Power Assisted Exoskeleton with Length Adjustable Spring based Passive Counterbalance

Jones Joseph Jebaraj.D 1, Uthranarayan.C 1, Manoj Kumar.G 1, and Keerthana.S 2

1 Department of Mechanical Engineering, Mepco Schlenk Engineering College, Sivakasi, Taminadu, 626005, India.
2 Department of ECE, Mepco Schlenk Engineering College, Sivakasi, Taminadu, 626005, India

a) Corresponding author: fabuvn@gmail.com
b) manojkumargmech@gmail.com, djonesjosephjebaraj@gmail.com

Abstract- Powered exoskeletons can help in the rehabilitation of the elderly and those who have suffered accidental loss of motion due to problems in the Central Nervous system. Additionally exoskeletons act as a protection to the wearer. The current information age has seen tremendous development in the fields of robotics and prosthetics. Humanoid robots like ASIMO are being developed and these robots can perform tasks similar to those performed by a human being. Advancements in prosthetics have helped people who have lost limbs to regain complete functionality by replacing those limbs with prosthetic limbs controlled by signals from the brain. This article describes about the design and development of a spring counterbalanced exoskeleton which allows the wearer to carry more load with minimal effort.

1. INTRODUCTION

The endoskeleton present inside our human body gives us our structure and helps us carry loads and at the same time protects our internal organs. Similarly exoskeletons are seen in insects and certain sea creatures. These exoskeletons give these creatures their structure and ability to carry heavy loads. The current information age has seen tremendous development in the fields of robotics and prosthetics. Humanoid robots like ASIMO are being developed and these robots can perform tasks similar to those performed by a human being. Advancements in prosthetics have helped people who have lost limbs to regain complete functionality by replacing those limbs with prosthetic limbs controlled by signals from the brain.

A powered exoskeleton is a robotic device that fits right over a human being and helps in performing tiring tasks while protecting from external dangers. These devices are programed to move along with a human being. These devices can be considered to be a combination of both robotics and prosthetics. Current exoskeleton suits are usually bulky and draw a lot of power for their operation. Bulky exoskeletons are usually built with a primary and a secondary interface. The primary interface is controlled by the user and the primary interface in turn controls the exoskeleton which acts as the secondary interface. Another type of suit where the user directly controls the exoskeleton is also available. These suits are bulky and are used to move heavy loads around.

2. DESIGN OF EXOSKELETON

A proper design for an exoskeleton would allow the wearer to lift weight with a minimal effort. Several attempts have been made by researchers to reduce the resultant torque. In the article by Rahman et al[1] counterbalancing by spring for a single link and multiple links were found out.
Figure 1. Spring counterbalancing

The stiffness of the zero free length spring was found to be \( K = \frac{mg l}{ab} \)

The innovation in the work is the usage of spring counter balance mechanism to lift heavy loads and the usage of lead screws to adjust the position of ‘a’ and ‘b’ as shown above. A spring counter balance mechanism uses the force created by a tensile spring to lift heavy loads. By using a spring counter balance mechanism, the size of motors required for lifting heavy loads can be drastically reduced. This will reduce the power consumed by the exoskeleton for its operation.

Figure 2. Design of exoskeleton and the arm

3. METHODOLOGY

A spring is used in the exoskeleton to counterbalance the weight at the fore arm. The values of the link length ‘a’ and ‘b’ as mentioned earlier are taken to be \( a = 0.05 \) m and \( b = 0.20 \) m. These values can be continuously changed by the motor connected with the lead screw assembly. Stiffness of the spring to counterbalance the weight of the arm and total load lifted is calculated to be 5.886 N/mm, diameter of the spring, D as 28.25 mm and length of the spring as 88 mm. The load cell measures the load carried by each hand. Then the link lengths are controlled by a lead screw actuated by a DC motor.
4. CONTROL SCHEMATIC

![Control Schematic Diagram]

Figure 3. Control Schematic

5. FABRICATION AND TESTING

The frames, hinges, arms and legs of the exoskeleton were fabricated and assembled. The motors were mounted on the lead screw using couplers and connected to the micro controller.

![Actual testing by the wearer]

Figure. 4 Actual testing by the wearer

6. RESULTS AND DISCUSSION

For a wearer of weight 61 kg, the following data was obtained.

| Table 1: Experimentation and Output |
|-------------------------------------|
| **Load condition** | **Load carried** |
| Wearer static without exoskeleton  | 27 kg            |
| Wearer static with exoskeleton powered down | 32 kg            |
It was found that the motors used in each arm could handle about 20 kilograms. With the wearer being static, it was found that almost 80% of the total load was carried by the exoskeleton alone. But when the wearer tries to move around, the load acting on the wearer increases due to the absence of a proper leg actuation mechanism. It was also observed that the total load of the exoskeleton was transferred to the ground through the legs attached to the exoskeleton. Hence the wearer does not feel the self-weight of the exoskeleton.

7. References

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