KAUNAS UNIVERSITY OF TECHNOLOGY

MECHANICAL ENGINEERING AND DESIGN FACULTY

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EXPERIMENTAL AND ANALYTICAL TESTING ANALYSIS OF GRAPHIC CARDBOARD PACKAGE RESISTANCE TO STATIC LOADS

Master's Degree Final Project

Supervisor

Assoc. prof. dr. Laura Gegeckiene

KAUNAS, 2017

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Industrial Engineering and Management (code 621H77003)

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KAUNAS, 2017

KAUNAS UNIVERSITY OF TECHNOLOGY

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(Title and code of study programme)

"Experimental and Analytical Testing Analysis of Graphic Cardboard Package Resistance to Static Loads"

DECLARATION OF ACADEMIC INTEGRITY

31 May 20 17

Kaunas

I confirm that the final project of mine, **Archana Kaliappan**, on the subject "Experimental and Analytical Testing Analysis of Graphic Cardboard Package Resistance to Static Loads" is written completely by myself; all the provided data and research results are correct and have been obtained honestly. None of the parts of this thesis have been plagiarized from any printed, Internet-based or otherwise recorded sources. All direct and indirect quotations from external resources are indicated in the list of references. No monetary funds (unless required by law) have been paid to anyone for any contribution to this thesis.

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KAUNAS UNIVERSITY OF TECHNOLOGY
FACULTY OF MECHANICAL ENGINEERING AND DESIGN

Approved:	______________________________
Head of Production Engineering Department	*(Signature, date)*
	Kazimieras Juzėnas
	______________________________
	(Name, Surname)

MASTER STUDIES FINAL PROJECT TASK ASSIGNMENT
Study programme INDUSTRIAL ENGINEERING AND MANAGEMENT

The final project of Master studies to gain the master qualification degree is research or applied type project, for completion and defence of which 30 credits are assigned. The final project of the student must demonstrate the deepened and enlarged knowledge acquired in the main studies, also gained skills to formulate and solve an actual problem having limited and (or) contradictory information, independently conduct scientific or applied analysis and properly interpret data. By completing and defending the final project Master studies student must demonstrate the creativity, ability to apply fundamental knowledge, understanding of social and commercial environment, Legal Acts and financial possibilities, show the information search skills, ability to carry out the qualified analysis, use numerical methods, applied software, common information technologies and correct language, ability to formulate proper conclusions.

1. Title of the Project

Experimental and Analytical Testing Analysis of Graphic Cardboard Package Resistance to Static Loads

Approved by the Dean Order No. V25-11-8, 21 April 2017

2. Aim of the project

The Main Aim of the project is to analyze which type of window shape, triangle, square and circle shape in Packaging provides the highest resistance when compressed.

3. Structure of the project

- Experimental testing
- Design of Packages
- Theoretical calculations
- Analytical testing
- Comparison of Experimental and Analytical Testing.

4. Requirements and conditions

- The weight of the Paperboard should not be less than 300 grammage.

5. This task assignment is an integral part of the final project

6. Project submission deadline: 2017 June 6.

Student	Archana Kaliappan	
	______________________________	____________________
	(*Name, Surname of the Student*)	(*Signature, date*)
Supervisor	Doc. Prof. Laura Gegeckiene	
	______________________________	____________________
	(*Position, Name, Surname*)	(*Signature, date*)

Archana Kaliappan. Experimental and Analytical Testing Analysis of Graphic Cardboard Package Resistance to Static Loads. *Master's* Final Project. Supervisor Assoc. prof. dr. Laura Gegeckiene. Faculty of Mechanical engineering and design, Kaunas University of Technology. Research field and area: Technological Science, Production Engineering. Keywords: Paperboard, Windows, Crash test, Force, Solidworks Modelling, Ansys, High Strength, Compression.

Kaunas, 2017, 51p.

SUMMARY

The Main objective of the project is the progression or methods used for analyzing the effect of windows in paperboard packaging to its strength and its test methodology. The test methodology is which the experimental carried out in a crash test machine and analysis using ANSYS software is carried out. The primary goal of the project is to find which window shapes provides more strength to increase the usage of paperboard packaging and to compare the Analytical and Experimental Results.

Archana Kaliappan. Grafinio kartono pakuočių atsparumo statinėms apkrovoms eksperimentinių ir skaitmeninių tyrimų analizė. Magistro baigiamasis projektas. Vadovas lekt. dr. Laura Gegeckiene. Mechanikos inžinerijos ir dizaino fakultetas, Kauno technologijos universitetas. Mokslo kryptis ir sritis: Technologijos mokslai, Gamybos inžinerija. Reikšminiai žodžiai: kartonas, gniuždymo jėga, ANSYS, Solidworks modeliavimas.

Kaunas 2017, 51p.

SANTRAUKA

Pagrindinis baigiamojo darbo tikslas - iškirtimo geometrinės formos įtaka grafinio kartono pakuotės atsparumui apkrovimo atveju. Metodologinėje dalyje atliktas eksperimentinis ir skaitmeninis tyrimai. Pirmuoju atveju atliktas eksperimentinis pakuočių, su skirtingais geometrinių parametrų iškirtimais (kvadratas, trikampis, apskritimas) tyrimas, kitas žingsnis – analogiškų pakuočių skitmeninis modeliavimas ir gniuždymo tyrimas ANSYS programa. Toliau pateikti eksperimentinio ir skaitmeninio tyrimų rezultatai ir jų analizė. Pateiktos išvados ir rekomendacijos.

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1. Introduction:

With an increasing usage of paperboard packaging all over the world, attention has been focused on all possible methods to increase the usage of paperboard packaging by increasing its strength. The investigation carried out and reported in our project has been confined by the effect of window shapes in paperboard packaging. This model considers the geometrical and mechanical properties of the corrugated cardboard constituents [1]. Three different types of window shapes were used. All three window shapes used in my project uses the same kind of paperboard and packaging. The packaging was tested one by one. These packages were used throughout the project.

The paperboard sector is primarily considered in conjugation with the paper industry. The Paper & Paperboard total commercial size is about 630.9 billion USD. In that 40.1% of Papers are used by Europeans and 50% are used by Packaging Companies. According to ProCarton, the economic usage of paperboard and paper are influencing the curves of Gross Domestic Product (GDP). Gross revenue from the carton in European Community add together to approximately 8 billion Euros worth, they are also very sensitive to atmospheric conditions [2]. Cartons make up one-third by paper and board packaging and 15% of all packaging. The waste papers are used by Europeans for recycling the paper process of the average of more than 54%. The manufacturing of this paperboard requires so much energy and capital amount investment.

Paperboard is a dense paper-based material which has less weight compared to Cardboard and more weight compared to Paper. The pallet uses corrugated cardboard sheets that are precision cut and scored to be formed about the rigid reusable support stringers [3]. In order to assemble the package adhesives are used. The need for glue introduces an extra step in the assembly process, increases assembly and material costs, and reduces the ability of the beam to be recycled. [4]. The paperboards are the papers which weigh more than 224 g/m2 as per the ISO regulations. However, there are prohibitions. Paperboard could be single- or multi-ply layout. Paperboard could constitute easily cut off and imprinted, are lightweight, and since it's strong, are utilized in packaging.

Figure 1: Paperboard Packaging [5]

1.1. Aim:

The Main Aim of the project is to analyze which type of window shape, triangle, square and circle shape in Packaging provides the highest resistance when compressed.

1.2. Tasks of the project:

- To find out which window shape provides maximum strength to compression.
- To compare the Experimental and Analytical value to check both yields the same results.
- To find out the stress value at break point, Maximum Force and Extension of Square shaped window packages.
- To find out the stress value at break point, Maximum Force and Extension of Triangle shaped window packages.
- To find out the stress value at break point, Maximum Force and Extension of Circle shaped window packages.
- To find out which shape of window extends more when compressed.

2. Production:

The fibrous material is reversed into a pulp (paper)/pulp and bleaching of wood bleached, to produce one or more layers of the board. Paperboard is acquired on pulping machines that could be used to produce higher grammage and many plies paperboard.

2.1. Raw Materials:

The above-mentioned fibrous material could either come up from fresh (pure) sources (e.g. wood) or reprocessed waste paper. Almost 90% of pure virgin paper are attained from wood pulp from the trees.Nowadays the paperboard manufacturers are concerned about environmental friendly so, new attention is given in order to deliver sustainably certified products to meet the demands. The several parts of the prior art collapsible boxes require the use of fasteners or connecting means which make use of adhesive material. The assembling of such separated plurality of parts is time-consuming and therefore extremely expensive [6].

