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Design and Fabrication of Walking Assistant

Akhil K A, Anantha Krishnan, Abhishek P, Achu S, Rajesh Menon B*

Department of Mechanical Engineering, NSS College of Engineering, Palakkad-678008, India

*Corresponding author email: brmenonnssce@gmail.com, Tel.: +91 9496466899

ABSTRACT

Probably the most common measure of mobility and freedom is the ability to walk. Unfortunately, due to ageing or chronic health problems, a significant portion of the population is losing mobility. As a result, structures that assist in the preservation of mobility for those in need are desperately needed. To provide walk assistance, most current devices rely on driven systems that apply complementary torques around lower limb joints. Nonetheless, they are not limited by financial constraints. As a result, passive alternatives are being built, demonstrating the feasibility of simple, low-cost devices. This paper proposes a prototype for the creation of a passive exoskeleton that improves stability during stance and walking in line with this advancement. In this model of assistive limb, the required torque on the hip and knees for gait are analyzed and appropriate DC motor are mounted on links attached to the thigh and shank. The direction of rotation of the motor is controlled by a PIC board. The motor provides appropriate torque on the links of the model. A 12 V battery is used to power up the motors. The passive exoskeleton is fabricated mainly by mild steel. This paper focuses on eco-support architecture and electronic control systems, offering food for thought and shedding light on exoskeletons' future.

Keywords – Assistive limb, Gait, Passive exoskeleton.

1. INTRODUCTION

The number of patients paralyzed due to stroke and other related diseases are increasing. Among these, spinal cord injury (SCI) is a hot topic since the patients are young people who need to work to make ends meet. Also, the aged ones are those who need assistance with their daily motions. As a consequence, medical equipment or assistive aids that can assist them in standing and walking are particularly important in order to enhance their quality of life. An exoskeleton is an external skeleton that supports and protects the body, as opposed to the internal skeleton. An operated exoskeleton is a wearable mobile system that uses electric motors, pneumatics, levers, and hydraulics to increase strength and agility. In this fast-moving era, people come up with ideas to help those, regain the ability to stand up and move. The exoskeleton is a typical example of this kind. Of these, ReWalk, HAL are popular. The development of exoskeleton has exploded over the last decade and they have mainly been focused on helping paralyzed people. Much consideration has not been made for the aged. Hence a different approach is been made to design an aid which can help the aged to stand up and sit down which is lightweight and lesser cost. There are different walker type aids available in the market that can help those affected with disability or age. The powered exoskeleton is basically a high-cost type. It may be actuated by hydraulics or pneumatics. It may cost up to lakhs of rupees and their practical uses may be limited to either rich families or big hospitals. We came up with the idea of developing a simple exoskeleton type assistive aid which is lightweight, more sturdy, mobile, and durable. A prosthesis refers to an artificial replacement for any missing body part like fingers, toes, ears, eyes, noses, and limbs as well. About 9000 products of the prosthesis have been developed. Artificial pacemakers, hip and knee replacements, intraocular lenses, coronary stents, bones, corneas, and human tissues are only a few examples. The first exoskeleton-like system was a series of walking, climbing, and running aided apparatus created by a Russian named Nicholas Yagin in 1890. The apparatus used compressed gas bags to conserve energy that would assist with movements, despite the fact that it was passive in operation and demanded human control. Leslie C. Kelley, a US inventor, invented a pedometer in 1917, which ran on steam and had artificial ligaments that moved in tandem with the wearer's movements.

The pedometer could generate energy without requiring the user's participation. The first true exoskeleton, which was a mobile computer that synchronized with human gestures, was developed by GE and the US military in the 1960s. The suit's name was Hardiman, and it made lifting 250 pounds (110 kg) sound like lifting ten pounds (4.5 kg). The suit, which was operated by hydraulics and electricity, gave the wearer a 25-fold boost in weight, making lifting 25 pounds as easy as lifting one pound. The wearer could feel the forces and objects being manipulated thanks to a feature called force feedback. While the general concept sounded promising, the Hardiman itself had significant flaws.

This paper aims at designing and fabricating a walking assistant which can be mount on the right leg of a human body. Despite the emerging designs of exoskeletons in the market, there is an increasing need for an affordable exoskeleton. The design and fabrication of an affordable exoskeleton is the primary goal of this paper.

