Finite Element Analysis and Design of Lower Extremity Exoskeleton

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Abstract

In order to assist the elderly and walking in the crowd,a wearable lower extremity exoskeleton robot was designed,based on the biological characteristics of human walking,the degree of freedom and sizes of each part of human bodies.The lower limb exoskeleton robot has 15 degrees of freedom(15-DOFs). The solid modelingl of exoskeleton robot is established by Solid Works,Finite element software ANSYS was used to analyze the single leg support of lower limb exoskeleton robot. The rationality of the model design is verified through the simulation analysis and study, which provides reference for further research.

Keywords

Lower extremity exoskeleton robot;Wearable;Structural design;Static analysis.

1. foreword

Exoskeleton robot is a human-machine integrated mechanical structure that can be worn outside the human body. It walks with the wearer to provide assistance and protection.Wearable exoskeleton robot is mainly used in both civil and military, in the civil field, it can be used to assist members are difficult to action, walking exercise, can also be used as a help limbs rehabilitative equipment defective patients recovery of the capability of its own activities;In the military field, the robot can improve the ability of soldiers to walk for a long time and carry equipment while carrying heavy loads.

At present, wearable exoskeleton robots have been studied at home and abroad, and the representatives of foreign countries are BLEEX of the United States, HAL of Japan and Rex exoskeleton robot of New Zealand.Domestic zhejiang university and hefei intelligent institute of Chinese academy of sciences have developed a prototype of wearable power-assisted robot .According to the research on human physiological structure, the structure design of exoskeleton robot was carried out.The research lays a foundation for the optimization of the kinematics and mechanical structure of the lower limb exoskeleton robot.

2. Structural Design of Lower Limb Exoskeleton Robot

2.1 Design Requirements

Lower limb exoskeleton robot design is based on the overall structure of the human leg, as a result, the exoskeleton mechanical legs motion needs to accord with human body motion law of the lower limbs, in the lower limb exoskeleton robot structure design should fully embody the anthropomorphic and bionics ideas, reasonable distribution and movement design degrees of freedom, the realization of the maximum possible human limb function.Second, people have a height or size, lower limb exoskeleton robot design should follow the compatibility of the design requirements, to meet people of different shape wear and the concrete embodiment in lower limb size must be within a certain scope can be adjusted.Finally, the design of lower limb exoskeleton robot should guarantee the safety of the wearer, in the design selection should meet the requirements of mechanical strength, stiffness, joint design reasonable limit structure of activity, to prevent accidental movement significantly harm the body.Human lower limb motion of each joint , the hip rotation/spin outside.

(- 50 ° ~ 40 °), adduction/abduction (20 ° to 45 °), flexion/extension (30 ° ~ 120 °), knee flexion/ extension (0 ° ~ 150 °), ankle dorsiflexion/plantar flexion (- 40 ° ~ 20 °), varus/eversion (- 35 ° ~ 20 °), turn inward/outward (30°~30°).

In order to the exoskeleton good combination between robot and determine the degree of freedom, The degree of freedom of a single leg is now determined: 3 hips, 1 knee and 3 ankle joints, hip within three degrees of freedom of hip screw/spin, outreach/adduction and flexion/extension; One degree of freedom of the knee realizes flexion and extension of the knee joint. The three degrees of freedom of the ankle realize the dorsal/plantar flexion, internal/external pronation and internal/external rotation of the ankle joint.

2.2 Design Scheme of Exoskeleton Robot Structure

The overall structure of the lower limb exoskeleton robot design as shown in figure 1, driven by motor drive way, unilateral lower limb with a total of seven degrees of freedom, respectively for hip adduction/abduction and internal rotation/external rotation, flexion/extension, knee flexion/extension, ankle joint screw/spin, varus/valgus, dorsiflexion/plantar flexion, whole body configuration with a total of 15 rotary joints, the back of the torso design a rotary joint, the purpose is to make the wearer to adapt to the movement of the legs to coordinate and adjust the initial wear.

