ISSN: 2414-1895 DOI: 10.6919/ICJE.202006_6(6).0043

Overall Scheme Design of Wearable Lower Limb Exoskeleton

Hongbing Wang[1, a], Jinyu Ren[2, b], Cong Liu[2]

[1]People's Hospital of Changzhi, Changzhi, Shanxi, China;

[2]Wuhan Technical College of Communications, Wuhan, Hubei, China.

[a]405157585@qq.com, [b]308810953@qq.com

Abstract

Exoskeleton can solve the problem that traditional unmanned equipment can not adapt to complex environment. It combines the agility of human body movement with the power endurance of the machine to improve the efficiency of field workers. Consult relevant domestic and foreign research literature and data, and summarize the characteristics of exoskeleton design and the problems that need to be solved. As a sports-assisted exoskeleton device, it should have the ability to quickly follow the movement of the human body, as well as the ability to provide auxiliary power to the human body without changing the movement state of the human body. The biomechanical model and kinematics model of the human lower extremity are analyzed, and the movement law of the human lower extremity is obtained. The design requirements of the exoskeleton robot are given through analysis and discussion. reference.

Keywords

Exoskeleton; Mechanical model; Kinematic model.

1. Introduction

A wearable exoskeleton robot, also known as a power-assisted machine, is a power-assisted robot that can increase the load-bearing capacity of the user, provide auxiliary power, and help it support the ground. It is a wearable smart device. As a hot research field, wearable exoskeleton robots have developed rapidly in recent years, and already have different types of exoskeletons for different work fields. Now outside

The application fields of skeletal robots are: military, medical and civilian. The lower extremity exoskeleton has a total of 3 joint components: hip joint, knee joint and ankle joint. The movement and force of each joint can affect the human body. This article will design the overall scheme of the exoskeleton for the lower limbs of the human body.

2. Human gait analysis

We usually call a healthy adult the most comfortable and comfortable walking posture called human gait. He is the most basic movement state of the adult body. The movement time between the heel of one side of the human lower extremity touching the ground and the next time the heel of the same side contacts the ground is called a gait cycle. We call the process that one heel touches the ground until the toes leave the ground as the support phase, which takes about 3/5 of the entire cycle; the process that one side toe leaves the ground until the same heel touches the ground is called the swing term, which takes about 2 / 5.

International Core Journal of Engineering
Volume 6 Issue 6, 2020
ISSN: 2414-1895
DOI: 10.6919/ICJE.202006_6(6).0043

3. Biomechanics model and kinematics analysis of joints of human lower limbs

3.1 Analysis of human lower limb biomechanical model

Usually, when researching the movement of human joints, the basic reference frame of the human body should be studied. The reference system commonly used in medical research and physical education is shown in Figure 1. The entire reference system is composed of three axes: the missing axis, the coronal axis, and the vertical axis. It also has three planes: coronal, sagittal, and transverse. The movement forms of various joints of the human body can be roughly divided into three types: flexion and extension, extension and rotation. As shown in Figure 3, there are many joints involved in the movement of the human lower limbs, and most of them

The number is a multi-degree-of-freedom joint. There are some motionless or immobile joints in some parts of the lower limbs during design. These joints have only a small amount of adjustment function, so only the hip, knee and ankle joints are considered in the simplified design of the exoskeleton.

