

Household Drill Innovative Design under the Guidance of Ergonomics

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ABSTRACT: The household drill is named 90 Degree, designed by Industrial Design Pilot Program Center (Hereinafter referred to as IDPPC) of Luxun Academy of Fine Arts (Hereinafter referred to as LAFA), which is the only national pilot program center in Chinese industrial design field. 90 Degree is designed for home environment, it helps inexperienced users, such as women and the elderly, complete the operation easily, and it makes sure that safe operation and assistance users solve the precise punching, location, storage trash and other operations. According to research among users who can understand or manipulate a drill, the designers find problems of users from the user central perspective, and then they integrate product innovative design methods to propose solutions. When the designers intend to design 90 Degree, they attempt using the user behavior record and analysis system, and start ergonomics study in subjects by double hands operation analysis, using gesture analysis, details of work analysis, time and motion study, etc; meanwhile taking advantages of user experience analysis, behavior intention analysis to do user subjective perceptual evaluation. The functions, structure, shape, color, material, details of 90 Degree should be consistent with the standard of usability evaluation. There are two characteristics in 90 Degree, the first one is a transparent cover installed in front of the drill, which can collect the dust, rubbish when drilling and keep the work environment clean. So it is applicable for households. When the transparent cover of the drill is removed, it also can be used as a normal hand drill; the second one is the shape of 90 Degree makes it and the operating surface fitting together, thus enhancing the stability in operation, so it is best for inexperienced users. When 90 Degree contacts with the operating surface, it can emit the laser ray which helps the user to punch accurately, and make array punch more easily. After obtaining the data, charts, creating Shadow observation by the designers, they make a comprehensive evaluation on research results; verification advantages of 90 Degree meet the requirement of usability, reducing operating failure rate; and increasing safety factors. 90 Degree, in 2011, won German Red Dot Design Award, which had become a representative excellent design example to resolve several drilling difficulties. The designers introduce ergonomics theory into design practice, and use scientific program and methods to evaluate the products which is useful to the development and promotion of products.

KEY WORDS: household drill; design innovation; value of ergonomics; behavior record and analysis method; usability evaluation

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90 Degree is a kind of portable drilling tool. With the emergence of DIY and personalization in family decoration, hand drill has become one of the necessary tools in lives. Many women, youth, the elderly become the users of it. When using the existing hand drill, the users need to wear rubber gloves, dustproof glasses, rubber cloth shoes and other equipment. During operation, the users need to pay attention to the rotating direction and angle of the hand drill. After the end of the process, the users could not touch the drill immediately, it would burn the skin; The users need to clean up the dust and miscellaneous debris generated in operation timely, to avoid them entering eyes or respiratory. In addition, due to improper operation, precautions omissions, lack of experience, the users always get injury and failure. To avoid such problems continue to occur, the design team of IDPPC (LAFA) used ergonomics theory and research methods designed a new type of

hand drill. Figure 1 shows the comparison between ordinary hand drill and 90 Degree.

Design features of 90 Degree are as follows. First, there is a transparent plastic cover in front of it, so the miscellaneous debris and dust generated during operation can be collected into it, which prevents dust and powder inhalation into eyes, nose or mouth, and makes the users no longer need to wear protective equipment. Second, the front of transparent plastic cover is close to the operating surface, which makes the drill and the operating surface forming a ninety degree angle, it can increase the operating stability and drilling accuracy, and it prevents drilling errors caused by incorrect operation. Third, the control button on top of 90 Degree could control using patterns, so it can be used as an ordinary hand drill without the transparent plastic cover; add the transparent plastic cover, the drill could be retractable. Fourth, 90 Degree can launch drilling ref-

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erence point on operating surface, it is easier to locate drilling and drilling arrays. Fifth, there is a scale on plastic transparent cover, which can assist drilling depth measurement.

1 Ergonomics experiment of 90 Degree

Due to the object of ergonomic experiment is hand drill, the designers apply the user behavior record and analysis system to the experiment^[1]. The human factors mainly including: human upper limb, double hands, eye vision, etc; the machine factors mainly including: function, structure, form, CMF, details, etc; environmental factors mainly including: family environment.

