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Design, Analysis and Fabrication of Walking Assistant for physically challenged people

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ABSTRACT

In recent years, exoskeletons have become one of the key areas in research. Even though many successful design of exoskeleton have done by many companies and research scholars, walking assistance for children are less and infrequent and expensive. This paper aims at design of walking assistant device for physically challenged children ages at 6 to 15 years old in an economical price. It can be used for two purposes: as walking practice and walking assistive device. The key feature of project is use of Arduino board as microcontroller to control stepper motor (NEMA34) linked to joints and links, which swings to make leg movements. It can be used with both SMPS and battery according to the convenience of the user.

Keywords: Exoskeleton, Walking Assistant, Robotics, Electric motor.

1. INTRODUCTION

Exoskeletons have got huge attention now a days. It has been used in military [1], rehabilitation [2] and medical assistance [3]. In military [4] it has been used to lift weight and to carry large weapons and as a guard. On the other hand, these are used medically for assisting the patients [5], who are injured during accidents in their spinal cord and to the old people [6] [7]. The graph represents the rise in number of people above 60 years [8]. From graph, it is evident that number of people in 2050 would be more than one billion. Hence, there will be great need for exoskeletons, which would help them to walk independently without anyone's help.

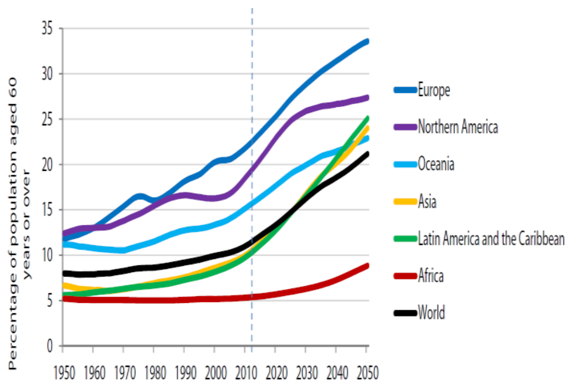

Fig. 1 Percentage of the population aged 60 years or over, estimated for 1950- 2050 [1]

There are many commercially available exoskeleton such as MIT exoskeleton, BLEEX and HAL. BLEEX has seven degree of freedom, one at knee, 3 DOF's at the hip and 3 at ankle. It follows sensitivity amplification controller strategy. Design is based on 75 kg human and clinical gait analysis data [9] but, wearer have to hold the weight of back pack that has controller and power unit.

MIT exoskeleton has followed pelvic harness technique [10], which will reduce the weight of back bag by transferring it to the ground due to linkages in the pelvic area. It has springs to add power to the joints [11]. HAL comes in different models and many purposes such as rescue support rehabilitation, labor support and entertainment [12]. It is based on electro myography signals from electrodes attached to the skin [13], which uses power and controller in its backpack to operate. Following this there are other walking assistive devices such as re-walk [14], e-legs [15] commercially available.

Major drawback of these devices is, it is not economical and some have problem of weight laid on the wearer. Hence, our design scope is to make a cost effective and economical exoskeleton with less weight carried by the wearer. First, the paper undergoes design stage of exoskeleton, then it follows selection of motor and analysis. Finally results are discussed.

2. DESIGN OF THE EXOSKELETON

Previous works regarding the successful design of lower limb exoskeleton [16] [17] were taken into account, while designing our lower limb exoskeleton and some of the basic concepts of design is derived from these examples, parameters such as, length of link ,motor range, joints, gear and harness.

Initially selection of motor is done and design of walking assistant followed concurrent steps of designing structure, joints and mounting clamps. Some basic requirements such as height adjustments, angle and speed limit are taken into account.

1.1 Selection of Motor

Selection of motor is one the crucial situation in exoskeleton process because whole exoskeleton is depend on the motor and drive. Hence, different motors available in market are explained and selected motor for our exoskeleton is justified.

1.1.1. Servo Motor Vs Stepper Motor

Basic difference between these motor is number of poles available, stepper has 50 to 100 poles without encoder attachment and servo has 4 to 12 poles with encoder attachment. Encoder is used to know exact position due to less number of poles in servo motor.

In our case, angle should be precise and holding torque should be more and weight should be less. So, stepper motor has precise angle control and less weight than its servo counterpart. It has added advantage of producing high torque in less speed .Hence bipolar stepper motor have been selected for this application.

1.1.2. Motor Rating and Torque

Table 1, shows different children of different ages, their weight, height of hip to knee and knee to ankle from a sample of 30 children. Children are grouped due to similar measurements in the intermittent ages and average result from each group are taken into account. In order to specify the torque requirement for our each joint, we have taken results of Royer TD el al. (2005) and Kerrigan et al. (2000) work in derivation of torque.

