ZIBELINE INTERNATIONAL™ PUBLISHING

ISSN: 2773-6202 (Online)
CODEN: JTIOCC

Journal of Technology & Innovation (JTIN)

DOI: http://doi.org/10.26480/jtin.02.2023.54.57

RESEARCH ARTICLE

IMPROVED MAN-MACHINE INTERACTION DESIGN OF MOULD CASE CIRCUIT BREAKER BASED ON QFD

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ARTICLE DETAILS

Article History:

Received 23 May 2023
Revised 04 June 2023
Accepted 12 July 2023
Available online 14 July 2023

ABSTRACT

This paper aims to improve and study the man-machine interaction defects of mould case circuit breaker. By changing the interface information layout, the interface information transmission effect was enhanced, with user pressure in information reading reduced. User demand information was acquired based on interview method, observation method and literature reading method. Information was classified by user demand levels according to KJ (affinity diagram) method, with its weight calculated by AHP (analytic hierarchy process) method. Finally, user demand was converted into design requirement by QFD (Quality Function Deployment) method and product improvement design function model was built. Guided by user demand, this paper rationally analyzes the man-machine interaction pain points in mould case circuit breaker, and takes this as the improvement and innovation points to build a functional design model for the improved design of man-machine interaction of mould case circuit breaker, hoping to improve the working efficiency of users, and provide new ideas for the improvement research on man-machine interaction of similar products.

KEYWORDS

Improved Design; Mould Case Circuit Breaker; QFD; Man-Machine Interaction

1. INTRODUCTION

Mould case circuit breaker also known as device circuit breaker, is an automatic air circuit breaker, whose primary role is to provide special protection for overload and short circuit of low-voltage distribution system and motor protection circuit (Chen, 2013; Zhang, 2019). According Mould case circuit breaker is generally composed of contact system arc extinguishing system, operating mechanism, trip and shell, etc (Li et al., 2021). Because of its reliability and stability, it now enjoys wide industrial applications (Li and Liu, 2021). The development of low-voltage electrical appliance manufacturing industry is accompanied by constant update in mould case circuit breaker technology. The products basically meet its functional requirements, but certain defects still remain in man-machine interaction (Ban and Cao, 2018). This paper takes 250A/3P mould case circuit breaker as the research object, uses QFD method to clarify user demand, and converts them into design requirements to redefine the man-machine interaction mode of mould case circuit breaker, thus rebuilding the user experience and interaction behavior through the humanized improved design (Zhang et al., 2021; Gao, 2016; Yao et al.2019).

2. PROBLEM ANALYSIS

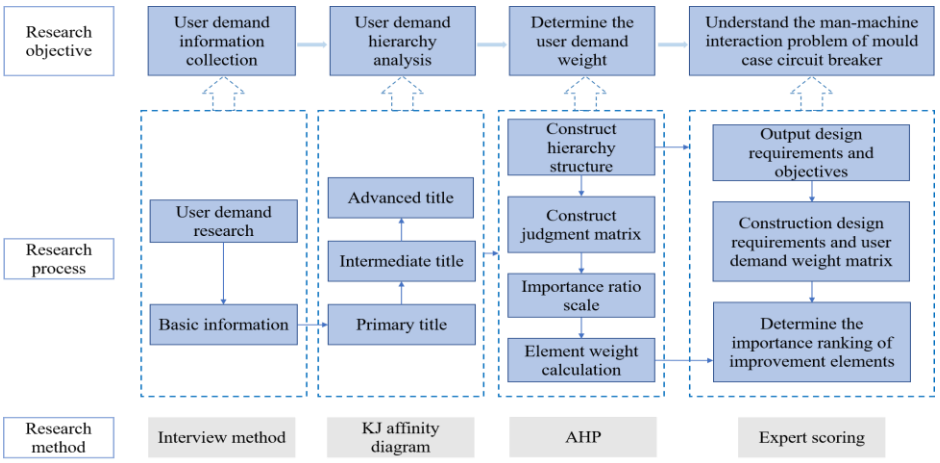

Figure 1: Research process of man-machine problem based on QFD

Quick Response Code	Access this article online	
	Website: www.jtin.com.my	**DOI:** 10.26480/jtin.02.2023.54.57

Cite The Article: Hesen Li, Ni Wu, Jing Dong, Yi LI, Dawei Yao (2023). Improved Man-Machine Interaction Design of Mould Case Circuit Breaker Based on QFD. *Journal of Technology & Innovation, 3(2): 54-57.*

First proposed as a quality management system by Japanese scholar Akao et al. in the 1960s, it was initially used in Mitsubishi Heavy Industries of Japan (Chen and Xue, 2019). QFD can transform the basic requirements described by fuzzy term into feasible alternatives(Chen et al., 2020) . This paper uses QFD to transform the fuzzy expression of user demand under investigation into feasible improvement schemes. Not limited to product planning, it generates a structured and versatile framework that can be used to meet the requirements of various systems and translate them into priority improvement activities. Figure 1 shows the main steps for solving man-machine interaction problem of mould case circuit breaker based on QFD.

