BUCKLING ANALYSIS OF A POLYETHYLENE 10-LITRE GALLON

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Abstract-**Materials behaviors are necessary to be understood in manufacturing consumers' products. Failure test and analysis is an essential tool to validate the strength of these products like 10-litre gallon under certain conditions. Stiffness, flexural and nonlinear analyses are carried out in a 1.8mm wall thickness 10-liter polyethylene gallon. The test results shows possible areas liable to failures for the products and possible stress concentration zone when loaded vertically and laterally respectively. This will enable the manufacturers design an instruction guild on the product for the consumers. Structural responses as creep, impact and fatigue on the product are long term values that are not discussed here. This will enable the gallon product to withstand severe stacking condition involving shocks when transported with liquid product.**

Index Terms: **Nonlinear analysis, buckling, stress concentration, polyethylene gallon.**

I.INTRODUCTION

Plastics must meet multiple demands in any one application. Beyond the need for specific physical and mechanical properties such as strength and stiffness. Plastics often encounter temperature, electrical and environmental stresses. In selecting the right plastic for an end use, designers must understand how key properties in these areas are measured. Choosing a plastic for a specic use can be a daunting task. Designers face a seemingly endless variety of resins and a host of properties that define them. Each market usually needs a unique set of properties for the plastics. Electronic connectors, for example, are complex, precision components that need good flow in thin section and high dimensional stability. Packaging materials, by contrast, need sti-ness, strength and good water vapor barrier properties. These requirements drive the process for selecting plastics. Plastics are either thermosets or thermoplastics. Thermosets flow before molding but undergo chemical change during processing, which cures or hardens them to create a complex, interconnected network. If too much heat is added after this, the polymer degrades rather than melts. Thermosetting plastics include phenolic, epoxy, alkyd polyester, polyurethane, urea-formaldehyde and unsaturated polyester resins. Natural and synthetic rubbers, such as latex, nitrile, millable polyurethane, silicone, butyl and neoprene, are also thermosets. Thermoplastics, by contrast, soften when heated and harden when cooled. Molding does not change their chemical structure. They have a performance-based hierarchy from commodity to engineering grades. Commodity thermoplastics include low and high density polyethylenes and polypropylene. Engineering thermoplastics include acetal, nylon, polycarbonate, polyphenylene sulde and liquid crystal polymer. Those higher in the hierarchy generally carry greater loads and withstand impact, high temperature and chemical attack better.

Most thermoplastics are rigid, but some are highly elastic (thermoplastic elastomers, or TPEs), and can be stretched repeatedly to at least twice their original length at room temperature, then return to near their original length. A plastic's physical and mechanical properties can be modified with additives, fillers and reinforcements. In plastics, mechanical properties are best increased by adding reinforcing fibers made of glass, metal, carbon or other materials. Particulate fillers like talc or ground calcium carbonate generally increase modulus, while plasticizers decrease modulus and enhanceflexibility. Other common additives include flame retardants, oxidation inhibitors, and thermal and UV stabilizers. Plastics are homogeneous if they have the same makeup throughout as in many unfilled thermoplastics, or they can be heterogeneous and vary from point to point. If properties are the same when measured in any direction, the plastic is isotropic. If not, then it is anisotropic.

II.SCOPE

This work covers the effect of compressive force on a 1.8mm wall thickness 10-liter polyethylene gallon. Stress concentration point and flexural analysis are done, the CAE was conducted with Solid Work 2013

III.AIMS AND OBJECTIVE

This work aims at

1. Exhibiting product test and standarzation.
2. Product evaluation and user guild design for users
3. Knowing areas of stress concentration when loaded vertically or laterally to enable better stacking method when gallons are transported with liquid products.

IV.SIGNIFICANT

Buckling analysis in gallon is done to analyze how suitable and strong the polyethylene gallon can withstand stress with fluid content under transportation or stacked with content in a warehouse.

