Structural Characteristics and Performance Analysis of Lower Limb Rehabilitation Robot

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Abstract: This paper introduces the working principle and structural characteristics of the lower limb rehabilitation robot, describes the mechanism components and control principle of the overall structure, and analyzes the key technologies. This paper introduces the rehabilitation mechanism of the lower limb rehabilitation robot in detail, and analyzes the shortcomings and deficiencies of the current domestic lower limb rehabilitation robot. Finally, it explains the future prospects and reasonable suggestions based on the existing.

Keywords: Lower limb rehabilitation robot; Structural features; Performance analysis

1. Introduction

At present, domestic research institutions have made great progress in the research field of lower limb rehabilitation robot. At the same time, they have a large number of data analysis in the analysis of its key technology, and through the computer software simulation structure simulation, and draw a detailed diagram of the movement mode [1]. The acceleration, angle and velocity of the lower limb rehabilitation mechanism are designed parametrically. This paper analyzes the principle and key technology of the lower limb rehabilitation robot according to the movement characteristics and transmission mechanism. The principle of the control system is described in detail, and the optimization points are found out by comparing the existing devices in this way, so as to make up for the shortcomings and defects of the existing devices.

2. Existing Problems and Deficiencies

Throughout the research and application of lower limb rehabilitation robot in China, there are theoretical researches in the market and universities, and the following deficiencies can be summarized. First, the movement coupling of the lower limbs in the rehabilitation device is limited. Second, when the actuator is combined with the patient's leg, the torque sensor and data collection are not enough, and it is difficult to sense the size and transformation of the patient's leg strength at all times and control the comfort strength [2]. Thirdly, the torque setting of actuator and driving mechanism is too large, so multiple protection mechanisms should be added to avoid secondary injury to patients. Fourth, it can combine the movement of modern Internet of things and vr virtual technology to make the whole device more intelligent.

3. Structural Characteristics of Lower Limb Rehabilitation Robot

In this paper, we propose a kind of lower limb rehabilitation robot with parallel mechanism, which can realize the rehabilitation training of the whole lower limb. Compared with the existing mechanism, the mechanism can achieve joint training of ankle joint, knee joint and hip joint by controlling the driving input of six motors. Because the mechanism has three branches and six driving inputs, it can carry out progressive rehabilitation training to meet the needs of rehabilitation in different periods. The structural parameters include the length of the upper and lower links and the circumcircle radius of the upper and lower dynamic and static platforms. The 6-DOF parallel mechanism consists of a moving platform, a static platform, two chains and one chain. The mechanism is composed of two types of branch chains, and it has six input drives. It can meet the rehabilitation training needs of patients in different periods by controlling the driving input.

Patients usually have difficulty in movement of lower limbs or their load-bearing capacity declines. Rehabilitation robot is to bind the actuator to the patient's legs to obtain a certain driving force through the driving device and use the driving mechanism to output the force to drive the patient's legs to move [3]. The pelvis structure is used to connect the vertical support mechanism with the user. The pelvis structure needs to satisfy a certain degree of freedom. When the human body is moving, the pelvis can have six degrees of freedom, that is, the front and back, left and right up and down translation and rotation around the vertical axis, coronary axis and

sagittal axis. The pelvis structure and the vertical support structure can adopt flexible connection to meet the freedom requirements. If it is a rigid connection, it can follow the rotation of the pelvis around the vertical axis through the parallelogram mechanism.

4. Control System Principle

4.1. Driving principle

In order to improve the accuracy and stability of the drive system to ensure that from assembly to design, usually by low friction, low inertia, high rigidity of the drive mechanism and the corresponding requirements of high resonance damping ratio. The drive chain can increase the stiffness of the system motion mechanism and shorten the controllable range of the drive chain. The transmission stiffness of the system can be increased by means of increasing the preload. At the same time, the preload is applied to roller guide and ball screw, and the preload of pretension is applied to the fixed guide screw bearing, and two axial ends of the structure are added to improve the transmission rigidity.

The control system of the leg rehabilitation robot is an important part of the transmission command and mechanism execution of the leg rehabilitation robot system. At present, the main ways to realize each research mechanism are hydraulic drive, cylinder drive and servo mechanism, while servo mechanism is the most common one in the field of robot, and it is also the most widely used driving mode, because the use of servo mechanism in engineering is more convenient, easy to control, stable transmission data, high output efficiency, less harmful vibration, six degrees of freedom parallel Mechanism leg rehabilitation robot is very suitable for motor drive, not only can meet the required power, but also easy to operate, so the rehabilitation mechanism chooses motor drive as the driving component.

4.2. PID control system analysis

In consideration of the generation of various external unstable factors and disharmony, in order to achieve the ideal state of the on-site control object value, after the control system of the lower limb rehabilitation robot is calculated, the design must be continuously optimized on this basis. If the value of the object such as the control field interference is changed, it will be sent to the PID controller through the detection element according to the scene change, and its value will be collected In order to obtain the predetermined deviation value, and the given control method, the deviation plate of the signal of the control system is processed. The controller involving the steering angle opening of the regulator can transform the control target value, and according to the content of the corresponding predetermined value, the actual PID proportion, integral and differential calculation operation will become the intermediate process of the transmission of the actuator, So as to achieve the control effect. After the control system of the lower limb rehabilitation robot is calculated, the design must be continuously optimized on this basis. If the value of the object such as the control field interference is changed, it will be sent to the PID controller through the detection element according to the scene change to be collected, and its value will be compared to obtain the predetermined deviation value. In addition, the given control method, the deviation board of the control system signal will be processed The controller of the steering angle opening involved in the regulator can transform the control target value and achieve the control effect according to the content of the corresponding predetermined value. In fact, the essence of PID is to carry out proportional, integral and differential operations on deviation (value), and control the process of executing components according to the operation results.