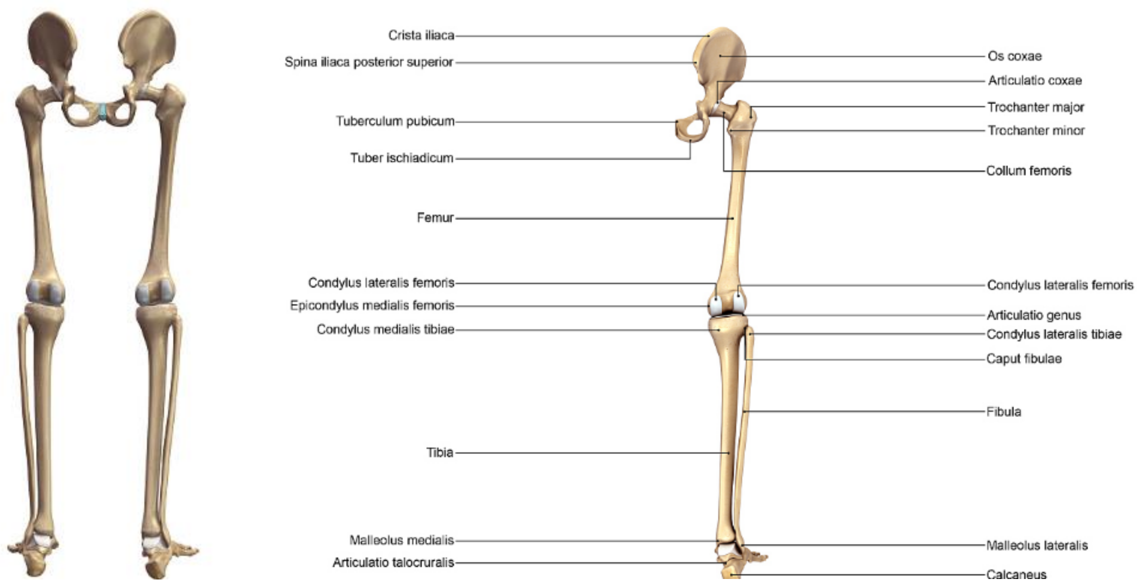

Figure 1. The reference system of human lower limb biomechanical model

3.2 Kinematic analysis of human lower limbs

The lower limbs of the human body have different forms of movement, most of which are mainly serial and parallel hybrid rotating structures, which can show different forms of movement in mechanism. When designing the exoskeleton mechanism, the kinematics of the human lower extremity should be considered in detail so that the exoskeleton

The structure also has the characteristics of the complex and precise mechanism of the human lower limbs (see Figure 2). Through the analysis of the skeletal mechanism of the human lower limbs, the hip joint and the ankle joint can be regarded as the ball joint mechanism with 3 degrees of freedom, and the knee joint can be regarded as the rotation joint mechanism with only 1 degree of freedom. The bones of the lower limbs are connected to the pelvis of the waist to form a kinematic chain of both lower limbs. The simplified skeleton configuration of the lower limbs is shown in Figure 5. Through the analysis of relevant data of ergonomics, we can get the approximate ratio of height and bones of normal young men in China. According to the ratio, the relative size of the joint centers of the human body can be obtained, so as to determine the size parameters between the connecting rods and pairs of the exoskeleton (see Figure 3), where: L0 = 0.039 H; L1 = 0.246 H; L2 = 0.245 H; lL3 = 0.191 H.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202006_6(6).0043

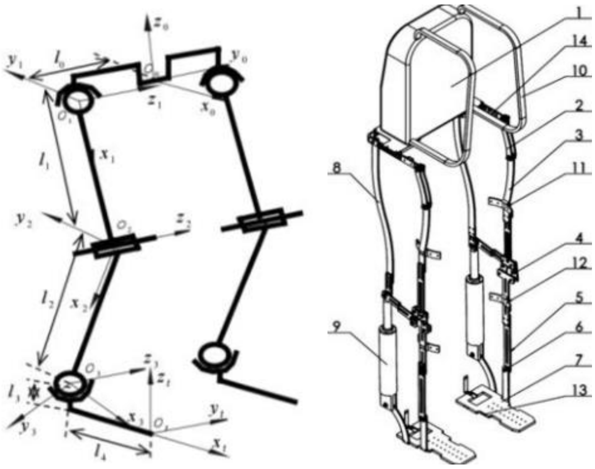

Figure 2. The characteristics of the complex and precise mechanism of the human lower limbs

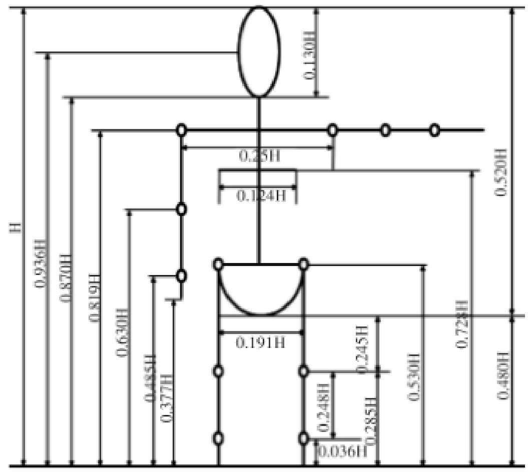

Figure 3. The size parameters between the connecting rods and pairs of the exoskeleton

4. Structural design of the exoskeleton ankle drive system

4.1 Design requirements for exoskeleton structure

Exoskeleton robot is a typical human-machine combination device, which needs to have good comfort and stability to ensure good efficiency of human-machine cooperation. The specific design requirements are as follows.

4.1.1 Design requirements for exoskeleton anthropomorphism

The anthropomorphic design of each joint of the exoskeleton is the premise that the joint mechanism of the exoskeleton is comfortable to wear and is consistent with the human motion function. According to the position of each joint of the human body, the position of the joint freedom is arranged as accurately as possible, and the reasonable alternative structure of the sports pair is designed; for the human body The characteristics of the lower limbs, the design of a reasonable restraint mechanism, and the size of the wearing part is adjustable.

4.1.2 Requirements for adaptability of exoskeleton man-machine motion

During the movement of the human body, the relative position of the device and the human body may be shifted. Therefore, some mechanisms need to be designed to adapt to the change in the relative position of the human machine during the movement of the human body. A certain space is self-adjusting for the human body. Such a space will cause a certain deviation of the man-machine during the movement. The key to ensuring adaptability is to design a reasonable space position for the device and the human body, and choose a more adaptable man-machine connection method. Or design an adjustment mechanism or in the structural body or in the drive system to adapt to the changes in the

ISSN: 2414-1895 DOI: 10.6919/ICJE.202006_6(6).0043

muscles of the lower leg driven by the flexion and extension of the foot to realize the self-adjustment of the positions of the joint components of the exoskeleton.

