MAIN PROJECT REPORT

MODELLING AND FABRICATION OF POWERED EXOSKELETON ARM

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IN

MECHANICAL ENGINEERING

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CERTIFICATE

This is to certify that the Main Project Report "**MODELLING & FABRICATION OF EXOSKELETON ARM"** that is being submitted by **K. SRAVANA SUMANTH (13241A03C6),G.M.V.SUDHARSHAN SAI(13241A03C1), P. SUBHASH(13241A03D2)** in the partial fulfilment for the award of **B. Tech in Department of Mechanical Engineering from Gokaraju Rangaraju Institute of Engineering and Technology** affiliated to **JNTUH** is a record of bonafide work carried out by him/her under the guidance supervision. The results embodied in this project have not been submitted to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

A powered exoskeleton (also known as exo-frame, hard-suit, or exo-suit) is a wearable technology that is powered by a system of electric motors, pneumatics, levers, hydraulics, or a combination of technologies that allow for limb movement, increased strength, and endurance. The objective is to model an exoskeleton frame in any CAD software and to make a good model which can give appropriate results. Then the model is manufactured and tested so that it lifts the required weights. The materials used are obtained from daily needs and a compressor. The aim is to list out the possibilities in which the manufactured object can be used in our daily lives.

The goal is to lift a certain weight using this exoskeleton for the maximum amount of time with low or even no effort by the human to the exoskeleton. Then to observe the maximum limits of the parameters and to provide it with maximum degrees of freedom possible.

In general, exoskeletons can be used to help firefighters and other rescue workers survive harsh environments.

Keywords: Exo-skeleton, fabrication, Pneumatics, solenoid valves, pneumatic cylinders.

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CHAPTER 1

INTRODUCTION

INTRODUCTION

1.1 PROBLEM STATEMENT

Imagine spending days at a time hiking through the sweltering heat of the desert carrying heavy backpacks and weaponry; Imagine loading two hundred pound missiles into aircraft and tanks for hours. Exhaustion would quickly take over, diminishing the limits of the human body. These are problems that military personnel face every day. The problems are not only faced by the military personal but also the people who are physically challenged. They have go through immense pressure to do any type of work like walking, lifting heavy objects, running etc. Anything that is related to movement of the body. Prosthetics may help in shorter run but in a longer run they need something they could depend on. The solution is in developing exo arms and legs.

1.2 INTRODUCTION

"To move things is all mankind can do; ... for such the sole executant is muscle, whether in whispering a syllable or in felling a forest." (Charles Sherrington, The Linacre Lecture, 1924)

A powered exoskeleton (also known as powered armour, power armour, exoframe, hard suit, or exosuit) is a wearable mobile machine that is powered by a system of electric motors, pneumatics, levers, hydraulics, or a combination of technologies that allow for limb movement with increased strength and endurance. This name is derived from exoskeleton (from Greek *éxō* "outer" and *skeletos* "skeleton") is the external skeleton that supports and protects an animal's body.

The human body consists of more than six hundred muscles, producing movements which are inseparably connected to its life. That does not necessarily refer to the vital functions of the body, like breathing or the heartbeat. It refers to movement in general, which is very important for all living creatures. Aside from the immediate needs to eat, or the desire to communicate, be it with words, gestures or the whole body posture, mobility is one of the most important things in life. It does not only mean to travel around by car to a neighbouring city or by airplane around the world. Already the common daily activities are very important for the quality of life: Getting up from bed in the morning and walking to the bathroom, the breakfast table, or the refrigerator. Or during work, whether inside an office or while carrying heavy parts in a factory. Furthermore, lack of mobility often results in lack of participation in social life, which in turn leads to an undesired reduction of communication. It is also important for the body health to move around to activate the circulation system of the body, the muscles, and to breathe fresh air. In this work a device and control system are presented which support a human operator with extra force in the knee joint. The device is worn around the leg and should increase his or her mobility by supporting the thigh muscles. Such devices are called exoskeletons.

"Exoskeletons in general, are structures of rigid links, mounted on the body of some living vertebrae and following the main directions and having the main joints of the living organism's endoskeleton."

FIG 1.2.1 Typical exoskeleton arm

To put it into the context of this work, the exoskeleton is in permanent contact with the human body, resembling the limbs, with the intelligence and flexibility to perform a task originating from the human operator, while strength and endurance is contributed by the machine. As far as the operator is able to, the cooperation between the two is designed in such a way that the human is in control of the movements. While the exoskeleton that is presented here - with one actuated degree of freedom in the knee joint - already offers some support, an extended exoskeleton covering more limbs and using the same interface has a variety of potential applications: For healthy people they can give support while carrying heavy loads, for example in a factory environment, on a construction site, or at home, transferring the major part of the load to the exoskeleton to protect the body. Depending on the size, weight, and handling of such devices, they could even be beneficial in everyday life at home, especially for elderly people, to improve mobility. But not only healthy people can take advantage of the support: Exoskeletons can offer assistance to patients during rehabilitation of the locomotor system by guiding motions on correct trajectories to teach motion patterns, or give force support to be able to perform certain motions at all. This could intensify the training leading to better results and reduce the cost of the whole rehabilitation process.

But exoskeletons do not always have to work in cooperation with the operator: Exoskeletons also offer a unique way of giving force feedback to the human body. By applying some resistance to the movement of the operator they can act as haptic interfaces for virtual reality, tele manipulation, games, and entertainment: The virtual world can be felt and manipulated. For example, stairs can be simulated, the walking on muddy ground, or the effect of obstacles in an unstructured environment. In a normal rather unstructured environment movement must be adapted permanently to the situation: Steps have to be climbed, inclinations of the floor have to be compensated, and finally, transitions between movements, like getting up from a chair, walking, and climbing a stair, have to be performed fluently.

If proper hardware exists that actuates sufficient joints to support those movements, the problem of recognizing the intended action of the operator arises. Only if this intention is known to the system it can properly react either by supporting the movement or by hindering it to simulate external influences. Such a system requires a flexible interface, because of the wide range of movements to be performed, which collects all required information so that the intended action of the operator can be successfully derived. As diverse as the applications are, so are the operators who will control the device: From healthy and fit persons, to weak and disabled patients. Sometimes, a defect in the locomotor system of the human body is also accompanied with a mental defect, complicating things even more.

Ideally, the control system has to be adaptable: The exoskeleton should offer maximum flexibility for healthy people who can take advantage of that. For disabled people the flexibility must be limited, to avoid undesired behaviour of the system if it cannot fully be controlled by the patient. Complex control devices may require too much mental effort, or simply cannot be handled. In such cases the control system must take over some additional functions, for example, maintenance of postural stability.

1.3 Electromyography (EMG)

There are two kinds of EMG: surface EMG and intramuscular EMG. Surface EMG assesses muscle function by recording muscle activity from the surface above the muscle on the skin. Surface electrodes are able to provide only a limited assessment of the muscle activity. Surface EMG can be recorded by a pair of electrodes or by a more complex array of multiple electrodes.

In the course of this work, electromyography always refers to *surface* electromyography, meaning that the sensors are put on the skin on top of the muscles. Beside the easier application of the electrodes, signals from those sensors give a better estimation of the overall activation of the muscle. Invasive electromyography is rather suited to investigate the internal processes within a muscle, which is not required here.

