Establishment and Simulation for flexible human lower limb model

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Abstract. the human lower limb model plays an important role in the simulation experiment, when it is used to do the rehabilitation training and the gait analysis. At present, the human lower limbs model is established in the experiment, that has a single function and does not have universality. In this paper, according to the characteristics of human physiological structure, a 14 degrees of freedom flexible lower limb human body model is proposed, which can meet the requirements of general experiment. The model is compared with the traditional parameterization model, the most outstanding characteristic is that the model can arbitrary adjust the length of the legs according to the experimental requirements. Meanwhile, the model was established by solidworks software and kinematics simulation analysis is used by ADAMS(Automatic Dynamic Analysis of Mechanical System) , and the simulation results are good.

INTRODUCTION

At present, with the development of science and technology and the need of experimental research, human body model plays a more and more important role in the simulation analysis. As a key component of human simulation experiment, the establishment of human model is one of the hot research orientations. When imitating a real human body with a variety of body shapes, a good human model can help researchers to establish and get reliable data, so that the results of the experimental study are more scientific and accurate. At the same time, the human body model is the basis of ergonomics research, with the extensive application of ergonomics design concept in various fields of social life, it promotes the rapid development of the human body model, which is applied in ergonomics design, evaluation and simulation. In addition, in the field of modern rehabilitation medicine, the human body model can be used in clinical trials for some rehabilitation tests. Therefore, the research on human body model has a great development space and application prospect.

The main types of human body modeling in the software are rod like model, surface mechanism model, and hierarchical structure model, although there are standard human model files in Creo, Catia, Delmia and other three-dimensional software. These models make the human model more accurate and realistic, but the model is only used as a gesture after its establishment, if the human body model is derived separately or matched with other mechanisms for simulation, the play will interfere with the error, so that the simulation test can not be carried out.

In this paper, through the study of the physiological structure of the human lower limb, the hip joint, knee joint and ankle joint of the lower limb of the human body are replaced by the equivalent kinematic pair, a kind of 14 degrees of freedom flexible lower limb human body model is designed. The model is compared with the traditional parameterization model, the most outstanding characteristic is that the model can arbitrary adjust the length of the legs according to the experimental requirements.

DESIGN OF HUMAN LOWER LIMB MODEL

From clinical experience and knowledge of anatomy can get lower limb of the human body physiological structural, hip joint motion can be divided into flexion, adduction and abduction and

pronation external rotation in three directions of movement, the knee joint can be simplified as a flexion and extension movement, and the ankle joint can be divided into three directions: dorsiflexion, flexion, pronation and eversion. Therefore, the hip joint can be replaced by a spherical equivalent, and the knee joint is replaced by a rotating pair. Because the spherical joints in the kinematics and dynamics analysis of the controllability is poor, and accurately control the rotating pair, from the institutional perspective, the higher pair generation, the spherical joints equivalent substitute into three mutually perpendicular rotating pair, as shown in figure 1. The lower limb body model using seven single rotation pairs design, the lower limb of the human body has fourteen revolute, its structure principle is shown in figure 2.
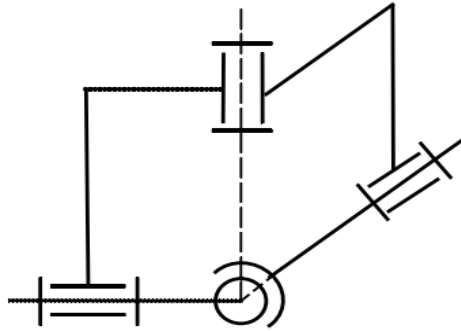

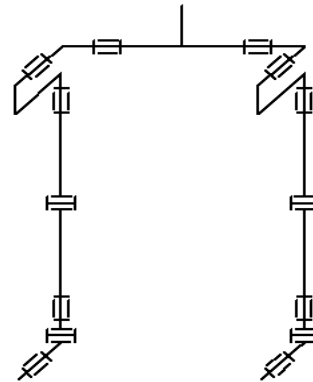**FIGURE 1.** The substitution of spherical joints.　　　**FIGURE 2.** Schematic diagram of human body model.

