Development of Pneumatic Exoskeleton Suit

Dhruv T. Bhogle[1], Jagannath A. Chipkar[2], Sumit G. Gavakar[3], Vivek D. Kolwankar[4],

Prof. S. V. Vanjari[5]

[1-4]Student, Dept. of Mechanical Engineering, SSPM College of Engineering, Maharashtra, India
[5]HOD, Dept. of Mechanical Engineering, SSPM College of Engineering, Maharashtra, India

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Abstract - *This project describe the mechanical design of a prototype of upper body exoskeleton suit by using pneumatic cylinder as an artificial muscle .This development of suit aiming towards to enhance human upper body strength for applications ranging from industry, construction and military due to hefty pneumatic cylinder. It has restricted number of motion and degree of freedom due to rigid construction. This prototype would work on all kind of terrains. Main focus is to develop upper body exoskeleton suit (UBES) for arm and only for curl motion with restricted DOF. Designing of frame and assembly of component for proper prototyping of the suit. The designed suit reviews the state of UBES for arms for ranging application and assistance.*

Key Words: Exoskeleton suit, UBES, DOF, Pneumatic cylinder, Artificial, Muscle.

1. INTRODUCTION

Most common indicator of mobility and independence is the ability to move. As the technology advances more help is provided to the persons in need or to increase productivity. There is an urgent need to develop some systems that would help provide mobility assistance for individuals. For this assisting Exoskeleton suit are the promising solution as this is a mechanical system that has close contact with human beings that integrates with human through some connections at operators preference.

A human's physical ability to perform tasks is limited to some extent but not the intelligence. So combine powerful mechanisms with human intelligence will make a change, this leads to idea of Exoskeleton Suit. Exoskeleton suit is a wearable external mechanical structure which transfers pneumatic power from the suit to the person wearing it. As exoskeleton suits are for assisting force and mobility which can be used to carry heavy loads, weapons, disaster management and material handling.

The Exoskeleton suit can lift heavy weights loads without even feeling it by the person wearing it. These suits are mainly developed for military purposes, however it can be used for medical care, disaster and construction as well as home applications. The Exoskeleton that we are developing is pneumatically powered as air is available freely in atmosphere and to reduce overall costing of the suit.

The design of exoskeleton is such that it has pneumatic cylinders attached on a frame which in a way resembles the human exoskeleton. What makes it an exoskeleton suit is that it is on the outside of the body and anyone can wear it. Structure which resembles our bones is made of steel. In order for movements we used ball joints.

2. PROBLEM DEFINATIONS

2.1 Small Scale Usage

In small scale industries because of their low budget they cannot use robot, cranes or high grade machineries. The workers have to take load from one place to another place so that chances of injury is more for workers due to this production decreases in the industry. In modern industries robots are used for various operations that decreases the employment. So we are developing such exoskeleton suit that will help to increase production rate and human capability by giving support and assistance to human body which gives employment.

2.2 Mobility Assistance

Many people suffer from various epidemics like paralysis muscle loss, any damage to the neural system so extra assistance can provided by the suit. In future this suit can be linked to neural system and can be automated without any button operation.

2.3 Enhancing Abilities

Enhancing strength individual for military application as suit can be given to the soldiers to increase their reflexes this suit can give them super human strength in future. People with disabilities who cannot handle heavy loads this suit gives them load handling capacity. It can be used in construction sites, disaster management and industries.

We are developing the exoskeleton suit for upper body that is for both the arms to lift the load given on it by using pneumatic cylinders powered by compressed air to overcome the problems mention above.

3. METHODOLOGY

3.1 Theoretical Work

In our project we are trying to design and fabricate an Exoskeleton suit which would work on compressed air systems. Compressed air is used in cylinders to transmit power to a mechanical device which can provide required motions. Cylinders which work on air systems are called

Pneumatic cylinders. These cylinders would work as an artificial muscle for the person which would take up the load that would increase physical ability. The suit is designed according to the motion required so other degrees of freedom are restricted. The variants are as follows.

