International Journal of Business and Management Invention (IJBMI)
ISSN (Online): 2319 – 8028, ISSN (Print): 2319 – 801X
www.ijbmi.org || Volume 7 Issue 3 Ver. II || March. 2018 || PP—51-56

Development of an Anti-Scald Temple Adjustment Tool Based On Design for Six Sigma (DFSS)

Chung Yi-Chan [1] , Chen Chiung-Mei [2]
[1, 2] Graduate Institute of Business administration, Yuanpei Universty of Medical Technology, Taiwan
[1] *Corresponding Author: Chung Yi-Chan*

ABSTRACT :This study identified the needs of users not yet satisfied and design directions during the adjustment of TR-90 frames through in-depth interviews. It combined Human Factors and Ergonomics Theory to allow tool design to have the functions of compliance with operational safety, comfort, and adjustment of the temples of frame glasses. It attempted to develop an anti-scald temple adjustment tool in accordance with IDDOV five stages of DFSS. This study finds that, the tool, designed from the perspective of Human Factors and Ergonomics Theory, allows wrists to maintain neutral positions, which greatly reduce wrist deviation and palm pressure. Through the steps of "identify", "define", and "develop", tool design can be more specific. The step of "optimize" can optimize the way to produce the adjustment tool. And the step of "verify" can ensure the results are in line with the targets set. The results of this study can serve as reference for creators and researchers who intend to develop the adjustment tool.

KEYWORDS- in-depth interview, Human Factors and Ergonomics Theory, Design for Six Sigma (DFSS)

DATE OF SUBMISSION: 26-02-2018 DATE OF ACCEPTANCE: 13-03-2018

I. RESEARCH MOTIVES AND PURPOSES

Among the routine tasks of personnel of a glasses company, adjustment of frame glasses requested by customers is inevitable. The adjustment of the parts of temples behind the ears is an important step. Poor adjustment of temples will affect optical effect, cause discomfort to ears or the head, and affect the overall appearance of the face. TR-90 is a new type of frame material launched recently. This shape-memory high polymer material finds favor in the eyes of manufacturers and consumers. And it is an ultra-light frame material popular internationally. Its characteristics include that, it is not easy to cause deformation under high temperature condition. It can resist 350℃ within a short period of time. It shall be heated before reshape, especially when it is applied to temples because of curved cartilages, ear shapes, and different bitamporal lengths. Some consumers need a frame with bigger bent. Hence, TR-90 frame needs to be heated for reshape to match with the ear shapes of customers and make them more comfortable to wear glasses. However, there are few anti-scald temple adjustment tools in domestic and foreign markets. This study endeavored to design such a tool to meet the needs of users. This study explored the needs of users which were not met during the adjustment of TR-90 frames via in-depth interviews. It adopted Human Factors and Ergonomics Theory for the modeling and functions of the tool. As different dimensions are corresponded to different procedures, this study also combined DFSS to design the temple adjustment tool which can better meet the needs of users. The research purposes are as follows:

1. Exploring the needs of temple adjustment tool in the current Taiwan glasses market.
2. Analyzing if the design of the existing temple adjustment tool is in line with the needs of users.
3. Identifying the needs not satisfied when users use the existing adjustment tool, and the directions and key points of design of an anti-scald adjustment tool.

II. LITERATURE REVIEW

This study employed in-depth interviews to investigate the deep discussions on the anti-scald temple adjustment tool among experts. Then, it adopted Human Factors and Ergonomics Theory and DFSS to determine the key points and steps of design of anti-scald temple adjustment tool.

2.1 In-depth interview

According to Wen and Yang (2000), in-depth interview was designated to obtain some significant information through purposeful and deep interviews. No questions or fixed procedures were prepared in advance. There was only a topic or outline. The interviewer and the interviewee could express their ideas on the topic or outline at will. There were no default answers. Bernard (1988) asserted that, different interview methods should be used according to different research purposes, natures, or subjects. By the degree of control over an interview by the interviewer, interview could be classified into four categories, that is, informal interviewing, unstructured interviewing, semi-structured interviewing, and structured interviewing. This study adopted semi-structured interviewing. To conduct a semi-structured interviewing, the interviewer shall prepare an interview outline based on research questions and purposes. The interviewer can make slight and flexible adjustments to the outline and ask questions during the interview, as appropriate. Before the interview, the interviewer shall learn the background and habits of the interviewee to better perceive the emotion of the latter and interview beyond the lines. Lastly, the contents collected via the interview were analyzed to see users' true opinions on adjustment tool and needs not yet satisfied. The purposes of the in-depth interviews conducted in this study include the following points:

