

Exoskeleton Arm with Pneumatic Muscle Actuation

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ABSTRACT

For centuries now, humans have developed machines for tasks that are to labor intensive for species cannot do. Therefore, inventive imagination and delicate engineering have to concentrate on the improvement of the mechanical exoskeleton. A device can be worn over the human body. A mechanical exoskeleton empowers a hominid to perform responsibilities, which are outside the physical capacity by reinforcing the solid developments. We have laid out the way toward building up an exoskeleton arm that expands the heap-lifting limit of a human. The essential incitation of the exoskeleton relies upon the longitudinal compression of a gathering of Mckibben muscles or pneumatic air muscles (PAMs). As a size of this association, an enormous compression power created can perform outer work at an expedient rate. In any case, non-linearity exists as the weight changes in the bladder since its territory grows consistently to the square of the width. What's more, as the external sheath material moves, its length is reliant on trigonometric connections including the external sheath material, which are non-straight. Since one conclusion of the PAM is associated over the elbow joint of the framework and the inverse conclusion underneath the elbow joint. (PAM shapes the hypotenuse and biceps and lower arm shapes the other different sides of the triangle), the system plays out the lifting activity because of muscle constriction.

1. Introduction

One of the main uses for an exoskeleton would empower a soldier to lift heavy weights (80-200 kg) while running or climbing war fields. Exclusively, a soldier could carry additional weight; he could use heavier armor and weapons for suitable wielding. Most models use a laptop-associated degree-controlled mechanism. An internal combustion engine, batteries or fuel cells might power them. Another space of application might be treatment, nursing in particular. Faced with the approaching shortage of medical professionals and also the increasing range of individuals in senior care, teams of Japanese engineers have developed exoskeletons intended to help medical attendants lift and convey patients.^[1]

Exoskeletons may even be applied within the space of rehabilitation of stroke or neural structure injury patients. Such exoskeletons are generally conjointly referred to as Step Rehabilitation Robots. A body covering may scale back the number of experts required by permitting even the foremost-impaired patient to be skilled by one therapist, whereas several are currently needed. Also coaching might be additional uniform, easier to analyze retrospectively and can be definitely customized for each patient. At this point there are many comes planning coaching aids for rehabilitation

2. Literature Survey

General Electric developed the first absolutely utilitarian and groundbreaking exosuit in relationship with the United States Military during the 1960s, which lifted 110kg with exertion decrease by the factor of 10. However; pneumatic muscles were first created during the 1950s for utilization of counterfeit muscle and afterward popularized by Bridgestone Rubber (Japan) during the 1980s. It was then when PAMs were utilized in an exoarm.

"ALTACRO: a Step Rehabilitation Robot"[1]. ALTACRO is a multidisciplinary research project that goes for the advancement and clinical testing of a stage recovery robot controlled by agreeable actuators. The ALTACRO venture is a commitment to the cooperative energy between mechanical technology and recovery. The acronym stands for Automated Locomotion Training using an Actuated Compliant Robotic Orthosis.

Yagin, Nicholas.[2] Et Proposed "Apparatus for Facilitating Walking". Practicing mechanical assembly uncommonly adjusted for molding the cardiovascular framework, for preparing spryness or coordination of developments including a practicing of arms by at the same time practicing arms and legs, e.g. diagonally in anti-phase

Ralph Mosher[3] Et Engineer at General Electric Company proposed Claim to fame Materials Handling Products Operation, "On Hardiman Prototype For Machine Augmentation Of Human Strength And Endurance," Hardiman was the primary endeavor to assemble a handy fueled exoskeleton, by General Electric somewhere in the range of 1965 and 1971. The machine was proposed to enable the wearer to lift heaps of 1500 pounds (680 kg) easily.

R.A.R.C. Gopura, Kazuo Kiguchi[4] Et proposed "Mechanical Designs of Active Upper-Limb Exoskeleton exoarms State-of-the-Art and Design Difficulties", The best in a class of dynamic upper-appendage exoskeleton robots that are connected in the territories of restoration and assistive apply autonomy. In addition, the primary prerequisites of the dynamic upper-appendage exoskeleton robot are recognized and the mechanical plans of existing dynamic upper-appendage exoskeleton robot are grouped. The structure challenges of a functioning upper-appendage exoskeleton robot are talked about.