Upper Limb Exoskeleton: This Exoskeleton suit focuses on upper body that is arms how the arms are used to lift things up and put in a place needed. We use Pneumatic cylinders as muscles to of the arm to take loads on it. Total of 4 cylinders are used 2 on each arm as we are trying to lift up to 35kgs without even feeling it for the person wearing the suit. As the suit is designed only for lifting things many degrees of freedoms are restricted.

Lower Limb Exoskeleton: This Exoskeleton suit focuses on lower body part that are legs. Pneumatic cylinders are used to take up the load of the person that is carrying weights. 2 cylinders are used 1 on each leg as the specifications of the cylinders will be different from upper limb exoskeleton suit as stroke length and power required will be more.

3.2 Working

Pneumatic systems works on compressed air, this compressed air is used to drive the pistons of the cylinders. Air is compressed through a compressor till a required pressure then this compressed air is passed through a FRL unit in which the air is filtered for any dust particles, regulated and lubricated to reduce 'drift' of cylinders.

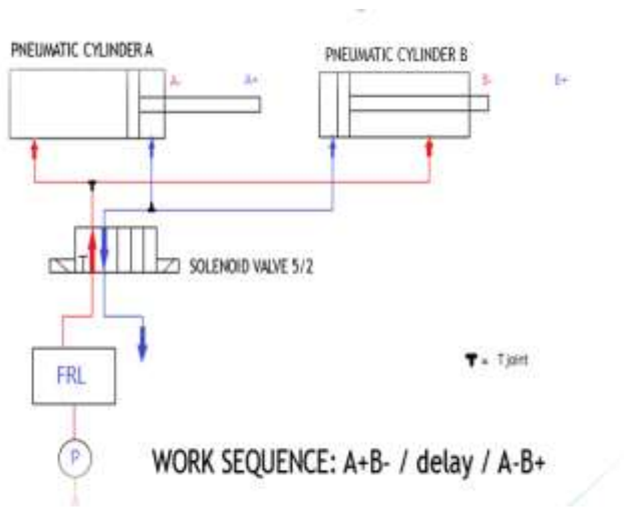

Fig -1: Pneumatic Circuit

Sequence of working-

A+ B- delay A-B+

Construction-

There are four double acting cylinder used in exoskeleton pneumatic suit. Each arm having two cylinders and one 5/2 valve. There are two T-joints are provided to equally separate the pressurized air. FRL unit is used which consist of filter, regulator and lubrication process are to be done. The pump is used to supply pressurized air.

As shown in above figure when pressurized air from the pump is drawn in FRL unit filtration, regulation and lubrication process are carried out. Then the air from FRL unit is supplied to the 5/2 valve through manifold. In between 5/2 valve and cylinder T joints are provided for equal distribution of air. Exhaust air from cylinder is released in atmosphere through 5/2 valve.

At initial stage the piston of cylinder A will be at A+ position as the arm is in rest and corresponding piston of cylinder B will be in B- position.

When the air is supplied to the cylinders through the valves the piston of cylinder A will be travelled at position A- and corresponding cylinder B at B+ with some delay.

3.3 Designing

Before manufacturing the back frame we made a virtual design in Autodesk inventor. On these designs we did some force analysis to find out the weak spots and bends. We made 3 variations in back frame design.

Table -1: Design specifications

Design Specification	
Back frame	**Arm**
GI pipe 20*20*1.2mm	GI pipe 25.4*25.4*1mm
weight per unit length:0.58 kg/m	weight per unit length:1.39 kg/m
Area=0.5*0.5inch=20*20=400 mm^2	Area=1*1inch=25.4*25.4=762mm^2
Weight of project=6 kg= 6*9.81 =58.86N	Weight of project=7 kg= 7*9.81 =68.67 N
Young's modulus=E=210GPa	Young's modulus=E=210GPa

3.3.1 Back frame version 1

We made a virtual back supporting frame on 3D modelling software called inventor 19.

