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Optimization of Corrugated Sheet Box Size for an Industrial Part – A Case Study

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Abstract-Corrugated box produced in large volume for packaging purpose an application which place high demand on its strength and structural stability of the corrugated sheet box. while studying the different industrial boxes it detect that the deformation of the boxes and strength are weak in load bearing capacity.so in this paper all the deformation and strength will be calculated by Reduce the clearance and change in dimension of actual corrugated sheet box. This is finding out by using optimization procedure for reducing the area and specific weight of corrugated board by using FEA. The present study focused on the optimization of the corrugated sheet box.
Keywords— corrugated sheet box, finite element analysis, packaging, strength, craft paper

I. INTRODUCTION

Corrugated containers are the most important structural application of paperboard. Corrugated cardboard is a paper based on material that consisting of a fluted corrugated sheet and one or two flat linerboard. It is widely used in the manufacture of corrugated cardboard boxes and shipping containers. Corrugated paper replaced the plain paper which was used to keep the shape of the tall, stiff hats worn by gentlemen. It is a machine which is used to crease the corrugated sheet and along that creased edges, the sheet is folded to make the box. Corrugated cardboard pertaining to papers family is one of the most used packing currently. This success is due to the different quality of this material: good protection of the product, minimum cost and can be recycled. A transport package is required to be strong and light weight in order to be effective cost. Furthermore, it should be recycled because of environmental and economic. Corrugated cardboard is according to DIN 55405 cardboard made up of one or more layers of corrugated paper, which is glued to one layer or between several layers of paper or cardboard. Corrugated cardboard is distinguished between single-layer or multi-layer cardboard. Corrugated cardboard is manufactured in a continuous automated process from pre-made paper and cardboard.

II. PROPERTIES OF CORRUGATED SHEET BOX

Tear strength
Burst strength
Fold ability
Stiffness increase as fibre length increase
High pressure steam
High elasticity

TABLE I

Density (kg/m3)	404.5
Poisson's ratio	0.01
Young's modulus (MPa)	7600
Thermal expansion(k dg)	3.75 E-6

III. EXPERIMENTAL AND NUMERICAL ANALYSIS FOR CORRUGATED SHEET BOX

Experiments on Product 1
Product No.1 (Bpergo Company)
Dimension (mm)
Product dimension:
Length x width x height: 630 x 600 x 880
Current Box Dimension for Product1

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Outer dimension of box : 670 x 640 x 920
Inner dimension of box : 660 x 630 x 910
Weight of product: 30 kg Box type: 7 ply



Fig.1 current box1

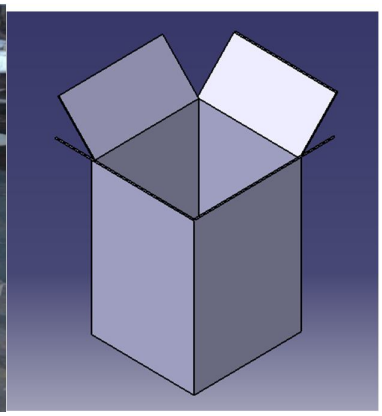


Fig.2 cad model of box1

Area of the Box:

L+W+50-----(1)
W+H+25-----(2)
A= (1)x(2)mm2
670+640+50=1360
640+920+25=1585
A=1360 x 1585
=2155600mm²
Area=2.2 m²

Weight of the Box:

W=Area x Used paper

Used paper for outer layer is 200gsm and for inner layer is 120gsm and for flute paper it is 40% more than that of plane paper as the box is 7ply so there are 4 plane layers and 3 flute layers are present.

For upper layer 200x1=200gsm
Inner layer 120x3=360gsm
For flute layer 168x3=504gsm
Since the total paper is 1064gsm
Weight = 2.2 x 1064
=2340
Weight of box is 2.3 kg

For parts specified by Edge Crush Test (ECT):

$$\frac{\text{Weight of box in n}}{\text{Width of the box in m}} = \frac{2.3 * 9.81}{0.640} = 35.2546 \text{ N/M}$$

Burst test:

The burst test carried out at industry given result as –

Compressor tester applied over square specimen of 7 ply sheet (1 X 1m^2), holding sheet in fixed supports at extreme edges. The specimen burst is 474.3 KPa

Numerical result for box1:

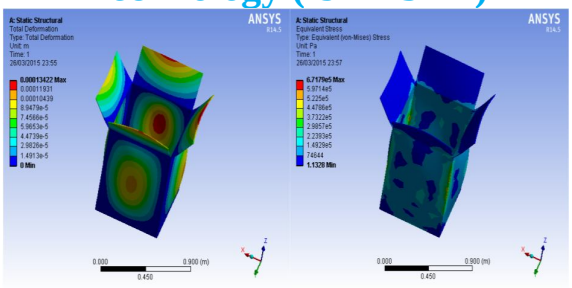


Fig.3 Total Deformation of box 1 Fig.4 Equivalent Stress of box 1

Design of Boxes on Trial and Error Basis for Box 1
First Consideration:
Outer dimension of box : 660 x 630 x 910
Inner dimension of box : 650 x 620 x 900
Area of the Box:

Area: 2.09 m²

Weight of the Box:

W=Area x Used paper
Weight = 2.09 x 1064
= 2128
Weight of box is 2.1 kg

For parts specified by Edge Crush Test (ECT):

Weight of box in n 2.1 * 9.81
---------- = ---------- = 32.7 N/M
Width of the box in m 0.630

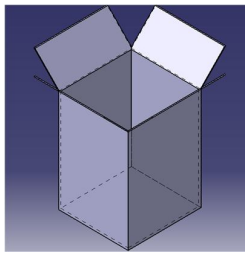


Fig.5 Cad model of second consideration box

Numerical Result for first consideration:

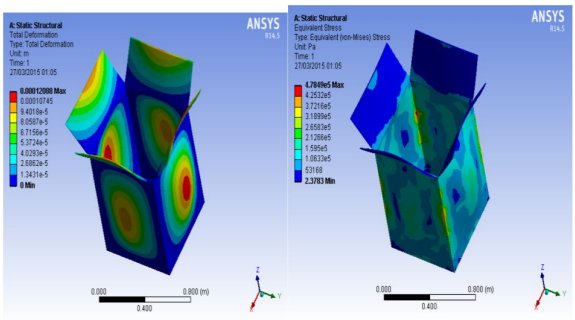


Fig.5 Total deformation of first consideration box Fig.6 Equivalent stress of second consideration box

Optimum Dimension of Corrugated Sheet Box1:

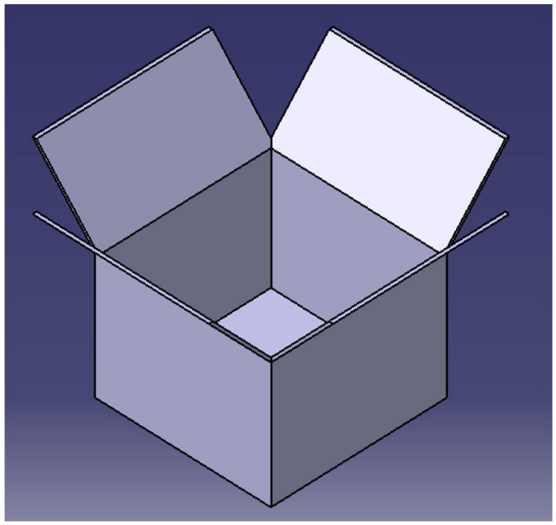
TABLE II

Dimension (mm)	Area (m^2)	Weight (Kg)	Minimum bursting test(BCT) (kpa)	Minimum edge crush test(ECT) (N/m)	Deformation (m)	Stress (kpa)
670 x 640 x920	2.2	2.3	474.3	35.2546	0.00013422	671.79
660 x 630 x910	2.09	2.1	474.3	32.7	0.00012088	478.49

Experiments on Product 2
Product no. 2(Mahindra Company)
Dimension (mm)
Product dimension:
Length x width x height: 400 x 400 x 250



Fig.7 Current box for product 2


Fig.8 Cad model of actual box 2

Current Box Dimension for Product
Outer dimension of box: 440 x 440 x 290
Inner dimension of box: 430 x 430 x 280
Weight of product: 20 kg Box type: 7 ply
Area of the Box:

L+W+50-----(1)
W+H+25-----(2)
A= (1)x(2)mm2
440+440+50=930
440+290+25=755
A=930 x 755
=702150mm2
Area=0.7 m2

Weight of the Box:

W=Area x Used paper

Used paper for outer layer is 200gsm and for inner layer is 120gsm and for flute paper it is 40% more than that of plane paper.as the box is 7ply so there are 4 plane layer and 3 flutes present.

