

# Form and CMF Design of Large-scale Intelligent Industrial Printing Equipment

Jianwei Yang<sup>1</sup>, Zhen Liu<sup>1</sup>, Yi Wang<sup>2</sup> and Chenyu Wei<sup>2\*</sup>

\*Corresponding author's e-mail: 20160086@xijing.edu.cn

Design Art College, Xijing University, Xi'an, shanxi, 710123, China<sup>1</sup>  
School of Art and Design, Xi'an University of Technology, Xi'an, shanxi, 710054, China<sup>2</sup>

**ABSTRACT:** Modern printing equipment has put forward higher requirements for product image while paying attention to product performance, which has become one of the important indicators affecting user satisfaction. Domestic printing equipment enterprises have strong international competitive advantages in technology, but they do not pay enough attention to the overall image design of products, resulting in a decline in competitiveness. In order to make up for the deficiency and meet the user's demand for high-quality, high-efficiency and high-value printing equipment, the design research focuses on the design practice of Shaanxi Beiren cigarette bag special unit intaglio printing machine. Through the research on the form of printing equipment and CMF (Color-Material-Finishing) design, and combining it with industry characteristics and CMF factors, it aims to improve the visual experience of large printing equipment and enhance product quality and brand image. During the research, the current situation of CMF and shape design of large industrial printing equipment was analyzed, and the design of cigarette package printing machine was completed through practical cases in combination with the needs of enterprises, and the CMF of the equipment was defined. It was proposed that the influence factors of visual weight perception should be incorporated into the CMF and shape design of printing equipment, which could better reflect the professional, reliable, easy to use and stable industrial quality sense of printing equipment, Further improve market competitiveness and product added value.

**Keywords:** CMF, Intelligent Industrial Printing Equipment, Modeling design

## 1. INTRODUCTION

Vision is a physiological academic term, which refers to the physiological perception of visual perception cells after information processing by the visual nervous system under the action of light [1-2]. People can recognize the color, size, brightness, color, texture and other information of objects through vision. Weight is a physical term that measures the size of an object under gravity [3]. Visual weight belongs to the category of visual psychology, which is the experience of giving people a sense of gravity. In the field of product design, it is to

measure people's feelings about the product caused by the visual factors of a product [4-5]. The factors that directly affect and affect the visual perception in product design include shape, color, material, surface treatment process, etc. Among them, "color, material, surface treatment process (CMF) [6]" design has been paid more and more attention in the product field [7]. China is currently in the rapid development period of the transformation from "Made in China" to "Created in China", and the upgrading of basic industrial equipment and the reconstruction of product image are particularly important [8]. The investment of the printing equipment industry in product image is gradually increasing, and the industrial design technology is used to further demonstrate the quality sense of equipment technology and function excellence through the shape design. For the CMF design of printing equipment, highlighting the sophisticated equipment and stable visual perception effect has become the trend of large-scale printing equipment modeling design. Therefore, the research aims at improving the quality of printing equipment and user experience, centering on the basic needs of user experience, according to the product status, combining the market trend, starting with the form of large-scale equipment printing equipment and CMF design, and completing the design practice verification. So as to enhance and enhance the sense of quality and value of products.

## **2. PROJECT SOURCING AND DESIGN INPUT**

### **2.1 Project source**

The project relies on Shaanxi Beiren Printing Machinery Co., Ltd. (Shaanxi Beiren for short), which is a manufacturer of packaging and printing equipment integrating scientific research, development, production, sales and service. The project will focus on the design and discussion of the special unit gravure printing machine for cigarette packs in North Shaanxi (referred to as cigarette pack printing machine), and carry out product form design on the basis of the functional framework, product style, CMF and achievability of the existing cigarette pack printing machine. and comprehensive evaluation.

### **2.2 Key technical indicators of the cigarette pack printing unit**

The list of authors should be indented 25 mm to match the abstract. The style for the names is initials then surname, with a comma after all but the last two names, which are separated by 'and'. Initials should not have full stops—for example **A J Smith** and *not A. J. Smith*. First names in full may be used if desired. If an author has additional information to appear as a footnote, such as a permanent address or to indicate that they are the corresponding author, the footnote should be entered after the surname.

