Study on Human - Machine Interface Design of Construction Machinery

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Abstract. Construction machinery is mainly used for construction, transportation, loading, etc., and its man-machine systems and working environment are very complicated. In this paper, the common human machine interface problems existing in the domestic engineering machinery are studied and analyzed. Through investigation and research and from the perspective of cognitive psychology, this paper analyzes the corresponding cognitive psychology process generated by the process of operator receiving and handling information sent by machines and environment. Thus, the interactive model of human-machine interface of construction machinery is established. In addition, combined with the principle of ergonomics design and application, taking truck crane as an example, this paper analyzes and summarizes the interaction elements of truck crane such as control and display interface. Specifically, this paper provides a theoretical support for the improvement and design of human-machine interface of construction machine through the analysis of the existing human-machine interface of truck crane, combing theory and practice. Simultaneously, it provides the following suggestions for the future human-machine interface design of construction machinery based on the existing human-machine interface design deficiencies.

Keywords: Construction machinery · Human-machine interface
Cognitive psychology · Ergonomics

1 Introduction

With "The Belt and Road" strategy put forward, the development of construction machinery industry ushered in new opportunities and challenges. Construction machinery is mainly used for construction, transportation, loading, etc. In general, its working environment is much complex, so security is its primary factor. With the advent of the experience economy, product competition is growing increasingly and the comfort of using the machinery, also attracts people's much attention.

At present, the man-machine interface design of domestic engineering machinery are only to meet the functional requirements, while ignoring the care of human nature. In the course of the operation, operator contact with the human-machine interface directly. If its design just meet the function and ignore people's work experience, the operating efficiency of the operator, the use of comfort and the operational accuracy will be affected. Therefore, as an important part of construction machinery, the design

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of human-machine interface need to focus on the operator, analyze physiological and psychological characteristics of human beings and combine with the characteristics of the machine itself and the working environment. As a result, it will make the human-machine-environment system more harmonious and unified and improve the safety and efficiency of operations, providing a comfortable working environment for operators, reducing the degree of fatigue and enhancing the overall value of the product.

2 Human-Machine Interface of Construction Machinery

The man-machine interface of engineering machinery includes display and control interface. The display interface is the terminal interface that reflects the running state of machine system, including a variety of display, instrument, signal lamp, symbols, graphics, buzzer, alarm, vibration, and so on. The interface that people send a special odor to is the control interface, including touch screen, handle, button, pedal and others. Machine's display and control interface focus on the completion of machine information and human information coding and decoding process, to achieve the interaction between human and machine [1]. During operation of the construction machinery, on the one hand, operators receive information displayed by machine, and on the other hand, they receive the information from surrounding environment, such as the command issued by the commander, etc. Man-machine interface is in the man-machine-environment system, and the process of the human-machine interactive information processing is shown in Fig. 1:

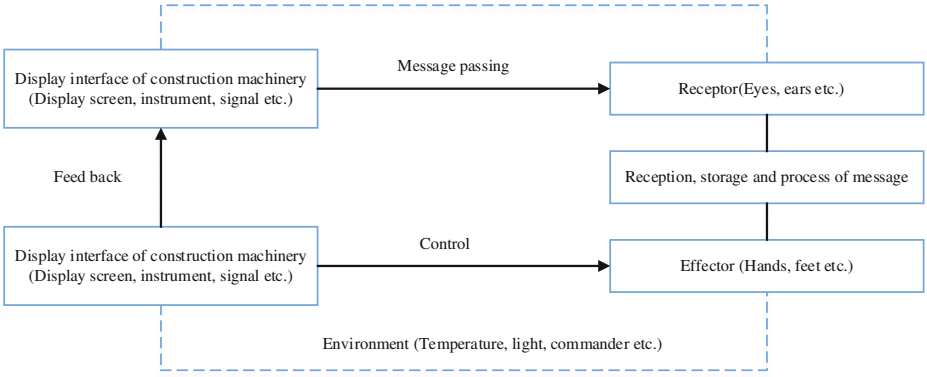


Fig. 1. Human-machine interaction of construction machinery

Truck crane is one kind of construction machinery, mainly consisting of truck chassis, container, power take-offs and crane. Its main function is to carry out, rotate and lift goods. Due to the particularity of its function, the functional interface is separate from the cab on the vehicle chassis, located beside the crane (As shown in the Figs. 2 and 3). Figure 2 is a truck crane of SANY PALFINGER, it is co-developed by SANY GROUP, Chinese famous construction machinery manufacturers and PALFINGER GROUP, which is the

world's top lifting equipment manufacturer. The technology of it is relatively mature and in the leading level of this industry.

