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Retraction

Retracted: Application of CAD in Semifinished Product Packaging Art Design

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] Y. Mao and T. Wu, "Application of CAD in Semifinished Product Packaging Art Design," *Security and Communication Networks*, vol. 2022, Article ID 8937896, 13 pages, 2022.

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Research Article

Application of CAD in Semifinished Product Packaging Art Design

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In order to solve the problem, the packaging CAD software developed in China is mostly the design software of carton and rarely involves the design of cushion liner. It is proposed to use Visual C++ program to develop this software for buffer packaging design, which liberates people from the complicated manual design, significantly shortens the product R&D cycle, and avoids the destructive test of the product. When the overall dimension, quality, brittleness value, cushioning performance parameters of cushioning materials, transportation conditions of packages, and liner parameters are known, the most economical material can be found in the database of cushioning materials through this software, and the liner size structure can be obtained. Based on this data, the structural design of corrugated box is further carried out. For the packaging of products, especially the packaging of precision electronic products, its economic benefits are considerable. Visual C++ 6.0 is used as the software development tool. Using the GUI (graphical device interface) characteristics of various tools and other high-level languages, a simple and friendly user interface is designed to verify the effectiveness of the experiment.

1. Introduction

At present, a lot of work in packaging design can be completed by computer. For example, the structural design of packaging can be completed with AutoCAD, as shown in Figure 1 [1]. The modeling design and surface decoration design of packaging can be completed with Photoshop and 3Dsmax, the stress analysis and buffer packaging design of complex packaging system can be carried out with ANSYS, and several aspects of packaging design can be completed with special packaging CAD. However, most of the packaging design with these methods is only a kind of computer-aided drawing. Whether it is the structural design of packaging or the artistic design of packaging, it is just to show people's design ideas with the help of computers, to help people give up and lose the drawing board. There are still a lot of gaps from the real packaging design system. Moreover, using these current methods for packaging design often requires several kinds of software, the design cycle is long, and the design results cannot be optimized. Therefore, it is necessary to introduce the concept of system and apply artificial intelligence technology to develop a real computer-aided packaging design system [2]. There are many kinds of packaging design, but it should meet the following six requirements. (1) Protection performance: it refers to the ability of packaging to protect various properties of packaging contents, such as moisture resistance , anticorrosion, and shock resistance, and to prevent packaging contents from harming people and the surrounding environment. (2) Promoting art performance: it mainly involves the modeling and decoration of packaging, as well as the function of text advertising, which is often very important for commodity promotion. (3) Service performance: on the one hand, it refers to whether the package is convenient to open, store, and handle and whether it will cause harm to users. On the other hand, it refers to the degree of standardized design and manufacturing adopted. (4) Economy: it mainly refers to whether the comparison between the cost of packaging and the value of content is reasonable. (5) Realizability: it refers to whether the packaging materials are easy to obtain, whether the packaging structure is feasible, whether the whole packaging is suitable for mechanized and automatic

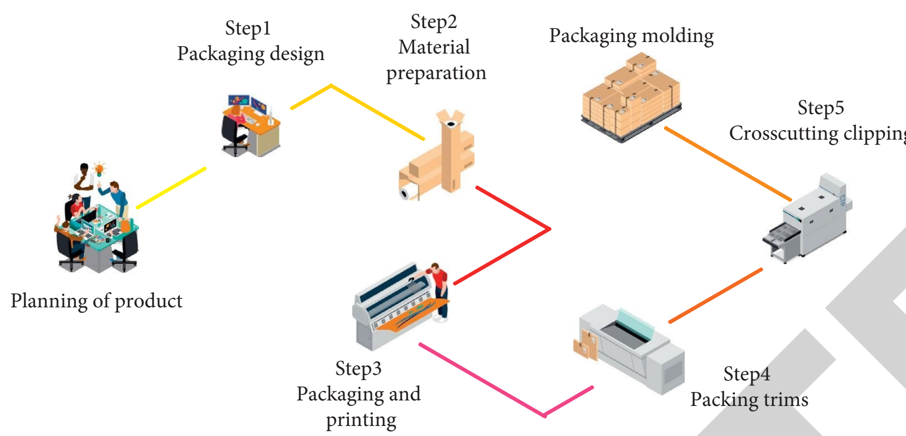

Figure 1: Flowchart of CAD packaging art design.

production, etc. (6) Protection performance: it refers to whether the packaging meets the requirements of environmental protection, such as whether it can be recycled and whether it will cause environmental pollution. In the whole process of packaging design, these requirements should be considered. Computer technology has played an increasingly important role in packaging design, bringing new design methods and concepts to packaging design [2]. The previous computer-aided packaging design is mainly limited to helping designers improve drawing efficiency, which cannot adapt to the development of computer technology. Only by introducing the concept of system and applying artificial intelligence technology to develop a highly intelligent computer-aided packaging design system can computers play a more important role in packaging design [3]. To develop such a system, we need to learn from some mature technologies in other fields, redevelop some special software, and establish the corresponding expert system. It is a huge, complex, and arduous work. However, from the perspective of market, such a computer-aided packaging design system is worth developing.