M.R Stalin John, Nirmal Thomas, V.P.R.Sivakumar[5] Et al proposed "Design and Development of Cable Driven Upper Limb Exoskeleton for Arm Rehabilitation" The framework was intended to make an expectation driven automated control approach, by which the exoskeleton can help the client to move the arm amid the restoration procedure. The miscreant model of an exoskeleton and its creation utilizing lightweight material and its kinematic investigation, Simulink recreation are clarified.

3. Problem Statement

Pneumatic exoskeleton framework is adjusted to facilitate the work and limit the worry of the prime zone for exoskeleton innovation. In this present focused world, there is an immense shortage of workforce, so there must be a choice to diminish this issue. Indeed, even in modern application, it needs numerous HR for everyday work and payload-taking technique is a ton away. Not all these above work should be possible, by primates.

The necessities of a functioning upper-appendage exoskeleton are distinctive as per the reason for the gadget. The upper-appendage exoskeleton exoarms likewise straightforwardly associate with the human client, security turns into a significant necessity. The exoskeleton for wrist movement help has given the tomahawks deviation of wrist flexion/expansion hub and wrist outspread/ulnar hub.

Development of the center of revolution of the condyloid joint in accordance with the upper-arm movements ought to be contemplated to clear out the wiped out effect brought about by that in style. In the event that upper-arm movements additionally must be helped by the exoarm just as lower arm movement, a component that permits moving of the focal point of revolution of the shoulder joint must be considered in the upper-appendage exoskeleton. This instrument is considered in to counterbalance the evil impacts brought about by the position distinction between the focal point of turn of the exoarm bear and that of the human shoulder.

The mechanical singularity should not occur within the workspace of the exoarm. Some styles have specially thought-about this in their styles. Although higher than explained necessary needs are consummated, researchers ought to contemplate the following aspects.

4. Objectives

- To reduce human efforts in terms of lifting weights
- To provide sophisticated prosthetics for handicap.
- Self-contained system.
- Invisible control approach.
- Fast in terms of velocity and strong in terms of force comparable to the human hand.
- To achieve 6 degrees of freedom observed in the biological hand.

5. Theory

4.1 Arm

One of the most style goals is to develop an exoskeleton arm that will operate safely within the presence of individuals, whereas still being comparatively robust and precise. In this context, "safe" is defined as not causing physical harm to a

nearby entity, even in the event of a collision. We approached this goal for the mechanical arm and hand in two ways: exploitation physically compliant mechanisms for the feat and coming up with the system with lightweight materials. This reduces the whole inertia within the system and allows mechanical compliance, both of which are ideal for a safe robot. As such, in the event of a collision, the arm will deflect and impart a minimal amount of force to a person or object in its path. Therefore, we tend to need to use associate degree mechanism that was each lightweight and automatically compliant. Consequently, series elastic actuators were a viable possibility, as they will exhibit each of those properties. Looking at gas systems, since the compressible nature of air permits for inherently compliant systems, we decided to use McKibben's muscle.

Air muscles because they are deformable, elastic, and physically lightweight. To minimize mass, we chose materials that had a high strength-to-weight ratio and that was easy to work with. For links, we used thin aluminum flat rods due to their very high strength-to-weight ratio and suitable precut lengths. The joints were fitted with nut and bolt arrangement.

