International Journal of Engineering and Science Invention (IJESI)
ISSN (Online): 2319-6734, ISSN (Print): 2319-6726
www.ijesi.org ||Volume 12 Issue 4 April 2023 || PP 57-65

Design and optimization of paperboard packaging using Finite element Modeling

Sathish Kumar Adapa[1], Sagar Yanda[2], R. Manoj[3], K.Suneel[4], M.Yatish[5], A.Lokesh[6], V.Harsha[7], K.Varaprasad[8]
Department of Mechanical Engineering, Aditya Institute of Technology and Management (A) Tekkali, India-532201

ABSTRACT: *Corrugated sheet boxes are produced in huge quantities for packaging purposes, a use that places a significant demand on their structural stability and strength. By examining several industrial boxes, it is discovered that the strength and resistance to deformation are weak. So, all deformation and strength in this study will be estimated by reducing clearance and changing the dimensions of the actual corrugated sheet box. In this paper we have adopted optimization to decrease its area and particular weight of the corrugated board using Finite Element Analysis (FEA), with improvement of the corrugated sheet box being the main focus of the current study.*

KEYWORDS - *Catia V, Corrugated packaging boxes , ANSYS*

Date of Submission: 09-04-2023 Date of Acceptance: 24-04-2023

I. INTRODUCTION

The most popular type for packaging is used for post-harvest handling and transporting of the fresh agricultural products is ventilated corrugated paperboard packaging. During transportation, the package may be exposed to moisture and other strength reducing parameters owing to various environmental factors. Normal and Supervened are the two commonly used varieties of ventilated paperboard packaging. The package's interior component is made up of a double "B" and "C" flute construction for both types of packing, while exterior component is made of a flute construction of the type "C." The quantity, size, and location of the various vent holes are the only differences between the two packages. The "Supervent" container features half-circular vent openings at the top and bottom of the sides, whereas the "Regular" container has two circular vents on each side at half height. Fresh fruit companies are increasingly using ventilated corrugated paperboard packaging because it allows for quick, consistent chilling and air distribution of the packed product while using the least amount of interior packaging material. Figure 1 shows a corrugated box that is used commonly for packaging.

Figure 1 Fabrication of Corrugated box

II. NUMERICAL SIMULATION AND PROCEDURE

Tear strength serves as a gauge for how well a material can tolerate tearing. Burst strength (Mullen burst test) is a useful metric for assessing the effectiveness of cold chain wrapping. An industry standard known as "burst strength" quantifies the level of force needed to rupture corrugated boxes and packing materials. Fold ability is the state or condition of being foldable. High elasticity is where the elasticity at which the number exceeds 1.0; indicates that there is change in the price of the good or service has an outsized impacts up on consumer's demand. TABLE 1 shows specifications of the paper board used for the boxes.

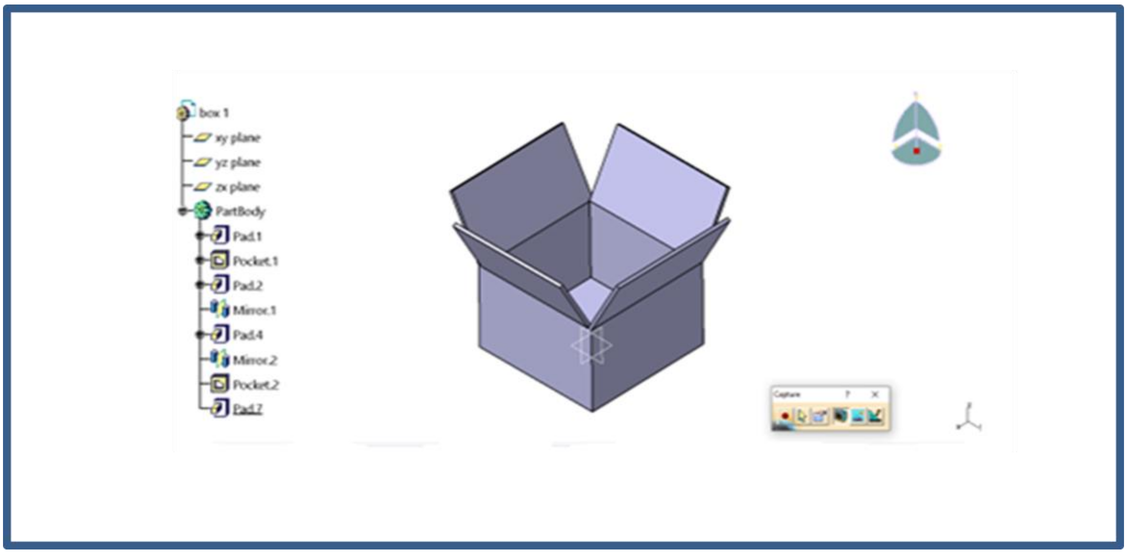
TABLE 1: Specifications of paper board used for the boxes