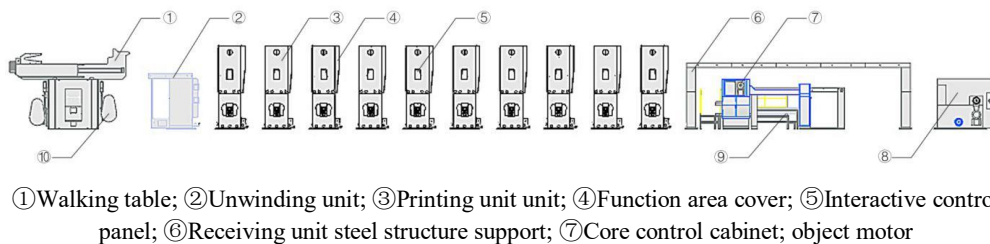
### **2.3 Formatting author affiliations**

The cigarette pack printing machine is mainly used to serve the cigarette pack industry, including flexible packaging printing and hard packaging printing needs. The design is based on the technical parameters and functional layout of the company's existing PRC250 cigarette pack printing machine. Main technical indicators: printing speed 250m/min; overprinting accuracy longitudinal  $\leq \pm 0.1\text{mm}$ , transverse  $\leq \pm 0.1\text{mm}$ , all tracked by intelligent automatic registration system; printed material width 820mm; rewinding and unwinding diameter  $\Phi$

1600mm;plate diameter:  $\Phi 140\text{mm} \sim \Phi 240\text{mm}$ ;the printing material is paper in the range of 20-250g/m<sup>2</sup>.Adopt high-end configuration such as German Bosch-Rexroth electronic shaft transmission system, American QuadTech color registration system, SIEMENS tension control system, etc., to maximize the color registration accuracy, cross-section accuracy and material feeding stability. Develop a talent training direction that meets the needs of the industry.

## 2.4 Functional composition and module division of cigarette pack printing machine

The basic functional structure of PRC250 cigarette pack printing unit is mainly composed of ten functional modules, such as walking table, printing unit unit, interactive control panel, steel structure bracket, and retracting and unwinding mechanism, as shown in Figure1.The overall size is 44.17\*3.96\*37.00 (length\*width\*height; unit m),and the design focus can be divided into four major modules: printing control, printing unit, main console and retracting and unwinding mechanism. Due to the large size of the cigarette pack printing machine, it is composed of a number of different functional modules, and each module has strong functional differences, which results in differences in product forms. Therefore, in the early stage of conceptual design, the division of modules is conducive to better human-machine analysis, travel path planning and conceptual design discussion of printing equipment, which is an effective means to understand products in the early stage.



**Figure 1.** Basic functional architecture of PRC250 cigarette pack printing unit

## 2.5 Investigation on the design status of cigarette label printing machines

### 2.5.1 Status quo of foreign large-scale printing equipment

Foreign printing machine companies started relatively early, and they are at the leading level in equipment technology, form, interactive experience and CMF design, forming a unified product image and modeling language. For example, Heidelberg, Germany, has advanced pre-press, printing and post-press equipment, and is also the first supplier of workflow management system (ie Prinect) in the industry. Their business model is built on three pillars: equipment, services and printed materials. Heidelberg is committed to the digitization of equipment, the integration of processes, and the intelligence of production. They provide customized products and services based on the needs of their customer base. The product form is straight and orderly, and the color uses black, white and gray in achromatic color as the main tone. Visually, it presents the semantic features of simplicity, technology, professionalism, reliability, stability, durability, integration and strong sense of wrapping. The minimalist interactive system brings a strong sense of ease of use and wisdom.

### **2.5.2 Status quo of large-scale printing equipment in china**

Domestic large-scale printing equipment started late, and most companies focus on product function research and development and technological breakthroughs, lacking attention and investment in product form and interactive experience. The appearance of the product is rough and simple, and there are many missing parts in the steel structure, which seriously affects the overall feeling of the product, and also indirectly brings some unsafe factors. In the process of product color definition, the color image of large printing equipment is easily affected by the corporate image of the user. This way of sacrificing its own brand image in exchange for customer satisfaction is one of the important reasons for influencing and restricting the formation of brand image. With the rise of China's creation, the comprehensive upgrading of industrial equipment, the breaking of technical bottlenecks, and the substantial increase in the quality of products demanded by users have led to intensified competition among enterprises. These sudden changes have forced enterprises to pay more and more attention to the product image design of equipment. Therefore, some domestic enterprises began to pay attention to the equipment form and CMF design, and gradually formed a brand image and tried to implant it into the equipment.

