Buckling Evaluation of a Plastic Bottle Design

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Abstract - *Plastic bottle are very commonly used in abundance for storing of liquids in the commercial world. In order to study the method involved in the reduction of the weight of a plastic bottle, the buckling mode of plastic bottles under longitudinal compression is analyzed by finite element simulation. A parameter to evaluate the buckling deformation is proposed, and the buckling deformation is estimated through the comparison of load-deformation and the history of the parameter. An explicit linear analysis was implemented to calculate buckling load and stress distribution, based on the Abaqus software. According to the numerically obtained results, we can optimize the structure of the PET bottle in order to increase the buckling load. After obtain to the stress contour of PET bottle by Abaqus, plastic distribution of PET bottle was optimized in order to improve the PET material efficiency and reduce the weight of PET bottle, The outcome of this work gives new procedure to study the static bending analysis to determine the maximum stress and maximum tip deflection. Buckling analysis is done to find out different stage of buckling modes. Optimization of the model subjected to explicit dynamic analysis will yield maximum vertical deflection and Maximum stress*

Key Words: PET bottle; Structural Optimization; Light weight Design; Buckling modes.

1. INTRODUCTION

The PET bottle is used in various filled drinks and chiefly divided into 5 types: water bottle, hot filled bottle, beer bottle and CSD bottles. Generally, there is a unit completely different accomplish testing needs from differing kinds of PET bottles. PET bottles area unit subjected to completely different kind of tests to bottle the buckling. However, owing to transportation and stacking, the pressure is applied vertically on PET bottle and compressed by an axial force. The vertical load is mainly affected due to the failure of bottles supported the statistically check statistics.

The motivation behind this investigation is to propose markers that are vital for the ideal plan of the bottle. A finite element investigation was performed to predict the buckling quality of the bottle under the pressure load. The connection between shape parameter (diameter, height, and thickness of bottle) and buckling load was examined in view of a numerical recreation. Trials were directed to decide the buckling strength of the external cylinder under the pressure load, and contrasted with the logical outcomes with research the validity of the investigation.

Raw material is added to PET bottle to ensure to reach the mechanical property. Throughout this text, ABAQUS are used to study numerical and experimental solution. FEA computer program to give complete information of the deformation and stress distribution behavior of PET bottle.

2. METHODOLOGY

The main basic steps are to create a geometric model of PET bottle will be demonstrated utilizing solid work instrument. Once geometry is made according to determination it is imported into ABAQUAS for meshing. The FEM is set up by meshing it with appropriate element like hexa, quad, contact element, and constraining the model by applying material properties and boundary condition. This finite element is import to ABAQUS to conduct static and dynamic analysis. Finally, outcome is seen by utilizing ABAQUAS software and this outcome are validation.

2.1 Static analysis

Static analysis is carried out at constant loading condition to get the stress level of the components.

2.2 Buckling analysis

A buckling analysis is conducted to identify the buckling modes for applied load. In buckling analysis, the value of buckling factor determines the safety of the equipment.

Table-1: Buckling load factor

Buckling factor	Remakes
<1	Failure occurs
=1	Need modification
>1	Safe zone

Above the table 1 it can be clearly shows that buckling factor is less than 1 the structure may fail but when buckling factor is greater than one structure will be safe

2.3 Dynamic analysis

Dynamic analysis carried out at different loading condition to get the stress level of the component

2.4 Material Properties

2.4.1 General properties:

Density: 1335 kg/m^3

2.4.2 Elastic property:

Elastic properties are assigned in the form of engineering constants

Table-2: Elastic properties

E_1(MPa)	E_2(MPa)	E_3(MPa)	ν_{11}	ν_{22}	ν_{33}	G_{12}(MPa)	G_{23}(MPa)	G_{13}(MPa)
1345.39	1254.74	1254.74	0.4	0.4	0.4	448.12	480.5	448.12