Properties	**Paperboard values**
Density	404.5 kilogram/m^3
Poisson's ratio (µ)	0.3
Young's modulus (Mega Pascal)	7600
Thermal expansion (kilo degree)	3.75E-6
Reference Temperature	27°C
Tensile Yield strength (Mega Pascal)	0.999
Compressive Yield strength (Mega Pascal)	1
Ultimate Tensile stress (Mega Pascal)	1.8
Ultimate Compressive stress (pa)	0

III. RESULTS AND DISCUSSIONS

3.1 Corrugated sheet box experimental and numerical analysis 1:

Product No.1 (Mahindra Company)
Numerical analysis with different product dimensions can be made for Mahindra Company corrugated boxes
Product dimension (mm):
l x b x h = $350 \times 350 \times 200$
Current box dimensions for Product No. 1
Outer dimensions of box = $390 \times 390 \times 240$
Inner dimension of box = $380 \times 380 \times 240$
Weight of the product = 18kg Box type = 7ply



Area of the box 1:

$$Length + width + 50............(1)$$

$$Width + height + 25........(2)$$

$$A = (1) \times (2)$$

$$390 + 390 + 50 = 830$$

$$390 + 240 + 25 = 655$$

$$A = 830 \times 655 = 543650 mm^2$$

$$Area = 0.54 m^2$$

Weight of the box: Area x used paper

Given that the box is of 7ply, so there are four plan layers and three flutes present. The inner layer's paper is , the outer layer's paper is $200 gsm$, and the flute paper is 40% larger than the plan paper. For upper layer,

$$200 \times 1 = 200 gms$$

Inner layer, $120 \times 3 = 360 gms$

For the flute layer is, $168 \times 3 = 504 gms$

:. The total paper is $1604 gms$

W = area x total paper

$$Weight = 0.54 \times 1064 = 0.574 kg$$

For those parts specified by edge crush test (ECT):

