# Research Work on Design and Analysis of Exoskeleton Arm

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***Abstract—*** For centuries now, humans have developed machines for tasks that are too labor-intensive for species cannot do. So, creative imagination and subtle engineering have led to the development of the powered exoskeleton. It is a device that can be worn over the human body. A powered exoskeleton enables a human to perform tasks that are beyond physical prowess by amplifying muscular movements. We have outlined the process of developing an exoskeleton arm that increases the load lifting capacity of a human. The PAM has a thin-walled, rubber bladder placed inside an axially stiff but radically compliant braided sleeve. As the rubber bladder expands due to an increase in pressure, the diameter of the combined sleeve and bladder assembly easily changes in the radial direction and the PAM shortens in the axial direction. As the consequence of this interaction, a large contraction force produced can perform external work at a rapid rate. However, non-linearity exists as the pressure changes in the bladder because its area expands proportionally to the square of the diameter. Also as the outer sheath material moves, its length is dependent on trigonometric relationships involving the outer sheath material, which are non-linear.

***Keywords: Pneumatic Actuation, Muscle sensor, Flex sensor, Rehabilitation, Degrees of freedom.***

## I. INTRODUCTION

The known definition for an exoskeleton in general is an artificial external supporting structure. In other words, exoskeletons are wearable machines. Those wearable machines can be operated by using different kinds of power sources such as: electro- mechanical, pneumatic, or hydraulic. Exoskeletons are systems that are considered as human-robotic systems. The optimum target of exoskeleton development is to augment human, or to provide physical improvement. An exoskeleton would assist in the lifting process to improve weightlifting ability or maybe giving the ability of faster moving while carrying a load.

From the study of many already existing upper body exoskeletons in the market, it has been concluded that the best frame to have for the exoskeleton would be made out of tubes. That is considering the fact of having ease of manufacturing as priority as well as cost of manufacturing of the frame.
The main target of the presented thesis is to form a methodology that would ease the definition of the best cross-section of the tubes being used as body frame structure for the body of the exoskeleton being manufactured while considering the parameters that would matter while designing and exoskeleton.

Current upper-limb exoskeleton designs are mainly built for haptic, tele-operations, rehabilitation and strength improvements applications. Tele-operation is the process by which a slave robot is controlled, at a distance, via the replication of forces and movements performed by an operator with the help of an exoskeleton arm. Haptic interface is the interaction of the exoskeleton and the operator through human touch which can be used in controlling virtual reality environments. Strength improvement is implemented in exoskeleton devices to aid individuals in bearing or carrying large loads.

Exoskeletons are a type of skeletal architecture that surrounds the wearer instead of the traditional internal design. Exoskeleton wearable robots follow the same principle of having the pivotal structures outside its user allowing the mechanical system to be used as a suit. Similar exoskeleton structures can be used as input devices for easy human control of separate mechanisms, as is being applied in surgical procedures allowing the remote control of specialized equipment, and in virtual environment interaction where the user can interact with objects rendered inside of digital devices. Such exoskeletons are called Step Rehabilitation Robots. An exoskeleton could reduce the number of therapists needed by allowing even the most impaired patient to be trained by one therapist, whereas several are currently needed. Also training could be more uniform, easier to analyze retrospectively and can be specifically customized for each patient. At this time there are several projects designing training aids for rehabilitation.

## II. LITERATURE SURVEY

**"Design, Analysis, and Experiment of A Non-humanoid Arm Exoskeleton for Lifting Load", Xin Li, Zhengwei Jia, Xiang Cui, Lijian Zhang Research Center of Human Performanc Modification Technology Beijing Institute of Mechanical Equipment Beijing, China Published in 2018 The International Conference of Intelligent Robotic and Control Engineering.[4]**

The arm exoskeleton is widely used in medical and industrial areas because of its assistant ability. Many universities and institutes do some relevant works describes a robotic-arm exoskeleton that uses a parallel mechanism inspired by the human forearm to allow naturalistic shoulder movements. The patients who survived a stroke and the elderly who do not have enough strength to move their limbs freely present the development of the exoskeleton system for amplifying human strength.

**"Design of Exoskeleton Arm for Enhancing Human Limb Movement ", ThunyanootPrasertsakul, TeerapongSookjit, and WarakornCharoensuk Published in: Proceedings of the 2011 IEEE International Conference on Robotics and Biomimetics December 7-11, 2011, Phuket, Thailand.**

Human motion is an important function that is related to the movement of the limbs. Patients who have injured or damaged parts of their brain will be lost the movement function. The designed exoskeleton arm has degrees of freedom. Three degrees of freedom are at the shoulder joint, i.e. flexion/extension. The elbow joint has two degrees-of-freedom that are flexion/extension and supination/pronation. Controlling the exoskeleton arm can be performed by the signals and a set of controller which composes of the electromyography amplifier, analog to digital converter, motor control, and motor driver.