Fig. 2. Truck crane of SANY PALFINGER

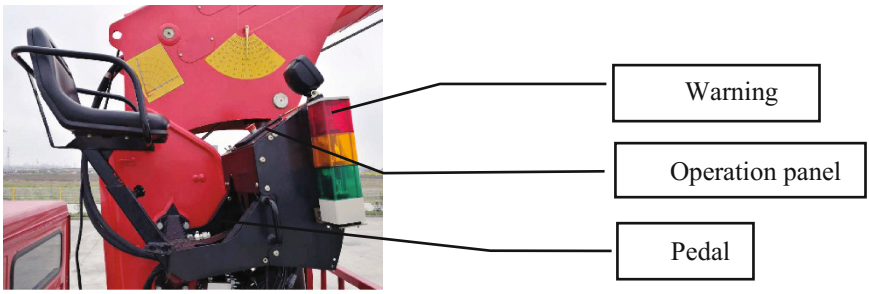


Fig. 3. Functional interface of truck crane of SANY PALFINGER

3 Analysis of Human-Machine Interface Design of Construction Machinery

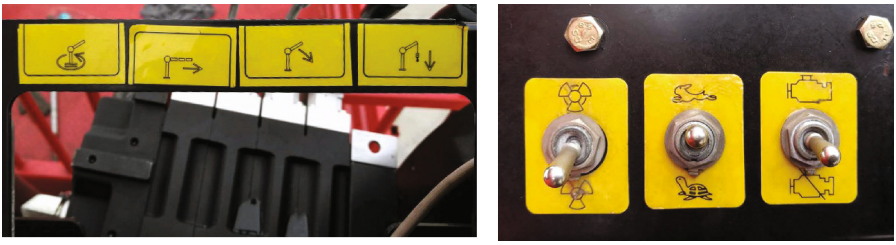
3.1 Cognitive Psychology Model

In the operation process, people need to deal with outside information brought from machines and environment, which will result in corresponding cognitive psychological process. The famous American psychologist Neisser emphasizes in the book Cognitive Psychology that cognition is the process of exchange, simplification, storage, extraction and application of information, including pattern recognition, attention memory, strategy, knowledge symbol, concept formation, problem solving, judgment and behavior [2].

In the process of operation, operators receive information sent by machine and environment through the sense of vision, hearing, touch and others. Then they respond to machine after the analysis, judgment and decision-making of brain and use hand, foot and other sports organs to operate it. Generally, the processing speed of different forms of information is different. Relative to the text information, people can understand and memorize the graphics more easily and clearly. Thus, in the human-machine

interface design of engineering machinery, we should make full use of simple and easy-memorized graphics and use few characters, maximizing the efficiency of operations and operational accuracy [3].

Take the truck crane of SANY PALFINGER for example, more graphic symbols take the place of textual description on its interface, as shown in Fig. 4. For instance, the handle direction indicators shown in the Fig. 4(a) are not only international general, but also can let the operator understand and remember information more easily in the process of operation. What's more, in the middle of the picture Fig. 4(b), the upper and lower are brief strokes of rabbit and turtle, when switch turn to the rabbit, the crane lift goods faster. And when the turtle, lifting speed is slower. It is well known that rabbits and turtles represent high speed and low speed respectively, so using this pattern as indications can make them more concise and clear. Consequently, the accuracy and efficiency of operation will be improved.



(a) (b)

Fig. 4. Details of interface of truck crane

The operation labor intensity of truck crane is not great, but require operators' high degree of concentration. In the operation process, people need to pay attention to changes in the surrounding environment, and listen to the commander's instructions. When the environment changes or having new instructions, the operator should make appropriate control behavior in the first time, and ensure the operation safety as well. Hence, human-machine interface design of the engineering machinery should be in accordance with the cognitive psychological process of human beings and ergonomics. All the human factors should be taken into consideration, in order to improve safety, efficiency and comfort of the operation process.

