bar equating to that measured (average: 23.92 bar). The burst location is clearly depicted in Figure 4 (numerical vs. experimental).



Figure 4: Burst location and shape: numerical (left) and experimental (right)

Both pop-up and burst pressure predictions are in good agreement to the experimental data, as summarised in Table 1.

Table 1: Pressure loading findings (maximum deformation pressure)

	Time (s)	Max. Deform. (mm)	Pressure (bar)	
			Simulation	Experiments
Pop-up start	10.335	4.79	20.05	-
Full Pop up	11.335	9.99	22.13	22.25
Burst	12.482	17.80	23.97	23.92

4- Experimental findings - Top load

To access the can buckling behaviour and determine the maximum top load, the can is fixed at the base and a crushing displacement of 12mm/min is applied to the bead. The maximum buckling load on the bead should exceed 981N under the

Packaging Standard. Experimental results are provided in Table 2.

Table 2: Experimental Top load for can qualification

Min (N)	Max (N)	Average (N)	Requirement (N)
1446.90	1608.70	1507.98	> 981

6 – Numerical Modelling - Top Load

To perform a top load simulation, a linear static analysis is first performed followed by a modal analysis of the perturbed pre-stressed can to extract the first mode of deformation. A nonlinear force displacement of 12 mm/min is applied to the bead, as in the experiment, to compute the reaction force. The maximum force indicates the maximum top load allowed on the can.

Buckling analysis and top load simulation on perturbed shape: A perturbed non axisymmetric can shape is extracted from the buckled can and adopted in the non-linear top load (Figure 6). As the displacement is applied, the can wall starts buckling and deforming at the waist region as shown in Figure 5.

Comparison of experimental and numerical top loads findings is presented in Table 3. Note the local deformation at the base showing an elephant foot shape. The top load is 45 % greater than the minimum required load of 981 N, indicating that the wall thickness might be reduced without affecting the can integrity.

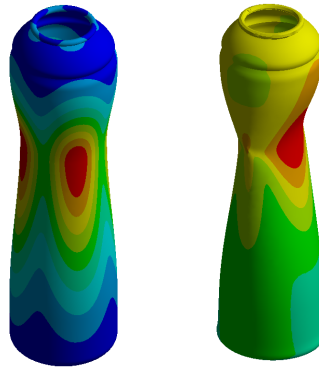


Figure 5: First buckling mode of deformation (left) and deformation on non-axisymmetric shape (right)

Table 3: Top load findings

Required	Experimental	Numerical	
Load (N)	Load (N)	Deform. (mm)	Load (N)
981	1430	1.07	1460

Conclusions

In the present work, simulations focuses on two major requirements for aerosol can accreditation by the European Packaging standard which relates to internal pressure and top compressive loadings. Non-linear analysis, based on a variable thickness 3D shell element, along with experimental trials, are carried out to predict the level of pop-up and burst pressure levels as the can is subjected to increased pressure loading, along with the determination to top load causing can buckling.

Analysis of the pressure loading has improved the understanding of the pop-up of the reverse dome and the burst conditions, highlighting area of improved design.

The top load analysis has accurately predicted the can buckling behaviour when subjected to top compressive load.

The good agreement between the simulation and the experimental results provides confidence for the use of the simulation tool, by demonstrating both the versatility of finite element analysis and, more specifically, the usefulness of such a simulation in pursuit of an optimum lightweight design solution.

The developed methodology has been applied to redesign de-dome shape (NDA protected) enhancing can performance and reducing can weight by 19.2%. Experiments have confirmed the computational modelling.

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