Steps of ergonomic experiment: the first step is setting the test content, and putting forward the test plans. The second step is inviting three groups of users which including: 5 novice (no using experience of hand drill); 5 knowledgeable users (using hand drill more than 10 times); 5 expert users (work on drilling exceed 2 years). 5 user test, proposed by Jay Nelson, could discover about 85% problems^[2]. In test, Nelson recommends to test repeatedly, if the budget could invite 15 users, the designers would test 5 persons for three times. The third step is setting up the required experimental simulation scene. The fourth step is arranging the experimental recorders and the experimental recording instruments. The fifth step is preparing the

prototype model of 90 Degree. The sixth step, in accordance with their own habits, the users complete several designated operating actions in a specified period of time, the recorder record them sequentially, and then finish the double hands operation analysis, using gesture analysis, details of work analysis, time and motion study. The seventh step, the users fill in the experimental questionnaire, collecting the experimental results and making data in tables and graphs. The eighth step is drawing the conclusion, carrying on the appraisal to the prototype model of 90 Degree.

1.1 Handle test of 90 Degree

Before the experiment, designers conducted multiple measurements of the user's hands, as shown in table 1, figure 1. In figure 2, keep users' hands in holding gesture, the designers measure the fingers maximum enclosed area, and then obtain the most comfortable area of the handle^[3]. Since the handle of 90 Degree frequent contacts with people in using, it adopts curve shape. The shape changes from rough to fine, which limits the holding area of the handle. In the experimental process, the designers used 3D printer to make central cross-section and prototype of the handle, test among the users, and they found whether the elements such as size, thickness, weight are suitable^[4]. So they adjusted the handle, printing and test for three times, making sure everything is comfortable, as shown in figure 3.

Tab.1 Hand measurement index

Research groups	Hand measurement Index/mm					
	Thumb length	Forefinger length	Middle finger length	Ring finger length	Palm length	Palm width
teenagers in 13~25 years of age	56.14±2.98	65.40±2.57	71.25±3.14	66.18±3.14	93.62±3.36	72.82±3.47
adults in 25~50 years of age	64.12±2.95	75.23±3.00	82.41±2.78	76.77±2.87	107.05±4.31	83.37±4.09
older people in more than 50 years of age	59.96±2.93	70.21±2.28	76.43±2.49	71.40±2.54	101.58±3.57	79.03±4.40



Fig.1 Comparison between ordinary hand drill and 90 Degree

When in operation, the user's palm will produce a certain action and reaction by holding the hand drill. Due to that the use of 90 Degree will produce vibration; the designers take into account the physiological factors, and have stress analysis of the palm. Long-term

(spend 1 hour for 4 ~ 5 days) using tool is easy to cause injuries of the palm, so the users need to avoid a sustained, high strength work. The designers test the best holding posture of the palm, the best holding angle of the wrist, the maximum intensity and scope of fingers. Through the handle shape and functional button location design minimized fatigue generated by the use of 90 Degree.

1.2 Positioning punch function test of 90 Degree

In order to test the function of 90 Degree is reasonable and effective, the designers used the 3D printer to make the proportional prototype model of it, as shown in figure 4, and they record the operations of the users. According to the scope of observation in ergonomics^[5]: the center sight of human eye is a benchmark, upward and downward 30 degrees is the best observing region, as shown in figure 5, the center sight is the best observing point, both sides gradually weakened. When using 90 Degree, coordinate ray launched by it, drilling depth scale on the transparent plastic cover, and drilling position, all of them need real-time observation, and it

