# DESIGN OF UPPER-BODY EXOSKELETON WITH MULTIFILAMENT MUSCLE ACTUATION AND BIOMIMETIC SUPPORT

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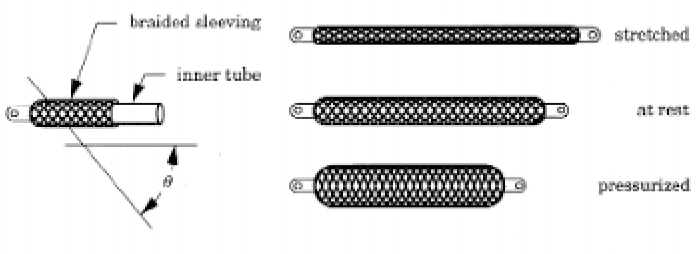
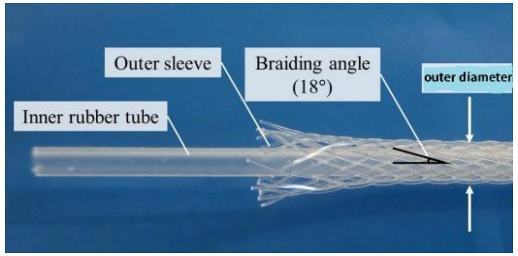
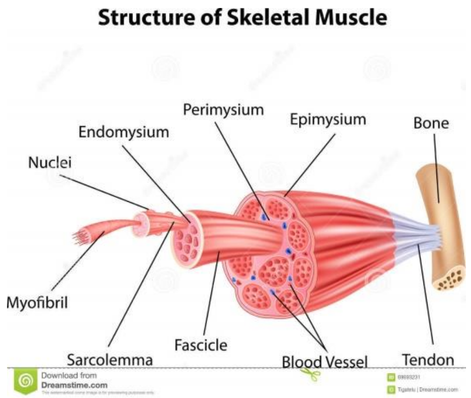
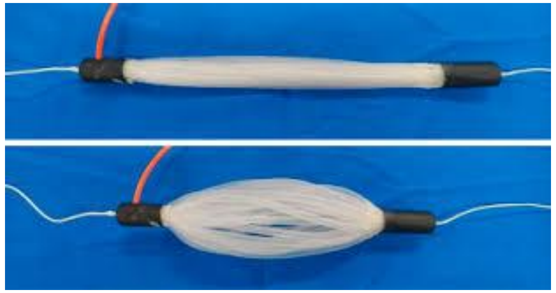
# Introduction

- These are smaller McKibben muscles that work on pneumatic actuation.



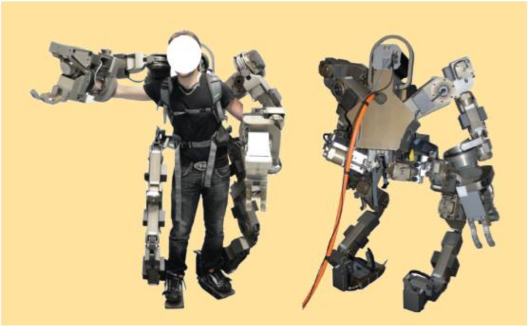



Main parts:

1. Inner tube
   OD=4.34 mm
   ID=3 mm
2. Outer Sleeve
   OD=0.4 mm

# Problem Definition

- PAMs are used usually in Exosuits ; these are sturdy & provide heavy forces but compromise on flexibility



- To tackle this we use thin Mckibben bundles called Multifilament muscles
- These muscles have been tested to replicate human-like motions in certain robotic designs

- This paper tries to conceptualize the use of such muscles in an Exo-suit to obtain force augmentations

# Theoretical Methodology

## Mathematical model

$$\mathbf{F}=5.0705\text{x}10^{-4}\,\boldsymbol{(P-P_{th})}\,-5.006\text{x}10^{-10}\,\boldsymbol{(P-P_{th})^2}\,-7.3828\text{x}10^{-16}\,\boldsymbol{(P-P_{th})^3}$$

$P_{app}$ =0.7MPa

$P_{th}$ = 0.1441MPa

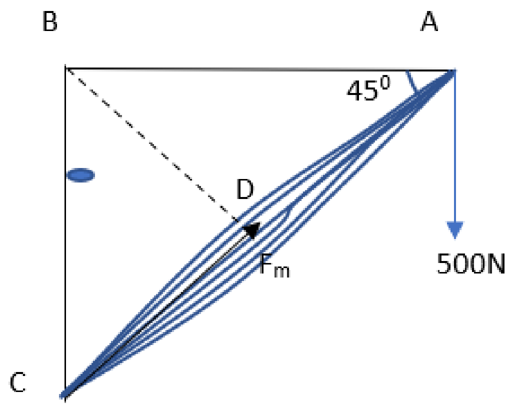
Braid angle = 18$^o$

**Bicep Muscles**

- Number of muscles = 16
- L= 200 mm
- $F_m$= 500 N
- $F_{single}$ = 500/16 = 31.25 N
- P = 0.652624MPa

