Stress Analysis of Lower Limb Exoskeleton for Walking Assistance using Finite Element Method

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Stress Analysis of Lower Limb Exoskeleton for Walking Assistance using Finite Element Method

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Abstract

Lower limb exoskeletons are well-known as powerful tool to help therapists in the patient rehabilitation who have suffered from neurological situations. In the present study, the design of the walking assistance lower limb exoskeleton is developed. The main object of this work is to carried out the stress analysis of such design using finite element analysis (FEA). FEA based commercial software ABAQUS is used. The simulation results show that the developed design of lower limb exoskeletons is safe for walking assistance. This result can be a guide to make a reliable design of exoskeletons.

Keyword: Exoskeleton, finite element analysis (FEA), paraplegic, stress

INTRODUCTION

Exoskeletons are defined as wearable mobile complex systems consisting of electric motors, hydraulics, pneumatics, levers and mainly used to help disabled people to retrieve some motion abilities with increased strength and endurance. Recently, the researches about exoskeletons have paid much attentions by numerous workers, and today powered exoskeleton suits are becoming a reality.

Kim et al. [1] proposed lower limb assistive exoskeleton device for paraplegic patients. The authors designed the mechanical hardware and a sensor system for an assistive exoskeleton device by considering the CoP as a method of determining the human intention to walk and stability criteria. Shaari et al. [2] derived the mathematical model and joint torque equations, to design a lower limb exoskeleton using electrical motors. The authors proposed a guide to select appropriate electrical actuators for an exoskeleton robot. Rakesh et al. [3] presented a control strategy for a lightweight exoskeleton. In their work, the exoskeleton runs in parallel to the human leg and transmits payload forces to the dampers. A designed pneumatic damper mechanical system was also introduced to compensate the metabolic activities and force impact on the leg. Later, Herianto et al. [4] proposed what so called rehabilitation robot for assisting the patient to recover from stroke or other extremity injuries. They developed lower limb rehabilitation robot control system with a low price by using a PWM controller for voltage manipulation. In recent publication, Lim et al. [5] developed the kinematic model of exoskeleton robot for lower limb that changes according to the gait phase detection of a human. Using the COP, they developed an algorithm that is capable of detecting gait phase with small number of sensors. Other interesting result is that to evaluate the developed insole sensor system and the gait phase detection algorithm, an experiment was also conducted.

Based on literature survey, different types of lower limb exoskeletons are currently proposed as tools for mobility assistance. The main aim of this study is to investigate the strength of the frame of lower limb exoskeleton with stress analysis varying the loading values. Finite element method based commercial software ABAQUS is used walking to analyse lower limb exoskeletons with for walking assistance.

ANALYSIS

1. Developed design of lower limb exoskeleton

In the mechanical design of the exoskeleton, different design criteria should be considered. In the present study, with the aim of walking assistance, the lower limb exoskeleton is developed as can be seen in Figure 1. This model presents the current state of the patient during gait. It can be seen that the position of the right and left femur have different positions. This difference is influenced by the difference in angle between the femur and the fibula.

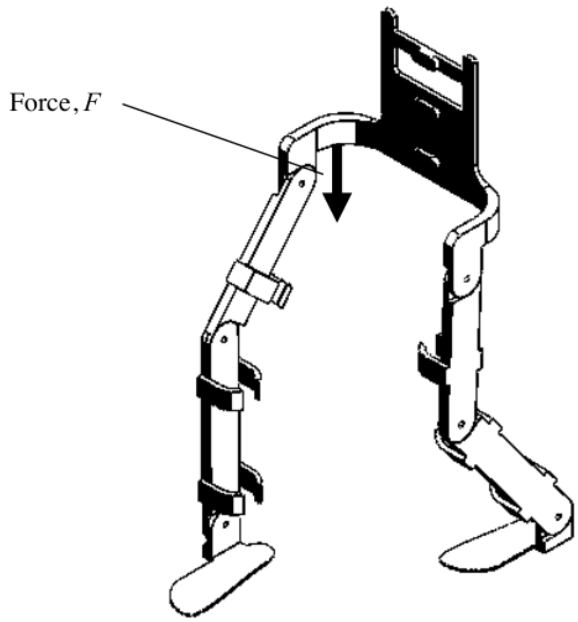

Figure 1: Schematic representation of lower limb exoskeleton used in this simulation.