2.1 Determine user demands and design requirements

User demand information is mainly collected by literature review, observation and interview methods. Basic user demand information mainly includes: information priority, product parameters, handle size, font size, character area, etc. Initially collected information is messy and fuzzy, so it is necessary to classify and grade the basic user demand information . According to the subjective thinking, the basic information considered as related is summed up together, and the subtitle is defined as "primary title", and so on. The "primary title" considered as related is summed up together to form the intermediate title, and then the advanced title is generated, as shown in Table 1. User demand involves four directions: status symbol, rated current, nameplate information and information distribution.

Table 1: KJ method for hierarchical analysis of user demand

Advanced title	Intermediate title	Primary title
Status symbol	Symbol shape	Alphabet symbol
		Visual language
	Symbol color	Recognition
		Color contrast
	Symbol scale	Symbol length
		Symbol width
	Symbol positioning	Display position
		Ambient light factor

The user's demand weight K is calculated by AHP method, and the user demand hierarchy is established according to the demand hierarchy established by KJ method. The weight of secondary user demand is calculated, and the K value is positively correlated with the user demand for mould case circuit breaker. Greater K value indicates greater importance of the corresponding demand for the user. The calculated user demand weight K, the user demand and the weight of secondary demand are shown in Table 2. User demand focuses more on product status symbol display and information distribution. From the perspective of demand importance, the scale design of status symbol ranks the first, followed by the module position design in information distribution design. The reason is that users pay more attention to the visualization effect of status symbol of mould case circuit breaker. As a circuit protection product, mould case circuit breaker is expected to be simple and easy to read, and the information distribution of the product panel should be orderly.

Table 2: User demand hierarchy and weight

Objective	Criterion	Subcriterion	Number	K
Information transmission function	Status symbol/C_1	Symbol shape	C_{11}	0.055
		Symbol shape	C_{12}	0.238
		Symbol color	C_{13}	0.123
		Symbol scale	C_{14}	0.350
	Rated current/C_2	Character scale	C_{21}	0.123
		Character color	C_{22}	0.084
		Character spacing	C_{23}	0.049
		Character selection	C_{24}	0.032
	Nameplate information/C_3	Character scale	C_{31}	0.039
		Character color	C_{32}	0.031
		Line spacing	C_{33}	0.008
		Character spacing	C_{34}	0.008
		Character selection	C_{35}	0.016
	Information distribution /C_4	Module position	C_{41}	0.276
		Module area	C_{42}	0.165
		Module spacing	C_{43}	0.110

2.2 Determine the relationship between user demand and design requirements

Determining design requirements is one necessary step for smooth design improvement. According to the principle of QFD, the user demands are classified and sorted by the affinity diagram method, and then transformed into design requirements in line with the improved design process. The specific design objectives of the information transmission function are clarified so as to better meet the user demand.

2.3 Determine man-machine interaction problems

Table 3: Relationship matrix between user demand and design requirements

User demand		C_1				C_2				C_3					C_4		
Primary demand	Secondary demand	C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}	C_{23}	C_{24}	C_{31}	C_{32}	C_{33}	C_{34}	C_{35}	C_{41}	C_{42}	C_{43}
D_1	D_{11}	●	△	○		△			○					○	○	○	△
	D_{12}	△	●				○				○						
	D_{13}	○		●	○	○			△	○		△	△		○	○	○
	D_{14}			○	●	△				○		△	△	△	○	○	△
D_2	D_{21}	△		○	△	●		○	△	△		△	△		○	○	○
	D_{22}		○				●	○	△		○						
	D_{23}					○	○	●	△	△			△	△	△	○	○
	D_{24}	○		△		△	△	△	●					○	△	△	△
D_3	D_{31}			○	○	△		△		●	△	○	○	△	○	○	○
	D_{32}		○				○			△	●			△			
	D_{33}			△	△	△				○		●	○	△	○	○	○
	D_{34}			△	△	△		△		○		○	●	△	△	○	○
	D_{35}	○			△			△	○	△	△	△	△	●		○	○
D_4	D_{41}	○		○	○	△		△	△	○		○	△		●	△	△
	D_{42}	○		○	○	△		○	△	○		○	△	○	△	●	○
	D_{43}	△		○	△	○		○	△	○		○	△	○	△	○	●

