Numerical control press design based on quantitative evaluation of appearance area features

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Abstract. The appearance characteristics of numerical control presses were quantitatively evaluated using eye-tracking technology, and a numerical control press design method was proposed to provide guidance for the design of such mechanical products. By investigating and analyzing the appearance of numerical control presses locally and abroad, the modeling characteristics of these products are summarized. The interest areas of the press are divided using the hot zone map data of the eye movement experiment, and people’s knowledge of each area of the press is quantitatively analyzed. Data generated by multiple eye movement experiments are combined with a subjective questionnaire to identify the mechanics of the press. The front and work areas are the main features of the press design. Based on the experiment result, the press design is conducted based on color and modeling elements. We used the Jiangsu CPTEK numerical control press as the actual case. We also re-matched the color, optimized the details, and developed an improved design scheme, thus verifying the proposed design method.

1. Introduction
The numerical control servo press is the third generation of presses (intelligent machines) that was popularized in the 1990s. The press combines organically high-tech technology with traditional mechanical technology, and it features high efficiency, high precision, low noise, energy saving, and environmental protection [1]. It marks the current development direction of the pressure press industry. Appearance is an extremely important part of the press design—most of which focuses on the internal mechanical structure and processing capacity of the press. With the vigorous development of China’s control presses, users raise various requirements in terms of appearance design of control press.

Based on eye-tracking technology, this study conducts a dynamic evaluation of the visual performance of the main press esquire domestically and internationally [2]. It seeks a control press modeling design method from the direction of color and modeling elements, and it applies such a method to practice[3].

2. Domestic and international situation of control press’ appearance design
By reference to control press machine-related websites, literature, and field visits, we found that Schuler, Amada, and Aida are among the top 20 control press machine brands globally. On this basis, an image scale distribution map of research samples’ appearance popularity is constructed . (Figure 1) This diagram shows a clear and intuitive view of their market position [4].
The product shape of the numerical control press is composed of various morphological features. The user would only be impressed by the characteristics of certain parts of the press; not every feature will affect the overall shape of the press. Therefore, the characteristic areas of the press should be divided for study[5]. By in-depth research on brands, such as Aida, Amada, Komatsu, SEYI, and Jiangsu CEPTK, studies are conducted from the appearance of the shape, color matching, and detailed form. The domestic and foreign numerical control press situation is as follows.

1) Overall shape: Straight lines are typical in foreign numerical control press modeling, and the design integrates the line design composition of the fuselage, reducing the clutter and dispersion of the overall shape. Based on the processing function of the bulk, the monotonous body is divided into various parts, resulting in a layered sense. In addition, foreign brands focus on the treatment of details. The enterprise logo is highly emphasized and placed reasonably, enhancing the identification of enterprises and making the overall visual characteristics consistent. In contrast to foreign brands, the location of the corporate logo on domestic presses appears to be unreasonable, with a relatively large area. Over-emphasis on brand logo makes the press modeling appear incongruous.

2) Color: The color of the domestic numerical control press is relatively monotonous, failing to attract users’ visual attention. It also weakens the balance and rhythm of the body color. Well-known foreign brands usually use more than two colors for color separation, showing a distinct difference by the contrast of colors, increasing the visual effect of the shape, and coordinating the overall visual effect.

3. Analysis of pressure press modeling characteristics based on eye movement experiments
Based on modeling evaluation, this study uses eye movement experiments to acquire the physiological emotion of users when evaluating product modeling. The eye-tracking experimental data will be used as the evaluation criteria for the characteristics of press modeling, thereby obtaining an intuitive, accurate, and objective quantitative evaluation; determining the image of product modeling and the degree of user preference; and providing a basis for analyzing the tendency of the visual characteristics of the product [6].