2. Literature Review

Meng and others found that, in recent years, with the rapid development of China's industrial economy, the improvement of people's quality of life, and the enhancement of environmental protection awareness, paper packaging has become the most potential green packaging form because of its wide source of raw materials, easy molding, degradable recycling, and other advantages [4]. According to the literature, the output value of corrugated paper industry in Sichuan has surpassed that of the packaging industry in Europe since 1999. [5]. According to Yu and Sinigh, the output value of corrugated paper industry in China has also surpassed that of the packaging industry in the world since 2003. Sidelnikov and others found that, in addition to the increasing share of paper packaging in various packaging materials, paper packaging is also developing in the direction of high quality, high strength, lightweight, and versatility, which have also become an important reason for the rapid and stable development of paper packaging industry in the packaging field [6]. With the rapid and stable development of the paper packaging industry, Deja and others have also been widely used in all walks of life in order to meet the needs of multi-Wu chemical industrial design outside China and fully meet the market development needs of small batch, personalization, interest, diversification, and short cycle, it has become a key technology to improve the product R&D capability and enhance competitiveness of various enterprises [7]. Tipsina and others found that, at present, this technology is mainly used in the design of packaging structure, packaging modeling, packaging decoration, packaging machinery, buffer packaging, etc. [8]. Cherevko and others believe that computer-aided technology not only injects new blood into Chinese traditional industry but also makes packaging CAD technology develop rapidly in a scientific and professional direction [9]. As a computer-aided design software widely used in the field of engineering design at home and abroad, Bakhadirov and others believe that it is impossible to meet various industry standards and the usage habits of each user, but AutoCAD has very powerful drawing function and provides rich programming interfaces for the majority of users. This provides very convenient conditions for us to quickly transform it into special software that meets our needs through secondary development in a short cycle [10]. Sahmel and others found that, in the era of rapid changes in science and technology, China's outer packaging industry is taking this opportunity to develop rapidly in the direction of networking, informatization, and intelligence. The existing packaging technology can no longer meet the needs of the development of packaging industry, so it is urgent to research and develop new packaging technology [11]. Golembovskaya and others found that, at present, intelligent packaging has attracted more and more attention because of its intelligent and humanized technical characteristics, extensive social effects, and huge market development potential. From "intelligent control" proposed in 1967 to "expert control" proposed in 1984, the "intelligent packaging" theory in 1992 and the subsequent trend of the Internet of things have the characteristics of one continuous line, which reflects the framework of the system development process of the packaging industry since the information revolution. At the same time, it also reflects that the interdisciplinary and multidisciplinary cross comprehensive application has become the mainstream of the times [12]. Hrudkina and others found that this multidisciplinary and multifield cross integrated application has become the mainstream of information age, and if the packaging industry can grasp the trend of the times and successfully combine the relatively mature high-tech in other disciplines with the existing packaging technology, it will help to improve the overall technical level of the packaging industry [13].

3. Method

The following development principles must be followed in the process of software development.

3.1. Modularization. Module is a relatively independent part of program logic. By means of decomposition, complex problems are divided into thousands of smaller, relatively independent, and easy to solve subproblems in time or scale. Subproblems should have good interface definition and then be solved respectively. For example, functions in C language and classes in C++ language are modules. Modularization helps to abstract and hide information and to represent complex systems [14].

3.2. Abstraction and Information Hiding. Abstraction refers to extracting the most basic features and behaviors of things, ignoring other details irrelevant to the problem. The sharing mechanism of software development process can be improved through hierarchical abstraction and layer-by-layer refinement. Information hiding is to design the module as a "black box," hide the details of data and operation inside the module, and shield the outside world. If users want to access the data in the module, they can only access the outside world through the interface of the module [15]. In this way, the independence of the module can be effectively guaranteed.

3.3. High Cohesion and Low Coupling of Modules. When dividing modules, we should consider concentrating the logically interrelated computer resources into one physical module to ensure loose coupling between modules and strong cohesion within modules. This helps to control the complexity of the solution [16].

3.4. Certainty. The expression of all concepts in the process of software development should be standardized, definite, and unambiguous. This helps people to communicate without misunderstanding and ensure that the whole development work can be carried out in a coordinated and smooth manner [17].

3.5. Uniformity. Consistency is one of the purposes of studying software engineering methods, which is to make software product design follow the guidance of unified and recognized methods and specifications and standardize the development process [18]. It requires that the whole software system (including programs, documents, and data) meet the following consistent characteristics: the concepts, symbols, and terms used are consistent; the internal and external interfaces of the program shall be consistent; the system specification is consistent with the system behavior; consistency of software format; workflow consistency.

3.6. Completeness. Considering the completeness of management and technology is to realize the functions required by the system within the time limit and ensure the software quality. In the process of software development and operation, strict technical review must be carried out to ensure the effectiveness of development results in each development stage.

Cushioning packaging CAD software is based on VC platform. It adopts local cushioning packaging method for products with regular shape (typical cuboid) and products with irregular shape (such as CRT display). At the same time, considering the deviation between product center of gravity and geometric center, it designs cushioning pad and corrugated box and can draw three-dimensional effect drawing of cushioning packaging through OpenGL technology [19]. The software flowchart is as follows (Figure 2).

The cushioning packaging CAD software has the following functions: input the weight, length, width, height, brittleness value, and equivalent drop height of the product to conduct the preliminary design of the buffer pad; input the projection coordinates of the center of gravity of the product, and design the volume, area, and thickness of each buffer pad when the projection of the center of gravity of the product and the geometric center of gravity on the bottom surface does not coincide (i.e., eccentric). According to the needs of users, through the selection of function buttons, the antivibration check, angular drop check, deflection check, creep check, and center of gravity check of buffer pad are carried out, respectively [20]. Select the type of product, refer to the design characteristics in actual production, and adopt OpenGL technology. Draw the three-dimensional effect drawing of buffer packaging scheme, so that users can have an intuitive understanding of the design scheme. Select corrugated type, corrugated box type, and corrugated board code to display the box type structure diagram of the selected corrugated box. The compressive strength can be calculated by the size and the thickness of the corrugated box. Cushioning packaging is a packaging technology that takes certain protective measures to reduce the impact and vibration of the contents of the package from external forces and avoid damage during the circulation of the package. Cushioning packaging is a technical measure to select appropriate cushioning materials and packaging structure to reduce the impact force and vibration force transmitted to the contents to less than the strength of the contents, to ensure the safety and integrity of the contents. The design basis of cushioning packaging is the characteristic parameters of contents, the parameters of circulation environmental conditions, and the parameters of cushioning materials.

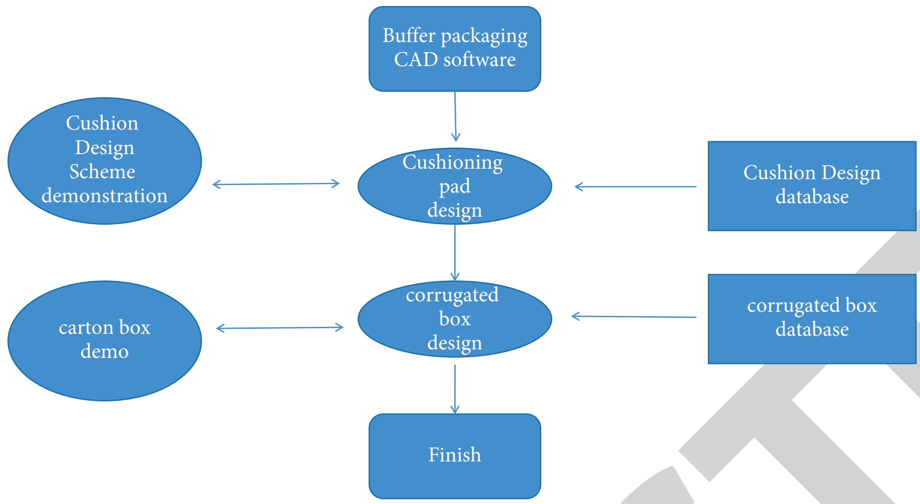

Figure 2: Flowchart of buffer packaging CAD software.

