iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 **Issue:** IX **Month of publication:** September 2021

DOI: https://doi.org/10.22214/ijraset.2021.38090

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 9 Issue IX Sep 2021- Available at www.ijraset.com

Design and Analysis of Lightweight Lower Limb Exoskeleton for Military Usage

Sumit Raut[1], Vishal Hase[2], Shreyas Kotgire[3], Swapnil Dalvi[4], Yogesh Maske[5]
[1, 2, 3, 4]Student, [5]Assistant Professor, MIT Academy of Engineering Alandi (D), District-Pune, Maharashtra-412105, India

Abstract: Nowadays, due to technological advancement, weapons are becoming smaller in size, which leads to the number of weapons carried by a single person increasing. As the number of weapons is increasing, then the capacity of the load carriage system of military personnel causes a great energy loss to carry weight. Also, carrying a weight of about 25 kg to 50 kg in different terrain causes different foot injuries which create a strain on the human body. An exoskeleton is a device used to replicate the motion of the human body so that humans can be used to control mechanical power for working on different operations which are beyond human strength. The exoskeleton technology makes it possible to reduce the energy loss of military personnel to produce controlled motion of the exoskeleton in different terrain. Hence, this project is aims to design a lower limb exoskeleton for carrying military load carriage systems. The designing and simulating the lower limb exoskeleton is done on fusion 360.
Keywords: lower limb exoskeleton, military exoskeleton, exoskeleton design, exoskeleton analysis

I. INTRODUCTION

An Exoskeleton is a wearable mechanical device that is used when a person is unable to perform human body motion. In that case, these devices are used as an external source of power for the motion of the body [1]. Thus, exoskeleton devices helped to improve and simplify the quality of the person. If there is some problem with people with disabilities in legs, these people use the exoskeleton. In the field of robotics, the exoskeletons are designed and developed to support the human limbs and to increase the range of motion of human limbs, even if they are disabled. Exoskeletons are used for human movement.

Due to advancement in weapons, the military personnel need to carry different weapons in their load carriage system during combat, which is up to load of 50kg. There are some leg injuries caused due to carrying such a high amount of weight and a high amount of energy is lost in carrying operation. There are so many loads in a bag of military personnel. This load is very heavy and harmful to military personnel. This exoskeleton can be used to carry this load carriage system as this device can easily replicate human motion which effectively decreases an effort in the military area and also provides comfort for military personnel [2].

This paper discusses the material selection, design, low cost, modification in design, analysis of design. Different materials are used for the exoskeleton body but in this case, the material should be light as much as possible and tough to transfer high torque and carry weight up to 60kg, which is given in [3]. In the exoskeleton design, the most important factor is the weight of the exoskeleton which can be reduced by proper material selection. By selecting proper material selection, the stiffness and load-carrying capacity of the exoskeleton is increased which is helpful for the proper functioning of the exoskeleton. The study of forces is carried out to find out the torque at each joint. For the proper functioning of the exoskeleton, the degree of freedom and force which act on the exoskeleton must be considered while designing the exoskeleton [4]. Then an analysis of each part of the exoskeleton is done to ensure that any part of the exoskeleton will not fail in the combat field condition [5],[6].

II. LITERATURE REVIEW

Norazam Aliman, et.al have discovered Design and development of lower Limb exoskeletons survey [7]. In that, they have discussed design consideration control strategy. Degree of Freedom, then Applied joints, Application domain then transmission design concepts. Also, they talked about multiple different types of joints concepts of Rehabilitation. In this, they found different types of actuators. That is nothing but the hybrid Actuator LLE devices. There is a different detailed specification of multiple Joint Lower limbs also given. Design and development in which regard LLEs for different augmentation and muscular weakness they do a lot of research on actuators and their design. Zhiguo Lu, et.al has discovered Design and Simulation Analysis of a Lower limb exoskeleton powered by hydraulic drive [8]. In that, they are said to be various simulations analysis of Lower limbs. Also, there are different hydraulic systems that are utilized in robotic devices for better accord in robotic devices in robotic devices for better accuracy & for control motions. And hydraulic control circuits have different mechanical structures. There are different concepts of hip joint structure, knee structural design, and Foot Structural design.