The rotation angle of knee joint of lower limb rehabilitation robot is controlled reasonably by PID control algorithm in microprocessor structure. The knee joint of lower limb rehabilitation robot consists of angle sensor, servo motor and worm. The angle sensor is used to sense the angle of the knee joint, and the output value is fed back to the microprocessor through PID to process the output, so as to drive the rotation angle of the knee joint of the lower limb rehabilitation robot.

For the knee joint control system of lower limb rehabilitation robot, the embedded programmable feedback system can not meet the requirements of response speed and control efficiency. In order to meet the requirements of response speed and control efficiency, PID controller is usually added to the knee joint control system. PID controller has the characteristics of simple structure and high system stability. The experimental results show that after adding PID controller to the knee joint control system of the lower limb rehabilitation robot, the response speed and control efficiency of the moving parts are greatly improved. The PID controller is applied to the engineering field.

5. Characteristics of Moving Components

For the lower limb rehabilitation machine actuator, when the knee joint and ankle joint are relatively static, the movement angle of the hip joint should be widened as much as possible, which has significant characteristics for the stretching movement of leg muscles and the movement of muscles and bones. Generally, the maximum range of motion of the mechanical leg hip joint is 40 ° - 80 °, which can exercise the ability of the lower limbs to the maximum extent. While keeping the hip joint and ankle joint still, the minimum or maximum angle of motion can reasonably reduce or increase the flexion and extension of the knee joint, which has a very

obvious stimulating effect on the neurons around the knee joint. The angle of the hip joint of the mechanical leg is kept at about 90 ° and the maximum range of motion of the knee joint is between 40 ° - 110 °. The mechanical leg can mainly exercise the dorsiflexion and plantar flexion of the ankle joint, which is helpful to improve the bearing strength and explosive force of the human knee joint. The range of ankle joint activity is 0 ° - 20 ° and the range of tiptoe up and down is 0 ° - 50 °. The adduction and abduction of ankle joint can be adjusted at will according to the needs. The lower limbs can do internal and external selective grasping exercise and rotation in the same range, and the range of activity can be increased and the blood circulation of plantar points can be improved. To make the hip joint and knee joint flexion to the maximum angle allowed by physiology at the same time can make the whole lower limb movement to maximize the flexion and extension movement. Generally, the maximum range of motion of the hip joint is between 80 ° - 110 °, and the maximum range of motion of the knee joint is also between 80 ° - 110 °. This mode is the synthesis of the above various lower limb motion models, which can be carried out in order to make the patients' lower limbs get comprehensive exercise in all directions.

6. Mechanism of Sports Rehabilitation

From the point of view of medical rehabilitation, patients with lower extremity movement difficulties should start with ankle joint training, and drive the lower extremity movement of patients through the traction work of rehabilitation sports institutions to achieve the purpose of rehabilitation. In the process of rehabilitation, properly add the coordinated linkage of knee joint and hip joint, which can make the whole movement system form a coherent mechanism, greatly accelerate the whole process of rehabilitation, but it should be noted that the whole activity process cannot be too large, and the movement speed cannot be too fast. The same patient's mentality is also the key, which also helps the whole rehabilitation treatment.

When the patient sits on the wearing equipment, the actuator of the equipment shall just meet the body shape requirements of the wearer, fix the leg on the strap of the mechanical leg, then fix the foot on the foot pedal of the mechanism, step on the mobile platform of the mechanism, and the mechanism shall be in the initial position. Through the driver for power output, the actuator can drive the patient's legs to overcome the gravity of the gait movement. The initial stage should not exceed the scope of meeting the rehabilitation needs. Rehabilitation training trajectory planning is the basis of mechanism simulation and the key of mechanism design of rehabilitation robot. The correctness and stability of trajectory planning directly affect the rehabilitation effect and avoid secondary injury. Rehabilitation training trajectory planning is to plan the motion range and motion form of the end actuator of rehabilitation robot according to the motion range of the whole lower limb joints of the human body, so as to establish the mutual coordination between the machine and the human. The main purpose of the planning is to obtain the desired gait of the robot and achieve the effect of the rehabilitation of the lower limb movement function of the human body.

7. Future Outlook

In recent years, the development of the lower limb rehabilitation robot has made great progress at home and abroad, and it is still unsatisfactory when applied to the actual medical rehabilitation. We should strengthen the optimization design in the aspects of overall design, transmission mechanism and structural design, and use the ergonomics to consider the patients' exercise space, rehabilitation effect and utilization rate. At the same time, we can also cooperate with medical institutions to deepen physical therapy for human sports and athletes' injuries. According to the human body's normal motion mode and parametric design, we boldly explore a reasonable mechanism suitable for various fields and people.

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