Advantages of using EMG signals in general are:

1. EMG signals are directly linked to the desire of movement of the person, whether the movement is executed voluntarily or is initiated through a reflex response (except for people with certain diseases).
2. No movement of the limbs is necessary: If the muscles are too weak or the external load too heavy, the intention of movement can still be detected, although no movement is performed.

3. EMG signals are emitted unconsciously by the operator while he or she is performing the desired movement or is trying to do so. No additional mental load is created.
4. The EMG signals are emitted early, before the muscles contract, because of signal propagation delays and because the muscle fibers need some time to contract.
5. The measurement of the signals is not influenced by temporary external influences like contact forces, in contrast to force sensors.

Importantly, EMG activity (as measured in microvolt) is linearly related to the amount of muscle contraction as well as the number of contracted muscles – or in other words, the stronger the muscle contraction and the higher the number of activated muscles, the higher the recorded voltage amplitude will be. Since EMG activity is even measurable when we do not display obvious actions or control our body to not perform certain behaviours, EMG recordings represent an additional source of insights into cognitive-behavioural processing which would be hidden based on pure observation techniques. Previous research indicates a close coupling between muscular EMG and motor-cortex EEG as reflected by significant correlations in signal features such as frequency power and phase in the (12 – 25 Hz) beta band. This emphasizes the power of EMG recordings for monitoring the interaction of cortical and motor systems.

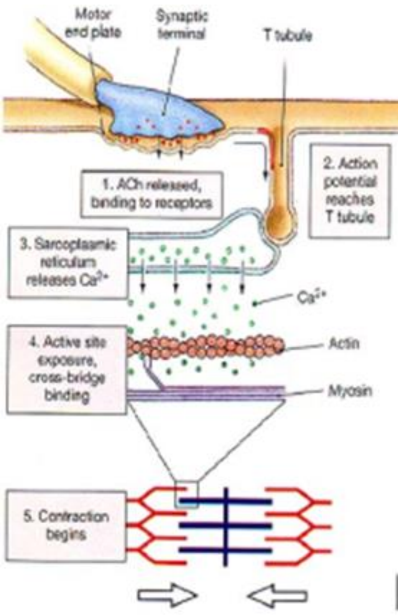

Fig 1.3.1 Working of EMG electrode.

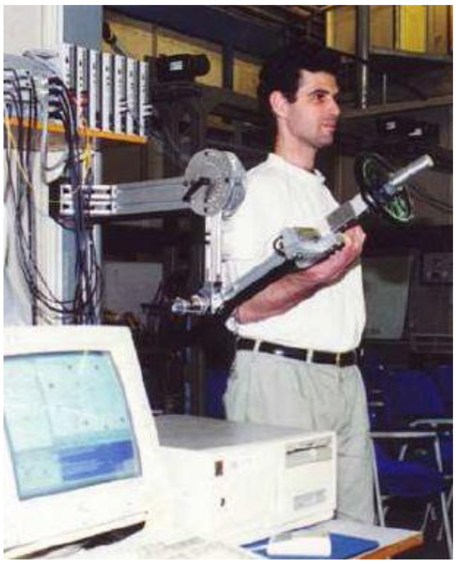

Fig 1.3.2 EMG controlled arm

CHAPTER 2

LITERATURE SURVEY

LITERATURE SURVEY

Exoskeletons that support a human operator in different tasks are not a new topic of interest for researchers around the world. Important scientific research started in the 1970's where the group around Vukobratovic played a pioneer role: They had a clear goal in mind to help patients with defects in their locomotor system to regain walking capabilities. At this time, lack of computer processor power, heavy actuators (both pneumatic and electrical), and heavy power supplies limited the realization of interesting theoretical results. But nevertheless, researchers have been far from discouraged, and continued their work that led to interesting results.

A large number of scientists have sticked to Patient with pneumatic exoskeleton with torso. upper limb devices with a focus on hand prosthesis, because the required forces are rather low and helpful devices can also be constructed with a reduced degree of freedom. In recent years, many exoskeleton projects emerged due to increased performance of computers, actuators, and power supplies. Potential applications that have occupied the minds of scientists and engineers for a long time seemed to become realizable. The mobility of the operator is becoming more important, and due to the reduced size and weight of the exoskeleton the operator can carry it in addition to his or her own body. By that it can also support existing muscles, in contrast to a prosthesis that replaces missing limbs. Potential applications range from military units to support soldiers in ground operations on one side, over support for factory workers, pure entertainment devices to rehabilitation aids and support for disabled or elderly people on the other side. But not only the mechanical part is an important field of research: If a lightweight and powerful exoskeleton existed, there still remains the problem of how to control the device. The interface between the operator and the exoskeleton is at least as important as the mechanical construction, since misinterpretation of the desired movement of the operator can lead to injuries or worse.

Institute Mihailo Pupin, Yugoslavia: Exoskeleton Walking Aid

The primary goal of this research of Vukobratovic and colleagues was to develop exoskeletal devices that can be worn by patients with deficits in their locomotor system.

Those devices were actively powered in the first versions by pneumatic actuators (around 1970), and in later versions by electrical actuators. The first version had four actuated degrees of freedom (hip and knee joints, both legs). The ankle joint was initially passive and actuated in a later revision. The air supply for the actuators and the computer were both separated from the exoskeleton because of their heavy weight and large size. Due to the low computational power of computers at that time, the joint angle trajectories have been computed off-line and were replayed during the experimental trials. No feedback from the patient or environment was incorporated. A full paraplegic patient unfortunately could not walk alone with this device. He needed two people for support or a rolling aid to maintain balance. To allow incorporation of overall stability control, the exoskeleton was extended in 1971 with a torso frame, adding two degrees of freedom to the system (in the frontal and sagittal plane). Software controllers were now responsible for moving the limbs along the desired trajectories, and overall stability was maintained by computing simplified correction terms with the zero moment point (ZMP). Those correction terms have been tailored to the task of walking on level ground. Actuation of the trunk was mainly used to maintain stability. Equipping the soles of the exoskeleton with force sensors allowed the incorporation of feedback from ground reaction forces to improve stability and safety. It allowed the patient to walk alone, only with the aid of crutches.

University of Berkeley, USA: BLEEX

The BLEEX project is running for several years already and has finally resulted in a company called Berkeley ExoWorks.
The focus of the Berkeley Lower Extremity Exoskeleton (BLEEX) project is to design and construct an exoskeleton for human strength augmentation. It should be used

by soldiers, firefighters, and disaster relief workers to carry heavy loads faster and over longer distances in outdoor environments than would normally be possible.

Two versions of BLEEX currently exist. Some conceptual details can be found for version 1 whereas details of version 2 are held secret because of the U.S. military. BLEEX 1 consists of a metal frame that holds a backpack and two exoskeletal legs. Actuation is performed at the hip, knee, and ankle joint in sagittal plane, the remaining degrees of freedom in hip and ankle can be moved passively. Force sensors are attached under the soles of both feet.

It is designed for autonomous operation by a small fuel engine that supplies the on board computer and the hydraulics with power. Since the desired field of application demands a mechanically robust system, no sensors are used which are directly attached to the operator to record biological signals. Furthermore, there are no sensors between the operator and the exoskeleton measuring the interaction forces since the points of contact between the two may be unknown or changing and are hard to measure. But nevertheless, the principle of the control scheme is to minimize the interaction forces between the human and the machine The machine gets "out of the way" of the operator as quickly as possible, not to hinder the movement. Since the payload is attached to the exoskeleton, the operator does not feel the weight of the load To achieve this, a model of the exoskeleton was developed, and the inverse dynamics of this model delivers the positive feedback for a closed loop controller with a target value of zero. The gain is set slightly smaller than 1.0 to compensate the major part of the weight and inertia of the exoskeleton.