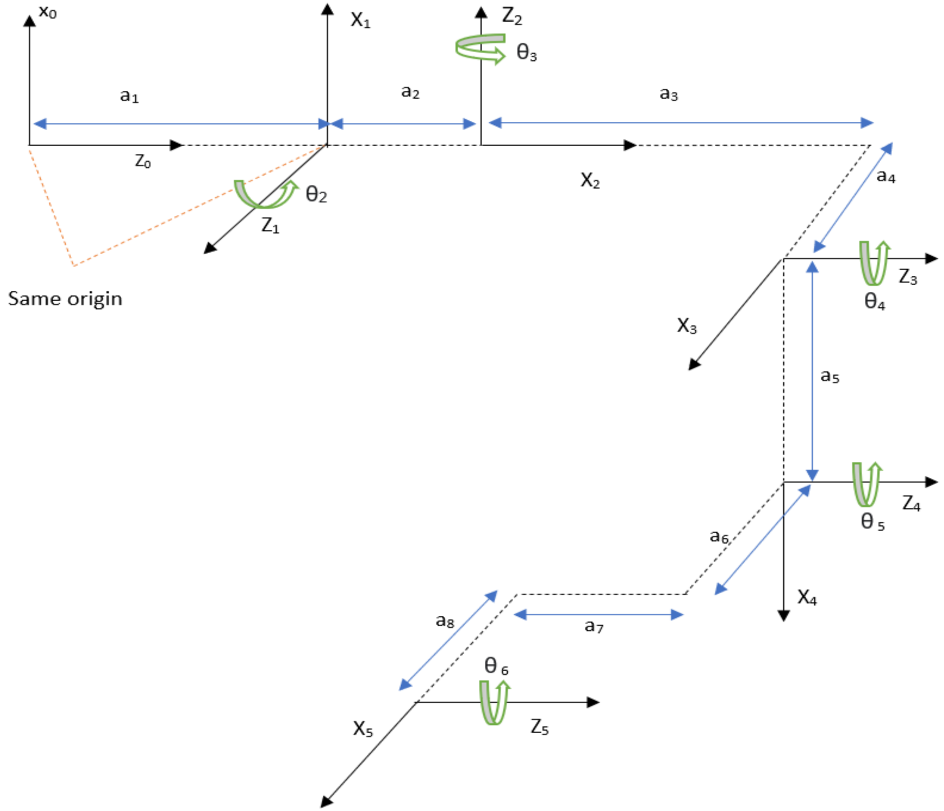
**Back Muscles**

- Number of muscles = 22
- L= 217.0817 mm
- $F_m$ = 500/sin45 = 707.10672 N
- $F_{single=}$ 707.10672/22 =32.14 N
- P = 0.6510683MPa



