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Egg Crate Production from Carton Wastes: An Approach for Transforming Waste

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Abstract: *An egg carton also referred to as egg paper crate is a carton designed for carrying and transporting whole eggs. These cartons have a dimpled form in which each dimple accommodates an individual egg and isolate that egg from eggs in adjacent dimples. In line with paper recycling, waste carton papers were used for the manual production of paper egg crates in this research work. From the research design, a permanent mould that was casted with aluminum was designed and manufactured. The permanent mould was successfully used to produce some paper crates and the 'cure time' was determined. The recommendations made from this research include the following: an oven should be inculcated in the design of the mould to overcome the problem of drying and a proper and better binder should be used in the paper egg production.*
Keywords: *Recycling, Egg crate, Paper crate, Casting, Mould, Pulp Machine*

I. Introduction

Paper recycling is the process of turning waste paper into new paper products. There are three categories of paper that can be used as feedstock for making recycled paper: mill broke, pre-consumer waste, and post-consumer waste. *Mill broke* is paper trimmings and other paper scrap from the manufacture of paper, and is recycled internally in a paper mill. *Pre-consumer waste* is material which left the paper mill but was discarded before it was ready for consumer use. *Post-consumer* waste is material discarded after consumer use, such as old corrugated containers (OCC), old magazines, old newspapers (ONP), office paper, old telephone directories, and residential mixed paper (RMP). Paper suitable for recycling is called "scrap paper", often used to produce molded pulp packaging.

Everywhere you look you see one thing: paper. From posters and notebooks to cardboard boxes, magazines and cartons. Paper is part of our everyday lives. Paper takes up over 40% of our waste stream, making it the top material that we throw away. That means for every 100 pounds of trash we throw away, about 35 pounds of it is paper! If we could just recycle one morning newspaper every day, we could save 41,000 trees from being cut down and greatly reduce our carbon footprint (Marcot, 1992).

Here are some of the most recognized recycled paper products: Newspaper, Shredded paper, Phonebooks, Cardboard, Magazines, Computer paper, Envelopes, Junk mail, Construction paper, electronic cartons etc.

When you recycle cardboard and other paper products you can create millions of new products such as: Egg cartons, Paper towels, Tissue, Toilet paper, Newspaper, Phonebooks, Paper bags, Notebooks, Stamps, Business cars, Calendars, etc.

There are so many other products that you can make with recycled paper. And the best thing about paper recycling is that it uses less chemicals and bleaches, which is safer for the environment. In addition, paper or waste recycling saves money, creates jobs, eliminates landfill waste, conserves natural resources such as timber, water, and minerals and has positive impact on the environment when it reduces pollution and green gas emission.

II. Literature Review

An egg carton or egg box or (the British English term) also referred to as egg paper crate is a carton designed for carrying and transporting whole eggs. These cartons have a dimpled form in which each dimple accommodates an individual egg and isolates that egg from eggs in adjacent dimples. This structure helps protect eggs against stresses exerted during transportation and storage by absorbing a lot of shock and limiting the incidents of fracture to the fragile egg shells (en.wikipedia.org).

The egg carton was invented in 1911 by newspaper editor Joseph Coyle of Smithers, British Columbia, to solve a dispute between a local farmer and hotel owner in Aldermere, British Columbia (near present day Telkwa, British Columbia) over the farmer's eggs often being delivered broken. Before its invention, eggs were carried in egg baskets. The egg carton "box" was further developed by H.G. Bennett during the 1950s and became the norm for egg transportation during this period (http://www.mypak.com/home.html).Unlike many products, trademarks and advertisements for egg brands are usually printed on the food container itself rather than on a separate container (as with breakfast cereals). This distinguishes egg cartons from different producers or quality on the retail shelf. Standard egg cartons has room for 12 eggs, others could be lesser or even up to 30 rooms.

Plate 2.1a An egg carton with accommodation 10 eggs **Plate 2.1b An egg carton accommodating 12 eggs**

2.1 Recycling

Recycling is the collection, processing, and reuse of materials that would otherwise be thrown away. Materials ranging from precious metals to broken glass, from old newspapers to plastic spoons, can be recycled. The recycling process reclaims the original material and uses it in new products (Http://encarta.msn.com/encyclopedia_761556346_4/recycling).

