Improvement in Performance of Corrugated Shipping Container with Relation to Raw Material Properties

Samina Jamil and Babar Ali

Packages Limited Shahrah E Roomi, P. O. Amer Sidhu, Lahore-54760, Pakistan

As the corrugated board is manufactured from natural and renewable resource and fully biodegradable and recyclable material, so no environmental pressures on this product and has better potential of growth than any other polymers or plastic product. So demand of corrugated board in whole world is increasing rapidly and developments or improvement in its structure is highly demanded. Manufacturing corrugated containers form wheat straw with high strength properties is an art in its own. In this paper the performance of CWC is related to raw material properties and effect of change in one property on other properties was observed. Wheat straw as a raw material for manufacturing CWC is very difficult to handle on paper machines. Number of trial is done to optimize final properties of paper used for manufacturing corrugated containers. The result of these trials is also shown in this paper. These trials are change in jet to wire ratio, head box consistency, press and calender load, starch spray between layers and surface sizing and influence on ring crush strength as well as other properties were observed. We have found that surface sizing is the best option to improve all strength properties with slight decreasse in production. A lab-scale study was also conducted to observed the effect of RH on properties of liner, fluting and Corrugated shipping containers when place under different humidity conditions. It shows that moisture, grammage, elongation and tear strength increases while burst, tensile index, stiffness and ring crush values decreases with the increase in relative humidity. Similarly the strength properties of CWC also decrease with increase of RH. The results of this lab-study are also plotted in this papers.

INTRODUCTION

Performance properties of the corrugated board

The performance propertied of corrugated shipping containers means that no failure during use, when stack with contents under difference environments for different time periods i.e., under service environment. For performance evaluation the service environment can be;

- Long-term compressive loading, which invoke a creep response.
- Short-term impact loading e.g., forklift or truck jerks.

Vibration during transportation.

Storage in a high and/or cycling humidity environment.

The following are the main properties :

- BCT (Box Compression Strength) which is related to the bulging of the shipping containers when stack in stores. The major contributing factors are edge wise compression strength, board thickness and the perimeter of the box. Whereas the height of the CWC, flat crush, flute formation, glue bonding, box creases and the scoring are also very important while prediction of the BCT.
- Bursting strength of the corrugated box, which is very important during transportation and when pass through different stress due to uneven shocks. The bursting strength (Mullen value) has long been the dominant strength criterion for corrugated board. A number of transport classification regulations require that bursting strength shall be measured and reported according to the Mullen Jumbo Principle.
- Equilibrium Moisture and the resistance to absorb water or water vapors when exposed to any severe environment is also a very important property for prediction is the CWC performance. Paper is hygro-expansive in nature. Whenever exposed to the moisture higher that its own it will absorb the moisture and expand. Similarly whenever exposed to in the environment having moisture lesser than its own will give up the moisture to the environment and contact. This expansion contraction causes the wrap in corrugated board. Second reason of this wrap is due to the too high moisture variation in the cross machine direction of any liner or fluting during manufacturing of fiber orientations problem in paper roll, and when converted, the different drying profile at corrugators may cause this wrap. This wrap may also be caused by uneven pre-heater temperature or uneven glue application crosswise.
- Flat Crush strength, which is the only property that

can be truly predicted only for single wall shipping container. And has a contribution to the final compression strength of the box.

- Thickness of the CWC is also very important because, higher the thickness more will be the cushioning effect and better will be the performance under shocks.

Experiments

We took one property at a time and will try to relate it with that property of raw material on which it is primarily based on or dependent. It is also tried that how we can improve or what are the critical areas, which should be considered during manufacturing of the raw material.

BCT (Box Compression Strength)

Most corrugated boxes are expected to withstand external compressive loading during their service life. This loading is usually the result of the stacking the boxes and their contents on top of one another. The ability to withstand compressive stress is not a simple property and depends on the storage conditions, magnitude or amount of the laod and also the loading duration. The flaps and flaps score lines have also a very strong influence on the compression resistance.

