iJRASET
International Journal For Research in Applied Science and Engineering Technology

# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

**Volume:** 8 **Issue:** VIII **Month of publication:** August 2020

**DOI:** https://doi.org/10.22214/ijraset.2020.31162

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
*ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429*
*Volume 8 Issue VIII Aug 2020- Available at www.ijraset.com*

# Static Structural Analysis of Robotic Adaptive Exosuit for Gait Assistance

Aswanth V Utham[1], Alifsha A[2], Alex Mathew[3], Kiran S[4]
[1, 2, 3, 4]*Mechanical Engineering Department, College of Engineering and Management Punnapra, Alappuzha, APJ Abdul kalam technological University, Thiruvananthapuram, Kerala*

***Abstract:*** ***Recently, due to ageing societal concerns, new scenarios for providing assistance to elderly people for carrying out daily living activities have also started to receive attention, and there is growing urgency for such assistive technologies to help elderly people remain independent. In past years there has been various development in the field of robotic system which paved to the development of wearable exoskeleton system. These systems mainly focused to be used for human power argumentation, robotic rehabilitation and human power assist. There have been various studies conducted in the development of these exoskeleton suits for people who lost their arms and legs or were paralyzed due to their neurological condition in particular due to stroke and spinal cord injury. In this paper focuses on development of a wearable lower limb exoskeleton suit that will be useful for assisting physically weak person, elderly person and for slightly disabled person in their daily life. By studying normal walking behavior of human's as human left leg is in forward motion our right leg will be in forward motion and by using still motion capture system, the desired trajectory of the targeted limb has been collected from a healthy subject and the control system is designed accordingly. An adaptive trajectory control has been developed to guide the patient's limb within the desired path. The design is subjected to various test in Ansys workbench software and the result shows that the design has certain stability and strength margin.***

***Keywords: Exoskeleton, Normal walking, Trajectory control, Stroke, Spinal cord injury***

## I. INTRODUCTION

The intention of this paper is to design a robotic adaptive exosuit for Gait assistance which is controlled by our hand motion and to analyse its working. This robotic adaptive exoskeleton will be helpful for the semi-paralyzed people to achieve their need of locomotion. This exoskeleton acts as actuators and powers up the semi-paralyzed one to move their leg which they can't move by their own. The control of this exoskeleton is based on our normal hand motion during walking [1].

This paper focuses on idea generation, theoretical designing, analysis using software and comparison of test results with latest model of robotic exoskeleton.

The concept of idea generation was based on a survey conducted by us which investigates certain aspects related to our walking manner. The results of the survey suit our idea, that is about 80% of people use to walk in normal manner,- moving their right hand forward when the left leg is in forward motion and moving their left hand forward when their right leg is in forward motion. This is the key point of working principle of the new design.

The design process includes material selection and theoretical design using software. The drafting of the design done using Solid works software. The framework of our design was inspired from certain existing conventional models of exoskeleton. Electronic components include power motors, microcontroller, battery and sensors. The control of the exoskeleton is carried out by a microcontroller called Arduino which receives electronic signals from the sensors provided in hand, analyzes them, give power to motors and move the limbs of the skeleton accordingly. The next part after completing the design was the analysis. We conducted Static, Transient analysis and FEA (Finite Element Analysis) on our design using Ansys Work bench software. The major evaluating criteria selected were, the weight, speed, load carrying capacity, DOF (Degrees of Freedom) etc [3].

## II. DESIGN OF EXOSUIT FRAME

The design limitations are determined and the robotic adaptive exosuit is designed according to these design constraints. Robot design is accomplished with SolidWorks® 2016. The parts of wearable exoskeleton robot designs are described; the working principles and the system elements are explained. In order to make wearable exoskeleton robot for paralytic and disable people walk, design constraints have to be defined. These constraints are listed below;

©IJRASET: All Rights are Reserved

1) Structure is not adjustable with height of the user.
2) Degree of freedom are limited.
3) Design load capacity limited to 1000N and it is useful for up to 70kg weighted peoples. Because actuator is designed for 70kg weight.
4) The actuation must apply torques at the joints of exoskeleton and human.
5) Robot must design to provide adjustability its balance using static walking character autonomously.