The relationship matrix between user demand and design requirements is built to clarify the relationship in between, as shown in Table 3. The user demand weight is converted into the weight of technical characteristics, and the demand importance of mould case circuit breaker is classified by three symbols: ●, ○, △. ● indicates strong correlation with a value of 9; ○ indicates intermediate correlation with a value of 5, meaning the relationship needs to be clarified. △ indicates weak correlation with a value of 1. The space indicates zero correlation with a value of 0. For example, in D11 symbol shape design and C11 symbol shape design, scale design is also one aspect of shape design.

In the matrix, the design requirements of key improvement factors are determined according to the importance of the design requirements of mould case circuit breaker. The calculation formula of demand weight K× matrix score S is used, taking D11 as an example:

Matrix score SD11=9+1+5+1+5+5+5+5+1=37, and according to AHP method, the weight KD11 is 0.055. In summary, the importance of D11 design requirements is SD11×KD11=37×0.055=2.035.

Where, D13 symbol scale design, D41 module position design, D42 module area design and D43 module spacing design are of high importance, as shown in Figure 2.

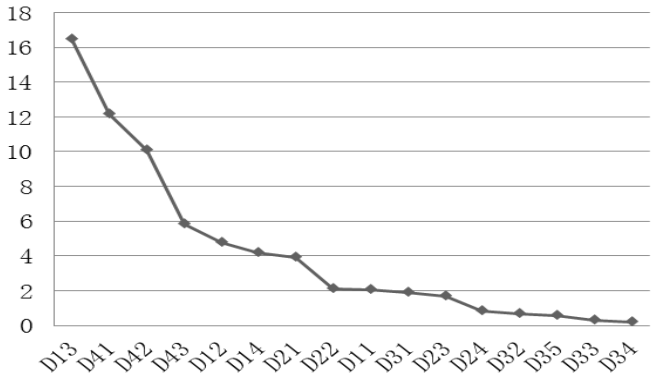

Figure 2: Importance ranking of improvement factors

2.4 Analysis of man-machine interaction problem

2.4.1 Panel information layout

According to regulations such as GB14048.1-2012 "Low-voltage Switchgear and Control Equipment", the panel information is graded. Lower grade indicates higher importance. The information importance is ranked as follows: status symbol information > current information > nameplate information. The panel information display area of the improvement object is mainly concentrated in the upper part of the product. By measurement and calculation, the panel information display area is 11949mm^2; the nameplate information display area is 3726mm^2, accounting for 31.18%; the display area of status symbol information is 1377mm^2, accounting for 9.25%; the current information display area is 297mm^2, accounting for 2.49%. To sum up, the proportion of panel information layout does not match the importance of panel information.

2.4.2 Status information symbol

There are two ways for users to identify the status information: one is through recognition of the colored symbol information; the other is to judge by observing the corresponding relationship between the handle and the status symbol information on the right side. The former is installed in the inner groove of the handle and the observation efficiency of the human eye will decrease in the dark environment. The latter adopts intaglio printing process and has no color distinction with other parts, which is also unconducive to observation. In summary, status symbol information has low recognition degree.

3. Improved Design Method

3.1 Change The Panel Information Layout

The current panel information is rearranged to increase the proportion of status symbol information in the panel information and weaken the secondary information in the nameplate information (Zhang et al.,2015). The status information symbols are distributed in the upper and lower ends of the handle to increase its area. The nameplate information is partitioned the brand information such as product model is arranged on the left side of the handle, the text showing current and voltage information is tabulated and placed on the right side of the handle (Yao and Liu, 2018).

3.2 Enhance the visualization effect of status information symbols.

The size of the status symbols is increased (Li et al.,2022). Without affecting the internal structure, the symbol size is enlarged to 15mm×30mm, the number is increased to two for separate placement on both sides of the lower end of the handle. The "ON" and "OFF" symbols of the original products are changed to the international standard graphic symbols "┃","▲", "◎"to reduce the user's reading difficulty.