1. The interviews were conducted to learn the awareness, attitude, and usage of users about temple adjustment tool for frame glasses.
2. The interviewees were asked to discuss the factors influencing their adjustment of frames, and express their opinions on adjustment tool, purposes to use adjustment tool, and usage condition of adjustment tool.
3. The interviewees were also requested to discuss their experience and feelings after using adjustment tool, including their willingness to continue to use such a tool and recommend them to friends.

2.2 Human Factors and Ergonomics Theory

Hsu, Peng, and Wu (2000) asserted that product design should take Human Factors and Ergonomics Theory into account. They utilized the various elements in the interaction between human and products, and paid attention to the interaction between human and the designed objects. They regarded their theoretical principles and methods as the benchmark for tool design, and hoped to achieve users' satisfaction in safety and comfort and increase work efficiency. Therefore, at the beginning of the design of anti-scald adjustment tool, this study considered Human Factors and Ergonomics Theory in order to achieve the expected goals. This study aimed to design a non-power-driven hand tool with the advantages of being portable, easy to operate, and inexpensive. Armstrong (1986) pointed out that the muscle injuries of upper extremities were mostly related to the action errors. Hence, the anti-scald adjustment tool must be designed in the principle to avoid excessive bent, extension, radial deviation, and ulnar deviation of wrists. Hedge (2003) argued that a basic component of a hand tool was the part for gripping. A tool should have the working end and the gripping end. And the gripping end should ensure comfort and stability for users to use. Hedge (2003) mentioned that good grip design should consider the size, appearance, length, quality, and material of the gripping end, as well as the balance between the gripping and the working ends. Grip size shall be as close as possible to the size of user's palm. The appearance of a grip shall match with the gripping action of users. The length shall be the same or longer than the palm's width to avoid pressure on the palm due to the gripping end. For quality, the ways to hold a tool by users shall be considered. And materials that are prone to be slippery due to sweat of the palm shall be avoided. Materials for the gripping end shall help reduce the pressure against the palm. Freivalds (1987) had described the diameter, length, shape, material, and angle of the gripping end of a hand tool in details:

1. **Grip diameter:**

Based on his research, Freivalds concluded that the optimal diameter of the tool that he studied should be 40mm. Based on the results of EMG, Ayoub and LoPresti (1971) suggested it to be 51mm. However, according to the maximum working cycles that a user could complete before he felt fatigue, and EMG grip force ratio, they suggested 38mm to be optimal. Pheasant and O'Neil (1975) discovered that, when the diameter exceeded 50mm, muscle force would reduce. Cochran and Riley (1983) found that, for both men and women, the perimeter resulting in the biggest pushing force was 130mm, equivalent to the diameter of 41.4mm of a round grip. Considering his work experience, Eastman Kodak (1983) suggested that the grip diameter should be between 30mm and 40mm. 40mm was the best in terms of gripping. As of the tool with the diameters between 8 and 16mm, 12mm rendered the optimal precision gripping. To sum up, the grip diameter shall be between 31mm and 50mm so as to produce the maximum torsion. As the anti-scald adjustment tool designed by this study shall be held precisely, its best grip diameter is between 8mm and 12mm.

2. **Grip length:**

For the grip that also requires fingers for operation, it shall have enough space to hold the four fingers except the thumb. From the 5th percentile palm width (71mm) of female to the 95th percentile palm width (97mm) of male, 100mm might be the minimum value acceptable, but 125mm might be more comfortable. Based on his work experience, Eastman Kodak (1983) suggested that the grip length should be between 30mm and 40mm. 40mm was the best in terms of gripping. As of the tool with the diameters between 8 and 16mm, 12mm rendered the optimal precision gripping. Thus, it can be concluded that the grip diameter shall be between 31mm and 50mm so as to produce the maximum torsion. The minimum value match with precise and speed gripping ways. The optimal grip length shall be between 8mm and 12mm. As the anti-scald adjustment tool designed by this study shall be held precisely, its best grip diameter is between 8mm and 12mm.