**"Improvement of Upper Extremity Rehabilitation Robotic Exoskeleton, NREX ", Won-Kyung Song and Jun-Yong Song Department of Rehabilitative and Assistive Technology, National Rehabilitation Center, Published in:2017 14th International Conference on Ubiquitous Robots and Ambient Intelligence (URAI) June 28 - July 1, 2017, at Maison Glad Jeju, Jeju, Korea.[10]**

NRC Robotic Exoskeleton (NREX), developed by the National Rehabilitation Center (NRC), is a lightweight, exoskeleton robot capable of assisting movements related to daily life activities. NREX has an exercise function for movements of hands and arms via a minimal number of electrical motors. It is based on the movement of one wrist joint and one elbow joint. Additionally, NREX has a handgrip function

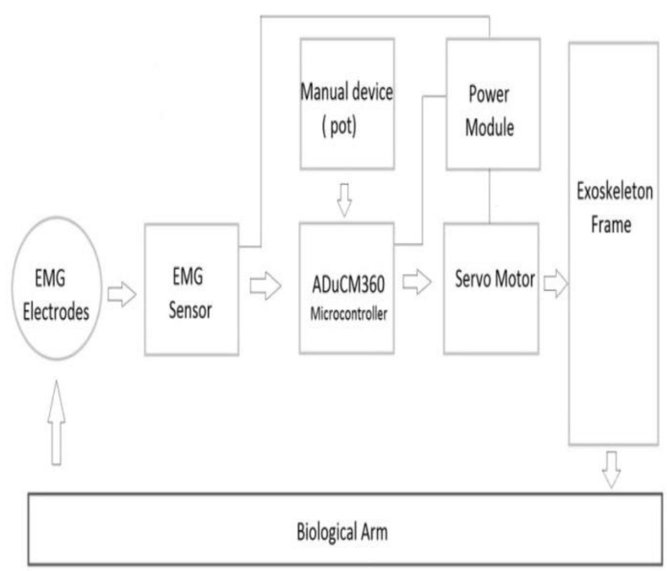
**"Design of Exoskeleton Robotic Hand/Arm System for Upper Limbs Rehabilitation Considering Mobility and Portability ", Yong-Kwun Lee Department of Biorobotics, Kyushu Sangyo University, Fukuoka, 813-8503, Japan Published in: The 11th International Conference on Ubiquitous Robots and Ambient Intelligence (URAI 2014) Nov. 12-15, 2014 at DoubleTree Hotel by Hilton, Kuala Lumpur, Malaysia[8]**

Hand and arm movement disorders can be caused by stroke, fractures, ligament tear, or loss of strength due to aging. Stroke is a disease accompanying partial paralysis in muscle contraction and expansion, but stroke patients can be improved by rehabilitation training or physiotherapy. To increase the effectiveness of rehabilitation training, continuous and repeated movement training with a physiotherapist is needed and enhancement can be achieved in the process by using such designs.

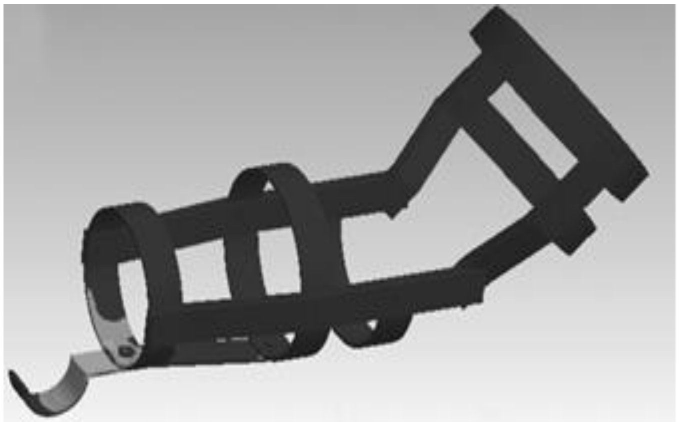
**"Exoskeleton Arm ", Pooja Jha, KinjalSavla, Dishant Shah, Department of Electronics and Telecommunication D. J. Sanghvi College of Engineering Mumbai, India.[14]**

In this paper, we propose the design of an efficient and comfortable option for commercial exoskeletons. Exoskeleton here refers to any wearable framework on the human body which eases and supports the muscles to perform work with lesser strain and greater comfort, using mechanical actuators and electrical power. The design proposed shall be capable of sensing the incentive to perform basic work procedures and routines making it natural and comfortable for the user to interact with and utilize this device, increasing its effectiveness and efficiency.

## III. PROPOSED DESIGN



## IV. DESIGN OF PROJECT



## V. COMPONENTS

- **Pneumatic Actuation:** A pneumatic control valve actuator converts energy into mechanical motion . The motion can be rotary or linear, depending on the type of actuator.

- **Muscle sensor:** The muscle sensors measures muscle activity through the electric potential of the muscle, commonly referred to as electromyography.