For a specific cushioning package, the characteristic parameters and environmental parameters of the contents are the determined parameter values. Therefore, the main way to require cushioning packaging to achieve the purpose of cushioning and antivibration is to solve it by adjusting the technical measures of cushioning materials and packaging structure. The purpose of cushioning packaging is to protect the performance and shape of the packaged products in case of impact, vibration, and other external forces during transportation and loading and unloading. The design shall meet the following requirements: reducing the impact, vibration, and other external forces transmitted to the products; dispersing the stress acting on the product; protecting the surface and convex part of the product; preventing mutual contact of products; preventing the product from moving in the packaging container; protecting other protective packaging functions.

Embrittlement value is a quantitative index used to express the strength of a product when it is subjected to impact and vibration, also known as the vulnerability of a product. This value indicates the bearing capacity of the product to external force and is the ratio of the maximum acceleration that the package can bear to the gravitational acceleration. It is one of the important parameters of buffer design. The purpose of buffer design is to reduce the external impact force below g value. The size of G value determines the difficulty of buffer design. In order to simplify the design and save cushioning materials, the brittleness value of the product should be improved as much as possible when designing the product. The brittleness value of the product in the software buffer design parameters is determined in Table 1.

The equivalent drop height represents the drop impact energy of the package during circulation. The higher the drop height, the greater the impact energy, the easier the damage to the product, and the higher the buffer protection requirements. Falling mainly occurs in manual loading and unloading and mechanical operation during loading and unloading. The impact energy during falling is mainly considered according to the comprehensive factors such as product weight, volume, personnel height, handling difficulty, and handling mode [21]. The equivalent drop height is usually determined by empirical formula method and standard value method.

3.7. Empirical Formula Method. During manual loading and unloading, the equivalent drop height of packages above 16 kg can adopt the following empirical formula:

$$h = \frac{300}{\sqrt{w}}, \tag{1}$$

where w is the weight of package in kg and h is the drop height in cm.

3.8. Standard Value Method. The standard value method is to determine the equivalent drop height according to some national standards and industrial standards of China, the United States, and Japan. The following is a brief introduction to determining the equivalent drop height through the classification of circulation environmental conditions. In the process of circulation, through the links of loading and unloading, handling, transportation, and storage, the conditions are divided into three levels, as shown in Table 2.

First-class circulation conditions are as follows: long transportation distance and many times of transfer, poor loading and unloading conditions, manual loading and unloading difficult to handle with care, etc. Secondary circulation conditions are as follows: first, the transportation distance not long and small number of transfers, when the loading and unloading conditions are better than the primary circulation conditions, and in case of rough loading and unloading conditions and good circulation conditions. According to the circulation condition level of the transportation environment, the equivalent drop height can be determined according to Table 2 in the design of buffer packaging.

In addition, the drop height can also be determined by the corresponding relationship between the weight and size

Table 1: Brittle value of common products.

Trade name	Allowable brittleness value
Large electronic computers, etc.	Below 10
Advanced precision equipment/electronic equipment, etc.	15~20
General electronics, precision equipment	25~40
Computer/general test equipment, etc.	40~60
Advanced watch, clock/advanced color display device	45~65
General household appliances/printing equipment, etc.	60~85
Egg	45~90
Light bulb	50~90
Beer bottle	130~170
Ceramics with complex structure	70~120
General machinery and equipment	Above 110

Table 2: Drop height values.

Weight (kg)	Drop height		
Circulation conditions	Class A	Class A	Class A
<25	90	90	90
26~50	65	65	65
51~75	50	50	50
76~100	45	45	45

of goods, their loading and unloading mode, and the maximum drop height, as shown in Table 3.

Vibration refers to the reciprocating motion of a particle relative to its equilibrium position. The most basic parameters describing vibration are frequency and acceleration. The factors affecting package vibration come from the types of transportation tools, transportation environment, packaging structure, loading weight, and so on. During the circulation of products (i.e., road transportation, railway transportation, air transportation, and sea transportation), they will be subject to vibration, and the vibration impact caused by each transportation mode is also different.

3.9. Automobile Transportation Vibration. The vibration acceleration of automobile transportation is related to the road condition, driving speed, vehicle type, and load capacity. The main factor is the fluctuation and unevenness of the highway.

3.10. Train Transportation Vibration. When the train passes through the rail joint, the wheels are impacted, which is a periodic excitation to the vehicle, which causes the periodic forced vibration of the running vehicle. In normal operation, station entry and exit, crossing, vehicle body shaking, vehicle body vibration, rail joint, bridge girder, and other operations, the vibration caused by rail joint is the strongest, as shown in Table 4.

3.11. Aircraft Transportation Vibration. During air transportation, the vibration of the aircraft mainly comes from the engine vibration, which shows the characteristics of single vibration and high frequency. Its vibration acceleration is small and stable, as shown in Table 5.

3.12. Marine Vibration. The following table shows the vibration data measured at different parts of the goods. It can be seen from the table that the left and right vibration accelerations of the tail deck, front compartment, and rear compartment are the maximum when the cargo ship is sailing [22], as shown in Table 6.

The cushioning packaging material shall be able to transfer the impact and vibration of the external action on the package to the contents after buffering, avoid stress concentration, protect the contents, support the contents, and protect the product structure and cushioning packaging system. Buffer characteristic curve mainly includes maximum acceleration static stress curve, buffer coefficient maximum stress curve, vibration transmission rate frequency characteristic curve, etc.

