

Review on Paper Corrugated Box Manufacturing used in Goods Packaging

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ABSTRACT: *This study summarizes the reducing principle of design of corrugated box used in the goods packaging. Then it makes a term-by-term analysis on the selection of raw materials for paper boxes, the optimization of prism types, and the overall design of paper box, with special emphasis on the method to realize moderate packaging of goods.*

I. INTRODUCTION

Corrugated box is a container [1] most extensively applied in goods packaging and transporting. It is made from paper, and machine-shaped from corrugated box board with hollow structure. Since 1903 when corrugated box was first accepted by legal freight classification organizations as the containers for freight transportation, the application history of corrugated box has been over more than 100 years. Because of its light weight, low cost, ease of assembly and disassembly, good sealing performance, certain cushioning and anti-vibration ability and easy recovery and waste treatment, corrugated box is widely applied in various fields.

China started to introduce and use corrugated box as the external packing box from early 1930s. At that time, 80% of the external packing boxes in use were wooden boxes, with cartons accounting for only about 20%. By the end of 1940 and the beginning of 1950s, the percentage of boxes in use increased to 80%. With the development of packaging materials and machine industries, 90% packing boxes in use nowadays are corrugated boxes [2]. The Yangtze River Delta represented by Zhejiang, Jiangsu and Shanghai is the region which has witnessed the most rapid development of corrugated box industry in China over the past few years. According to the statistics of Paper Committee of Shanghai Packaging Technology Association, the sales volume of corrugated box industry in Shanghai in 1990 was 1 billion. By 2002, it had increased to 6 billion RMB, and to 13 billion RMB in 2007, with an average annual increase of about 30% [3]. Apparently, China's production capacity of corrugated box is soaring dramatically. However, with the constant rise of resource and manufacture costs, many manufacturers at home and abroad are considering increasing the income while decreasing expenditure, especially the reduction of packaging expenditure. This is not only a response to domestic and international financial crises, but also an indication of the shift in priority from cutting down the cost of the product itself to the cost of the external packaging when taking into account of products cost. It is indeed progressive

2. Optimal combination of raw materials

2.1. The principle of "light weight"

Weight lightening of corrugated box can be realized through the selection and application of base paper, which is an important measure to achieve moderate packaging. This principle demands the selection of base paper characterized by low gram weight, high strength and weight lightening, which is mainly applied in the packaging of some large electrical household appliances and equipments. By considerably reducing the overall weight of the freight, it makes the handling and transportation more convenient. "Light-weight base paper" advocated currently has significantly lower gram weight of unit area of base paper than that of normal base paper, while its strength is comparable to that of normal base paper. Therefore, this type of "light-weight base paper" will inevitably become the superior choice in the future.

In 1950s, due to the backward development of China's paper making, the gram weight of box averaged between 320g to 360g, and the base paper used for the manufacture of export boxes and domestic sale boxes was of poor quality [4]. There are several opinions concerning the selection of "light-weight" base paper. According to one opinion, the ration of base paper should be as low as possible; while according to another opinion, there should be explicit requirements on the selection of "light-weight base paper", and at least one of the following three requirements, namely, processed by special techniques, manufactured by independent equipments, with gram weight of less than 150g, should be satisfied. There is a more widespread opinion: the ration of base paper should range between 100-180g/m²; indicators, such as ring pressure and breaking

length should comply with certain standards [5]. And, as to the aspects of base paper application in domestic, part of the electrical household appliances industry has adopted 3 layers of corrugated cardboard to replace 5 layer of corrugated cardboard previously used. For the outer and inner layer of corrugated cardboard, high-strength light-weight base paper is adopted, while for the middle layer, the high-strength corrugated cardboard. In this way, the consumption quantity of boxes was reduced tremendously, but with equal strength.

2.2. High-strength corrugated honeycomb composite board

The compressive strength as principle technical performance indicator of this high-strength corrugated composite box is as follows: when the pressure is 10560N, residual deformation $\leq 17.6\text{mm}$ [6]. When this high strength corrugated composite box replaces wooden box, not only its appearance and printing has been improved, but more importantly, it satisfies the environmental protection requirement, at a remarkably reduced cost.

2.3. Intensified sandwich corrugated cardboard

Intensified sandwich corrugate paper is called “corrugated cardboards of corrugation”. Generally, two, three or five layers of corrugated cardboard are used as outer paper and inner paper (board), between which corrugated cardboard or corrugated paper-tube specially arranged is sandwiched to form wave-type sandwich layer [7]. Reasonable structural design endows the intensified sandwich corrugated board with high strength. It is measured through testing that the total thickness of the board is 3.2cm (adjustable at will); corrugation density of sandwich layer is 38-40 prism/m; there are five layers of ordinary corrugated cardboard (C prism B prism) as outer layer (ration 780g/m^2); three layers of ordinary corrugated cardboard (C Prism) as inner layers (ration 470g/m^2); three layers of ordinary corrugated cardboard (B prisma) as sandwich layer (ration 680g/m^2), with a total ration of $1900\text{-}2000\text{g/m}^2$ [8]. “Corrugated cardboard of corrugation” is an application of the mechanical principle of multi-azimuth support. It is made of high strength corrugated cardboard, which is deformed and arranged by special technique to form optimal mechanical structure. It can be applied in the manufacture of the packing box of six facades, by forming strong tubular matrix. Its superiority is mainly manifested in its ability to prevent damages to the objects contained in the box, especially for the packaging of large-volume, heavier, fragile and pressure susceptibility items. Moreover, because of its compact structure, seamless, absence of nails, fold ability and forming ability, the overall packaging cost can be reduced by about 30%, and its appearance and integrity are also improved. Therefore, this kind of structure is very applicable for the packaging and transportation of large electrical household appliances and electromechanical equipments