Fig 2.1 Model of that University of Berkeley, USA

CHAPTER 3

COMPONENTS REQUIRED

COMPONENTS REQUIRED :

- Pneumatic Cylinders
- Flow control valves
- Solenoid valve
- Stainless steel square tubes
- 8mm t-fit
- 8mm dia Tube
- Air compressor

3.1 PNEUMATIC CYLINDERS

Pneumatic cylinders are mechanical devices which use the power of compressed gas to produce a force in a reciprocating linear motion. Like hydraulic cylinders, something forces a piston to move in the desired direction. The piston is a disc or cylinder, and the piston rod transfers the force it develops to the object to be moved. Engineers sometimes prefer to use pneumatics because they are quieter, cleaner, and do not require large amounts of space for fluid storage. Because the operating fluid is a gas, leakage from a pneumatic cylinder will not drip out and contaminate the surroundings, making pneumatics more desirable where cleanliness is a requirement.

BORE DIAMETER 32MM

STROKE LENGTH 100 MM

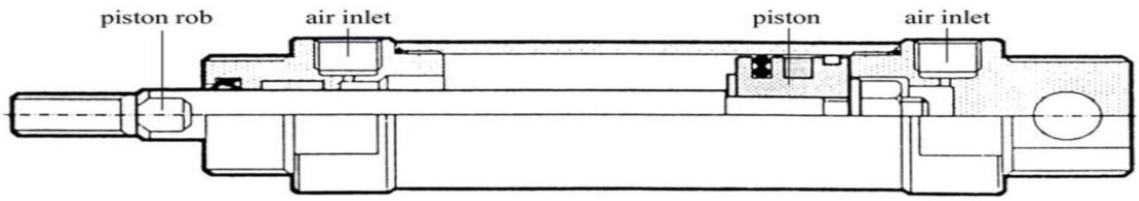

Fig. 6 Cross section of a double acting cylinder

Fig 3.1.1 Cross section of the double acting cylinder

The Cylinder used in this project has a bore of 32mm and stroke of 100mm and can carry a max. pressure of 10 Kgf/cm^2 or 145PSI.

3.2 FLOW CONTROL VALVES

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.

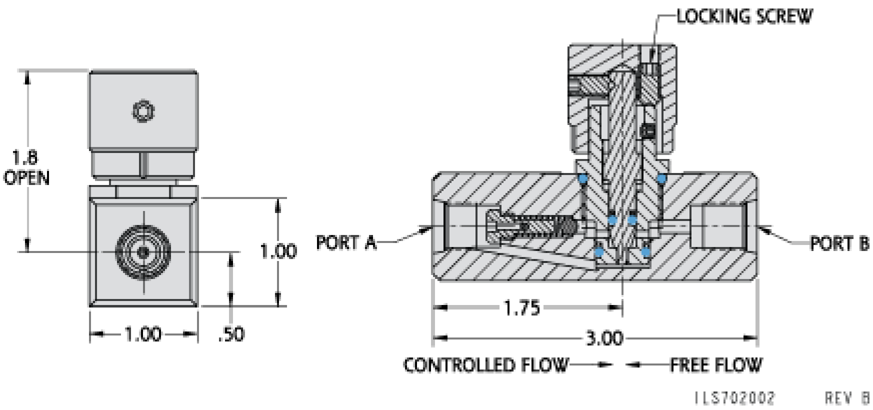

Fig 3.2.1 Cross sectional view of control valve **Fig 3.2.2 Control valve**

3.3 SOLENOID VALVE

A solenoid valve is an electromechanical controlled valve. The valve features a solenoid, which is an electric coil with a movable ferromagnetic core in its centre. This core is called the plunger. In rest position, the plunger closes off a small orifice. An electric current through the coil creates a magnetic field. The magnetic field exerts a force on the plunger. As a result, the plunger is pulled toward the centre of the coil so that the orifice opens. This is the basic principle that is used to open and close solenoid valves.

"A solenoid valve is an electromechanical actuated valve to control the flow of liquids and gases."

Solenoid valves are amongst the most used components in gas and liquid circuits. The number of applications is almost endless. Some examples of the use of solenoid valves include heating systems, compressed air technology, industrial automation, swimming pools, sprinkler systems, washing machines, dental equipment, car wash systems and irrigation systems.

Circuit Functions of Solenoid Valves:

Solenoid valves are used to close, dose, distribute or mix the flow of gas or liquid in a pipe. The specific purpose of a solenoid valve is expressed by its circuit function. A 2/2-way valve has two ports (inlet and outlet) and two positions (open or closed). A 2/2-way valve can be 'normally closed' (closed in de-energized state) or 'normally open' (open in de-energized state). A 3/2-way valve has three ports and two positions and can therefore switch between two circuits. 3/2 way valves can have different functions such as normally closed, normally open, diverting or universal. More ports or combinations of valves in a single construction are possible. The circuit function can be expressed in a symbol. Below are some examples of the most common circuit functions. The circuit function of a valve is symbolized in two rectangular boxes for the de-energized state (right side, visualized by) and energized state (left). The arrows in the box show the flow direction between the valve ports. The examples show a 2/2-way Normally Open (NO) valve, a 2/2-way Normally Closed (NC) valve and a 3/2-way Normally Closed valve. For more information about valve symbols and circuit functions, please visit the page about valve symbols.

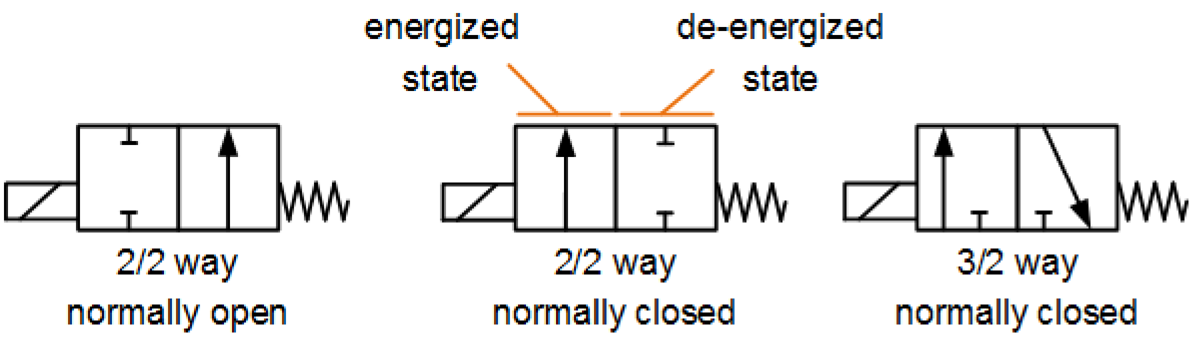

Fig 3.3.1 Working of solenoid valve

Type of Operation:

Solenoid valves can be categorized into different groups of operation.