In the above-mentioned parameters, which are contributors of box compression strength, the one major property, which is dependent on the raw materials, is the edge crush strength and the second one is the flat crush strength. If thickness and flute formation is perfect then Edge crush and flat crush both are totally dependent on the strength properties of the liner and the fluting.

We have done a trial by having boxes of 6x6x6 in size from three reels of Liner and fluting made form known furnish. We have developed an analogy and a relationship based on our furnish which related the size, thickness and edge crush to BCT

BCT = Constant x ECT x (Z x t) ^ 0.5

where

BCT = Box Compression strength in Newton

ECT = Edge Crush Strength in KN/m

Z = perimeter of the box in m

T = caliper of the box in m

Constant is totally dependent on furnish, creasing or scoring and flap formation, when we have calculated it for our boxes based on wheat straw, it is in the range of (5700-6500).

An empirical relation ship for the ring crush Vs. edge crush strength is also developed during experimentation and data analysis.

ECT = constant x $\{CD-RCT_{L1}\ \ CD-RCT_{L2}\ \alpha^*\ CD-RCT_{F1}\} + 1$

ECT = Edge Crush Strength in KN/m

$CD-RCT_{L1}$ = Ring crush stength in Cross machine direction of liner 1

$CD-RCT_{L2}$ = Ring crush strength in Cross machine direction of liner 2

$CD-RCT_{F1}$ = Ring crush strength in Cross machine direction of fluting 1

The constant for the wheat straw based furnish by using straw CTMP pulp comes out to be for our boxes (0.93-0.97)

The ring crush strength of the liner and the fluting is dependent on the fibers properties are used to make these products. The longer the fiber more will be the ring crush strengths. But as the cost is also very important in this competing world, so some other factors, which should can be considered while manufacturing of these liners and fluting.

- Jet to wire speed ratio
- Head box consistency
- Load at press section
- Load on the Calendar
- Starch spray between the nips of the two layers
- Surface sizing of the liners as well as fluting

Jet to wire speed ratio

when this ratio is kept near to 1, then the RCT or SCT may be have a maximum value from that furnish but the bursting strength and md/cd tensile ratio will be minimum that are also essential for run-ability and final bursting strength of CWC. So optimized way to achieve both the properties at their best level small drag or rush is recommended, preferably the rush.

We have made a trial and varied the R/D ratio and our results are in figure 1.

Head box consistency

Higher head box consistency is required to get excellent Scott bond and CMT but bursting strength may suffer.

Load at press section

The maximum load can improve the ring crush strength but may kill the stiffness of the board by killing the bulk of the finished paper. We have done a trial on KLB-165gsm at different loads to see the effect. Results are below.

In this trial five different loads were tried at press section and effect on stiffness and ring crush was observed. With the increasing load the stiffness reduced due to the reason that pressing of wet causes the reduction in

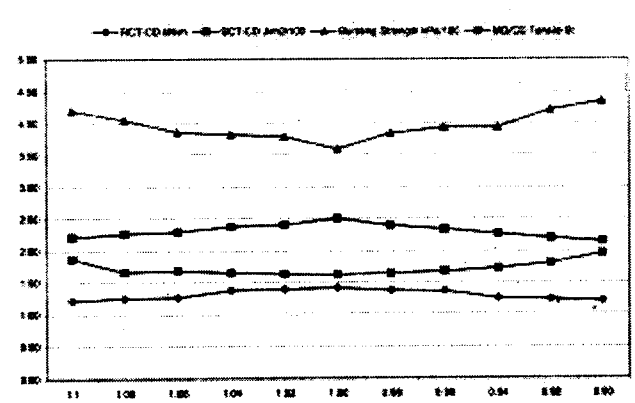

Figure 1

bulk, but ring crush increased due to increased density.

Starch spray between the nips of the two layers

This can improve the ring crush as well as the Scott bond strength if large amount of the recycled fires are used in the recipe. But too high Scott bond may cause the cracking especially in CMP during flute formation.

Surface sizing of the liners as well as fluting

This will contribute to the increase of strength properties without affecting other properties negatively. A trial was done on KLB 125, on single layer machine using size press by applying 1.5gsm starch layer on both sides.