4.2 Actuators

The arm is actuated by custom-built PAMs, which follow a McKibben type design wherein an expanding bladder causes a braided mesh sleeve to contract along its axis. Instead of using discrete bladder and mesh components, however, we used a fiberglass reinforced mesh tube with a layer of stretchable silicone bonded to the inner surface (Silicone Flex Glass, Techflex, Inc.). The muscles were fabricated by inserting a pneumatic plug into one end of the tube and an elbow connector inserted through the tube wall on the other end. These pieces were held in place by metal-reinforced ties. The excess tube on every finish was folded over and tied right down to type loops, both of which house a metal split ring onto which a swaged cable was fastened. The propulsion behavior of our gas muscle with completely different air pressures. Muscles were used either singularly or in bundles, depending on the loads experienced at each joint

4.3 Type of Actuation

4.3.1 PAM (Pneumatic Air Muscle)

McKibben air muscles were fictional for orthotics within the Nineteen Fifties. They have the benefits of being light-weight, simple to fabricate, area unit self-limiting (have the most contraction) and have load-length curves like a human muscle. The muscles consist of a silicon inner tube/bladder inside a braided mesh, clamped at the ends. When the inner bladder is controlled and expands, the pure mathematics of the mesh acts sort of a cut linkage and interprets this radial growth into linear contraction. Standard McKibbens contract in a linear motion up to a maximum of typically 25%, though different materials and construction may yield contractions around 40 %. Though they will technically be designed to elongate also, this can be not helpful because the soft muscles buckle.



Figure 1: McKibben air muscles

4.4 Pneumatic Valve Selection

The required valve is a three-stage valve, In-Hold-Exhaust. For this purpose, a proportional valve is available in the market. However, 5/2 pneumatic valves have been used to reduce the cost. It works exactly as a proportional valve and can be controlled at a wide range of open-close frequency. The arrangement is shown in figure 1.

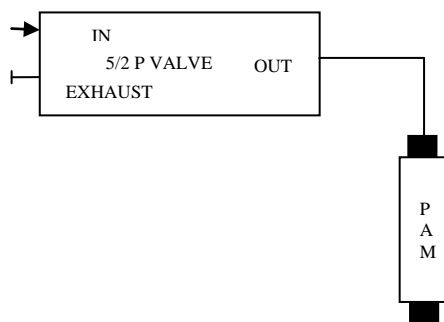


Figure 2: valve configuration for air flow control

5.5 Sensor Selection

The acceleration sensor is selected for this purpose. The main function of the acceleration sensor is calculating angles in different axis and when we lift the weight then we fold hand from elbow joint that time for the specific angle the pneumatic valve get open and hand gets lifted.



Figure 4: Picture of Acceleration Sensor

5.6 Valve Control Circuit

Solenoid Valve is Control via microcontroller circuit. The acceleration sensor is connected to microcontroller circuit (ATMEGA 308). microcontroller will open the pneumatic valve at a specific angle embedded in a program of the microcontroller.

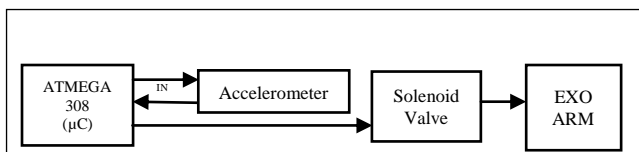


Figure 3: Block Diagram of Valve Control Circuit

6. Design

6.1 Exoskeleton Arm

The basic CATIA V5 modelling of exoskeleton arm with aluminium frame and at the end we are giving hinge support for lifting the weight. Supplementary this model is used for analysis purpose.

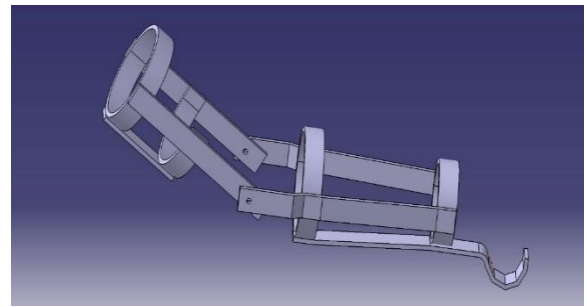


Figure 4: Proposed Model of Exo Arm

Torque Calculations

Torque calculation for the exoskeleton is done by considering an average person of weight 72 kg and height 180 cm. From the mean segmented weight of the body based on the study done by Plagenhoef. et al for males, we can calculate the weight of the arm segments. Based on this study Upper arm is 3.25 % of total body weight and Forearm is 1.87 % of total body weight.