Direct Operated

Direct operated (direct acting) solenoid valves have the most simple working principle. The medium flows through a small orifice which can be closed off by a plunger with a rubber gasket on the bottom. A small spring holds the plunger down to close the valve. The plunger is made of a ferromagnetic material. An electric coil is positioned around the plunger. As soon as the coil is electrical energized, a magnetic field is created which pulls the plunger up towards the centre of the coil. This opens the orifice so that the medium can flow through. This is called a Normally Closed (NC) valve. A Normally Open (NO) valve works the opposite way: it has a different construction so that the orifice is open when the solenoid is not powered. When the solenoid is actuated, the orifice will be closed. The maximum operating pressure and the flow rate are directly related to the orifice diameter and the magnetic force of the solenoid valve. This principle is therefore used for relatively small flow rates. Direct operated solenoid valves require no minimum operating pressure or pressure difference, so they can be used from 0 bar up to the maximum allowable pressure. The displayed solenoid valve is a direct operated, normally closed 2/2-way valve

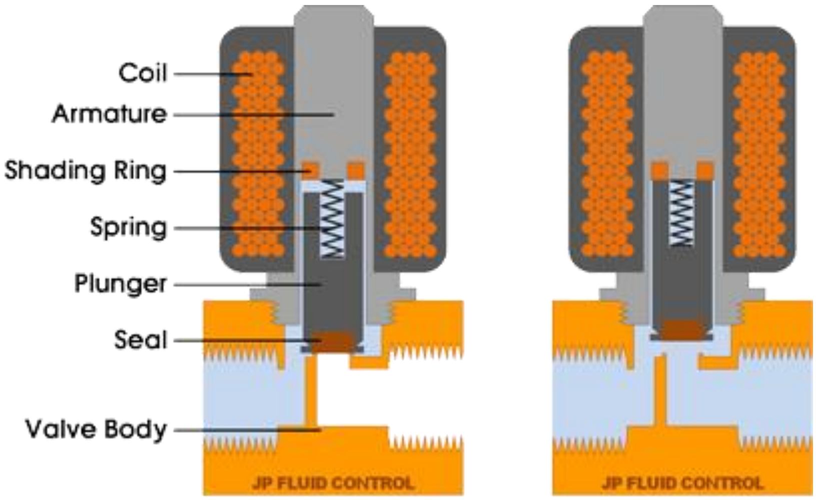

Fig 3.3.2 Schematically representation of a direct operated solenoid valve (2/2-way, normally closed).

The short video below explains step by step the operating principle of direct operating solenoid valves. For the example a 2/2-way normally closed valve is used. Although direct operating solenoid valves exist in many forms, the basic working principle is always the same.

Fig 3.3.3 2-way solenoid valve

The solenoid valve we use is the 2- way solenoid valve. The major use is it regulates the pressure between two cylinders simultaneously.

Then the solenoid valve is fitted to the pipe fittings and the solenoid valve other side is fitted to the air compressor.

The solenoid valve regulates intake and exhale of the cylinders thus providing the movement to the arm tube that is connected to the cylinder.

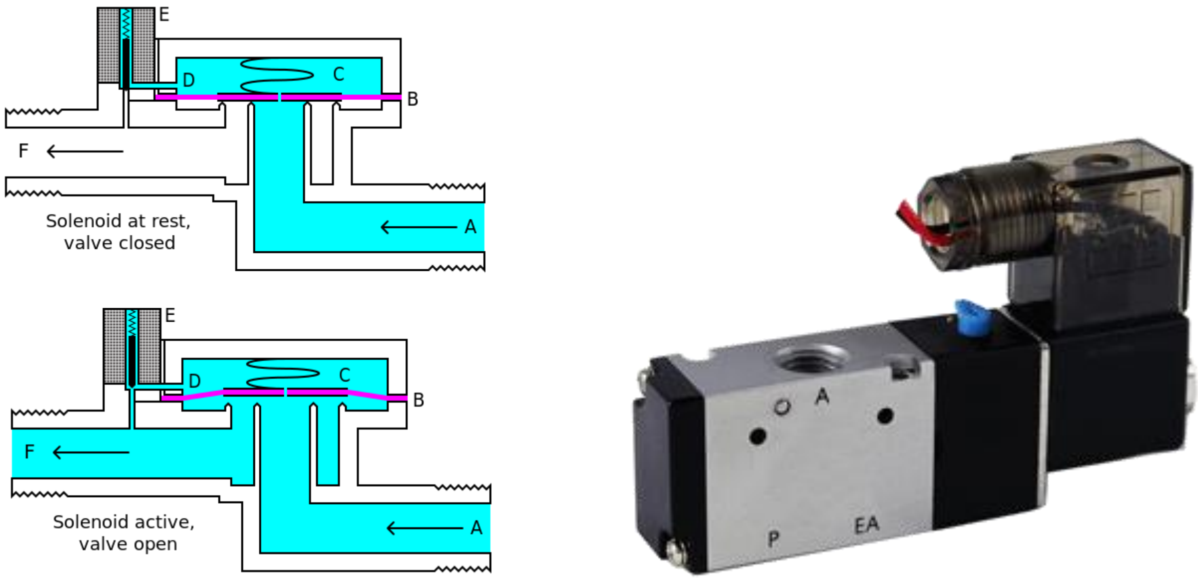

Fig 3.3.4 Working of solenoid valve

3.4 STAINLESS STEEL SQUARE TUBES

Two Stainless Steel 3041 tubes of square cross-section (25mmx25mm) are used. The thickness of walls of these tubes is 1.6mm. The lengths of these two tubes are 565mm and 435mm.

Fig 3.4.1 Stainless Steel Square tubes.

Material:	Stainless Steel - Grade 304 (UNS S30400)
Composition:	Fe/<.08C/17.5-20Cr/8-11Ni/<2Mn/<1Si/<.045P/<.03S

Table 3.4.1 composition of the material

Density : 7.85 – 8.06 Mg/m^3

3.5 8mm T-Fit

The 8mm T-Fit is used for joining two tubes to a single tube.

Fig 3.5.1 T- Fit

3.6 8mm Dia Tube

The 8mm dia plastic tube is used for necessary tubing for the flow of compressed air.

Fig 3.6.1 8mm Dia tube

3.7 Air Compressor

An air compressor is a device that converts power (using an electric motor, diesel or gasoline engine, etc.) into potential energy stored in pressurized air (i.e., compressed air). By one of several methods, an air compressor forces more and more air into a storage tank, increasing the pressure. When tank pressure reaches its upper limit the air compressor shuts off. The compressed air, then, is held in the tank until called into use. The energy contained in the compressed air can be used for a variety of applications, utilizing the kinetic energy of the air as it is released and the tank depressurizes. When tank pressure reaches its lower limit, the air compressor turns on again and re-pressurizes the tank.

Compressors can be classified according to the pressure delivered:

1. Low-pressure air compressors (LPACs), which have a discharge pressure of 150 psi or less
2. Medium-pressure compressors which have a discharge pressure of 151 psi to 1,000 psi
3. High-pressure air compressors (HPACs), which have a discharge pressure above 1,000 psi.

Fig 3.7.1 Air compressor

CHAPTER 4

FABRICATION STEPS

FABRICATION STEPS:

4.1 CUTTING OF THE STAINLESS STEEL SQUARE TUBES:

Two Stainless Steel 304l tubes of square cross-section (25mmx25mm) are used. The thickness of walls of these tubes is 1.6mm. The lengths of these two tubes are 565mm and 435mm.

