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Research On Toilet Re-Design Based On Ergonomics

Yu, Sinan
School of Urban Design, Wuhan University
Corresponding Author: Yu, Sinan

----------ABSTRACT----------

With the application of ergonomic principles, this essay analyzes the structural problems in the existing toilets that cause irrational phenomena in postures and methods of use. To follow the assessment principles of products, which are "convenience", "comfort", "reliability", "value", "safety", "efficiency" and so on, the existing toilets are re-designed and a new design scheme is proposed. It is exhibited that in toilet design, the shape of the product will match with ergonomics perfectly only when the consideration is based on ergonomics. This means using psychology as the center, physiology as the radius, and the method that could build up a harmonious man-object (product) relationship, to maximize human potentials, to use human function comprehensively and evenly, to protect human health, and therefore to improve efficiency. Meanwhile, it also illustrates that a series of social and material factors, for example social development, technological improvement, the renewal of products, the quickened life pace and so on, call on people to focus more on the issue of humanized design, which is usually mentioned in product design, while they are enjoying the material life.

Keywords. Ergonomic Principles, Re-design, Universal Principle, Humanized Design

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I. INTRODUCTION

1.1 Ergonomics

Ergonomics is a newly-rising frontier science, which is originated in Europe, formed and developed in the United States. This term "ergonomics" was first coined by a Polish scholar Jastrzębowski. It is made up of two Greek roots, with "ergo" meaning "labor" or "work" and "nomics" meaning "rule" or "law". Therefore, the meaning of "ergonomics" is "laws of laboring" or "laws of working", which means this science studies regular issues about how people could use their energy reasonably and properly in the process of production or operation. In the US, "ergonomics" is called "human engineering" or "human factor engineering". In Japan, it is called "人机工学", or the transliteration of the European term "ergonomics" is used. Its transliteration in Russian is "Эргнотика". In China, various terms are in use, like "人类工程学", "人体工程学" (both literally "human engineering"), "工效学" (literally "science of efficiency"), "机器设备利用学" (literally "machine equipment utilization"),"人机工程学" (literally "human-machine engineering") , and so on. To help with the development of this discipline, it is necessary to unify the term, and most people call it "ergonomics" now. "Ergonomics" is specifically defined as methods that employ anthropometry, body mechanics, labor physiology, labor psychology and many other disciplines, using human-machine-environment system as the basic research subject, to study the structural and functional characteristics of human body, and to provide characteristic parameters of physical structure, for example the size, weight, body surface area, proportion, gravity center of various parts of human body, as well as the relationship and the approaching range of body parts in activity. It also provides characteristic parameters of human body function, for example the range of strength of body parts and the habit of an action. It analyzes functional characters of human's vision, audition, touch, skin sense and other sensory organs, as well as human's physiological changes, energy consumption, fatigue mechanism in different kinds of labor and human's adaptability to various labor loads. It explores factors that affect human's mental states in work and the effect of psychological factors on work efficiency. Also, it rationally distributes functions to humans and machines according to their conditions and characteristics, and help them adapt to each other, therefore to create a comfortable and safe working environment for people. It is a comprehensive discipline that optimize working efficiency（https://baike.baidu.com/item/人机工程学/3994）.

1.2 Re-design

In simple terms, it means to design something again. Its inner pursuit lies in returning to the start, re-examining the design around us, and exploring the essence of design in the most easily approachable way. Making something from nothing is surely creating, while changing something known to something strange is also creating. "Re-design" is design that aims to re-examine daily necessities that already exist, but not to improve the

original design with the hands of various excellent designers. Daily necessities are a group of mature designs that have gone through the test of time and been thoroughly refined. They are design objects that contemporary designers are very interested in but could not get extraordinary results in a short time. Apart from that, every design has a clear concept, and has quite obvious differences in ideas compared with the original design. It should be said that it is these differences that reflect the concept a designer is trying to express. Undoubtedly, this is the part that really deserves our attention. Therefore, the real purpose of re-design is to find out the meaning of design in these differences.

II. THE UNIVERSAL PRINCIPLES OF TOILET DESIGN

Universal design is a creative design activity of which the product design and the environmental consideration are for all users. Universal design is also known as design for all, inclusive design, or general design, which refers to products, environments and communications that can be used by everyone without any improvements or special designs. The meaning it conveys is that if it can be used by people with disabilities, it can be used by all people. The core idea of universal design is to treat everyone as individuals with different levels of disabilities, that is, people have limited abilities, people possess various abilities, and in different environments people have different abilities（https://baike.baidu.com/item/通用设计/1346349）.

