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PNEUMATIC MUSCLE ACTUATOR

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ABSTRACT: *Today's world requires speed on each and every field. Hence rapidness and quick working is the most important. Nowadays for achieving rapidness, various machines and the equipments are manufactured by the man. Robotic exoskeleton is getting important to human in many aspects such as power assist, muscle training, regain motor function and rehabilitation. The research and development towards these functions are expected to be combined and integrated with the human intelligent and machine power, eventually becoming another generation of robot which will enhance the machine intelligent and human power. This paper reviews the upper extremity exoskeleton with different functions, actuators and degree of freedom (DOF). Among the functions, rehabilitation and power assist have been highlighted while pneumatic actuator, pneumatic muscle, motor and hydraulic actuator are presented under the categories of actuator. In addition, the structure of exoskeleton is separated by its DOF in terms of shoulder, elbow, wrist and hand.*

Key Words: Rapid, Power Assist, Rehabilitation.

INTRODUCTION

As humans, we constantly use our bones and muscles to accomplish everyday tasks. To some, using their muscles is strictly for accomplishing necessary tasks; to others, they may just enjoy the feeling of building up a good sweat from exercise. Regardless of the reasoning, it is vital to utilize your muscles and exercise them for a long and healthy life.

Certain situations in life however bring a need to exercise for a specific purpose. This could mean just a general exercising of a certain limb for a particular task or even further controlling specific muscles to train for specific tasks. Examples of specific tasks could be training your legs for maximum endurance for a marathon run or even just a sense of basic mobility when coming back from space.

Regarding applications such as space, as humans inevitably extend their domains to the reaches of space; either travelling to Mars, a space station, etc., they must account for the effects of micro-gravity on their bones and muscles. A human's physiology adapts to the physical environment they are currently in. As this environment changes from an Earth to a micro-gravity environment such as space, this leads to muscle atrophy and bone loss due to the loss of the constant force of gravity.

In humans, there is a system of cells that work in unison to break down old bone and create new bone in its place. The cells that reabsorb and break down old bone are Osteoclasts and the cells that build new bone are Osteoblasts. The cells for a normal, healthy adult on Earth work to create an equilibrium where the rate of bone loss is equal to the rate of bone creation. New bone is normally deposited in proportion to the compressional loads directed on a bone.

In space however, with little to no applied loads due to micro-gravity, bone formation decreases and net bone loss occurs. Some causes of bone loss on Earth (osteoporosis) occur due to age, lack of physical activity, malnutrition, and lack of oestrogen secretion in women after menopause. For either a space or earth based bone loss case, it is useful to understand why bone loss occurs to find a solution for this problem.

OBJECTIVES

1. Design and analysis of Pneumatic Actuator Mechanism.
2. The proposed exoskeleton uses a dynamic model of the musculoskeletal system of the lower leg combined with the dynamics from a pneumatic actuator to provide resistive forces to the muscle forces.
3. To make affordable treatment of disability.
4. To help activate muscles and maintain blood flow.
5. To provide physiotherapy 24/7.
6. The exoskeleton will use a quasi-dynamic (useful for slow to moderate human movement speed) force-feedback control method to determine how the pneumatic actuators should apply forces at desired positions and times.

LITERATURE REVIEW

1. **Alex Ansari, Christopher G. Atkeson, Howie Choset, and Matthew Travers Carnegie Mellon University "A Survey of Current Exoskeletons and Their Control Architectures and Algorithms (Draft 4.0)" Issue: October 1, 2015**

The importance of producing hardware that is physically capable of achieving dynamic performance is fundamentally linked to how mass is distributed throughout the system.

Directly measuring user intent is difficult to implement using standard sensing modalities. For instance, EMG data is notoriously noisy and presents both modelling and calibration challenges. It would also be extremely difficult to keep these sensors in place to obtain accurate readings in dynamic environments or activities.

The design objective is often achieved by focusing actuation and leaving certain degrees of freedom passive (leading to an under actuated system). Under actuated control is a complicated problem that is often ignored in the sense that controllers assume the operator will provide.

2. **A Thesis Presented to The Academic Faculty , Gregory Clark Henderson ,In Partial Fulfillment of the Requirements for the Degree Master of Science in the School of Mechanical Engineering ,Georgia Institute of Technology, "PNEUMATICALLY-POWERED ROBOTIC EXOSKELETON TO EXERCISE SPECIFIC LOWER EXTREMITY MUSCLE GROUPS IN HUMANS" Issue:- March 20th, 2012**

It has been determined that muscle forces cannot be controlled directly and can only be controlled indirectly through an external force such as a pneumatic actuation. To indirectly control this force, an iterative method was devised to solve for the inverse of the minimization problem that the nervous system accomplishes normally to determine how much a muscle should activate for a certain external torque needed at a certain moment arm of the muscle.