The tubes are cut with the help of cutting machine so that the accurate measurements are taken so there are no structural defects in the rod.

The main intension of taking stainless steel tubes are because of their strength and durability to heavy weights. Also when loads are applied on the tubes no buckling or bending should take place. The tubes shouldn't limit the ability of the machine.

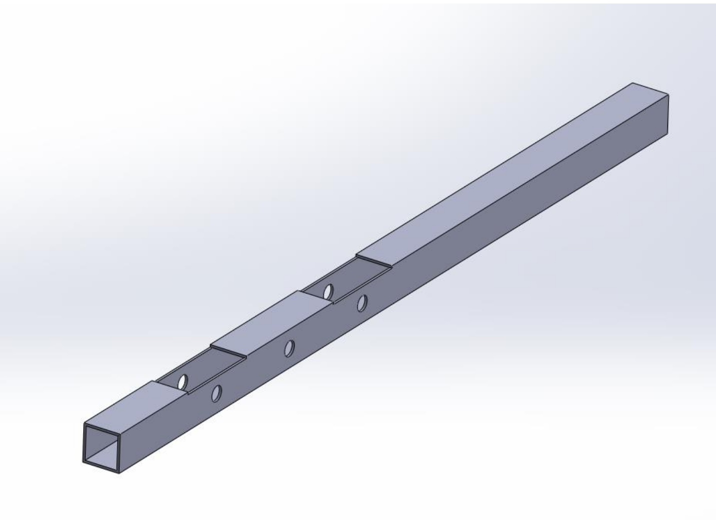

Fig 4.1.1 Arm of exo skeleton

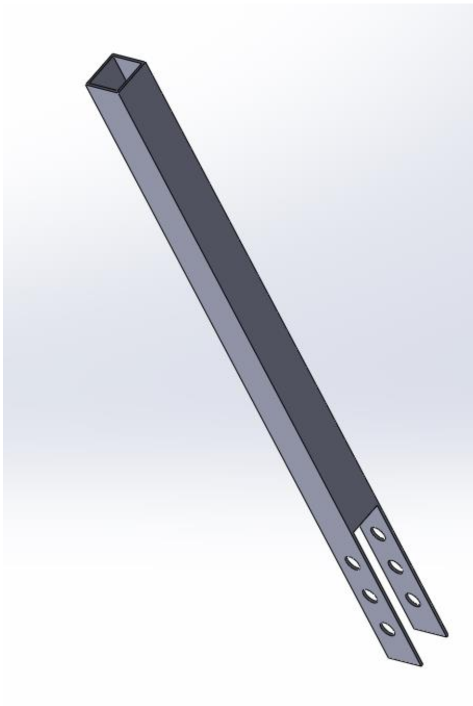

Fig 4.1.2 Elbow of exo skeleton

ARM LENGTH 565mm

ELBOW LENGTH 435mm

4.2 FORMATION OF BASIC STRUCTURE:

ARM STEEL TUBE:

After the cutting of the tubes are finished the arm tube which is of length 565cm is taken and holes of diameter 10mm are placed with the help of drilling machine in the respective locations.

Fig 4.2.1 Drilling of the tubes

Then the elbow tube which is of 435mm length is taken and holes of diameter 10mm are made at respective places.

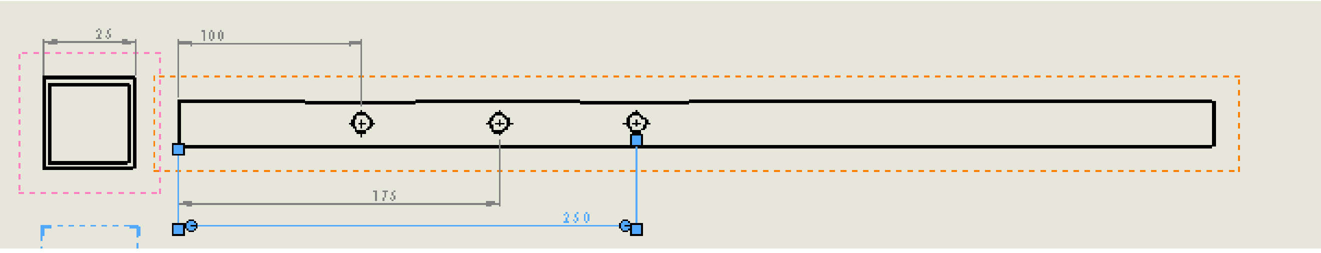

Fig 4.2.2 Dimensions for drilling

The dimensions of the arm tubes are given above. And with the help of it we know where to keep the holes and drill it.

Then the steel tubes are cut with the help of cutting machine the respective parts that are shown in fig 4.2.3 The square pieces are cut with the length of 25mm and width 60mm.

Then the buffing is done so that and rough surfaces are surfaces are removes after cutting.

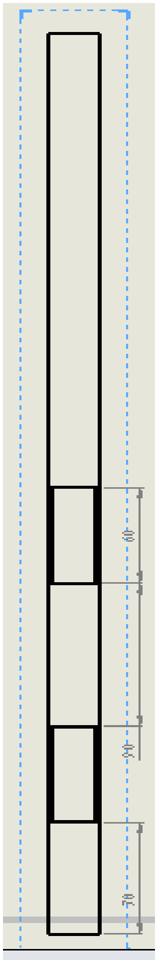

Fig 4.2.3 Dimensions for cutting squares on the tube

Fig 4.2.4 Cutting the square edges

ELBOW STEEL TUBE:

The elbow steel tube is cut with the length of 435mm with the help of cutting machine. The required adjustments are done to the elbow tube so that the tube fits the arm steel tube.

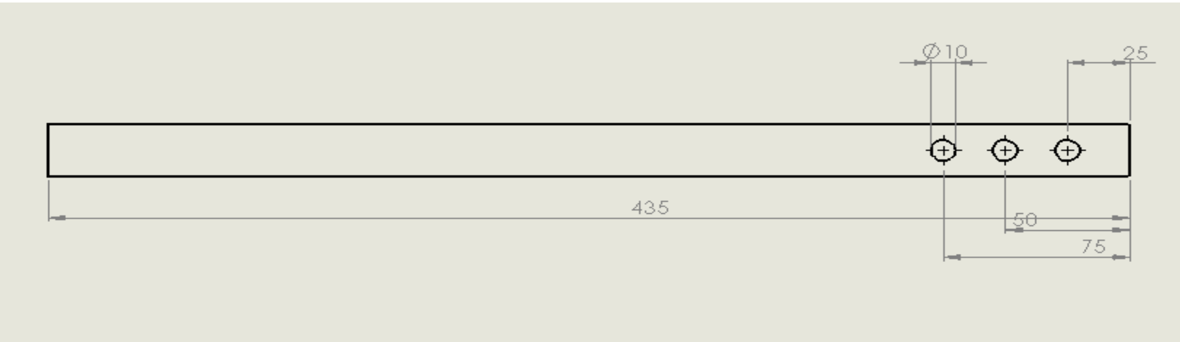

Fig 4.2.5 Dimensions for the elbow tube

After drilling the holes into the tube, some part of the tube is removed with the help of cutter as shown in the figure below.