## Kinematic Modelling

### DH parameterization



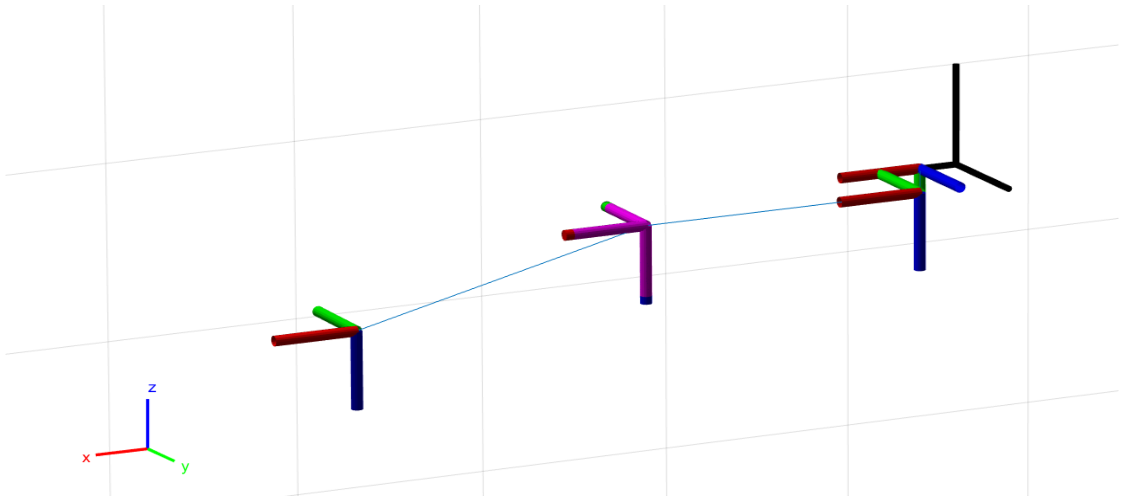

$$^{0}T_5 = A_1 A_2 A_3 A_4 A_5$$

## Dynamic Modelling

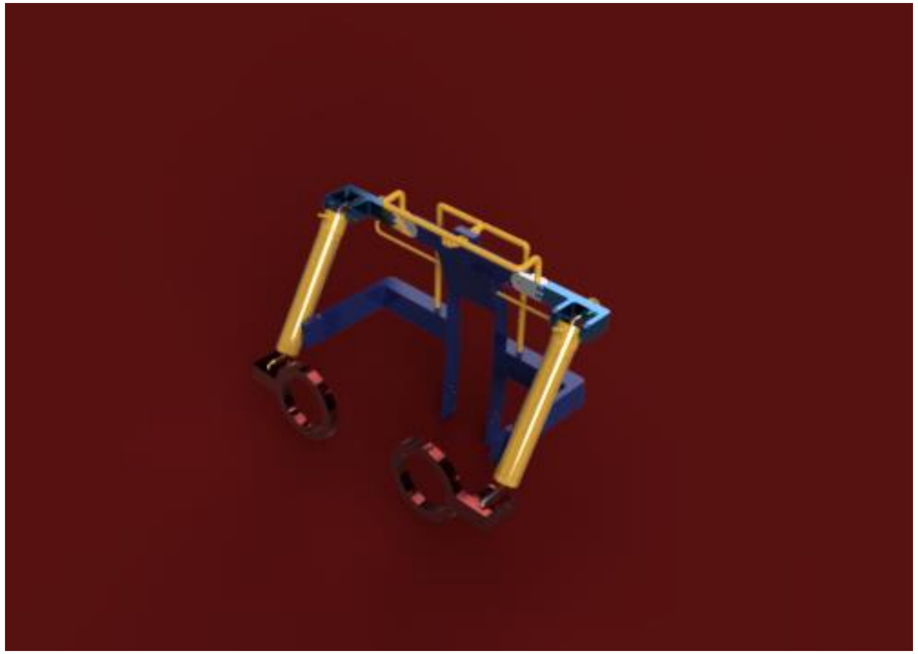
### Rigidbodytree creation

Robot: (5 bodies)

| Idx | Body Name | Joint Name | Joint Type | Parent Name(Idx) | Children Name(s) |
|---|---|---|---|---|---|
| 1 | body1 | jnt1 | revolute | base(0) | body2(2) |
| 2 | body2 | jnt2 | revolute | body1(1) | body3(3) |
| 3 | body3 | jnt3 | revolute | body2(2) | body4(4) |
| 4 | body4 | body4_jnt | fixed | body3(3) | body5(5) |
| 5 | body5 | jnt5 | revolute | body4(4) | |