2.4. Four-layer corrugated cardboard (also called double-arch composite corrugated cardboard)

Four-layer composite corrugated cardboard is also called double-core superimposed corrugated cardboard, double-arch corrugated cardboard or UPS resulting force corrugated cardboard. It is generally made by smearing the adhesive with special performance on two layers of corrugated base paper, so that adhesive can filter into the cardboard fibers. Thus, the softness of paper can be modified, and the two layers of corrugated base paper are combined together. The corrugation is rolled under heating conditions; then it is adhered to outer layer to form firm and stiff four layer corrugated cardboard. The structure of its corrugated core is the double arch “honeycomb” structure which is made by adhering double-layer core papers and then formed by corrugation roller. The two arch’s of four-layer corrugated cardboard adopts the shape of ordinary corrugation—U-shaped or V-shaped corrugation, which can be divided into 2A, 2B and 2C type [9].

The research, development and application of four-layer corrugated cardboard have been very widespread in Japan, Europe and America. Due to its late start in China, only a small number of corrugation cardboard manufactures have introduced the manufacture and processing technique of four-layer corrugated cardboard. However, its promotion and application have not been realized yet.

3. Optimization of overall design of corrugated box

Design optimization refers to the optimization made by designers according to the theory of meeting specific properties, so that different configuration complying with new standards will be obtained.

3.1. Forming process

The forming process of corrugated boxes has significant impact on the quality of corrugated box. Groove, slotting, printing, and gluing all need to be optimized in actual operation. First, the strength of corrugated box is associated with the width and depth of press mark line of cardboard. Excessive width and depth of press mark will lead to the rupture of inner paper; while insufficient width and depth lead to the non-fold ability of the corrugated box. Therefore, investigation has to be made into the groove process of corrugated cardboard, so as to determine the optimal operational parameters. Second, the printing process is

another factor affecting the load bearing strength of corrugated box. Research shows that with the increase of printing pressure, the contraction and deformation will occur to corrugated cardboard; its compressive strength declines until the crush of the corrugated box. It is thus necessary to adopt the smallest printing pressure possible while ensuring good printing appearance. Third, the slotting and gluing process optimization also need exploration, since the compressive strength of corrugated box dramatically decreases with the deepening of the slotting; inadequate dosage of adhesive leads to the weak cohesion.

As a result, adhesive failure is very likely to happen under pressure, leading to crushing and the decline of compressive strength. On the other hand, excessive dosage will bring about glue overflow, which affects the appearance of the products; or, it will result in cohesion between corrugated boxes, with a waste of production cost [10].

3.2. Optimization of size and proportion

To ensure moderate packaging, the arrangement number and arrangement orientation of the packaged commodities, as well as the internal and external size of the corrugated box can be optimized during the transportation [11] [12]. In actual practice, various kinds of cushioning pads are placed inside the corrugated box to prevent the packaged commodity from being damaged. By this means, the volume of commodity after packaging is usually larger than that of the commodity itself, sometimes by 5-10 times. In this case, prodigious waste is incurred with a several-fold increase in consumption quantity of corrugated cardboard. Therefore, much can be done in reducing the size of corrugated box in accordance with the reducing principle of corrugated box.

3.3. Palletized corrugated packaging

The use of pallets in logistics has already reached maturity, including wooden pallets, plastic pallets, and metal pallets. The application of pallets makes the handling, loading and unloading, stacking and classification much more convenient. Over the recent years, the emergence of paper pallet has facilitated the seamless linkage of logistics packaging and retail packaging. The use of corrugated pallets, by protecting the bottom and facades of the commodity, makes the packaged commodities easier to be stacked. The remaining part is wrapped by plastic thin films or other packing methods. By this means, the consumption quantity of corrugated cardboard can be reduced by 60% or more. With its visibility and air permeability, pallets are extensively applied in the integrated packaging of carbonated soft drinks, mineral water, beer and other kinds of soft drinks [13].

To sum up, the reduction measures discussed above are not applied solely, but in combination by enterprises. In this way, the reduction design of corrugated boxes is implemented, which provides the first step to achieve moderate packaging. Due to its characteristics of being cost-saving and environmental friendly, the reduction principle in packaging design deserves more thorough research in future commodity packaging. Moreover, it will definitely make its own contribution to the effective utilization of natural resources.

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