2.4.3 Plastic property:

Table-3: Plastic properties

Yield stress (MPa)	Plastic properties
75.49	0
155.26	0.928

2.5 Geometric modeling

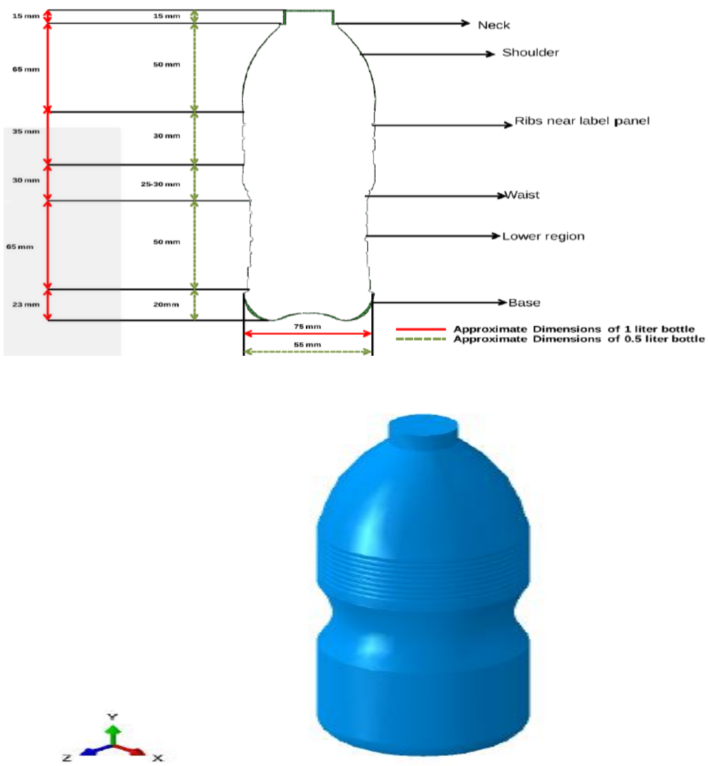

Fig -1: Geometric model

A geometric model of the PET bottle is made in solid work as appeared above the figure.

To assemble a model in solid work begins off with a 2D outline. The model involves geometry, for example, lines, point, conic, circular segments, and splines. To perfect the size and location of the geometry dimension are added to model or outline. Relations are measure utilized to outline attributes like, parallelism, tangency, circularity, and perpendicularity. Measurement and relations drive the geometry demonstrating the constant quantity nature of the solid works. The measurements within the diagram are often controlled freely, or by relationship to totally different parameters outside or within the portray.

At long last, drawing is often produced either from assemblies or parts. Views are measure mechanically created from the solid structure, and notes, dimension, and tolerance would then be able to be effectively addition to the drawing as required. The sketch incorporates most paper size and standards.

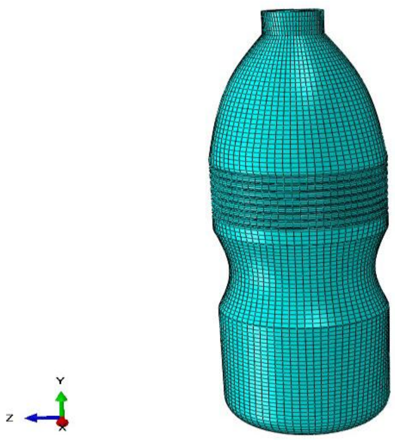

Fig -2: FE Meshed model

2.5 Loading conditions

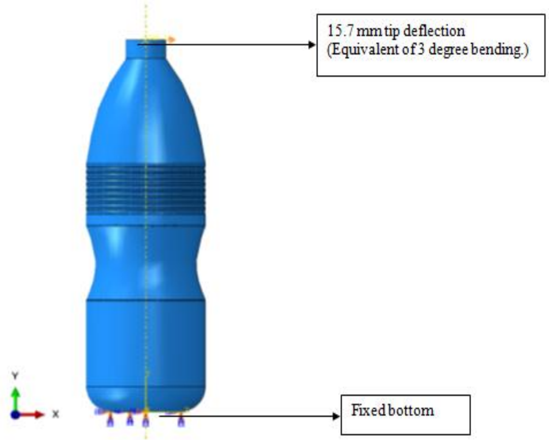

Fig -3: loading conditions

The boundary condition is the one of the major important factors to govern the output result of FEA and loading condition or loads are forces, acceleration or deformations applied to a structure or its components. Load cause deformations, displacement and stress in structures. Similar loads are applied to below structure at the top of model the tip deflection is 15.7mm and equivalent to 3 degree bending of structure.