### **2.5.3 Design intention and enterprise appeal**

Understanding the company's design intentions for products is conducive to the formulation and achievement of design goals. The enterprise is deeply in the front line of industry competition, and has a very keen judgment on market demand, industry development trend and user pain points. For this reason, the research team has visited the enterprise three times and conducted on-the-spot inspections, and fully communicated with engineering and marketing personnel. The company's demands are summarized as follows: First, integration, breaking the form and way of existing products, and making multiple product function modules more integrated through design methods. The second covering property, from the perspective of man-machine, safety and aesthetics, reduces the leakage of a large number of structural parts existing in existing products. The third sense of quality, systematically design the product CMF, pay attention to the unity of similar components, and improve the sense of reliability, professionalism, wisdom and quality of the product. The fourth refinement is to pay attention to product detail design, enrich the layering of product form, increase the implantation of brand characteristic elements, and design necessary indicative symbols and safety protection devices from the perspective of users.

## **2.6 Form design of cigarette pack printing machine**

### **2.6.1 Unit design**

The design of the whole machine should highlight the sense of integration and wrapping, and reduce the leakage of steel components. The image of the equipment needs to create a professional, reliable, accurate, humanized, intelligent and modern high-quality industrial atmosphere[9].The morphological design process has gone through nine nodes—keywords—image board analysis—intent feature extraction—conceptual design—internal audit optimization—engineering analysis—company-level review—data production—scheme freezing. The program will be explained in detail.

The shape design of the cigarette pack printing machine has a lower visual center of gravity to highlight the stability of the equipment. Through the scientific planning of shape and color, the original various functional parts of the equipment are neat and orderly. In the design, the ten printing unit units are transformed from a single vertical visual experience to an overall horizontal visual experience, which greatly improves the integrity of the equipment. It can be seen intuitively from the comparison pictures before and after the design that the original plan. A emphasizes the individual printing units, showing a vertical visual sense, thus giving people an independent and unstable visual experience. In the freezing plan B, the unit units are integrated, and the horizontal design elements are strengthened. In people's visual experience, the horizontal features can reflect the sense of stability, security and reliability more than the vertical. The functional area cover is symmetrically designed, which increases the layering of the form and also protects the inner printing rollers.

### **2.6.2 Main console design**

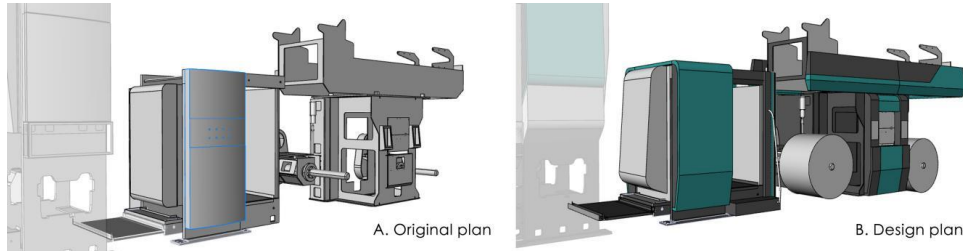
The shape design of the main console further strengthens the concept of integrity. It can be seen that the console in the original design is very simple and chaotic, the leakage of the functional structure of the steel structure is serious, and the key components such as the retention beam have a strong mechanical sense. As the core control area of the cigarette pack printing machine equipment, the staff come and go frequently, and the gap between the components is too large, and there are potential safety hazards during the operation and maintenance of the equipment. Therefore, in the shape design of the cigarette pack printing machine, the walking table adopts an integrated design, and the angle of slanting is more suitable for the operator to carry out. The control panel areas on the left and right sides are integrated with the structural beams and are functionally distinguished by color. This encircling and enveloping shape can effectively reduce the leakage of structural parts, and at the same time, there is a strong connection between the morphological features.

### **2.6.3 Printing control and receiving mechanism design**

The shape design of the printing control module also follows the principles of integrity and wrapping. On the basis of the steel components of the original plan, the external accessories are added to the walking platform, and the external accessories are divided into a 1:2 shape. The top area is attached with gray-black mesh sheet metal, which can effectively reduce the visual weight and at the same time play the role of rich morphological features. Both the walking platform and the lower end of the central control area are retracted inward by  $15^\circ$ , breaking the single-dimensional change of the original form. The lower end of the central control area is designed to be retracted inward, which is also conducive to the user's operation and observation.