2.1.1. Raw materials include:

1. *Hardwood*: Calcium. 0.05 inches (1.3 mm) in length. Birch is most commonly used. It has a lot of difficult work but it provides high durability over tensile strength, low tear and additional durable Qualities. Although its fibers are not as durable as softwood they attain more inflexible quality specified from some stiffness tests. Hardwood fibers are better and consequently help to attain a smoother paper that is much opaque and better for impressing. Hardwood attains a superior corrugating intermediate.
2. *Softwood*: Ca. 0.13 inches (3.3 mm) long e.g. Pine and spruce are commonly used. It gives more strength. The best liner board can be attained using softwood.
3. *Recycled*: Used paper is collected and mixed with pure fibers to produce new material. This mixing is done because while the paperboard is recycled the purity will become less and the newly added pure fibers will tend to increase its durability. The decoloring process is carried out to remove the colors, adhesives and some other residuals. Products attained by reprocessed board

typically bear a less predictable composition and poorer operational attributes than pure fiber-based boards.

4. *Others*: They are as well as possible attributes to utilize the fibers of sugarcane Bagasse, drinking straw, Hemp, Cotton, Flax, Kenaf, Abaca and additional plant products.

2.2. Pulping:

Two principal processes for extracting fibers from their sources are:

1. Chemical pulping uses chemical solvents to turn wood into pulp, yielding about 30% less than mechanical pulping; however, pulp attained by the kraft method has excellent durability, inspired by the gridwork homogenization model of Timoshenko, decompose plate torsion into two beam torsions [7].
2. The thermo-mechanical pulp is a two-stage technique which results in a very high yield of wood fibers at the disbursement from durability.

2.3. Bleaching:

The pulp could not be bleached to change the color or purity. The pure pulp/mesh extracted will be in brown in color naturally, because of the presence of lignin. The recycled paperboard could have the traces of inks, adhesives and another form of residuals. Bleaching is not carried for the purpose of whole end use but there is some process employed according to a measure of factors, for example, the degree of color alteration obligatory, chemicals was chosen and the process of treatment. There are three classes of bleaching techniques:

1. Bleaching by lignification employing chlorine gas, which comprises a technique that has been mostly superseded by operations which are gentler to the surroundings such as the use of oxygen as an alternate for the chlorine gas.
2. Bleaching by oxidization employing chemicals such as chlorine dioxide, hydrogen peroxide or sodium hypochlorite.
3. Bleaching by reduction employing chemicals such as sodium bisulphite

2.4. Plies:

Multi-ply paperboard has higher strength compared to single ply and thus it is not easily collapsible. In multiply, the individual layers are processed and worked separately/ individually to produce higher convincible caliber products.

2.5. Coating:

The main goal is to provide good quality of whiteness, smoothness, and shine. For this requirements, one or numerous layers of coating are arranged together to be employed in the work. Coated paper is comprised of:

1. A pigment, which could be china clay, calcium carbonate or titanium dioxide, generally a combination of two.
2. An adhesive or binder as styrene-butadiene emulsions or asylums and water.

Further components could comprise OBA (optical brightening agents)

3. Types of Paperboard:

3.1. Paperboard Grades:

Good packages commence with the correct material - one that can bear functioning, caliber and dependability for the production it houses. Paperboard packaging gets in numerous dissimilar grades that have unique features attaining each form appropriate for dissimilar packaging necessities and needs.

3.1.1. Solid Bleached Sulfate (SBS):

Bleached paperboard or solid bleached sulfate (SBS) is a is a predominantly covered paperboard frame that is procured from an outfit involving no less than 80% virgin blanched wood mash. SBS paperboard is secured with a thin layer of kaolin earth to enhance its printing surface and might be additionally secured with polyethylene tar for wet quality bolster bundling. SBS are the most popular in the U.S.A.

3.1.1.1.Major commercialize segments that use SBS:

- Medical packaging
- Milk and juice gable top cartons
- Sterile beverage packages
- Cosmetic and aroma packaging
- Frozen foods packaging
- Candy packages

3.1.2. Coated Unbleached Kraft Paperboard:

Clay natural kraft (CNK®) or solid unbleached sulfate (SUS®) is a remarkable toughness paperboard shape that is gained from an outfit containing no under eighty rates unadulterated unbleached, ordinary wood Mash. Most unbleached or characteristic Kraft paperboard is covered with a dingy bed of kaoline dirt to improve its wing surface and can also be covered with polyethylene (potential vitality) sap for wet sturdiness nourishment bundling. Major commercialize segments that use CUK:

- Frozen foods packaging
- Beverage Cartons and Carriers
- Pharmaceutic packaging

3.1.3. Uncoated Recycled Paperboard:

Uncoated recycled paperboard, a duplicate material, is gained from hundred rate regained paper collected from paper making up and converting plants and post-industrial sources and symbolizes the separate greatest commercialize for cured paper in the U.S.A. Some uncoated paperboard is acquired with a top ply of white regained fiber or is vat dyed for color.

3.1.3.1.Major commercialize segments that use uncoated recycled paperboard:

- Shoe packages
- Composite cans and fiber barrels

3.1.4. Coated recycled paperboard:

Coated recycled paperboard, various materials, is created from 100 percent recuperated paperboard simply like uncoated reused paperboard. Notwithstanding, it is normally covered with a thin layer of kaolin earth over a top handle of white recuperated fiber to progress its printing surface.

3.1.4.1.Major commercialize segments that use coated recycled paperboard:

- Soap and washing detergent packaging
- Cookie and cracker packaging
- Paper commodity packaging (facial tissue and napkins)
- Cake mix packaging
- Cereal packages
- Another dry food packaging

4. Types of Packaging:

There are three noteworthy sorts of packaging: corrugated boxes, boxboard or paperboard containers, and paper packs and sacks.

4.1. Corrugated Boxes:

Corrugated boxes are generally used to convey heavier items. They are frequently used as a bulge shipper, handing over a lot of alike products in the identical box.

Several layers of paper fiber give the corrugated box the durability properties required: a top and bottom layer (called liner board) and a center layer (addressed corrugating medium). The crinkly, ripple-like shape of the medium in the center affords the box its durability. Think of the Roman arch or a corrugated tin roof. A corrugated box all the time features this ripple layer (or flute) in the center. That’s wherefore it’s called corrugated. Corrugated board can be used for a lot than just shipping products.

Figure 2: Corrugated Boxes [8]

4.2. Boxboard or Paperboard Containers:

These are the thin, lighter weight carton generally used to convey a lighter thing or product, for example, breakfast cereals, a toy, etc. It doesn't have the wavy center layer (corrugating medium) like as in Corrugated boxes to add box durability. Boxboard besides has non-packaging uses, non-bundling utilizes, as the top and base layer in gypsum wallboard items, and it is usually utilized and reused for kids' crafts.

Figure 3: Boxboard or Paperboard Containers [9]

4.3 Paper Packs and Sacks:

These may fundamentally be divided into 2 types: the paper packs used to carry groceries and/or household goods, and multi-wall sacks that are utilized for flour and cement for the accumulation of leaf and yard waste and organics (food scraps).

Figure 4: Paper Packs and Sacks [10]

5. Paperboard Packaging Types:

The different types of paperboard packaging are:

5.1. Aseptic Packaging:

A package in which aseptic contents are filled up and sealed off into a multi-laminate package under controlled, aseptic surroundings.

Figure 5: Aseptic Packaging [11]

5.2. Blister Pack:

A thin bubble or dome of inflexible plastic accompanied a piece of paperboard to form a package

Figure 6: Blister Pack [12]

5.3. Carded Packaging:

Type of packaging that consists of a tight paperboard card onto which a product is carried by a pre-formed plastic whip. Blister cards are generally covered with an exceptional coating that provides the blister to be heat-sealed to the card.

Figure 7: Carded Packaging [13]

5.4. Contour (or Skin) Packaging:

The overwrapping of an irregular basis forged object with a flexible film implemented to a paperboard base. The air surrounding the product is exhausted, inducing the film to accommodate or adhere closely to whole parts of the packaged item.

Figure 8: Contour (or Skin) Packaging [14]

5.5. Folding Carton:

Containers made up by bending forms of plain or impressed boxboard, cut and creased in a variety of sizes and forms. Folding cartons are delivered to the exploiter in a flat, or glued and collapsed form.

Figure 9: Folding Carton [15]

5.6. Rigid Box:

A Rigid paperboard box in 3-dimensional construction, by and large, created from non-twisting chipboard that is overwrapped with inspired paper or other covering materials and given over "set up" and prepared to use.

Figure 10: Rigid Box [16]

5.7. U-Board:

A “U”-shaped boxboard arrangement of a body and 2 finishes or sides, set apart to render resoluteness and lighten overwrapping of the item with adaptable bundling material.

6. Paper Packaging Benefits:

Whenever we prefer paper-based packaging, we know that we are preferring an inexhaustible, reusable substratum perfectible for engaging consumers and pushing back gross sales. However, there are a lot of dissimilar carton styles, each with singular benefits.

6.1. Folding Cartons: The Economic Carton for Customization and Printability:

A Case of paperboard packaging that folds up directly for storage and shipping, folding cartons are made of 10 to the 36-point board and could comprise fabricated using a wide array of virgin and/or recycled board types (SUS, SBS, CUK, CRB, FBB, etc.).