*A. Measurement of Human Based on Anthropometry*

1) *Anthropometry:* Anthropometry is the major branch of anthropology that studies the physical measurements of the human body to determine differences in individuals and groups. A wide variety of physical measurements are required to describe and differentiate the characteristics of race, sex, age, and body type. In the past, the major emphasis of these studies has been evolutionary and historical. However, more recently a major impetus has come from the needs of technological developments, especially man-machine interfaces: workspace design, cockpits, pressure suits, Armor, and so on. Most of these needs are satisfied by basic linear, area, and volume measures. However, human movement analysis requires kinetic measures as well: masses, moments of inertia, and their locations. There exists also a moderate body of knowledge regarding the joint centres of rotation, the origin and insertion of muscles, the angles of pull of tendons, and the length and cross-sectional area of muscles [9].
2) *Human Body Dimension Based on Anthropometry*

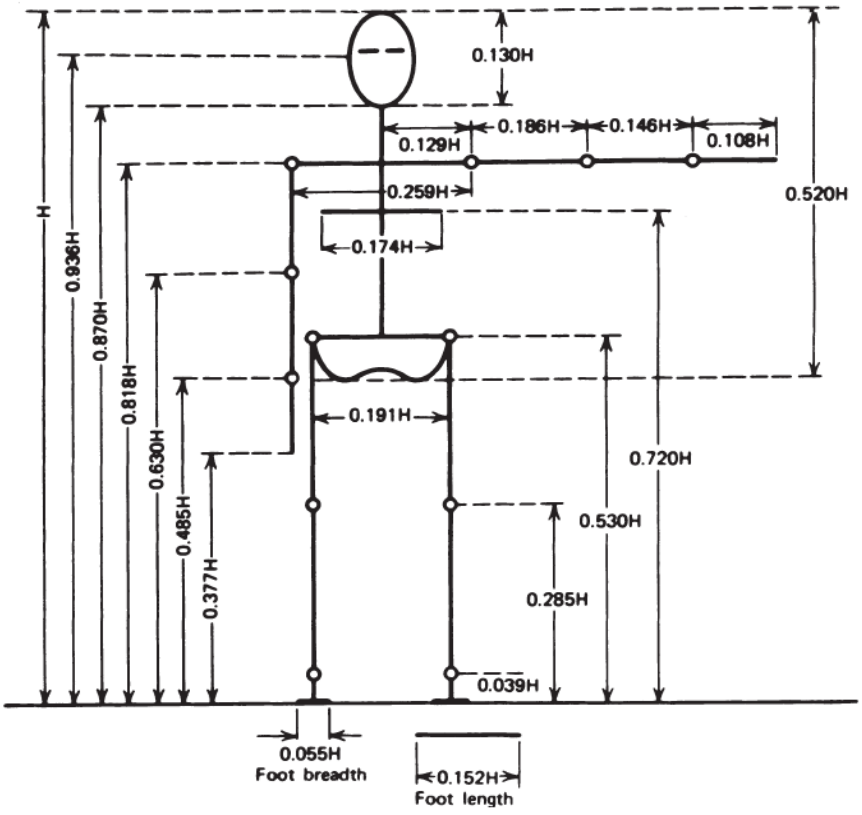



Fig. 1 Body segment lengths expressed as a fraction of body height H.

The most basic body dimension is the length of the segments between each joint. These vary with body build, sex, and racial origin. Dempster and coworkers (1955, 1959) have summarized estimates of segment lengths and joint center locations relative to anatomical landmarks. An average set of segment lengths expressed as a percentage of body height was prepared by Drillis and Contini (1966) and is shown in Fig. 1. These segment proportions serve as a good approximation in the absence of better data, preferably measured directly from the individual [9].

©IJRASET: All Rights are Reserved

*3) Calculation of human body measurment*

Table I Human lower limb meaurement

| | height ratio | Length in cm | Length in mm |
|---|---|---|---|
| Total limb length | 0.530H | 84.8 | 848 |
| Hip joint to knee joint | 0.245H | 39.2 | 392 |
| Knee joint to angle joint | 0.246H | 39.36 | 393.6 |
| Angle joint to ground | 0.039H | 6.24 | 62.4 |
| Foot breadth | 0.055H | 8.8 | 88 |
| Foot length | 0.152H | 24.32 | 243.2 |
| Waist length (hip to hip joint) | 0.191H | 30.56 | 305.6 |

*B. Structural Design of Lower Limb Exosuit*

Fig. 2 Exosuit structure

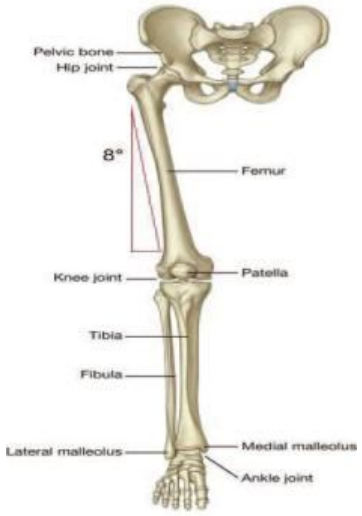



Fig. 3 Human lower limb skeleton

©IJRASET: All Rights are Reserved

## III.STATIC STRUCTURAL ANALYSIS OF LOWER LIMB EXOSUIT

In this, Analysis of approximate conditions in which the position, direction and magnitude of applied load does not vary based on time, ignoring the inertial and damping effects.

The loading is static when;

*1)* Magnitude and direction do not change with time.

*2)* All loads are applied slowly and gradually until they reach their full magnitudes. Inertial and damping properties are ignored due to negligibly small accelerations and velocities.

