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Package Structure Design of in-door air conditioners

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Abstract. In this paper, we discussed the package structure design of in-door air conditioners aiming the current status and problems. Box types such as 0201, 0203, and improved 0440 are used, and comparison experiments are carried out on compressive strength of empty boxes to optimize the structure design. By improving product package to increase efficiency, can effectively reduce product cost, and assure product quality.

Introduction

Currently, restrictions and regulations to package materials such as original wood and EPS foam plastic and their packaging waste are applied in Europe Union. In order to avoid “green” trade barriers and reduce “white pollution”, new package materials are developed to replace EPS foam plastic liners and wooden plate racks. Corrugated cardboard is popular in the market because of light weight, low cost, high flat crush resistance, and recyclable. It is a new type of green packaging which can save resources and protect the environment. But compared to other environmentally friendly packaging materials, there are still some shortcomings, such as buffering performance is not as good as EPE expand able poly ethylene and low bursting strength. If the advantages of corrugated cardboard can be used, and the advantages of other environmental materials can be used in combination, better protection to the products can be achieved, and the application fields can be widen.
In-door air conditioners usually use corrugated boxes of type 02 combined with other materials, such as paper angle, honeycomb, composite multi-layer board, EPE, EPS, etc.

Problem analyzing

According to our survey, following problems of air conditioner package boxes of type 02 exist in packaging in process of storing and transporting: boxes tend to become concave or convex, the boxes damaging, damaging in folding areas, unreasonable design of inner packages, or breaking of packing belts. See fig. 1.


(a) Concave


(b) Convex

Figure 1. Concave or convex of 02 paper box in storing and transporting

Influence of materials

The following elements may influence the resistance capacity of boxes: central pressure level of original board, the edge pressure level of corrugated cardboard, the shape, model, number of layers, types, and moisture content of corrugations.

Influence of structure of boxes

(1) Structure of the boxes. The resistance capacity of corrugations is best in the vertical direction; the more the layers in supporting, the better are the resistance capacity; spliced multi-layer board has better resistance than separated boards. Thus, the structure of boxes is an important element affecting the resistance capacity of boxes [1].
(2) Shape of the boxes. Perimeter of boxes: Theoretically, boxes with longer perimeter have better resistance capacity. But experiments show that, the increasing of perimeter and resistance capacity are not proportional. When the perimeter is increased to a certain value, the influence of perimeter to resistance capacity will decrease obviously [2]. The ratio of length of width of boxes, R_L: Normally, the best resistance capacity appears at the box corners; the resistance capacity decreases when the distance to the corners increases. Experiments show that the global peak of resistance capacity of boxes appears when the R_L is approximately 1.4 to 1.5.

Influence of manufacturing process of boxes

The elements with the greatest impact are the moisture content of paper boards, the amount of adhesives, and the changing of the board thickness and density caused by the shaping of corrugations.

Influence of circulation environment

(1) Storing time. The longer the storing time, the greater the resistance capacity loss.
(2) Relative humidity. The changing of relative humidity affects the moisture content of box [3], and the moisture content of boards affects the contraction and expansion of paper boards.
(3) Stacking height. According to surveying, packages are normally calculated assuming the maximum stacking height as 4 meters. But in practice, stacking height usually takes the storing space as reference, thus it often occurs that the storing space is higher than maximum stacking height, and the boxes appears convex or crush. Thus, number of stacking layers should be re-calculated based on experiments.
(4) Stacking style. The stacking style may affect the resistance capacity of boxes in the bottom layer. In practice, there is tilt in different degree in almost all the storage stack, and the goods are normally not very neatly stacked. In most cases, air conditioners are stacked with storage trays. There are coordinate problems between the size of boxes and size of trays [4].