The Folding Cartons can be added flutes in some cases Called “mini flute,” these cartons boast a small E, F, G, or N-fluted (wavy) substrate that is sandwiched between two liner boards.

Since foldable cartons bend flat and consequently take up brief space, they are sparing to ship. And since they are published in sheets of paper containing a lot of carton flats, folding cartons generally accept lower per-unit prices and firmer product accelerates than fixed boxes. They allow first-class impress quality (color enrolment, consistency, fine detailing), and different rigid boxes or eminent print-quality corrugated, the external coat of folding cartons can be published at once, hence saving a step in the product process.

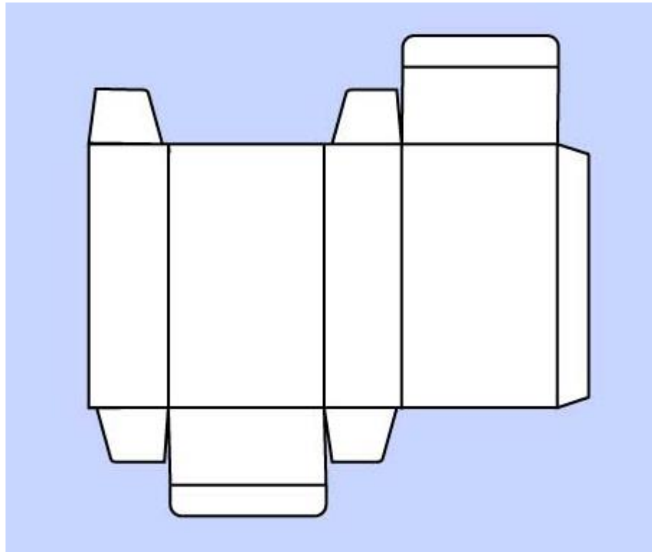


Figure 11: Folding Cartons [17]

6.2. Rigid Boxes:

Generally bigger than foldable cartons, fixed (apparatus) boxes are made of blockheaded 36 to 120 pt. board covered with an impressed paper enclose. These boxes broadly do not bend flat.

The Visual appearance and the impressive surface provides a feel of Prestigiousness, lavishness, elegance, and caliber, and are idealistic as lower, high-end details such as jewelry or electronics

Contrary to closing cartons, which are embarked compressed and consequently ask fabrication ahead constituting filled up with the product, rigid boxes commonly continue to raise and consequently accept inferior fabrication prices.

6.3. Corrugated Packaging: The Unbeatable Box for Strength:

Generally produced of cheap brown Kraft fluted (or crinkled) paperboard that is sandwiched between layers of liner board. In fact, corrugated could constitute easy custom-made for dissimilar applications that require altering levels of durability and product protection: flutes are available in an extensive variety of heights (A, B, C, E, etc.), and liner board layers can constitute double- or triple- layer walled for additional durability. The box arrangement has its quality depending upon the side dividers or parcel outlines so that if these are fortified, when the substance is evacuated, the side dividers or segment outlines can't be expelled mostly and particularly, it is extremely cumbersome to remove small articles received in the container or unused box materials in the folded conditions [18].

For imprinting process, Corrugated boxes have a long run restrictions. The best impress caliber and crispness for corrugated is attained using mottled white or bleached white liner board, or by impressing on a tag that is then affixed to the corrugated board. The box has exterior panels, top and bottom flaps, and interior pads [19].

7. Paperboard Properties Differences:

Properties	Corrugated	Folding Carton	Rigid Box
Renewable and Recyclable	X	X	X
Superior Print Quality	Sometimes	X	X
Wrap or Laminate Required for High-Quality Printing	X		X
Variety of Board Types/Printing Surfaces Available	X	X	X
Variety of Thicknesses Available	X	X	X
Ideal for Strength & Durability	x		x

Ideal for Reusability (i.e., continued brand recognition)			X
Ideal for Conveying Luxury			X
Ideal for Cushioning (Fluted)	x	Sometimes	
High-End Finishing Treatments Available	Sometimes	X	X
Ships and Stores Flat	X	X	Sometimes
Produced One at a Time			X
No Assembly Required Before Filing			X
Aseptic/Direct Food Contact		X	

Table 1: Paperboard Properties Differences

This table explains about the different properties of Corrugated Boxes, Folding Cartons, and Rigid Box.

8. Methods:

To do Experimental and Analytical Testing of Windows in Paperboard packaging. The two methods performed are Experimental and Analytical.

8.1. Experimental:

To Perform Crash test for the different shapes of windows to the same type of Paperboard Packaging and to analyze the damage done to the package. Three different shapes for windows are Triangle, Square, and Circle and totally there were 15 packages, 5 in each of the shapes. The Paperboard used here is Arktika and it is 300 grammage. The dimension of this paperboard packaging is 40*20 cm.

Every Package weighed the same. Crash test was carried out for Circle, Triangle, Square separately for the 5 packages out of 15 packages to obtain three different graphs for Circle, Triangle, and Square windows Packaging. Experiment 1 was carried out for Square, Experiment 2 for Circle and Experiment 3 for Triangle respectively.

8.2. Equipment used:

The experimental setup is explained in Figure 1. A tension-compression stand, Tinus Olsen H10KT, was equipped with a fixed plates and sensor.

Experimental tests were carried out by using the same type cardboard packaging with three different shapes of cuttings.

The tests were carried out at the temperature of 20±2°C and air humidity 65± 2%.

Compressive stands top plate 3, during compression has moved 12.5 mm/min speed. Deformation data were recorded on a computer with specialized software QmatPro 1.0.20 support. Compressive strength was used for graphic paperboard packaging with different forms of the local cut-out (Fig 14). In determining the geometric shape of the compression, the survey provides five samples with a square window, the same number of samples with triangular and circle-shaped windows.

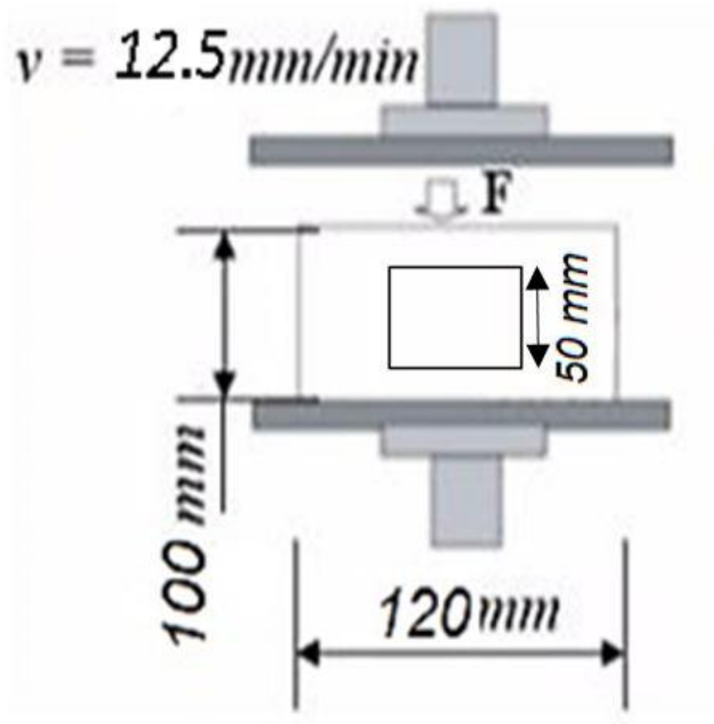


Figure 12: General view of the equipment and samples used for studying the compression process of paperboard packages: Geometric parameters and operation principles of the package

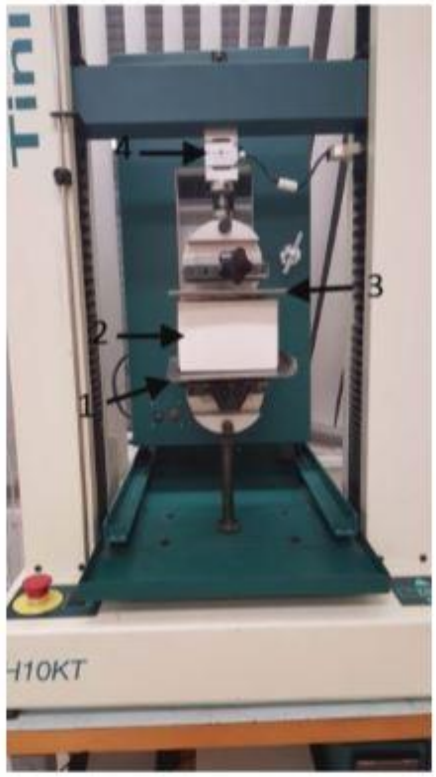


Figure 13: Compression test view of a package under the action of vertical load F, N: 1 – bottom base plate, 2 – package under compression, 3 – top base plate, 4 – sensor

Figure 14: Testing Equipment used

Figure 15: Paperboard Packages

These are the 15 packages made for Experimental Testing. 5 packages for circle shaped Window, Triangle shaped window, and Rectangle shaped window respectively. The dimension of each box is same but the windows shape dimensions of Square, Triangle, Circle differs as they are of different shapes.