3. RESULTS

3.1 Static Analysis Results

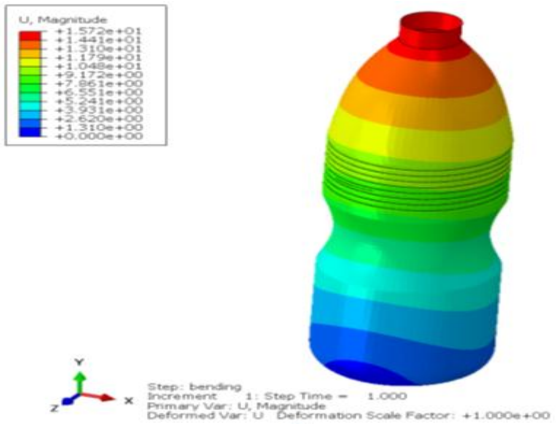

Fig -4: Maximum tip deflection

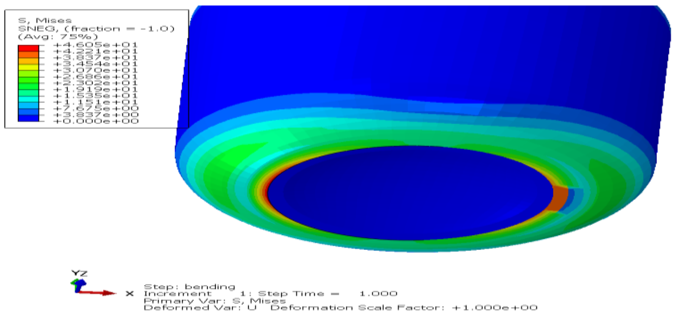

Fig -5: Maximum stress

Static analysis is carried out for the entire assembly by considering the gravity effect. Displacement is the change in the position of the nodes in the model with respect to the original position of that node in that model as shown above the fig 4 the maximum tip deflection is 15.7mm and Fig 5 shows the maximum stress obtained is 46Mpa.