In the present study, the material used is Aluminium Alloy 7075-T6 due to the lightweight but sturdy. In detail, the mechanical properties of this material is shown in Table 1.

Table 1. Material properties of Aluminium Alloy 7075-T6

Property	Value	Unit
Elastic Modulus	72,000	N/mm^2
Poisson's Ratio	0.33	-
Mass Density	2,810	Kg/m^3
Tensile Strength	570	N/mm^2
Yield Strength	505	N/ mm^2

2. Constraint and loading

The loading that exists in all models of the exoskeleton are influenced by the patient's body weight. In this study, the body mass applied here is set to 80 kg. The mass of body equals to the loading F (in this case F = 784.8 N) applied on the back of exoskeleton for the simulation, see Fig. 1. It should be note that during walking activity, the load is assumed to be on the back support. The assumption of the application point of force is chosen based on the real situation, i. e. standing conditions.

In computational model of exoskeleton in this study, the foot section is fixed so it cannot move in any direction. The back of exoskeleton is assumed to move only in the direction of the y-axis or vertical axis of the body while standing. The sides of the right and left legs are made unable to move.

The type of element applied here is tetrahedral. The number of elements and nodal is about 57,065 elements and 31,855 nodal.

RESULTS AND DISCUSSIONS

Figure 2 shows the von Mises distribution of the lower limb exoskeleton in walking situation. It can be seen from these figures that maximum von Mises stress is about 10.4 MPa, which is much lower than the yield strength of the material used. It should be noted that the yield strength of the material is about 505 MPa. Under these conditions, it can be said that the structure of lower limb exoskeleton is safe for walking condition.

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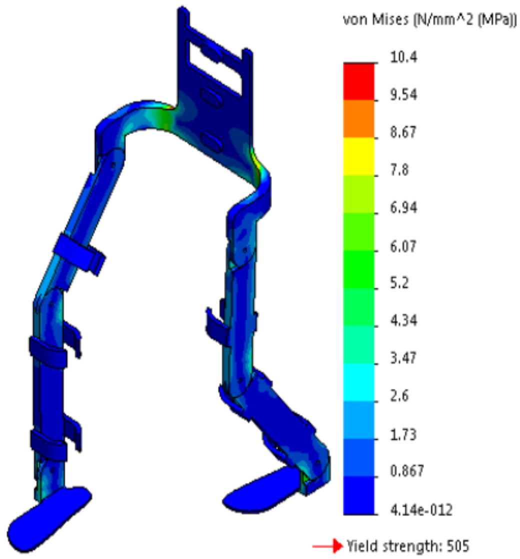

Figure 2: von Mises stress distribution of lower limb exoskeleton

Figure 3 shows the vertical or *y*-axis deformation of lower limb exoskeleton for walking assistance. It can be observed that the maximum deformation value based on the simulation result is about 0.0834 mm. If this value of deformation is compared to the dimension of lower limb exoskeleton developed here, the deformation value range is acceptable.

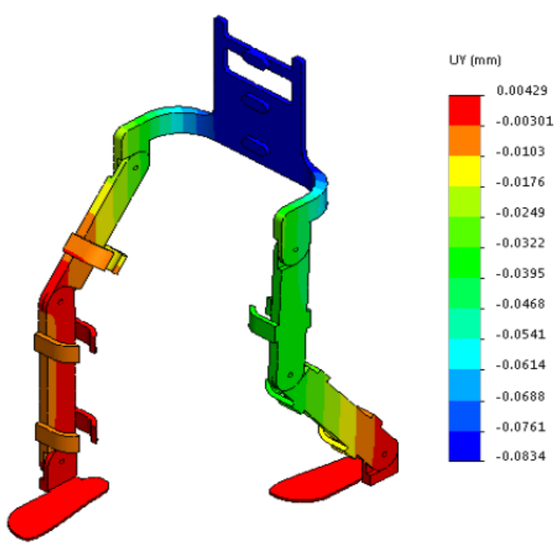

Figure 3: Deformation distribution of lower limb exoskeleton

CONCLUSION

In the present paper, the design of lower limb exoskeleton for walking assistance is proposed. Stress analysis of the strength of exoskeleton based on the finite element method is of particular interest. Based on the analysis presented in the previous section, the conclusion can be drawn as follows:

1. The design of lower limb exoskeleton for walking assistance is successfully developed.
2. The simulation results show that the design of the exoskeleton is safe during walking assistance with the average loading.

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