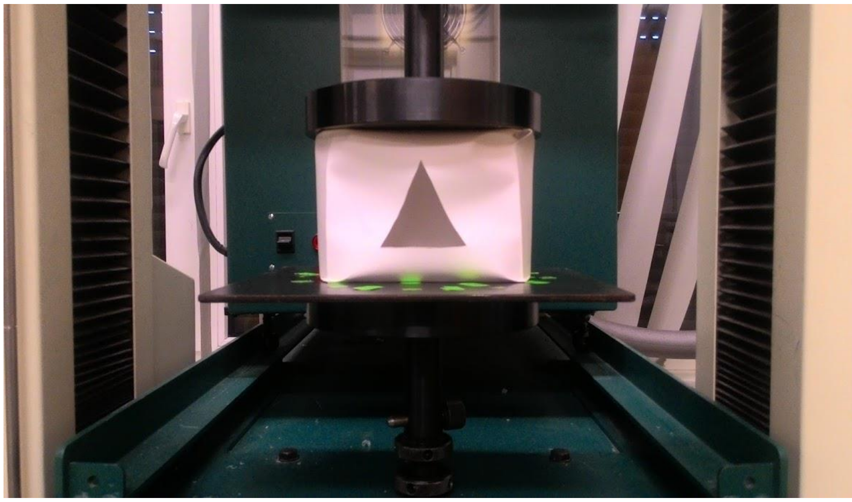


Figure 16: Crashing test

This Figure shows the package when the Crash test is carried out for triangle shaped windows Packaging and the deformation of the package under crash test is shown.

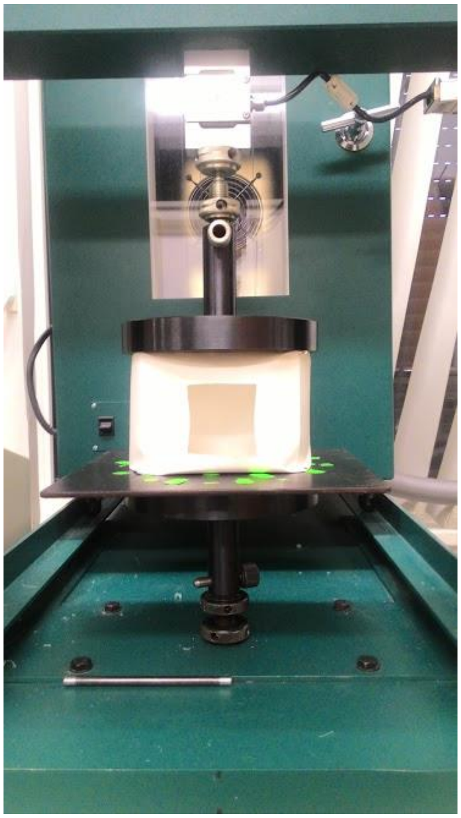


Figure 17: Crash Test

This Figure shows the package when the Crash test is carried out for triangle shaped windows Packaging and the deformation of the package under crash test is shown clearly.

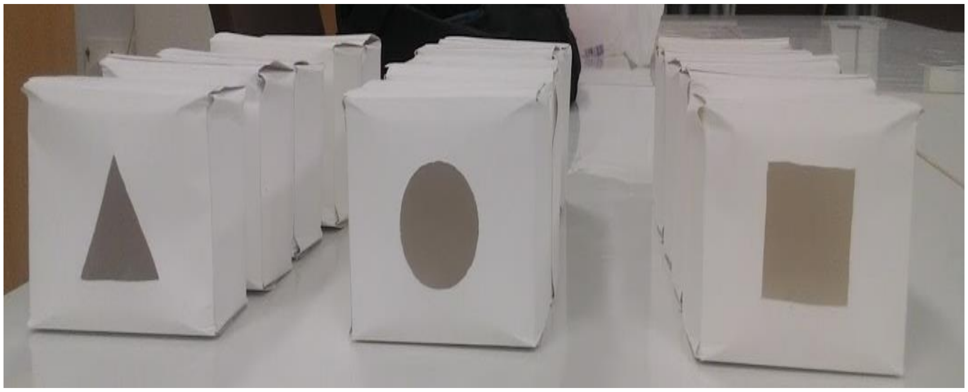


Figure 18: Crashed Paperboard Packages

This figure shows all the Crashed packages after the experimental testing is carried out. The deformation for each package can be seen clearly.

9. Experimental Results:

- The load bearing capacity for Square window is given by the graph below:

Figure 19: Experimental Graph Results for Square windows

The graph shows the experimental results for all the square windows. The Extension is displayed in X-axis in mm and to the Force in Y-axis. The maximum force is at 162.6 N and stress at break point is 0.0211 Mpa.

- The load bearing capacity of Triangle window is given by the graph below:

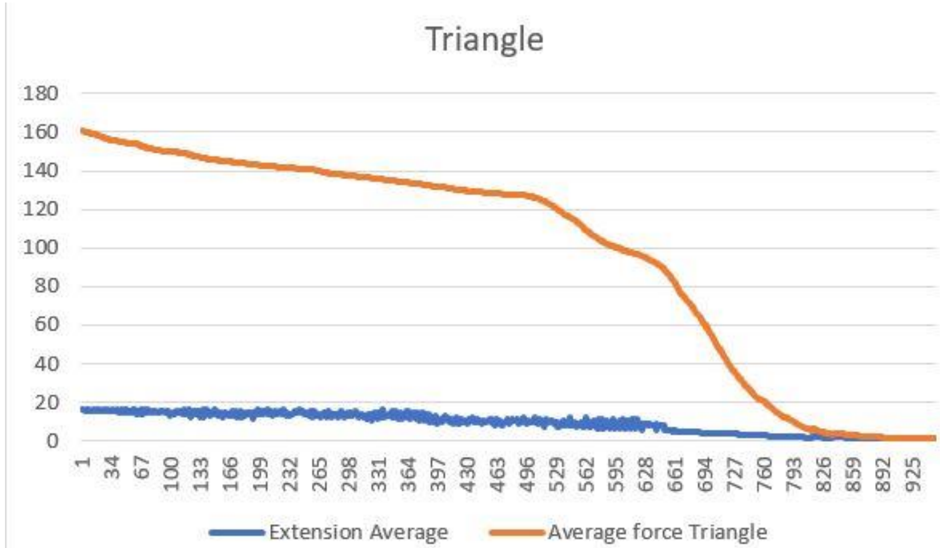


Figure 20: Experimental Graph Results for Triangle Windows

The graph shows the experimental results for all the Triangle windows. The Extension is displayed in X-axis in mm and to the Force in Y-axis. The maximum force is at 160.68 N and stress at break point is 0.0171 Mpa

- The load bearing capacity of Circle window is given by the graph below:

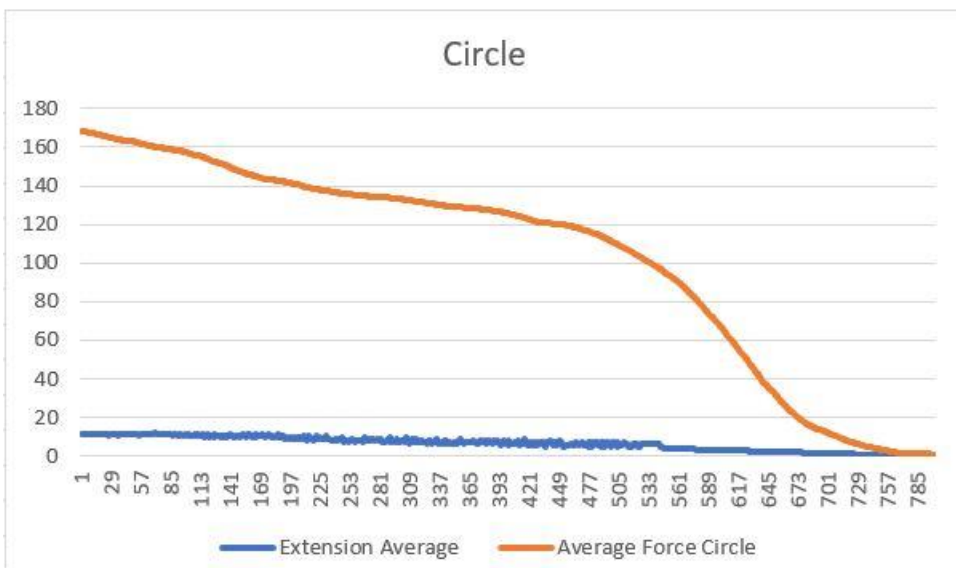


Figure 21: Experimental Graph results for Circle Windows

The graph shows the experimental results for all the Circle windows. The Extension is displayed in X-axis in mm and to the Force in Y-axis. The maximum force is at 168.31 N and stress at break point is 0.0242 Mpa.