For upper layer 200x1=200gsm
Inner layer 120x3=360gsm
For flute layer 168x3=504gsm
Since the total paper is 1064gsm
Weight = 0.7 x 1064
= 744.8
Weight of box is 0.744 kg

For parts specified by Edge Crush Test (ECT):

$$\frac{\text{Weight of box in n}}{\text{Width of the box in m}} = \frac{0.744 * 9.81}{0.4401} = 16.5878 \text{ N/M}$$

Numerical result of current dimension box2:

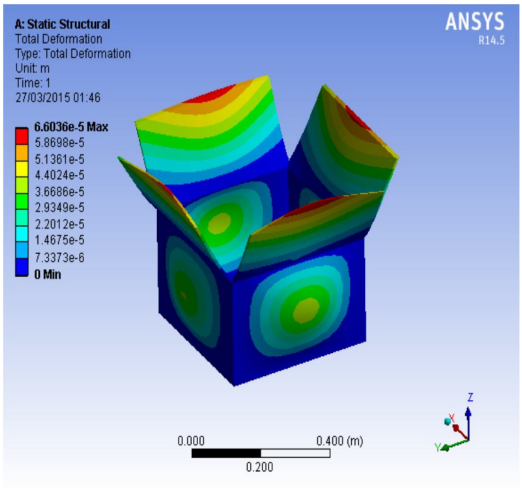


Fig.9 Total deformation of actual box 2

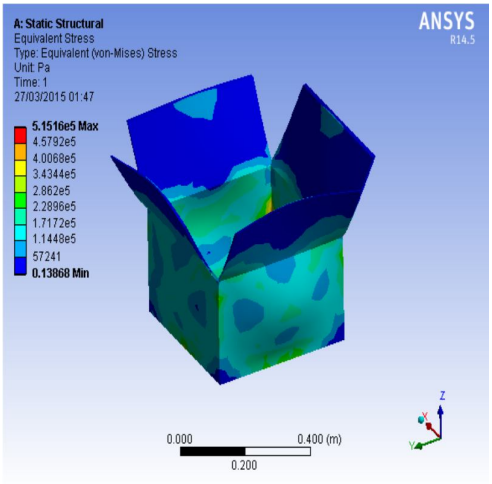


Fig10 Equivalent stress of actual box 2

Design of Boxes on Trial and Error Basis for Box 2
First Consideration:
Outer dimension of box : 425 x 425 x 275
Inner dimension of box : 415 x 415 x 265
Area: 0.65 m²
Weight of the Box:

W=Area x Used paper
Weight = 0.65 x 1064
=691.6
Weight of box is 0.691 kg

For parts specified by Edge Crush Test (ECT):

$$\frac{\text{Weight of box in n}}{\text{Width of the box in m}} = \frac{0.691 * 9.81}{0.425} = 15.9268 \text{ N/M}$$

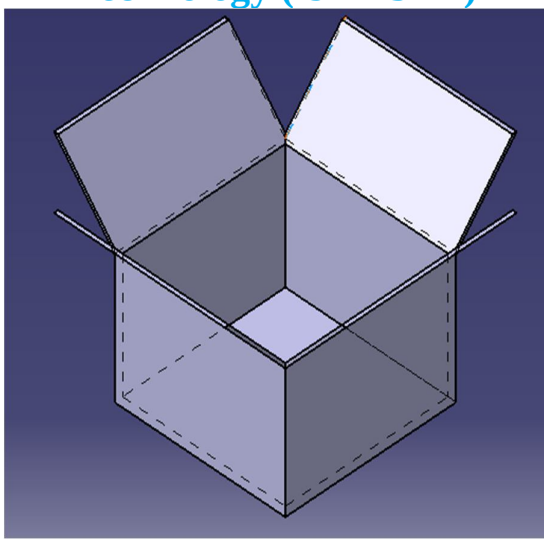
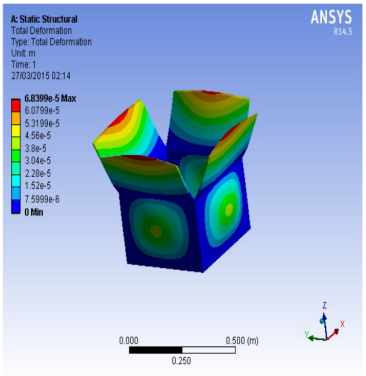


Fig.11 Cad model of first consideration box2

Numerical Result for first consideration:



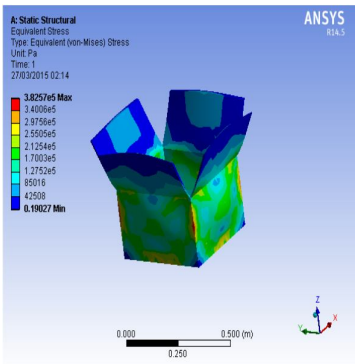


Fig.12 Total deformation of first consideration box 2 Fig.13 Equivalent stress of first consideration box 2

Optimum Dimension of Corrugated Sheet Box1:

TABLE III

Dimension (mm)	Area (m^2)	Weight (Kg)	Minimum bursting test(BCT) (kpa)	Minimum edge crush test(ECT) (N/m)	Deformation (m)	Stress (kpa)
440 x 440 x 290	0.7	0.744	474.3	16.5878	0.00006603	515.16
425 x 425 x 275	0.65	0.691	474.3	15.9268	0.00006839	382.57

