

Research status and summary of treadmill design

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Abstract: With the continuous improvement of people's material living standards, more and more people begin to realize the importance of fitness. As a fitness product, treadmill could provide exercise conditions for people, and it has a good market prospect and development potential. This article summarizes the current research status and theoretical guidance of treadmill design through three major design factors: function, structure and modeling, to found out the problems and then proposed suggestions for improvement. Hope to provide guidance for future treadmill design research.

Keywords: treadmill design; function; structure; modeling

1. INTRODUCTION

The treadmill is a commonly used fitness equipment in the home and gym. It has the characteristics of safety, convenience, efficiency, simplicity and humanization, and it avoids the uncertainties brought by outdoor running, consequently, it is popular among the public. treadmills have been popular since the 1980s. From the first generation of mechanical running to the fourth generation of digital treadmills, all aspects during the process are gradually optimized. According to its characteristics, treadmills can be classified according to the using place, training function and driving system. Nowadays, the technology of electric treadmill has become the mainstream of the market [1]. Related literatures used electric treadmills as research objects in the study of treadmills. In order to respond to the changes in the market, and make a breakthrough in design of the treadmill. This article systematically analyses and summarizes the current situation of the design and application of electric treadmill from its function, structure, modeling and other design factors, and puts forward relevant suggestions to provide reference for future treadmills and related fields. And optimize the characteristics of the treadmill, making it safer, more durable, quieter, more energy-efficient, more stable.

2. FUNCTIONAL DESIGN ANALYSIS

According to the training function, treadmills can be divided into single-function treadmill and multi-function treadmill. The single-function treadmill is a treadmill that provides only running. With the development of urbanization and the continuous improvement of living standards, people are increasingly demanding treadmills, and it have evolved from a single running function to a multi-functional [2]. Yude Liu *et al* [3] optimized the design of multi-functional treadmill based on ergonomics. A removable multi-functional bracket was installed on the treadmill bracket, this multi-functional bracket come with three kinds of fitness equipment: dumbbell, sit-ups and vibration massager. Chengshi Zhu [4] designed and researched the multi-functional treadmill by optimizing the structure and adding the twist waist disc and sit-up structure on the treadmill. These two structures not only increase the function of the treadmill, but also make the physical exercise more comprehensive and accurate. Jun Zhang [5] uses the sensory association idea (SAM) to construct the product design creative process. In terms of function, the treadmill and the ladder can be combined according to the user's needs, not only can exercise and have the function of ascending the object. Through research and analysis, the above scholars have proved that the function could be determined according to the needs of consumers.

On the basis of adding subsidiary functions to treadmills, along with the development of the times, the definition of products by designers and users has evolved from the previous function-based development to the pursuit of interactive experience, form, function, technology and emotion. The coexistence of symbiosis and interaction in products will be an important trend in future product design [6]. There are two main ways of interaction between user and treadmill: hardware interaction and software interaction. The hardware interaction of treadmill usually refers to the interaction user directly with the machine or through the remote control. Software interaction is generally through the interface output of the treadmill to interact with users. The combination of functional design and computer programming can make running more effective and easy to control [7]. Therefore, some scholars have carried out in-depth research on treadmill and virtual reality technology, combining virtual reality technology with treadmill, using hardware and software to produce a high-lifelike three-dimensional virtual environment, and then users interact with the virtual environment with the necessary auxiliary equipment, The device interacts with the virtual environment to create a feeling and experience that seems to be in the real world [8-12].

Through the research results of the above shows that the domestic treadmill's technological innovation and emphasis on humanization are gradually increasing. However, with the number increase, it will bring problems in the convenience of operation. Therefore, the treadmill interface should conform to the user's reading order and operation habits, making the interface elements more reasonable, so that the interaction efficiency between the treadmill and the user can be improved [7].

Ling Yuan [13] Through research, it is shown that the size of distal finger is chosen as the basis of keystroke size design when gymnasts operate treadmill. In order to enable most people to use buttons conveniently and accurately, the width of the male's percentile finger should be chosen to design the size of keys, so the length of keys should be at least 16 mm. The spacing needs to be determined according to the size of the operation panel, and the spacing should be arranged reasonably without wasting resources, so that there will be no mistake.