3.13. Common Cushioning Materials

3.13.1. Foam Plastics. Foam plastics is a material blended with gas and plastics. It is made of foam resins such as PE, PS, and PU. It has excellent cushioning and vibration absorption properties, light weight, easy forming, good protection, high quality and low cost, and being easy to spread. Commonly used foam plastics are EPS and EPE, which are widely used in cushioning packaging of fragile materials such as precision instruments, household appliances, and medical devices. Although foamed plastics have good protective properties and cost performance, they also have disadvantages such as difficulty in recycling, natural weathering, and incineration, which cause harmful gas and environmental pollution. From the perspective of development trend, foam plastics will develop towards being biodegradable and environmentally friendly [23].

3.13.2. Corrugated Board Cushion. Corrugated board has the advantages of good workability, low cost, wide use temperature range, wide plastic foam, and no pollution. But at the same time, there are also some disadvantages: hard surface, inability to directly contact the product when packaging high-grade products, poor moisture resistance, and small recoverability, which is not suitable for the situation of large impact load. From the development trend, corrugated board will develop in the direction of

Table 3: Loading and unloading environment and drop height.

Goods		Loading and unloading mode	Drop parameters	
Weight (kg)	Size (cm)		Attitude	Height (cm)
9	122	One throw	An end face or corner	107
9~23	91	Carried by one person	An end face or corner	91
23~45	122	Two-person handling	An end face or corner	61
45~68	152	Two-person handling	An end face or corner	53
68~90	152	Two-person handling	An end face or corner	46
90~272	183	Mechanical handling	Bottom surface	61
272~1360	Unlimited	Mechanical handling	Bottom surface	46
>1360	Unlimited	Mechanical handling	Bottom surface	30

Table 4: Vibration caused by railway and highway transportation.

Type of transportation	Operation		Maximum acceleration (g)		
			Up and down	Left and right	Front and back
Railway wagon	Vibration during operation (30~ 60 km/h)		0.2~0.6	0.1~0.2	0.1~0.2
	Vibration during deceleration		0.6~1.7	0.2~1.2	0.2~0.5
Automobile	General highway	Good pavement	0.4~0.7	0.1~0.2	0.1~0.2
	20~40 km/h	Bad pavement	1.3~2.4	0.4~1.0	0.5~1.5
	Paved highway	The full load	0.6~ 1.0	0.2~0.5	0.1~0.4
	50~ 100 km/h	No load	1.0~1.6	0.6~1.4	0.2~0.9

Table 5: Vibration generated during air transportation.

Flight status vibration quantity	Vertical (g)	Longitudinal (g)	Transverse (g)	Loading condition
Engine start	0.45	0.1	0.2	No load
Glide	0.38	0.05	0.03	No load
Flight	0.36	0.10	0.04	Load
Turn and circle	0.60	0.08	0.03	Load
Landing	0.40	0.14	0.18	No load

Table 6: Vibration caused by sea transportation.

	Frequency (Hz)			Acceleration (m/s^2)		
	Up and down	Left and right	Front and back	Up and down	Left and right	Front and back
Engine room	17~95	35~128	49.5	0.17~8.2	0.11~3	0.03
Stern deck	21~95	30~132	43~148	0.1~2.8	0.02~2.2	0.02~0.04
Front compartment	21~145	35~153	31~121	0.02~0.25	0.014~2.1	0.003~0.014
Rear compartment	41~207	12~153	45~48	0.01~0.74	0.01~1.7	0.006~0.007

miniaturization, diversified structure, small quantity, low cost, and high quality.

3.13.3. Honeycomb Paperboard Liner. Honeycomb paperboard has a unique inner core structure which is full of air and is not circulated. It has good toughness, resilience, sound insulation, high rigidity, and less consumables. It has the highest unit volume energy absorption value in all cushioning materials, and high thickness honeycomb paperboard can replace plastic foam cushion. Compared with corrugated paperboard, honeycomb paperboard has better pressure bearing performance and bending resistance. The combined application of corrugated paperboard and honeycomb paperboard, combined with their advantages, has better performance. The production of honeycomb paperboard adopts recycled paperboard materials and water-soluble adhesives, which can be completely recycled and avoid the harm to the environment caused by recycling. It is suitable for the transportation and packaging of precision instruments, instruments, household appliances, and fragile products. However, due to the short development time of honeycomb paperboard, the utilization rate of production equipment is still low, and the price of honeycomb paperboard is high. Therefore, improving the production technology of honeycomb paperboard and further reducing the price are the focus of future research.

3.13.4. Pulp Mold. Pulp molded products are made of pulp or wastepaper as the main raw material, which is crushed, pulped, seasoned, molded into various shapes through a drainage metal mesh mold, and then compacted and dried. The product has rich sources of raw materials, pollution-free production and use, light weight, and high compressive strength. Pulp molded products have developed rapidly in China, but so far, the structural design of products still adopts empirical design method, which lacks mature theory and specification. At present, it is only limited to the packaging of small electronic products and eggs.

3.13.5. Plant Fiber Cushioning Material. Plant fiber buffer materials are made of plant fiber (wastepaper and other plant fiber materials) and starch additive materials. At present, the developed materials include foam packing made of straw buffer packaging material, polylactic acid foam packaging material, wastepaper, and starch. It has the characteristics of no environmental pollution, simple production process, low cost, and rich source of raw materials. In the future, the research focus of plant cushioning packaging materials will be the formulation of production technology and the determination of cushioning performance parameters in the actual use of materials.

3.13.6. Expanded Perlite Cushion. Expanded perlite is a white or light colored high-quality thermal insulation material made of acid volcanic glassy lava (perlite) after crushing, screening to a certain particle size, preheating, and instantaneous high-temperature roasting. The inside of the particles is honeycomb structure, nontoxic and tasteless, noncorrosive and noncombustible, and acid and alkali resistant. Different adhesives can be used to make products with different properties. It is characterized by light weight, good heat insulation and sound absorption performance, rich raw materials, low price, safe use, and convenient construction. The expanded perlite cushion liner is made by foaming and molding technology during the bonding process. It is suitable for cushioning packaging of small electronic products and has broad development prospects.

The performance comparison of common cushioning materials is shown in Table 7.

The buffer design is shown in Figure 3.