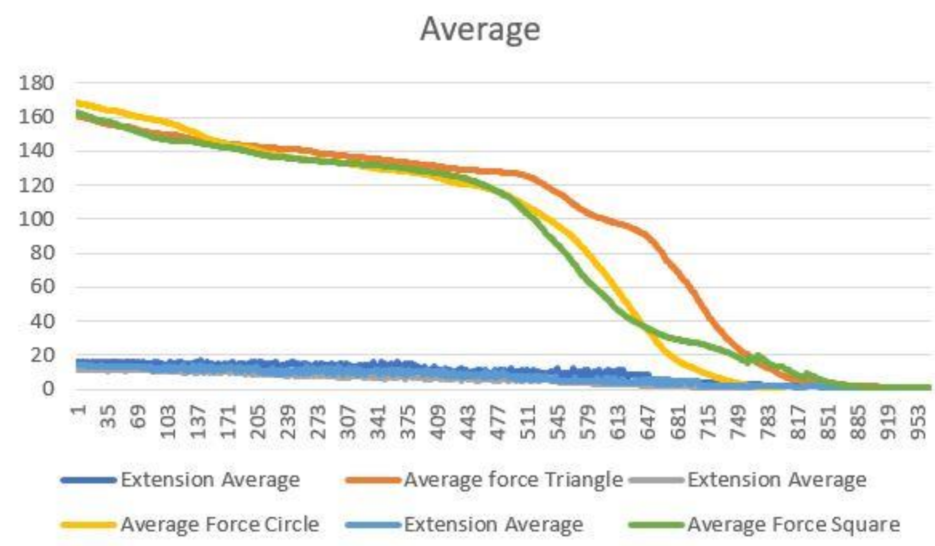


Figure 22: Average Compiled Graph results

This Graph is a compilation of all the average Extension and average force capability for each window shapes. The circle window is capable of taking more load and less deformation while the Triangle shows more deformation even with lesser load values.

10.Experimental Result Analysis:

1. From the experimental data, we have found out that Square window bears a maximum force of 162.6 N with a maximum stress of 0.0211 Mpa
2. From the experimental data, we have found out that Triangle window bears a maximum force of 160.68 N with a maximum stress of 0.0171 Mpa
3. From the experimental data, we have found out that Circle window bears a maximum force of 168.31 N with a maximum stress of 0.0242 Mpa

11.Analytical:

11.1.Solid Works:

Solid modeling is a predictable arrangement of standards for numerical and PC demonstrating of three-dimensional solids. Strong demonstrating is recognized from related ranges of geometric displaying and PC illustrations by its accentuation on physical devotion. Together, the standards of geometric and strong demonstrating from the establishment of PC helped plan and when all is said in done bolster the creation, trade, representation, movement, cross-examination, and comment on computerized models of physical articles.

Originally, solid modelers were based on solid objects being formed by primitive shapes such as a cone, torus, cylinder, sphere, and so on. This evolved into solid objects being created and formed from swept, lofted, rotated, and extruded 2D wireframe or sketch geometry.

Solid Works feature-based, associative solid modeling software. It is one of a suite of 10 cooperative applications that give strong demonstrating, get together displaying, 2D orthographic perspectives, limited component investigation, immediate and parametric demonstrating, sub-divisional and NURBS surfacing, and NC and tooling usefulness for mechanical planners. Solid Works offers a range of tools to enable the generation of a complete digital representation of the product being designed. In addition to the general geometry tools, there is likewise the capacity to create the geometry of other coordinated outline teaches, for example, modern and standard pipework and finish wiring definitions. Devices are likewise accessible to bolster community oriented improvement.

1. Open ⟹ New ⟹ Part ⟹ Select any plane ⟹ Sketch (Draw Square or Circle or Triangle; In case of rectangle, go to center rectangle and give dimensions for exact size of each shape)

2. Go to Features ⟹ Extrude

3. Exit the sketch

4. In Feature select the option Shell and then select front face; Give value of diameter as 0.5 mm in the pop window then pick Mark

5. Hollow shape will appear

6. Extrude it with the thickness of 0.5 mm and select the front face and draw the required shape for windows (Square or triangle or circle) and give dimension as 0.5 mm

7. Go to Feature ⟹ Extrude Cut

8. The first five steps are similar since the 3 packages are same but only the windows differ.

9. Repeat the steps 6 and 7 for a hollow cut for windows for different shapes.

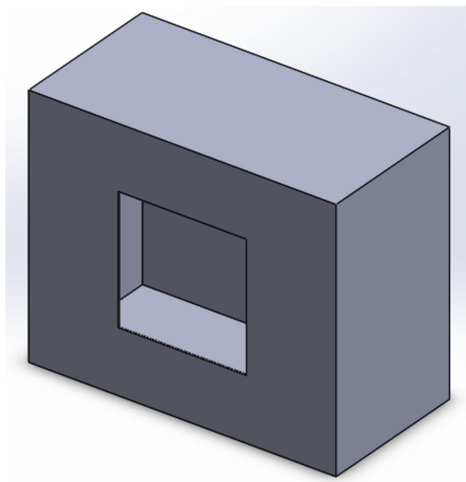


Figure 23: Picture of square window package in SolidWorks

This Figure shows the solid works picture for the square shaped window package.

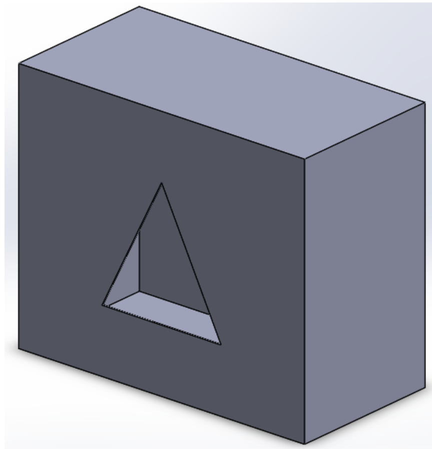


Figure 24: Picture of triangle window package in SolidWorks

This Figure shows the solid works picture for the Triangle shaped window package.

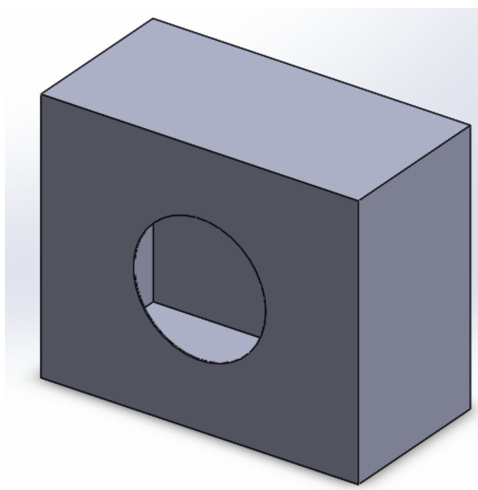


Figure 25: Picture of circle window package in SolidWorks

This Figure shows the solid works picture for the Circle shaped window package.

11.2.SolidWorks Isometric View:

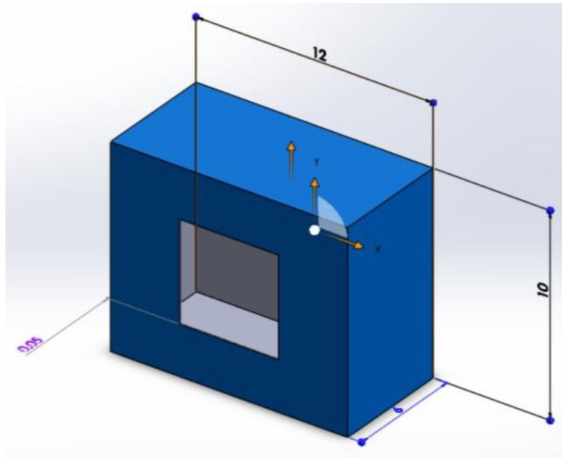


Figure 26: Isometric View of Square Window Package

This Figure shows the isometric view of square window package using solid works.

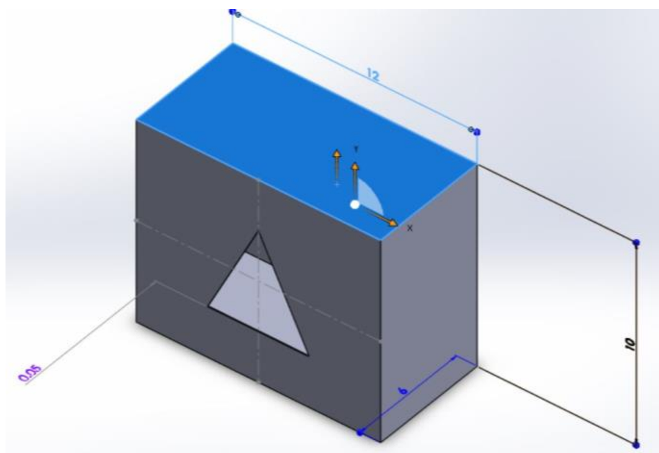


Figure 27: Isometric View of Triangle Window Package

This Figure shows the isometric view of Triangle window package using solid works.