Weight of box in n/width of box in m = (0.574 x 9.81) ÷0.390 = 14.438 N/m

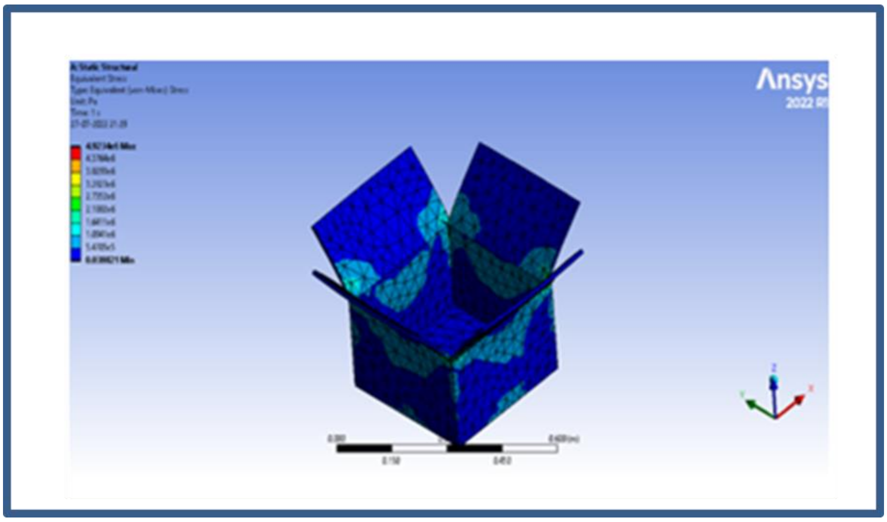


Figure 3 Equivalent stress for packaging box 1 of Mahindra Company

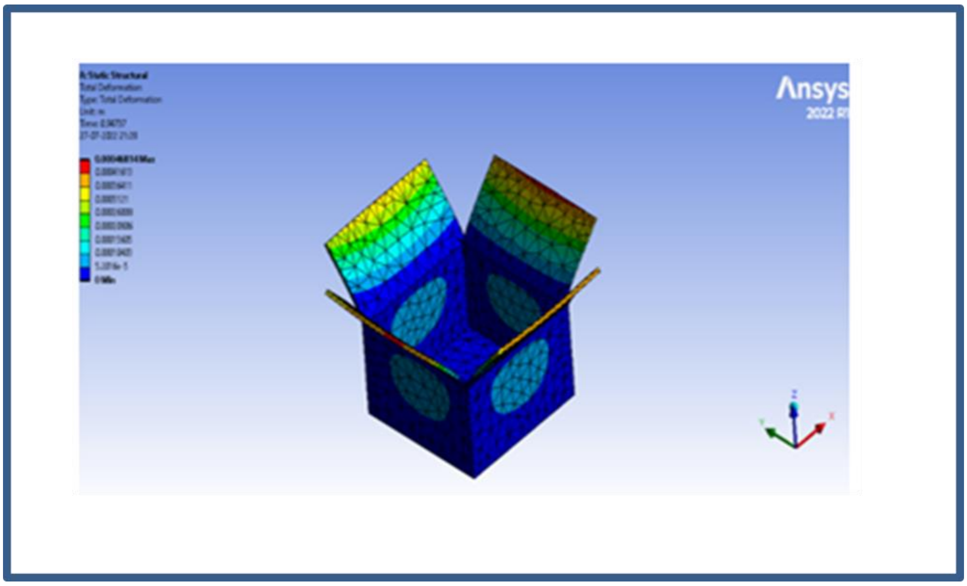


Figure 4 Total deformations for packaging box 1 of Mahindra Company

Design of the boxes by trial-and-error approach of box 1
We need to consider,
Outer dimension of box = $375 \times 375 \times 225$
Inner dimension of box = $365 \times 365 \times 215$
Area:

$$Length + width + 50.......(1)$$

$$Width + height + 25.......(2)$$

$$Area = (375 + 375 + 50) \times (375 + 225 + 25)$$

$$Area = 0.5m^2$$

Weight= Area x Paper that is used

$$Weight = A \times 1064$$

$$Weight = 0.5 \times 1064 = 0.532kg$$

ECT:
Weight of the box in n/width of the box in m = $(0.532 \times 9.81) \div 0.375 = 13.91N/m$

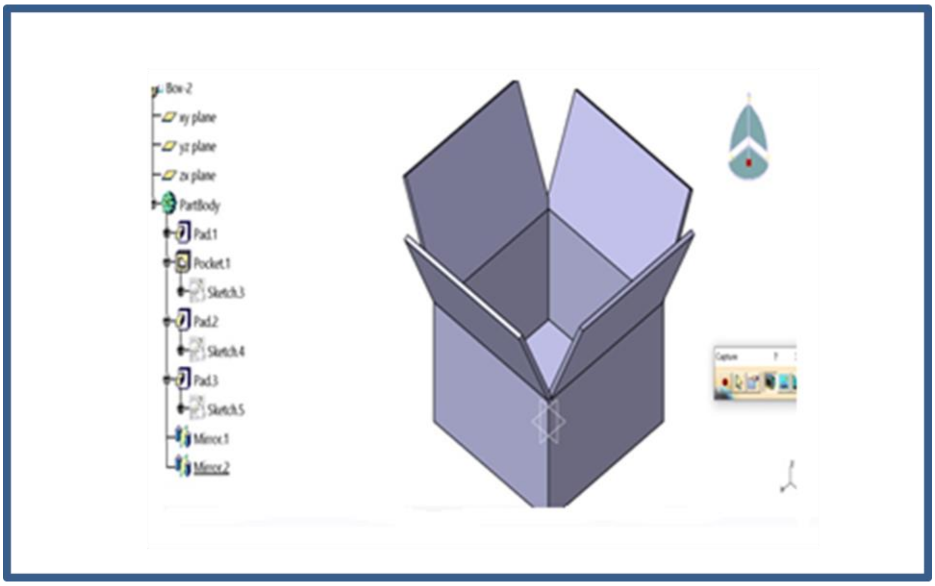


Figure 5 CAD model of second considered product

Numerical consideration for second considered box:

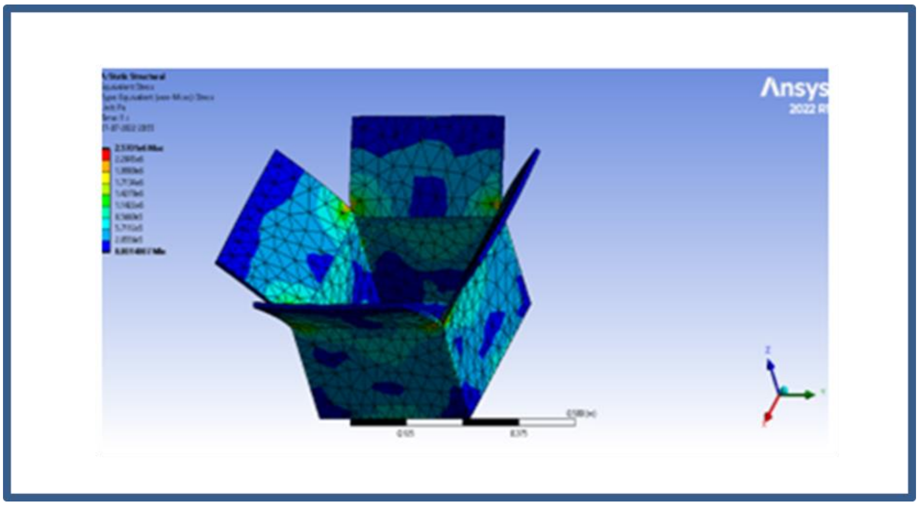


Figure 6 Equivalent stress for packaging box 2 of Mahindra Company

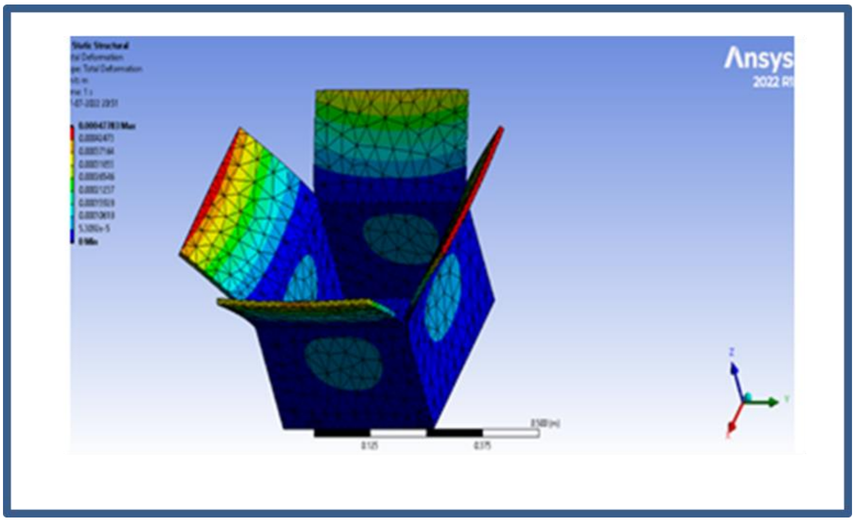


Figure 7 Total deformations for packaging box 2 of Mahindra Company

Table 2 shows the optimum dimensions of corrugated sheet box of Mahindra Company

Dimensions *mm*	*Area* (m^2)	*Weight* (kilogram)	Minimum Bursting test (BCT) (kilopascal)	Minimum edge crush test (ECT) (N/m)	(*Deformations*) (m)	Stress (kilopascal)
$390 \times 390 \times 240$	0.54	0.574	474.3	14.438	0.0001468	492.34
$375 \times 375 \times 225$	0.5	0.532	474.3	13.91	0.0001477	257.01

3.2 For the Bpergo Company's corrugated sheet box, experimental and numerical analysis:

Product no.2 (Bpergo Company)
Numerical analysis with different product dimensions can be made for Bpergo Company corrugated boxes
Numerical result for box1:
Design of boxes for box 1's trial-and-error methodology
First consideration:
Dimension (mm)
Product dimension:

$L \times w \times h = 580 \times 580 \times 830$

Current Box dimension for product
Outer dimension of Box: $620 \times 590 \times 870$