# Mechanical Design & Assembly

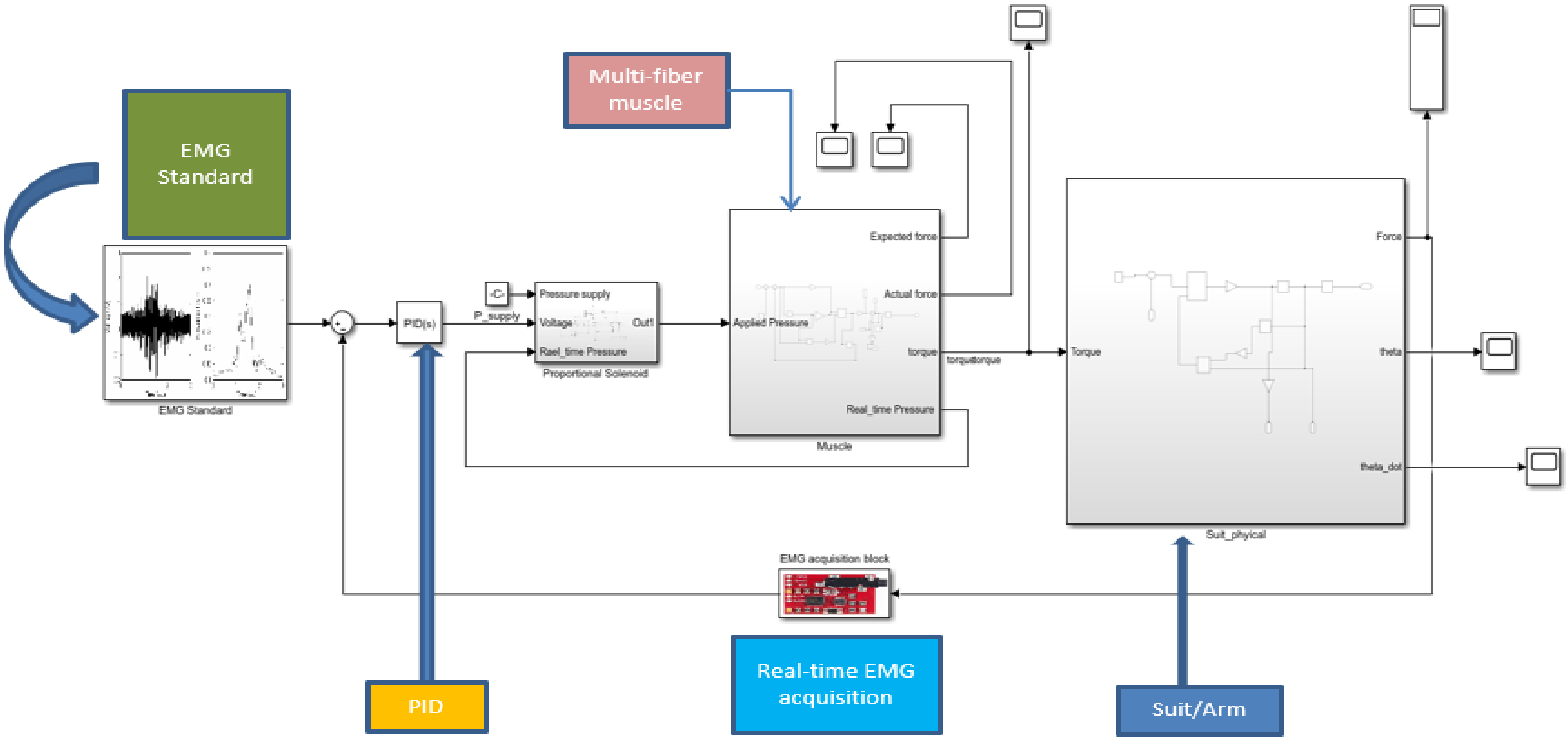



- Four complexes
  - Back Complex
  - Shoulder Complex
  - Elbow Complex
    - Upper Limb part
    - Elbow Joint
    - Forearm Part
  - Hand Complex

- Muscle complexes (yellow)
  - Elbow Muscles
  - Shoulder Muscles

# Sensing & Control

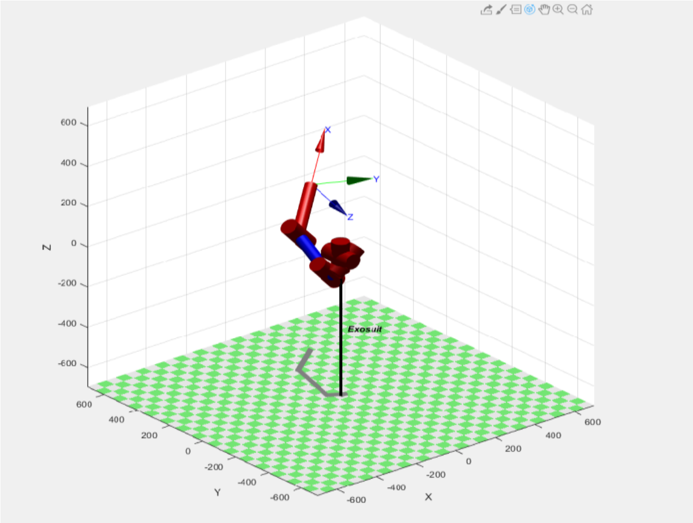
## Overall Svstem Control Block:



# Results and Discussion

## 1. Mathematical modelling:

- The observed actual force is less than theoretical force – due to ***"dead space"***