3.1. Experimental environment and requirements
The experiment selected 20 subjects aged between 20 and 30 years old. Of the subjects, 10 were mechanical engineering professionals, and 10 were industrial design professionals. Thus, the subjects represent scientific and professional experimental data from the perspective of product function and appearance. Before the experiment, testers were told the operation method to ensure that they reach a stable state during the test to ensure the reliability of data output [7].
3.2. Experiment equipment
The experiment was conducted in a clean, undisturbed indoor environment. The observation already uses a machine produced by Tobii of Sweden, namely, Eye T60, with a sampling frequency of 60 Hz. It also employs an image material rendering instrument with a 17-inch screen display with a resolution of 1280 x 1024 pixels. Material presentation and data analysis are conducted via Tobii Studio.

3.3. Experiment material
The samples selected in the experiment are the current mainstream brand servo control press product image in the domestic and foreign markets. Guided by the early analysis and research of the shape, color, and material of the press as well as comprehensive market research feedback, the samples selected in the experiment are high-end brands with similar shapes, functions, and structures. The samples were Aida DSF-N1-A series, Komatsu H1F composite series, Amada SDE series, mid- and high-end brand Chin Fong OCPS series, SEYI series, and BLISS HR-C1 series presses (Figure 2). All images are selected from the official website of each company. In response to the requirement of the experiment that the clarity of all images must be adjusted, the backgrounds and colors of samples were removed, and samples were reset in a light gray background with the assistance of Photoshop. The different presses in the picture are in the same position, with similar size and angle. This alignment facilitates the accuracy of the visual gaze point. Thus, the main parts of the pressure press’ visual features can be observed in the eye-tracking experiment. During the experiment, six samples of experimental material were randomly presented.

3.4. Experiment process
The complete experiment process needs about 8 minutes. First, the testers sat in the test seat to prepare for the work and were told that a follow-up test with the relevant questionnaire would be conducted. Then, they began to practice. A sample of the press product diagram was presented on the screen, and the testers were required to observe the samples carefully and record the sample pictures in detail. At the end of the practice, the formal experiment was started. Similar to the practice experiment, the testers were asked to observe six images, with a black transition page lasting 3 s in between, to remove the visual residue from the tester. Twenty testers participated in the test experiment in sequence, and the numbered records were saved in the software for subsequent data analysis. The testers needed to complete the relevant questionnaire in the end [8].

4. Experiment result analysis
After the experiment, the samples were screened. Six items of unqualified experimental data were removed because the tracking rate of the subjects was less than 80% during the experiment, and the gaze point deviated too far from the press. Finally, 14 interest areas and hot zone maps of samples and 14 subjective evaluation questionnaires were extracted. The information displayed in each sample was superimposed by 14 groups of eye action data, and 6 pictures were exported.
4.1. Hot zone map analysis
The hot zone map can visually reflect the testers’ interest in each region of samples. The area with a concentration of gaze points is red, creating a hot zone [9]. Based on the press hot zone map, the tester's focus is mainly on the front and work areas of the machine. In addition, the control area of the machine body is also a concern (Figure 3). Based on experimental data, different testers focused on various areas. Volunteers with professional backgrounds in industry design focused on the front of the machine body. The shape of the front is full, rich in color, and distinctively featured. The logo area is highly concentrated, indicating that the characteristics of the region elicited high attention from testers. Testers who understood the structure of the press mostly focused on the control area, button station, and operator's station.

4.2. Analysis of interest areas

4.2.1. Division of interest areas. The interest area is the area in which the testers remain longer and return to frequently during the experiment. The interest area is divided based on the concentrated area presented in the hot zone map [10]. The area is divided into four main areas, namely, front fuselage, control area, work area, and base (Figure 4).

4.2.2. Focus duration analysis. Focus duration refers to the length of the tester’s visual residency in the area of interest. The longer the focus duration, the more important the display area [11]. In the
In our experiment, we used SPSS 19.0 software to conduct a single-factor analysis of the duration of the interest area gaze point of the CNC press. In Table 1, a comparison between the two areas indicated that the differences between the base and the control area are not significant \((P = 0.242)\), which is related to the testers’ sight movement in the interest area of samples. Significant differences were observed in the comparison between other areas. The line chart (Figure 5) can reflect the data distribution clearly and intuitively, showing that the base is the area of least concern. This result is consistent with the top-down, left-to-right visual cognitive rule. The work area was the subject of the longest gaze point duration, and it has a very significant difference from other areas \((P < 0.01)\). Thus, the work area attracted the highest level of attention and had the most distinctive regional characteristics.