Inner dimension of Box: $610 \times 580 \times 860$

Weight of product: $30kg$ Box type: $7\,ply$

Area of the Box:

$$Length + width + 50.......(1)$$

$$Width + height + 25.......(2)$$

$$(1) \times (2)$$

$$620 + 590 + 50 = 1260$$

$$590 + 870 + 25 = 1485$$

$$A = 1260 \times 1485$$

Area of the box = $1871100mm^2$

Area of the box= $1.8m^2$

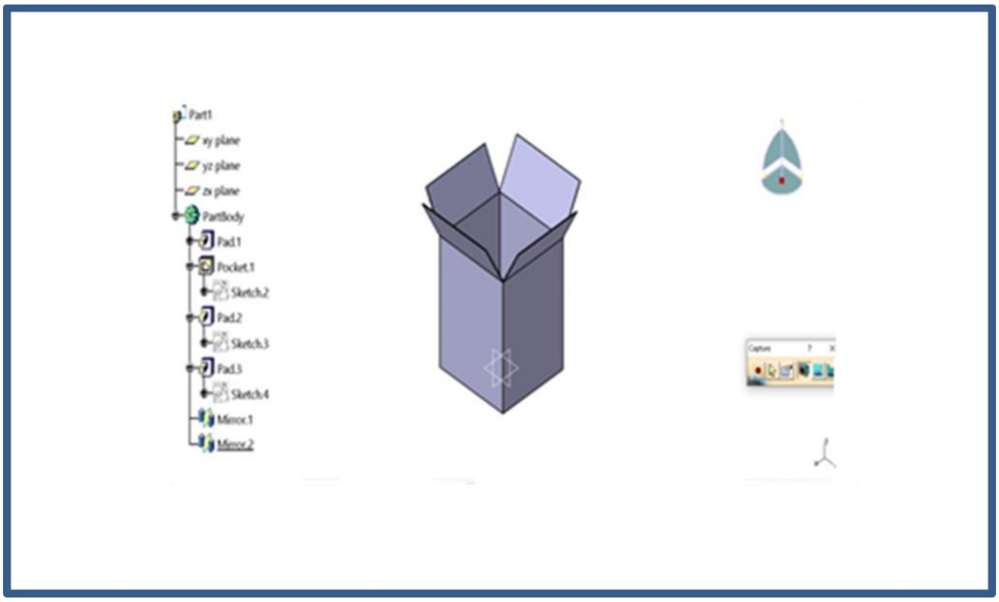


Figure 8 CAD model of product 1 of Bpergo company

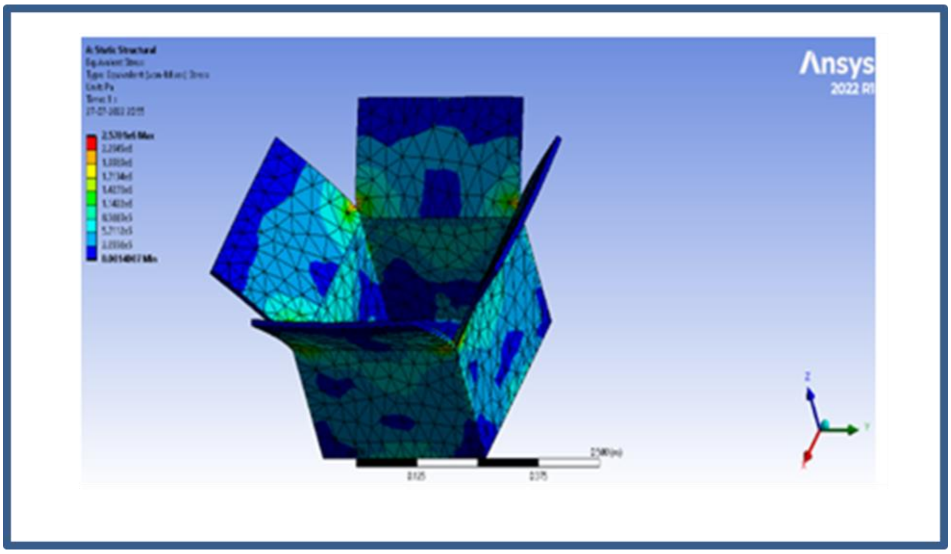


Figure 9 Equivalent stresses for packaging box 1 of Bpergo Company

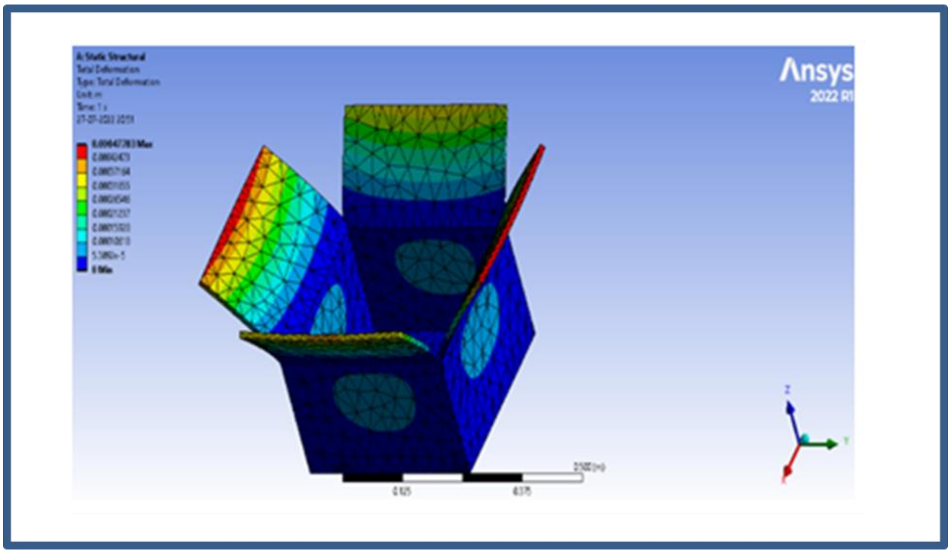


Figure 10 Total deformations for packaging box 1 of Bpergo Company

Weight of the Box:
Weight = Area x used paper
Upper layer: $200 \times 1 = 200gms$

Flute paper is used for the outer layer, which is 200gsm, and the inner layer, which is 120gsm, due to the box's 7-ply construction. As a result, there are 3 flute layers and 4 plane levels.

Inner layer: $120 \times 3 = 360gms$

For flute layer: $168 \times 3 = 504gms$

Since the total paper is $1064gms$

$W = 1.8 \times 1064 = 1915.2kg$

For the parts which are specified by Edge Crush Test (ECT):
Weigh of the box in $n \div 0.590 = 31.757N / m$
Burst Test:
A square specimen of 7-ply edges sheet (1 x 1 m2) and a compressor tester were used to acquire the results of the burst test done by the industry. The sheet's extreme borders were where the holding supports were fixed. The sample's burst speed is 474.3 kilopascal.Numerical result for box2:
Box 2 was created using a trial-and-error methodology.
First consideration:
Outer dimension of box: $610 \times 580 \times 860$
Inner diameter of box: $600 \times 570 \times 850$
Area of the box:

$$Length + width + 50......(1)$$

$$Width + height + 25.......(2)$$

$$A = (1) \times (2) mm^2$$

$$610 + 580 + 50 = 1240$$

$$580 + 860 + 25 = 1465$$

$$A = 1240 \times 1465 = 1816600 mm^2$$

Area of the box= $1.81m^2$

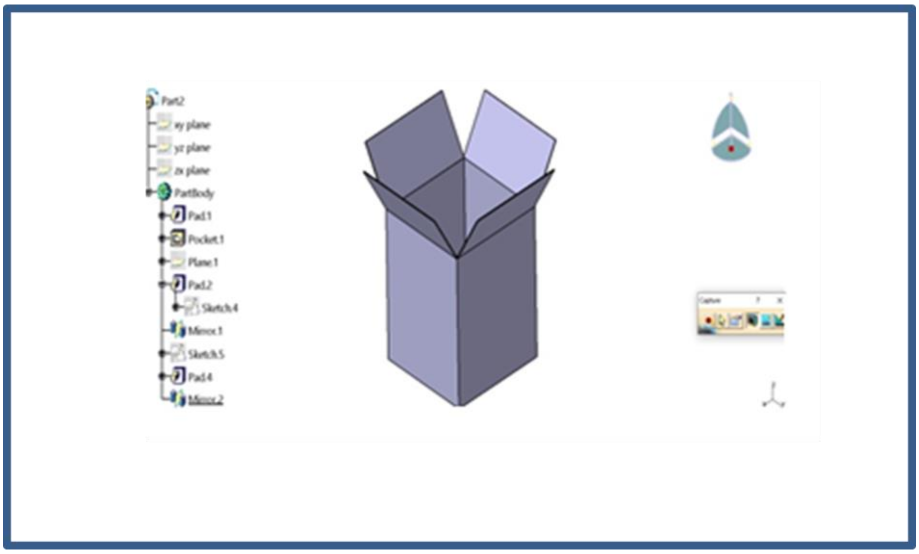


Figure 11 CAD model of second considered product

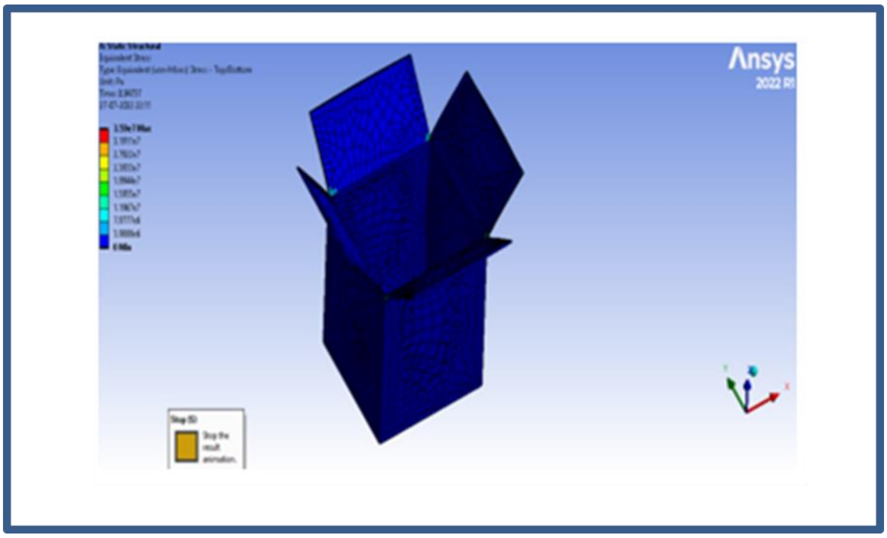


Figure 12 Equivalent stress for packaging box 2 of Bpergo Company

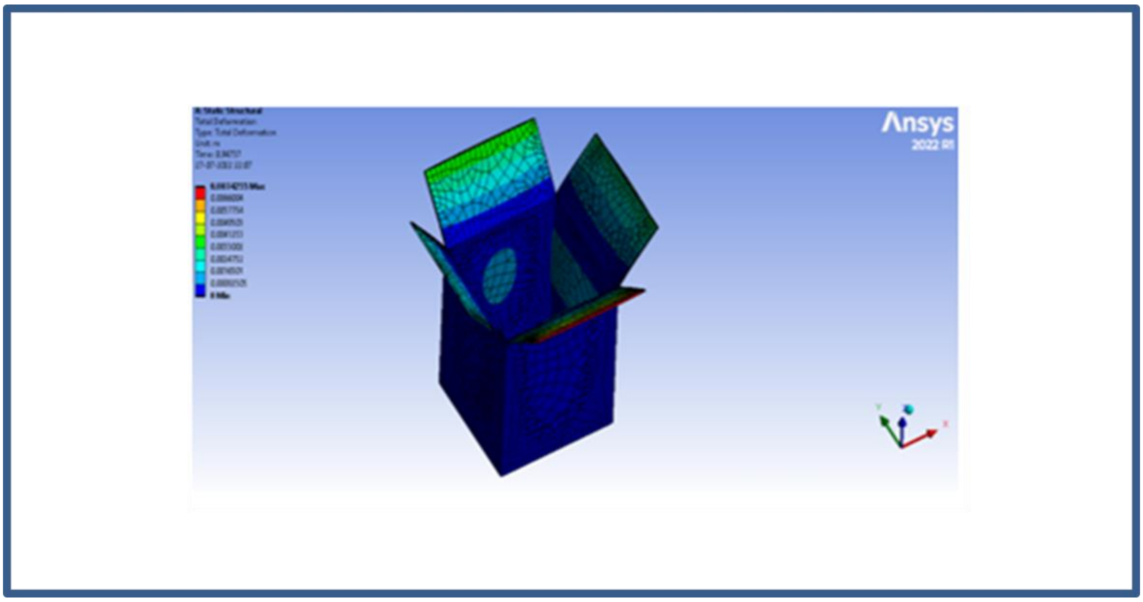


Figure 13 Total deformation for packaging box 2 of Bpergo Company

Weight of the box:
W=Area× used paper
Weight= $1.81 \times 1064 = 1925.84$

Weight of the box is $1.92kg$

For the parts, whichare specified by Edge Crush Test (ECT):
Weight of the box in n ÷ Width of the box in m $= (1.92 \times 9.81) \div 0.580 = 32.47 N/m$

Table 3

Table 3 shows the optimum dimensions of corrugated sheet box of Bpergo Company

Dimensions (mm)	*Area* (m^2)	*Weigh* (kg)	Minimum Bursting test(BCT)	Minimum edge crush test (ECT) (N/m)	*Deformations* (m)	Stress (kilopascal)
$620 \times 590 \times 870$	1.8	1.91	474.3	31.75	0.0007221	462.31
$610 \times 580 \times 860$	1.81	1.92	474.3	32.47	0.00072255	359.07

IV. CONCLUSION

By researching the various industrial boxes, it was discovered that the load-bearing strength and deformation of the boxes were weak. Thus, all deformations and box strength will be calculated in this work by reducing its clearance and changing the real corrugated sheet box's dimensions. This study demonstrates how the finite element analysis approach can be optimised in order to decrease the clearances between the product and the box dimensions. Deformation in finite element analysis result is extremely modest with reduced dimension and falls within acceptable results. According to the results of the above experiment, the maximum stress was discovered on actual box in relation on the product dimension using Finite Element Modelling and discovered by using a compressor tester machine. After reducing its clearance between the product and the box dimensions, we obtained different stress values, and we used these values to determine the ideal size of the box where the stress and deformation were found to be at their lowest values.