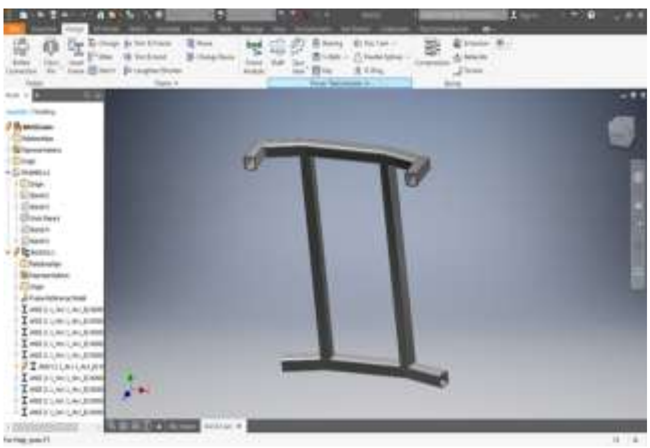

Fig -2: Back frame version 1

3.3.2 Back frame Version 2

2 Straight supports: 65cm
Horizontal edged supports (full length): 33cm angled at 115 degrees

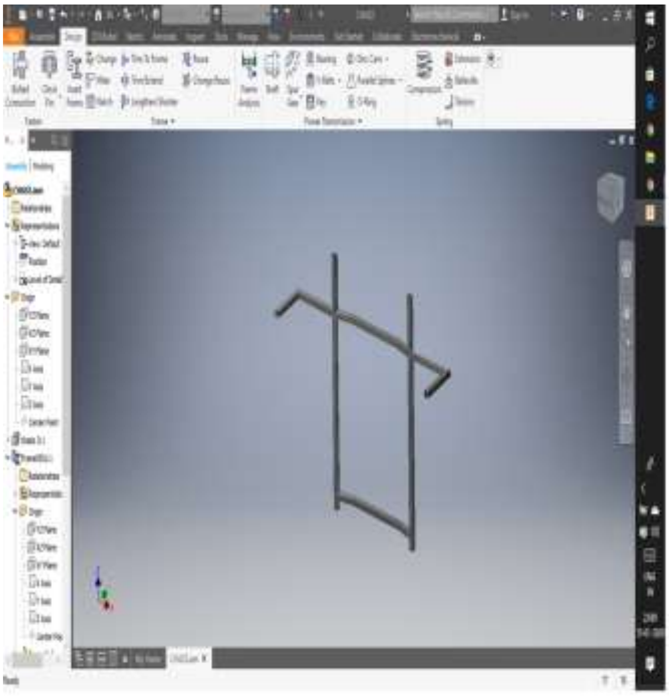

Fig -3: Back frame version 2

3.3.4 Back frame version 3

Extra cross members are given to sustain more loads on the arms.