2. MATERIALS AND METHODS

2.1 DC Motor

An armature rotates within a magnetic field in a DC motor. The basic working principle of a DC motor is that whenever a current-carrying conductor is placed inside a magnetic field, that conductor will be subjected to mechanical force. As a result, establishing a magnetic field is critical when building a DC motor. A magnet is used to create the magnetic field. Different types of magnets can be used, including electromagnets and permanent magnets. A Magnet that is on a permanent magnet is used to create the magnetic field required for DC motor operation in a DC motor (or PMDC motor). The construction of these motors is straightforward. They are widely used in automobiles as starter motors, windshield wipers, washers, blowers in heaters and air conditioners, and to raise and lower windows – as well as in toys. Since the magnetic field strength of a permanent magnet is constant and cannot be controlled externally, field control of this type of DC motor is difficult. A permanent magnet DC motor is used where there is no need to regulate the motor's rpm (which is usually done by controlling the magnetic field). In small fractional and sub-fractional KW motors, permanent magnets are widely used. Table 1 shows the specifications of the DC motor used in the model.

2.2 Frame

Mild steel is used to construct the frame. Mild steel is a carbon steel that has a low carbon content. It's also referred to as "low carbon steel." The amount of carbon found in mild steel is typically 0.05 percent to 0.25 percent by weight, whereas higher carbon steels are typically described as having a carbon content of 0.30 percent to 2.0 percent, depending on the source. The steel would be classified as cast iron if any more carbon was added.

Table 1 Specifications of DC Motor used

Voltage	12 V
Rated power	24 W
Speed	60 rpm
Stall torque	6 Nm

Mild steel is not an alloy steel, so it does not have a lot of other elements in it besides iron. You won't find a lot of chromium, molybdenum, or other alloying elements in mild steel. Due to its low carbon and alloying element content, it has a range of characteristics that set it apart from higher carbon and alloy steels.

Mild steel has less carbon than high carbon and other steels, making it more ductile, machinable, and weldable; however, it is nearly impossible to harden and strengthen through heating and quenching. Because of the low carbon content, there are not much carbon and other alloying elements to block dislocations in the crystal structure, resulting in lower tensile strength than high carbon and alloy steels. Mild steel is magnetic due to its high iron and ferrite content.

Because mild steel lacks alloying elements like those found in stainless steel, the iron in it is susceptible to oxidation (rust) if not properly coated. However, mild steel is relatively inexpensive when compared to other steels due to the small number of alloying elements. The affordability, weldability, and machinability of this steel make it a common customer option. The properties of the mild steel used are shown in Table 2.

Table 2 Properties of Mild Steel

Yield strength	190 MPa
Tensile strength	340 MPa

2.3 Bearings

Since the bearings could break if hammered, they are pressed smoothly into the bearing cap, which is welded to the chain. Steel is used for the bearing, and mild steel is used for the bearing seal. In the model, SKF6302 bearings are used to serve the purpose.

2.4 Rivets

A rivet is a mechanical fastener that is permanent. Throughout the model, 10 mm diameter rivets are used. A rivet consists of a smooth cylindrical shaft with a head on one end before it is attached. The tail is the opposite end of the head. The rivet is inserted in a punched or drilled cavity, and the tail is upset or bucked, to around 1.5 times the initial shaft diameter, keeping the rivet in place. To put it another way, pounding produces a new "head" on the other end by flattening the "tail" material, resulting in a dumbbell-shaped rivet. The original head of the rivet is referred to as the factory head, while the deformed end is referred to as the shop head or buck-tail. A tension load can be borne by a mounted rivet since it has a head-on either end. It is, however, much more capable of withstanding shear loads. In the construction of the walking assistant, 10 mm diameter rivets were used.

2.5 Battery

A battery is a device that contains one or more electrochemical cells that are wired to the outside world and is used to fuel electrical devices like flashlights, cell phones, and electric vehicles. When a battery is supplying electric power, the positive terminal is the cathode and the negative terminal is the anode. The negative terminal is the source of electrons that can travel through an external electric circuit to the positive terminal. When a battery is connected to an external electric load, a redox reaction occurs, converting high-energy reactants to lower-energy components and transferring the free-energy difference to the external circuit as electrical energy. Historically, the word "battery" applied to a device made up of several cells; however, the term has come to apply to devices made up of only one cell.

