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Hominal Enhancement Lower Extremity Exoskeleton

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Abstract:- **Lower Extremity Exoskeletons are used in medical field for improving the quality of life of wheelchair bound people who suffer from partial or total loss of lower body motor functions either in accident or by birth, by providing assistive technology to enable system-assisted walking or restoration of other motor controls. Our aim is to create a lower extremity exoskeleton which can be used by people suffering from C5 - C8 spinal column injury or people with underdeveloped legs. It can also be used as device to augment healthy people to carry more loads while walking. HELEX is an electrically powered exoskeleton with linear actuators which helps in miming the Gait cycle.**

Keyword: Exoskeleton, augmentation, bionics, Spinal column injury, rehabilitation.

1. INTRODUCTION

A powered [1] is a wearable mobile machine that is powered by a system of electric motors, pneumatics, levers, hydraulics, or a combination of technologies that allow for limb movement with increased strength and endurance. The earliest [1] -like device was a set of walking, jumping and running assisted apparatus developed in 1890 by a Russian named Nicholas Yagin. As a unit, the apparatus used compressed gas bags to store energy that would assist with movements, although it was passive in operation and required human power. In 1917, United States inventor Leslie C. Kelley developed what he called a pedomotor, which operated on steam power with artificial ligaments acting in parallel to the wearers movements. With the pedomotor, energy could be generated apart from the user.

The first true [1] in the sense of being a mobile machine integrated with human movements was co-developed by General Electric and the United States Armed Forces in the 1960s. The suit was named Hardiman, and made lifting 110 kilograms feel like lifting 4.5 kilograms. Powered by hydraulics and electricity, the suit allowed the wearer to amplify their strength by a factor of 25, so that lifting 25 kilograms was as easy as lifting one kilogram without the suit. A feature dubbed force feedback enabled the wearer to feel the forces and objects being manipulated.

One of the main applications would be medical by improving the quality of life of persons who have, for example, lost the use of their legs, by providing assistive technology to enable system-assisted walking or restoration of other motor controls lost due to illness or [4].

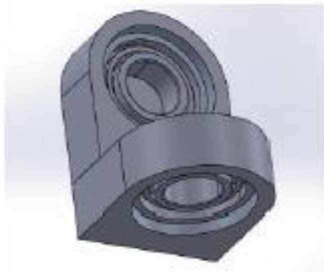
Another area of application could be military. It can help to decrease fatigue and increased productivity whilst unloading supplies or enabling a soldier to carry heavy objects while running or climbing stairs. It can also help the soldier to wear heavy armours, carry more arms and ammunition

II. DESIGN OF EXOSKELETON FRAME

The Frame of the [1] is the crucial part of the structure as it holds both the wearer as well as the actuating components along with its own power supply module. While designing the frame major factors such as weight and strength of the material were kept in mind. Aluminium is used as the raw material in mist of the components of the project to keep the weight in check. Instead of milling aluminium blocks or ingots to get the required shape as in conventional [1]architecture, a tubular frame with threaded joints was selected in order to ensure versatility and to cut down machining costs.

A. PERPENDICULAR BEARING BLOCK

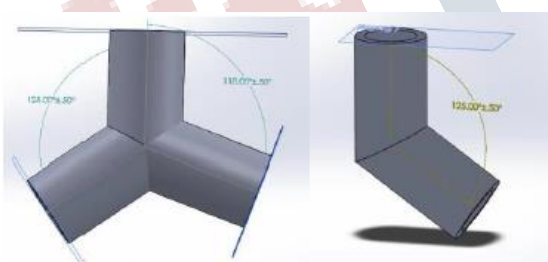
The perpendicular bearing block is one of the major components of the [1] frame as it is the part that connects the components on the sagittal plane with the connecting member of the horizontal plane. The assembly consists of two bearing housings whose bearing axes are placed 90 degrees apart from each other. They are welded adjacent to each other using an aluminium right angle shank. The design of the component was created using Solid works 2016.



