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Design of folding bicycle based on ergonomics

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Abstract: The development of bicycles did not stop because of the emergence of motor vehicles. Folding bicycles have special folding functions and are increasingly favored by consumers. In this paper, the design problem of folding bicycle is studied, and a design scheme of folding bicycle based on ergonomics is proposed. Firstly, the ergonomics theory applied to the design of folding bicycles is introduced. Then, a human-vehicle system was established to analyze the relationship between the human body and the guidance system, the drive system and the support parts. Finally, based on the results of human-machine analysis, the saddle, handlebar and crank of the folding bicycle were designed.

Keywords Folding bicycle; Ergonomics; Guidance system; Drive system; Support part

INTRODUCTION

With the improvement of people's quality of life, people's awareness of health and environmental protection is gradually strengthening. In recent years, the sales of bicycles have not decreased due to the increase in other vehicles such as automobiles or electric vehicles [C Orsi *et al.*, 2017]. In daily life, bicycles, which are commonly used as means of transportation, have their own irreplaceability compared to vehicles such as automobiles or electric vehicles. Due to the concept of efficient use of space, higher requirements are placed on the bicycle form. People often need to change to different modes of transportation when traveling, and the location of vehicles parked in the city is obviously insufficient. Therefore, the folding function of the folding bicycle makes it a highly competitive product [Roh, Jongryun *et al.*, 2018].

The ordinary folding bike consists of two parts: the frame folding joint and the riser folding joint [G J Edgar *et al.*, 2016]. After folding, the two wheels will fold together and the length will be reduced by about 45% compared to before folding. The folded bike can be placed directly into the trunk of the car or placed in a boarding or folding bag. There is no need to use other tools during the folding process of the bicycle. The bicycle can be folded and unfolded by hand alone or folded by itself.

Whether the folding bicycle products can be operated efficiently and conveniently will directly affect the efficiency and safety of people when they travel [Wu Jing *et al.*, 2018]. Since the folding bicycle is significantly different from the ordinary bicycle, the man-machine system design of the folding bicycle is very demanding. This paper presents a design scheme for folding bicycles based on ergonomics. First of all, the relevant theoretical knowledge in ergonomics is analyzed. In the design of folding bicycles, it is necessary to analyze the human-machine factors of bicycles from the aspects of folding form and riding form. Then, the advantages and disadvantages of different folding forms are analyzed. Finally, the size and positional relationship of the various components of the folding bicycle body is summarized based on anthropometry.

ERGONOMICS THEORY

Ergonomics is mainly a discipline that studies the relationship between people, machinery, and the environment [Morag, I. *et al.*, 2018]. The discipline integrates a variety of related discipline theories and methods in research. Ergonomics is a comprehensive discipline involving a wide range of content and use. Ergonomics can provide scientific data about people for the design of products and environments. Based on ergonomics, the best coordination between people, machinery and environment can be achieved, so that the entire system can operate efficiently.

Characteristics of human force

Ergonomics analyzes human body data models from static and dynamic dimensions of the human body. In order to analyze the changes of human labor adaptability and work efficiency, it is necessary to study the human body information processing methods, fatigue mechanism and psychological reflection. Through ergonomics, industrial design can be made to meet the needs of people [AM Nieuwesteeg *et al.*, 2016].

In the industrial design process, in order to meet the requirements of ease of use and suitability, it is necessary to measure the human body. The measurement content is divided into static measurement and dynamic measurement. Static measurement mainly measures the size of various parts of the human body at rest, including height, sitting height, and high hand function. The content of dynamic measurement is the range of physical activity of the human body in different postures.

The force of the human body is caused by muscle contraction. The size of the force is related to the strength of the muscle tissue and the direction of the force applied, the posture of the force applied, and the way the force is applied. For example, the thrust of the arm changes in the standing position as the angle of the arm and the body changes. The maximum thrust is generated when the arm is raised above the head. In the sitting position, the leg force varies with the angle of the leg. The arrangement of the leg force in Figure 1 is C>B>A.

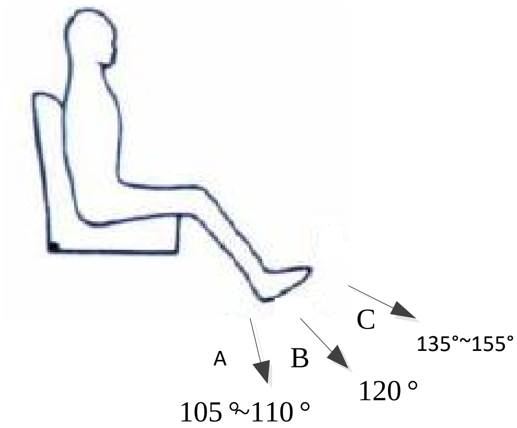

Figure 1. Schematic diagram of leg force during sitting posture

Human activity is bound by muscles and ligaments, so the body must have a range of activities. Because the force applied at different positions of the muscle is different, there is a relatively labor-saving comfort zone. Therefore, reasonable force is one of the industrial product design goals.

Human-computer interaction in folding bicycle

The folding bike saves storage space due to the folding function [Mattson Markp *et al.*, 2012]. The deformation of the folding body causes the bicycle to exhibit two forms in life, namely, a folding shape and a riding form. Therefore, the design of the folding bicycle requires an analysis of the human factors of the two forms. According to the use of bicycles in different forms, the design plan is drawn up.