The data is promising and prompts interest into further research to determine reasons of error

in the EMG signals and slowly eliminating or lessening them. This could then result in a system that is able to impose more fine-tuned realization of different muscle forces of the muscles.

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3. **Kwok-Hong Chay, Jer-Vui Lee, Yea-DatChuah and Yu-Zheng Chong ,Department of Mechatronics and Biomedical Engineering, Faculty of Engineering and Science, UniversityTunku Abdul Rahman, Kuala Lumpur, Malaysia "UPPER EXTREMITY ROBOTICS EXOSKELETON: APPLICATION, STRUCTURE AND ACTUATION", (IJBES), Vol. No 1, Issue:-. 1, April 2014**

The development of exoskeleton benefits the human which includes weaknesses or healthy people. In this paper, rehabilitation and power assist robots have been reviewed. The robotic exoskeleton can help physical weak or motor function reduced patient to regain their movement. In additional, it can help healthy people to train up their strength or to distribute out the weight gained by the users. The motor actuator has the advantages of easy control and good accuracy while pneumatic actuator has the advantage of spend zero power in holding the position of robot. Furthermore, the pneumatic muscle mimics the human muscle perfectly while the hydraulic actuator gives high power output.

1. **Irshaidat, MAE, Soufian, M, Al-Ibadi, A and Nefti-Meziani," A novel elbow pneumatic muscle actuator for exoskeleton arm in post-stroke rehabilitation" Conference or Workshop Item, Issue:- 2019**

The goal of this paper is to introduce a soft robotic arm that can independently be used by individuals who suffer from lack of mobility due to stroke or other similar disabling illness. One of the major future work and aims in developing such a solution is to create a rehabilitation device that is portable, easy to use at home so that users can practice intensive rehabilitation without therapists at home in parallel with daily living activities.

2. **DARWIN G. CALDWELL∗ and N. G. TSAGARAKIS, Italian Institute of Technology, Genève, "SOFT EXOSKELETONS FOR UPPER AND LOWER BODY5 REHABILITATION — DESIGN, CONTROL AND TESTING" IJHR, Issue:- September 4, 2007**

In these paper issues through the development of lightweight upper and lower body systems that are powered by braided pneumatic muscle actuators (PMAs) which provide systems with high power, good control, accurate motion and compliant behaviour that permits a soft, and therefore safer, interaction with the user. These systems are shown to be able to augment the power of users (either able-bodied or unwell) providing up to 100% assistance for seven DOFs in the arm and five DOFs in the legs. Along with the above functionality, the system was designed to meet the specifications of lightness, gravity compensation, ease of fitting and adjustment and relatively low mechanical complexity, which are essential for any system that is in direct contact with the human operator.

METHODOLOGY

- We are developing a pneumatic exo-arm for handicapped or specially-able person. So we use a pneumatic actuator mechanism attached to a body frame as follows.
- First we make mild steel frame which is of the size 20*20*3 mm square hollow angle for body frame.
- This frame is as per our body shape and, hence, is a rectangular shape. Size of body frame is mentioned as per drawing.
- Then we make right hand arm by using kinematic pair mechanism, and we make 8 mm drill holes for mounting of actuator and link joint.
- We use dual acting actuator for arm motion. This actuator is then mounted on the frame.
- Then we attach 230V operated 5/2 Direction Control Valve on the frame for reciprocating motion of actuator.
- We use an actuator with dimensions 20 mm diameter and 150 mm stroke for motion.

COMPONENTS

(ALL DIMENSIONS IN mm, unless mentioned)

1. **Mild Steel Angle (20x20x3)**

Fig. - Mild Steel Angle

A mild steel angle is a L- shaped cross-section used in the construction of buildings and structures. The most commonly used MS Steel angles are the ones forming a 90-degree angle with two sides of equal length and width. The angles uniform slides are called equal angles and the ones with one side bigger than the other are called unequal angles.

2. **Square Hollow Pipe (Standard)**

Fig. - Square Hollow Pipe (Standard)

Square hollow sections or square tubes are cold formed and welded form either hot rolled, cold rolled, pre-galvanized or stainless steel.

In order to form the square steel section the appropriate mother tube, a round steel tube, has to be formed first. From a round tube rolls are used that progressively press the round tube into a square hollow section.