Perpendicular Bearing Block

B. ANGLED JOINTS

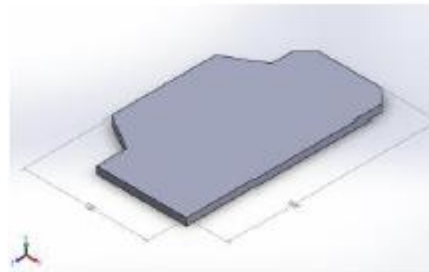
As per the design calculations, the various angles that are required for low power consumption actuation are fabricated using Mild Steel Couplings. Two of these joints are required for one side of the frame. One of these joints consists of three couplings which are placed 110 degrees and 125 degrees apart from the centre coupling to achieve the required design criteria. The other joint is a two sided joint and has a coupling welded at an angle of 125 degrees from the centre coupling. The two sided coupling joins the components of the ankle joint whereas the three sided coupling holds the components of the knee joint. Threaded joints are used so that the aluminium frame members can be attached to form the exoskeleton. The design of the components was created using Solid works 2016.



Angled Joints

C. BASE

The base of the [1] is the important part of the frame as it accommodates all the components of the [1] such as joints, actuators and rotary components along with the entire weight of the payload and operator. The base is made up of aluminium plate of 3mm thickness. The geometry of the base is selected such that the surface area of the base is much larger than that of the human foot such that the balance of the exoskeleton is maintained during operation by keeping the centre of gravity of the entire body within the base. The base also acts as the hosing for two of the eight actuators used in the exoskeleton. The design of this component was created using Solid works 2016.



Base

D. FINAL ASSEMBLY

The joints used in the exoskeleton are threaded joints which ensure easy mounting and removal. If the length of the leg dimensions of the operator is changed, the length of the shank can be changed by replacing an existing shank with the corrected length. The assembly of the various components of the exoskeleton was carried out using Autodesk 123D.

Assembled View

III. WORK MATERIAL

The work material used is Aluminium alloy 1100. The 1100 Aluminium alloy is an Aluminium-based alloy in the "commercially pure" wrought family (1000 or 1xxx series). With a minimum of 99.0% Aluminium, it is the most heavily alloyed of the 1000 series. It is also the mechanically strongest alloy in the series, and is the only 1000-series alloy commonly used in rivets. At the same time, it keeps the benefits of being relatively lightly alloyed compared to other series, such as high electrical conductivity, thermal conductivity, corrosion resistance, and workability. It can be strengthened by cold working, but not by heat treatment.

Element	Content (%)
Aluminum	99-99.5%
Copper	0.05-0.20%
Iron	0.95% max
Manganese	0.05% max
Silicon	0.95% max
Zinc	0.1% max
Residuals	0.15% max

Chemical Composition

IV. WORKING

TWO CHANEL RELAY MODULES

Since a single relay can only be in one of the two states at any given time, NO and NC, it is not possible to establish bidirectional motors control using them. Therefore two relays are used simultaneously for clockwise and counter clockwise. Both of the relays are controlled by the 5V,15-20mA driver current from the arduino.

The rated capacity for the relays is
AC supply: 250V, 10A
DC supply: 30V, 10A

Since the capacity of the actuator motor does not exceed 12V and 7A, it is within the rated capacity for the relay to handle.

CONTROL LOGIC

The simulation of gait cycle by HELEX is based on the 8 actuators at various strategic positions and a synchronized on or off of the various actuator motors after defined period of delays with the push of a button. The motors can be rotated in either clockwise or counter clockwise

STEPS INVOLVED IN WORKING

Step 1: Start
Step 2: Detect button press.
Step 3: Actuate the motors Hip abduction left in clockwise direction and hip abduction right in counter clockwise direction to shift the weight towards left.
Step 4: Actuate hip right in counter clockwise direction to move the right leg.
Step 5: Actuate knee right in counter clockwise direction to shorten it.
Step 6: Actuate ankle left in counter clockwise direction to balance the body on the right leg.
Step 7: Actuate knee right in clockwise direction.
Step 8: Actuate hip abduction right actuator in clockwise direction and hip
abduction left in counter clockwise direction to shift the weight towards right.
Step 9: Actuate hip left in clockwise direction to move the left leg.
Step 10: Actuate knee left in counter clockwise direction.
Step 11: Actuate Hip left in counter clockwise direction.
Step 12: Actuate knee left in clockwise direction.
Step 13: Actuate Ankle left actuator in counter clockwise direction.