During the entire folding bike ride, the riding action drives most of the muscles in the body. Cycling is also considered a fitness program. For this type of performance-oriented exercise, the consideration of ergonomics of the vehicle is particularly important. The positional design of the entire folding bicycle body structure, especially the contact position with the human body, should be based on the measurement data in the ergonomics.

During the riding process, the body muscles are in different states of exertion. The body parts that are applied at rest are mainly the forearm, upper arm, shoulder, back and waist. According to the characteristics of human body force, the static part of the force should avoid the body part in an uncomfortable angle, so as not to accelerate muscle fatigue. In the state of exercise, the leg muscles are dynamically applied. At this time, the main way to apply force is pedaling. It is necessary to analyze the relationship between the force-applying characteristics of the different postures of the human body and the position of the pedals, thereby improving the comfort of the folding bicycle when riding.

Figure 2. Cycling posture

CYCLING POSTURE HUMAN -MACHINE ANALYSIS

After the folding bicycle body structure and folding mode are selected, the human factors of the bicycle riding pattern need to be analyzed in detail. Firstly, based on anthropometric and human motion characteristics, how to improve the comfort of the human body during riding. Then, based on the analysis results, the size and spatial interaction of the various components of the bicycle are confirmed.

Guidance system

The body guide is operated by the arm. A key consideration in this part of the analysis is the determination of the handlebar width based on anthropometric data. The handlebar and saddle affect the upper body posture of the human body. The distance between them depends on the force applied to the back and arm muscles during riding. In addition, the main function of the handlebar is the guide, and the angle of the front fork of the handlebar affects the convenience of the rotation of the front wheel.

Drive System

The main transmission method for folding bicycles is chain drive. In addition, some folding bicycles use gear shaft transmission, electric drive, and the like. The transmission mode affects the transmission efficiency. The gear shaft drive increases the feel of the car body, but the transmission effect is not as good as the chain. And the gear shaft drive cannot be effectively shifted. The electric drive generates motion power through the rotation of the ankle to reduce the body power output. Power transmission is more convenient, but the weight of the car body increases significantly. The rotation of the crank sprocket is to transfer the flat power into a rotational force, which can increase the continuity of the power output.

Supporting part

The frame requires corresponding strength and stiffness as it is the skeleton that supports the entire body. The frame is also an embodiment of the overall shape of the car. The saddle bears most of the weight of the human body, and its contact with the buttocks affects the comfort of the human body. The saddle size should depend on the body's hip structure and riding posture. The positional relationship between the saddle and the handlebar affects the upper body posture. The position of the saddle and ankle affects the working space of the lower body. The operation triangle composed of the saddle and the handlebar and the ankle is the key to the design of the positional relationship between the human body and the vehicle body.

FOLDING BICYCLE DESIGN

Structural analysis

The saddle is a decisive factor in the bicycle riding posture because it is an important link to the operating triangle. The position of the handlebars and ankles depends on the position of the saddle. The height of the saddle affects the efficiency of the ride. A large number of statistics show that too low a saddle will reduce riding efficiency. This is because the saddle affects the period of motion of the legs. Therefore, the height of the saddle should be set according to the height of the human perineum.

The handlebar is the control part of the bicycle guidance system. The guiding system has a great influence on the comfort of riding. As the human body leans forward while riding, the arm will share part of the weight. This part of the weight requires the handlebar support. The height and width of the handlebar affect the force on the arm muscles. Too low a handlebar can cause pressure on the nerves of the hand, which can easily cause muscle paralysis. The difference between the height of the handlebar and the height of the saddle is the determining factor of the body's upper body posture. The width of the handlebar affects steering efficiency. The wider the handlebar is turned, the better. Due to the size of the human body, the width of the handlebar should be set according to the width of the human shoulder. Usually, the maximum shoulder width of the human body is considered to be 431 mm. The actual handlebar width should be greater than this value.

The crank and the center shaft and the ankle constitute a bicycle drive unit. The mode of movement of the three determines the sustainability of the driving force and the periodicity of the human body. The longer the crank, the easier it is to apply force. The positional relationship between the center axis and the saddle affects the space in which the lower body moves. According to the comfort characteristics of the human body, the seat and the central axis should have a certain distance in the horizontal direction. The length of the sitting tube affects the range of leg movement. The length of the sitting tube needs to be designed according to the size of the leg measurement, the comfort range of the knee joint, and the length of the crank.

Design result

After the ergonomic analysis of the above-mentioned folding bicycle, we have a clear understanding of the dimensions and positional relationship of the components of the folding bicycle body. The ergonomic folding bike design is as follows. The height of the saddle is 109% of the height of the human perineum. The value is usually 798-861mm. The handlebar height is 858-951mm. The handlebar width is 500-625mm. The distance between the handlebar and the saddle is 583-632mm. The distance between the center shaft and the saddle is 637-688mm. The center axis inclination is 62° - 75° . The crank length is 150-185mm.

CONCLUSION

Folding bicycles have become a modern means of transportation. Folding bicycles bring great help to people's life travel, but also bring more thinking on the design of the car body. In the design process of the folding bicycle, factors such as the comfort of the car body, the rationality of the space for folding, the convenience of retracting and the like must be taken into account. This paper presents a design scheme for folding bicycles based on ergonomics. This design can significantly improve the ride comfort of the rider.

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