For instance, the 80 kg and 1.80 m height man would require 45 Nm to walk but, we require torque for people with weight below 40 kg. Hence, NEMA bipolar motor of rating 34 kg cm torque and current ratings of 4 amps is selected, which will produce 3.4 Nm in order to amplify torque, an attachment of planetary gear box of ratio 10:1 is added to it, which will provide the required torque. The planetary gear box have different varieties like 3:1,5:1,10:1 or 20:1, we selected 10:1,which is appropriate for the application. It will increase torque by reducing speed

Table 1 Categorization of children with different age group

Age group (average)	Hip to knee (average) (mm)	Knee to ankle (average) (mm)	Foot (average) (mm)
5-8	267	318	152
9-12	350	330	178
12-15	410	380	203

1.2. Design of Structure

Initially, weight of motor, driver, battery, and transformer for power supply, were taken into account. Each motor weighted about 185 kg and driver weighted 0.3 kg for each set and transformer weights about 3kg. Whereas, there are four sets of motors and drivers. Hence by taking these into consideration, we have designed a base structure with square iron tube of the thickness 2mm as shown in figure 2. Several supports are given at the joints and welded in order to hold the whole weight and wheels are provided at the bottom for movement. We have avoided cross triangulation instead, we made short triangulation which serve the purpose.

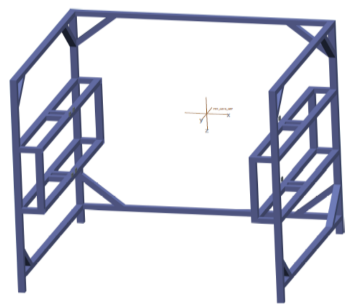

Fig. 2 Design of main frame

1.3. Design of Links and Joints

Links are the important parts that transfer power from motor to the leg of human, hence it should designed in a manner to transfer whole power produced by the motor without any loss. During walking action links have to move adjust slightly in vertical direction for convenient movement of legs due to change of angle during movement. The link material used is aluminum 6025.

Fig. 3 Links attached with one another with aluminum rivet

Table 2 Length of links 1, 2 and 3

LINK	LENGTH OF LINK (mm)
LINK 1	275
LINK 2	170
LINK 3	100

Especially, this 6000 series aluminum is selected due to the economic cost and easy machining. The weight of aluminum 4000, 5000 series would have weighed less due to its low density but, it is not economical and availability in market is less. The mounting of motor to link is also made with same metal as used for links. The density of the metal comes around 2.8 g/cm^3 and elastic modulus comes with 70 Gpa, Which is the appropriate range for the application. Aluminum rivets are used to joint different links and motor to one another. In the final link there is cavity given for the harness, which will stick the link to the thigh and the calf muscle. All the links were designed in Creo and sent to CNC for machining.

3. CONTROLLER FOR THE EXOSKELETON

3.1 Motor Drive

Since, motor with 4 amps is selected, driver must be 4 amps or above. Hence 4.5 amps driver is selected as shown in figure (4), which would control the amount of current passing through motor. It has various micro stepping options ranges from 2 to 250. There are eight switches are provided in the drive in which first three switches are used to regulate current, fourth and fifth switches are used according to half and full current and other three switches are used to attain micro stepping. There are fourteen micro stepping options are available in the drive. By making switch on and off, we can change pulse per revolution, which eventually changes stepping of motor.

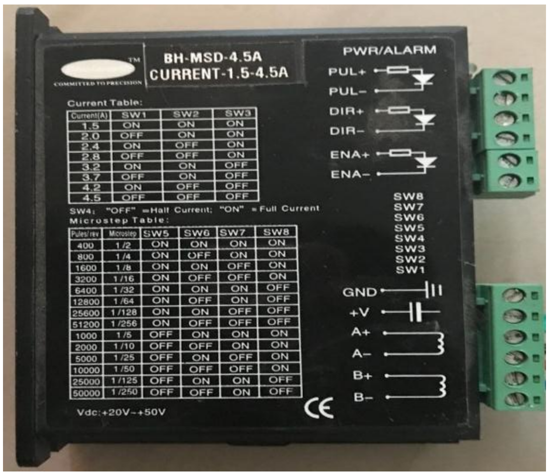

Fig. 4 12V and 4.5 amp motor drive

3.2 Arduino

The Arduino is used as microcontroller for the exoskeleton, we have options for microcontroller such as PLC, Raspberry Pi etc. but, we selected Arduino due to its accuracy ,simple programming method and wide number of add on attachments like sensors and joystick that may rooted in the future. It can be coded with both c and c++ program. The Arduino is connected to the drive which controls the motor angle and rpm. The change of angle, while walking is measured manually, and also with potentiometer using Arduino. Finally angle is derived and programmed to Arduino, which sends signal to the drive makes motors to rotate clockwise and anticlockwise that makes links attached to thigh and cough muscle to move, eventually makes man to walk.

4. ANALYSIS

Analysis of different links and joints are done with HYPERMESH. The models that are designed in Cero are imported to the HYPERMESH and maximum forces are applied in the each ends of the joints, links and to the structure, their stress and strain reports are analyzed using HYPERMESH.