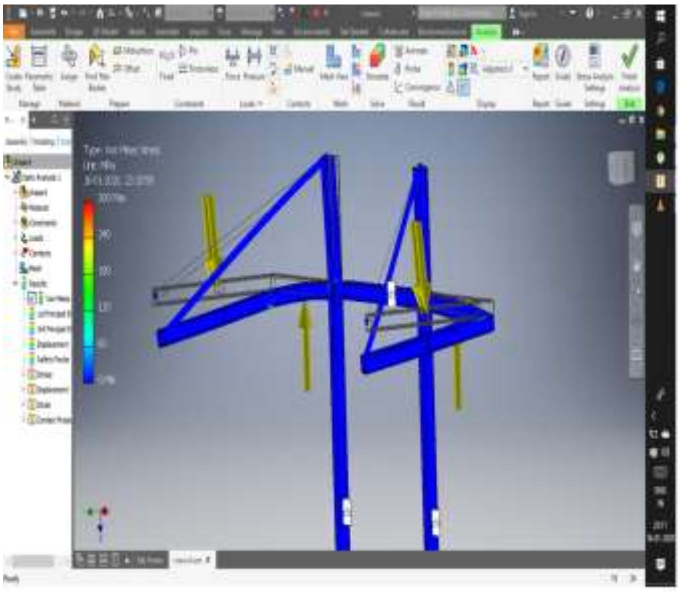

Fig -4: Back frame version 3

3.3.5 Arm design

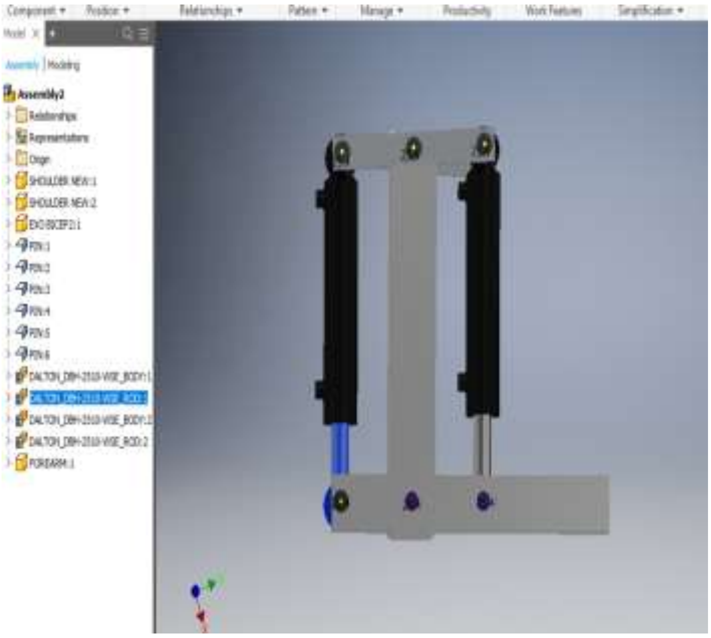

Fig -5: Pneumatic arm

3.4 Calculations

These calculations are done to find out the approximate specifications of a pneumatic cylinder that can be operated on the defined loads.

First we have calculated force for constant pressure and diameter

Assumption

Pressure- 200 psi or 1378.93 kpa

Stroke length- 12 inches

Formula: force = pressure*area

F = P*A

1. Calculation for 20mm (0.787 inch) diameter

A = 0.486 square inch

F = 200*0.486

= 97.29 lbs or 44.13 kg

2. Calculation for 25mm (0.98 inch) diameter

A = 0.754 square inch

F = 200*0.754

= 150.85 lbs or 68.42 kg

3. Calculation for 30mm (1.181 inch) diameter

A = 1.095 square inch

F = 200*1.095

= 219.08 lbs or 99.37 kg

After that we fixed force and pressure and then calculated the diameter

Force F = 40 kg or 88.18 lbs

Pressure P = 200 psi or 1378.95 kpa

F = P*A

88.18 = 200*(π/4)*d2

d = 18.79 mm approx...20mm

Eye ball joint calculations:

Bolt is to be fastened tightly also it will take load due to rotation. Stress for C-25 steel ft =420 kg/cm2 Standard nominal diameter of bolt is M12*1.25mm. From table in data book.

Let us check the strength:

Also initial tension in the bolt when belt is fully tightened.