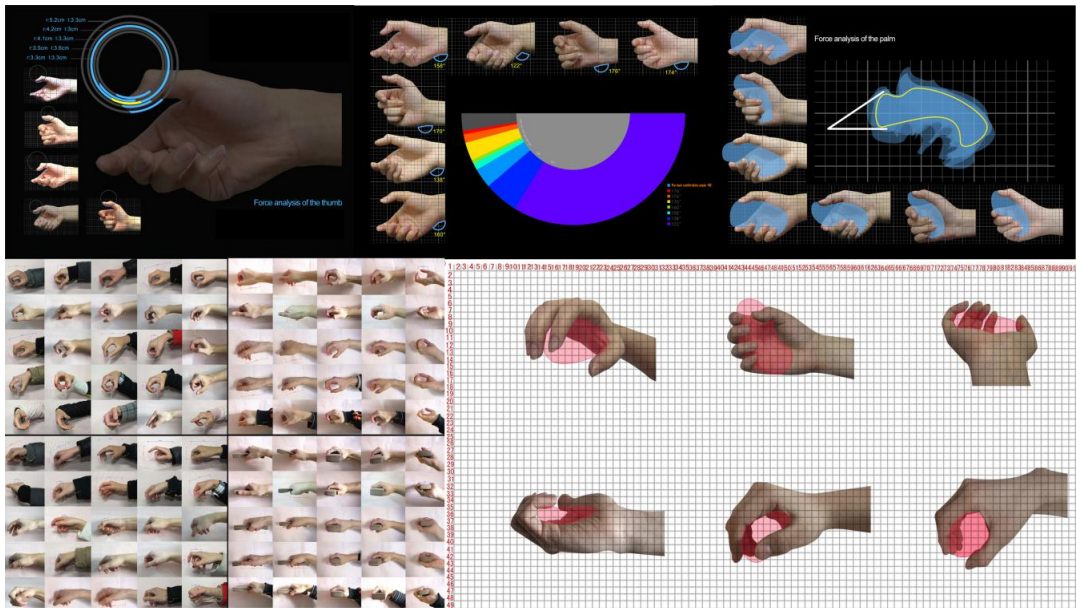


Fig.2 Hand force analysis chart

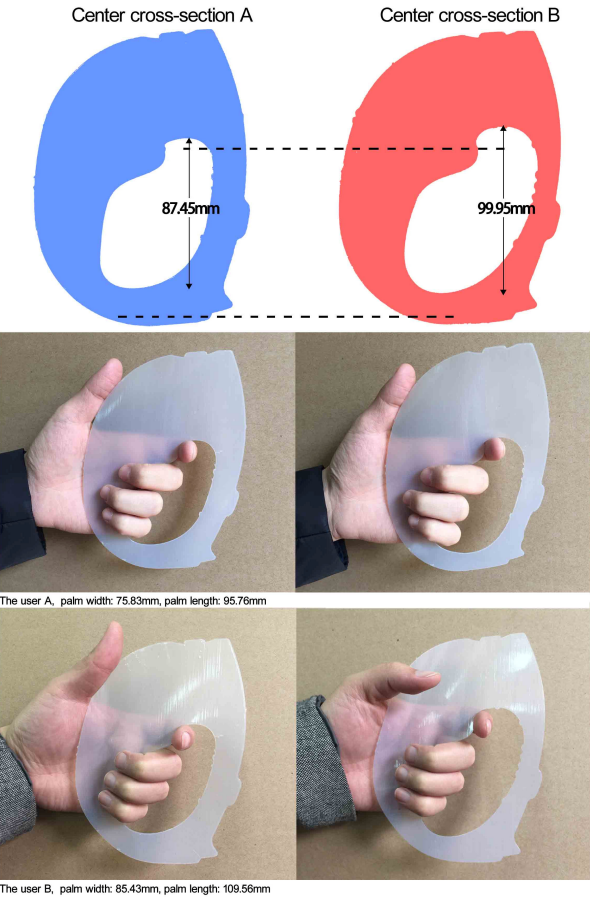


Fig.3 Central cross-section of 90 Degree's handle

is better to make sure they are within the best observing region.

Through drilling in different condition, the designers verify that coordinate ray launched by 90 Degree, drilling depth scale on the transparent plastic cover achieve the anticipated effect, they are convenient for observation and improve the drilling efficiency.