*3)* Time variant loads which induce considerable inertial and/or damping forces will not be applied.

### *A. 3d Model of the Wearable Lower Extremity Exoskeleton*

As a result of the actual situation of the human body and the use of actual demand, the robotic adaptive exoskeleton mechanical structure is devised by the anthropomorphic mechanical design. The anthropomorphic mechanical design is based on the body, the design of institutional space configuration is based on the human body. The institutions are moved by the human body, presented the same space motion with the human body. So the space character is specific to the human body, and its motion compatible for the human body. This mechanism is based on the human body, the movement of human nature as a reference, it reflects the body's natural motion, this design method is greatly difficult, but it can fully guarantee that the robotic adaptive exoskeleton is coordinated with the man-machine movement and worn comfortably. According to the China Youth average basic physical member of the human body, the size of exoskeleton was designed. The exoskeleton system includes four parts, such as the portion of weight-bearing, the hip part, the knee joint part, the ankle and the sensing part on the foot. When the exoskeleton is designed, the adduction/abduce is putted in the human body after the

waist back, the pronation/supination and the antexion/extension are connected at the human hip; at the knee, there are two degrees of freedom: the pronation/supination and the antexion/extension; at the ankle, there are pronation/supination and the antexion/extension, the adduction/abduce three degrees of freedom, the antexion/extension are active joints, the rest are passive joints. The active joints are drived by the stepper motor that executed the drive function of the joints [8].

### *B. Select the Pose of the Exoskeleton for Static Analysis*

The normal human lower limb is regularly landed and lift, it can be regarded as a periodic move about the left and right leg. The periodicity swing can be divided into some stages: the double legs are supported (normal stand), the left leg is supported, the double legs are supported, and then the right leg is supported. Standing on two legs with weight-bearing accounts for the entire cycle is 27%, standing on single leg with weight-bearing accounts for the entire cycle is 67%, so standing on two legs or on one leg is the most dangerous state of the exoskeleton. Standing on one foot, on two feet, one foot support and one foot is redundance are four analysis positions our positions are shown in Figures below. In Fig 4 represents that the two legs are supported: two feet stand on the ground (normal stand), the body center of gravity are back to its original position, and the body weight is average loaded on the left and right side of the exoskeleton. Fig 5 represents that a foot redundancy and a foot is touched the ground: the right foot is on the ground and the left foot's tip is touched the ground, most of the body weight is loaded on the right of the exoskeleton, a little part of weight is loaded on the left. In Fig 6 represents that the two legs are supported: two feet stand on the ground at same time, the body center of gravity are back to its original position, and the body weight is average loaded on the left and right side of the exoskeleton. Fig 7 represents that a single foot support: Left foot stands on the ground, the right foot is forward, the body center of gravity is on the left the weight of the human body are loaded in the left external exoskeleton[6].

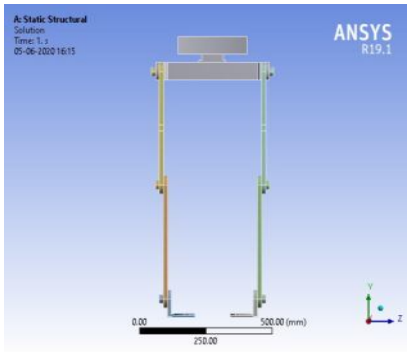



Fig. 4 Actual position (posture 1)