Preparation of design

Restricted by cost, we mainly improve the resistance capacity by modifying the boxes structures [5]. Currently, boxes of type 0201 and 0203 are mainly used as packages for in-door air conditioners. The most prominent problem of these types of boxes is the "Swell" (convex of box wall), that is, when stacked with several layers, the walls of boxes in the lower layers bend outward, and the resistance capacity of the boxes is reduced. The reducing of resistance capacity of a single box will impact the whole stacking unit [6].
Determined by the shape of the in-door air conditioners, the length-width ratio (R_L) of package boxes is normally greater than 2:1. According to experiments, the resistance capacity of empty boxes of type 02 decreased when R_L is greater than 1.5. As shown in fig. 2, the loading capacity in the middle part of the long side of in-door air conditioner package is quite fragile when R_L reaches 3:1. The loading capacity reaches the maximum at the end point of the boxes (conjunctions of 3 edges), and decreases when approaching middle parts of the edges. As the length of the long edge increases, the middle point gets more and more fragile, thus cause the bending of the box walls.
In addition, foam plastic or pearl cotton lining structures are distributed in the box at both ends, which actually increase the loading capacity at the ends (short side). And because the liner is relatively thick, large "holes" appear at the center of the long edges, which makes the center of the long edges more

vulnerable, resulting in "the strong stronger and the weak weaker". Only adding a piece of strengthened cardboard is not enough.

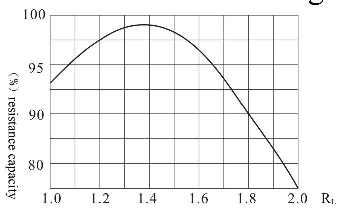


Figure 2. Relationship between resistance capacity of empty boxes and R_L of type 02

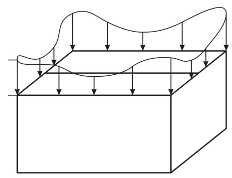


Figure 3. Vertical loading capacity of edges of box type 0201

Thus, when the size and ratio of the boxes cannot be changed, the solutions should focus on how to increase the loading capacity of the long edges. The box structures could be modify to types 0427, 0440, or 0431, adding layers of cardboard in the long edges to increase the vertical loading capacity.

Structure design and experimental analysis

Impact factor to resistance capacity of corrugated boxes should be expressed by experiments. Comparison experiments of resistance of corrugated boxes for in-door air conditioners are carried out to choose the most suitable corrugated boxes with the best resistance capacity.

Resistance capacity test on boxes of type 0201, 0203 and improved 0440, and edge crust test on two types of cardboard are taken out. In which, normal board and enhance board are compared on boxes of type 0203, and boxes with or without U-shape liner are compared on type 0201.

Analyze of box structures

(1) Structures of type 0201 and type 0203

Boxes of type 0201 and 0203 are both made by a single page of cardboard with four cover pans. The advantages of these types are saving of materials, solid, and with high efficiency. They are suitable in automatic producing. For boxes of type 0201, the width of upper and lower out cover pans is half of the width of the box. The out cover pans meet together when sealing the boxes. For boxes of type 0203, the width of upper and lower out cover pans equals to the width of the box. The out cover pans overlap when sealing the boxes to form double cover and bottom. Double cardboards appear in length and width of type 0201 to bear vertical loadings. Double cardboards appear in top and bottom of type 0203 to strengthen the loading capacity of bottom of boxes, which is usually used in packages of heavy products or when the products need to be transports multiple times.

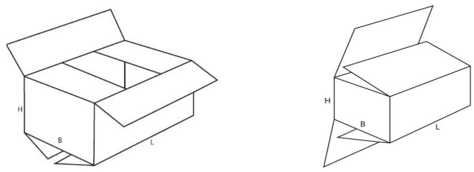
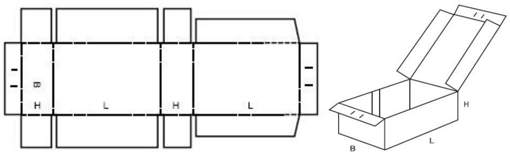


Figure 4. Structures of boxes of type 0201 and type 0203

(2) Structure of type 0440

The bottom of box of type 0440 is made of an entire board, with better puncture strength than type 0201. The advantage of this type is with high resistance capacity, and suitable in automatic producing. The improved type 0440 is made by a single piece of cardboard with locking structure. The outer and inner side boards in the long-side edge are fixed with certain adhesive. Four anti-dust boards are added to standard type 0440 so that there are 4 layers of board supporting the force in vertical direction to share the pressure. The width of anti-dust board is widened to make anti-dust board to support vertical pressure, thus there are 2 more layers supporting in vertical direction to improve the resistance capacity of boxes.