3.2 Buckling Analysis Result

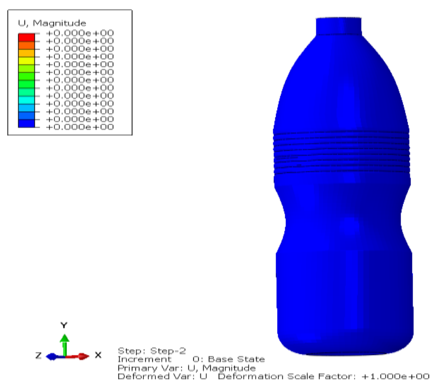

Fig -6: Base state

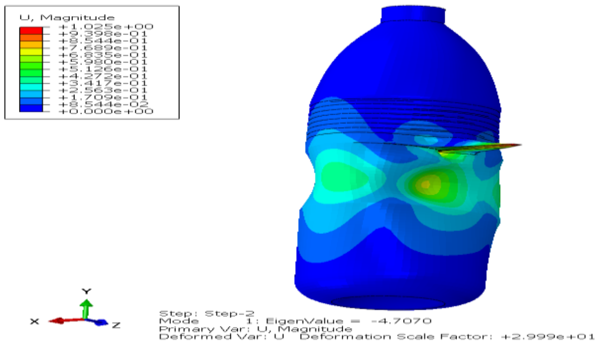

Fig -7: First buckling mode

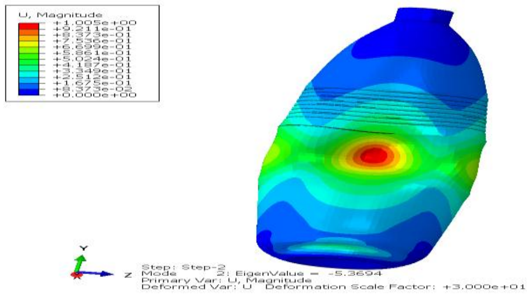

Fig -8: Second buckling mode

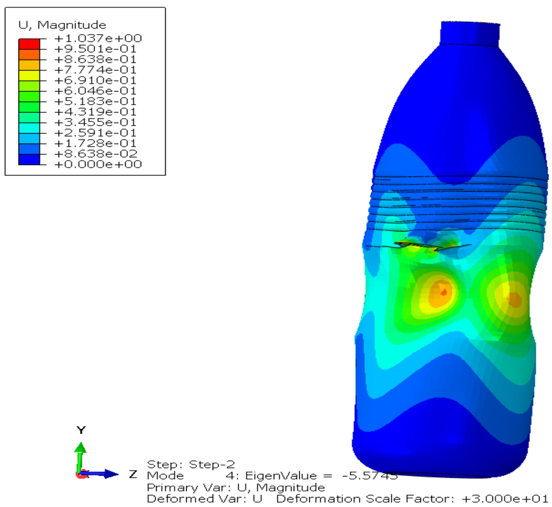

Fig -9: Third buckling mode

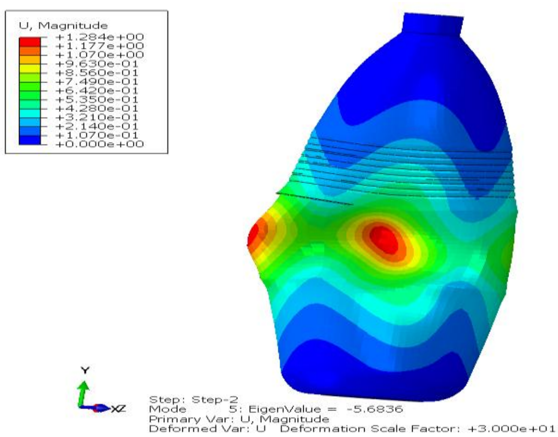

Fig-10: Fourth buckling mode

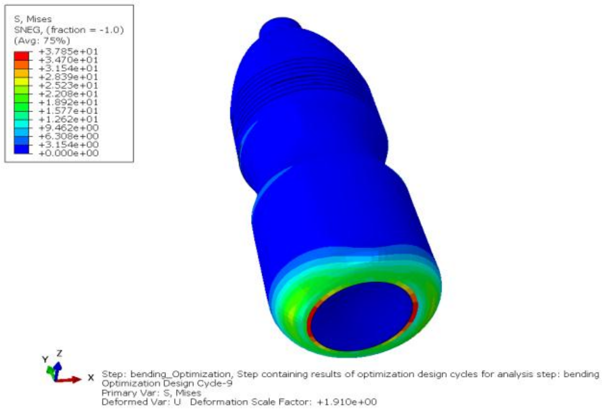

Fig-11: Stress distribution is optimized

The four buckling mode analysis was done to obtain maximum Eigen value and maximum displacement obtained in 4th buckling mode and minimum Eigen value and minimum displacement obtained in 1st buckling mode of buckling analysis.

3.3 Optimization

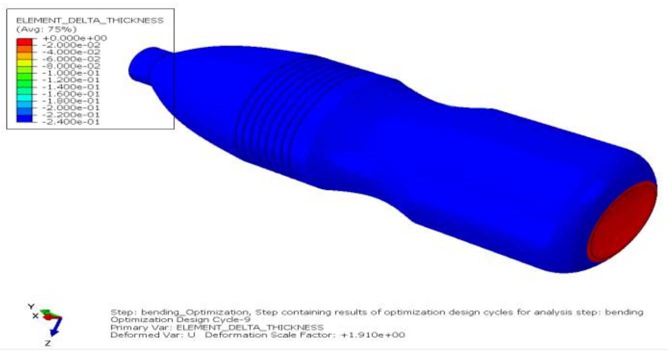

Fig-12: reduction of thickness of bottle

Optimization refers to minimize the shape and size of the masses without affecting their characteristics. The change in the wall thickness to get required size of model as shown in fig 12 and wall thickness measurement of 1.5L bottle and bending optimization step containing result of optimization design cycle-9. The bottle thickness is reduced by 0.24mm. The final thickness of the bottle is 0.96mm and stress distribution reduced to37.9Mpa as shown in fig 11.

3.4 Top Load Testing

Top load test is widely utilized in the PET bottle industry. This test a look at reveals the stacking load-bearing capability of the bottle once keep in an exceedingly warehouse or throughout the transits, a load from the top is applied on the specimen in an exceedingly controlled manner. This force is applied unit deformity or buckling seems.