In general, using recycled materials to make new products costs less and requires less energy than using new materials. Recycling can also reduce pollution, either by reducing the demand for high-pollution alternatives or by minimizing the amount of pollution produced during the manufacturing process. Recycling decreases the amount of land needed for trash dumps by reducing the volume of discarded waste (Http://encarta.msn.com/encyclopedia_761556346_4/recycling).

Recycling can be done internally (within a company) or externally (after a product is sold and used). In the paper industry, for example, internal recycling occurs when leftover stock and trimmings are salvaged to help make more new product. Since the recovered material never left the manufacturing plant, the final product is said to contain pre-consumer waste. External recycling occurs when materials used by the customer are returned for processing into new products. Materials ready to be recycled in this manner, such as empty beverage containers, are called post-consumer waste (Twede and Renee, 2007).

2.2 History

People have recycled materials throughout history. Metal tools and weapons have been melted, reformed, and reused since they came in use thousands of years ago. The iron, steel, and paper industries have almost always used recycled materials. Recycling rates were modest in the United States up through the 1960s, although rates increased during World War II (1939-1945). Since the 1960s, recycling has steadily increased. Recycling in the United States between 1960 and 2000 rose from 5.35 million metric tons (5.9 million U.S. tons) per year to 63.4 million metric tons (69.9 million U.S. tons). In 1930 about 7 percent of municipal solid waste was recycled. By 2000 that amount had climbed to 30.1 percent (Http://encarta.msn.com/encyclopedia_761556346_4/recycling).

European countries have a long history of recycling and, in some cases, stiff requirements. In 1991 the German parliament approved legislation setting recycling targets of 80 to 90 percent for packaging materials and banned the sale of products from companies that do not cooperate. France has set specific recycling goals. Other countries with significant overall recycling rates include Spain at 29 percent, Switzerland at 28 percent, and Japan at 23 percent (Twede and Renee, 2007).

2.3 Paper and paper Products

Paper products that can be recycled include cardboard containers, wrapping paper, and office paper. The most commonly recycled paper product is newsprint (American forest and Paper Association, 2000).

The use of paper spread from china through the Islamic world and entered production in medieval Europe in the 13^{th} century, where the first water-powered paper mills were built and mechanization of papermaking began (Twede and Renee, 2007). The industrial production of paper in the early 19^{th} century caused significant cultural changes worldwide, allowing for relatively cheap exchange of information in the form of letters, newspapers and books for the first time. In 1844, both Canadian inventor Charles fenerty and German inventor F.G. keller had invented the pulp machine and process for the use in paper making (Robert, 2007). This ended the nearly 200 years of pulped rags and start a new era for the production of newsprint and eventually all paper out of pulped wood.

In newspaper recycling, old newspapers are collected and searched for contaminants such as plastic bags and aluminum foil. The paper goes to a processing plant where it is mixed with hot water and turned into pulp in a machine that works much like a big kitchen blender. The pulp is screened and filtered to remove smaller contaminants. The pulp then goes to a large vat where the ink separates from the paper fibers and floats to the surface. The ink is skimmed off, dried and reused as ink or burned as boiler fuel. The cleaned pulp is mixed with new wood fibers to be made into paper again.

Paper and paper products such as corrugated board constitute about 37 percent of the discards in the United States, making it the most plentiful single item in landfills, (American forest and Paper Association, 2000). American Paper Institute (1982) estimates the average office worker generates about 5 kg (about 11 lb) of wastepaper per month. Every ton of paper that is recycled saves about 1.4 cu m (about 50 cu ft) of landfill space. One ton of recycled paper saves 17 pulpwood trees (trees used to produce paper).

2.4 Description of the Pulping Machine for a Recycling System

The design of a waste paper recycling plant included the determination of the volume of the refiner, hydropulper and head box and also the selection of a convenient material for the construction of the individual units **(**Keyes, 1904). The bulk of the parts of the plant were fabricated using mild steel, this is because it is the easiest to be joined among all other metals. It is a very versatile metal, necessitating its use by many industries for fabrication of process unit equipment. Apart from its versatility, it is also very cheap and readily available compared to other metals.