4.1.3 Exoskeleton body motion range requirements

The design of the exoskeleton mechanism should meet the body's range of motion greater than the normal body's range of motion, to ensure that it can meet the needs of the human body during the specified range of movement without the machine interfering with or colliding with other components; then add limit parts at each joint

Pieces for protection.

4.2 Exoskeleton joint layout plan

It is known that there are 7 degrees of freedom that affect the gait movement of the lower limbs of the human body. The lower limbs only

Total 6 degrees of freedom. Among these 6 degrees of freedom, the hip joint has 3 degrees of freedom of flexion, extension, rotation, and extension; the knee joint has 1 degree of freedom of flexion and extension; the ankle joint has 2 degrees of rotation, flexion and extension. Through the known degrees of freedom, design two feasible joint arrangement schemes, as shown in Figure 7.

When the human-machine wearing exercise is performed, the joints of the exoskeleton are relatively external to the human body, and do not coincide with the movement axes of the joints of the human body, and the actual trajectory deviation of the exoskeleton and the lower limb of the human body during the movement will be very large. In order to solve this problem, the joint position of the exoskeleton

It is designed based on the layout to ensure the comfort required by the human body while ensuring consistent with human body movement.

During design, because the flexion and extension degrees of freedom of the three joints can easily meet the axis of motion of the human body, the design focus is often on the expansion and rotation of the hip joint and the rotation of the ankle joint. As shown in Figure 7, 2 types

The scheme is provided with three rotation pairs at the connection point of the waist and the thigh that are perpendicular to each other, which can meet the hip joint normal thigh pendulum movement, thigh flexion and extension movement and thigh internal rotation and external rotation movement; in the thigh and calf The joint is provided with a horizontal rotation pair, which can meet the flexion and extension of the knee joint in the horizontal direction; at the connection between the lower leg and the foot, two rotation pairs with vertical rotation axes are provided, which can meet the internal rotation and external rotation of the ankle joint. Flexion and extension. The biggest difference between the two design schemes is the two degrees of freedom position change of hip joint flexion and extension. In Option 1, the hip extension axis is behind the waist, which can be coincident with the human hip extension axis when wearing the machine, while in Option 2, the hip extension freedom is between the thigh and the waist, which is difficult It coincides with the axis of the human hip expansion movement, and the theoretical error is much larger than that of the first scheme. It is known that the length ratio between normal human bones is approximately the same. If a person is H, then his thigh length, that is, the length of the hip joint to the knee joint is 0.245 H; The length of the ankle joint relative to the ground is about 0.039 H. According to statistics, the average height of males is 175.24cm, and a 6cm extension and shortening structure should be designed in the skeletal structure to ensure this adjustable range. Adopt relative movement of inner rod and outer rod.

5. Conclusion

By analyzing the human gait, the gait is first divided into six states according to the movement of the human lower limbs, and then the biomechanical model of the human lower limb is analyzed and analyzed, and the model is simplified for kinematics analysis. Finally according to the lower limbs, experiments prove that the machine matches the human body well.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202006_6(6).0043

The biomechanical model of each joint and the motion law propose that the design of the exoskeleton requires the overall design of the exoskeleton.

Acknowledgements

The authors would like to Funded project (2018A03025) , (2018C01044) , (LMB2019004), (2006A01)and(2012Z004).

References

[1] Steele K M, Jackson R W, Shuman B R, et al. Muscle re-cruitment and coordination with an ankle exoskeleton [J]. Journal of Biomechanics, 2017 (59).

[2] Chen B, Ma H, Qin L Y, et al. Recent developments andchallenges of lower extremity exoskeletons [J]. Journal of Orthopaedic Translation, 2015 (9): 26-37.

[3] Xiang Kui, Yi Chang, Yin Kaiyang, etc. Design of an ankle joint walking assist exoskeleton [J]. Journal of Huazhong University of Science and Technology (Natural Science Edition), 2015 (S1): 367-371.

[4] Li Tandong, Wang Shoujun, Shi Caihong, etc. Research status and trends of wearable exoskeleton robot [J]. Medical and health equipment, 2016, 37 (9): 116-119.

[5] Robotics. ReWalk human exoskeleton let paraplegic patients take to the streets [J]. Business Observation, 2015 (2): 56-57.

[6] Yang Ren. 7-Design and simulation of DOF lower limb exoskeleton robot drive system [D]. Xiamen: Xiamen University, 2014.

[7] Lim D H, Kim W S, Kim H J, et al. Development of real-timegait phase detection system for a lower extremity exoskeletonrobot [J]. International Journal of Precision Engineering & Manufacturing, 2017, 18 (5): 681-687.