Fig.4 Proportional prototype model of 90 Degree

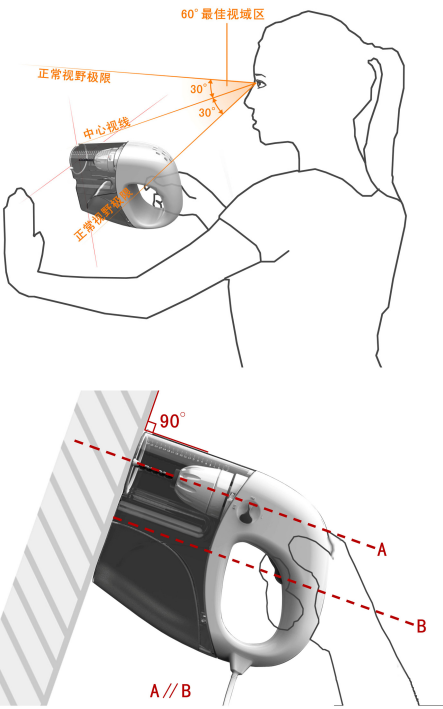


Fig.5 Best observing region analysis and operation angle analysis

1.3 Punch accuracy test of 90 Degree

Through the test records, the designers found that arm and palm frequently stress in the use of 90 Degree, which directly involved in the different operation. When operating, the direction of palm power is parallel to the direction of the drill, it is the most accurate and labor-saving operation, in order to ensure that they remains parallel attitude, and the contact surface of transparent plastic cover is flat.

Through the experiment, the contact surface of transparent plastic cover is closed to the operating surface, which makes the drill and the operating surface into a ninety degree angle. This design can effectively improve the drilling accuracy, and it complies with the principle of usability.

1.4 Users subjective factors research of 90 Degree

After the participants using 90 Degree, they need to fill in the questionnaires, the questionnaires should be researched based on the user experience and behavior intention^[6]. For example, "Question 1, what is your feeling when using the control buttons of 90 Degree: A. They are more comfortable and convenient. B. There is no difference between the former hand drills. C. They are not comfortable and do not comply with operation requirements"; "Question 3, the adjust button of 90 Degree is located in the middle of the top surface, do you think it will meet the operating requirements? A. Easy to operate. B. Not easy operation. C. Suggested settings

in other positions, such as ____"; "Question 6, what is your feeling about the overall shape of 90 Degree? A. It has the affinity and easy to accept. B. Beautiful shape is one of the purchasing factors. C. I prefer angular products. D. I only pay attention to the function and price"; "Question 8, in the use of 90 Degree, which part do you want to add some soft elastic materials, such as rubber, in order to increase comfort: A. inside the handle. B. Outside the handles. C. The buttons. D. The lower part of the transparent plastic cover. E. No require".

According to the questionnaire (as shown in figure 6), the experimental results with the data as a standard, the designers comprehensively evaluate whether the highest score option of each question is consistent with the design of 90 Degree, if there are objections, the designers need to be adjusted accordingly, and regard they as an important reference to deeply design^[7], as shown in figure 7. The question 3 summary 30 questionnaires and the conclusion: there are 10 people who choose A (Easy to operate); there are 3 people who choose B (Not easy operation); there are 2 people who choose C (Suggested settings in other positions, such as ____), one of them think that adjusting button location should be more close to the handle, the other people think that adjusting button position can be set in one side of 90 Degree. Through research on this question, the adjusting button complies with 83.3% users' demands, and the designers also found some new design possibilities.