V.MECHANICAL PROPERTIES

In the real world, many factors occur at once as they affect and influence engineering material and processes, so parts should be evaluated in actual use to gauge how varying force, temperature and other factors affect them. The most significant mechanical properties include:

a.Toughness

This is ability to absorb mechanical energy without fracturing by an engineering body. High-impact, unfilled resins generally have excellent toughness. Brittle resins, which lack toughness, often have less impact strength and higher stiffness. Many glass-reinforced and mineral-filled materials are brittle.

b.Tensile strength

The maximum amount of tensile load per unit area a material can withstand.

c.Tensile elongation

How much length increases in response to a tensile load expressed as a percent of the original length. Elongation at break is the maximum elongation an engineering body or the plastic can undergo.

d.Flexural strength

How much of a bending load an engineering body or a plastic can withstand before it ruptures.

e.Creep

A plastic is deformed under load (tension, compression or flexure) over time. It does not include the initial change in dimension when the load is applied. The rate of creep depends on applied stress, temperature and time. It is usually measured at four or more stress levels and plotted as strain vs. log of time. Crystalline resins usually have lower creep rates than amorphous ones. Glass ber reinforcement improves creep resistance. A plastic part will fail when too high a strain is imposed for too long a time

f.Impact loading

This tell how well an engineering body absorbs energy from an impact and is dependent on the shape, size, thickness and type of material. Tests can be done on notched or unnotched samples. Notched tests measure how easily a crack propagates through a material. Impact tests are not analytical, but can be used to compare the relative impact resistance of materials

g.Izod impact strength (mainly the U.S.)

A pendulum arm is swung from a height to impact a notched cantilevered specimen. The distance the pendulum travels after fracturing the material indicates the loss of energy, which is the Izod strength in ft-lb/in or J/m. This test also has unnotched or reversed notched (facing away from pendulum) versions

h.Charpy impact (mainly in Europe)

like the Izod measurement, except the beam is supported at both ends. The pendulum hits the beam at its midpoint.

i.Falling dart impact

This involves dropping a weight onto a at disk. Height of release and dart weight is varied until half the specimens break.

j.Fatigue endurance

This is the mechanical deterioration and failure of parts that are cyclically stressed. This test subjects a cantilevered beam to reverse flexural loading cycles at different stress levels

VI.THERMAL PROPERTIES

Higher temperatures make plastics more sensitive to mechanical stresses and vulnerable to chemical attack, while lower ones generally make them less ductile. In designing an engineering body ,it is important to understand what thermal conditions it will meet during processing, assembly, nishing, shipping, and end use to ensure it retains its integrity and risk of failure is minimised. The main thermal properties of plastics to be discussed in this regard include:

1.Melt index

This measures how much plastic is extruded through a heated apparatus in 10 minutes (reported as g/10 min.). Greater ow rates indicate greater viscosity. The results guide the selection of molding conditions.

2.Vicat softening point

This is the temperature at which a small, circular, heated and lightly loaded probe penetrates a set distance into a specimen. It indicates a material's ability to withstand short-term contact with a heated surface. It is useful for crystalline plastics, but of limited value for other types that can creep during the test.

3.Coefficient of linear thermal expansion (CLTE) –

It is measure of change in one dimension against the original dimension per unit change in temperature (in./in./°F·10-5 or cm/cm/°C·10-5) (Table 1). This is important in gauging stresses when assembling dissimilar materials. CLTE can vary with temperature, and anisotropic materials have different CL TEs in different directions.

4.Thermal conductivity

It is the rate heat energy travels along or through an engineering body like a plastic. This is important in heat generating applications and where heat dissipation is needed or predominant.

5.Aging at elevated temperatures

It looks at how a plastic's physical, mechanical, thermal or electrical properties change over time when samples are stored at high temperature. Elongation increases at higher temperatures and the effects of strain manifest more quickly. At lower temperatures, plastics tend to lose impact strength

VII. MODELING

The model of 1.8mm wall thickness 10-liter polyethylene gallon made of polyethylene plastic is designed with solid works 2013 and the CAE work is done with assumption stated bellow using buckling analysis.

i.ASSUMPTIONS

The following assumption are made

1. Material is isotropic

2. No friction on application of compressive load
3. The temperature of the product is normal with the ambient condition.
4. Normal reaction at static equilibrium is applied
5. The gallon is empty.