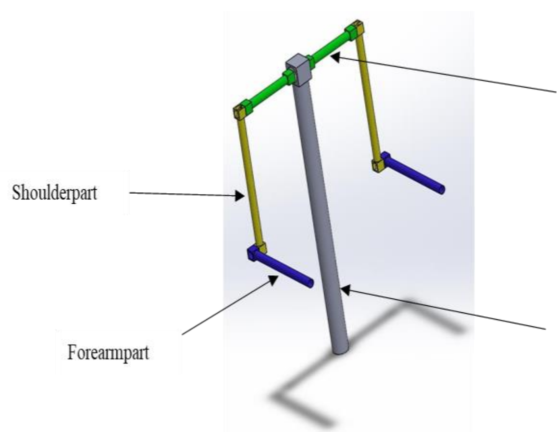
- **Flex sensor:** A flex sensor is a sensor that measures the amount of deflection or bending. Usually, the sensor is stuck to the surface, and resistance of sensor element is varied by bending the surface.

- **Rehabilitation:** Rehabilitation is a set of interventions designed to optimize functioning and reduce disability in individuals with health conditions in interaction with their environment.

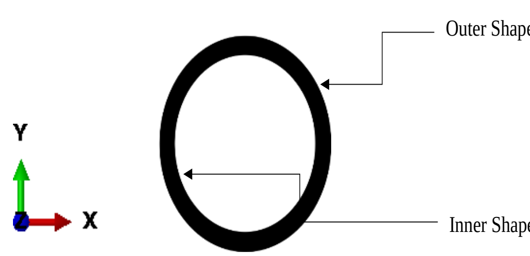
- **Degrees of freedom:** Degree of freedom refers to the maximum number of logically independent values, which are values that have the freedom to vary, in the data sample.

## VI. WORKING METHODOLOGY

The exoskeleton is analysed as 4 main parts which are: the forearm, shoulder, back to shoulder connector, and back. In the presented thesis, each part is studied separately with FEA as the analysis is optimally used as simulation for standard tests that are done to specimen such as tension test, bending test, torsion test, and compression test, those tests will give more focused results on the solid part as structure more than the entire structure as a body. Since the aim for the thesis is to find a way to evaluate the best cross-section to be used for exoskeleton frame, so many cross-sections have been considered to be studied. The process started by searching for a regular standard pipe that is having cross-section geometry of hollow round shape as shown in figure 3.2. that is extruded, then use different geometrical shapes that can be extruded.Extrusion process include pushing through a die that has the required cross-section. There are several ways to do the extrusion process including the direct and indirect extrusion. Both ways can be used to manufacture seamless pipes, but that is explained further in the subsection of manufacturing process .




In the presented thesis, the geometries of the cross-sections that are selected are basically switching between the circular, rectangular, and elliptical shape for the internal and external profile of cross-section shape.



## VII. APPLICATION

- ❖ It can be used in construction, agriculture, and automobile industry.
- ❖ It can be also used in medical industry.

## VIII. ADVANTAGES

- ❖ Less fatigue, with the ability to complete more work than their bodies could typically handle due to the decreased strain on various body parts.
- ❖ Exoskeletons reduce fatigue and shoulder and back muscle strain, as well as reduce work-related injuries to the neck, shoulder, and back..
- ❖ Exoskeletons offers many benefits in a variety of sectors, including construction, agriculture, and automotive. Their primary function is to boost human performance.
- ❖ More appropriate than full-body powered suits.
- ❖ The exoskeleton arm is a support system which helps the subject to lift heavy loads without bearing any strain.

## IX. CONCLUSION

The main objective for this project has been the enhancement and the assist of natural upper body motion of the human skeleton. Here, calculations of the required forces and estimation of the dimensions required were finalized. After the prototype test and the fabrication of a mechanical harness for the actuators, the potential applications would be in diverse fields such as defense, physiotherapy and manufacturing. The proposed method to use EMG electrodes will enable people with muscular defects to still be able to perform daily tasks like a fully functional human.

The exoskeleton arm has been analyzed using transient structural analysis for different load conditions at the hook keeping the upper elbow of an arm fixed. The analysis is carried out in ANSYS v18.0 software for the time period of 1 second. The load is increased from 10 N to 90 N and the results are obtained for each condition for body deformation or displacement, stress-strain (Von-Mises) and the factor of safety. Thus, it has been observed that at load of 80 N, the results are optimum where minimum factor of safety is found out equivalent to 1. Hence, it can be concluded that the exoskeleton arm design is safe for the maximum hook load of 80 N or 8.15 kg approximately.

It is safe to design other external power source for the required load condition so that it will operate the exoskeleton arm which may handle or bear approximately 80 percentage of total load for lifting any object which ultimately helps to minimize or reduce the human limb stresses. The design and analysis of the exoskeleton arm helps to identify the strong and weak parts of the design and hence suitable modification is to be done before final fabrication. Further, in future, the whole body of the exoskeleton arm can be more realistically optimized using suitable transient dynamic structural models with appropriate boundary conditions.

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