3. **Grip shape:**

Freivalds held that no one grip shape could be perfectly conformed to any form of operation, because grip shape depends on the operations and actions of users. With respect to a hand tool which needs to be gripped firmly, its design shall offer big area for gripping so as to ease the unit pressure against the palm. For a hand tool that needs to be pushed hardly, the grip cross section shape with the maximum pushing force shall be triangle. In contrast, round cross section shape produces the minimum pushing force.

4. **Grip angle:**

Freiveds thought that if a wrist was deviated from the neutral posture, it was prone to suffer from a variety of cumulative damages under repeated load. And performance of operation would be reduced. Terrel and Pruswell (1976) probed into the influence of different wrist postures on gripping force, and found that, in the supination position, the best gripping force (100%) would be generated. In the pronation position, approximately 88% of gripping force would be generated. And in the neutral posture, approximately 99% of gripping force would be generated. When the palm was bent, it would produce 73% of gripping force. Wrist dorsiflex would produce 77% of gripping force. Radial deviation would produce 83% of gripping force. Thus, like a power machine, it is necessary to keep your wrist straight when holding a tool.

2.3 DFSS

DFSS improves the uncertain factors in the development process from the perspective of the development or the process so as to solve problems perfectly. The hand tools to be designed by this study are at the initial stage of development. The key point now is to design competitive anti-scald adjustment tool. Subir Chowdhury (2002, translated by Wei-shan Hu) deemed that, at the stage of product or process development, DFSS could help identify the core of problems and solve problems. The feelings and opinions of users were collected so as to pursue products and design with better quality and develop more perfect tools and methods. This study followed IDDOV proposed by Subir Chowdhury (2002) as its DFSS procedures, because Subir Chowdhury (2002) stressed the application and establishment of "concept" rather than the usage and limits of tools, which would be beneficial for this study to analyze the topic in a broader sense. This study employed DFSS procedures and Human Factors and Ergonomics Theory to design products.

DFSS in this study was user demand oriented. It was expected that things could be done well for the first time. Ax-ante "prevention" replaced ex-post "remediation". The main purposes of adopting DFSS by this study include:

1. Understanding the core procedures of DFSS and the timing and steps to use the main tools so as to maximize manpower and financial resources and enhance the ability to solve problems.
2. A tool or product R&D model had been set up for future reference based on the actual research methods and implementation of this study.

III. RESEARCH METHOD

Nowadays, all kinds of product design are influenced by new technologies and ideas. Increasingly complicated factors shall be considered for product design and invention. Design shall be combined with ergonomics and biomechanics and offer comfortable and safe operation to users. Many operational problems were identified according to the literature discussion. Poor tool design is prone to cause cumulative damages and further influence operational performance. Literature data could only facilitate the understanding of key points and results of tool design rather than the opinions of users during operation. In order to make up for the lack of such data, this study employed semi-structured interviewing to interview relevant experts and collect relevant data for analysis. Besides, in combination with anatomy and physiology of human hands, this study investigated and analyzed the interviews with relevant experts, made correction, and hoped to speed up the design. In line with the research topic and purposes, interview outline was prepared before interviews. The interviewees were requested to answer questions according to the outline. And the actual answers of the interviewees were analyzed. Then, based on Human Factors and Ergonomics Theory and DFSS, this study identified the most suitable product model and operational method, designed the best anti-scald adjustment tool and method, and clarified steps and key points. The anti-scald temple adjustment tool was then examined and approved based on literature review and expert interviews so as to truly meet the demands of users.

Among different versions of DFSS, this study followed IDDOV proposed by Subir Chowdhury (2002) as its DFSS procedures, because Subir Chowdhury (2002) stressed the application and establishment of "concept" rather than the usage and limits of tools. Subir Chowdhury (2002) classified DFSS steps into two stages. The 1st stage aims to design the correct things. It includes the first two steps of "identity" and "define". Detailed tool design schedule shall be made. And opportunities shall be defined so as to guide future design. The 2nd stage is designated to design the correct things correctly. It covers the last three steps of "development", "optimize", and "verify". The final goal of this stage is to develop the tool which can meet the demands of customers and have the lowest failure rate.