©IJRASET: All Rights are Reserved

The exoskeleton consists of different bar mechanisms and different knee joints and proper movement trace, angle, and speed tendency. An exoskeleton is controlled with a micro-hydraulic system pumps which depend on control cylinders. In this, they discussed different hydraulic designs and simulations of an exoskeleton.

Renee L. Attwells, et. Al "Influence of carrying heavy loads on soldiers' posture, movements, and gait [9]. In this paper, they have studied the effect on a soldier's body while carrying a load ranging from 8 to 50 kg. The study is done on about 20 soldiers. For reducing the stress on their body, the major load of carriage is applied close to the centre of gravity of a body. The research is about the carriage energy cost, an effect of speed and biomechanical effects like changes in posture and gait mechanics of military personnel while carrying the load. The observation carried about stride length, stride frequency, speed, femur angle, mean ankle, knee. The study is carried in different four conditions control, webbing, backpack, LAW. In the study, as the load increases, the ROM of the knee is increased and the femur angle is increased, but stride length and stride frequency are reduced to half. The increase in the load also caused some problems like ankle extension and flexion. Due to this lower back injury, increased stress on neck muscle, musculoskeletal dysfunction, craniofacial and shoulder pain.

Joseph J. Knapik, USA "Soldier Load Carriage: Historical, Physiological, Biomechanical, and Medical Aspects" [3]. In this research, they have studied the soldier load carriage system during the war with respect to historical, physiological, biomechanical aspects. Load carriage systems used in wars carried by soldiers include components to enhance efficiency like belts, shoulder straps, backpacks. The load-carrying capacity of the soldier has been increased since the advancement in the military equipment in the 18th-century average carriage weight is about 15 kg and in recent years it ranges from 45 to 60 kg. To compensate for carrying capacity, the physical requirement for soldier selection is also increased. In the 1st world war, the requirement is about 163 cm height and 56 kg weight 1998 US male recruits is about 177cm and 79 kg body mass. There are various medical injuries caused due to this heavy load carriage like foot blister, back pain, metatarsalgia, leg strain, sprains, and knee pain.

Hina Najam, Burak Bal and Ramazan Ünal "Material Selection for Knee Exoskeleton Frame [10]. The paper explains material selection for exoskeleton with respect to the different aspects like strength to weight ratio, stiffness, fracture toughness, ease of manufacturing and cost also terms like density, tensile strength, Young modulus, fracture toughness. The exoskeleton should be as light as possible and be able to withstand torque generated by the actuator and the body weight. The comparison takes place with different metals, alloys, and composites. From different Al7075 and carbon fibre used for finite element analysis. After FEA, carbon fibre has less deformation than Al7075. But after considering the cost term carbon fibre has much higher value than the Al7075.

Rafael Rodriguez-Martinez1, et.al` Proposal by the simple design of the lower limb exoskeleton of continuous use, provided of own mobility and body load support. Case: application due to an illness" January 2018 [11]. They did research to design an inexpensive lower limb exoskeleton for walking disabilities due to neurological, orthopedic, and traumatic. The study is about the gait cycle which involves stride length, step length, speed, and rhythm using neurological principles that control the movement. The main movement of the knee is flexion and extension which can be replicated by using a polycentric four-bar mechanism. In the knee joint, 15-degree to 95-degree flexion can be obtained. In the ankle joint the ankle flexion is about 20-degree.

A. Problem Statement

The ground troops of the military need to carry large weight in their load carriage system in combat, which leads to loss of energy and also foot injuries. This load carriage system can be carried by the device which is easy to replicate human motion due to this it is easy to handle and carry high weight. To design and analyses an exoskeleton which can carry high weight up to 50 kg, tough to resist extreme combat condition and cost-effective for mass production.

III.DESIGN

The main aim of this paper is to design a lower limb exoskeleton for the military personnel usage for load carriage system. The exoskeleton must be cost-effective, lightweight, tough, can handle smoothly in the combat situation, and can be easily disassembled and assembled so that it should have fewer working components. For that purpose, material selection for the structure is to be done as the major portion of the exoskeleton.