3. **Mild Steel Strip (25x3)**

Fig. - Mild Steel Strip

Mild steel is a type of low-carbon steel that is widely used for vehicle bodywork and chassis construction.

4. Nut & bolts (M4, M5, M6)

Fig. - Nut & bolts

Nut - A small block with internal screw thread to be fitted onto a bolt.

Bolt - A screw that screws into a nut to form a threaded bolt.

5. Pneumatic Actuator (20, stroke-100)

Fig. - Pneumatic Actuator

Pneumatic Actuator is a device that converts the energy of compressed air or gas into a mechanical motion that regulates one or more final control elements.

6. Pneumatic Hose(s)(O.D.= 8mm, I.D.= 6mm)

Fig. - Pneumatic Hose(s)

Pneumatic hose and tubing is used to deliver pressurized air to where its needed, such as tools, valves, and actuators,... Pneumatic hose is usually made up of an inner tube, one or several layers of reinforcing fiber and an outer protective cover.

7. Pneumatic fittings (8mm)

Pneumatic fittings are parts used to connect sections of pipe, tube, and hose in pneumatic systems.

8. Flow Control Valve (Standard)

Fig. - FLOW CONTROL VALVE (Standard)

A Flow control valve regulates the flow or pressure of a fluid. Control valves normally respond to signals generated by independent devices such as flow meters or temperature gauges.

9. Plastic Strap Locks (Standard)

Fig. - Plastic Strap Lock (Standard)

A strap lock is a device that secures onto the element so that it won't inadvertently fall off, allowing the instrument to plunge to the floor.

10. Directional Control Valve (5/2)

Fig. - Directional Control Valve (5/2)

Directional control valves are one of the most fundamental parts of hydraulic and pneumatic systems. DCVs allow fluid flow into different path from one or more sources.

11. Belt (1inch)

Fig. - Belt

A belt is a flexible band or strap, typically made of leather, plastic, or heavy cloth, worn around the natural waist or near it.

12. Compressor

Fig. Compressor

A compressor is a device that increases the pressure of a substance by reducing the volume of the substance.

CONSTRUCTION

1. M.S. square angle frame is used. Smaller frame (strip) is used to support it.
2. Plastic belt is attached to lock hand and leg mechanism.
3. Mount an pneumatic actuator of 20mm dia. On hand and leg part, using nut-bolts.
4. Install Pneumatic Fittings for reverse and forward stroke for air inlet. Attach pneumatic pipe to the fittings.
5. Connect Directional Control Valve having 5 ports and 2 flow positions to actuator through pneumatic pipe.
6. Attach Direction Control Valve to M.S. frame by nut-bolt.
7. Compressor input 2.5kg air. 2.5 x 10> 3
8. Place Flow control valve in fittings, one on each actuator.(To avoid sudden contraction Flow control valve is used)
9. Complete the setup by attaching the mechanism to a Compressor having output ofat least 2.5kg air i.e. 2.5 x 10^3 Bar.

WORKING

- We use two joints for exo-skeletal arm: one for arm and second for forearm, and other three supports for body.
- We strap that skeleton model on body with the help of lock belt so arm works smoothly and comfortably.
- We then attach 5/2 Direct Control Valve for actuator and its motion.
- Because of this valve we can change the direction of the actuator.
- First with the help of compressor, compressed air is derived, then this air is passed through the 5/2 Direct Control Valve.
- When we operate the electrical switch and switch it on and off, the Pneumatic Actuator will reciprocate as per switch operation.
- For slowing down the motion of the operation we use air flow control valve.

- Because of that arm will goes slowly upwards and slowly downwards, so that the scope of getting injury of the arm or any joint is completely eradicated.

CONCLUSION

- The development of exoskeleton benefits the human which includes weaknesses or healthy people. In this paper, rehabilitation and power assist robots have been reviewed.
- The robotic exoskeleton can help physical weak or motor function reduced patient to regain their movement. In additional, it can help healthy people to train up their strength or to distribute out the weight gained by the users.
- Pneumatic actuator, pneumatic muscle, motor actuator and hydraulic actuator are found to be commonly used in research study about actuator among exoskeletons.
- The motor actuator has the advantages of easy control and good accuracy while pneumatic actuator has the advantage of spending zero power in holding the position of robot.
- The overall performance of the pneumatic mechanism was satisfactorily fulfilling.

REFERENCES

- **Alex Ansari, Christopher G. Atkeson, Howie Choset, and Matthew Travers Carnegie Mellon University "A Survey of Current Exoskeletons and Their Control Architectures and Algorithms (Draft 4.0)" Issue: October 1, 2015**
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