Yuzhe Zhu [14] studied the human-machine interface of treadmill by combining the needs and usage characteristics of various users on the treadmill man-machine interface, and applied the eye tracking technology to the treadmill interface usability test. After research, it is pointed out that it is necessary to optimize and simplify the interface content, that is, to design the most commonly used function keys in the interface first, and to exclude the keys that not frequently used from the central of the interface. At the same time, it should optimize the layout order of the interface content, arrange the positions of keys according to the degree of need and frequency of use, and design the interface according to the visual habits from the visual center outward, from left to right, from top to bottom, and clockwise. And put the keys of related content together. The above results could provide a basis for future research. On this basis, combined with subjective and objective multi-dimensional usability evaluation method, some suggestions are put forward to improve the experimental results: (1) the display screen and button area are combined into one; (2) the running speed and volume functions could be distinguished by color, pattern and color; (3) visual design of running speed and volume; (4) increase physiological information display, so that the treadmill interface is optimized in more detail [15]. On the other hand, the color of treadmill keys should be adjusted appropriately according to the function and the use characteristics of different keys on the basis of determining the main color of keys [16]. Therefore, in order to design a natural and comfortable treadmill man-machine interface, it is necessary to follow the principles of accuracy, simplicity and layout. To sum up, the most important thing to define in the design and development of treadmills is product function. And in the function, the user first considers the basic function, then considers the product expansion function, performance function, entertainment function and other functional factors.

3. STRUCTURAL DESIGN AND ANALYSIS

In the structural design of treadmill, ergonomics theory plays a vital role. In order to achieve the coordination of "man-machine-environment", the structural design of treadmill is more reasonable and safer, users feel comfortable and the fitness effect is improved. Therefore, the positioning of product type, function, users and so on is closely related to the application of ergonomics. The design of functional size of treadmill should follow the use of most fitness practitioners. According to the use and operation needs of fitness practitioners, the size percentile is selected and combined with the functional correction amount and the psychological correction amount to determine the functional size of different use parts [16]. The main components of the electric treadmill are: frame, motor, motor cover, running belt, electronic display and armrest. Among them, the main parts of running mechanism about ergonomics theory are: running belt, armrest, main frame and electronic display. According to the research of relevant scholars, the humanized attributes of these treadmill components are analyzed.

3.1 Running Belt

Considering the user of different age groups, the size of running belt will directly affect people's fitness effect. Running belt is too small, which leads to limitations in running. Likewise, excessively large could also waste material and affect aesthetics.

Yuan Ling [13] found that the length of the running belt is closely related to the stride length and the choice of the crowd. Therefore, the length of running belt can be set between 1425mm—1540mm, taking into account the influence of environment and household accommodation. Width setting refers

to the basic size map of the male human body, which is based on the shoulder width of the male. Considering the change of winter sportswear, it is necessary to increase the physiological correction of the left and right sides by 10mm—30mm on the basis of the 95th percentile size of shoulder width to 49th percentile size 403mm—415mm. So the best width of the running belt is between 413mm and 445 mm. The thickness of the running belt is considered to meet the needs of most exercisers, so the thickness of the running belt is selected to be 3.1mm [17].

3.2 Handrails

The function of the handrail is mainly used to prevent accidents due to instability during running. The upper limb muscles can be exercised by supporting both arms when running and not running. Therefore, the height of the handrails should be set according to the elbow height when human standing. The height of the handrail is calculated according to the size of the elbow height of the standing position with 95 percentiles in the age group of 18-60 years in GB/T 10000. Taking into account the height of the base and the design allowance, the maximum height of the handrail for men is 1321 mm and that for women is 1248 mm. Therefore, the height of the handrail can be designed to be 1240 mm — 1325 mm adjustable. Users could adjust to their height to ensure a comfortable fitness experience [3].

The shape of treadmill handrail is mostly straight or curved. If use straight-pole handrails, when trainer running, because the height of the handrail is higher than the elbow of the trainer, the arm must be lifted up during use so that raise the muscles of the shoulders, back and hands, making people feel tired [18]. Therefore, the slightly curved shape should be adopted, when trainer hold the curved part during running, they don't have to raise the arm too high, which reduces the fatigue when lift the arm, so that the wrist can be kept smoothly and enter the relaxed state [19]. The research shows that the diameter should be set to 30mm—35 mm. The length of the handrail also affects the comfort of users. In order to ensure that most people can use it comfortably, the size of P98 should be taken as the design benchmark, and the length should be set to 160mm—180 mm[20].