4. Improved Design Concept

The improvement concept regarding interface information layout of mould case circuit breaker is as follows (Li et al., 2022):

I. Increase the front area of the handle module, and the status symbol information display area is 34mm×65mm after improvement, which accounts for the largest proportion in the whole panel information area.

II. Enhance the visual effect of the working status symbol of the product, increase the size of the status symbol in area, use red letters on black background in color to make it more eye-catching, and move the symbol to the top of the handle shell, so that it is no longer affected by the position of the light source.

III. Partition the nameplate information, place the brand information such as product model on the left side of the handle, tabulate the text showing current and voltage and place it on the right side of the handle.

5. Conclusion

The confused panel information layout of the research object leads to user identification difficulty, which is common in the molding design of most brands of mould case circuit breaker. Therefore, by mining user demand based on QFD, the interface information layout is changed to improve the user efficiency in judging the operating state of mould case circuit breaker, which has certain reference value for the design and research of man-machine interaction display mode in other brands of mould case circuit breaker.

The deficiency of the research herein is that, to add the carrier for displaying the breaking and closing symbol information on both sides of the handle, it is necessary to add additional assembly space under the panel of the research object, which increases the overall product thickness and may lead to higher production costs. In addition, the improved design of the linkage between the breaking and closing symbol and the handle is only applicable to the mould case circuit breaker with the same functional prototype and use mode as the research object herein.

Acknowledgments

The major program of higher education for the study of philosophy and social sciences in Hubei Province in 2021. (Social Science Foundation of the early funding project in Hubei Province) (Project number: 21ZD107)

The major research and cultivation funding project of Hubei Institute of Fine Arts in 2020. (Project number: 20ZD03)

References

Ban, Y. Y., and Cao Y. J., 2018. Optimized design based on intelligent manufacturing plastic shell circuit breakers. El-ectrical and energy efficiency management technology (18), Pp. 27-31.

Chen, D. G., 2013. Current development trend of low-voltage molded case circuit breakers at home and abroad. Lowvol-tage appliances (04), Pp. 1-4+23.

Chen, L., Dou, H., Wei, H., Liu, X. M., Chen, B. W., 2020. The innovative design of product innovation bas-ed on quality function development, invention solution theory and bionics. China Machinery Engineering (11), Pp. 1285-1295.

Chen, X., Xue, B., 2019. Research on interactive design of aging smart home product based on QFD/TRIZ. Packaging project (20), Pp. 74-80.

Gao, H., 2016. The design and implementation of the electron deduction of the plastic shell cutter. Electric and energy efficiency management technology (11), Pp. 54-57+61.

Li, H. S., Liu, G. Z., Hu, Y. R., Wu, Y. R., Mo, D. W., 2022. Research on modeling design evaluation of intellig-ent molded case circuit breaker. Mechanical design (01), Pp. 140-145.

Li, H. S., Liu, G. Z., Mo, D. W., 2021. 4P-250A-type plastic shell circuit breaker series model design. Mechanica-l design (04), Pp.147.

Li, H. S., Liu, G. Z., Yao, D. W., 2022. Improved design of human-computer interaction mode of molded case circuit breaker. Mechanical design (09), Pp. 142-147.

Li, H., S., Liu, G. Z., 2021. Smart plastic shell -breaking road panel shape design based on human -machine engi-neering. Mechanical design (05), Pp. 127-131.

Li, Y. N., Cai, Z., Zheng, X. J., Zhang, K., 2016. Application of feature integration theory to optimize information visualization design based on image symbols. Journal of Computer Aided Design and Computer Graphics (01), Pp. 16-24.

Yao, J. C., Liu, G. Z., 2018.Objective evaluation method based on image content visual perception. (10), Pp. 241-258.

Yao, J., Tang, X. T., Li, Y. J., Guo, Y. C., Huang, H. T., 2019. QFD -based pneumoconiosis home rehabilitati-on product system design. Packaging engineering (06), Pp. 152-158.

Zhang, H. G., Cheng, S. Y., Fu, Z. C., 2021. Optimization of low -voltage plastic -shell circuit breakers based on TRIZ theory. Electrical appliances and energy efficiency management technology (07), Pp. 40-44+50.

Zhang, M. X., 2019. The reliability design of the plastic shell circuit breaker operation agency. Electrical and Energy Management Technology (21), Pp. 29-32.

Zhang, N., Wang, J. M., Yang, Y. P., 2015. Evaluation method of beauty image of human-machine interface morp-hological element layout design. Mechanical Science and Technology (10), Pp. 1594-1598.