The development of a manually operated paper-recycling machine is much cheaper than the automated recycling industries worldwide (Kenneth, 1970). Kenneth W.B. reported that the fabricated machine can serve dual purposes, it can be manned permanently at a stationary position or it could be shifted from one place to another as the case may be.

One great advantage to be derived from the use of this machine is that the cost of running it is minimal compared to what it takes to run a full plant (Keyes, 1904). The simplicity of operation of this machine ensures that no too much technical skill is needed to operate it (Meyers, 1992). When the machine is well maintained, its durability is guaranteed.

III. Methodology

3.1 Conceptual Design

This paper on the production of egg crates is hinged on a pulping machine (already fabricated) which produces the pulp from carton papers. Fig. 3.1 and 3.2 show the orthographic projections of both the drag and cope respectively, while Fig. 3.3 and fig. 3.4 depict the sectioning and the isometric views of both the cope and drag.

To achieve this, an already existing egg crate sample was used in getting the necessary dimensions. From the sample, a pattern was made which comprised of the drag and cope, and then from the pattern, sand casting process was employed as the production process through which the permanent mould for the paper (carton) egg crate was produced.

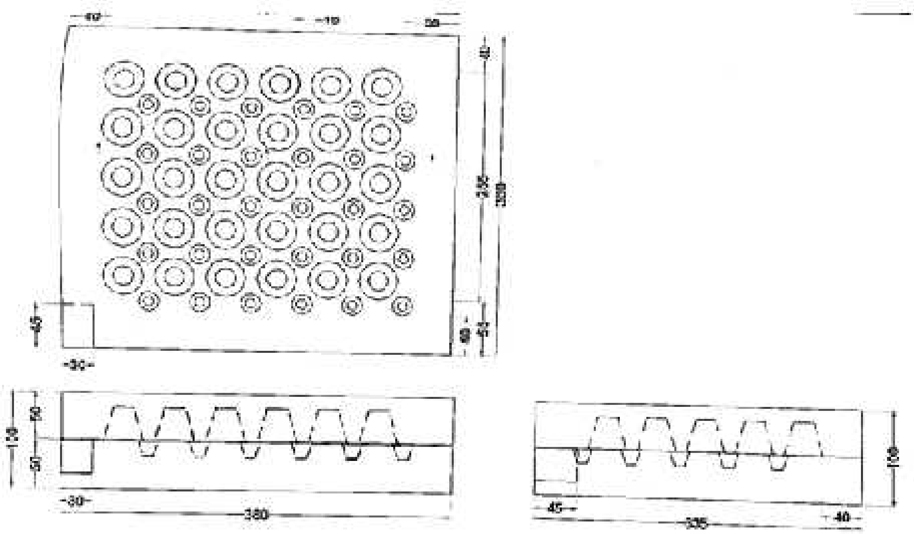

Fig. 3.1 Orthographic Drawing of the Cope

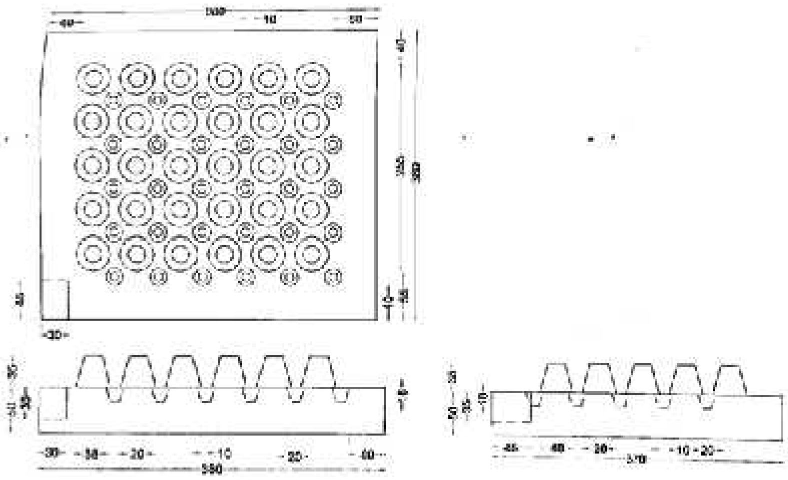

Fig. 3.2 Orthographic Drawing of the Cope

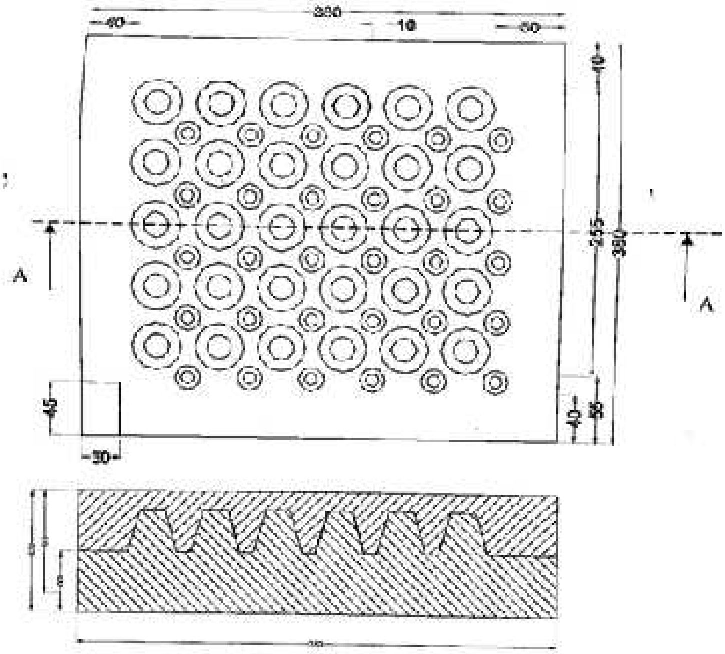

Fig. 3.3 Sectioning

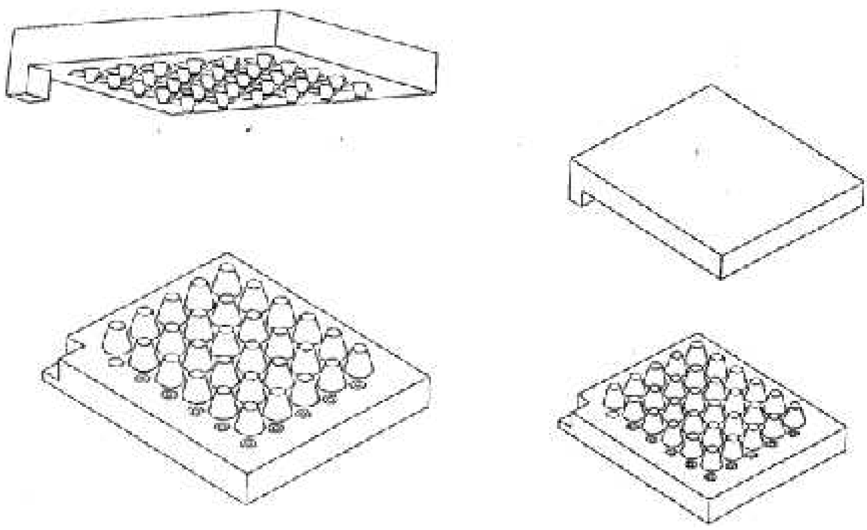

Fig.3.4 Isomeric views of both the Drag and Cope

The production of the permanent mould was however made possible with the designs for the riser and the gating system which comprises of the sprue size, runner size, ingate size etc. Below are the 3D views of both the cope and the drag.

3.2 Selection of Material

The casting material used for the egg crate mould is profile aluminium (could also be referred to as aluminium alloy). I chose aluminium as my casting material because of its many properties. It has a density of 2.70 g/cm^3 and a melting temperature of 660^o C (John, 2004)). Aluminium alloy is light weight, it has high thermal and electrical conductivities, and also corrosion resistance. Another important consideration in the selection of aluminium is that it is cheaper in terms of cost when compared to other casting materials like cast iron, brass etc.