3.3 Arrangement of Electronic Display

The position of the display is determined by the distance between the human eye and the display panel when using the machine[21]. People's vision should be perpendicular to the display so that people can watch more comfortably. According to the analysis of the optimum visual area of the human eye in the vertical visual area at 10 degrees below the horizon, the good visual area is from 10 degrees to 30 degrees. And considering that the exerciser will bow the head properly when looking at the display, the horizon will move down about 30°, so that the good visual area of the human eye will become -20°—-60°. the angle of the electronic display and the horizontal plane of 30 °—70 °. This is the maximum range, generally taking the middle range of 35°—50°, the visual effect is better [3] (Fig. 1).

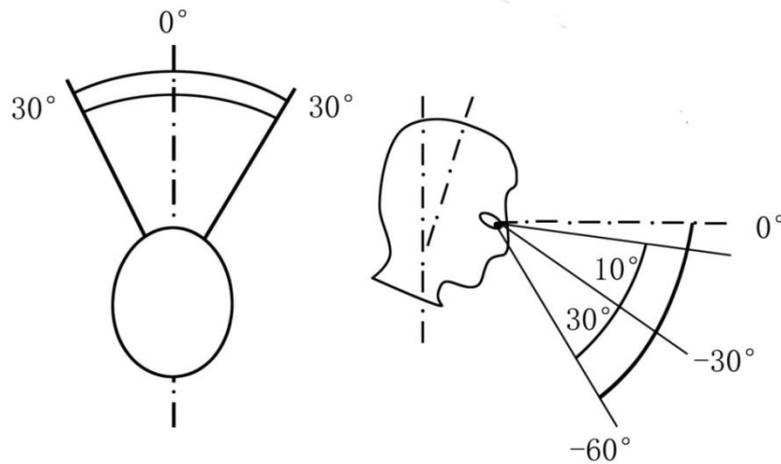


Fig. 1 Optimal visual field analysis diagram

3.4 Base Frame

The design of the base frame is the basis of the whole design. It is based on the dimensions of all aspects of human motion engineering, and is 45 cm x 130 cm. A sufficiently wide chassis is specially designed to provide two locations for another malfunction as an instantaneous motion. If there is an accident or a malfunction of the treadmill during running, people can quickly remove feet from the rotating drive belt and provide a safe position [22].

In the design of treadmill, the guidance of ergonomics theory is indispensable. Through good control in this area, the advantages of ergonomics can be better play, and higher value can be created in future work construction. At the same time, improving the combination form of optimized components can be explored from the user. Chungshing Wan et al [23] through interpret structural model (ISM), transform the drawing of the component, and theory of inventive problem solving (TRIZ) and design structure matrix (DSM) and interpretive structural model (ISM) were systematically integrated into the design of electric treadmills. This way can shorten the process of development of new product design, construct product varieties and make the structure conform to user's operating habits and facilitate the processing and manufacturing, and rationally arrange the components, because the shape of the components will affect the final realization of the treadmill, and at the same time enhance the product. The quality of the design leads to better innovation in product design [24].

4. APPEARANCE DESIGN ANALYSIS

In the highly competitive consumer market, consumers pay more attention to emotional needs than functionality and usability. In order to standing in the market, it is necessary to design products that conform to the psychological of consumers. As product homogeneity becomes more and more obvious, the similarity of functional technology has not been favored by consumers. Therefore, in order to solve the above problems, it should focus on the modeling aspect. Product modeling can reflect the material function and spiritual needs and it is an important part of treadmill design.

4.1 Colors

In the treadmill modeling design, color is a major factor. The perfect combination of color and product form could attract consumers to use and buy in the first time. When people observe products, the color perception of the product is higher than the shape of the product, and the color can convey people's personality and concept, and it can resonate with consumers. In product design, if want to have a sense of unity and harmony, it is necessary to unify the color with the function of the product, the environment, the object of use and other factors [25].

The main color of the treadmill mostly uses black, white and grey, which can reflect the treadmill's solid and strong and show the desire of users. And it also can be unified with the use environment. The side of the treadmill is mostly adorned with bright decorative lines, which adds a little sense of sport and fashion to the monotonous main color. The display is mostly determined by the main color of the treadmill, the reason is to coordinate with the overall style, it is necessary to maintain the same color system and avoid visual acuity. The overall use of color as far as possible in 3 to 5 kinds, too much will give people a messy and cheap feeling. The color of products has a profound impact on people's psychological feelings and emotional state when they view and use products, and also implies the way consumers use products and matters needing attention. Usually the emergency stop button is red, while the normal opening button is green [26]. In the display panel design, the font is clear and concise, the color should be compared with the panel color, so that users could operate easily.