V. PROGRAM CODE

```
#define IHL A0
#define OHL A1
#define IKL A2
#define OKL A3
#define IAL A4
#define OAL A5
#define IHAL 2
#define OHAL 3
#define IKR 4
#define OKR 5
#define IAR 6
#define OAR 7
#define IHAR 8
#define OHAR 9
#define IHR 10
#define OHR 11
void setup() {
pinMode(IHL, OUTPUT);
pinMode(OHR, OUTPUT);
pinMode(IKL, OUTPUT);
pinMode(OKL, OUTPUT);
pinMode(IAL, OUTPUT);
pinMode(OAL, OUTPUT);
pinMode(IHAL, OUTPUT);
pinMode(OHAL, OUTPUT);
pinMode(IHR, OUTPUT);
pinMode(OHR, OUTPUT);
pinMode(IKR, OUTPUT);
pinMode(OKR, OUTPUT);
pinMode(IAR, OUTPUT);
pinMode(OAR, OUTPUT);
pinMode(IHAR, OUTPUT);
pinMode(OHAR, OUTPUT);
```

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```
}
void loop() {
digitalWrite(OHAL, HIGH);
digitalWrite(IHAR, HIGH); //Leans towards left//
delay(1800);
digitalWrite(OHAL, LOW);
digitalWrite(IHAR, LOW); //right leg forward//
digitalWrite(IHR, HIGH);
delay(2000);
digitalWrite(IHR, LOW);
digitalWrite(IKR, HIGH);//right knee bends//
delay(1500);
digitalWrite(IKR, LOW);
digitalWrite(IAL, HIGH);//body moves forward//
delay(1000);
digitalWrite(IAL, LOW);
digitalWrite(OHR, HIGH);//right leg straightens
delay(2000);
digitalWrite(OKR, HIGH);
delay(1500);
digitalWrite(OHR, LOW);
digitalWrite(OKR, LOW);
digitalWrite(OHAR, HIGH);//body leans right//
digitalWrite(IHAL, HIGH);
delay(1800);
digitalWrite(OHAR, LOW);
digitalWrite(IHAL, LOW);
digitalWrite(IKL, HIGH);//left knee bends//
delay(1500);
digitalWrite(IKL, LOW);
digitalWrite(IHL, HIGH);//left leg moves forward//
delay(2000);
digitalWrite(IHL, LOW);
digitalWrite(OHR, HIGH);//left leg straightens//
delay(2000);
digitalWrite(OKR, HIGH);
delay(1500);
digitalWrite(OHR, LOW);
digitalWrite(OKR, LOW);
}
```

VI. RANGEOF MOTION

The HELEX kinematics are close to human kinematics so the HELEX joint ranges of motion are determined by examining human joint ranges of motion. At the very least, the HELEX joint range of motion should be equal to the human range of motion during walking, which can be found by examining Clinical Gait Analysis (CGA) data. Safety dictates that the HELEX range of motion should not be more than the operator's range of motion. For each degree of freedom, the second column of Table lists the HELEX range of motion which is in general larger than the human range of motion during walking and less than the maximum range of human motion

	HumanWalking Maximum (deg)	HELEX Maximum (deg)
Ankle Flexion	14.1	14.7
Ankle Extension	20.6	20.3
Knee Flexion	73.5	59.5
Hip Flexion	32.2	20.4
Hip Extension	22.5	20
Hip Abduction	7.9	8
Hip Adduction	6.4	8

VII. ADVANTAGES OF HELEX

- The [1] has a pseudo anthromorphic architecture in which joints may look similar to that of a humans but the method of actuation is different.
- HELEX has totally Five degrees of freedom with two degrees of freedom at the hip, one degree of freedom in the knee (Along the Sagittal Plane), and two degrees of freedom at the ankle allowing it to perform most of the tasks carried out by a normal human being.
- In order to maintain the centre of gravity of the exoskeleton and the wearer to prevent falling, a wide base is selected which has plenty of room for actuator mounting and to safely place the wearer's foot without directly coming in contact with the actuator.

Final Assembly

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VIII. CONCLUSION

The Hominal Enhancement Lower Extremity Exoskeleton can also be used for [5] purposes by allowing the wearer performs various stances.

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The [1] has the ranges of motion as that of human beings and the angle of travel of various joints such as hip; knee and ankle are slightly less than that of the average human being so as to ensure that the [1] does not harm the wearer accidentally.

Majority of the components of the [1] is fabricated using Aluminium as raw material with the exception of certain strategic load bearing elements which are fabricated using Mild Steel. These load bearing elements include the clamps used for integration of DC motor with the power screw, the angled joints used in the frame and the cradle bearing the power supply.

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