©IJRASET: All Rights are Reserved

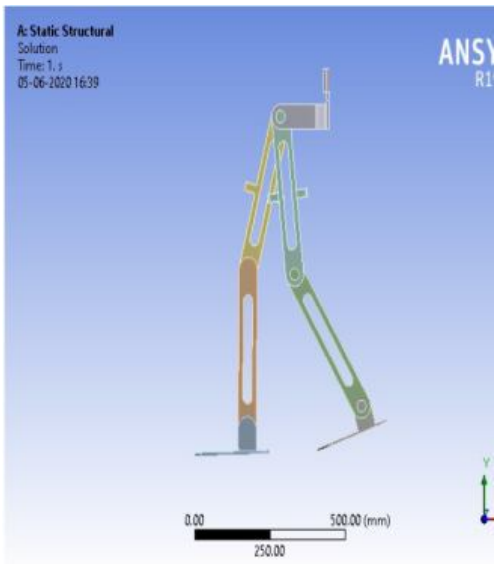



Fig. 5. posture 2

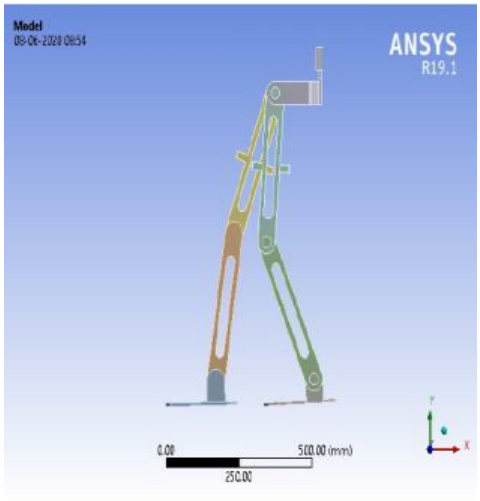



Fig. 6 posture 3

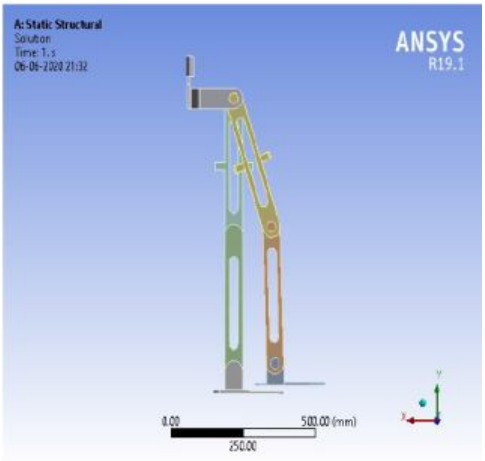



Fig. 7 posture 4

©IJRASET: All Rights are Reserved

*C. Procedure of Static Structural Analysis*

1) *Selection the Material:* The material of the robotic adaptive exosuit mechanical structure is aluminium 2024 T6, the modulus of elasticity is $7.24\times10^{10}$Pa, the Poisson Ratio of the aluminium alloy is 0.33,the density of it is 2700kg/$m^3$ .
2) *Meshing:* The basic idea of FEA is to make calculations at only limited (Finite) number of points and then interpolate the results for the entire domain (surface or volume). Any continuous object has infinite degrees of freedom and it's just not possible to solve the problem in this format. Finite Element Method reduces the degrees of freedom from infinite to finite with the help of discretization or meshing (nodes and elements). The Finite Element Method only makes calculations at a limited (Finite) number of points and then interpolates the results for the entire domain (surface or volume).Meshing is the most important step of the finite element simulation analysis, the Hexa dominant meshing method is used our project. In this project, structure is not complex compared to another lower limb exoskeleton or exosuit so that here we use quad/tri element for the analysis. In meshing process quad element give more accurate result than tri element. But the processing time of quad element is more compared tri element. In this analysis element size 2mm that is grid resolution is 2mm and the exoskeleton assembly contact is custom contacting. The custom contact mean all assembly contact are bonded. Result of meshing shown in the fig. 8 and fig. 9. Result of meshing contain 1666683 nodes and 392619 elements.

Fig. 8 meshed exoskeleton

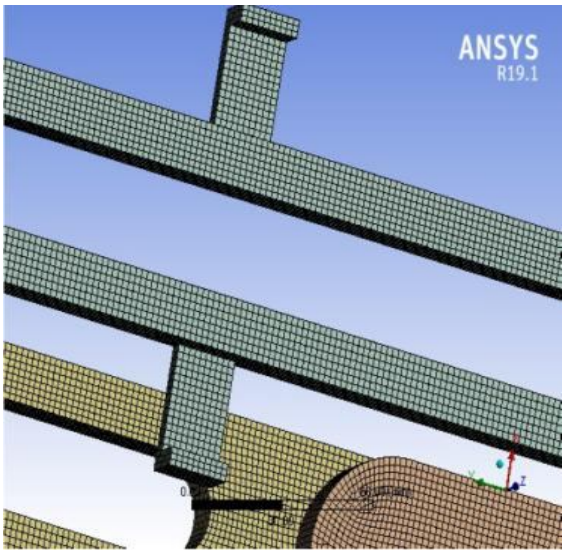


Fig. 9 Quad element arrangement

©IJRASET: All Rights are Reserved

*ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429*
*Volume 8 Issue VIII Aug 2020- Available at www.ijraset.com*

3) *Applied the Constraint and Load:* Exoskeleton is worn outside the human body, and beared the load of itself and the human body. Therefore, the design bearing capacity of the exoskeleton is 100Kg(including the weight of the back frame, battery, motor and other object) but actual weight human not exceed 70kgbecause weight taken on the basics height 160cm. So the force of 1000N is applied on the model in the negative Y direction. The constraint and the style of load applied method as shown in Figure ,Fig 10 presents that the constraints of UX,UY,UZ are applied on the left foot and right foot in the posture 1,and the force of 500N is applied on the right and left back in the direction of negative Y. Fig 11 presents that the constraints of UX,UY,UZ are applied on right feet and also end of left foot or left foot toe in the posture 2, and the force of 1000N is loaded in the left back. Fig 12 expresses that the constraints of UX, UY, UZ are loaded on the right and left foot and force of 500N is applied on the right and left back in the direction of negative Y. Fig 13 present that the constraints of UX, UY, UZ are applied on the left foot in the posture 1, and the force of 1000N is applied on the left back in the direction of negative Y [6];

