Motion Analysis-based Design of Wall Painting Tool Storage

Tang Ruoyue¹, a, Chen Luwei², b and Wang Jingya³, c

¹Faculty of Industrial Design, Zhejiang Gongshang University Hangzhou College of Commerce
²Faculty of Industrial Design, China Jiliang University College of Modern Science and Technology
³Industrial Designer, Hangzhou Jiuyuan Network Technology Co., Ltd.

a tanguoyue_hit@163.com; b Frie1118@hotmail.com; c 931204848@qq.com

Abstract. While the wall painting is applied frequently in interior design and decoration, many problems exist in the wall painting tools usage and transportation. With the interview method conducted in the investigation of the wall painters, based on the motion analysis and the economic principle of the related action, the design prototype of the wall painting tool storage was proposed. Conducting the multiple actual working scenes motion test, this design was continuously improved aiming to offer an ergonomic optimization with the appearance and function balanced design.

Keywords: Wall painting tool storage; Motion analysis method; Product design

1. Introduction

In the decoration of clubs, exhibition halls, restaurants, bars, departments, wall painting has become a preferred choice its economic efficiency. This trend has become increasingly popular in recent years. While there are many problems existed in the process of usage and carrying of the wall painting tools. For instance, the toolbox is always bulky with less function, most of which can only be carried by hand inconveniently. During the painting operation, wall painting staff need to repeatedly search the targeted tools. Obviously, this process is not integrated designed to offer an efficient usage experience. The targeted problems of this design solution is how to use and carry these various painting tools. Furthermore, this design process is aimed to explore the optimization motion path during wall painting process.

Gilbreth proposed the Therblig action classification (Table 1), which decomposes human work into three categories of eighteen elements. The first category is the necessary action to complete the work, and the second one is the auxiliary action. The third category is redundant action. Gilbreth also proposes the principle of obtaining the most efficient action with minimal fatigue, seeking the most reasonable action [1,2]. Through the improvement of Ralph, Baenes and others, this principle has evolved to an action economic principle system. Some of these principles, such as: effective use of limbs, making movements as economical as possible, making movements appropriate to human motion characteristics, rational allocation of movements, avoiding static and continuous exertion, etc., can be used not only for production management, but also for improving product design[3,4]. The application of the action classification and the economic principles in product design is instructive for solving the problems of wall painting process faced by wall painters.
Table 1. The Therlig Action Classification of Gilbreth

| category | Motion element                        |
|----------|---------------------------------------|
| 1        | Transport empty [unloaded] (TE)       |
|          | Group (G)                             |
|          | Transport loaded (TL)                 |
|          | Position (P)                          |
|          | Assemble (A)                         |
|          | Disassemble (DA)                     |
|          | Use (U)                              |
|          | Release load (RL)                    |
| 2        | Search (Sh)                           |
|          | Find (F)                             |
|          | Select (St)                          |
|          | Inspect (I)                          |
|          | Plan (Pn)                            |
|          | Preposition (PP)                     |
| 3        | Hold (H)                             |
|          | Unavoidable delay (UD)               |
|          | Avoidable delay (AD)                 |
|          | Rest in peace (R)                    |

2. Design analysis and prototyping

2.1. Design research

More than 30 wall painters were interviewed with the following questions.

i. What is the most troublesome in the usual wall painting?
ii. What is the most afraid of encountering in the process of wall painting?
iii. What tools are needed? How to take the tools to the workplace?
iv. Is your current toolbox easy to carry and what problems exist?
v. What tools are used and replaced most frequently during the wall painting process?

Through the analysis of interview results, the existing toolbox is very inconvenient to use and carry. The main reasons include its bulky size, less function, fixed internal structure, and the limited place for tool placement. Furthermore, as the acrylic paints are difficult to clean, wall painters are most afraid to soil their clothes. The use and replacement of brushes is also considerably frequent during the operation, which brings a lot of trouble to the wall painter. There are two situations about the tools’ transportation to the workplace. Firstly, when time permits, the wall painter will express the bulky paint directly to the workplace, and carry the small tools such as brushes by himself. Secondly, in the case of tight time, painters have to carry cumbersome tools and heavy paints to the workplace by themselves[5].

Through the on-site observation of the wall painter’s work process, the actions in the wall painting process are divided into three categories according to the Gilbres' Therbig action classification (Table 2)

Table 2. Motion classification in the wall painting process

| category | Motion element |
|----------|----------------|
| 1        | Rise hand      |
|          | Hold the pen   |
|          | Move           |
According to the economic principle of motion, the third type of motion should be avoided, and second type of motion should be reduced. And with optimization of the first type of motion, a relatively higher efficiency should be achieved by minimum fatigue.