In practice, the circulation process of products is very complex. There are other requirements for cushion pad besides cushion. Therefore, after the preliminary design of the buffer pad is completed, various performance checks should be carried out to adjust the material and size of the buffer design, and the antivibration check, angle drop check, deflection check, center of gravity check, and creep variable check of the buffer pad should be carried out, respectively.

3.13.7. Antivibration Check. From the initial elastic rate E and bearing area a of the buffer pad, the natural frequency f_o of the buffer package can be obtained. From f_o, the maximum transmission frequency T_m can be obtained from the buffer material database. From the vibration acceleration a in the circulation environment database, the maximum response speed $p = T_m \cdot a$ can be obtained. After void Step4: onshockproof() calculation, if the p value is less than the allowable brittleness value of the product, it is considered to meet the antivibration requirements. If the p value is greater than the allowable brittleness value of the product, redesign it, as shown in Figure 4.

3.13.8. Angle Drop Check. In the actual circulation process, the falling posture of packages can be divided into three types: angular landing (called angular drop), corrugated landing (called corrugated drop), and surface landing (called surface drop). When the package falls, the stress changes greatly, so it is necessary to check and adjust the preliminary design size of the buffer pad. This subject adopts the local buffer packaging method to design and check the angle drop.

$$\frac{3lbh}{\sqrt{l^2 + b^2 + h^2}} > A, \tag{2}$$

where l, b, and h are the length, width, and height of the product, respectively.

The length, width, and height of the product are passed in by the global variable's length, width, and height, and the pad area a is passed in by the global variable area.

After void Step4: onconnerdrop() calculation, assign the pad area to the global variable area.

3.13.9. Deflection Check. When the slenderness ratio (i.e., the ratio of area to thickness) of the pad exceeds a certain limit, the pad is easy to flex or bend, which greatly reduces the load-bearing capacity of the pad. In order to avoid deflection, the ratio of the minimum bearing area a to the thickness t shall comply with the following provisions:

$$A_{\min} > (1.33T)^2. \tag{3}$$

The pad area a and thickness T are passed in through the global variables area and thickness.

After void Step4: 0nflexibility() calculation, assign the pad area to the global variable area.

3.13.10. Creep Check. Under the action of long-term static pressure, the plastic deformation of the buffer material will gradually increase, resulting in the smaller size of the liner and the cracks in the container. This will increase the vibration of the product and the friction with the container and reduce the cushioning capacity of the liner. Therefore, it should be considered to increase the creep compensation value for the pad size in the design.

$$T_c = T(1 + C_T), \tag{4}$$

where T_C is the corrected thickness in cm, C_T is the creep coefficient in %, and T is the original design thickness.

The liner thickness t is introduced through the global variable thickness, and C_T is taken as a constant of 10%.

After void Step4: onwiggle() calculation, assign the pad thickness to the global variable thickness.

3.13.11. Verification of Center of Gravity. Projected from the center of gravity to the pad, the pad is divided into S_1, S_2, S_3, S_4 according to the bearing area. Weight of each

Table 7: Comparison of characteristics of cushioning packaging materials.

Material science characteristic	Residual deformation	Impact attenuation	Density	Processability		Operating temperature range
				Formability	Adhesion	
Polyethylene foam	Tiny	Excellent	Small	Good	Good	Wide
Polyurethane foam	Tiny	Good	Small	Good	Good	Wide
Styrofoam	Slightly worse	Excellent	Small	Excellent	Good	Narrow
Air cushion plastic film	Difference	Good	Small	Bad	Good	Wide
Foam plastic wire	Varies by material	Good	Small	—	—	Depending on the material
Foam rubber	Nothing	Excellent	Large	Good	Good	Narrow
Wood silk	Difference	Bad	Commonly	—	—	Wide
Corrugated board	Difference	Bad	Commonly	May not	Good	Wide
Crepe paper pad	Difference	Bad	Commonly	May not	Good	Wide
Cellulose acetate silk	Slightly worse	Good	Small	—	—	Slightly narrow
Cellulose acetate silk	Slightly worse	Good	Small	May not	Good	Narrow

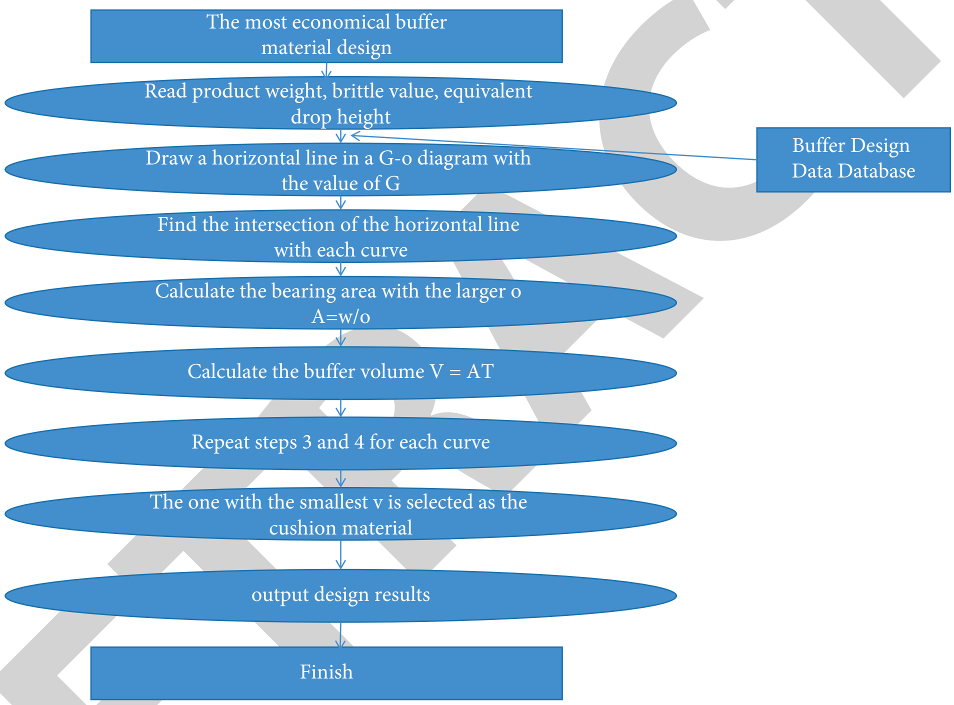

Figure 3: Design flowchart of cushion pad.

pad $W_1 = (S_4/S) \cdot W$, $W_2 = (S_3/S) \cdot W$, $W_3 = (S_2/S) \cdot W$, $W_4 = (S_1/S) \cdot W$. The bearing area of each pad shall be greater than or equal to a. The formula is as follows:

$$A_i = \frac{W_i}{\sigma_{si}}, \quad (5)$$

where A_i is the area of each pad in cm^2 and w_i is the area of each pad, n.