The electrode materials are irreversibly modified during discharge, so primary (single-use or "disposable") batteries are used once and then discarded; an example is the alkaline battery used in flashlights and a number of portable electronic devices. Secondary (rechargeable) batteries may be discharged and recharged several times with an applied electric current; reverse current may be used to restore the electrodes' original composition. Lead-acid batteries used in cars and lithium-ion batteries used in portable devices such as laptops and cell phones are two examples.

Batteries come in a range of shapes and sizes, ranging from tiny cells that power hearing aids and wristwatches to lightweight, thin cells that power smartphones, to large lead-acid or lithium-ion batteries in cars, and, at the most extreme, massive battery banks the size of rooms that provide standby or emergency power for telephone exchanges and computer data centers.

Compared to traditional fuels like gasoline, batteries have much lower specific energy (energy per unit mass). In vehicles, this is partly compensated by electric motors' higher efficiency in converting chemical energy to mechanical work as compared to combustion engines.

Alkaline batteries, such as AA, AAA, C, and D cells, are regular sizes and shapes of 1.5 volts. The chemicals used decide the voltage of a cell. The amount of electricity it can generate is determined by the size of the cell and the chemicals it contains. A battery's charge is usually measured in ampere-hours. Since the voltage remains constant, a larger cell may supply more amps or operate for longer periods of time. The battery used in the model is depicted in Figure 1, and its specifications are described in Table 3.

Fig. 1 Battery used

Table 3 Specifications of Battery

Voltage	12 V
Electric discharge	7.5 AH
Max. current	1.4 A

2.6 PIC

The PIC16F877A, Programmable Interface Controller is one of the most well-known microcontrollers on the market. This microcontroller is very easy to use, and its coding or programming is also very simple. Since it uses FLASH memory technology, one of the key benefits is that it can be write-erase as many times as desired. It has a total of 40 pins, with 33 pins dedicated to input and output. Many pic microcontroller projects use the PIC16F877A. PIC16F877A is also commonly used in digital electronics circuits.

2.6.1 PIC16F877A microcontroller

The PIC16F877A can be used in a wide variety of devices. Remote sensors, protection and safety systems, home automation, and a range of industrial instruments all use it. It also has an EEPROM, which allows it to store certain information indefinitely, such as transmitter codes and receiver frequencies, as well as other related details. This controller has low cost and is simple to run. It's versatile, enabling it to be used in places where microcontrollers have never been used before, such as microprocessor applications and timer functions.

Features:

- It has a 35-instruction set that is smaller.
- It can run at a frequency of up to 20MHz.
- Between 4.2 and 5.5 volts is the operating voltage. If you give it more than 5.5 volts, it could be permanently damaged.
- It lacks an internal oscillator, as do other PIC18F46K22 and PIC18F4550 chips.
- Each PORT can sink or source a maximum current of around 100mA. As a consequence, each GPIO pin on the PIC16F877A has a current limit of 10 milliamps.
- It comes in four different IC packages: 40-pin PDIP, 44-pin PLCC, 44-pin TQFP, and 44-pin QFN.

2.6.2 PIC16F877A microcontroller pin configuration and definition

The 40 pins of this microcontroller IC have already been mentioned. It has two 8-bit timers and one 16-bit timer. It also has capture and compare modules, serial ports, parallel ports, and five input/output ports. The general pinout diagram of the PIC16F877A is shown in Fig.2.

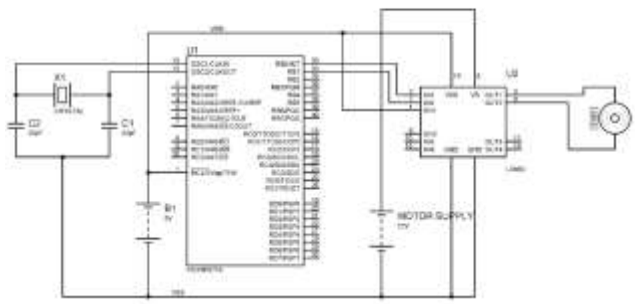

Fig. 2 Pinout diagram of PIC16F877A

PIN 1: MCLR: This IC's first pin is the master clear pin. It resets the microcontroller and is active low, which means it should be given a voltage of 5V at all times, and if 0 V is given, the controller will be reset. When you reset the controller, it will return to the first line of the code that was burned into the IC.