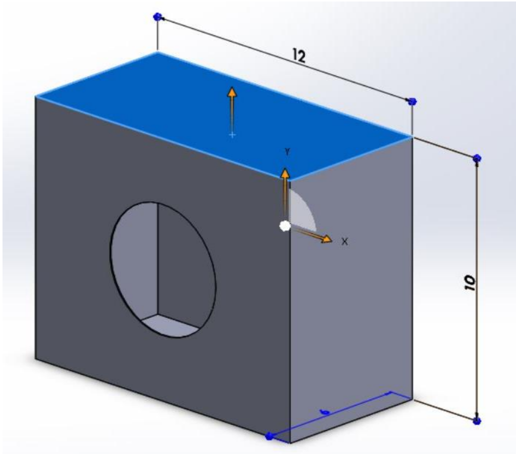


Figure 28: Isometric View of Circle Window Package

This Figure shows the isometric view of Circle window package using solid works.

All the 3 packages have the same dimensions except the windows. The basic dimension of the box is given below:

Length= 12 cm

Breadth= 10 cm

Width= 6 cm

Thickness= 0.05 cm

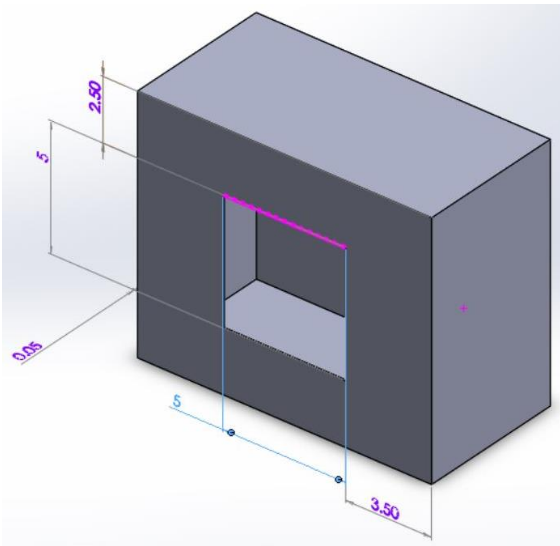


Figure 29: Dimensional View of Square Window Package

The square of side 5 has been cut off from the box of thickness 0.5 mm and is placed 2.5 cm from the top and 3.5 cm at the sides.

This Figure shows the Dimensional view of square window package using solid works.

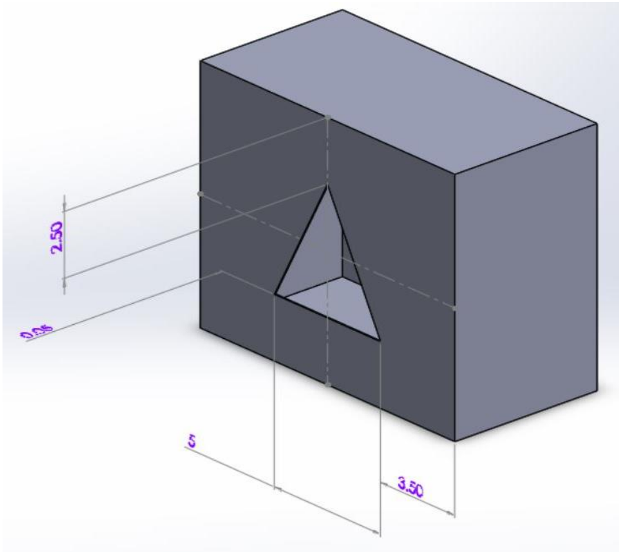


Figure 30: Dimensional View of Triangle Window Package

The triangle of height 5 cm and base 5 cm with an angle of 63.43, 63.43 & 53.14 degree and sides of 5.59cm has been cut off from the box of thickness 0.5 mm and is placed 2.5 cm from the top and 3.5 cm at the sides.

This Figure shows the Dimensional view of Triangle window package using solid works.

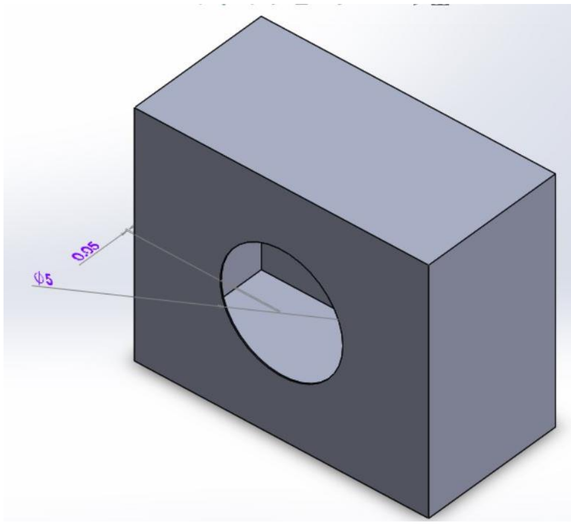


Figure 31: Dimensional View of Circle Window Package

This Figure shows the Dimensional view of Circle window package using solid works.

The circle of diameter 5 cm has been cut off from the box of thickness 0.5 mm and is placed 2.5 cm from the top and 3.5 cm at the sides.

11.3.Ansys:

- Ansys 14.0 is used here for Analysis.
- The drawings from Solidworks are imported to Ansys using step format.

Generally, Analysis is divided into 3 types:

1. Pre-Processor
2. Solver
3. Post-Processor

Pre-Processor includes Geometry Model, Material Property, Mesh and Boundary Conditions.

- Solver- Run and solve to get results.
- Post-Processor- To get Results.

11.3.1. Steps:

1. In static structural click Geometry option and Import the Geometry.
2. In Engineering Data give the material properties as input to get the results.
3. Go to Model and do Meshing to get the accurate results.
4. Give the values of Boundary Conditions to support the loads.
5. Then click Solve and Run to check conditions.
6. Finally, the result will be processed.

The Input values are given to get the required output or results. The Values given are:

- Young's Modulus,
- Poisson's Ratio and
- Density

11.3.2. Calculations:

1. For Circle:

   a) Young's Modulus (E):

E = stress / strain

(or)

$= \sigma / \varepsilon$ = Compressive stress/ Compressive strain

Stress(σ) = F / A

Where,

F = Load; A = Area

F = 0.002 N

$A = 2*(LW+WH+HL) - 2\Pi r$

$= 2*\{(0.12*0.06) + (0.06*0.1) + (0.1*0.12)\} - (2*3.14*0.025)$

$= 2*(0.072+0.006+0.012) – (0.157)$

$= (2*0.09) – (0.157)$

$= 0.18 – 0.157$

$= 0.023\ m^2$

Stress(σ) = 0.002 / 0.023

$= 0.0869\ N/m^2$

Strain = Δl / L

= Change in Length / Original Length

= 0.122 / 0.12

= 1.01

E = 0.0869 / 1.01

$= 8.6e^{(-11)}$ GPa

   b) Poisson's Ratio (μ):

$\mu = - \varepsilon l / \varepsilon t$

where,

εt = transverse strain or lateral strain

εl = longitudinal or axial strain

Strain can be expressed as,

$\varepsilon l = (L' - L) / L$

where,

L'= change in length (m)

L = initial length (m)

= (0.122 – 0.12) / 0.12

= 0.0166

$\varepsilon t = (d'-d)/d$

where,

d' = Change in height (m)

d = Initial height (m)

= (0.0947 – 0.1) / 0.1

= -0.053

$\mu = - \varepsilon l / \varepsilon t$

= - 0.0166/ (- 0.053)

= 0.31

For most common materials, the Poisson's ratio is in the range 0 - 0.5

c) Density (ρ):

$\rho = m/v$

ρ = density

m = mass, in g

V = volume, in cubic cm

= 23.94 / 23.94

= 1.00 grams per cubic centimeter

2. For Triangle:

a) Young's Modulus (E):

E = stress / strain

(or)

$= \sigma / \varepsilon$ = Compressive stress/ Compressive strain

Stress(σ) = F / A

Where,

F = Load; A = Area

F = 0.002 N

A = 2* (LW+WH+HL) – (1/2*h*b)

= 2* {(0.12*0.06) + (0.06*0.1) + (0.1*0.12)}- (1/2*0.0025)

= 2* (0.072+0.006+0.012) – (0.00125)

= 0.18 – 0.00125

= 0.17875 m^2

Stress(σ) = 0.002 / 0.17875

= 0.01118 N/m^2

Strain = Δl / L

= Change in Length / Original Length

= 0.124 / 0.12

= 1.033

E = 0.01118 / 1.033

= $1.73e^{(-10)}$ GPa

b) Poisson's Ratio (μ):

μ = - εl / εt

where,

εt = transverse strain or lateral strain

εl = longitudinal or axial strain

Strain can be expressed as,

εl = (L' - L) / L

where,

L'= change in length (m)

L = initial length (m)