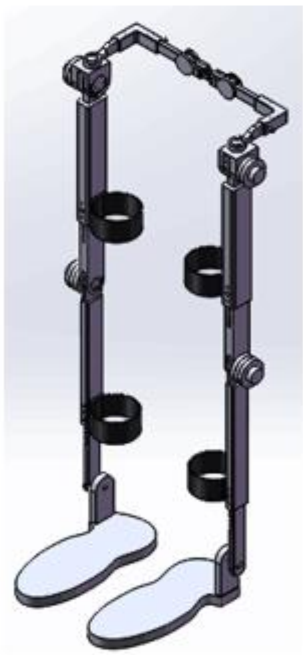
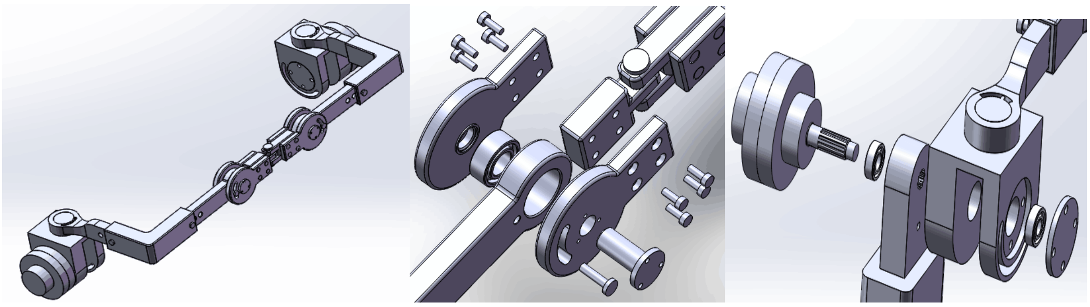


Fig. 1 The Overall Structure of the Lower Extremityexoskeleton Robot

1) design of dimension parameters. According to GB/ t1000-1988 Chinese adult human body size.Human height is H, thigh length is 0.245H, crus length is 0.246H, ankle joint is 0.039H from the ground, and hip joint transverse width is 0.191H.In human body height 1750 mm, for example, the reference of relevant parameters, the final design of leg length is 430 mm, lateral hip width 335 mm, the design length of leg is adjustable range is 100 mm, lateral hip width adjustable range of 75 mm, satisfy the height 1500 mm - 1850 mm people wear, through bolt holes to cooperate, implementation is adjustable.In order to prevent the Angle of the human joints from being too large, the limits are designed at each joint according to the range of motion of the lower limbs.

2) joint design. The design of hip joint is shown in figure 2 (a). The hip adduction/abduction joint is located at the back of the body, and the flexion/extension, internal rotation/external rotation joint is

located on the outside of the body.Outreach/hip adduction structure diagram as shown in figure 2 (b), hip joints with hip fixed by screw connection, rotating rod and bearing outside diameter interference fit , the shaft through screws and hip joints, interference fit inside diameter of the shaft and bearings with arc wall on the hip joints, rotating bar one end face limited a screw hole, nail spacing by arc wall with spacing hole, bar turns, through banking pin and arc wall, realize the rotation Angle limit (other rotational joint limit principle is the same).Hip flexion/extension structure as shown in figure 2 (c), hip flexion/extension movement, directly by the motor and speed reducer drive, drive shaft and the thighs through the rectangle spline connection, Two bearings play a supporting role.



(a) (b) (c)

Figure 2. Hip Joint Structure

3).Ankle joint design: in terms of structural function, ankle joint can also be regarded as a ball-and-socket joint.In the design of the exoskeleton ankle joint, since all three degrees of freedom are passive degrees of freedom, the spherical head joint axis is adopted.The method of bearing direct substitution not only avoids the common design of the ankle joint of the exoskeleton robot due to the high side and low side.The resulting problems of asynchrony and so on make the structure more compact.

4) The leg rod structure mainly includes an inner rod and an outer rod. A combination of the outer rod and the inner rod is used, and the outer rod and the inner rod can be relatively interacted with each other according to a moving pair so as to extend or shrink. The round hole is designed on the inner rod, and the length of the adjustable leg rod can be adjusted by adjusting the cooperation of the bolt and the screw hole.