ii.MODELS

Mass:7.39261 kg,Volume:0.0077817 m^3,Density:950 kg/m^3,Weight:72.4476 N

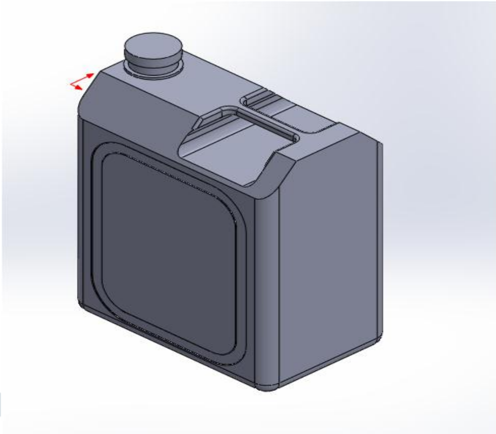

Fig 1. 3-modell of polyethylene gallon

MATERIAL PROPERTIES

Table 1. properties of polyethylene plastic culled from solid works 2013

Property	Value	Units
Elastic Modulus in X	600000000	N/m^2
Poisson's Ration in XY		N/A
Shear Modulus in XY		N/m^2
Mass Density	950	kg/m^3
Tensile Strength in X	18000000	N/m^2
Compressive Strength in X	14000000	N/m^2
Yield Strength		N/m^2
Thermal Expansion Coefficient in X		/K
Thermal Conductivity in X		W/(m·K)
Specific Heat		J/(kg·K)
Material Damping Ratio		N/A

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MESH DETAILS

Table 2. MESH PROPERTIES

Total Nodes	Aspect Ratio	Jacobian Points
19703	24.068	4 Points
Total Elements	Mesh Type	Element Size
9972	Solid Mesh	24.9235 mm

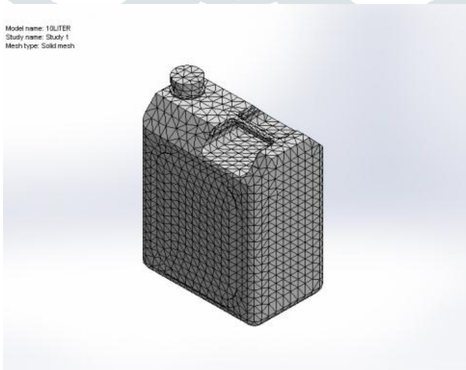
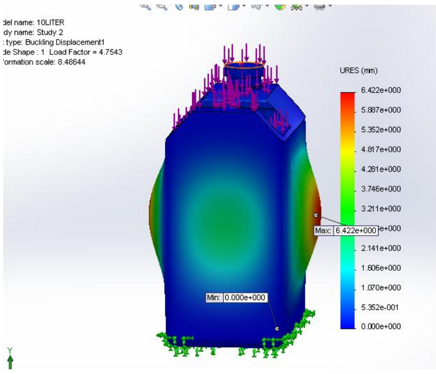


Fig2. 3-D solid mesh of polyethylene gallon



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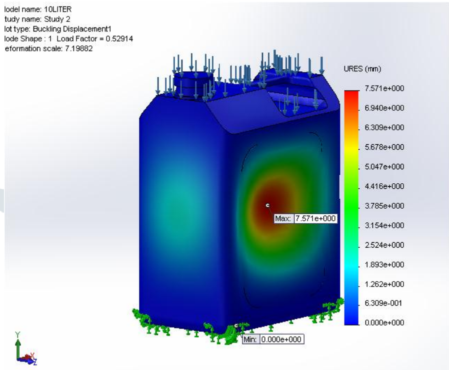

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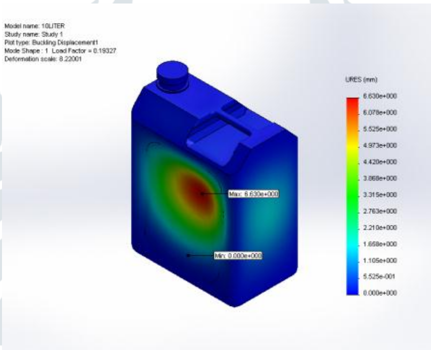

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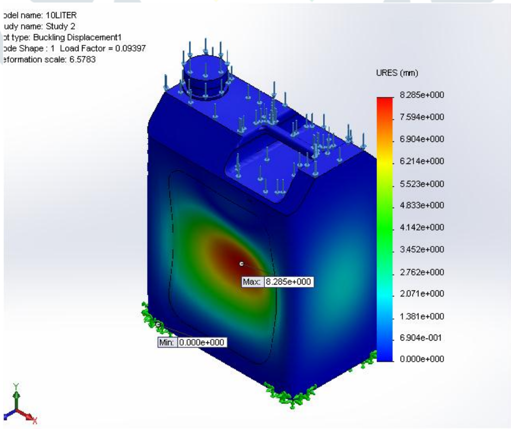

iv.

fig3. Buckling linear Displacement results at different wall thickness

TABLE 2. SIMULATUTION VALUES BUCKLING ANALYSIS

Compressive load=6000N

Normal reaction=6000N

S/N	Wall Thickness,mm	Number of nodes	Displacement,mm	Load factor
A	10	3666	6.42201	4.7543
B	08	4886	6.48852	2.6052