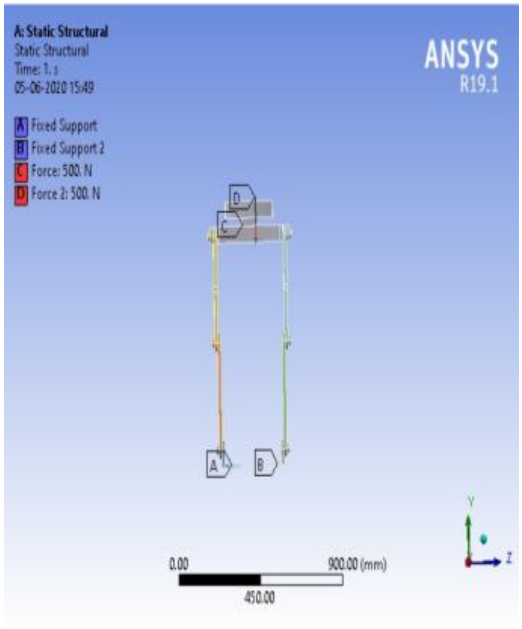



Fig.10 pose 1(force acting)

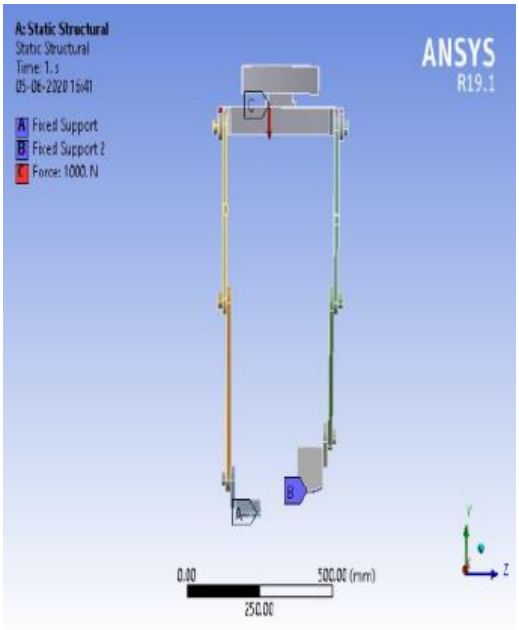



Fig 11 pose 2

©IJRASET: All Rights are Reserved

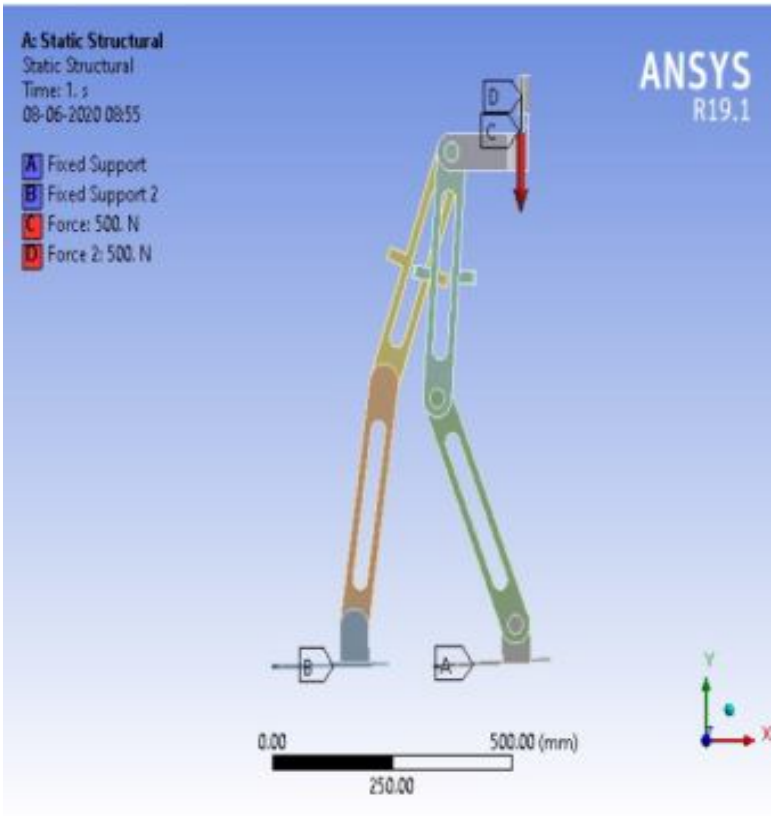



Fig.12 pose 3

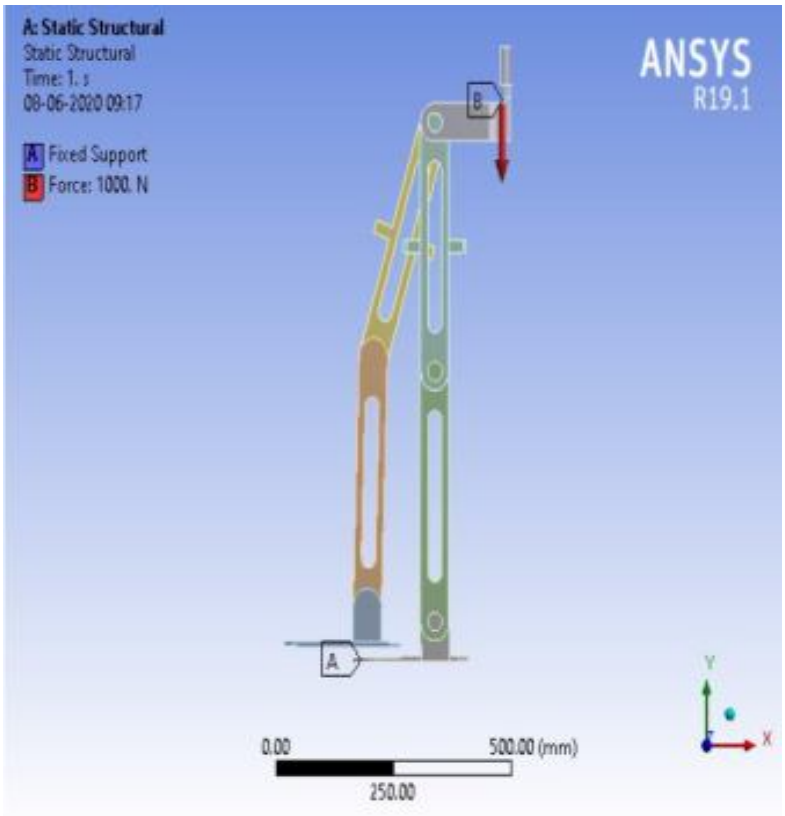



Fig. 13 pose 4

©IJRASET: All Rights are Reserved

## IV. RESULTS AND DISCUSSION

After applying load and constraints, the simulation and analysis is done, then the stress diagram is obtained. Those are shown in Fig 14 to fig 17. Fig 14 show the posture 1 so the maximum stress is 45.675MPa and maximum stress act on left hip joint of the frame. The value obtain is less than the material yield stress. Fig 15 express the posture 2 so the maximum stress is 153.01MPa and it act on left foot toe. The value obtain is less than the material yield stress value. Fig 16 show the posture 3 so the maximum stress is 40.059MPa and it act on the left hip joint of frame. Its value also less than the material yield stress value. Fig 17 show the posture 4 so the maximum stress is 49.811MPa and it is on left hip joint of frame. The value also less than the material yield stress value.