2.2. Proposal of design prototype
According to the design survey and analysis above, the design prototypes are shown in Figure 1 and Figure 2.

**Figure 1. “vest-Handbag” section.**

**Figure 2. Large capacity paint bag with wheels**

The entire design solution consists of two parts. The first part (Fig. 1) can be used as both a vest (Fig. 1 left) and a handbag (Fig. 1 right). This section is used to store brushes, artboards, and other common
4. Design verification and improvement

3.1. Design proofing and verifications

Based on the relevant ergonomic roles[6] to determine the specific dimensions (Figure 3), the samples were made for the real user scene test (Figure 4).

Figure 3. the dimensions of the sample

Figure 4. Product sample

Figure 5. Transformation between the vest mode and handbag mode
The grey and waterproof nylon was chose as the main material of the product sample, which is tested in the real usage scene. Particularly, the carry-on handbag can transform to a wearable vest when opening the zipper on the side (Figure 5).

Selecting two wall paintings with roughly the same area and similar difficulty, one wall painting team conduct the same painting project. The first time, this team works with previous wall painting tools. In order eliminate the unrelated influence factor, such as fatigue and painting adapting, the second experiment was conducted several weeks later. In the next time, same team works with this product sample instead of previous ones. The number of times of each motion occurred were recorded by a 5-minute period over every 25 minutes. Record the average value of each motion in 8 recording periods within 4 hours, as shown in Table 3.

Table 3. Comparison of the times of occurrences of each motion in the average 5 minutes wall painting process

| category | Motion element          | With sample | Without sample |
|----------|-------------------------|-------------|---------------|
| 1        | Rise hand               | 70          | 62            |
|          | Hold the pen            | always      | always        |
|          | Move                    | 5           | 3             |
|          | Position                | 9           | 3             |
|          | Bow                     | 64          | 62            |
|          | Rise head               | always      | always        |
|          | Wave hand               | 2           | 2             |
|          | Place                   | 64          | 62            |
| 2        | Find                    | 3           | 0             |
|          | discover                | 3           | 0             |
|          | Choose                  | 3           | 3             |
|          | Change                  | 3           | 3             |
|          | Think                   | 3           | 0             |
|          | Pre-place               | 3           | 0             |
|          | Wash the brush          | 2           | 0             |
|          | Color mixing            | 2           | 2             |
| 3        | Grip                    | 3           | 0             |
|          | Upper and lower scaffolding | 3       | 0             |

According to the data above, the third and second types of motions are significantly reduced by using this product sample. This product design reduces the occurrence of unnecessary motions by a certain extent, improves the work efficiency, which conforms the human movement characteristics[7].

At the same time, some problems were found during the previous experiment. Firstly, the fabrics is too light and thin, which is easily deformed during the shipping, causing abrasion and even damage to the internal pigment boxes. Secondly, the size of the clothes is too small while it feels tight when wearing. Thirdly, the amount of brushes that can been insert into the pocket of the vest is not enough[8].

3.2. Design evaluation and development

According to the problems above, this product design is further adjusted. The waist circumference of the vest is expended to 76cm, and the chest circumference is expended to 95cm while whose length is expended to 90cm. The brush pocket is increased from the original two to three. Considering the material used is too soft, with re-examination of a variety of materials for comparison, final material selection is nylon 420D (D - Daniel = g / L * 9000, expressed the weight of the wire within the unit length[9]). This fabric is moderately soft and has good water resistance and a certain breathability. The soft crease-
resistant nylon 75D was selected as the inner lining, and used in the second proofing experiment (Fig. 6, Fig. 7).

The result of second sample experiment was considerably improved. Finally, the appearance of the product was redesigned. Choosing the cloth with splashing ink on the white background, this solution is aims to solve the problem of inadvertently staining during the wall painting process, while balance the aesthetics aspect. The final product is shown in Figure 8.

4. Conclusion

Based on the motion analysis method, and detailed investigation and analysis conducted into the working process of the wall painters, this wall painting tool was designed. Through the continuously
proofing and trial to evolve the solution, a shape and function balanced product design which satisfies the economic principle and ergonomic optimization was developed. This design has got the appearance and utility patent, and won the second prize of the 9th “Flash Cast Cup” industrial design competition in Zhejiang Province. It has also won the 2019 China Packaging Creative Design Competition as the shortlisted product design.

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