### Table 1. One-way ANOVA results of interest area fixation duration.

| (I) AOI       | (J) AOI       | Mean Difference (I–J) | Standard error | Significance | 95% confidence interval          |
|---------------|---------------|-----------------------|----------------|--------------|----------------------------------|
| Base          | Work area     | -1.05000              | 0.09391        | 0.000**      | -1.2459 to -0.8541               |
|               | Front fuselage| -0.37167              | 0.09391        | 0.001**      | -0.5676 to -0.1758               |
| Work area     | Front fuselage| -0.11333              | 0.09391        | 0.242        | -0.3092 to 0.0826                |
|               | Control area  | 0.67833               | 0.09391        | 0.000**      | 0.4824 to 0.8742                 |
| Front fuselage| Control area  | 0.93667               | 0.09391        | 0.000**      | 0.7408 to 1.1326                 |
|               | Control area  | 0.25833               | 0.09391        | 0.012*       | 0.0624 to 0.4542                 |

Note: *\(p<0.05\), **\(p<0.01\).

**Figure 5.** Interest area fixation duration and access times chart.

4.2.3. **Access times analysis.** “Access times” refers to the number of testers’ back-looking times to interest areas, indicating the attractiveness of the area. The number and the duration of the gaze point increase accordingly, representing an important factor that affects the judgment of the press. Table 2 presents that a single-factor is performed on access times to the four areas of interest. No significant difference was found between the values of the front fuselage and the control area \((0.390, P > 0.05)\), which may be caused by the proximity of the two areas. The testers can visit adjacent areas as they browsed a certain area. In addition, a significant difference is found among the base and the work area,
the front of the machine body, the control area, and the work area and the front and control area of the machine body (P < 0.01). Combined with the specific gaze point duration in Figure 6, access time to the working area was the highest, followed by the front fuselage. The two areas are superior to the control area and base.

Table 2. One-way ANOVA results of interest area access times.

| (I) AOI      | (J) AOI      | Mean Difference (I–J) | Standard error | significance | 95% confidence interval lower limit | 95% confidence interval upper limit |
|--------------|--------------|-----------------------|----------------|--------------|------------------------------------|------------------------------------|
| Base         | Work area    | -3.82667              | 0.48363        | 0.000 **     | -4.8355                            | -2.8178                            |
| Front fuselage | Work area   | -1.59667              | 0.48363        | 0.004 **     | -2.6055                            | -0.5878                            |
| Control area | Front fuselage | -2.02167              | 0.48363        | 0.000 **     | -3.0305                            | -1.0128                            |
| Work area    | Front fuselage | 2.23000               | 0.48363        | 0.000 **     | 1.2212                             | 3.2388                             |
| Control area | Control area | 1.80500               | 0.48363        | 0.001 **     | 0.7962                             | 2.8138                             |
| Front fuselage | Control area | -0.42500              | 0.48363        | 0.390        | -1.4338                            | 0.5838                             |

Note: *p<0.05, **p<0.01.

4.3. Analysis of the results of questionnaires and interviews

After completing the eye-tracking experiment, the testers were asked to complete a questionnaire about their cognition of presses [12]. The testers were asked to encircle what they thought to be the most important part of the press in the questionnaire. Most testers chose the front fuselage and the work area. The results are consistent with their eye movement statistics. Interviews show that testers majoring in mechanical engineering focus on color and brand identity first when selecting their favorite presses (this conclusion is associated with people's behavioral cognition)[13]. They selected the relatively complex work area as the most important part of the press. The first area of concern for testers majoring in industrial design is the front of the machine body, the appearance, and color matching. These areas are the decisive factors in their choice of a favorite press.

4.4. Experiment conclusion

Based on the experimental test results, the guidelines for the press design are proposed as follows.

1) The main features of the product shapes should be included in the most concerned area. Combined with experimental data and hot zone maps, the front and work areas of the press are the most focused areas for the testers. Therefore, the design of these two areas should be innovated upon, and breakthroughs should be made.