Top load test determines the weak points within the bottles once the bottle falls freely carrying weight. Except that, this take a look at detects the failings in blow moulding line if buckling is continual occurring on constant point.

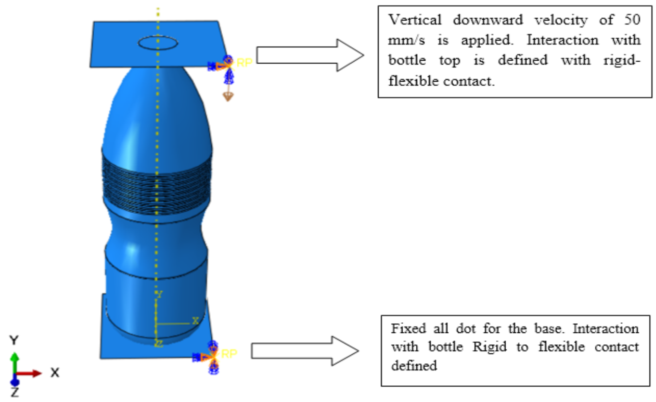

Fig-13: Both top and bottom plates are fixed

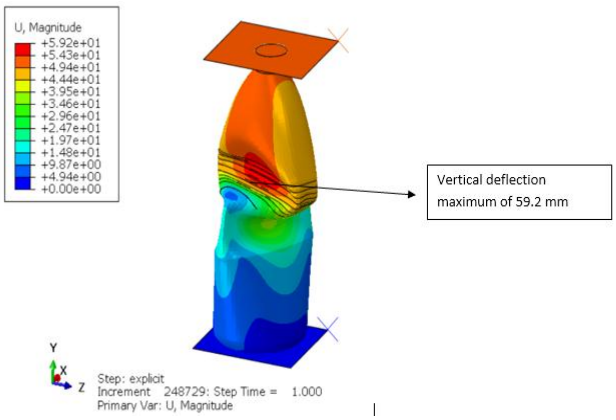

Fig-14: Vertical deflection of bottle

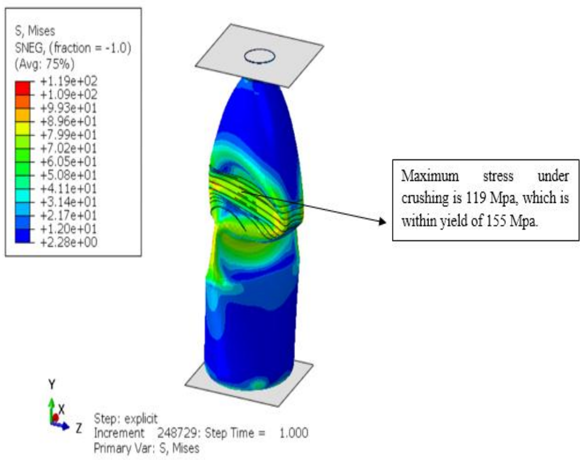

Fig-15: Maximum stress under crushing

Fig 13 as shown the boundary conditions. The base and top plate was fixed in all direction. Aside from the Y (vertical) direction. The model displacement takes place only in Y direction and apply vertical downward velocity at top of plate is 50mm/s and The vertical deflection of bottle maximum up to59.2mm as shown in fig 14 .The bottle subjected to the compression test, the bottle is often deformation takes place under the applied load. The maximum stress under crushing is 119Mpa, which is within yield of 155Mpa. We have finally concluded that stress within the yield point hence bottle is safe as shown in fig 15.

4. CONCLUSION

The 1.5-liter PET bottle design validation is completed for strength based on the bending, buckling and compression assessments. The results show a stable bottle design. The optimization of the bottle is additionally finished the thickness and also the reduction was achieved for regarding 20%. The Finite component model results were valid with experimental results. The bending analysis result show a deflection of 15.7 mm and stress of 46 Mpa.that is safe. The Buckling analysis shows a stable buckling with horizontal buckling modes for 1st to 4th buckling modes. The compression check is completed using explicit dynamic analysis with rigid plates at high and bottom of the bottle. The deflection of up to 59.2 mm is obtained, and also the maximum stress found to be regarding 119 Mpa. Indicated it as safe design. The optimization is completed using the model and the regarding 0.24 mm can be reduced for the thickness.

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