This study proposed the interview outline based on literature discussion. It regarded tool functions, human engineering, and tool appearance as the main research dimensions. All the interview contents had been summarized as follows based on content analysis method:

1. The respondents said the rear ends of temples should be heated with a frame heater for the purpose of reshape and adjustment, when they adjusted the temples of frame glasses made of TR-90. Reshape could not be realized in case of inadequate heating. Eight respondents expressed that, they normally heated the frame with the frame heater and then bent the temples directly with their hands. If they fail to bend them, they would re-heat and re-bend. Other three respondents said that, as it required time and experience to heat and bend the temples, sometimes, the personnel of a glasses store only fastened the two front ends of the temples. Soon, consumers had to go to the store to readjust.
2. The respondents felt that such frame material was light and comfortable, and not easy to cause deformation. Such glasses became more and more in the frame glasses market. It was often that the temples did not match with the ears of consumers and were easy to fall off. The consumers had to visit glasses companies to have their frame glasses adjusted. All the respondents agreed that the fitness between the frame and ears was important. However, as it is necessary to heat the frame to 100℃, one may get burned. They were looking forward to an anti-scald adjustment tool.

The results of the interviews contributed to this study in the following two aspects:

1. Supporting the feasibility of this research topic and understanding the degree of fit between the inference on anti-scald adjustment tool and the actual situation;
2. Beneficial to propose design directions of adjustment tool.

According to the principle related to hands and gripping end of a tool obtained based on literature review and interviews, and the design principle of "accommodate tool to man" and "adjustable and anti-scald", the design with the best goodness-of-fit was obtained. The main results are described as follows:

1. The adjustment tool shall be gripped rather than pinched to avoid ulnar or radial deviation.
2. The design shall contain a gripping plate so that a user to exert force with his arms, wrists, and palm muscles to avoid mere reliance on the force of fingers and reduce fingertip soft tissue pressure.
3. The gripping end shall be longer than the palm width to provide better gripping, avoid tissue compression, and increase comfort.
4. Wood materials that are readily available in the market are selected. In consideration of different palm lengths, the grip length is set to 10cm, while the diameter, 2.5cm.
5. The length of gripping plate is set to 10cm (slightly smaller than the palm length) to avoid wrong actions like ulnar deviation (too much force on the front end of the plate) or radial deviation (too much force on the rear end of the plate).
6. One shall grip the plate naturally and keep his wrist straight (When the gripping plate is perpendicular to the horizontal plane, the angle between the forearms and the horizontal plane shall be 30degrees).
7. The weight of an adjustment tool shall not be more than 50g.
8. The angle between the gripping plate and the horizontal plane shall be maintained at 60 degrees. In other words, when the gripping plate is perpendicular to the desktop (push downward), the angle between the forearms and the horizontal plane shall be 30degrees, which is the best operational posture.

IV. DESIGN EXECUTION

After literature review, interview result analysis, and the confirmation of the above key points of design, this study set the design goals of tool in line with user demands, identified the key quality characteristics of anti-scald adjustment tool, and established measurable goals. According to DFSS procedures, it proposed the design methods for each stage. Then, it formally started tool development. The design steps are described below. And the results of DFSS development procedures are confirmed.

4.1 Identify

Grasping the status quo of problems and confirming targets of improvement. This study interviewed experts, investigated the demands of users of adjustment tool, learned the difference between the understanding of adjustment tool and anti-scald adjustment tool of users, and attempted to identify unique value of anti-scald adjustment tool. Based on interview conclusions and analysis results, the demands of users for adjustment tool and anti-scald adjustment tool are similar. But, they need and look forward to the anti-scald function. Hence, anti-scald adjustment tool shall not only be able to adjust frame glasses, but also have the practical value of being anti-scald, to meet user demands. Hence, the interview results are confirmed.

4.2 Define

When the step of "identify" is completed, the next is "define". The key point of this step is to convert the user demands identified to key points in design to facilitate designers to design and create products that users need. Through 4.1 Identify, this study confirmed user requirements for anti-scald adjustment tool. The next step is "define". The above analytical conclusions and the key points of product design served as reference for the quality characteristics of tool development. In addition to the compliance with user demands and anti-scald function, modeling and cost are also relevant factors. Modeling shall be used to give full play of the characteristics of adjustment tool, but cost shall also be considered. Therefore, importance shall be attached to the development of anti-scald adjustment tool which are both attractive to users and profitable.