There are many types of aluminum alloy used for casting. Silicon, copper and magnesium are the main element added to enhance strength and hardness. Aluminum-based cast alloys have many applications, including automotive engine blocks or cylinder head, decorative, aerospace and electrical parts (John, 2004).

3.3 Pattern Size Determination

Sand and cement was used for making the pattern for both the drag and the cope. In making the pattern (drag and cope), an existing plastic crate sample was used. The dimension of the sample is 290mm by 290mm, having 30 dimples. After the making of the pattern, the following dimensions for both the drag and cope were arrived at:

Drag length	--------- 380mm
Drag breath	--------- 360mm
Cope length	--------- 380mm
Cope breath	--------- 360mm
Thickness of drag	--------- 56mm
Thickness of cope	--------- 37mm

3.4 Runner Size (Diameter)

The main function of the runner is to slow down the molten metal, which speeds up during its free fall through the sprue, and it takes it to all the in-gates. This implies that the total cross-sectional area of runner(s) must be greater than the sprue area. In general, a sprue area, As: runner area, Ar: in-gate area, Ag should have a gating area ratio of 1:2:1.5 respectively for ferrous metals (Ravi, 2003). The runner must be filled completely before letting the molten metal enter the n-gates. Since the runner diverges into two equal parts, each part should have an elemental area of $\frac{As}{2}$ i.e. $\frac{Ar}{2}$

$\frac{\pi}{4}d^2 = 2.18 \text{ X } 10^{-2}m^2$ But, runner elemental area Ar ≡ As.

That is, for the drag,

Where d = diameter of the runner.

d = 0.16m

$\frac{\pi}{4}d^2 = 1.15 \text{ X } 10^{-2}m^2$ For the cope,

d = 0.12m

3.5 In-gate Size (Diameter)

The in-gates lead the molten metal from the gating system to the mould cavities. From the gating area ratio above, the in-gate elemental area = 1.5 As. The fact that the in-gate diverges into two equal parts, each part should have an elemental area of $\frac{1.5\,As}{2}$.

i.e. $\frac{\pi}{4}d^2 = \frac{1.5\,As}{2}$

$$d = \sqrt{\frac{4 \text{ X } 1.5 \text{ X } 2.18 \text{ X } 10^{-2}}{2 \text{ X } \pi}}$$

For the drag,

d = 0.14m

$d = \sqrt{\frac{4 \text{ X } 1.5 \text{ X } 1.15 \text{ X } 10^{-2}}{2 \text{ X } \pi}}$ For the cope,

d = 0.10m

IV. Manufacturing, Testing And Costing

4.1 Manufacture of a permanent egg crate mould

The type of materials for the permanent casting has already been identified in the previous chapter. It will be ideal at this point to give the various steps for the manufacture of the egg crate mould. The manufacture of the egg crate mould is categorized into: Making of pattern, Sand mould and Permanent mould casting.

4.1.1 Making of Pattern

In making the pattern, an existing plastic crate sample was used. The dimension of the sample is 290mm by 290mm, having 30 dimples. The processes undergone in making the pattern are stated below.

- Make a sand bed.
- Place the sample crate on the bed and make sure it is well leveled with a plump.
- Place a box of length 380mm, width 370mm and height 60mm around the sample. But make sure the placement is uniform.
- Mix clay and a binder (in this case, cement) in appropriate proportion. Add little amount of water (up to 30cl) to the mixture.
- Filter the mixture to remove stones, thereby getting finer mixture.
- Start adding the mixture (i.e. Sand and cement) to the drag and then ram with the ramming stick intermittently. Continue to add and ram until the box is filled to the brim.
- Remove excess sand mixture and turn the box upside down.
- Remove the sand mixture inside the cavities of the sample.
- Remove the sample from the box.

The above processes will give us the one-half of the pattern (drag). The second half of the pattern was made just the same way as the first one only that the sample was turned upside down to get the cope.


Plate 4.1: Left; cope pattern, Right; drag pattern

4.1.2 Sand moulding of the pattern

In making the sand mould for the pattern already made, the following six steps where followed:

- Place a pattern in sand to create a mold.
- Incorporate the pattern and sand in a gating system.
- Remove the pattern.
- Allow the sand mould to dry.