The center of gravity's projection coordinates are transmitted through the global variables coordinate X and coordinate X, the product weight W is transmitted through the global variable weight, and the pad area s is transmitted through the global variable area.

After voidstep4: OnBaryCenter() calculation, assign the pad area of each block to the global variables area, area2, and area3area4, as shown in Figure 5.

4. Experiment and Discussion

Corrugated board is made of corrugated base paper into corrugated shape, and then the surface layer is bonded from both sides with adhesive, so that the center of the board is a hollow structure, which has high strength, stiffness, hardness, pressure resistance, burst resistance, extensibility, and elasticity. The carton made of it is strong and has a wide range of uses [24]. The compressive strength of corrugated board is directly related to the shape of corrugated board. According to the waveform classification seen in the cross section of corrugated board, the corrugated shape is generally divided into U shape, V shape, and UV shape.

The U-shaped corrugated peak is in the shape of circular arc and has a large radius. Corrugated board is elastic, with good extensibility and good reduction performance within

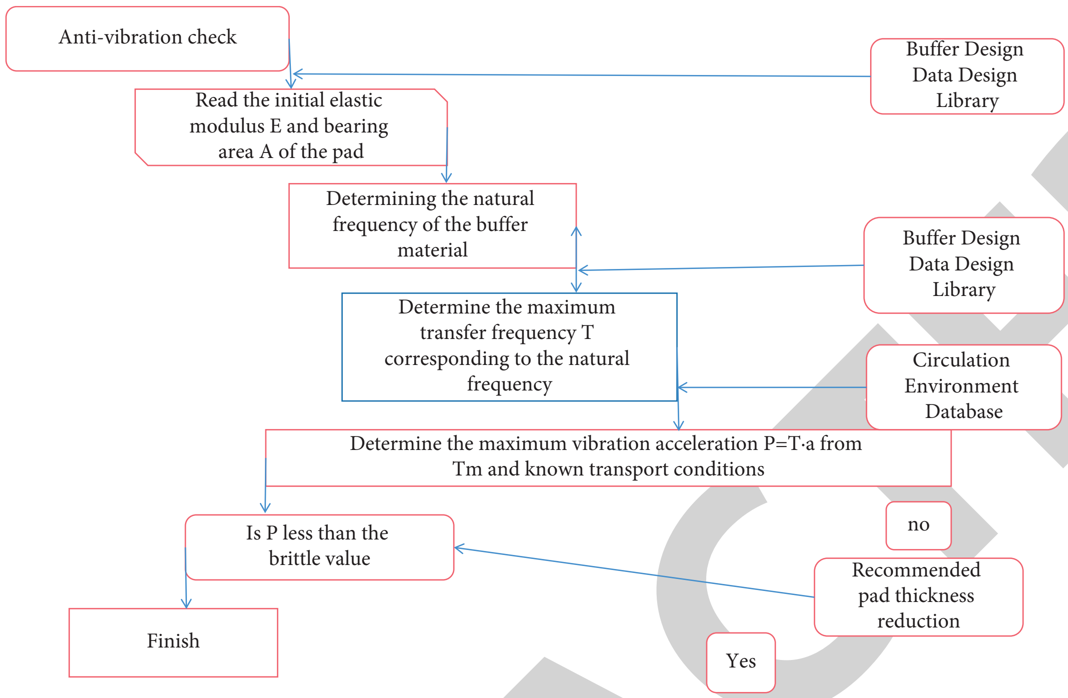

Figure 4: Flowchart of vibration check.

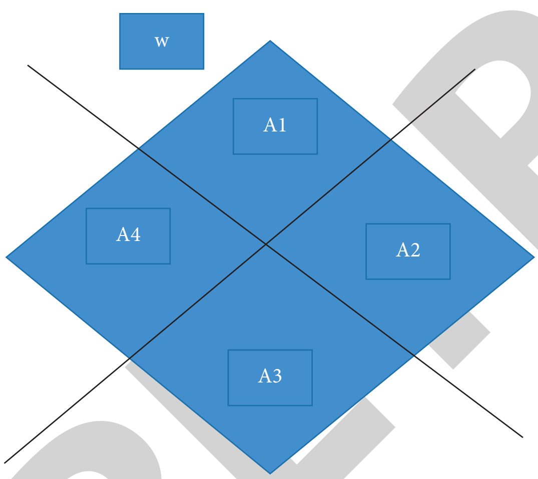

Figure 5: Projection of center of gravity on the bottom.

the elastic limit. It can absorb high energy in the process of compression deformation and has a good cushioning effect. The bonding surface between the top surface of the corrugated board and the surface paperboard is wider than that of the VV shaped paperboard. The amount of adhesive and paper is more, the bonding strength is good, and the wear of the corrugated roller is less. Under the action of large external force, the wave crest of the corrugated core paper is rarely crushed, and most of the straight lines on both sides are bent. The processing performance of U shape is better than that of V shape, but the compressive strength is not high due to the instability of arc force point [25].

V-shaped corrugated board has good stiffness, hardness, and reliability and uses less paper. Because the wave crest radius of V-shaped corrugated board is small and sharp, and the bonding surface between the corrugated top surface and the cardboard surface is narrow, and the amount of adhesive is small, so the bonding strength is also low. During pressing, the corrugated top surface of the core paper is easy to crush and crack, and the corrugating roller wears fast. In practical application, it will be subjected to pressure in three directions, namely, plane pressure, vertical pressure, and parallel pressure. If the V-shaped corrugated board is subjected to plane pressure, the skew is small at the initial stage of pressurization, but it will be damaged when the pressure exceeds the limit point of the board, and the corrugated board cannot return to the initial shape. Due to the poor resilience and poor elasticity of V-shaped corrugated board, it is almost not used now [26].