Taking the hip joint as an example, assuming the flexion and extension angle of the hip is θ_x, the rotation angle of the hip is θ_y, the propagation angle of hip angle is θ_z, The motion of the hip joint can be obtained by the attitude transformation matrix :

$$t = Rot(X, \theta_x) \bullet Rot(Z, \theta_z) \bullet Rot(Y, \theta_y)$$

$$= \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_x & -\sin\theta_x \\ 0 & \sin\theta_x & \cos\theta_x \end{bmatrix} \begin{bmatrix} \cos\theta_z & -\sin\theta_z & 0 \\ \sin\theta_z & \cos\theta_x & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos\theta_y & 0 & \sin\theta_y \\ 0 & 1 & 0 \\ -\sin\theta_y & 0 & \cos\theta_y \end{bmatrix}$$

$$= \begin{bmatrix} \cos\theta_z \cos\theta_y & -\sin\theta_z & \cos\theta_z \sin\theta_y \\ \cos\theta_x \sin\theta_z \cos\theta_y + \sin\theta_x \sin\theta_y & \cos\theta_x \cos\theta_z & \cos\theta_x \sin\theta_z \sin\theta_y - \sin\theta_x \cos\theta_y \\ \sin\theta_x \sin\theta_z \cos\theta_y - \cos\theta_x \sin\theta_y & \sin\theta_x \cos\theta_z & \cos\theta_x \sin\theta_z \sin\theta_y - \sin\theta_x \cos\theta_y \end{bmatrix}$$

Kinematics simulation of lower limb model

According to the requirements of the structure diagram, consulting national standards for adult human dimensions(GB10000-88), which has been put into effect in July 1989. from the table of main parameters of Chinese adult lower limb, when the human body size data percentile is 50, this can almost meet the percentile of female body size of 90, therefore, the human body size of human body measurement data is selected as the design reference standard for the design of the parameters of 50, that the design standard is the height of 1678mm, thigh length of 465mm and calf length of 369mm, the adjustment range of the thigh in the human model is 420mm—510mm, the adjustment range of the calf is 332mm—406mm. As can be seen from the above data, the adjustable range of the thigh and calf almost meet the requirements of the vast majority of adult leg size. The flexible three-dimensional model of the human lower limb is established in Soildworks , as shown in figure 3. The main motion of the hip joint is completed by 3 revolute joints. The main motion of the knee joint is simplified as a pair of revolute joints. The main motion of the ankle joint is accomplished by 3 revolute joints. At the same time, the thigh and calf size can be adjusted within a certain range, and then saved as.X_t Parasolid format, in order to import ADAMS. Various parts of the material density, stiffness, elastic deformation, gravity acceleration, name and so on are set in the ADAMS software environment. Because of the more parts of the model, it is necessary to simplify the model by Boolean operation. In order to realize the walking function of the human body model, it is

necessary to add the hinge pair and the corresponding driver, the kinematic model in the Adams environment is shown in figure 4.
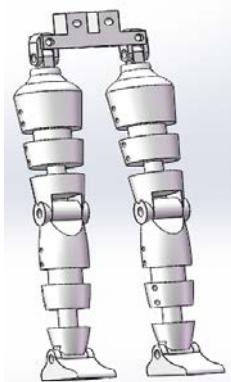

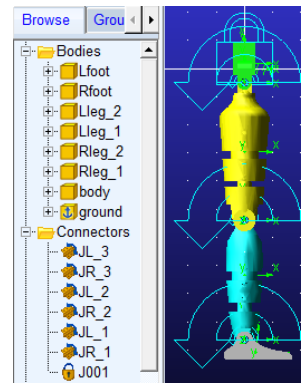**FIGURE 3.** Flexible human lower limb model.

FIGURE 4. Adams kinematic model.