(3) Structure of type 0427

Boxes of standard type 0427 are made of a single piece of cardboard without staples or adhesive, which can be shaped only by folding. Locking structures are design at the ends. There are 3 layers of boards supporting pressure in the length direction, and more than 6 layers in the width direction, which can greatly improve the resistance capacity of the end surfaces. Improved type 0427 swaps the length and the width to use the side wings in supporting more efficiently. There are more than 6 layers of boards supporting pressure in the length direction, the paste boards in the vertical direction of length are also used as supporting boards.

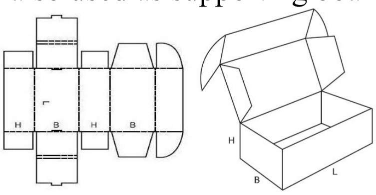


Figure 5. Structure of standard type 0427

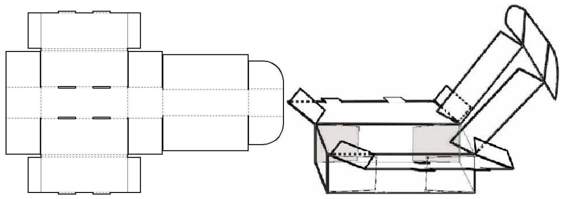


Figure 6. Improved type 0427

(4) Structure of type 0431

Similar to type 0440, the bottom of box of type 0431 is made of an entire board, with better puncture strength than type 0201. Improved type 0431 is made of a single piece of cardboard, the outer and inner side boards in length direction need to be fixed with adhesive. Clamshell cover is applied over cover pans to make it easier to load contents into the box. The anti-dust wings are designed to also supporting vertical pressure to improve the resistance capacity of the box.

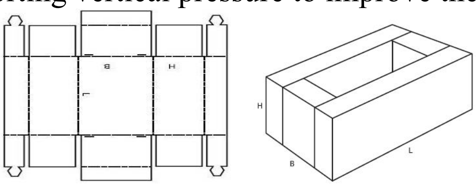


Figure 7. Structure of standard type 0431

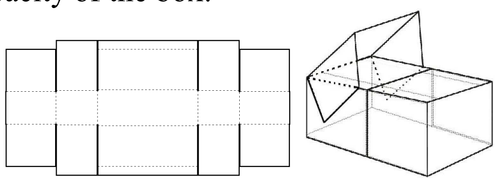


Figure 8. Improved type 0431

Expriments on empty boxes of type 0201, 0203 and improved 0440

Two types of corrugated board are used in experiments. One type is with higher intensity, which is referred as enhanced board; the other type is with lower intensity, which is referred as normal board. Three types of boxes are made with normal boards and enhanced boards. The resistance capacity is analyzed by experiments. The resistance capacity of corrugated boxes with or without supporting.

(1) Edge crust test of the boards

a. Experimental materials:
Normal board: five layers, BC corrugation, thickness 7 *mm*, density 706 g/m^2;
Enhanced board: five layers, BC corrugation, thickness 7 *mm*, density 1020.83 g/m^2.
Pretreatment of temperature and humidity was taken out before the resistance test: temperature 23 □, relative humidity 50% RH, 24 hours.
b. Experimental result (Mean values)

Table 1. Edge crust test result on cardboard before printing *N*

Board type	Loss of cold edge crust drop (*N*)	Edge crust (*KN/m*)
Normal board	441.18	47
Enhance board	710.18	28.407