= (0.125 – 0.12) / 0.12

= 0.04166

εt = (d'-d)/d

where,

d' = Change in height (m)

d = Initial height (m)

= (0.09 – 0.1) / 0.1

= -0.1

$\mu = - \varepsilon l / \varepsilon t$

= - 0.04166/ (- 0.1)

= 0.33

For most common materials, the Poisson's ratio is in the range 0 - 0.5

c) Density (ρ):

ρ = m/v

ρ = density

m = mass, in g

V = volume, in cm^3

= 24.30 / 24.30

= 1.00 grams per cubic centimeter

3. For Square:

a) Young's Modulus (E):

E = stress / strain

(or)

= σ / ε = Compressive stress/ Compressive strain

Stress(σ) = F / A

Where,

F = Load; A = Area

F = 0.002 N

A = 2* (LW+WH+HL) – (a^2)

= 2* {(0.12*0.06) + (0.06*0.1) + (0.1*0.12)}- $(0.05)^2$

= 2* (0.072+0.006+0.012) – (0.0025)

= 0.18 – 0.0025

= 0.1775 m^2

$$Stress(\sigma) = 0.002 / 0.1775$$

$$= 0.01126 \ N/m^2$$

$$Strain = \Delta l / L$$

= Change in Length / Original Length

$$= 0.123 / 0.12$$

$$= 1.025$$

$$E = 0.01126 / 1.025$$

$$= 1.09e^{(-11)} \ GPa$$

b) Poisson's Ratio (μ):

$$\mu = - \varepsilon l / \varepsilon t$$

where,

εt = transverse strain or lateral strain

εl = longitudinal or axial strain

Strain can be expressed as,

$$\varepsilon l = (L' - L) / L$$

where,

L'= change in length (m)

L = initial length (m)

$$= (0.123 – 0.12) / 0.12$$

$$= 0.025$$

$$\varepsilon t = (d'-d)/d$$

where,

d' = Change in height (m)

d = Initial height (m)

$$= (0.093 – 0.1) / 0.1$$

$$= -0.07$$

$$\mu = - \varepsilon l / \varepsilon t$$

$$= - 0.025 / (- 0.07)$$

$$= 0.35$$

For most common materials, the Poisson's ratio is in the range 0 - 0.5

c) Density (ρ):

ρ = m/v

ρ = density

m = mass, in g

V = volume, in cm^3

= 23.67 / 23.67

= 1.00 grams per cubic centimeter

11.3.3. Meshing:

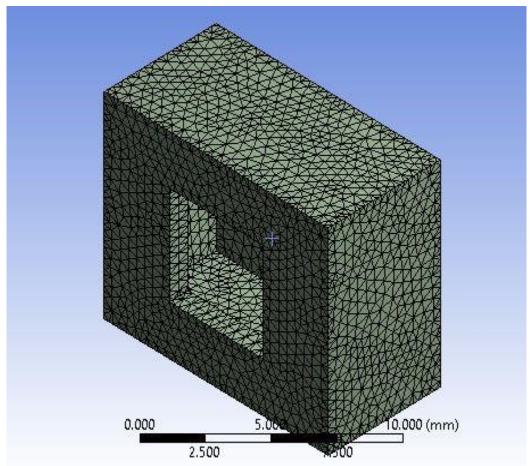


Figure 32: Meshing of Square Windows

This Figure Shows Meshing of Square Window Packaging using Ansys.

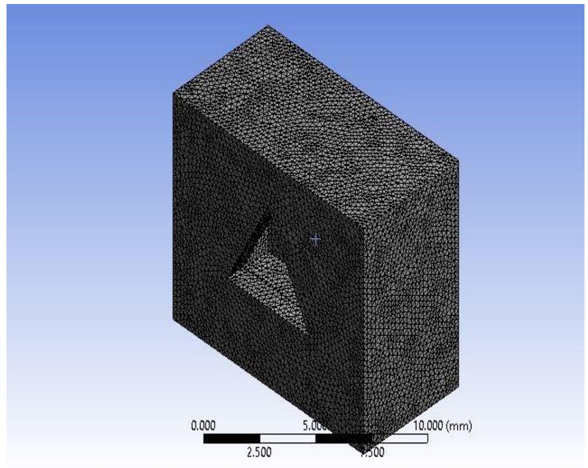


Figure 33: Meshing of Triangle Windows

This Figure Shows Meshing of Triangle Window Packaging using Ansys.

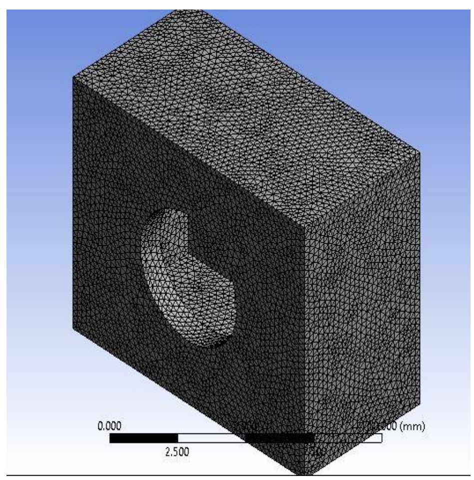


Figure 34: Meshing of Circle Windows

This Figure Shows Meshing of Circle Window Packaging using Ansys.

- Meshing divides the whole component into several sub-Components to analyze each sub-component precisely.

11.3.4 Analysis:

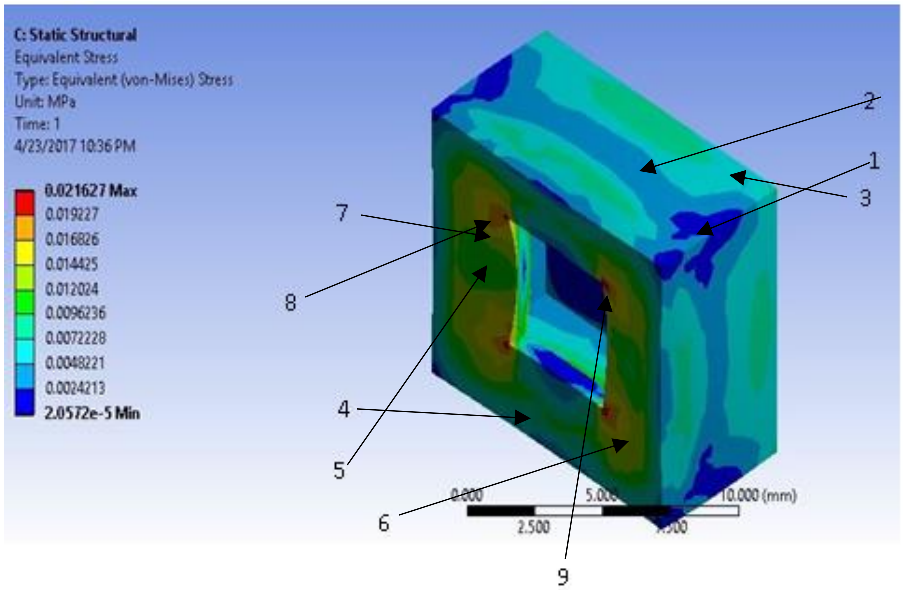


Figure 35: Analysis of Square Windows: where 1 - the minimum stress (2.0572 e-5); 9 – maximum stress (0.021627)

The Figure shows the analysis carried out for Square windows Package using Ansys. The different stress acting at different points are as follows:

1. 2.0572 e^{-5}
2. 0.0024213
3. 0.0048221
4. 0.0072228
5. 0.0096236
6. 0.012024
7. 0.014425
8. 0.016826
9. 0.019227
10. 0.021627

The amount of stress acting at a point is given by the color code with the highest point of stress being 0.021627 and the lowest being 2.0572 e^{-5}.

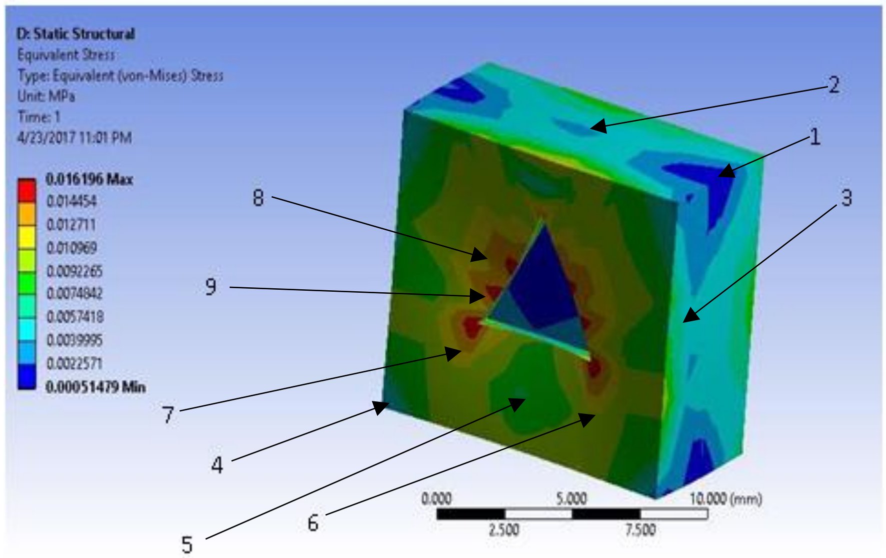


Figure 36: Analysis of Square Windows: where 1 - the minimum stress (0.00051479);

The Figure shows the analysis carried out for Triangle windows Package using Ansys. The different stress acting at different points are as follows:

1. 0.00051479
2. 0.0022571
3. 0.0039995
4. 0.0057418
5. 0.0074842
6. 0.0092265
7. 0.010969
8. 0.012711
9. 0.014454
10. 0.016196

The amount of stress acting at a point is given by the color code with the highest point of stress being 0.016196 and the lowest being 0.00051479.