A. Material Selection

The entire document should be in Times New Roman or Times font. Type 3 fonts must not be used. Other font types may be used if needed for special purposes.Material is the most important part of the exoskeleton, and properties like toughness, stiffness, strength, and light in weight take into consideration the material performance index.

©IJRASET: All Rights are Reserved

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue IX Sep 2021- Available at www.ijraset.com

The material performance index is the most important part of the selection of material for an exoskeleton. There are so many considerations in a material selection that are further discussed [10].

Index for strength to weight ratio

M1= Yield strength / density

Index for maximizing stiffness

M2= Young's modulus / density

Index for maximum fracture toughness

M3= Fracture toughness / Density

Performance index

Z= 10M1 +5M2 + 3M3

Those materials having a maximum value of Z are selected for an exoskeleton frame. M1, M2, M3 are different important material indexes. Metals, alloy, and fiber are considered for material selection for high strength and stiffness. The cost is an important factor as a large amount of cost will get incurred for structural material and for processing of that material.

Table I: Comparison Of Material Properties For Exoskeleton Structure

Sr. No.	Material	E GPA	Yield Strength MPA	Density G/CM^3	Fracture Toughness MPa.m1/2	M1	M2	M3	Z	Cost/Kg
1	Aluminium 6061-T6	68	240	2700	29	0.089	0.003	0.011	0.936	505
2	Aluminium 7075	71.7	572	2810	24.7	0.204	0.003	0.009	2.077	750
3	Nitronic-60 Stainless Steel	180	400	8060	22	0.050	0.002	0.003	0.513	800
4	15 5 ph. Stainless Steel	196	1275	7780	18	0.164	0.002	0.002	1.655	380
5	Duralumin	73	300	2950	35	0.102	0.003	0.012	1.067	650
6	Carbon Fibre	228	1600	2490	20	0.643	0.006	0.008	6.480	5200
7	Fibre Glass	85	1500	2600	30	0.577	0.004	0.012	5.822	300
8	420 Stainless Steel	205	345	7800	40	0.044	0.002	0.005	0.467	200
9	630 Stainless Steel	203	1415	8061	22	0.176	0.002	0.003	1.772	399
10	Ti-6Al-7Nb	110	900	4530	75	0.199	0.002	0.017	2.107	1650

The carbon fiber has the highest performance index, i.e., 5.822, but the material cost is also high as PRs 5200/-. Also, the aluminum 7075 and titanium alloy has same performance index as 2 the titanium alloy cost double that of aluminum alloy also 630 stainless steel also has a performance index of about 1.7 which is given in Table I.

B. Torque Calculation

The lower limb exoskeleton can be moved by three rotational joints at the hip, knee, and ankle joints. To find out the speed and torque of each joint, we need to do a force analysis of each limb of the exoskeleton [12]. The torque is calculated by forces at each joint and limb which are shown in the free-body diagram as shown in Fig. 1. For calculating the torque mass of each limb and joint, the following are required which are given below. For a given person, the mass of the person is about 79kg and the height is 1.79m is taken for the torque analysis. The ratio of the length of the human limbs and height are considered for the calculation from the example of [13].

Height of person = H = 1.79 m

Mass of person = W = 79 kg

L1 = Distance between hip assembly and knee joint = 0.245 H

L2 = Distance between knee joint and ankle joint = 0.242 H

L3 = Distance between ankle joint and top of toe = 0.130 H

MA1 = Mass of actuator assembly at hip = 3.280

MA2 = Mass of actuator assembly at knee = 2.650

MA3 = Mass of actuator assembly at ankle = 0.140

©IJRASET: All Rights are Reserved

MB1 = Weight of thigh = 10.5 % of body weight (W)
MB2 = Weight of leg = 4.75 % of body weight (W)
MB3 = Weight of foot = 1.43 % of body weight (W)
ML1 = Mass of structural support at thigh = 0.456
ML2 = Mass of structural support at leg = 0.450
ML3 = Mass of structural support at palm = 0.340