The results are improved for all strength properties. The only negative effect is that speed of the machine has reduced by 10% By applying starch all strength properties has incresased because we are just coating the fibers by protechting it from environment just by starch and not killing the fiber structure.

Table 1

Load at Press section	Stiffness		Ring Crush St.	
	MD	CD	MD	CD
35kN/m	50	25	1.41	1.18
45kN/m	46	23	1.57	1.26
55kN/m	43	22	1.59	1.28
65kN/M	41	21	1.61	1.31
75kN/m	40	20	1.65	1.31

Load on the Calender

The more will be the load on the calendar better will be the finish or roughness but it will destroy the fiber strength or less will be the ring crush strength. So to have better strength properties the load should be optimized at wet end i.e., press sections not the dry end i. e. the calendar.

Table 2

Properties	Units	Without Size Press	With size Press
Bursting Strength	kPa	268	372
Tensile Index, MD	Nm/g	54.1	72.5
Tensile Index, CD	Nm/g	32.3	33.6
Elongation, MD	%	2.4	2.9
Elongation, CD	%	4.7	3.3
Stiffness, MD	mN	26	34
Stiffness, CD	mN	11	12
Ring Crush St. MD	kN/m	1.09	1.52
Ring Crush St. MD	kN/m	0.80	1.18

Bursting Strength of CWC

This is the property, which is not increased or reduced by Corrugators. It is totally dependent on the bursting strength on of the liner and the Bursting strength of the fluting. The 80-85% contribution is of the bursting strength of the liner whereas remaining 15-20% is of the bursting strength of the corrugating medium paper. A rule of thumb is that the sum of the bursting strengths of the liner layers and 10% of the bursting strength of the fluting medium is the usually a good estimate of the bursting strength of the corrugated board. If we compare this property of CWC of B-type flute with CWC of C-type flute, made by using liner and fluting of grammages, strength properteis, the value will be the same. Which means that bursting strength is dependent on the grammage and properties of the raw material not on the corrugating process.

RD Ratio and head box consistency

Low head box consistency will be better for the high burst with a little compromise on CMT and Scott bond. Similarly rush in Jet to wire ratio will give better burst and md/cd tensile ratio. See figure 1

Surface Sizing

This will improve the bursting strength remarkably by having no effect on any other property See table 2

Refining

Refining can improve the bursting strength but due to short fiber the ring crush will be reduced to some extent. The elongation will also reduced by refining will may cause cracking especially in the liner while converting at corrugators.

In this trial when increased the, the length was shorten due to this effect the elongation,stiffness and ring crush has reduced but as the fiber structure are more open and voids between fibers were less the bursting strength can be improved.

Speed increase

Bursting strength can also slightly be improved by slight increase in the speed keeping all other machine parameters constant. This is achieved by slightly higher moisture in the end product but may reduce the other strength properties.

MD/CD tensile energy absorption

Bursting strength can also be improved by increasing the area under the curve of the graph plotted between Stress and strain while performing tensile strength

Equilibrium Moisture and Moisture resistance of CWC.

Equilibrium moisture is the moisture of the corrugated

Table 3

Load at Calendar	Roughness(ml/min)	Stiffness(mN)		Ringh Crush St. (KN/m)	
		MD	CD	MD	CD
Without Calendar	2100	42	23	1.78	1.42
0.2 bar	2050	42	23	1.77	1.42
0.5 bar	1800	43	22	1.74	1.39
1.0 bar	1200	41	21	1.69	1.36
2.0 bar	900	40	20	1.65	1.31

board that it attain when exposed to the final condition combining by different layers of the liner and CMP may or may not be having the same moisture.

Because the board is hygroscopic, the strength properties of the corrugated board product are dependent on the ambient temperature and relative humidity. Different properties of corrugated board and its components have different sensitivities to change in moisture content. A good rule of thumb is that every 1% moisture increase will cause about 8% decrease in the compressive strength properties. Bursting strength is not effected very much by moisture change. So the compressive strength of the corrugated board depend on the atmosphere to which it is exposed irrespective to the moisture content at which it is formed, if it is not made water resistant or water proof. A lab-study in done by using humidity chamber at different humidifies. The observations are given showing the effect on our KLB and CMP and Corrugated box properties. Figure 2 and 3.