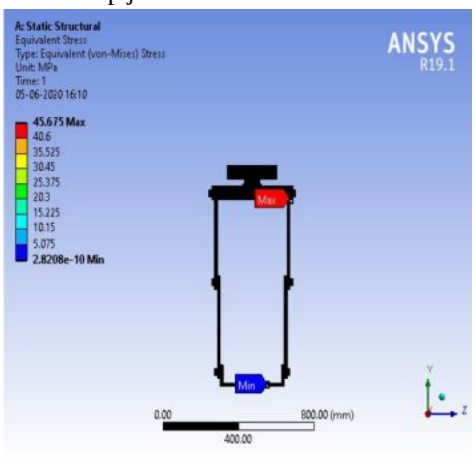



Fig. 14 posture 1 von-mises stress

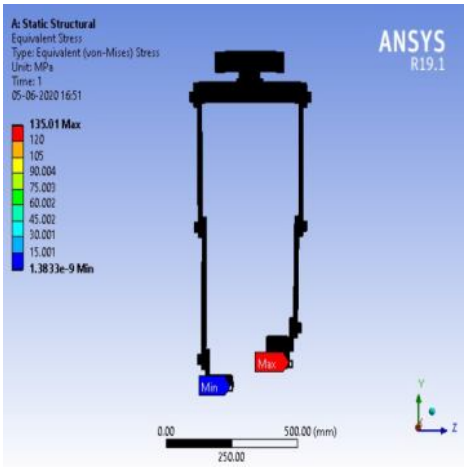



Fig. 15 posture 2 von-mises stress

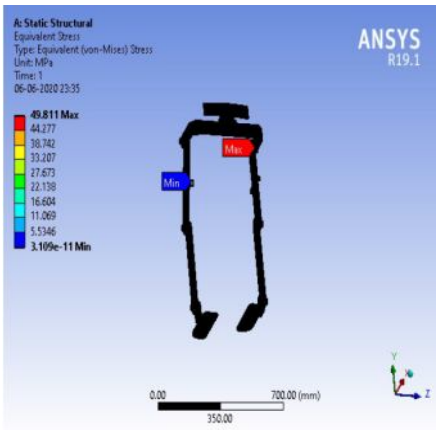



Fig. 16 pose 3 von-mises stress

©IJRASET: All Rights are Reserved

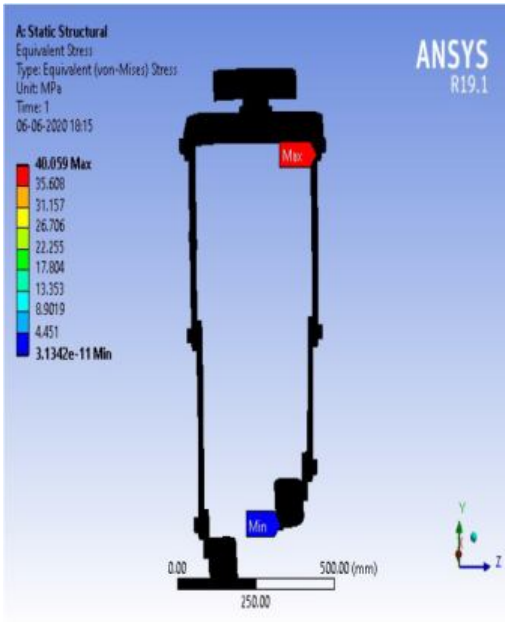



Fig. 17 posture 4 von-mises stress

From the results of Static analysis, the maximum stress is about 135.01MPa (acting on left foot toe in postures 2), which is less than the maximum yield stress of Aluminum 2024 T6 (415MPa). Also the maximum deformation (in millimetre) is about 5.9104mm, which is safe when considering the safety specifications referred from the supporting journals. That is, the overall result of Static Analysis state that design of the exoskeleton is safe. The results obtained from the analysis is illustrated in the table II

Table II static structural analysis results

| Posture | Equivalent stress (von- mises stress) Mpa | Total deformation (mm) |
|---|---|---|
| 1 | 45.675 | 1.6345 |
| 2 | 135.01 | 5.9194 |
| 3 | 40.059 | 3.4043 |
| 4 | 49.811 | 4.6062 |

## V. CONCLUSIONS

The Robotic adaptive exosuit is successfully designed for common people. The designed exosuit rectify all the defects of the previous design. In this project, all the things are analyzed i.e. static analysis of the respected structure with ansys workbench and all the design factors are checked so the design is now safe. Also in order to make the exosuit affordable to common people, for this paper we incorporated material that is of low cost since the proposed exo is based on normal walk so the additional training for wearer is not required hence any person who are wearing the suit can ReWalk again. This paper mainly focusing paraplegic patients who are unable to walk and designed this structure which could be easily wearable to those patients.

The major achievement through this project is that, designed a new exosuit on solidworks. This design resolved all the negatives of the previous design by making the design more simple and affordable to common people. Also the expense for making this exo is not too much compared to existing one. Also changing the driving mechanism as well as control by means of hand motion. These are the speciality of this paper. The analysis result got after importing the design on ansys workbench shows the success i.e. all the parameters for the design are within the limit and hence the design is safe and affordable to common peoples.

©IJRASET: All Rights are Reserved

Inorder to improve the step climbing, the exo is designed in such a manner by considering ankle joint. The chains are given motion to ankle joint. By considering user interaction with the exo all the things are incorporated which gives comfort to the wearer while walking. So in total our design is safe and secure as well as aesthetic to the respective user. The exo is designed by asking design comfort aspects by taking small surveys so the design included all the things which will attract the users in all the way.