REFERENCES

[1] 'Tomasz Garbowski', 'Tomasz Gajewski', and 'Jakub Krzyszt of Grabski', 'Estimation of Compressive Strength of Corrugated Cardboard Boxes with Various Openings', 2021

[2] 'M. A. Jiménez-Caballero', 'I. Conde', 'B. García', and 'E. Liarte', 'Design of Different Types of Corrugated Board Packages Using Finite Element Tools', Jan. 2009.

[3] 'Daxner', 'Flatscher', and 'Rammerstorfer', 'Optimum Design of Corrugated Board under Buckling Constraints', pp. 349–358, May 2007

[4] 'ArsalanJamialahmadi', 'Experimental and numerical analysis of the dynamic load distribution Ina corrugated packaging system', pp. 1–56, Aug. 2008.

[5] 'Poorvi Patel', 'Tomas Nordstrand"', and 'Leif A. Carlsson', 'Local buckling and collapse of corrugated board under biaxial stress ', 1997

[6] M. A. Jiménez-Caballero, I. Conde, B. García, E. Liarte "Design of Different Types of Corrugated Board Packages Finite Element Tools"C/ María de Luna 7-8, 50007 Zaragoza. SPAIN

[7] Daxner, Flatscher, and Rammerstorfer, F.G. "Optimum Design of Corrugated Board under Buckling Constraints" COEX Seoul, 21 May - 25 May 2007, Korea

[8] ArsalanJamialahmadi "Experimental and numerical analysis of the dynamic load distribution in A corrugated packaging system" mechanical engineering at blekinge institute of techonology jan2008-aug 2008

[9] Tomas Nordstrand "Analysis and Testing of Corrugated Board Panels into the Post-buckling Regime" SCA Research, Box 716, 851 21 Sundsvall, Sweden

[10] P. Patel, Nordstrand, T. and Carlsson, L.A. "Local Buckling and Collapse of Corrugated Boardunder Biaxial Stress" Composite Structures, Vol. 39, No. 1- 2, pp. 93-110, 1997.

Sathish Kumar Adapa, et. al. "Design and optimization of paperboard packaging using Finite element Modeling." *International Journal of Engineering Science Invention (IJESI)*, Vol. 12(4), 2023, PP 57-65. Journal DOI- 10.35629/6734