Note: the above steps apply for both drag and cope. For the sand used, typical mix: 90% sand, 3% water, and 7% clay.


Plate 4.2: Left: Finished sand mould (Drag); RIGHT, finished sand mould (Cope)

4.1.3 Permanent Mould Casting

In chapter three, profile aluminium was selected as the metal to be used for the casting and the reasons for the selection were highlighted. The steps taken to make the permanent mould for the egg crates are:

- ❖ Set-up of the riser and the gating system on the sand mould.
- ❖ The aluminium profile material is placed in the crucible to be heated (temp. of 660^{o}C) to a molten stage.
- ❖ The sand mould is preheated. There will be no need for the insertion of core since the mould has a self-core.
- ❖ When the aluminium profile has been melted by the furnace, the molten substance is then poured into the system through the pouring basin.
- ❖ The aluminium cast should be allowed to solidify and then the cast removed.

Note: the steps above are used to get the cope and drag for the egg crate mould.


Left: Plate 4.3: female part of the permanent mould; RIGHT, male part of the permanent moul

4.1.4 The Process of Making the Egg Paper Crate

The following are the steps taken to produce a paper egg crate:

1. soak waste cartons of not less than 400g in water for at least 3days to enable it soften;
2. crushed to a pulp/slurry stage by the pulping machine;
3. the pulp which should not be too watery has to be mixed with a binder (in this project, a local starch made from cassava was used) to hold the pulp together and to also make it dry;
4. before pouring into the drag mould ensure that the mould (both the drag and cope) are oiled or covered with a cellophane to prevent the pulp from getting stock to the mould;
5. after pouring a considerable amount of pulp on the drag, the cope should be used to match the pulp on the surface of the drag to form the crate;
6. remove the cope once an appropriate pressure has been applied and then take the drag to either the sun or oven to dry the crate; after the crate has dried, remove it from the drag and do some finishing to it.

Plate 4.4: Soaked waste carton paper in a bucket

Plate 4.5: The paper crate on the drag undergoing drying bucket

4.2 Testing
The egg crate mould after manufacture was tested to help ascertain its actual level of effectiveness.

4.3.1 Testing of the egg crate mould
To check for the effectiveness of the mould, the cope was used to cover the drag to see if it properly laps. It was discovered after thorough machining that the cope could lap on the drag.

4.3 Cost Analysis
Below is the bill of materials and its corresponding costs.

Table 4.1 Bill of Materials and Costing

MATERIAL	QUANTITY	COST (N)
Sample Egg Crate	1	200
Parting Powder	1	200
Profile Aluminium	-	12,000
Starch	-	100
Transportation	-	500
Miscellaneous	-	2000
Overall Cost		15,000

V. Results Conclusion

5.1 Mould Testing
As stated in the previous chapter, after proper machining of the mould, the cope was able to lap on the drag. The lapping was however not 100% due to some manufacturing errors that resulted in the casting. It should be stated here that the paper crate product gotten from the mould was not affected by the mould not been able to lap perfectly well.

5.2 Curing Time

The term “curing time” is used to refer to how long it takes something to fully cure, undergoing a series of chemical reactions which allow it to set, harden, and develop traits which will allow it to persist for weeks, months, or years. This test was carried out in my work.

The time for the pulp to cure on the mould was determined for two products. Both took 3days to cure naturally in the sun. It is clear from the curing time gotten that using natural means for drying will not be ideal for mass production.

VI. Conclusion

This research paper is an attempt to help sustain the environment for future generations, create job for our youth, conserve natural resources such as timber, water, and minerals and to reduce greenhouse gas emissions that contribute to global climate change.

However, there are other contributions that could still be use to improve this research work. Paper is usually made with some binder-like clay and this tends to wear-off when these papers are soaked in water. This is another reason why the pulp does not have that tendency to adhere together and dry fast. The local starch from cassava which was used should also be looked into because it is too heavy and doesn’t dry fast. I recommend that proper and better binders should be discovered and used in the paper egg crate production and this why Top-Bond as a binder though costlier, should be tried. Furthermore, an oven should be inculcated in the design of the mould to overcome the problem of drying.

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