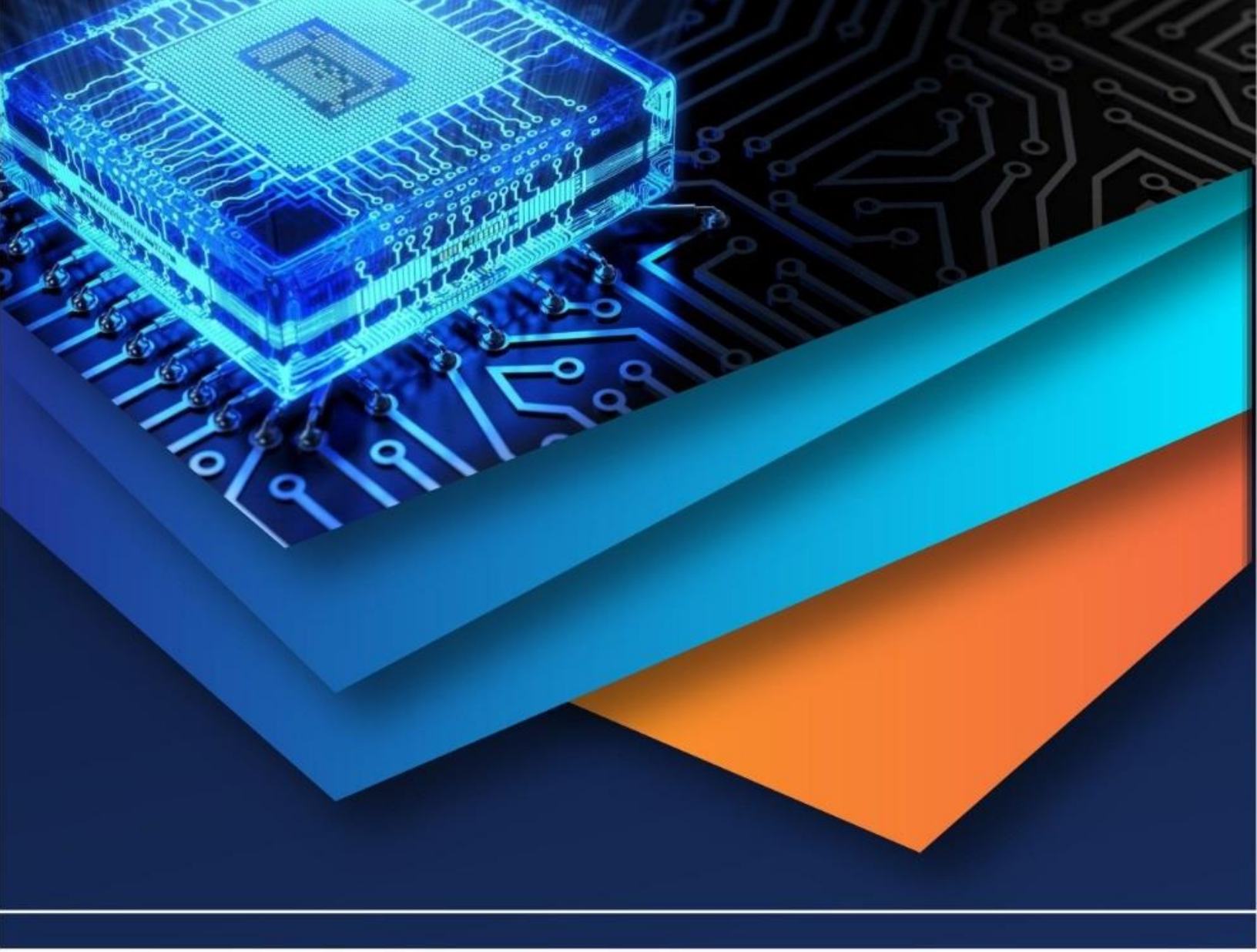
## VI. ACKNOWLEDGMENT

Primarily we devote our gratitude towards the almighty God for his grace and blessings.
First and foremost, we wish to place on records, my ardent and earnest gratitude to Dr.V.KAMALAKANNAN, *Head of the department of Mechanical Engineering* for providing me with all facilities for the completion of this work**.**
We are extremely honoured to mention great words of gratitude to our project guide Mr. JAYAMOHAN K G**.** *Assistant professor, Dept. of Mechanical Engineering.* His tutelage and guidance was the leading factor in translating our efforts to fruition. His prudent and perspective vision has shown light on my trail triumph.

## REFERENCES

[1] YuH, Cruz M.S.T.A, Chen G "Mechanical design of portable knee-ankle –foot robot" International conference on Robotics and Automation (ICRA), 2013, .2183-2188.
[2] Onen U, Botsali F.M, Kalyoncu M "Design and actuator selection of a lower extremity exoskeleton" IEEE/ASME Transaction on Mechatronics, Vol 19, issue 2, 2013, p.623-632.
[3] Yali Han, Xingsong Wang ".Dynamic analysis and simulation of lower power assisted exoskeleton" Journal of system simulation, Vol.25, issue 1, 2013.
[4] Sheih W.B., Tsai L.W., and Azarm "4.Design and optimization of a one degree of freedom six bar leg mechanism for a walking machine " journal of robotic system Vol.14, pp. 871-880.
[5] Tung, Wein Yi-Wei "Design and Operation of Minimally Actuated Medical Exoskeleton for individuals with paralysis" University of California Berkeley 2018.
[6] Li-Mei-Cheng, Chen Dai-min, WAND-Li-rong, TAO Jing-jing, Chen Dong et al "The Static Analysis of Wearable Lower Extremity Exoskeleton Based on ANSYS Workbench" 2013 IEEE 9th International Conference on Mobile Ad-hoc and Sensor Networks.
[7] Yali Han, Xingsong Wang et al. "Dynamic analysis and simulation of lower power assisted exoskeleton" Journal of system simulation, Vol.25, issue 1, 2013
[8] Walsh C.J, Paluska D, Pasch K, Grand W,Valiente A, Herr H, et al. "Development of a light weight under actuated exoskeleton for the load carrying augmentation" International conference on Robotics and Automation..
[9] DAVID A. WINTER "biomechanics and motor control of human movement" Fourth Edition Published by John Wiley & Sons,Inc.,Hoboken,

©IJRASET: All Rights are Reserved



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089 (24*7 Support on Whatsapp)