2) Questionnaires and interviews show that color is important in the shapes of presses. By analyzing the color matching of six presses (Figure 6), we learned that colors, such as blue, gray, and black make mechanical products look strong, technological, and layered. Bright colors, such as orange, yellow, and red, feel safe and gentle. These colors received high evaluation from the testers. The design of the press shape should emphasize the sense of layers by color matching, weakening the sense of heaviness of the press itself and making the shape of the machine body acquire visual features of simplicity, strength, and technology [14].

5. Practice case design

Based on the appearance design requirements of servo presses of Jiangsu CPTEK, the above conclusions and methods are illustrated with an example. The color of CPTEK’s press is monotonous, and complex hardware accessories are exposed, resulting in visual confusion. Brand characteristics are not emphasized and recognition is relatively low. In Table 3, the reference direction is provided for
this design by extracting the shapes and colors of six presses. A final design was developed via 3D modeling and rendering (Figure 7).

![Figure 6. Color distribution of six press machines.](image)

**Figure 6.** Color distribution of six press machines.

### Table 3. Press feature extraction.

| Brand   | Style Extraction | Color Extraction (RGB) |
|---------|------------------|------------------------|
| SEYI    | ![Style](image)  | ![Color](image)        |
| CHEN FONG | ![Style](image)  | ![Color](image)        |
| BLISS   | ![Style](image)  | ![Color](image)        |
| AMADA   | ![Style](image)  | ![Color](image)        |
| KOMATSU | ![Style](image)  | ![Color](image)        |
| AIDA    | ![Style](image)  | ![Color](image)        |

![Figure 7. CPTEK servo press machine tool front and rear design comparison chart.](image)

**Figure 7.** CPTEK servo press machine tool front and rear design comparison chart.

1) Main feature design. The preliminary research and experimental conclusions indicate that the front of the machine body and the working area are the main characteristic areas of the press. Design factors considered on the front include corporate identification, screen, sheet metal, and decorative craft. Guardrails, sliders, discs, and other design factors should be considered in the work area. A press is a large-scale mechanical product, and its main characteristics should reflect a sense of technology.
and strength [15]. By extracting the geometry of high-end brand presses, the front shape of the press body is designed. The side is a simple geometric design. Such designs do not destroy the overall sense of the shape on the front of the machine body, and they introduce variety in the shapes of the press. Simple shapes will decrease burdens on production, transportation, processing, and maintenance of presses. The protective plate in the work table area is designed with hollow horizontal stripes, breaking the heaviness of the work area and creating a certain cushioning effect visually.

2) Color design. The front and sides of the press are color coded in large areas, resulting in a sharp contrast of colors. Warm brown and white are the main colors, and orange is auxiliary. The large area of the front fuselage is white, representing simplicity and cleanliness, which weaken the machine’s visual effect of heaviness while emphasizing the corporate brand logo. Therefore, this aspect increases enterprise recognition and is important to overall coordination and unity. The work table area’s color is orange, facilitating fresh and bright feelings. The design of the slider area follows the modeling of warning, emphasizing the importance and safety of the area. The design plays a role of functional emphasis and operational notice, making the layout prominent in the background or other parts and attract attention.

3) Detail design. Eye tracking experiments, questionnaire interviews, and people’s visual cognitive rules indicate that the brand logo is a relatively major focus of attention. Thus, the design of the brand logo cannot be ignored. The model logo on the control press is well designed with artistic lines, and it creates visual effects that echo the side shape of the machine body, coordinating and unifying the overall shape of the press. The enterprise logo placed on the side of the machine body provides users an opportunity to clearly observe the corporate image logo, enhancing the identification of the enterprise.

6. Conclusion
This study explores the design method of CNC presses, summarizes the modeling characteristics of such presses by combining pre-research and analysis of the press, and uses the eye tracking analysis method for quantitative analysis of the appearance evaluation of the control press. The design of the press product can be effectively guided by the design of the press from the color elements and the modeling elements. This study is only based on a small number of experiments, in which the questionnaires and samples have certain limitations. Hence, the sample size can be enlarged at a later stage for related research and export.

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