C	**06**	**10169**	**6.61319**	**1.2725**
D	**04**	**2606**	**7.57069**	**0.52914**
E	**02**	**11677**	**8.28482**	**0.09397**
F	**1.5**	**3638**	**9.45386**	**0.048066**

GRAPH

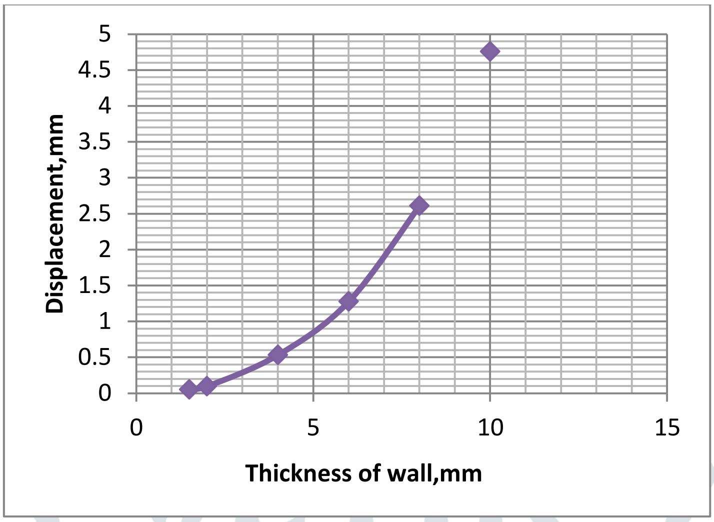

Fig 4.linear displacement due to buckling versus wall thickness of polyethylene gallon

This shows displacement increase with decrease in wall thickness of the gallon under buckling test

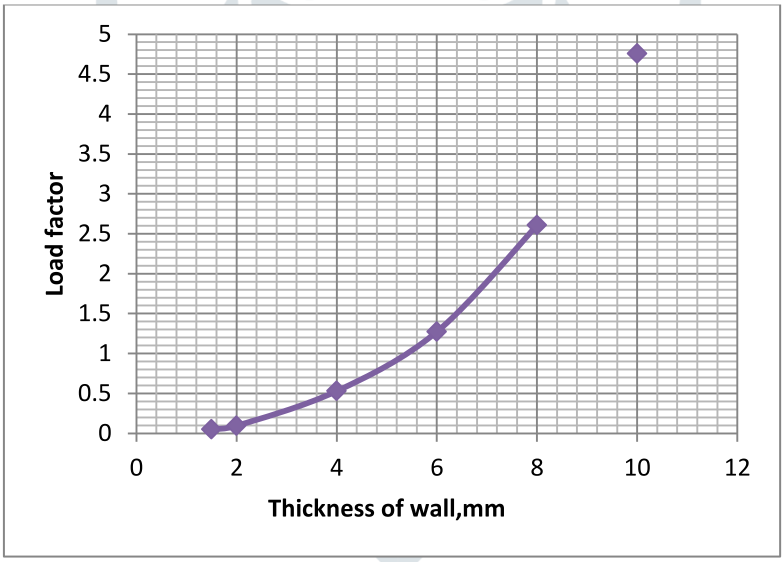

Fig5. Load factor and wall thicknes

The safety of th gallon is a measure of the load factor as the wall thickness increases the safety under compressive load is guaranteed .