UV corrugated wave crest is between U-shaped and V-shaped corrugated boards, which combines the advantages of the two. It has high compressive strength, strong bearing capacity, and good bonding strength. When the external force exceeds its bearing capacity, it will not destroy the whole shape of the ridge, and the shape can be basically restored after the external force is eliminated. At present, all kinds of corrugating machines basically use this toothed corrugating roller.

The experimental results show that the three kinds of corrugated boards are subjected to different plane limit pressures, and the deformation degree is V shape, U shape, and UV shape in turn.

The quantity of corrugated board refers to the weight per square meter, expressed in g/m^2. In actual production, you can cut a certain size of corrugated board with a paper cutter and then weigh it. Generally, before production, the theoretical quantity of corrugated board can be estimated according to the raw materials used, that is,

$$G = \sum g_1 + \sum g_m \gamma + \sum g_j + \sum g_a, \quad (6)$$

where G is the quantity of corrugated board in g/m^2, g_1, g_m, g_j, g_a are the consumption of a box of board paper, corrugated base paper, laminated paper, and adhesive in g/m^2, and Y is the corrugated coefficient.

By comparing the theoretical quantitative results with the actual measured results, we can analyze the problems existing in the quality and shape of base paper [27].

The thickness of corrugated board is a very important factor in the design of corrugated box, which can be measured by a special corrugated board thickness meter. Its structure is the same as that of ordinary paperboard thickness gauge, but the contact surface with the sample is 10 cm^2 and the pressure is 20 kPa. The estimated thickness can be calculated by the following formula:

$$T = \sum t_1 + \sum t_m, \quad (7)$$

where T is the thickness of corrugated board in cm, t_1 is the thickness of carton board in cm, and t_m is the height of corrugated core paper in cm.

The actual measured thickness of corrugated board is generally less than the calculated value, which shall not be lower than the lower limit of corrugated standard height according to the regulations; otherwise, it is related to the improper control of production process conditions. When designing cartons, the thickness of corrugated cartons does not need to be accurately calculated but can be directly checked in the table.

Corrugated box is a kind of packaging container with a wide range of uses. It is popular because of its unique material structure mechanism, unique packaging effect, and economic benefits. At the same time, it can replace wood and plastic and meet the requirements of environmental protection and low cost. It has a good development prospect.

After finishing the operations such as line pressing, corner cutting, slotting, and printing on the corrugated board, the blank of corrugated box is obtained, as shown in Figure 6.

4.1. Indentation. There are three common indentation types of corrugated boxes: (a) one point type, that is, a single V-groove; the concave surface is a plane, and the punch has a flange. It is mainly used for corrugated folding carton. (b) Three point: this indentation process has two flanges for the female die and one flange for the male die. It is mostly used in the production of double-sided corrugated board and double-core double-sided corrugated board. (c) Five-point type: basically the same as three-point type, but the female die has three flanges and the male die has two flanges. Special for double-core double-sided corrugated board. The above are all rotary indentation processes. They are paired dies that rotate in a disk shape, and the paperboard can leave an indentation between the paired dies. The indentation depth can be changed by adjusting the gap between the female die and the male die.

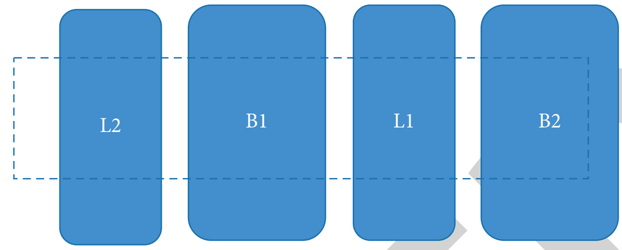

Figure 6: Structure of corrugated box blank.

4.2. Slotting. Slotting refers to cutting a notch on the corrugated board machine that is convenient for folding, and its width is generally the thickness of the board plus 1 mm. The center line of slotting shall be aligned with the center line of indentation as much as possible, and the smaller the deviation, the better. Slotting is closely related to indentation and has an impact on the dimensional accuracy and appearance of cartons.

4.3. Joint. The joint is an essential part for corrugated boxes, especially for type 02 corrugated boxes. When the joints are joined to make cartons, the position of the joints often causes some errors in the internal dimensions of the cartons, so attention must be paid to the design of cartons. The joint mode is the same as the sealing mode. There are three forms: adhesive tape bonding, adhesive bonding, and metal nail bonding.

Based on the inner wall, the effective dimensions in three directions of the box are called the inner dimension of the box.

Factors for Determining Internal Dimensions. The internal dimension is determined by the following factors: the maximum outer diameter of the product and the number of containers of the product; characteristics of packaged goods; considering equipment limitations; arrangement of packages; relevant dimensions of grid lining and buffer in the box.

Calculation formula of internal dimension is as follows:

$$x_i = x_{\max} + T + K, \quad (8)$$

where x_i is the inner dimension of carton, divided into three directions of length, width, and height, in cm, x_i is the inner dimension of carton, divided into three directions of length, width, and height, in cm, $x_{\max}$ is the maximum external dimension of the contents, divided into three directions of length, width, and height, in cm, T is the thickness of buffer pad in cm, and K' is the internal dimension correction factor in cm.

The maximum external dimension parameters (length, width, and height) of the contents are input from the global variable's length, width, and height, the thickness of the buffer pad is obtained from the global variable thickness, and the internal dimension correction coefficient is taken from Table 8.

Table 8: Correction factor of inner dimension of corrugated box/cm.

L_i	B_i	H_i		
		Small box	Medium box	Large box
0.3~0.7	0.3~0.7	0.1~0.3	0.3~0.4	0.5~0.7

After void Step4: oncartoninside() calculation, assign L_i (long) to global variables L_1, L_2. Assign B_i (width) to global variable B_1, B_2 and H_i (height) to global variable H.