In the Adams working environment, take the Curve of flexion and extension of hip, knee and ankle as the driving function, the changes of the knee and ankle flexion and extension angles were shown in Figure 5 and Figure 6, the hip drive function is as follows:

Motion_Right_leg_hip joint：

step(time,0,0,0.5,15d)+step(time,1,0,1.5,2.1483d)+step(time,2,0,2.5,17.1483d)+step(time,3,0,3.5,10d)+step(time,3.5,0,4,-29.9956d)+step(time,4.5,0,5,34.9956d).
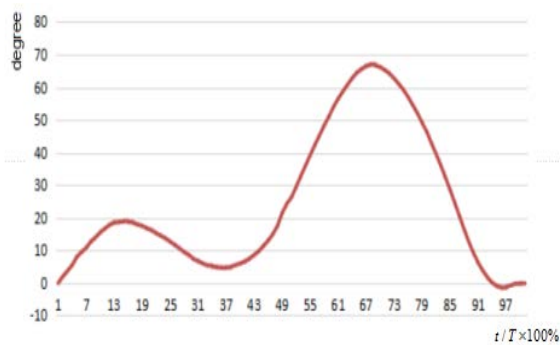

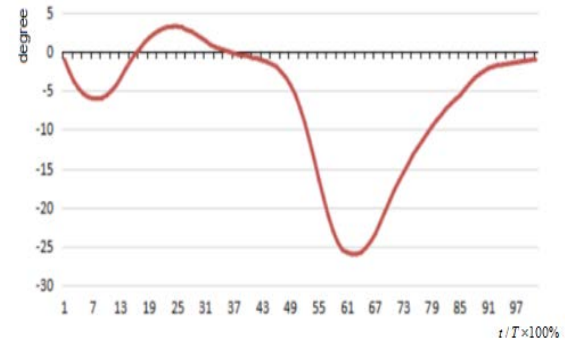**FIGURE 5.** Knee joint angle curve.

FIGURE 6. Ankle joint angle curve.

In the working environment of Adams, taking the height of 1678mm as the standard reference, the simulation results of the trajectories of the foot particles are shown in figure 7. Changing the length of the leg of the human body model, according to the main body size parameters of adults, select the height of 1604mm, 1678mm, 1754mm and 1775mm model for multiple experiments, the position of foot particle change curve is shown in Figure 8, and the speed of foot particle change curve is shown in figure 9. The simulation results show that the motion process of the leg model is similar to that of the human body. Compared with the two groups of particle position and velocity curve, we can see that the trend of the two groups of curves is approximately the same, the correctness of motion analysis is verified. There are some differences in the curve, it is possible to change the height of the body model, the size of the leg has also changed, So that the range of motion of the foot has been changed, but the range of fluctuation is still in line with the requirements of normal gait. It can be concluded that the designed flexible human body model is able to meet the requirements of human motion.
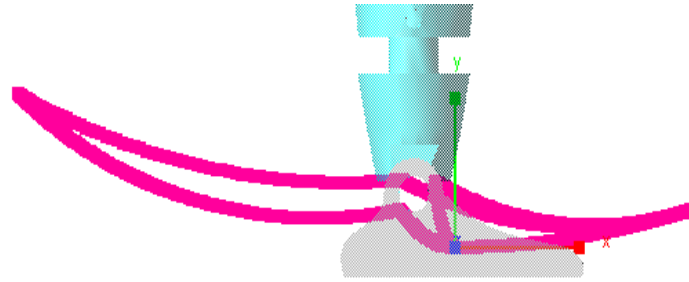
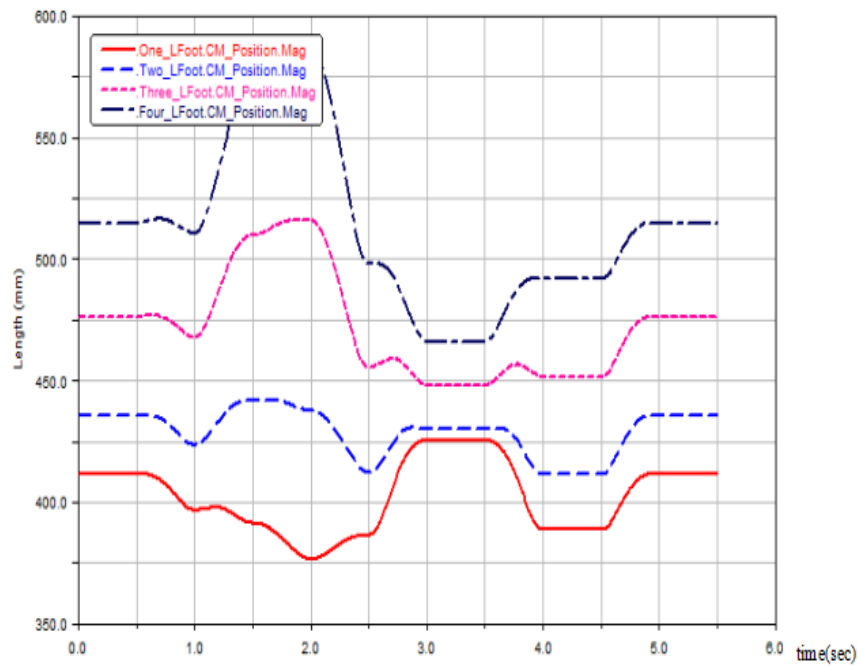**FIGURE 7.** The trajectories of the foot particles.