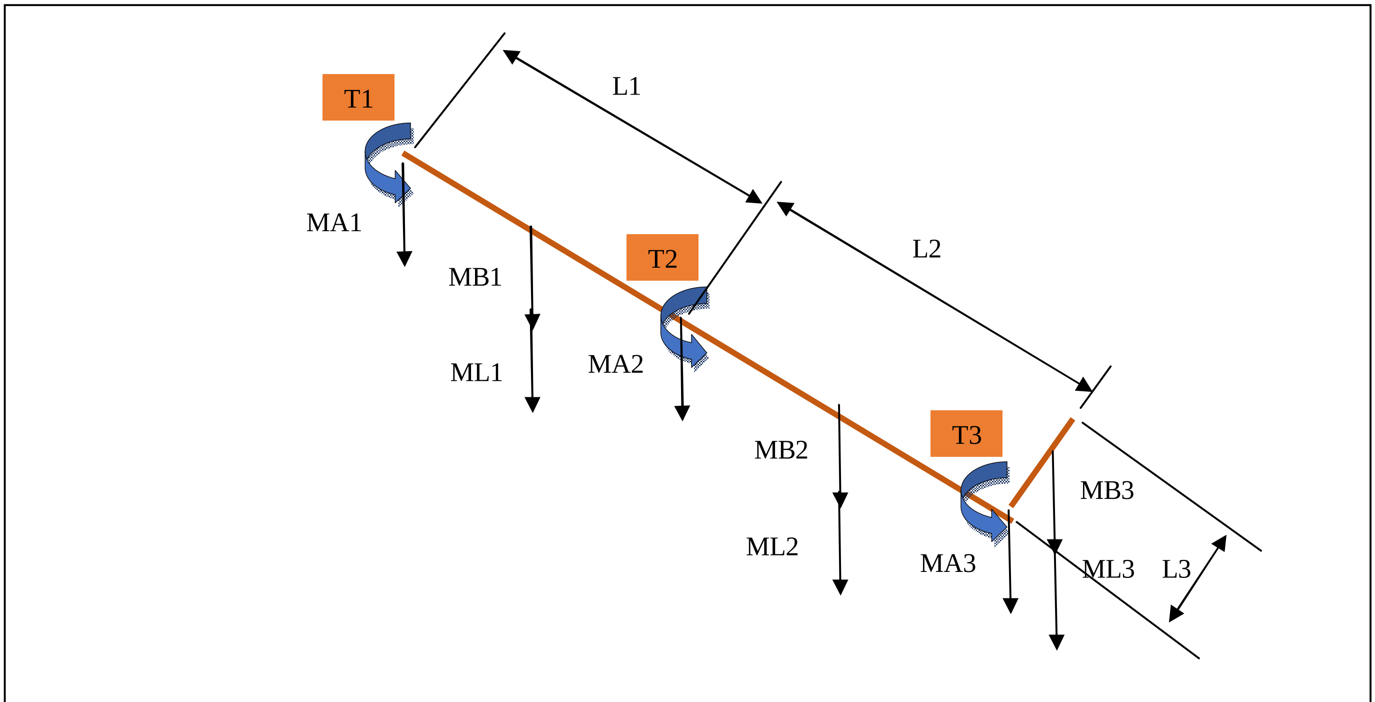


Fig. 1 Free body diagram of an exoskeleton

For the torque calculation at each joint given formula is used which is just simplified as tangential force * distance of the force from the joint centre and the force is calculated from the masses and the gravitational force.

T_1= sinϴ [(MB_1 + ML_1)*g*(l_1/2) +MA_2*g*(l_1)] + sinϴ [(MB_2 + ML_2)*g*(l_1+(l_2/2))] + sinϴ [MA_3*g*(l_1+l_2)] + sinϴ [(MB_3 + ML_3)*g*(l_1+l_2)] + cosϴ [(MB_3 + ML_3)*g*(l_3/2)]

The above formula is given to find out the torque required at the Hip joint. While moving or walking the hip joint will lift all the weight of the exoskeleton at that part so it will have the maximum torque. While normal walking the range of motion of the hip joint is about -15 to 20 degrees but in some extreme cases, it can reach about 90 degrees. For that purpose, the torque is calculated at a different angle from o to 90 degrees as shown in Fig. 2 from which maximum torque is taken for the calculation and requirement of the motor. The mass of the exoskeleton is first converted into the tangential forces and then multiplied with the length to find the torque.