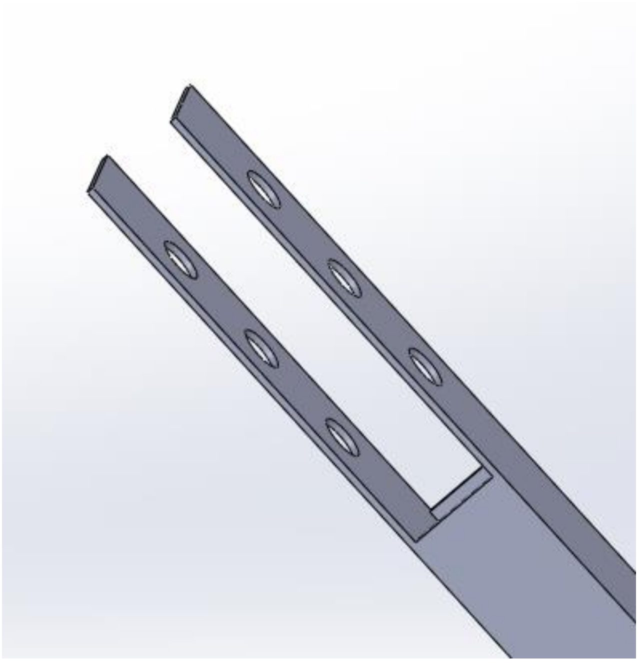

Fig 4.2.6 Cutting two sides of the tube

It is cut 100mm from the side where we drilled the hole for the arm tube be fitted. Slight variations may occur during assembly because the tolerances are not taken into consideration.

The elbow and the arm tubes are joined together with the help of the M10 bolt. The pitch length is taken 30mm so that the bolt will smoothly pass through the holes.

Necessary buffing is done on the edges so that there are no pointy edges. The arm and elbow tubes joined as shown in the figure below.

Fig 4.2.7 After fixing both arm and elbow tube

FIXING THE PNUMETIC CYLINDERS:

As we have joined the tubes together the next step is to join the pneumatic cylinder to the tubes. The pneumatic cylinders have the bore diameter of 32mm and stroke length of 100mm. to maximise the stroke length of the cylinder they should be placed parallel to the elbow tube.

The distance between the two cylinders is 160mm from both centres. The distance from the arm tube is 339mm. Then the pneumatic cylinders are fixed to the elbow arm with rectangular bars of 100mm length as shown in the figure.

Fig 4.2.8 Joining pneumatic cylinders with help of TIG welding

The pneumatic cylinders are joined to the square plates with the help of M10 bolts. And tightened so that the maximum pressure is kept on this area when load is lifted.

JOINING THE PNEUMATIC CYLINDER TO ARM TUBE:

The cylinders are joined to the arm tube with the help of the U-clamp and it has the hole with diameter 10mm to fit M10 bolts while joining them as shown in the figure.

Fig 4.2.9 U-Clamp fitting

T- fittings:

The pneumatic cylinders are fixed with T- fittings so that the piping work is done to the cylinders. The fittings are done which have the diameter of 10mm so that the 10mm dia fittings are done to the pneumatic cylinder.

Fig 4.2.10 T- fitting

Pipe Fittings:

The necessary piping work is done to the pneumatic cylinder so that the compressed air from the air compressor is sent to the cylinders.

Fig 4.2.11 Pipe fittings

SOLENOID VALVE:

A solenoid valve is an electromechanical controlled valve. The valve features a solenoid, which is an electric coil with a movable ferromagnetic core in its centre. This core is called the plunger. In rest position, the plunger closes off a small orifice. An electric current through the coil creates a magnetic field. The magnetic field exerts a force on the plunger. As a result, the plunger is pulled toward the centre of the coil so that the orifice opens. This is the basic principle that is used to open and close solenoid valves.

Solenoid valves are amongst the most used components in gas and liquid circuits. The number of applications is almost endless. Some examples of the use of solenoid valves include heating systems, compressed air technology, industrial automation, swimming pools, sprinkler systems, washing machines, dental equipment, car wash systems and irrigation systems.

The solenoid valve placed is most effectively works when the given pressures are employed.

Fig 4.2.12 Solenoid valve

HOLDINGS:

The necessary holdings are placed to the arm so that it is fixed to the hand properly when tried and no harm is done to the person while trying it.

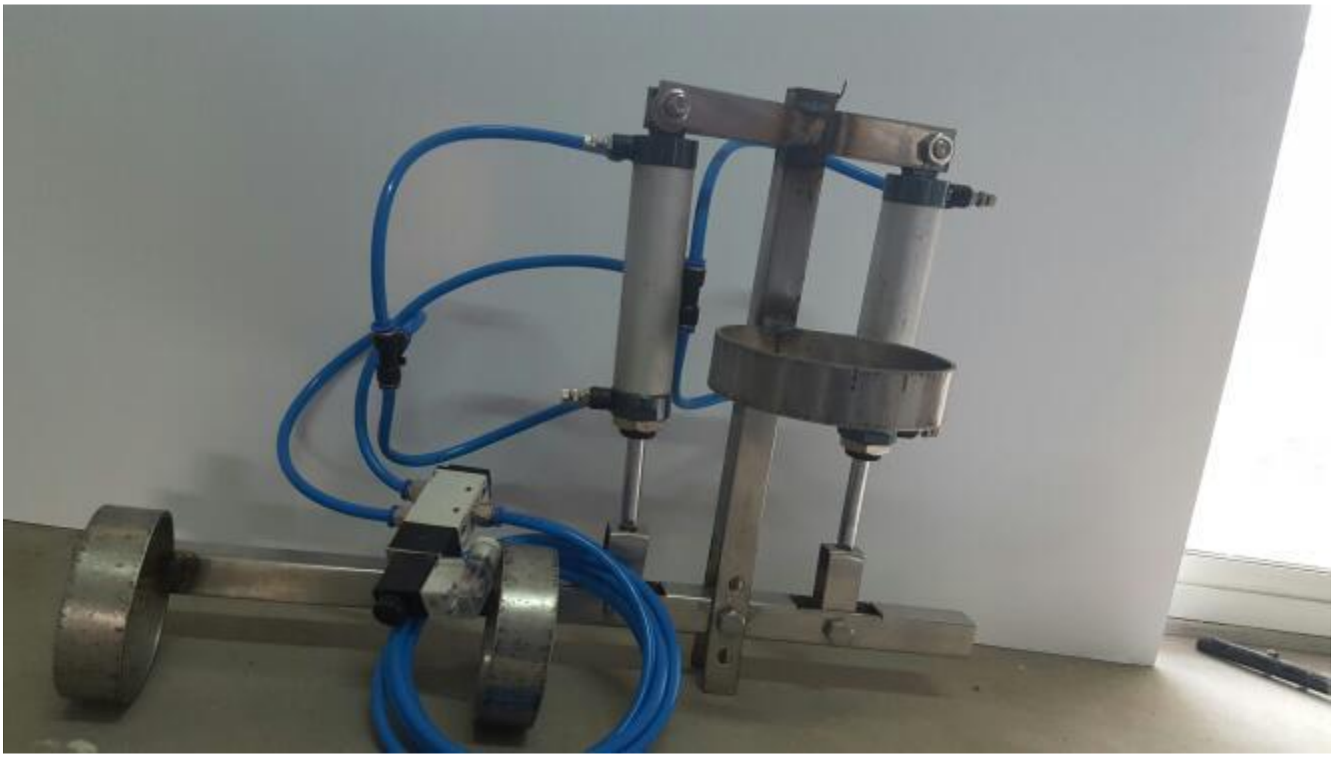

Fig 4.2.13 Holdings

CHAPTER 5

CALCULATIONS

EXO ARM CALCULATIONS :