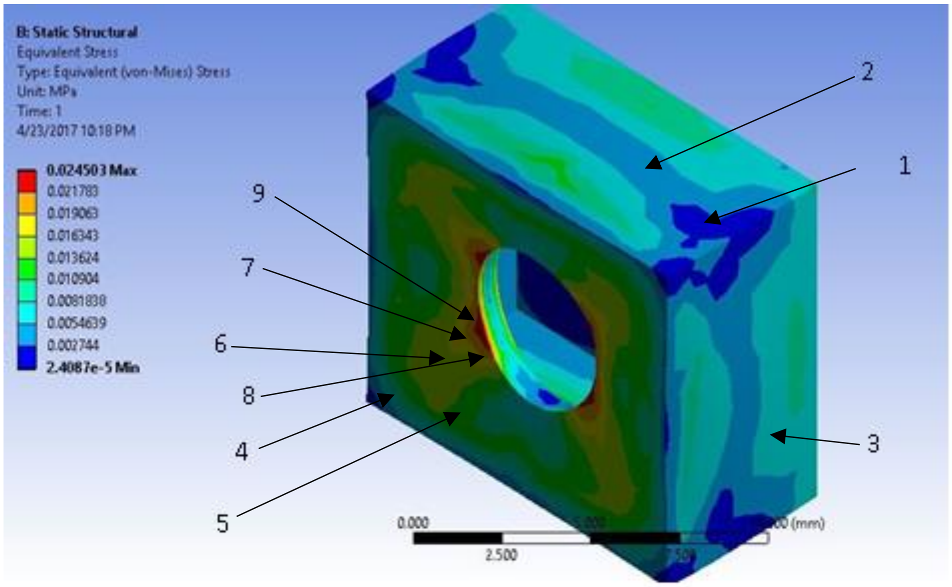


Figure 37: Analysis of Square Windows: where 1 - the minimum stress (2.4087 e^ (-5));

The Figure shows the analysis carried out for Circle windows Package using Ansys. The different stress acting at different points are as follows:

1. $2.4087e^{-5}$
2. 0.002744
3. 0.0054639
4. 0.0081838
5. 0.010904
6. 0.013624
7. 0.016343
8. 0.019063
9. 0.021783
10. 0.024503

The amount of stress acting at a point is given by the color code with the highest point of stress being 0.024503 and the lowest being $2.4087e^{-5}$.

The minimum stress is at 1 and gradually the stress increases and the maximum is at 9 and the values of stress are shown in the pictures 33, 34 and 35 for Square, Triangle and Circle Window Packages.

12.Results:

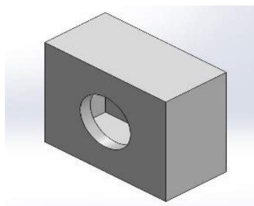
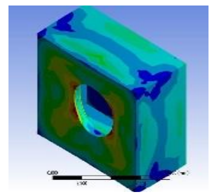
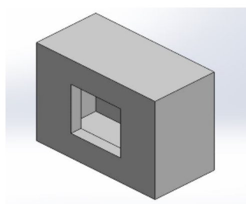
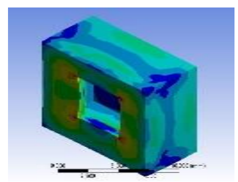
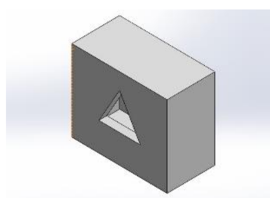
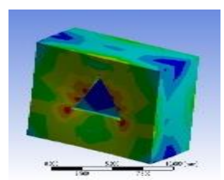
Shapes	Experimental (Max. Stress)	Analytical (Max. Stress)
Circle	0.0242 	0.0245 
Square	0.0211 	0.0216 
Triangle	0.0171 	0.0161 

Table 2: Results

- The circle window has a stress value of 0.0242 Mpa for experimental and 0.0245 Mpa for analysis.

- The Square window has a stress value of 0.0211 Mpa for experimental and 0.0216 Mpa for analysis.
- The Triangle window has a stress value of 0.0171 Mpa for experimental and 0.0161 Mpa for analysis.

Both Analytical and experimental results are similar when compared. From the results, it's found out that circle window has the highest load bearing capacity

12.1.Results verification:

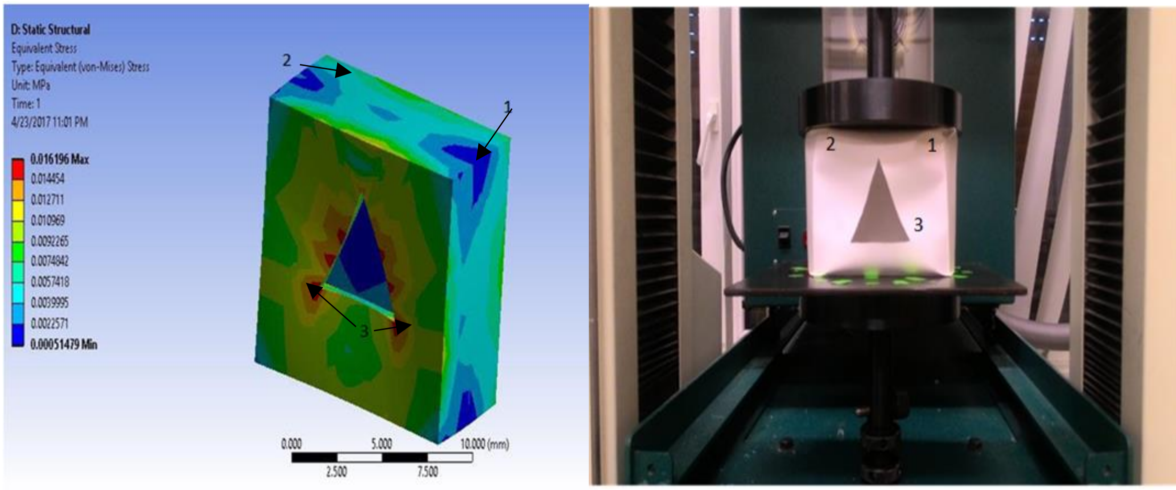


Figure 38: Experimental and Analytical Methods

At the point 1 and 2 act, the minimum stress whereas the maximum stress acts in point 3. It is clear from the above picture that the minimum and maximum stress acts exactly at the same point in both experimental and analytical.

13. Conclusions:

- From the above results and calculations, it is concluded that the Circle Window Packaging provides Maximum Stress for the force applied compared to Triangle and Square and thus having more Strength.
- The three kinds of Packaging are tested and analyzed in Results and the results are same in both experimental and analytical and thus the results are accurate.
- The Square shaped window package stress value at break point for:
  a) Experimental- 0.0211 Mpa and b) Analytical- 0.0216 Mpa; Maximum force are at 162.6N and Extension of 7.96 mm.
- The Triangle shaped window package have stress value at break point for:
  a) Experimental-0.0171 Mpa and b) Analytical- 0.0161 Mpa; Maximum force are at 162.6N and Extension of 7.96 mm.
- The Circle shaped window package have stress value at break point for:
  a) Experimental- 0.0242 Mpa and b) Analytical- 0.0245 Mpa; Maximum force are at 162.6N and Extension of 7.96 mm.
- The Circle window has more Extension when compared with Square and Triangle windows.
- And from this experiment, it is also concluded that the experimental and analytical results are similar. So that, we can use analytical testing to reduce the wastage of paper or material used in experimental testing since both yields the same result and also reduces time.

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10. http://www.paperbagsltd.co.ke/assets/images/img-01.png
11. http://paperbox.org/portals/0/KNOWLEDGE/Paperboard%20Examples/aseptic%20packaging.jpg
12. http://paperbox.org/portals/0/KNOWLEDGE/Paperboard%20Examples/blister%20pack.jpg
13. http://paperbox.org/portals/0/KNOWLEDGE/Paperboard%20Examples/carded%20packaging.jpg.
14. http://paperbox.org/portals/0/KNOWLEDGE/Paperboard%20Examples/contour%20packaging.jpg
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