4.3 Develop

The demands of users were transcripted into texts. Key functional and technical requirements were noted. The next step is "develop" the concept which could meet customer demands and have low failure rate. In other word, this step is about development and solution. At the beginning of the step of "develop", the conception of anti-scald adjustment tool was based on the conclusion of step 4.2. The requirements of users for anti-scald adjustment tool expressed during the interviews, and human engineering were considered as the development direction. Draft design of adjustment tool was made via brainstorming with the design team.

4.4 Optimize

After the above several steps, the next step is "optimize". It started from modeling and processing. When design was confirmed and modeling was created, the step of "produce" could be carried out. Then, the completed tool should be adjusted. After the most suitable modeling was confirmed, this study used the cutting machine to conduct experiment. The production procedures could be roughly classified into three steps. The 1st step was "construction of modeling" so that the cutting machine could start to produce the modeling. And the modeling should be adjusted and confirmed if it met the user demands in this study. The 2nd step was "production of finished products of adjustment tool". This step truly started to produce the tool. This step was based on the model and data in the above step. It aimed to produce the products with the best quality. The 3rd step was "correction of finished products". It aimed to correct the tool and complete the whole production process.

4.5 Verify

The last step is "verify". It aimed to ensure if the final results were in line with user demands and the purpose of development of adjustment tool. This study conducted trial production of adjustment tool in a small scale to verify the feasibility of tool production. Trial production could verify if the tool quality met the demands planned. After the plan, R&D, and design of adjustment tool, the last step, "verify", aimed to ensure that the key functions and quality of the tool comply with the standards set.

V. RESEARCH CONCLUSION AND SUGGESTIONS

This study collected information about the adjustment of temples of frame glasses and explored such adjustment. It proposed to design adjustment tool during exploration. And after actual operation, it finds that the design coupled with human engineering is safer. Such tool shall be anti-scald and can be gripped by four fingers (the thumb, the middle finger, the ring finger, and the little finger) to reduce palm pressure. The application of force does not rely on the gripping ability of the five fingers, but on the muscles between the thumb and the point finger so as to apply bigger force, reduce the burden of muscles of lower arm, and enhance certain operational performance. Meanwhile, it proves that the design principle of adjustment tool is effective. The results of this study are concluded as follows:

1. **Maintaining the neutral posture of wrists:**

Previous studies showed the possibility of wrist deviation and failure to operate in the neutral posture, resulting in discomfort of wrists. The tool design in this study follows the principle of maintaining the neutral posture of wrists. It is effective to reduce the load of muscles due to wrist deviation.

2. **Plane instead of dot:**

At the bottom of the tool, arc shape replaces cross section to disperse the pressure against palm.
Through DFSS-based commodity development procedures, the design method of adjustment tool can be presented in a digital manner. In this way, people of other fields can also understand the design process. And the studio has a stronger basis for product development. Such procedures can make some design tasks transparent. In accordance

with the framework and results of this study, the following suggestions and follow-up research directions are proposed as follows:

(1) Tool design

1. The structure of anti-scald adjustment tool in this study can still be improved. For instance, adjustable parts and available adjustments can be added. This researcher looks forward to adjustment tool which can be as flexible as real hands. Hence, the anti-scald adjustment tool can be re-designed and corrected.
2. Follow-up studies can consider ethnic groups, gender, and strong hand for design.
3. And more design examples of adjustment tool for frame glasses can be provided.
4. And actual test can be done to verify the effectiveness of the adjustment tool design.
5. The products to be designed now are based on anti-scald adjustment tool. The tool that requires hand operation like ear ruler, temples, and frame of nose can be simulated for correction.

(2) Research and analysis

This study adopted qualitative analysis method and did not conduct large-scale investigation. It only selected relevant professionals to conduct interviews. The content analysis and research findings only have partial validity. Follow-up researchers can adopt quantitative research method, or combine qualitative and quantitative research methods, to expand research dimensions and present more complete research results.

REFERENCES

[1]. Armstrong,T.J.(1986),Upper-extremity posture: Defition measurement and control,In: Corlett,N.ED.,Ergonomics of Working Posture,Taylor and Francis ,Philadelphia,PA. pp.59-73.