Reset circuit - The pin is attached to a push button and a resistor. The pin is already operated by a constant 5V supply. When we want to reset the IC, we simply press the button, which resets the controller by taking the MCLR pin to 0 potential.

PIN 2: RA0/AN0: PORTA has six pins, numbered 2 through 7, all of which are bidirectional input/output pins. This port's first pin is Pin 2. This pin can be used as an analogue pin AN0 as well. It also has an analogue to a digital converter built in.

PIN 3: RA1/AN1This may be analogue input number one.

PIN 4: RA2/AN2/Vref-: It also has the ability to act as an analogue input 2. It can also be given a negative analogue reference voltage.

PIN 5: RA3/AN3/Vref+: It could be seen as an analogue input 3. Alternatively, it can function as an analogue positive reference voltage.

PIN 6: RA0/T0CKI: This pin can be used as the clock input pin for timer0, and the output form is open drain.

PIN 7: RA5/SS/AN4: This may be analogue input 4. The controller also has a synchronous serial port, and this pin can be used as the slave select for that port.

PIN 8: RE0/RD/AN5: PORTE is a bidirectional input/output port that runs from pin 8 to pin 10. It can be analogue input 5 or, in the case of a parallel slave port, a ‘read control' pin that is active low.

PIN 9: RE1/WR/AN6: It may be analogue input 6. It can also serve as the parallel slave port's 'write power,' which will be active low.

PIN 10: RE2/CS/A7: It can be analogue input 7 for the parallel slave port, or it can be the ‘control select' for the parallel slave port, which will be active low like the read and write control pins.

PIN 11 and 32: VDD: The positive supply for the input/output and logic pins is given by these two pins. Both of them should be plugged into a 5V power source.

PIN 12 and 31: VSS: Input/output and logic pins have a ground reference on these pins. They need to be connected to 0 volts.

PIN 13: OSC1/CLKIN: This is the external clock input pin or oscillator input pin.

PIN 14: OSC2/CLKOUT: This is the output pin for the oscillator. To provide an external clock to the microcontroller, a crystal resonator is connected between pins 13 and 14. In RC mode, OSC2 outputs a quarter of the frequency of OSC1. This is the rate at which instructions are cycled.

PIN 15: RC0/T1OCO/T1CKI: 8 pins make up PORTC. It also functions as a bidirectional input and output port. Pin 15 is the first of them. It could be timer 1's clock input or timer 2's oscillator output.

PIN 16: RC1/T1OSI/CCP2: It could be timer 1 oscillator input or capture 2 input/compare 2 output/PWM 2 output.

PIN 17: RC2/CCP1: It can be one of the following: capture 1 input, compare 1 output, or PWM 1 output.

PIN 18: RC3/SCK/SCL: It can be used as an output in SPI or I2C modes, as well as an input and output for the synchronous serial clock.

PIN 23: RC4/SDI/SDA: It is likely that it is the SPI data in a pin. It can also be a data input/output pin in I2C mode.

PIN 24: RC5/SDO: It could be data coming out of SPI in SPI mode.

PIN 25: RC6/TX/CK: It could be the USART Asynchronous transmit pin or the synchronous clock.

PIN 26: RC7/RX/DT: This may be the USART receive pin or the synchronous data pin.

PIN 19,20,21,22,27,28,29,30: These pins are all part of the PORTD port, which is a bidirectional input and output port. It can be used as a parallel slave port when the microprocessor bus is to be interfaced.

PIN 33-40: PORT B: PORTB owns all of these pins. RB0 can be used as an external interrupt pin, while RB6 and RB7 can be used as debugging pins in-circuit. Fig. 3 shows the pinout diagram of the model.

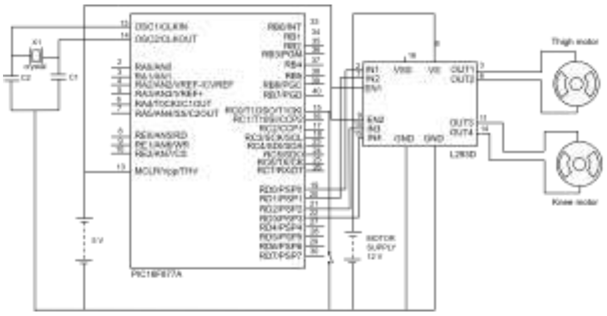

Fig. 3 Pinout diagram of the model

2.7 Connecting Wires

A wire is a single metal strand or rod that is typically cylindrical and flexible. Mechanical loads, power, and telephone signals are all borne by wires. Drawing metal through a hole in a die or draw plate is a common way to create a wire.
Fig. 4 to fig. 6 shows the isometric, front, side and top views respectively of the walking assist mechanism.