P =30 kg = 300 N is the value of force applied by hand

Also, P = Π /4 dc2x ft

300 x 4 ft. = 3.76 N / mm2

3.14 X (12 x 0.84)2 the calculated ft. is less than the maximum hence our design is safe.

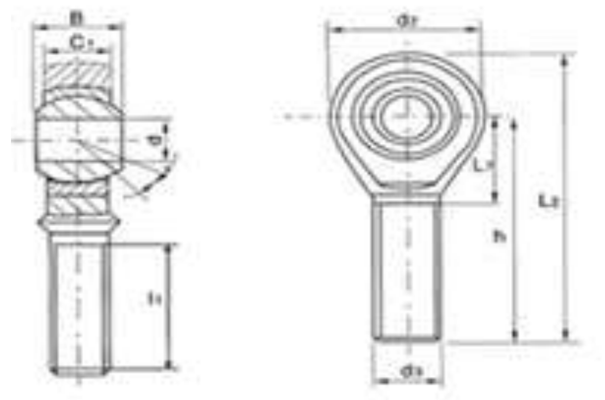

Fig -6: Eye ball joint (male)

We select d3=M8*1.25mm.

3.4 Components

According to all the calculations we considered the specifications of components on market survey basis by relating the value approximately near to the calculations.

Table -2: Components

Components		
Srno.	**Component**	**specification**
1	Pneumatic Cylinders	Double acting Bore diameter: 25mm Stroke length: 100 mm Operating pressure: 0.5 to 10Bar Temperature range: 5° C to 60° C
2	Solenoid valve	5/2 solenoid valve 3 ports and 2 positions 12V DC Size: ¼ regulator
3	Flexible hoses	Diameter 6mm
4	Pressure regulator	Size: ¼ regulator Pressure gauge: 150 psi

4. ANALYSIS

Load analysis of frame.