4.2 Scale Design

On the basis of meeting the functional and technical requirements, the design of reasonable collocation and planning dimensions should be carried out. Proportion is the quantitative relationship between the whole and the part or the part and the part. The scale determines the proportional relationship between the product size and the human body size, so as to make the product and human physiological characteristics comfortable and safe. The correct order of modelling design should first determine the scale, and then determine and adjust the proportion of shape according to the scale. Different sizes and proportions also bring different experiences to consumers. From the existing treadmill products, it can see that the commercial treadmill is large, suitable for placing in the gym to give people a sense of stability. However, the home treadmill is slightly smaller, compared with the commercial treadmill is more portable and simple. Nowadays, some house treadmills have added folding function and reasonable utilization space. People can choose according to their own environment and personal needs. Designers should design treadmills in a variety of combinations without affecting treadmill functions and structures, so as to meet the shape characteristics required by consumers and have good performance.

4.3 Line Design

The treadmill line design can reflect the stylistic characteristics of the model. Line is the most emotional and expressive visual element in modelling design [27]. Linear selection needs to consider the characteristics of physical function, and people achieve physical and mental health through exercise. However, some scholars believe that the choice of line in treadmill design should adopt a lively flow curve to reflect the dynamic characteristics of the treadmill, while some scholars believe that the choice of line should reflect the characteristics of strength and speed. Therefore, the choice

of line should consider the psychological feelings of consumers. Every product has a fixed image characteristics in people's mind, while highlighting personality, it should not affect people's understanding of the product itself. Lines can be represented by the changes of contour lines, decorative lines and segmentation lines. Therefore, the location and direction of the line should be planned reasonably (Fig. 2).

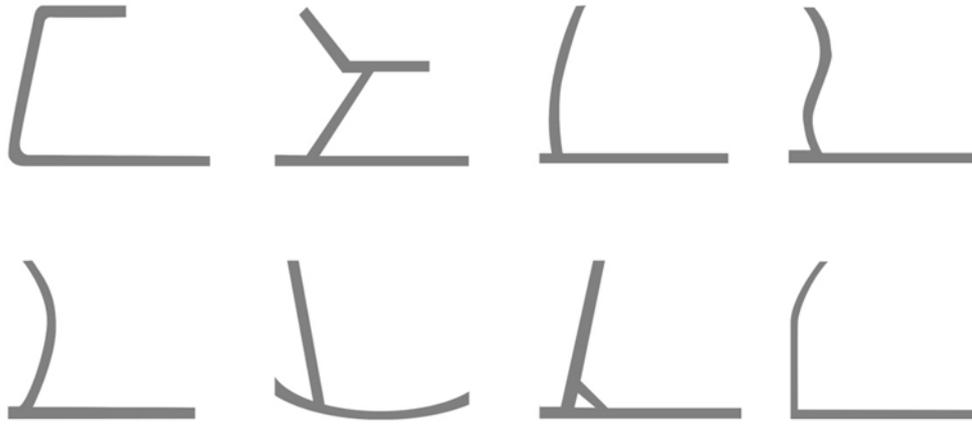


Fig. 2 Analysis of integral modeling lines

4.4 Material

Material is an important form of expression in treadmill design. The shape and structure of treadmill are indirectly affected by material characteristics and forming technology. And the development of materials has extent products with more perfect functions. The main frame of the treadmill fuselage and rack is made of high carbon steel, which can show a simple and sturdy material to show the sense of security. Handrail gloves are made of raw polyurethane PU, and the texture is soft and gives an intimate feeling. High friction and easy to use. When used on the armrest, the user can feel comfortable when grasping [28]. The motor cover and control panel are made of engineering plastics, and in technical aspects: the surface of main frame steel is treated with baking paint technology to make the texture elegant. Engineering plastics used in motor cover and display panel show smooth and delicate material characteristics [27].

5. SUMMARY AND PROSPECT

The above research summary shows that the treadmill, like other industrial products, has interdependence, mutual restriction and mutual penetration among the three elements of function, structure and shape. Domestic literatures on treadmills are mostly focused on functional exploration, technological improvement and innovation research, but lack of comprehensive attention to user groups. Therefore, more attention should be paid to the design of details and humanization in the research process. In addition to the above three factors, it should also analyze the factors of technology, service, marketing and consumers' psychological. It should use the method of combining subjective and objective to vectorize consumers' perception, find out their commonness and individuality to carry out in-depth research, so as to provide powerful support for the design and development of treadmills. Applying systematic and methodological design concepts to carry out new research and integration on these issues to make up for the shortcomings of domestic treadmill design theory.

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