(2) Experiments of resistance capacity on empty boxes

Corrugated boxes of type 0203 are currently used in the market as package for in-door air-conditioners. Three schemes of experiments are carried out to discuss and analyze the varying.
Scheme 1: Making boxes of type 0203 with two types of cardboards to analyze the difference of resistance capacity caused by materials.
Scheme 2: Making boxes of type 0201 and 0440 respectively to compare with type 0203 on resistance capacity.
Scheme 3: In order to analyse the contribution of supporting boards to the resistance capacity of boxes quantitatively, we made supporting boards with residual boards of making boxes. We also compared the resistance capacity of boxes of type 0201 with or without supporting boards. The schemes of making testing boxes are listed in Table 2.

Table 2. Schemes for testing boxes and supporting boards

Items	Quantity	Material	Remark
0201 with normal board	10	normal board	
U-shape liner	5	normal board	
0203 with normal board	5	normal board	
0203 with enhanced board	5	enhanced board	
0440 with enhanced board	5	enhanced board	

For wet boxes, pretreatment of temperature and humidity was taken out before the resistance test using constant temperature and humidity box: temperature 23 ℃, relative humidity 50% RH, 24 hours. The resistance capacity of boxes is taken out using a resistance testing machine. The operating speed of upper pressure board is 10 mm/min to test the distortion and pressure of boxes. The maximum resistance capacities are listed in the following table.

Table 3. Calculation result of resistance capacity experiment of boxes before printing *N*

Box type	Maximum resistance (N)
0201 with normal board	1412
0201 with normal board + supporting boards	2282
0203 with normal board	1055
0203 with enhanced board	2234
0440 with enhanced board	5930

We did not make 0440 boxes with normal boards, thus we calculated the equivalent resistance efficiency of "0440 box with normal board" approximately from the resistance efficiencies of "0203 box with normal boards", "0203 box with enhanced boards", and "0440 box with enhanced boards" as 1100 N/m2. When ignoring the influence of materials, we have the resistance efficiencies of the different schemes as: "0201 box with normal board + Supporting boards" is the highest, "0440 box with normal board" is the second, "0201 box with normal board" is the third, and "0203 box with normal board" is the lowest.

Table 4. Equivalent resistance efficiency of different box structures

Box type	Surface of materials (m^2)	Equivalent resistance efficiency
0201 with normal board	1.37	1000
0201 with normal board + supporting boards	1.88	1200
0201 with enhanced board	1.37	2135.7
0201 with enhanced board + supporting boards	1.88	2570.36
0203 with normal board	1.96	28
0203 with enhanced board	1.96	1117
0440 with normal board	2.62	1100
0440 with enhanced board	2.62	2325

(3) Force analysis of other box types

The loading boards in vertical direction of different box types are listed in Table 5. Combined with Table 4, we can see that the more the loading boards, the higher the resistance capacity. The type with the largest number of loading boards is type 0427, followed by types 0440 and 0431. There are 2 layers board in length direction and 1 layer in width direction less in 0431 than 0440, but the resistance capacity of the two types are approximately equal.

Table 5. Loading boards of different box types

Box type	Vertical in length	Vertical in width	Paste boards	Anti-dust boards
0201	2	2	0	2
0203	2	2	0	2
0440	4	3	4	0
0427	6	3	4	2
0431	2	2	4	2

Conclusion

Boxes of type 0201 can be used as package for in-door air conditioners instead of type 0203. In the condition of using least material, the resistance efficiency of type 0201 is higher than 0203.
Experimental result shows that, the resistance capacity is obviously improved with supporting boards, thus it is feasible to improve resistance capacity of boxes using structures with supporting boards. The structure of supporting boarding needs to be proved by further experiments.
With the comparison of box types, in case of permitted with enough material, new box type – improved type 0440 can be chosen. The resistance capacity of type 0440 is normally higher than type 0203, even equivalent with type 0201 with enhance board and using supporting boards.

Acknowledgements

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