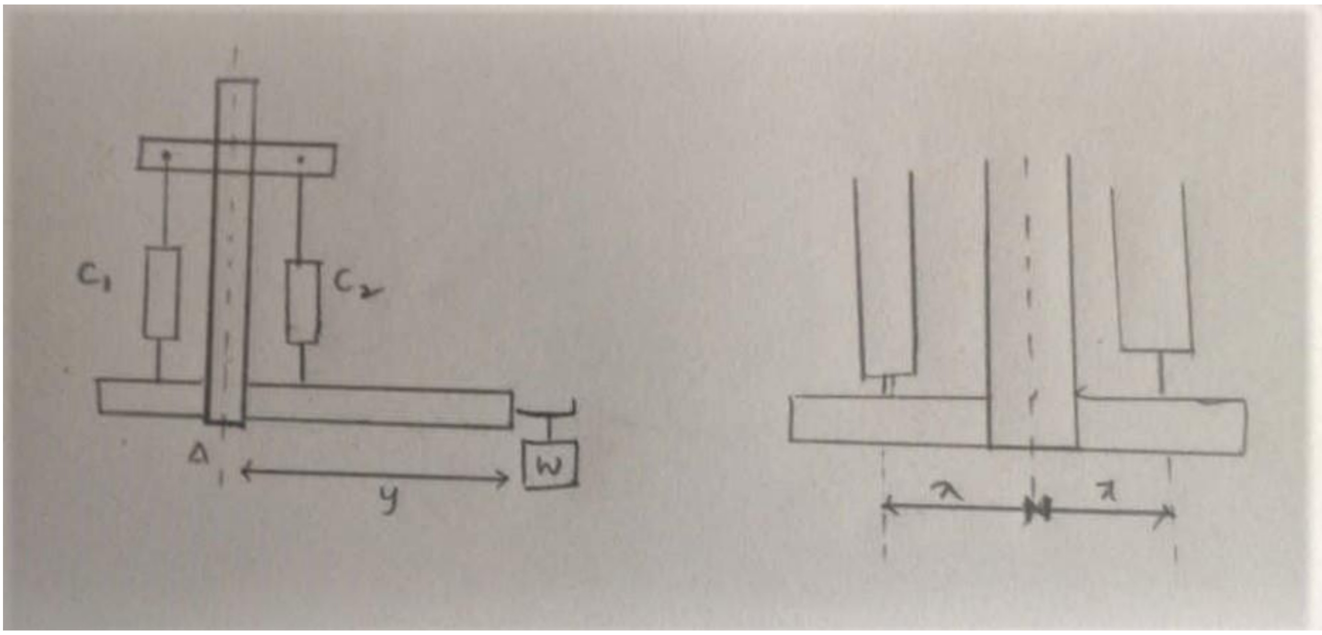

Fig 5.1 Point diagram of tubes

Let the load load applied on the arm is “w”.

Pressure supplied to pneumatic cylinder be p_p.

Pneumatic cylinder dimensions

Bore diameter-32mm

Stroke length-100mm

Area of cylinder cross section

$$A_c = \pi*(32)^2 = 256\pi\ mm^2$$

Let the force exerted by cylinder = F_p

$$F^p = (P_p)*A_C$$

$$= 256\pi P_p$$

The arm is pivoted at point A

There are three moments developed whenever load is lifted at the end of the hook.

Moment developed at the end of the cylinder 1 is given by

M_1 = force* distance from pivot point A

$= \mathbf{(256\pi P_p) * x}$

Similarly, moment developed at the end of the cylinder 2 is given by

M_2 = force* distance from pivot point A

$\mathbf{= (256\pi P_p) * x}$

The cylinders are aligned in a way that the moments added up each other for lifting up the weight.

Third moment is developed by the weight load mass "m" at the end of the arm that is given by

M_3 = (Force or weight) * distance from pivot.

$\mathbf{= mg * x}$

For the lift

$\mathbf{M_1 + M_2 = M_3}$

$\mathbf{(256\Pi P_p * x + 256\pi P_p * x) = mgy}$

$\mathbf{512P_p * x = mgy}$

$\mathbf{P_p = mgy/512\ \pi\ x}$

$\mathbf{P_p = mg/512\pi(x/y)}$

In the assembly the values of “x” and “y” are taken as

x = 75mm y = 565mm

The equation of weight /load lifted changes as follows

$$\mathbf{W= (512\pi)\ (75/565)\ Pp}$$

$$\mathbf{W = 213.14\ P_p}$$

As the length/dimensions are in “mm” we take pressure in “N/mm^2”

By substituting various pressures (P_p) supplied to the pneumatic cylinders, we get various loads lifted.

1 atm = 0.101325 N/mm^2

Pressure variations:

1) **Atmospheric pressure**

$P_p = 0.101325\ N/mm^2$

$W = 21.596\ N$

For pressure of $0.101325 N/mm^2$ supplied it can lift 21.596 N that is 2.201 Kgs.

2) **$P_p = 0.5\ N/mm^2$**

$W = 213.14\ (P_p)$

$W = 106.57\ N$

For a pressure of 0.5 n/mm^2 supplied it can provide a force of 106.5 N which is 10.863 Kgs.

3) P_p = 1 N/mm²

W = 213.14(1)

= 213.14 N

For a pressure of 1N/mm² the force obtained for the lift is 231.14 N which can be used to lift a mass of 21.727 Kgs.

4) P_p = 1.5 N/mm²

W = 213.14(1.5)

W = 319.71 N

For a pressure of 1.5 N/mm² the force obtained for the lift is 319.71 N which can be used to lift a mass of 32.59 Kgs.

5) P_p = 2 N/mm²

W = 213.14(2)

W = 426.28 N

For a pressure of 2 N/mm² the force obtained for the lift is 426.28 N which can be used to lift a mass of 43.45 Kgs

Hence the calculations reveal that a lot of weights can be lifted by using required amount of pressure.

TABLE OF CALCULATIONS:

Pressure (N/mm^2)	Force (N)	Weight (Kg)
0.101325	21.596	2.201
0.5	106.57	106.5
1.0	213.14	21.727
1.5	319.71	32.59
2.0	426.28	43.45

CHAPTER 6

FUTURE SCOPE

FUTURE IMPROVEMENTS THAT CAN BE DONE IN EXO SKELETONS:

Design challenges and future directions:

Although great progress has been made in the century-long effort to design and implement robotic exoskeletons and powered orthoses, many design challenges still remain. Remarkably, a portable leg exoskeleton has yet to be developed that demonstrates a significant decrease in the metabolic demands of walking or running. Many complicated devices have been developed that *increase* consumption, such as the Spring Walker and the MIT load-carrying exoskeleton.