The manufacturing size of corrugated box is the blanking size when making box. Its value should be greater than the inner diameter dimension, which is the basis of calculation and design dimension. Generally, when measuring the size of cartons, the products are packed and tied tightly and then amplified according to the tolerance coefficient to ensure that they are not too tight during packing. When making boxes, the manufacturing and cutting dimensions are calculated according to the inner diameter specification and considering the extension value. Therefore, the dimensions of corrugated boxes are subject to the measured outer diameter, so the actual outer diameter must be printed when printing the box surface of corrugated boxes. The theoretical value of the manufacturing size of corrugated box is equal to the inner diameter size plus several times the thickness of corrugated board (total thickness) and the shrinkage caused by indentation (called enlarged value), among which the thickness of corrugated board and the size of shaking cover structure play an important role. The calculation formula is

$$x = x_i + k, \tag{9}$$

where x is the manufacturing dimension of corrugated box, divided into five directions: I, L_2, B, B_2, and h, in cm, X_i is the inner dimension of carton, divided into three directions of length, width, and height, in cm, and K is the correction coefficient of inner dimension of carton manufacturing, in cm.

The dimension parameters (length, width, and height) in the carton are imported from the global variables L_1, B_1, H, the dimension correction coefficient K in carton manufacturing is taken from Figure 7, and the corrugated shape is imported from the global variable corrugating, as shown in Table 9.

In the case of butt sealing of carton swing cover, such as 0201, 0204, and 0207, the theoretical value of manufacturing dimension of swing cover width shall be 1/2 of the manufacturing dimension of carton width. However, due to the impact of the rebound effect of the rocking cover, a gap must be generated at the butt joint of the rocking cover, so that the box is not tightly sealed, resulting in dust pollution of the contents, as shown in Figure 8.

When storing and transporting goods packed in corrugated boxes, the calculation method used and the volume of the marked box printed on the box surface are based on the outer diameter. Therefore, the outer diameter of the corrugated box should be calculated in the design. Generally, the size of corrugated box is determined according to the inner diameter size, and the outer

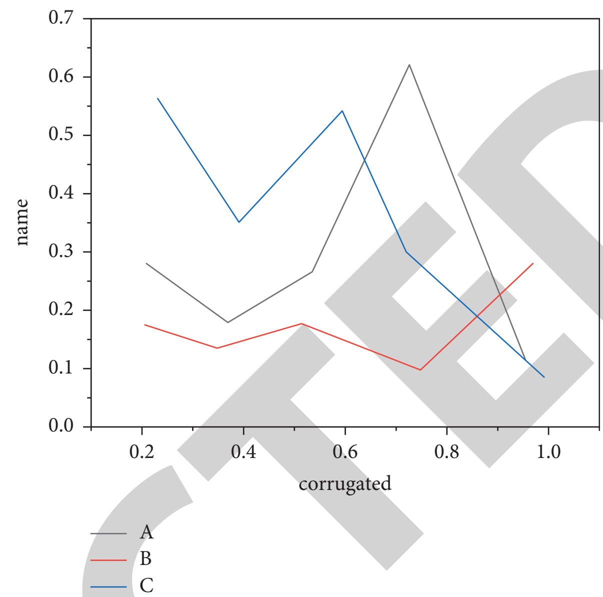

Figure 7: Correction factor of manufacturing dimension of corrugated box/cm.

Table 9: Correction factor of external dimension of corrugated box/cm.

Ridge type	A	B	AB
K	0.5~0.7	0.3~0.5	0.8~1.2

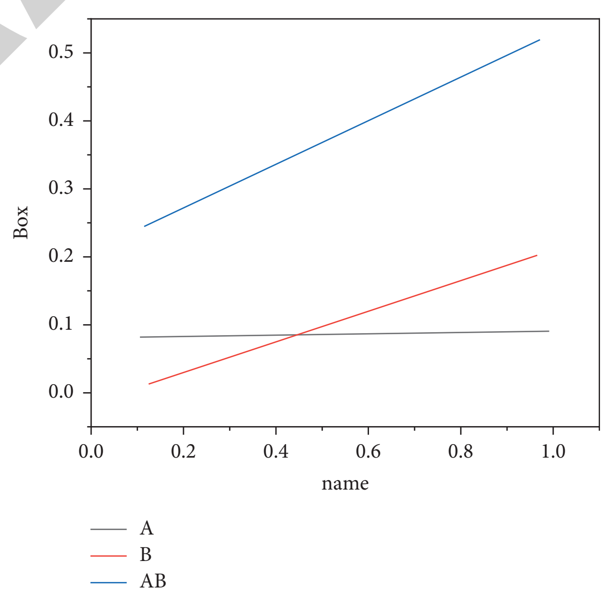

Figure 8: Elongation coefficient of type 8 carton flap/cm.

diameter size is calculated according to the manufacturing size, as shown in Table 9.

After void Step4: oncartoninside() calculation, assign L_i (long) to global variables L_1, L_2. Assign B_i (width) to global variable B_1, B_2 and H_i (height) to global variable H.

According to the calculation formula of corrugated box compressive strength, the necessary corrugated box strength

Table 10: Thickness of corrugated board.

Ridge type	Paperboard thickness
A	5.3
B	3.3
AB	8.1

can be calculated according to the predetermined conditions to see whether it meets the requirements. On the contrary, a certain corrugated board can also be selected according to the predetermined strength, and then a certain corrugated board base paper can be selected. The formula of compressive strength can be divided into two categories: one is calculated according to the test strength of corrugated board base paper, i.e., face paper and core paper. The other is calculated directly according to the test strength of corrugated board, as shown in Table 10.

5. Conclusion

The development of corrugated box structure CAD system adopts the software engineering method and compiles the program with VC++ 6.0. The main characteristics are as follows: the popular and mature Windows 98 is used as the operation platform of the system, which gives full play to the characteristics of easy use and operation of windows graphical interface. It has low requirements for users and can operate skillfully without mastering a lot of professional knowledge. Visual C++ 6.0 is used as the software development tool, and the GUI (graphical device interface) features provided by various tools and other high-level languages are used to design a simple and friendly user interface. MFC application framework is used to create applications. MFC application framework integrates some basic functions required by applications and carries out software development and function expansion on this basis. Using the basic concepts and characteristics (encapsulation, inheritance, and polymorphism) of classes and objects in C++, a user-defined class is established. Establish the data structure (data and operation) of the graphic elements required for the corrugated box plane expansion drawing; that is, establish the basic graphic element classes, including straight line class, rectangle class, arc class, ellipse class, free curve class, and text class. On this basis, establish the data model of the plane expansion drawing and draw it.

Data Availability

The labeled datasets used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

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