The shape design of the receiving mechanism connects the left and right panels by pulling through the beam area to form the surrounding and wrapping of the mechanism, so that the receiving mechanism presents a seamless feeling. The bottom end of the panel is retracted by  $15^\circ$  to echo with other components, and the inner casing is designed to be inclined to the right by  $8^\circ$ , so that the overall receiving mechanism presents a shape that is wide at the bottom and narrow at the top, visually conveying a stable and solid feeling. The turning of the component surface has replaced the right-angle turning method in the original scheme with large rounded corners. The purpose is to reduce the cold mechanical feeling in the original scheme. The

implantation of rounded corners also enriches the morphological characteristics and indirectly improves the quality of the equipment. The shape design of the printing control module and the receiving mechanism is shown in Figure 2.



**Figure 2.** Form design of printing control module and receiving mechanism

### **3. CMF DESIGN OF IV CIGARETTE PACK PRINTING MACHINE**

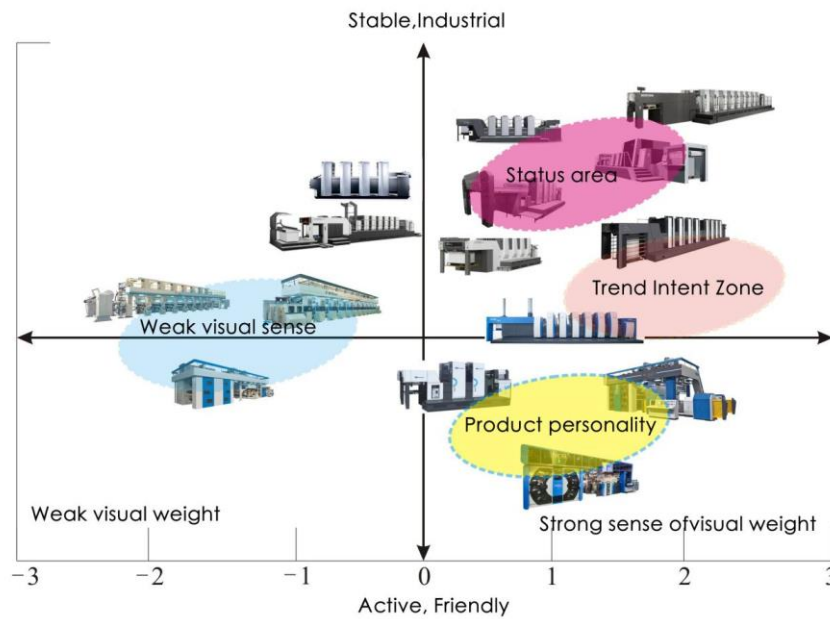
#### **3.1 Key factors in CMF design of large printing equipment**

The factors that directly affect and affect the visual perception in product design include form, color, material, surface treatment process, etc. Among them, "color, material, surface treatment process (CMF) [10] The pros and cons of the visual perception experience of printing equipment will directly affect the From the perspective of design, good printing equipment should be the result of the balance of function, form, material, craftsmanship and color elements. With the continuous improvement of people's consumption level, the market competition will become more and more. In addition to the influence of technology and brand, the primary factor that affects the attention, attraction and purchase of printing equipment by users is the visual appeal and attention of the equipment. The quality of CMF design largely affects the visual experience. The difference in the perception of visual weight of printing equipment reflects the difference in product style, brand image and sense of quality. The key factors affecting the visual weight are the shape, color, Materials, textures and human experience [11].

#### **3.2 Visual weight perception analysis of cigarette pack printing machine**

Using the expert evaluation method and the intention scale method, the visual weight perception evaluation of the products of the top ten brands of printing equipment is carried out to obtain their dimensional coordinate positions in the semantic space, and the visual weight and product style are established as shown in Figure 3. Through comparative analysis, it can be seen that there is a close relationship between visual weight perception and product style, and the impact of product CMF design on product style plays an important role. The printing equipment with a strong sense of visual weight mostly adopts the color matching method of dark bottom and top light, heavy color as the main color, supplemented by bright color, small area with color embellishment, and the material selection is mainly sheet metal parts. The product style is stable and industrial, and it is the mainstream printing equipment style in the market. Printing equipment with weak visual weight, mainly bright colors, supplemented by

colors. There are many missing parts in the steel structure of the product, so it has a strong sense of industry. The material is composed of metal castings and sheet metal parts. The CMF style of such products is not the current development trend. The product style is relatively active and friendly, and the printing equipment is rich in modeling and rounded corners. CMF has a novel design, a variety of material mixes, and a large area of colored use. With black gray and light gray, it creates a unique printing equipment style, which is a direction worthy of reference and development.