The universal principles of toilet design include:

1). Cleanness. The flush toilet was invented after the primitive urinal. Its initial role is to collect feces and flush them away timely. In the meantime, this invention was rewarded as the beginning of private toileting mode. Since flush toilet was created, no matter aristocrats or common people have changed the bad habit of that time to relieve themselves anywhere and have behaved well on toileting. Also, the way to connect urinals to rivers directly, which had been passed for thousands of years, was gradually transformed to a cleaner process, that was to take it out of room afterwards. As something one must consider, toileting is closely related to “cleanness” from earliest times to the present day.

2). Comfort. The early toilet inclined more to solve users’ problems of collecting and storing feces and maintaining their own hygiene. Therefore, it did not have a tube connected to the outside to take and release water. The flushing device was composed of a large wooden storage tank with large capacity, which aimed to ensure the area that would touch skin when toileting should be clean. Also, due to the requirement of its flushing function and royal users’ strict demands for physical fitness, the toilet was designed to be stool-like, which could alleviate the stress on the knee joint when the middle-aged and old people squat in the lavatories.

3). Health. Modern toilet has employed some ergonomic concepts on the basis of traditional toilet, including the streamlined smooth outer case, which has greatly enhanced the comfort level for users, shortened the distance between the flushing tank and the main body of toilet, which helps users touch the button behind them more easily after relieving. In the meantime, a proper difference of water level between the tank and the main body has made the flushing force easier to be controlled and ensured that the spray will not be hit and then spatter on the users’ skin when flushing. Now, more and more people have realized that the traditional toileting way that seems comfortable and easy is actually threatening our health.

III. CASE STUDY

3.1. Traditional Squat-style

The most primitive way for human defecation is squatting, which prevents human from being polluted by feces, and this process of defecation saves more efforts. In the beginning, our ancestors relieved themselves on the flat ground, leaving feces everywhere which affected dwelling lives. Shortly after, feces pit appeared, which was used to limit the area for defecation so as to optimize the living environment.This kind of "squat toilet" tradition has been followed up to now, and it has become the most basic toilet style for modern people. Some public toilets and home toilets in the early cities used squat toilets.

The ergonomic principles of modern ordinary squat toilets are mainly based on the footstep size(Yuan, 2005) and the relative position of the squatting posture (Figure 1). When people use it, the knee joints bear most of the weight and struggle to keep body parts balance in coordination with calf muscles. Because of the continuous exerting of knees and calves, when using squat toilets, ordinary people usually feel the pain in legs is too severe for them to stand up, let alone old people who have difficulty getting about. Standing up too quick after squatting for a long time is likely to cause transient cerebral ischemia, and therefore lead to accidents like falls, fractures and so on.Error!

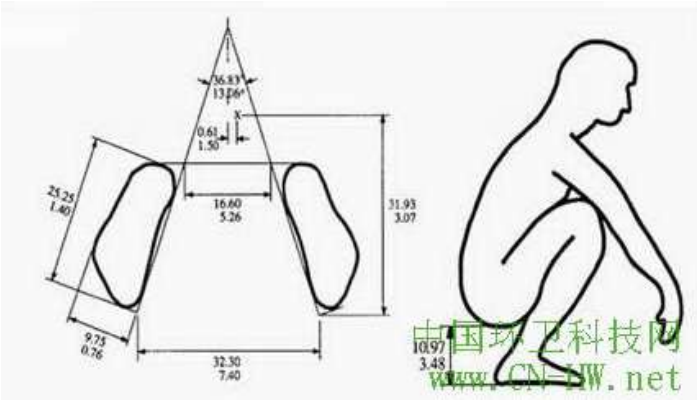


Fig.1. Foot size of squatting posture (www.cn-hw.net)

It is worth noticing that because people want as little tension on muscles or tissues as possible, knees cannot afford more efforts to maintain the pressing between calf muscles and thighs, and therefore calves and thighs must be pressed together to keep balance more easily. However, for people with strong calf muscles, calves and thighs cannot be together. So, their bodies will lean back, and the center of gravity will deviate backwards. They will have to lift their heels to adjust the center, which leads only the front parts of sole touch the ground and bear all the body weight. Maintaining this position for a long time also causes discomfort.