H and W are the average height and weight respectively

$$H = 180 \text{ cm}$$

$$W = 72 \text{ kg}$$

Upper arm length (u) of a human of height H and mass W can be calculated from the

$$u = 0.186 H$$

$$= 0.186 \times 180$$

$$= 3348 \text{ mm}$$

Forearm length can be calculated by,

$$l = 0.146 H$$

$$= 0.146 \times 180 = 2628 \text{ mm}$$

Total length of the arm (a) can be calculated by the

$$a = u + l$$

$$= 3348 + 2628$$

$$= 5976 \text{ mm}$$

Based on Plagenhoef.al study, mass of the upper arm (W_{ua}) and Forearm (W_{fa}) can be calculated

$$W_{ua} = 3.25\%W$$

$$= 3.25\% \times 72 = 2.34 \text{ kg}$$

$$W_{fa} = 1.87\%W$$

$$= 1.87\% \times 72 = 1.3464 \text{ kg}$$

W_{tp} is the total mass of the arm, using the total mass of the arm can be calculated.

$$W_{tp} = W_{ua} + W_{fa}$$

$$= 2.34 + 1.3464 = 3.686 \text{ kg}$$

W_{eq} is the mass of the exoskeleton in the forearm and is assumed to be 1.5 kg,

$$W_{eq} = 1.5 \text{ kg}$$

W_{te} is the total mass of the forearm and exoskeleton, it is calculated

$$W_{te} = W_{fa} + W_{eq} = 2.846 \text{ kg}$$

T_e is the torque required for elbow movement with the exoskeleton part.

$T_e = W_{te} \times l$
 $= 2.846 \times 0.2628 = 0.74792 \text{ kgm} = 74.792 \text{ kg cm}$
 W_{ex} is the total mass of the exoskeleton,
 $W_{ex} = 3 \text{ kg}$

W_t is the total mass, when the exoskeleton attached to the full arm can be obtained using

$W_t = W_{ex} + W$
 $= 3 + 3.686$
 $= 6.686 \text{ kg}$

T_s is the torque required for the mass W_t

$T_s = W_t \times a$
 $= 6.686 \times 0.5976$
 $= 4 \text{ kg m}$
 $= 400 \text{ kg cm}$

Actuation of the exoskeleton is done based on the torque calculated.

Compressor Calculations

Assuming compressor speed 300 rpm

$$\text{Power} = \frac{2\pi NT}{60}$$

$$P = \frac{2 \times \pi \times 300 \times 39.81}{60}$$

$$P = 1.232 \text{ KW}$$

$$P = 1.232 \times 0.746 = 1 \text{ HP}$$

Weight to lift 200 kg

$$\text{Force} = 200 \times 9.81 = 1962 \text{ N}$$

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} = \frac{1962}{\pi \times d^2} = \frac{1962}{\pi \times 25^2} = 1 \text{ N/mm}^2 = 145 \text{ psi}$$

$$= 1 \times 10^6 \text{ N/m}^2$$

CALCULATION FOR COMPRESSOR CAPACITY OR FLOW RATE

$$\text{Power} = \text{Pressure} \times \text{Flow Rate}$$

$$1.232 \times 10^3 = 1 \times 10^6 \times \text{Flow Rate}$$

$$\text{Flow Rate} = 1.232 \times 10^{-3} \text{ m}^3/\text{s} = 73 \text{ lpm}$$

7. Implementation

7.1 Prototyping

Prototyping is model development (mechanical system development). It is a primary stage of development in which necessary calculations and manufacturing changes are done. Until we get a final product. In exoskeleton, the frame is made up of the aluminium flat plate and it is manufactured with different processes.



Figure 5: Final prototype of Exo arm

8. Conclusion

- In this present aggressive world, there is an immense shortage of labour, so there must be a choice to decreasing this issue
- Indeed, even in mechanical application, it requires increasingly HR for day-by-day work and the burden-conveying process is more.
- All these above work is impossible, people. To defeat this circumstance the pneumatic exoskeleton framework is adjusted to facilitate the work and limit the worry of the prime zone for exoskeleton

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