**Figure 3.** Visual weight and product style dimension distribution

The CMF design of large-scale printing equipment should highlight, stability, reliability, safety, precision, quietness, order, and industrial characteristics of the equipment. Guiding the CMF design of printing equipment through the dimensional partition characteristics of visual weight will greatly improve the accuracy of product style definition. Since the volume of large-scale printing equipment is much larger than that of general products, there are certain similarities and differences in visual weight perception. After participating in the design experience of Beiren satellite flexographic printing equipment in the early stage, the following points can be summarized as a guide: First, the smoother the surface of the external accessories of the equipment is. The stronger the sense of weight. The most commonly used external accessories in printing equipment are sheet metal parts. The thickness of the accessories is less than 1.2mm and the area is greater than 1.5m<sup>2</sup>. The processed surface presents an uneven visual sense under natural light, giving people the impression of thinness, unreliability, poor quality and low price. psychological feelings. The more inclined the shape of the second device, the stronger the visual weight. The sloping form loses its center of gravity and stability, giving a feeling of falling, so the visual sense of weight is strong.

When the third device adopts the color matching of light bottom and dark top, the visual weight and stability of the device will decrease. Therefore, the CMF design can guide the upper weight to the bottom to balance the visual weight and stability.

When the dark-colored parts of the fourth printing equipment use a large area, the parts can be meshed, replaced with materials or semi-transparent to adjust the visual weight.

### 3.3 CMF design

The communication of CMF semantics is one of the effective means to show the brand image and quality of products, so that the products have stronger identification, thereby enhancing the competitiveness of enterprises. The cigarette pack printing machine has a large volume and a large number of components. In order to ensure the integrity of the equipment, the visual weight layout design principle should be followed in the CMF design. It can reduce the types of materials and reduce the production cost of enterprises. The CMF of the cigarette pack printing machine defines 10 kinds of materials. The renderings and the main part numbers are shown in Figure 4. The CMF definition and material samples are shown in Table 1. The non-specific functions of the steel components in the equipment are all gray-black, which can visually weaken the small workmanship flaws of the parts. For example, in the printing unit module, the lower ends of the 10 printing units cannot be covered in sheet metal form due to the mechanical parts that move laterally, resulting in leakage of the cast wall panels. If the color treatment is not done, the integrity of the equipment will be seriously affected. Therefore, the gray and black treatment method can not only effectively reduce the process defects of castings, but also bring a solid and orderly mechanical beauty.

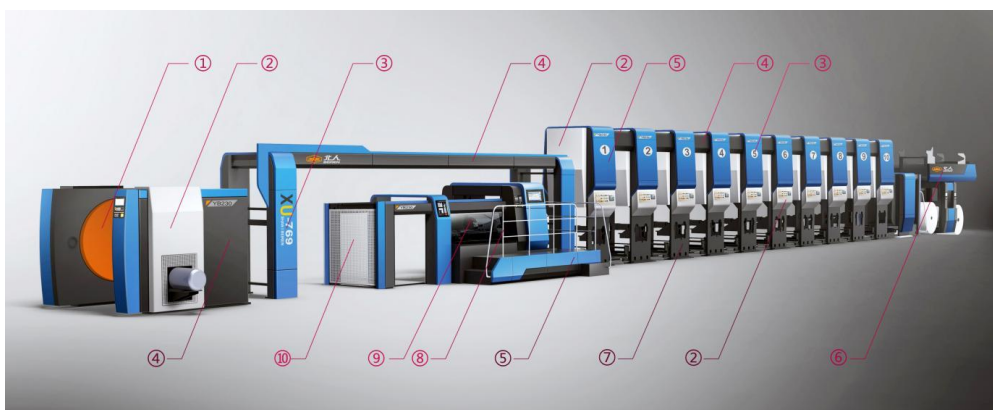


Figure 4. Cigarette pack printing machine CMF number

Table 1. Definition of CMF for cigarette pack printing machine

serial number	Color Definition	Material	Process and Surface Treatment
1	1505C	Carbon steel plate	Laser cutting, laser cutting simple mold, CNC