3.2 Design of Human-Machine Interface Interaction Element

Control Interface

Control interface of truck crane is exposed outside and located next to the crane, so that it is convenient for people to keep an eye on the movement of the object and changes of the surrounding environment. No matter what kind of its position, design must be based on the size of human body. And it is the premise of accuracy and comfort of operation. Most of the crane operators work on the seat, so the display and control panel should be

designed according to the display platform and console in the situation of sitting working. It is surveyed that the sight distance from operation's eye to the display platform is from 550 mm to 710 mm, in this range, our human eyes are not easy to be tired [4].

Normally, the visual signal recognition clarity and speed can be divided into four viewing areas: the central visual area, the best visual area, effective visual area, and the largest visual area [5]. The dimensions and layout of the man-machine interface of engineering machinery should take full advantage of the best visual area and the effective visual area, so the operator can receive interface message and operate the machine both quickly and accurately. To the human eye to see the level of sight for the basis, downward sloping 15° to 40° is the best viewing angle of people. In this angle range, people watch the objects most clearly and comfortable [6].

Figure 5 shows the reference pattern for the design of display and control panel in the sitting position [7]. Among the two pictures, picture (a) is applicable to small number of display and control interface, the height below the level of sight. While the larger number of it can take reference to picture (b). In addition, it will be convenient for people of different height to operate machine comfortably, if the height of seat beside the crane is designed to be adjustable.

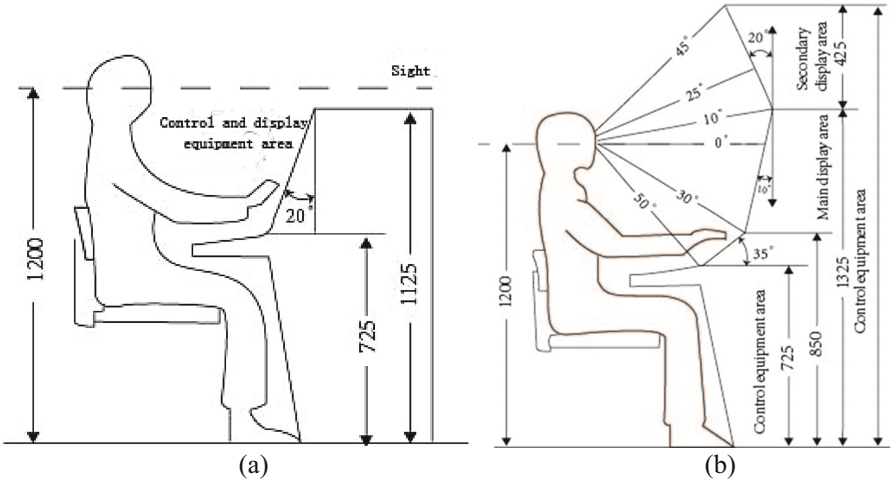


Fig. 5. Reference pattern and size for the display and control panel in the sitting position

Display Interface

The way people receive information is various, such as through the sense of visual, hearing, touch and smell etc. And people accept the information from environment mainly through visual and auditory. In the man-machine interface of the construction machinery, the application of visual display and auditory display is the most extensive, and proportion of visual display is the largest [7].

Visual display device can be divided into the instrument display, screen display, light display and so on, with quantitative, qualitative and warning function. To construction machinery, the quantitative display interface transfer parameters during machine operation to the operator, and the qualitative display interface shows the state and trends of machine. The interface for warning has clear visual stimulation, and it can send the signal that reflects the state of machine to the operator directly or provide operational guidelines, reducing the burden of memory. And then the operator will make the appropriate control behavior.

At present, the function of truck crane is relatively simple on the market, so its display interface is much concise and mainly ensure the safety, convenience and efficiency of operation. As shown in Fig. 6(a), there are three large lights in the front of the operator's right side. Consistent with the general cognitive of human, green light represents the normal operation of the machine, the red light indicates that crane exceed the rated pressure range and sends warning signal, the job suspended. Yellow light means that the machine itself is faulty. As we can see, the position and brightness of indicator light is very obvious, making operator know of the running state of machine and make appropriate control behavior quickly. When the red light is on, which means a situation of emergency, the operator will press the red emergency stop button in Fig. 6(b). Generally, the operator concentrate on work extremely, the signal lamp for warning indication should be more obviously and the size and position of the corresponding emergency stop device should also let the operator at a glance, so as to ensure the safety of the operation.