Fig. 4 isometric view

Fig. 5 front view

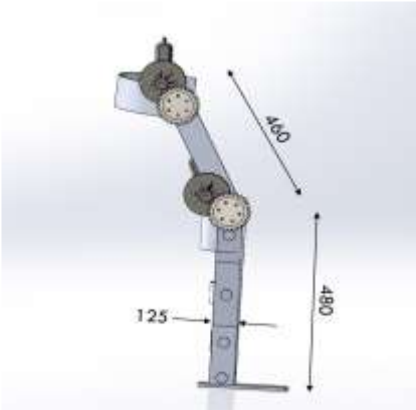

Fig. 6 side view

Fig. 7 top view

2.8 Working Principle

The walking assist consists of DC motors attached to the hip and knee joints. The basic working principle of this model is to effectively convert the rotary motion of the motors to the rotary movement of the links by the use of speed reduction using spur gears. The rotation of links is restricted in forward motion using mechanical stoppers. The links are retracted using the reversal of the DC motors.

2.9 Working

The experiential setup is made up of a leg frame with pin-jointed thigh and bottom leg frames that can be folded and stretched like a normal leg. The model is to be fixed to a human leg using belts. DC motors can be used to control the angular motion of the thigh and shank ties due to the set requirement of high torque and low speed. The direction of the two DC motors is programmed in such a way that a normal gait cycle is obtained at the links. The motors are actuated by a battery which can be included in a backpack. As a result, when the button is pressed and the operation is turned on, the battery's supply enters the engine, allowing the motors to turn on. The spur gears receive power from the engine, which rotates. For the required speed reduction, spur gears are used. The larger spur gear, being welded to the link, provides an angular rotation of the link, when actuated by the pinion on the motor. The rotation of the links is restricted using mechanical stoppers. The PIC switches the polarity to the DC motors hence enabling the forward and backward movement of the links. As a result, the walking motion is formed. If the button on the opposite hand is pressed, the whole process is shut off.

3. CONCLUSION

In comparison to the internal skeleton, an exoskeleton is an external skeleton that supports and protects the body. It aids the human body and decreases the amount of work that must be performed by the human body. The exoskeleton mentioned in this paper is designed to assist a human leg during the gait cycle. The angular motion of the thigh and shank ties is controlled by a microcontroller and DC motors that meet the requirements of high torque and low speed. So, the sole aim of the model is to obtain a lightweight design of exoskeleton and a cost-effective system.

The design inputs are obtained by calculating the weight distribution of the human body at various joints. The weight of the exoskeleton is also to be accounted during design and analysis. Only when the total weight of the whole system is determined, the motor specifications can be calculated. After setting safe parameters of the design, fabrication of the system is done.

The body was equipped with the exoskeleton prototype and the movements were observed keeping it at no load or raised leg. Without much resistance, the exoskeleton movement matched that of the wearer. When the exoskeleton is worn, less muscle activation is needed while walking, according to the findings. A wearable exoskeleton for one limb was fabricated and was tested for the movements of the links. This prototype focuses on the economic aspect of exoskeletons. The handling of the equipment is easy as it does not incorporate any heavy elements. It is easy to use as the whole process is automated using a microcontroller. Also, it is easy to maintain as standards elements are used in the fabrication. The use of mild steel has paved the way for achieving a cost-effective model.

Despite the cost-effectiveness of the model, the walking assistant has its own limitations. The use of DC motors avoids the provision for speed variation. The position of the links has to be adjusted before each operation by controlling the individual motors. Therefore, there is a scope for further modifications to the existing model. The existing model is only suitable for people of specific thigh and shank link measurements. It can be made versatile by the use of adjustable thigh and shank links. There needs to be a self-positioning system to bring back the links to a default position after the working. This will help for the easy storage and handling of the equipment. Also, mild steel can be replaced with aluminium to reduce the weight of the model, thereby decreasing the power requirements.

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