3. Finite Element Analysis of Mechanical Structure of Exoskeleton Robot

3.1 Establishment of Finite Element Model

The lower leg of the exoskeleton robot bears the main pressure, and the main source of stress is the human body through the waist frame to the mechanical leg pressure.When the human body is in the single-leg support phase, the exoskeleton robot has the maximum stress, and the analysis object is selected for the single-leg standing support of the exoskeleton robot.The 3d model is established and adjusted in solid works, where motors, bearings and parts that have little impact on the results are removed, and then the model is imported into ANSYS Workbench through the program interface .

3.2 Grid Division

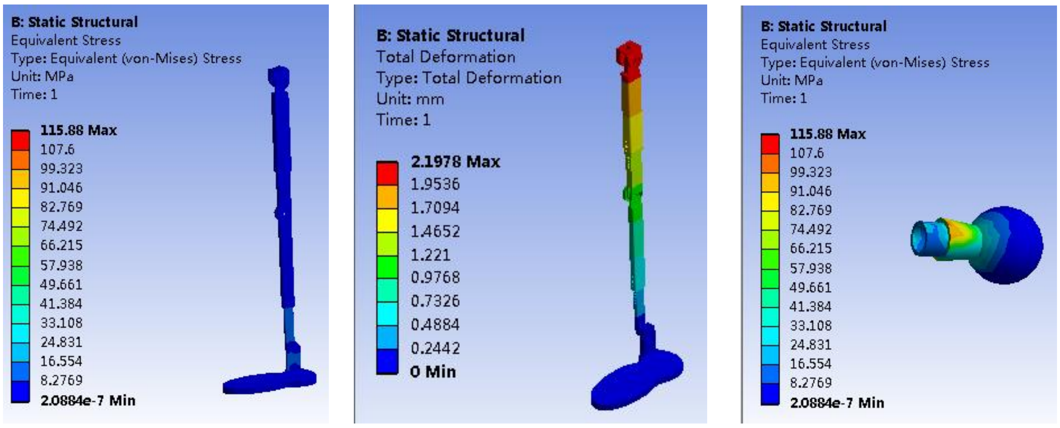
Exoskeleton mechanical legs adopt aluminum alloy material, the density of 2700 kg/m3, poisson's ratio is 0.33, the elastic modulus of 72 gpa, modeling using mm system, choose Bonded contact, in ANSYSWorkbench properties of mechanical components of the leg allocation unit, using free meshing, divided after the finite element model generated as shown in figure 3.

Fig. 3 Finite Element Model of Exoskeleton Mechanical Leg

According to the design requirements, the capacity of the exoskeleton robot to stand on one leg is 80kg. In the model, 800N vertical downward load is applied, and the sole of the foot is fixed.

3.3 Static Analysis and Result Evaluation

According to the finite element model for strength calculation, get the exoskeleton mechanical leg strain stress nephogram, as shown in figure 4, you can see from the results of the analysis, the maximum deformation of 1.8158 mm, occurs in the thigh and parts on the connection of the hip flexion and extension;Maximum stress is 115.88 MPa, occurred on the ball head ankle joints, the limit stress of aluminum alloyσs=280MPa, the allowable stress of material [σ]=σs/sH, sH for safety coefficient, the value is 1.5, calculation can be the ultimate stress of aluminum alloy is 186.7 MPa .The maximum stress is less than the allowable stress. From the stress analysis, it meets the strength requirement of the mater



(a) Strain Cloud Diagram (b) Stress Cloud (c) Ball Joint Stress Cloud

Figure 4. Strain Stress Cloud Diagram in Static State

4. Conclusion

Designed a kind of lower limb exoskeleton robot, including the design of adjustable mechanism easy and convenient, suitable for different people wear, joint spacing is reasonable, meet human body normal walking, foreign single leg bones finite element static analysis, through the simulation analysis result, has been clear about the security requirements, for lower limb exoskeleton robot kinematics and mechanical structure optimization to provide the reference.

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