However, in the aspect of the physiological structure, squatting-style defecation conforms to the physiological structure, and defecating in this way is the smoothest. In a squatting posture, the anal muscles are the most relaxed, which can be explored from the aspect of the anorectal angle. There is a U-type puborectalis in human body. It starts from one side of the pubic bone, circles around the rectum, and connects to another side of the pubic bone, forming a ring which just pull the hook of the rectum, making it point to a forward angle. This is the anorectal angle (see Figure 2).

Texts in the picture: symphysis pubis (耻骨联合), rectum (直肠),coccyx (尾骨), the 80 degree angle of the rectum (perineum) located in the anorectal junction (80 度的直肠角（会阴曲）位于肛直肠连接处),puborectalis (耻骨直肠肌), anal canal wall (肛管壁).

Fig.2. Morphologic map of anorectal angle (Popularization of Medical Science)

In a squatting posture, the anorectal angle can reach 100° - 110° (see Figure 3). Theoretically, the greater the anorectal angle is, the more straight the rectum is, the smoother the defecation is. In addition, the squeezing of abdomen can also push defecation, reduce abdominal exerting, and partly relieve the symptoms of difficult defecation.

Fig. 3. Anorectal angle in a squatting posture (Popularization of Medical Science)

In a squatting posture, the straining force for defecation is small, while defecation straining is an important inducement for cardiovascular and cerebrovascular accidents. People who are at high risk of heart attack or stroke, apart from taking defecating pills, can also use squat toilets to reduce the effect of defecation straining, which is theoretically beneficial to prevent and treat accidents during defecation.

3.2. Traditional Sit-style

The origin of toilet can be traced back to ancient China. Toilet, formerly known as "huzi", was held by servants of the emperor, in case he would want to relieve himself at any time. When it came to the Tang Dynasty, to avoid a taboo, its name was changed to "mazi", later known as feces stool, faces pot, which is the predecessor of sit toilet. The ergonomic principles of sit toilet are based on the ergonomic size in a sitting posture(Chen, Shen, Guo, 2009). The toilet bears human's weight and the anorectal angle is about 80° - 90° (see Figure 4).

Fig. 4. Anorectal angle in a sitting posture (Popularization of Medical Science)

Therefore, people will feel more comfortable when defecating in a sitting posture than in a squatting posture, but it is more time- and energy-consuming. On the one hand, there is no trend of pressing between body and thighs in human's sitting posture, and the rectal muscle habitually hooks the rectum. No matter how the angle of upper body changes, the anorectal angle cannot be adjusted effectively, resulting in feces blocked in rectum by the rectal muscle. On the other hand, sitting on the toilet is comfortable, so we usually play cell phones, read books or newspapers while defecating, which prolongs the defecation time. Reading while defecating will distract the attention of the brain, and therefore the signals that gastrointestinal peristalsis brings to the brain will be weakened. In the long run, this may cause constipation. However, doctors suggest that old people should use sit toilets. This means that a house is best equipped with two types of toilet facilities, squat and sit, to meet the daily needs of all family members.

3.3. Improve style

When people are using squat toilets, their feet are parallel to the toilet, therefore the body weight relies on nothing and is all bore by knees, calves, ankles and soles. The method that raises feet directly is to use the toilet to release the soles, and in the meantime, raising soles will not give more body weight to legs and knees. People are actually sitting directly on the toilet when squatting. The body movements basically stay unchanged.

Fig. 5. Picture display (Medical Atlas)

According to the measurement and integration of footstep movements and sizes when people squat down, a footstool with corresponding height, size and angle to adapt to human posture has been designed (see Figure 5). This design (Figure 6) is a chair-shaped platform, with an arc gap in the middle to fill in the base of toilet. The position size design of pedals on both sides follows the average design principles and aims at people of all age groups. It can easily and skillfully solve unsmooth defecation and relevant health issues when people are using sit toilets(Zhou,2001).

Fig. 6. Finished product picture of footstool (product picture from Taobao)

However, with further research, a new problem has been found. This design actually cannot solve the defecation problem effectively when people are using sit toilets -- the anorectal angle is not directly determined by the height difference between the hip and the soles. There is a pressing force between the upper body and thighs of the person squatting, that is the pressure of the abdomen. It is the key to the relaxation of the U-type puborectalis. However, people who use footstools have their body weight borne by toilets, which bring an upward force for the hip. Therefore, there is no pressing force between the upper body and thighs, and the U-type puborectalis is still in a state of tension. This method cannot effectively solve the human's problems of defecating in a sitting posture.