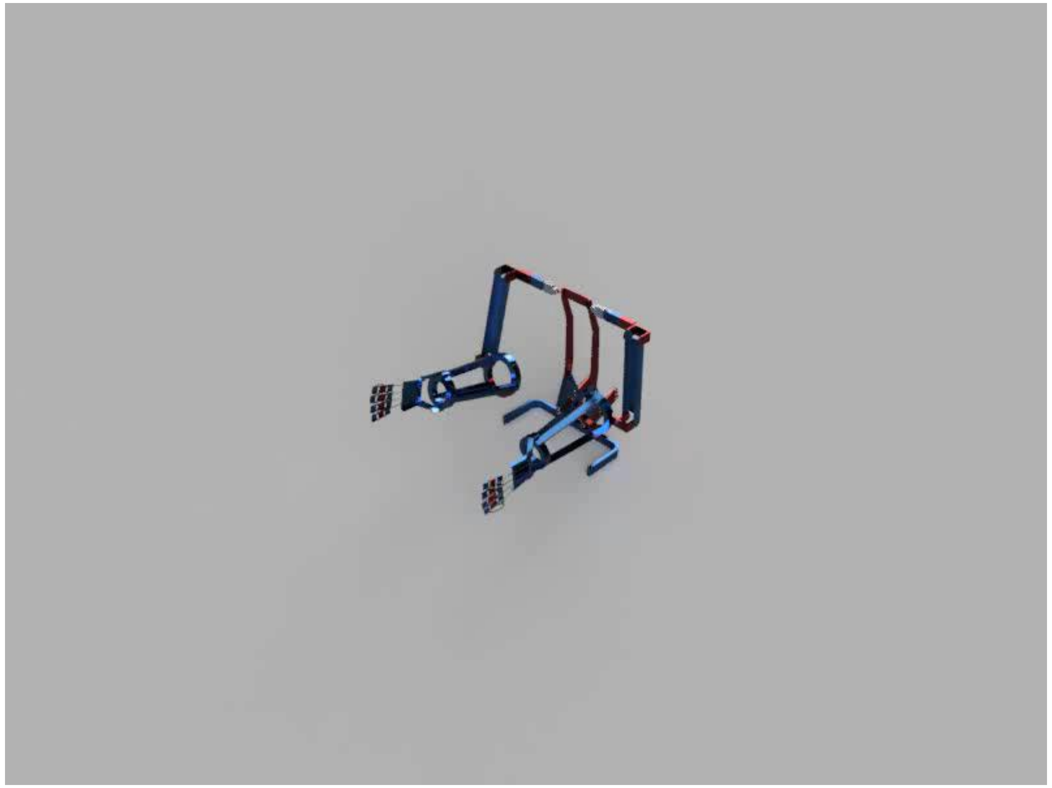



## 2. Kinematic and dynamic modelling:

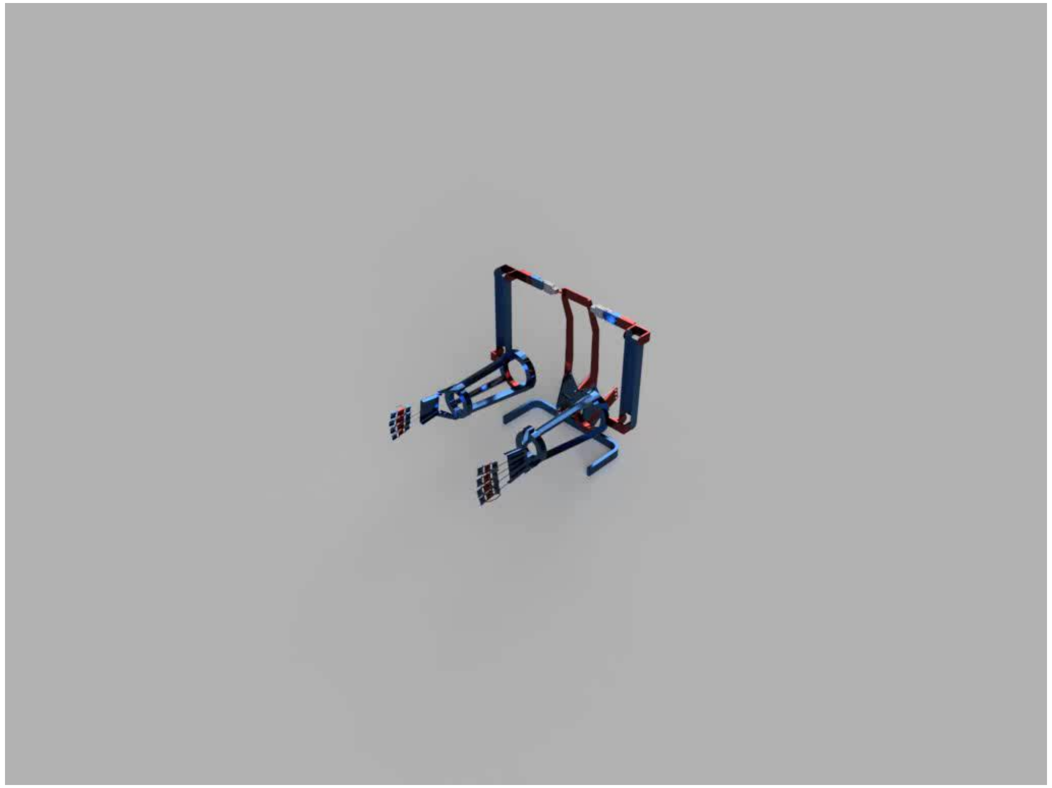
- Dynamic modelling was done using MATLAB robotic system toolbox using DH parameters and transformations
- Forward and inverse dynamic analysis were obtained using the inbuilt functions in MATLAB