There are many factors that continue to limit the performance of exoskeletons and orthoses. Today's powered devices are often heavy with limited torque and power, making the wearer's movements difficult to augment. Current devices are often both unnatural in shape and noisy, factors that negatively influence device cosmesis. Given current limitations in actuator technology, continued research and development in artificial muscle actuators is of critical importance to the field of wearable devices. Electroactive polymers have shown considerable promise as artificial muscles, but technical challenges still remain for their implementation. These challenges include improving the actuator's durability and lifetime at high levels of performance, scaling up the actuator size to meet the force and stroke needs of exoskeletal/orthotic devices, and advancing efficient and compact driving electronics. Although difficulties remain, electroactive polymer muscles may offer considerable advantages to wearable robotic devices, allowing for integrated joint impedance and motive force controllability, noise-free operation, and anthropomorphic device morphologies. An improved understanding of muscle and tendon function during human movement tasks may shed light on how artificial muscles should ideally attach to the exoskeletal frame (monoarticular vs. polyarticular actuation) and be controlled to produce enhanced biomimetic limb dynamics. For example, neuromechanical models that capture the major features of human walking may improve understanding of musculoskeletal morphology and neural control and lead to analogous improvements in the design of economical, stable and low-mass exoskeletons for human walking augmentation.

Another factor limiting today's exoskeletons and orthoses is the lack of direct information exchange between the human wearer's nervous system and the wearable device. Continued advancements in neural technology will be of critical importance to the field of wearable robotics. Peripheral sensors placed inside muscle to measure the electromyographic signal, or centrally-placed sensors into the motor cortex, may be used to assess motor intent by future exoskeletal control systems. Neural implants may have the potential to be used for sensory feedback to the nerves or brain, thus allowing the exoskeletal wearer to have some form of kinetic and kinematic sensory information from the wearable device.

Current exoskeletal/orthotic devices are also limited by their mechanical interface. Today's interface designs often cause discomfort to the wearer, limiting the length of time that a device can be worn. It is certainly an achievable goal to provide comfortable and effective mechanical interfaces with the human body. Contemporary external prosthetic limbs attach to the human body most commonly via a prosthetic socket that is custom fabricated to an individual's own contours and anatomical needs. Although not a perfectly comfortable interface, today's prosthetic sockets nonetheless allow amputee athletes to run marathons, compete in the Ironman Triathlons, and even climb

Mount Everest. One strategy employed in the fabrication of modern prostheses is to digitize the surface of the residual limb, creating a three dimensional digital description of the residual limb contours. Once the amputee's limb has been scanned, their geometric data are sent to a computer aided manufacturing (CAM) facility where a new prosthetic socket is fabricated rapidly and at relatively low cost.

In the future such file-to-factory rapid processes may be employed for the design and construction of exoskeletal and orthotic devices. In this framework, a three dimensional scanning procedure would produce a digital record of the human body's outer shape. This geometric data along with other anatomical information, such as data on tissue compliance and anatomically-sensitive areas, would be combined with strength and endurance information from a physical fitness diagnostic examination. Such anatomical and fitness data, combined with the wearer's augmentation requirements, would provide an individual's design specification profile. An exoskeleton, customized to fit the wearer's outer anatomical features and physiological demands, would then be designed as a 'second skin'. Such a skin would be made compliant in body regions having bony protuberances, and more rigid in areas of high tissue compliance. The exoskeletal skin would be so intimate with the human body that external shear forces applied to the exoskeleton would not produce relative movement between the exoskeletal inner surface and the wearer's own skin, eliminating skin sores resulting from device rubbing. Compliant artificial muscles, sensors, electronics and power supply would be embedded within the three dimensional construct, offering full protection of these components from environmental disturbances such as dust and moisture. Once designed, device construction would unite additive and subtractive fabrication processes to deposit materials with varied properties (stiffness and density variations) across the entire exoskeletal volume using large scale 3-D printers and robotic arms.

Exoskeletons and the future of mobility:

During the 20th century, investments in human-mobility technology primarily focused on wheeled devices. Relatively little investment was focused on the advancement of anthropomorphic exoskeletal technologies that allow humans to move bipedally at enhanced speeds and with reduced effort and metabolic cost. It seems likely that in the 21st century more investments will be made to drive innovation in this important area. The fact that large automobile companies, such as Honda and Toyota, have recently begun exoskeletal research programs is an indication of this technological shift. Perhaps in the latter half of this century, exoskeletons and orthoses will be as pervasive in society as wheeled vehicles are today. That would allow the elderly, the physically challenged and persons with normal intact physiologies to achieve a level of mobility not yet achieved. That would be a day in which the automobile – that large, metal box with four wheels – is replaced with wearable, all-terrain exoskeletal devices, allowing city streets to be transformed from 20thcentury pavement to dirt, trees and rocks. One can only hope.

CHAPTER 7

ADVANTAGES

DISADVANTAGES

& APPLICATIONS

ADVANTAGES:

- Day to day life process becomes easier.
- The work strain that falls on people reduces drastically through it.
- It can be greatly helpful for physically challenged people.
- For military personal to do hard labour is reduced.
- Time can be saved by using it so the work that should be done completes in much less time than the original ones.
- Exoskeletons can also be beneficial for medical use.

DISADVANTAGES:

One disadvantage to using exoskeletons in the medical field is the specificity that each patient would require. Creating a custom exoskeleton to meet the unique needs of a patient would be very expensive. This is why one of the biggest challenges is creating an exoskeleton that could help a wide range of patients. Another tricky issue is how much assistance the exoskeleton would provide in cases where the patient has muscular atrophy or tissue damage. If the exoskeleton provides too much support the patient will never be required to use the damaged tissue and therefore won't help to rehabilitate it. On the other hand, if it does not provide enough assistance then it is totally useless. The trick is finding the exact amount of work for the exoskeleton to perform. This is another issue like customization that will make it hard to create exoskeletons appropriate for unique patients.

APPLICATIONS:

Certainly, most of the perks goes to either medical or military because the most usage of main power or labour is done in that areas.

Medical industries can produce artificial exo arm for the patients who lost their limbs. It not fixed in arms and legs but by various advances this technology can be utilised in many other fields for their advantage.

There is lot of scope for development in this field because it is in its early stages who knows major advances can lead to better usage of exo skeletons.

CHAPTER 8

CONCLUSION

CONCLUSION:

To advance exoskeleton technology at the fastest rate possible, it is critical that scientists and engineers document and share their successes and failures with the research community. This special thematic series is intended to highlight that need. A major factor limiting the development of powered prostheses in the past has been the lack of carefully controlled scientific studies and open publication of technological advancements. While it is understandable that for-profit companies do not readily publish their research and development work, researchers at universities and institutes need to focus more on how they can move the field forward in cooperation with for-profit companies. University and institute researchers can identify basic principles governing human movement with robotic technologies (exoskeletons, prostheses, etc.) with carefully designed experimental studies. They can also provide unbiased assessment of new technologies with controlled tests using adequate sample sizes. Lastly, they can reach out to for-profit companies working on research and development to offer their services and expertise in mutually beneficial collaborations. While the collaboration work may still not yield peer-reviewed publications, it does provide opportunities for scientists and engineers to learn from each other in a way that would greatly benefit the field.

CHAPTER 9

REFERENCES

REFERENCES

- https://en.wikipedia.org/wiki/Powered_exoskeleton
- http://www.bc-robotics.com/tutorials/controlling-a-solenoid-valve-with-arduino/
- http://www.azom.com/properties.aspx?ArticleID=965
- https://en.wikipedia.org/wiki/Air_compressor
- http://www.instructables.com/id/IRON-MAN-EXOSKELETON/
- **Strength of Materials by RS KHURMI**