IV. CONCLUSIONS

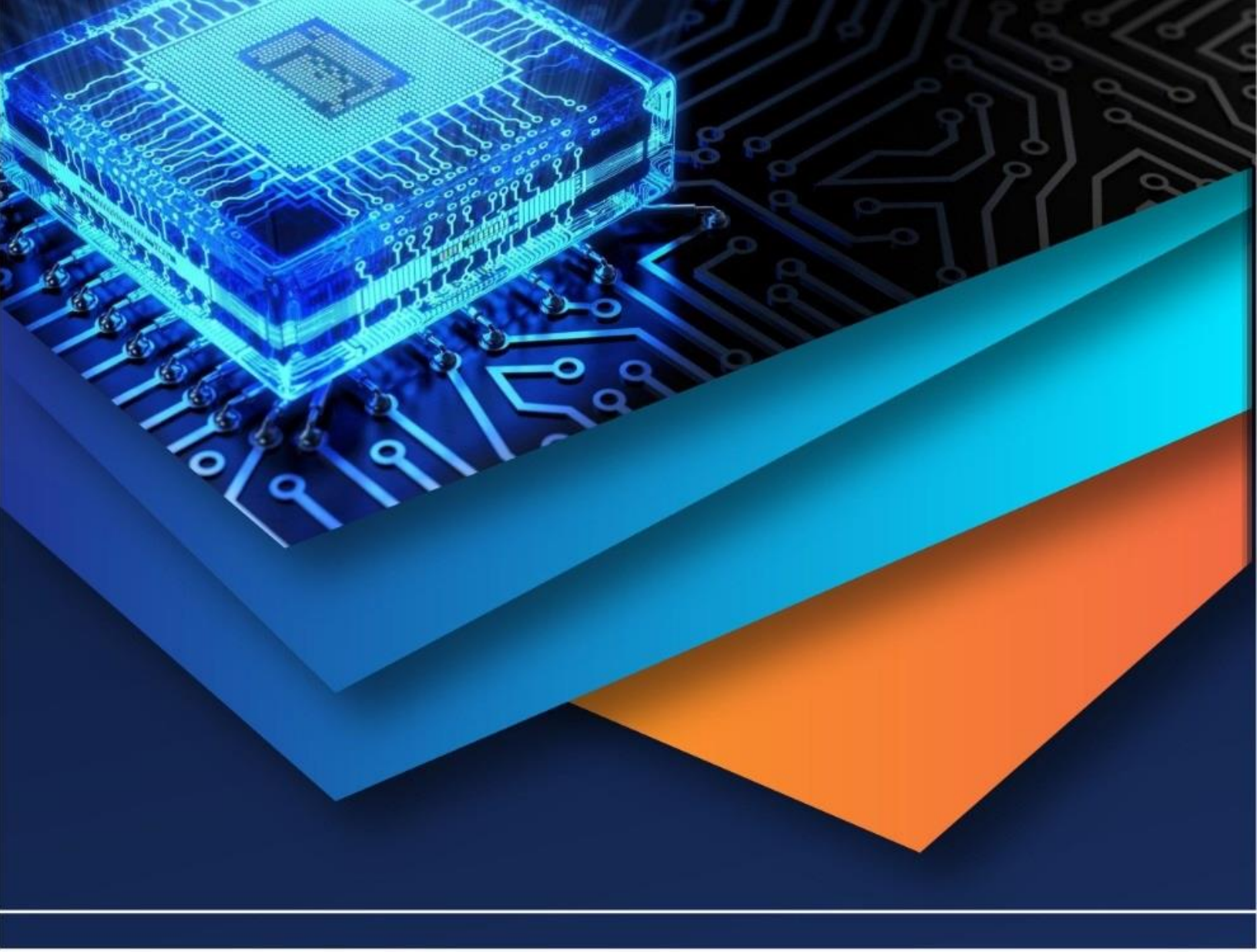
While studying the various industrial boxes it observe that the deformation of the boxes and strength are weak in load bearing capacity.so in this paper all the deformation and strength will be calculate by Reduce the clearance and change in dimension of actual corrugated sheet box. This study shown the optimization of finite element analysis method on the reducing the clearance between product and box dimension.With reducing the dimension deformation occurred in finite element analysis result is very small that is within permissible results.

From above experiment it concludes that there are maximum stress found on the actual box with respect to product dimension by using FEM and found from compressor tester machine, after reducing the clearance between the product and box dimension we get the difference stress values, to get the optimum size where the stress and deformation are minimum values are found that dimension will get the optimum size of box.

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