# Motion Analysis

- Shoulder

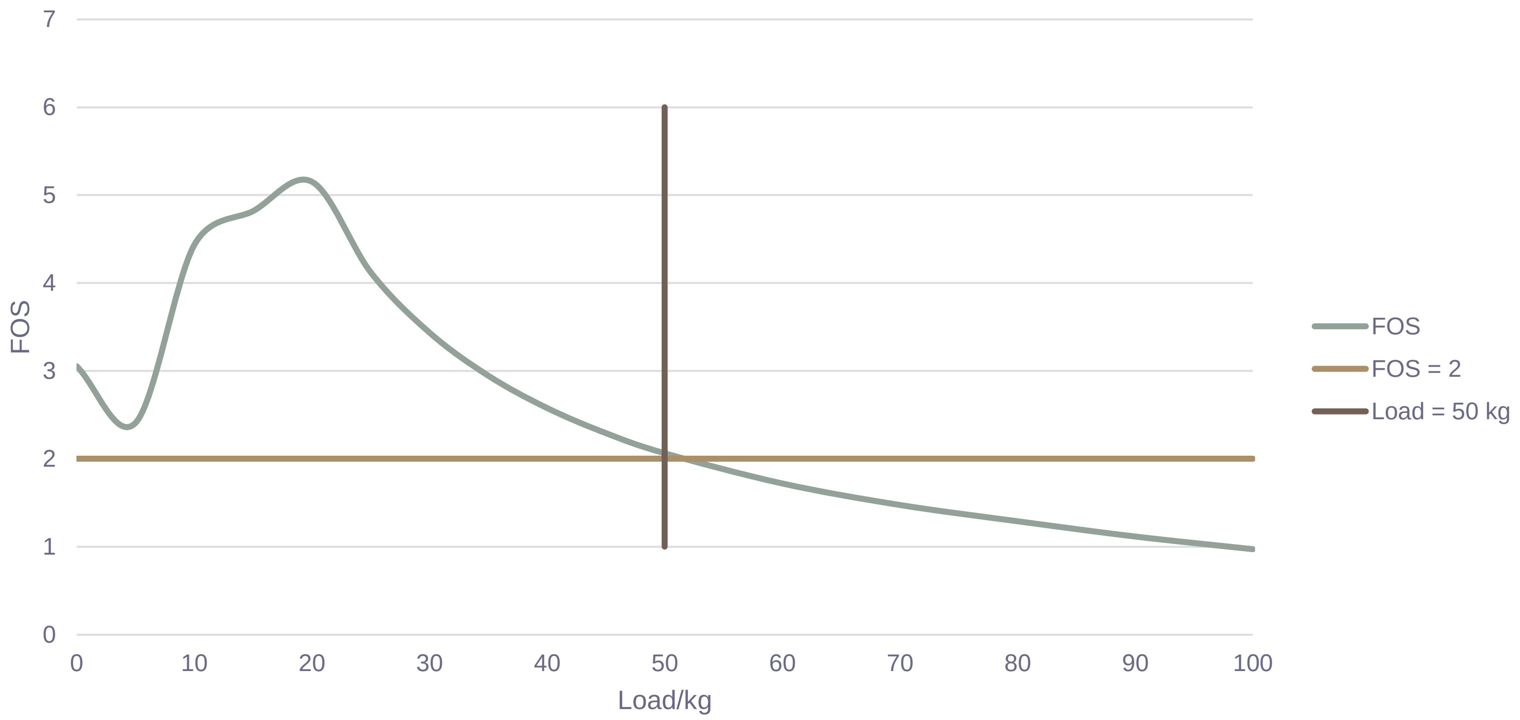


- Elbow

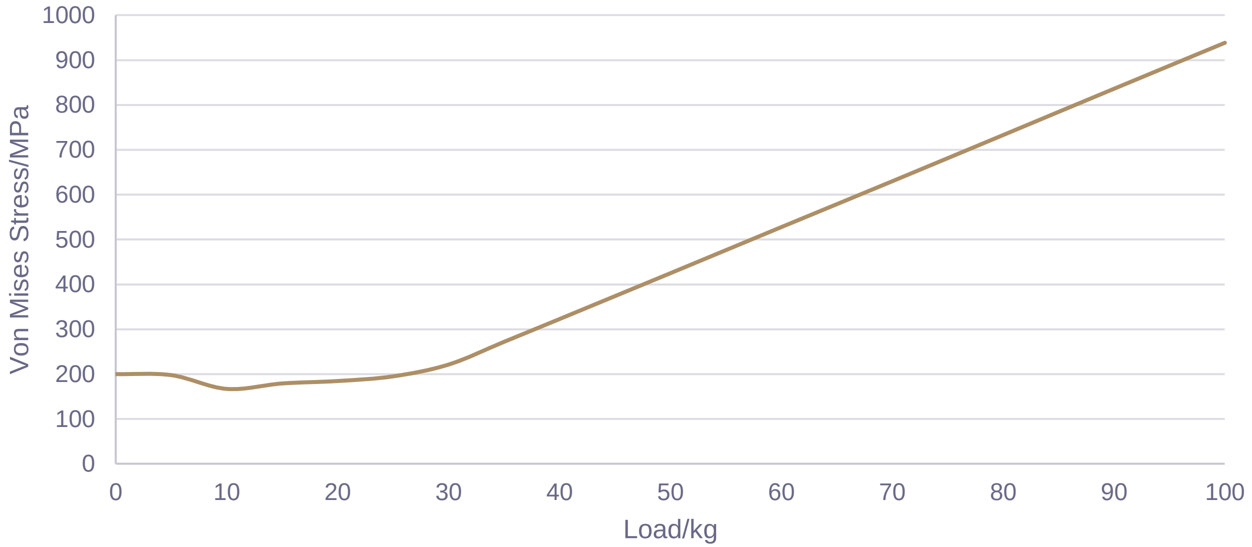


# 3. Mechanical design:

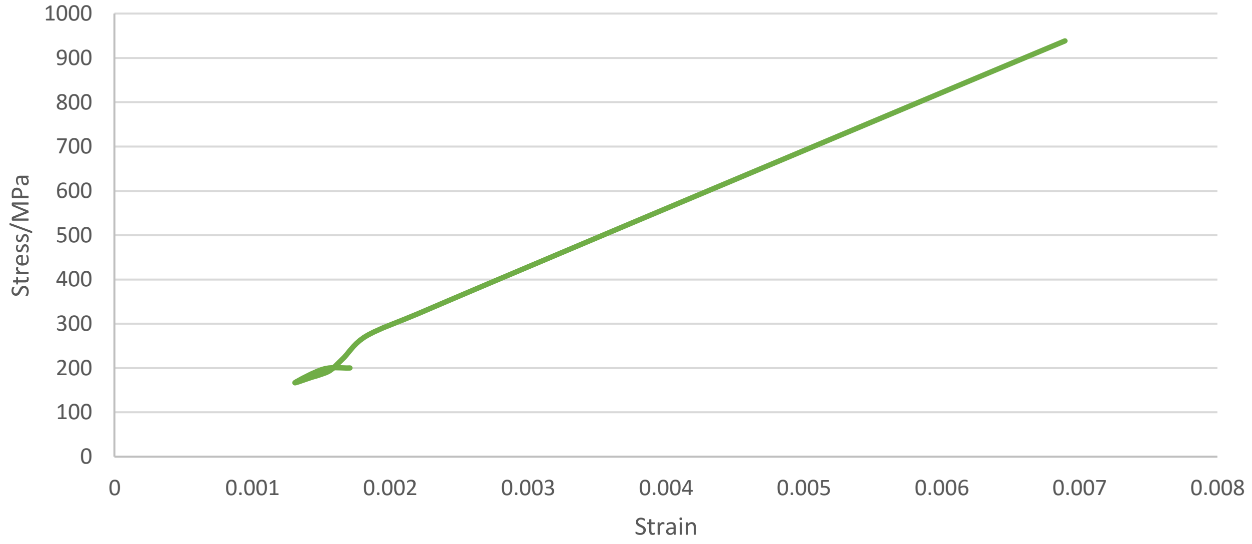
- *Variation of FOS w.r.t Load*



- *Variation in Stress w.r.t Load*

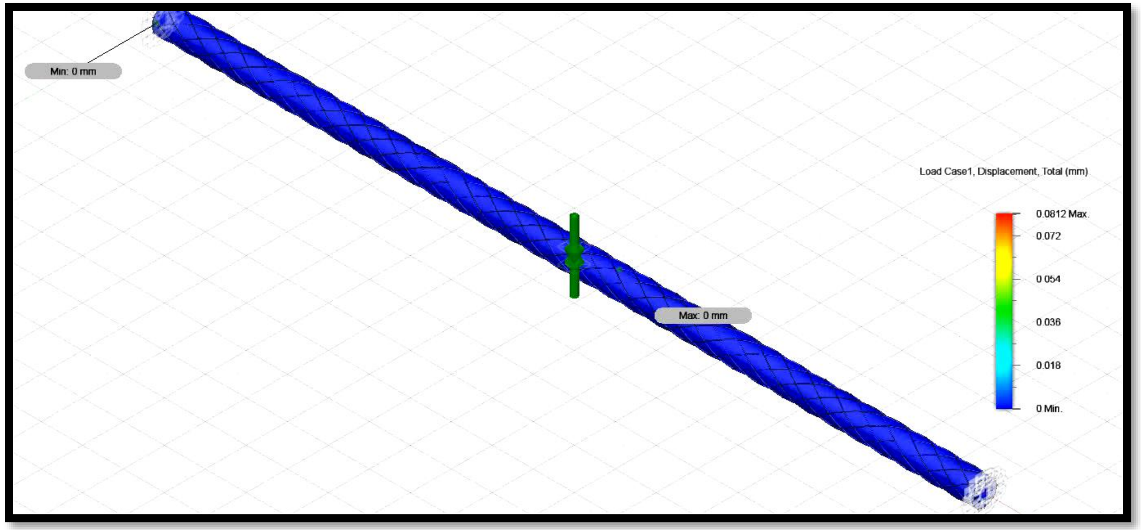



- *Stress-Strain Curve of the suit*



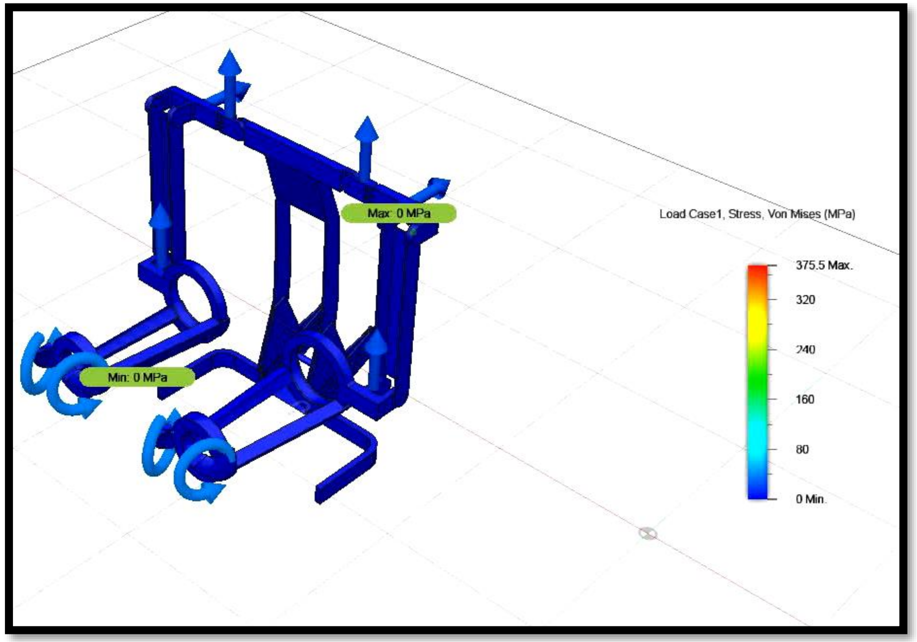
## Simulation of Mckibben Fibre

- Maximum Displacement observed in a single Fibre is 60 microns




## Simulation of Exoskeleton

- Minimum Factor of Safety = 2.356



## 4. Sensing & Control :

- EMG acquisition test : Used to standardize muscle pattern
- Commercial gel electrodes were used which has noise in the input signal. Clinical EMG test will give more accurate results
- Control of the suit was done using a PID model with a proportional valve
- Control variable here is the spool position
- A memory block can be added  to counteract any overloads created
- As a safety precaution , include **deadman's switch**

# Conclusion

- The concept of dead space present during bundling of fibres reduce the expected force received.
- Although multiple EMG tests were conducted, the absence of precision sensors in turn affects the control of the suit. However, using proper AgCl coated electrodes have been seen to tackle this issue fairly.
- The use of an AFC control would have been able to tackle the noises that arise from the inputs as well as during the working cycle.
- Although the use of a proportional solenoid valve gives better control, the price of such an apparatus much higher than the conventional directional valves and increases complexity.

# Scope for future work

- Better design of individual strands and modification of dead space
- Adding more bundles to represent each muscle sector
- Providing a dense energy source to the suit
- The biggest challenge for precision control is precise input acquisition
- Inclusion of ML and/or AI
- Experiments can be done conducted to improve the utility range of use of the suit

# References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# THANK YOU