Table 4

SR of the Straw Pulp	Bursting Strength (kPa)	Elongation (%)		Stiffness (m/N)		Ring Crush Strength (kN/m)	
		MD	CD	MD	CD	CD	CD
Without refining	2.2	2.6	4.3	71	28	1.92	1.39
40	2.3	2.3	3.7	68	28	1.91	1.36
50	2.5	2.1	3.5	65	25	1.85	1.37
60	2.6	1.6	2.6	58	26	1.82	1.34
70	2.7	1.5	2.0	50	22	1.76	1.29

If we want that corrugated board should behave similar in different humidity conditions, then we have to make it with water resistant liner as well as fluting. The glue used for binding should also be such that after making bond it should act like waterproof material. If we just sized the liner and not fluting, then water or moisture will penetrate from the fluting size and box will not be the water resistant. The majority of the glues used in corrugators is natural starched and water soluble, so some special additives should be added to make it water proof after bond making.

Box life will be less when more recycled fiber is used in medium paper. So the sizing of the medium paper can also improve the life of the box. Recycled fiber has more tendencies to absorb moisture due to increased available surface area. When surface is sized so the film will protect the box to absorb water or moisture from it.

The effect of RH on properties of liner, fluting when place under different humidity conditions is presented or plotted in figure 2. It shows that moisture, grammage, elongation and tear strength increases while burst, tensile index, stiffness and ring crush values decreases with the increase in relative humidity. Figure 3

A lab-study was also conducted to see the same RH effect on the CWC properties when place under different humidity conditions. It was observed that the strength properties of CWC also decrease with increase of RH. The results of this lab-study are also plotted figure 3.

Test Methods For Measurement

Following are the test methods followed for

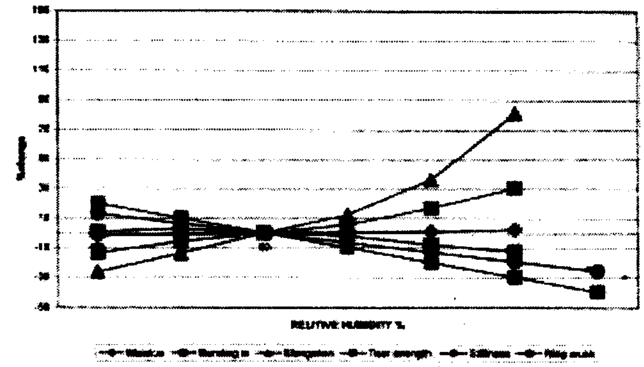

Figure 2 : Effect of RH on KLB and CPM

measurements

Bulk : Scandinavian Test Method No. SCAN-P 7:75

Stiffness : TAPPI Test Method No. T 489 om-92

Ring Crush Strength : Scandinavian Test Method No.

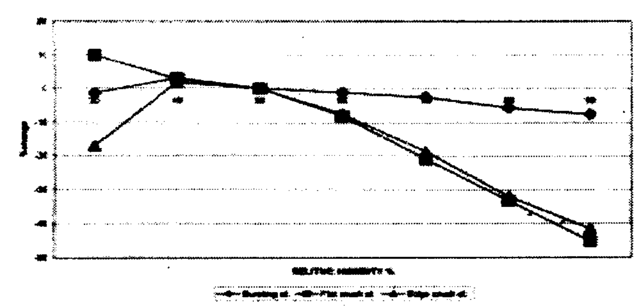

Figure 3 : Effect of RH on CWC Properties

SCAN-P 34:71

Tensile Strength & Elongation : TAPPI Test Method No. T 494 om-88

Bursting Strength : TAPPI Test Method No. T 807 om-94

Roughness : Scandinavian Test Method No. SCAN-P 21 : 67

Moisture: TAPPI Test Method No. T 412 om-94

Tear Strength : TAPPI Test Method No. T414 om-88

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