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DESIGN AND FABRICATION OF PNEUMATIC MUSCLE ACTUATOR

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ABSTRACT: *Pneumatic Muscle Actuator (PMAs) are mobile and flexible linear pneumatic actuators which produce human muscle like actuation. Due to these properties, the muscle actuators have an adaptable compliance for various robotic platforms as well as medical applications. While a variety of possible actuation schemes are present, there is still a need for the development of a mechanical actuator that is very light-weight, compact, and flexible with high power-to-weight ratio. To achieve this, the development of the PMA actuators has become an interesting topic for many researchers. In this research, the development of the different kinds of PMA available to date are presented along with manufacturing process and the operating principle. The various force models for artificial muscle presented in the literature are broadly reviewed with the constraints. Furthermore, the applications of PMA are included and classified based on the fields of medicine, and industry, along with advanced medical instrumentation. Finally, the needful improvements in terms of the dynamics of the muscle are discussed for the precise control of the PMAs as per the requirements for the applications. This study will be helpful for researchers working in the field of robotics and for designers to develop new type of artificial muscle actuator depending on the applications.*

Key Words : *flexible, linear, adaptable*

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INTRODUCTION

As we know muscles are very important and supporting part of a human body as they support movement for lifting heavy weights and many basic function in our day to day life. It is vital to utilize muscle and excercise them for the betterment of your body and muscle. Some situations in life bring the need of excersie or an unexxpected disease like Paralysis where u wont able to move some of the body parts. There in comes the need of Muscle Actuator. Mechanical parts combined to form the model with its mobility and strentgh for the use of physically challenged body. Example of specific task could training your legs for maximum endurance for a marathon run or even just a sense of basic mobility when coming back from space and also physically challenged body. Mobility of this model favours the indivdual.The experimental characterization of the muscle gives the relationship between actuation pressure, maximum contraction, and blocked force. These tests also aid in comprehending factors such as compliance and hysteresis error. A pneumatic muscle actuator (PMA) is a type of actuator that uses compressed air or gas to produce motion. PMAs consist of a flexible, inflatable bladder, also called a pneumatic muscle, that expands and contracts in response to changes in air pressure. These muscles are made of materials like rubber or elastomer and are typically shaped like cylinders or tubes.

When pressurized air is supplied to the PMA, it expands and creates a pulling force that can be harnessed to move objects. When the air pressure is released, the PMA contracts and returns to its original shape. PMAs are known for their ability to produce smooth, fluid motion and can generate high forces in a compact space**.**

PMAs are commonly used in a variety of applications, such as robotics, prosthetics, and aerospace. They are also used in rehabilitation and physical therapy for human patients. Because they are lightweight and energy-efficient, PMAs have gained popularity in recent years as a cost-effective alternative to traditional actuators such as electric motors and hydraulic cylinders.

OBJECTIVES

1. Design and fabrication of Pneumatic Actuator Mechanism.
2. To provide resistive forces to the muscle forces.
3. To make affordable treatment of physically challenged body at home.
4. To help activate muscles and maintain blood flow.
5. To provide physiotherapy 24/7.
6. PMAs produce low levels of noise and vibration, making them suitable for applications where noise or vibration would be a problem

LITERATURE REVIEW

Larry E Miller, Angela K Zimmermann & William G Herbert (2016) Clinical effectiveness and safety of powered exoskeleton-assisted walking in patients with spinal cord injury: systematic review with meta-analysis, Medical Devices: Evidence and Research, 9:, 455-466, DOI: 10.2147/MDER.S103102

Powered exoskeletons are prescription devices comprising an external, powered, motorized orthosis that is placed over a person's paralyzed or weakened limbs for the purpose of facilitating standing, walking, climbing stairs, and performing activities of daily living. Powered exoskeletons are classified as class II medical devices by the US Food and Drug Administration.[Citation12] Although several systematic reviews of powered exoskeletons have recently been published,[Citation13–Citation15] there are no known meta-analyses that have examined the clinical effectiveness and safety of powered exoskeletons in spinal cord-injured patients. We report herein the first meta-analysis of powered exoskeletons in SCI patients and conclude that exoskeleton use allows safe ambulation in real-world settings at a physical activity intensity conducive to prolonged use and known to yield health benefits.

1. **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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2. **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)

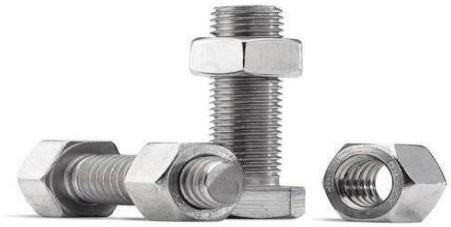


Fig. - Nut & bolts

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)

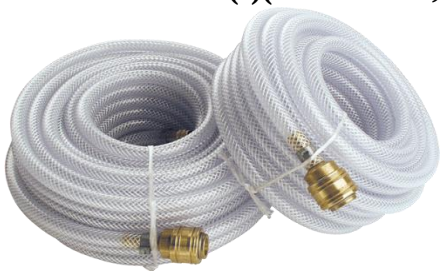
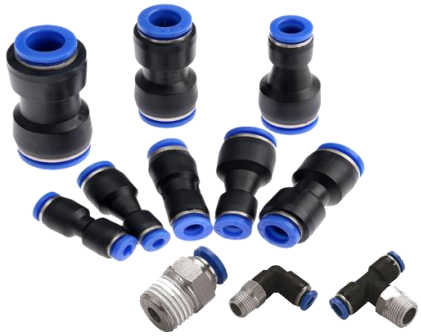


Fig. - Pneumatic Hose(s)

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.



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

7. Flow Control Valve (Standard)

Fig. - FLOW CONTROL VALVE (Standard)

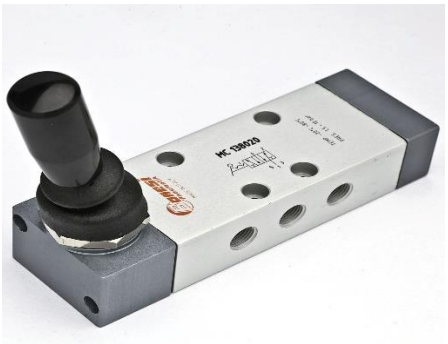
A Flow control valve regulates the flow or pressure of a fluid. Control valves normally respond to signals generated by independent devices such as flow meters or temperature gauges.

8. 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.

9. 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.

10. 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.

11. Compressor

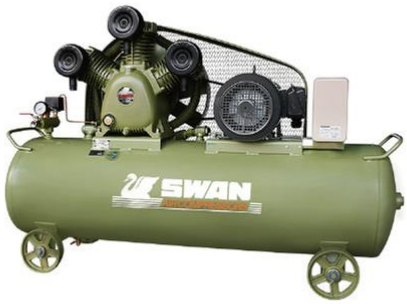


Fig. Compressor

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

- Firstly, PMAs can provide a more controlled and repeatable environment for rehabilitation exercises, which can help to ensure that the exercises are performed consistently and accurately. This can be especially important for individuals who may struggle to perform certain movements consistently or who need to maintain a particular level of intensity during their exercises.

- Finally, PMAs can be used in situations where physiotherapy is not available or not

possible, such as in remote locations or during a pandemic. This can provide individuals with access to rehabilitation and exercise programs that they may not otherwise have had access to.

- In conclusion, PMAs can offer several advantages over traditional physiotherapy methods, including a more controlled and repeatable environment for rehabilitation exercises, more targeted and specific resistance training, and the ability to provide rehabilitation in situations where physiotherapy is not possible.

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