IV. TOILET RE-DESIGN

Although using what defecation posture is more of a question about personal choice, it is hard to tell which one is healthier. However, the author think that sit toilets can be more humanized and fitter with ergonomic principles with slight modifying. Since the anorectal angle affects the level of muscle straining which is the fundamental reason that determines whether a defecation method is healthy, the main direction of this reforming research is on changing the anorectal angle during sitting. This time, the re-design of toilet, or how to change the anorectal angle, is considered as the central issue(Ding,2005).

4.1 Source of Idea

First of all, the solution starts from the aspect of posture: how to effectively ensure the pressure between the upper body and thighs? The W Chair (Figure 7) designed and developed by a German design team W team has inspired me.

Fig. 7. Using effect graph (product picture from Taobao)

Figure 8. Finished product picture (webpage from Taobao)

At first glance, the style of W Chair makes many people think it is not a so-called chair in our cognitive range. The seat of the chair is slightly tilted, with two warped shapes that can be used to support legs and knees (see Figure 8). When people sit on it, it allows them to maintain an upright and natural sitting posture in a very natural way. Bowing or bending down to operate a computer will make you feel very uncomfortable. The author decided to use the chair's warped shapes for reference as the load-bearing device for the new type of toilet, making the effect of "pressure between the upper body and thighs".

4.2 Creative Scheme

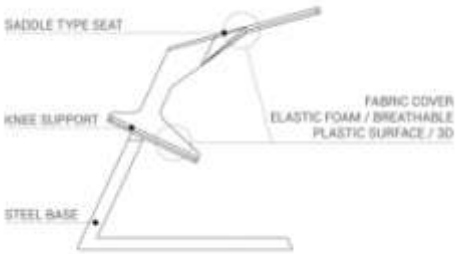
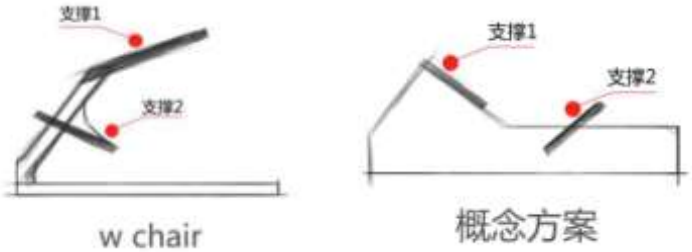


Fig. 9. Working principles of the chair (Product exhibition on the official website)



Texts in pictures: brace 1 (支撑 1), brace 2 (支撑 2), conceptual scheme (概念方案).

Figure 10. The convention of working principles (drawn by the author)

This re-designed sit toilet moves the original seat of the chair to the bottom as the foot pedal (see Figure 9, Figure 10), achieving the requirement of comfort without changing the number of load-bearing units. In the meantime, angles and sizes of two types of pedals have been designed according to sizes of a human body in a

squatting posture (see Figure 11). Thus, the removal of the support to hip could ensure the acting force between the upper body and legs, achieving the effect that entirely change the anorectal angle. Also, according to previous researches, to set the pit in the back-end could effectively enhance the comfort and satisfaction level of user experience(Yan,1998).

Texts in the picture: pressing between the upper body and thighs (上半身与大腿挤压), brace 1 (支撑 1), brace 2 (支撑 2).

Fig. 11. The simulation of human action (drawn by the author)

V. Conclusion

Social development, technological improvement, the renewal of products, the quickened life pace and many other social and material factors, have led people to pay more attention to assessments on "convenience", "comfort", "reliability", "value", "safety", "efficiency" and so on, which are issues about humanized design that is frequently mentioned in product design. while they are enjoying material lives. Toilets are widely used in family lives, but some aspects that does not follow ergonomic principles can still be found. There is still a distance between them and the ideal models that can protect human health, including the aspect of forming the anorectal angle. Therefore, as a designer, based on a careful study on characteristics of three elements human, machine, environment, I should not simply focus on whether an individual element is good or bad, but see the human who will use the "object", the designed "object", and the environment where both human and "object" exist, as a system to study and consider, and therefore to design products that are more humanized.

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