Hence figure (5-9) shows that all the links are in the safe zone. Initially, links with different thickness are analyzed, which showed maximum amount of stress region in the link. Every time thickness of the link is raised slightly and observed various results in HYPERMESH. Finally, link of 100mm thickness is derived, which showed safe zone in the entire link and the design is subjected to manufacturing. In structural analysis, more stress is seen in the edges due to load of motor and weight of wearer. Hence triangulation is given at the each edge of the frame. After application of support, stress distribution is throughout the frame and passes to the ground that makes it to be in safer zone as shown in figure (5). As a result, there is no over stressed areas and all parts of exoskeleton are in safe zone, which is ready to operate at full load.

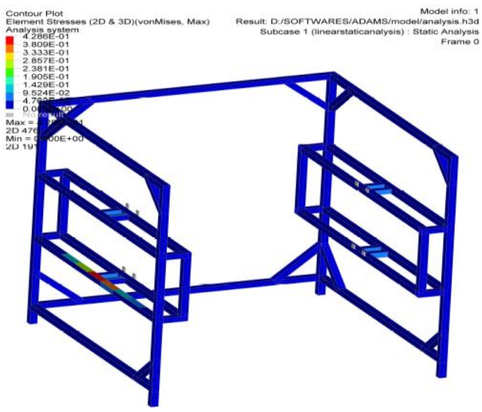

Fig. 5 Stress analysis of frame setup

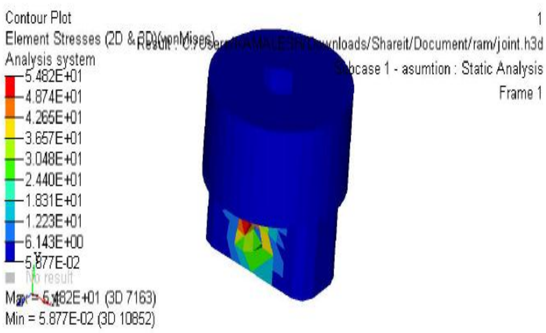

Fig. 6 Stress analysis of motor link

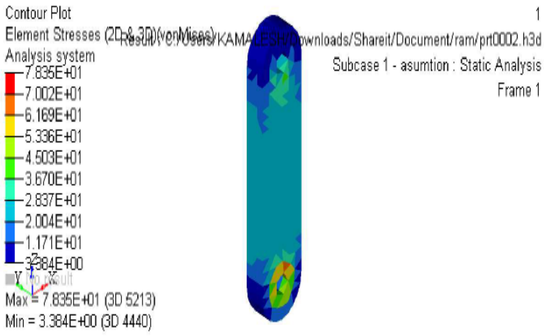

Fig. 7 Stress analysis of Frame 1

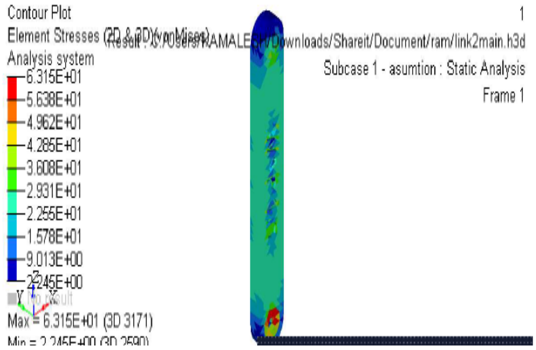

Fig. 8 Stress analysis of Frame 2

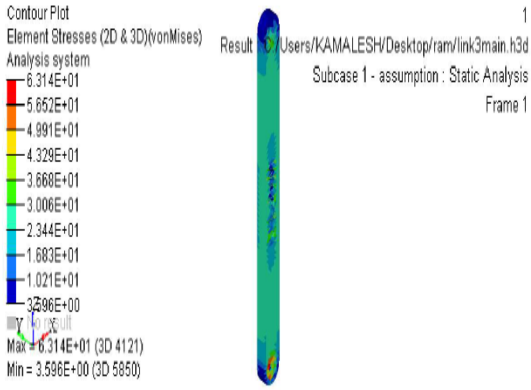

Fig. 9 Stress analysis of Frame 3

5. CONCLUSION

Thus, the required movement of the leg has been formulated. Use of NEMA motor with planetary gears along with drive and Arduino as micro controller has highly reduced cost of the exoskeleton. Angle of motor and speed of motor can changed easily by changing the value in Arduino program. The whole setup along with transformer as power supply has come around 80k INR, which is negligible compared to other exoskeletons such as HAL, Re-Walk etc. Mounting of links, drivers and motor to the frame makes fewer burdens to the wearer, which is an added advantage of this design. Final setup is as shown in figure 10.

6. FUTURE WORK

Mounting of sensor to the motor to know the exact angle of motor and joystick for the manual control of motor are some of the future works.

Fig. 10 Final setup after assembly

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