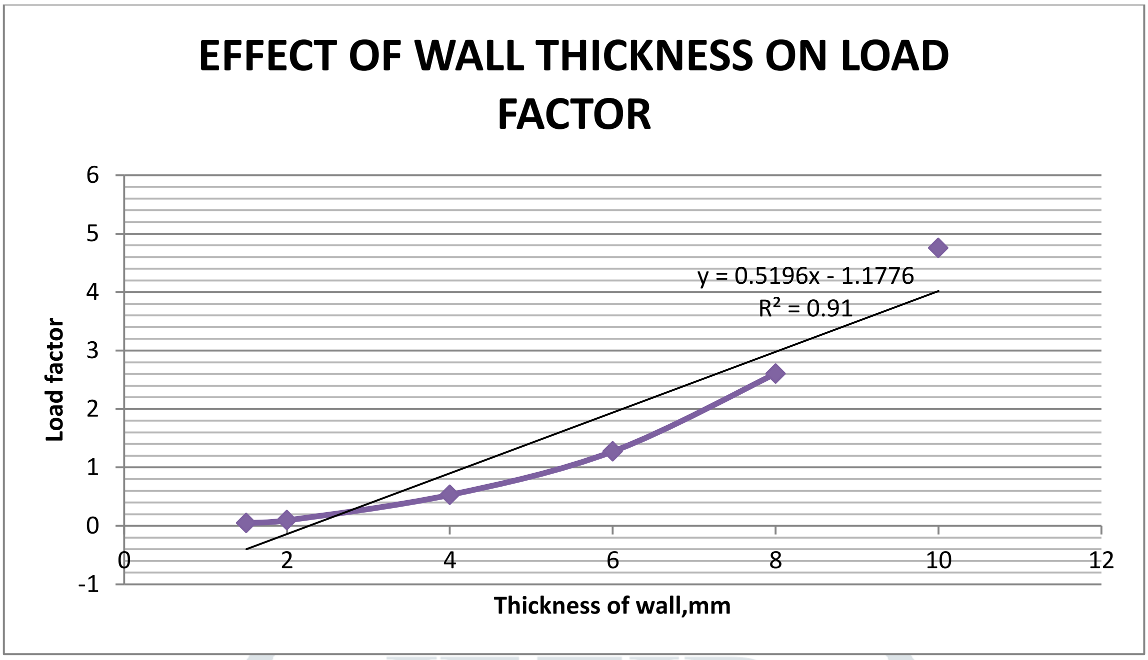

Fig 6. Linearizing the load factor versus wall thickness

The equation 1 . describes the line equation that will depict a linear relationship between load factor and wall thicknes of the gallon under a compressive load

$y = 0.5196x - 1.1776$ [1]