		1.5mm	bending, precision 0.2mm; matt reflective gloss of 40 degrees, sand pattern. Spray treatment.
2	Cool Gray3C	Carbon steel plate 1.5mm	Laser cutting, laser cutting simple mold, CNC bending, precision 0.2mm, cleaning and rust prevention; matt reflective gloss of 60 degrees, orange peel.
3	447C,1505C Gray3C	paint	Decorative wordmark spray treatment.
4	447C	Carbon steel plate 1.5mm	Laser cutting, laser cutting simple mold, CNC bending, precision 0.2mm, cleaning and rust prevention; matt reflective gloss of 60 degrees, sand pattern.
5	8184C	Carbon steel plate 1.5mm	Laser cutting, laser cutting simple mold, CNC bending, precision 0.2mm, cleaning and anti-rust; matt reflective gloss of 40 degrees, sand pattern.
6	425C	Carbon steel plate 1.5mm	Laser cutting, CNC NCT punching; aperture $\Phi 3\text{mm}$ , density $165*165/\text{m}^2$ ; cleaning and anti-rust; matt reflective gloss of 60 degrees, sand pattern.
7	447C	cast iron HT250	Resin sand casting process production line casts wall panels, secondary thermal aging treatment.
8	Primary colors	304 stainless steel	25*1.2 round tube, the surface is brushed.
9	transparent	Plexiglass board	Thickness 5mm, 45°1.5m right-angle edging.
10	Cool Gray3C	Carbon steel plate 1.5mm	Laser cutting, CNC NCT punching; square hole, side length 3.5mm, density $165*165/\text{m}^2$ ; matt reflective gloss of 60 degrees, sand pattern.

#### 4. CONCLUSION

In recent years, the research on large-scale printing equipment has gradually begun to explore the relationship between technology and design. Using the industry characteristics and visual psychology of printing equipment to guide the CMF and modeling design of printing equipment, and integrating the psychological perception factor of visual weight into the design is an important means to shape the image of the product. CMF design is an easily overlooked link in the design of large-scale printing equipment. The psychological factor of visual weight plays a key role in the process of CMF design, and there is a strong correlation with the results of CMF design. Visual weight perception provides the basis and direction of the visual balance of the design, while CMF design is the presentation method and result. The combined effect of the two can strengthen the product image, which is also based on design psychology and Kansei engineering. At the same time, visual weight perception is also affected by the external environment, which will be further researched and summarized later.

**Fund Project:** 2018 National Social Science Fund Art Project "Interaction Design of Screenless Smart Products under the Effect of Multisensory Synesthesia" (Project No.: 18BG132)

## REFERENCES

- [1] Tian Meng. Fault Feature Extraction and Analysis of Automotive Gearbox Based on CMF-EEMD [J]. *Automotive Maintenance*, 2022 (04): 37-39
- [2] Wang Fuhao, Cai Jifei, Wang Kang, Li Jinwei, Hu Fengxian. Analysis and research on intelligent shield of printing equipment based on VOCs collection [J]. *Journal of Printing*, 2022 (04): 53-57
- [3] Hu Bingbing, Tang Jiahui, Wu Jimei. Research on Intelligent Diagnosis Method for Bearing Faults of Printing Equipment Based on Perception v3 [J]. *Packaging Engineering*, 2022,43 (13): 189-195
- [4] Cheng Xiangyu Research and development of equipment monitoring system for face-to-face intelligent printing factories [D]. Xi'an University of Technology, 2021
- [5] Yang Xiao. Artificial Intelligence Improvement for Automatic Cleaning of Printing Machine Accessories [J]. *Shanghai Packaging*, 2019 (06): 39-42
- [6] Su Chen, Tian Tian, Cheng Chuangji, Liu Xu, Peng Wei, Xu Dehua. Study on the Comprehensive Evaluation Method of the Form Design Discretion of Printing Equipment [J]. *Packaging Engineering*, 2018,39 (12): 92-99
- [7] Liu Shangzhong, Intelligent CNC high-speed carton printing equipment development Hebei Shengli Carton Equipment Manufacturing Co., Ltd., July 15, 2017, Hebei Province
- [8] Xue Wei, Chen Yijun, Gong Xiaofang, Han Dong, Gao Huan. Embedded Intelligent Devices for Printing Machines [J]. *Printing Today*, 2017 (05): 60-62
- [9] Gu Huan. Key Technology of Printing Equipment Informatization and Intelligent Factory [J]. *Today Printing*, 2016 (04): 69-70
- [10] Han Xiaoliang. Intelligent Manufacturing of Printing Equipment and "Internet plus" [J]. *China Printing*, 2016 (03): 17-18+20+22
- [11] Yu Pu. The role of intelligent registration systems and other auxiliary devices in rotary printing [J]. *Journal of Printing*, 2005 (07): 24-26