(a) (b)

Fig. 6. Control and display platform of truck crane

Color Design of Operational Panel

The color design of interface including overall color and local color. Considering the complex environment of operating construction machinery, the need for a high concentration of people's attention and the stable psychological feeling to people, the overall color should not be too stimulating and exciting. At the same time, in order to keep operators in a good mood and prevent fatigue, the color of some details can be used in low-purity and high-brightness color, such as sliver gray, light blue, light yellow etc.

For the interface detail, its color can be designed by the means of color coding, which can integrate each independent element from the interface together and make the target and key factors located more effectively [8]. That the elements of same function are designed into same color and different colors represent different functional categories, can reduce the processing load of the brain, so that people can quickly find the corresponding function and reduce the error frequency. For the details color of human-machine interface of construction machinery, it can designed by the means of color coding according to the principle of functional partition, as shown in Fig. 7. Using color encoding of the same interface and making the same function of the control interface with the same color, operators can fix position of the object quickly and accurately, improving the efficiency and reducing the frequency of errors.

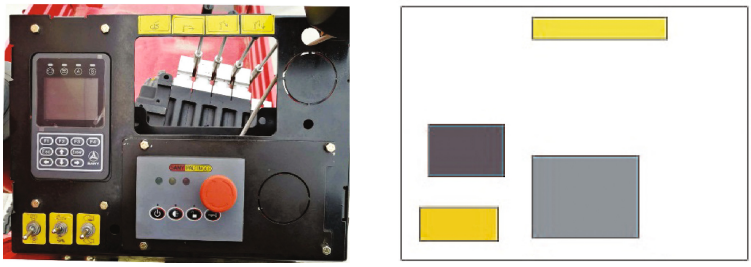


Fig. 7. Color coding of the interface

4 Conclusions

Based on the theory of cognitive psychology and ergonomics, this paper analyzes the human-machine interface of construction machinery, and take the truck crane of SANY PALFINGER as an example. With combination of theory and practice, this paper provide theoretical support for the improvement and design of human-machine interface of construction machinery, making the design more safe and humanized. Based on the above analysis, several suggestions are put forward.

(a) In the design process of human-machine interface of construction machinery, especially when it comes to tips, manipulation instructions or warnings and other parts, using more concise and easy to understand graphical symbols and less text
(b) In the course of operation, the operator must response quickly and accurately. Therefore, the core interface of operation panel should be within the best vision that is the human eye level as the benchmark, down 15° to 40°, human eyes to the operator panel distance in the range of 550 mm–710 mm.
(c) In the operation process, security is its primary factor. Therefore, the visual display interface used for warning and indicating should be consistent with the general visual cognition, intuitive and easy to understand. At the same time, in the case of possible, to increase the auditory warning design will play a complementary in the visual warning.

(d) The overall color of construction machinery should not be too exciting. At the same time, in order to keep the operator in good mood and prevent tiredness, designers could adopt the colors of low purity and high brightness, such as silver gray, light blue and light yellow.
(e) The color coding method can be used to make the same functional interface have the same color, which can reduce human processing load of information, improve work efficiency and relieve human fatigue.

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References

1. Jing, G., Zhang, D.: Analysis of human machine interface safety of industrial equipment based on Ergonomics. J. Zhongyuan Univ. Technol. **1**, 53–56 (2012)
2. Qiang, W.: The Design of Excavator Cab Man-Machine Interface. Xian University of Architecture and Technology (2015)
3. Yang, M., Wang, H.: Perceptual analysis of human - computer interaction interface design. Packag. Eng. **28**(11), 11–13 (2007)
4. Chen, K.: Truck Crane Operating Room Man-Machine Interface Design. Central South University (2012)
5. Meng, Q.: Research on design of mechanical operation panel based on ergonomics. Ind. Instrum. Autom. **6**, 8–10 (2011)
6. http://baike.baidu.com/link?url=rWSKm6M8XVkXCRa22Ah4MKxJ5TlTTtK0a12jbbESG7pj3l60HcO7IJJWpiNZRB-DV_uKrLskmca9rooj3b2zXLjskRnwz0D9wp9T9jp2a2DsQMLLIkv6zvLCsC9MvUa
7. Ding, Y.: Ergonomics. Beijing Normal University Press, Beijing (2011)
8. Wichens, C.D.: Justin Hollands, Engineering Psychology and Human Performance (2000)