With a root mean square value ,$R^2 = 0.91$

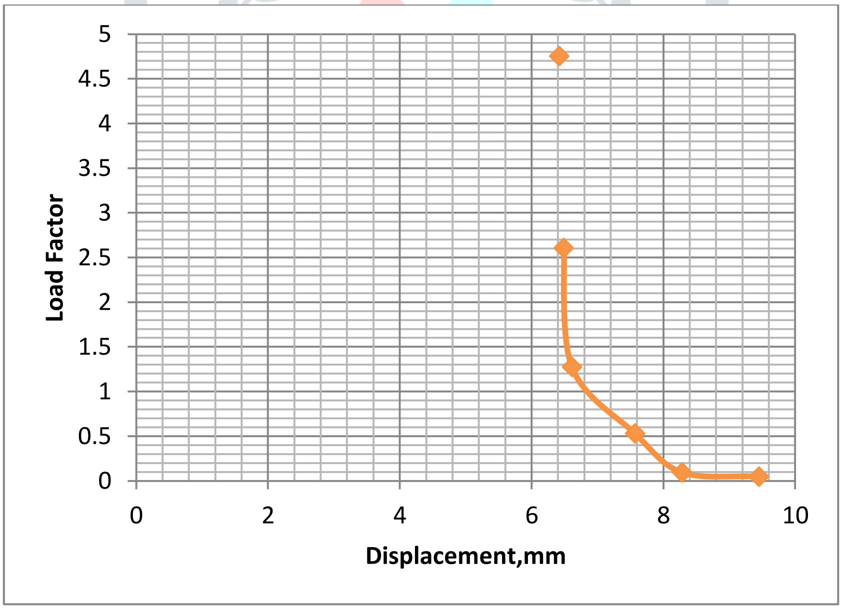

Fig7. Load factor versus displacement

Load factor decreases as displacement increases

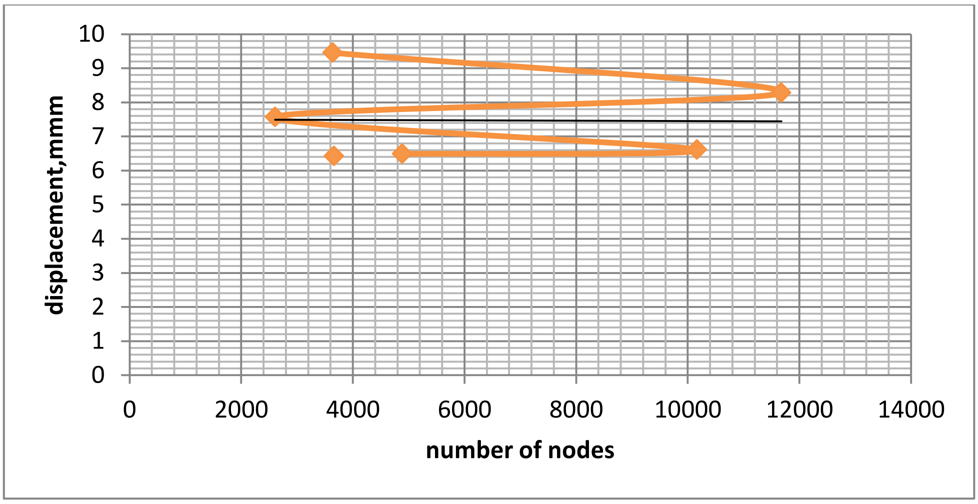

Fig8.displacement versus number of node

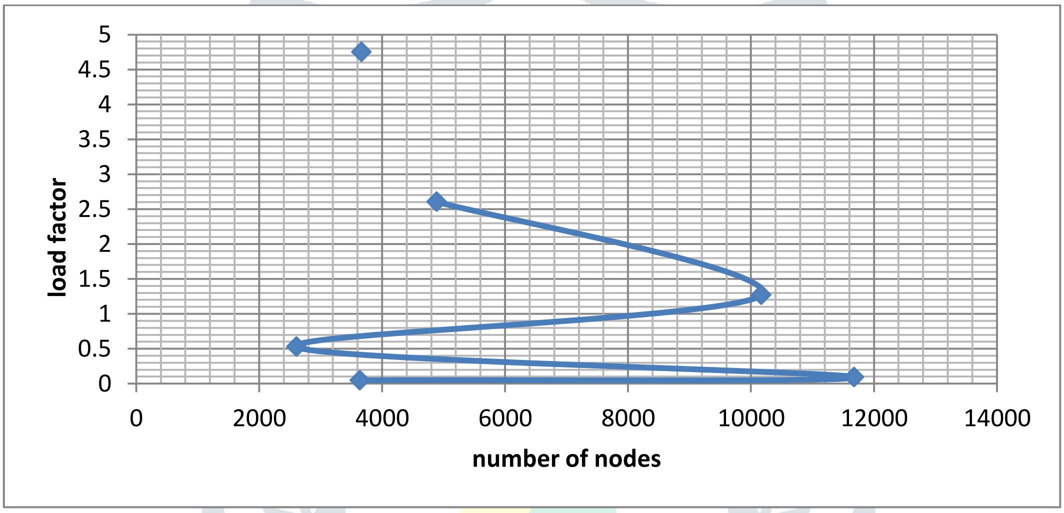

Fig 9. Load factor versus number of nodes

Irregularities or non-linearity in figs 8 & 9 in numbers of nodes are due to buckling analysis

VIII. STATIC LOAD ANALYSIS

The static analysis type used here is to affirm that buckling analysis is suitable with minimum displacement than the static analysis,and the displaced areas or stress concentration areas do not conform areas where the gallon is liable to fail when compressed. See figures 10 & 11

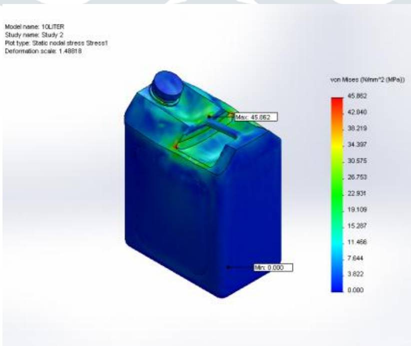

Fig10 von mises stress on static loading

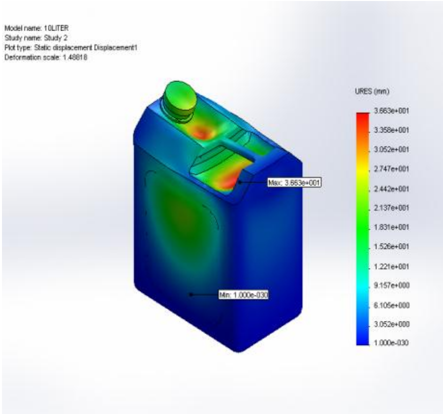

Fig 11. Displacement on static loading

This has a maximum displacement of 36.6281 mm with 9559 Nodes

IX. CONCLUSION

Buckling analysis like other nonlinear analyses is suitable for product design test like the 10liter gallon made of polyethylene. This is essential to avoid manufacturing defective products that will increase production cost and material wastage, and user guild initiative to ascertain loading condition during stacking in containers, cargos ,or warehouse. Nigeria like most countries, fluid ,oils or grease products are transported via gallons in vehicles . buckling analysis reveals wall thickness under which heavy compressive loading is possible with considerable load factors.

X.Acknowledgement.

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