[2]. Ayoub,M.&LoPresti,P.(1971),The determination of an optimum size cylindrical handle by use of electromyography，Ergonomics,Vol.14, pp.509-518.

[3]. Bernard,H.(1988),ResearchMethods in Cultural Anthropology,NewburyPark,CA: Sage Publications.

[4]. Chang,H.S.(2006),Principles and Techniques to Find the Right Spectacle FrameChina Glasses Science-Technology Magazine. (9), 41-44.

[5]. Cushman WH; Rosenberg DJ (1991),Human,Factors In Product Design.

[6]. Eastman Kodak Company(1983),Ergonomic design for people at work (Belmont,CA:Lifetime Learning Publications),pp.140-159.

[7]. Fess, EE, Philips, CA.(1987),Hand Splinting: Principles and Methods. 2nd ed, St. Louis, Mo: Mosby.

[8]. Freivalds, Andris (1987) The ergonomics of tools, in Oborne, David J, ed, International Reviews of. Ergonomics, Taylor & Francis, London, pp. 43-75.

[9]. Neville Anthony Stanton,AlanHedge,KarelBrookhuis,EduardoSalas,Hal W. Hendrick(2004),Human Factors in Consumer Products.

[10]. Frederic H. Martini, David Seibel(1995),Human Anatomy.

[11]. Hsu,S.H.,Chen,Y.H.(1998),The Establishment of Ergonomic Design Guidelines on Non-Powered Hand Tools. Journal of Occupational Safety and Health, 6(1), 101-111.

[12]. Hsu,S.H.,Peng,Y.,Wu,S.P.(2000),Human factors in engineering and design (Vols. I & II). 2st ed., Taichung: Tsang Hai Publishing.

[13]. Huang,T.H.(1999),Influence of Gripping Posture and Object Weight on the Power of Gripping. Master's thesis, Chung Hua University.

[14]. Kuo, H.Y.(2001),Evaluating the Effects of Grip Span，Maximum Wrist Extension/Flexion，and Gloves on Grip Strength and Time Needed to Reach Different Levels of Exertion. Institute of Logistics Management, Defence Management College.

[15]. Lee, Z.L.(1996),On the Research Procedures of Human Engineering. Institute of Labor, Occupational Safety and Health, MOL. Extracted from Biman Das &Arijit K. Sengupta.

[16]. Silverman D.(1997),Interpreting Qualitative Data: Methods for Analyzing Talk, Text and Interaction. London: Sage.

[17]. Stöppelmann,G., Hoffmann, B., Hewel,M.(2008),GrilamidTR High-performance Polyamide Composition, European Patent Office Patent No.: EP2196494A1, EP2196494B1, Patent No. of State Intellectual Property Office of the P.R.C.: CN101746769A, CN101746769B, Patent No. of United States Patent and Trademark Office:US9290635, US20100159175, US20130164477.

[18]. SubirChowdhury(2002),Design for Six Sigma：The Revolutionary Process for Achieving Extraordinary Profits.

[19]. SubirChowdhury(2002),Design for Six Sigma：The Revolutionary Process for Achieving Extraordinary Profits (Financial Times Series).

[20]. Ting,H.Y.(2007),Influence of Selection and Adjustment of Frames on the Suitable Progressive Lenses. China Glasses Science-Technology Magazine, (9), 54-55.

[21]. Wan,W.L.(2004),Application of In-depth Interviews in Qualitative Research. Living Technology Education, 37(4), p17-23.

[22]. Wang,C.Y.(2008),Construction and evaluation on tool handle for Taiwanese, Master's thesis, Department of Industrial Design, National Yunlin University of Science and Technology.

[23]. Wang, M.T. (2003),The Spectacle, Taipei: Yi Hsien Publishing.

[24]. Wen, C.Y., Yang, G.S.(2000),Visiting Survey, Social Approach and Behavioural Science Approach (Vol. II) Social Approach and Behavioural Science Approach (Vol. II). Taipei: Dong Hua Books.

[25]. Wu, S.P. (1998),Human factors in engineering and design (Vol. II). McGraw-Hill Education

Chung Yi-Chan and Chen Chiung-Mei, "Development of an Anti-Scald Temple Adjustment Tool Based On Design for Six Sigma (DFSS)" International Journal of Business and Management Invention (IJBMI) , vol. 07, no. 03, 2018, pp. 51–56.