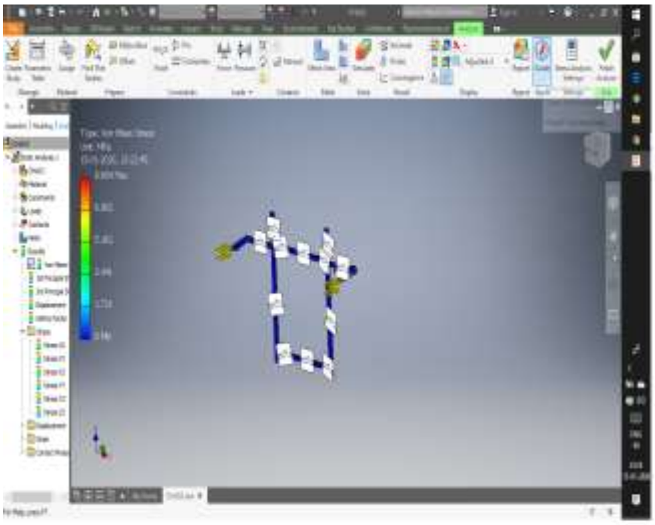

Fig -7: Analysis 1

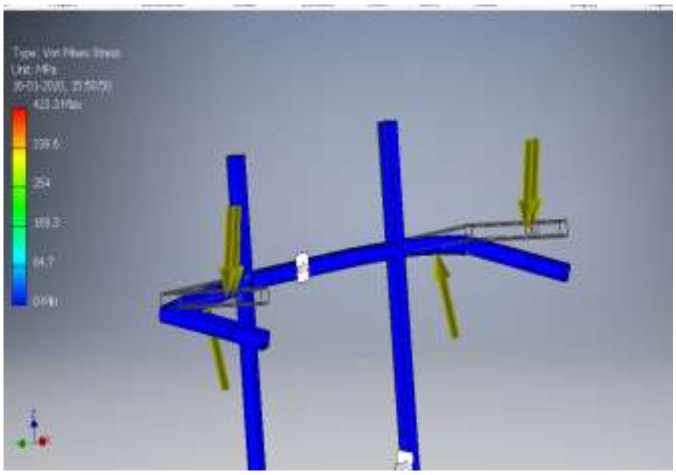

Fig -8: Analysis 1

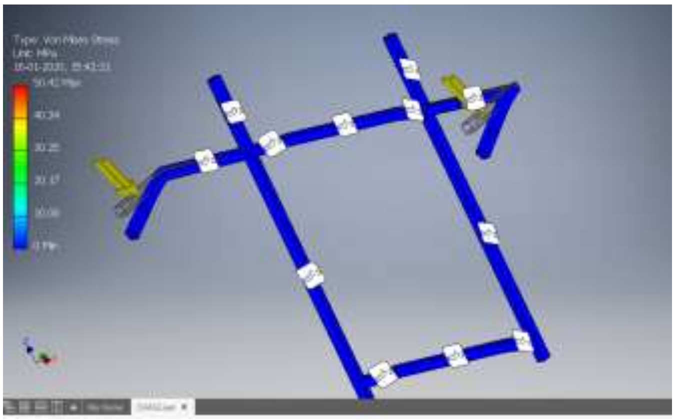

Fig -9: Analysis 1

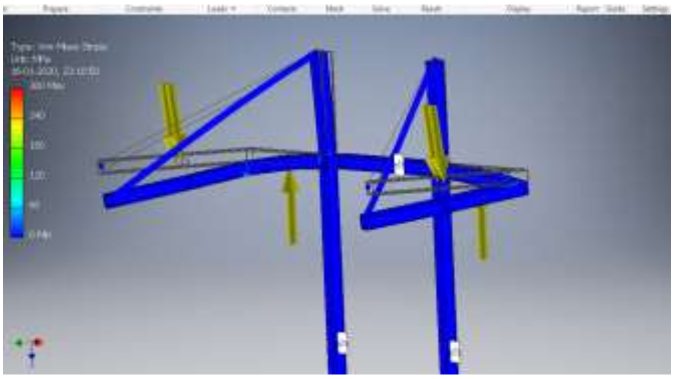

Fig -7: Analysis 2

5. ADVANTAGES AND DISADVANTAGES

5.1 Advantages

1. Lifting heavy weight: The exoskeleton suit can lift up to 30 kgs without even feeling it to the person wearing.

2. Skilled worker not required: Due to buttoned actuation and simplicity any worker/person can operate it without any special skills.

3 Increase in productivity: As some work has to be done by humans in any industry this suit helps to increase productivity rate by increasing physical abilities. As small scale industry cannot afford costly robotics machines for carrying and lifting loads this suit would help reduce unemployment and overall costing.

4. Mobility assistance: Providing assistance to person having disability like paralysis and muscle loss etc.

5.2 Disadvantages

1. Compressor is required all the time.
2. Weight is transmitted on the lower body.
3. Mobility is limited to a certain space.
4. Degrees of freedom are less.

6. FUTURE SCOPE

Many different exoskeleton suits have been developed at the earlier stages and can be categorized in several ways: by actuators, by structure, by function, by power source and by application. In this competitive world there is huge scarcity of man power, to overcome this issue industries have turned towards robots which led to unemployment. This led to an idea of exoskeleton suits which would assist and increase human abilities which can be used in industries to carry heavy loads, medical sectors and also military application. As technology advances day by day mechanical linkages are reduced to electronic links which would control the motion that will let to more variants of the exoskeleton suit designed for special purposes. More degrees of freedom can be acquired by intermeshing electronics and mechanical component. The exoskeleton suit can be given neural connections to make them fully automatic it would include PCB's that would send and receive signals from the brain to the actuators. The exoskeleton suit can be made more portable by usage of a storage tank in which the tank can sustain some air at required pressure.

As innovations are already made reduction in usage of pneumatic system for exoskeleton suit is possible.

7. CONCLUSION

In this paper a brief review of upper extremity exoskeleton systems is presented. The concept of an exoskeleton system was identified as an extension of the exoskeleton in biology. The challenges for an upper extremity robotic exoskeleton were identified. Special efforts have to be made when developing exoskeletons for human shoulder, wrist, and thumb since human shoulder, wrist and thumb motions are robots can be classified according to the applied segment of the upper extremity, the DOF, the actuators used in the system, power transmission methods, purpose of the robotic system and/or the control methods. Our aim was to lift up 20 kgs without more human effort. We achieved it without and interruptions.

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