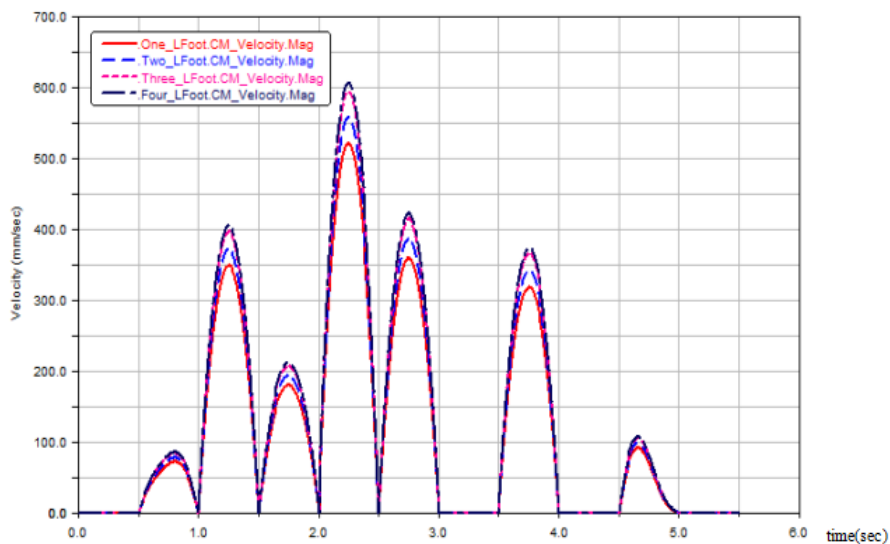**FIGURE 8.** The position of foot particle change curve.

FIGURE 9. The speed of foot particle change curve.

CONCLUSION

In this paper, a new type of flexible lower limb human body model is designed based on the motion law of human lower limb, Three dimensional modeling software is used to accurately model and analyze the kinematics. Solidworks software and Adams software were used to analyze the workspace and motion simulation, the simulation has achieved good results. The results show that

the model can be used to control the joints accurately to achieve the desired trajectory, the rationality of the human body model of flexible lower limb is demonstrated. It has laid a good foundation for the research of the physical prototype and the exoskeleton device.

ACKNOWLEDGMENTS

REFERENCES

[1] Qu Youan. Research and Application of 3D Medical Modeling [D]. University of Electronic Science and technology of China, 2010.

[2] Zhang Honglei. Human Action Recognition Based on Structure Information [D]. Xidian University, 2013.

[3] Gu Qifang, Lu Liting. Analysis of Computer Modeling and Man-Machine Model Kinematics [J]. Electronic Science and Technology, 2013, pp. 127-130

[4] Yang Xifei. Design and Analysis of Power Assisted Exoskeleton System for Lower Limbs [D]. Tianjin University of Science and Technology, 2012

[5] Ge Xujun. Selection and Application of Human Dimensions in Interior and Furniture Design [J]. Forestry Machinery and Woodworking Equipment, 2011, pp. 37-41

[6] Meng Qingxin. Study on the Exoskeleton Gait and Control Strategy of Wearable Lower Limb Rehabilitation [D]. Changchun University of Science and Technology, 2014