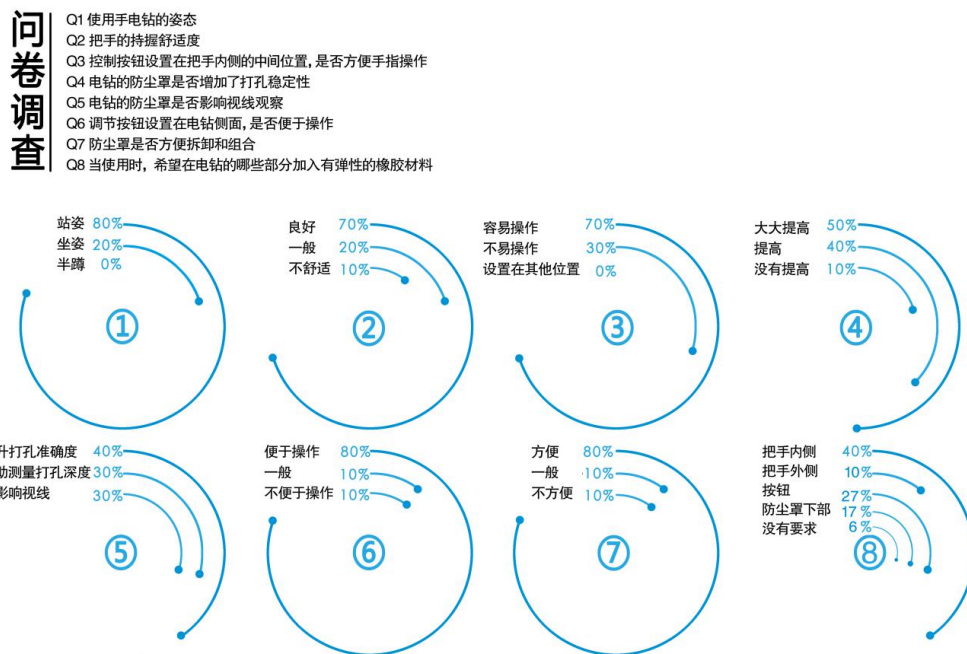


Fig.6 Questionnaires

2 Ergonomics valuation of 90 Degree

The experiment verifies the design innovation of 90 Degree can really improve the existing problems of hand drill, increases the operational safety, and improve work efficiency. At the same time, research and devel-

opment of it has value and effect in deeply level, which can be evaluated by the following aspects.

2.1 Guiding role of design innovation

The telescopic drill and the transparent plastic cover of 90 Degree creatively solves punch failure of

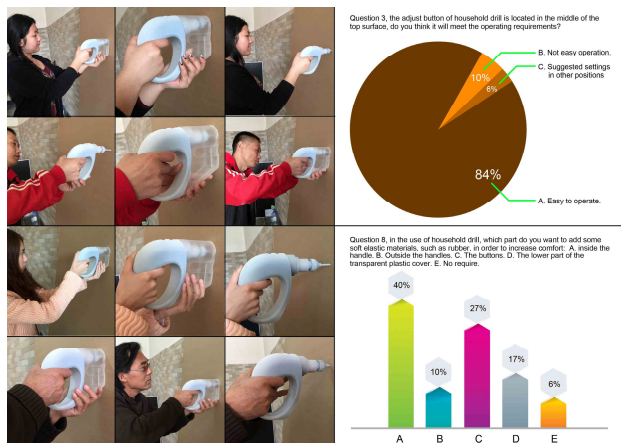


Fig.7 User behavior record and user's questionnaires analysis

ordinary hand drill. It complies with the requirements of ergonomics, and solves the problem of collecting dust, miscellaneous scraps. With the innovation of the hand drill's internal structure, 90 Degree will be transformed into real products, and it will become a classic case, to inspire and guide the hand drill's research and development. At the same time, 90 Degree's advantage lies in integrating a variety of practical functions. On the one hand, it is an effective way of innovation for designers; on the other hand, it provides more convenience to users. In addition, it is more competitive in the similar products.

2.2 Normative role of usage

Firstly, 90 Degree tries to provide a correct, safe mode of use. Through ergonomics experiment, it can reduce errors and the injury to the users. Secondly, operation with the transparent plastic cover could guide users to work in a accurate, safe, comfortable mode. It makes complicated work more simple and smooth, and it provides convenient conditions for people without operational experience. And finally, 90 Degree can play a positive role of encouraging the use, exercising ability, developing creativity, it could eliminate hidden dangers of hand drill, and it will convert the conventional passive using mode into positive, proactive, easy mode.

2.3 Optimizing role of user's environment

90 Degree provides a clean operating environment for the users. It avoids chaos and destruction in family environment caused by partial work with hand drill, or causing to some family facilities difficult to clean. At the same time, with the transparent plastic cover, users need not to wear the dustproof glasses, protective masks, rubber gloves, etc. So 90 Degree is more suitable for use in families.

2.4 Promoting role of social development

Each innovation of product design will have a cer-

tain role in promoting the progress of the society. A local innovation may bring the whole system upgrade^[8]. In the development of hand drill, from manual punch to electric tool assisted drilling, and then more and more advanced electric drilling tools appear, however, the aim of these products are always to reduce human errors, and improve work efficiency^[9]. Ergonomic knowledge has played an increasingly important role in product design and various sectors of production, so the people's production, living environment and social productive forces will continue to improve^[10].

3 Conclusion

The dissertation contains design practice and ergonomic test. The record of the test would give the designers the methods and inspiration of assessment. To assess a product, ergonomics is an important benchmark, it covers lots of subjects and knowledge, designers evaluate the product via human-machine- environment. Meanwhile, when reverse the design works, ergonomics also provides the standard of estimation.

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