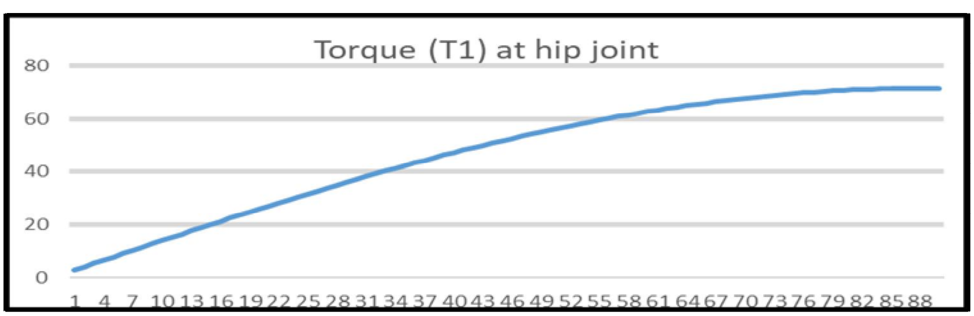


Fig. 2 Torque at the hip joint in Nm vs theta (ϴ) in degree

T_2 = sinϴ [(MB_2 +ML_2)*g*(l_2/2)] + sinϴ [(MA_3 + MB_3)*g*(l_2)] + cosϴ [(MB_3 + ML_3)*g*(l_3/2)]

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue IX Sep 2021- Available at www.ijraset.com

The torque requires at the knee joint can be calculated by the above formula. The knee joint has a range of motion from 0 degrees to 40 degrees which are effectively used in the extension and flexion of the knee joint. The moment at the joint can be calculated by the load applied by the parts which are below the joint. The maximum torque was calculated as 14.43 Nm which is maxed at an angle of 90 degrees as shown in Fig. 3.

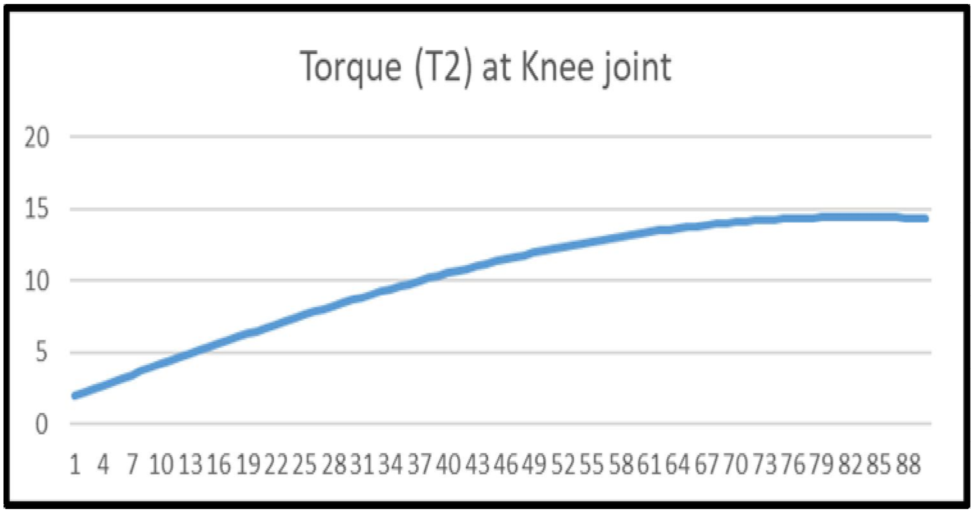


Fig. 3 Torque at the knee joint in Nm vs theta (Ө) in degree

$T_3 = \cos\Theta\ [(MB_3 + ML_3)*g*(l_3/2)]$

The torque calculated at this joint is very less as there is very less load is applied which fever parts. The range of motion of this joint is -15 degrees to 20 degrees which can be easily obtained by human power and spring-back force. The torque calculated at this joint is about 1.677 NM as shown in Fig. 4.

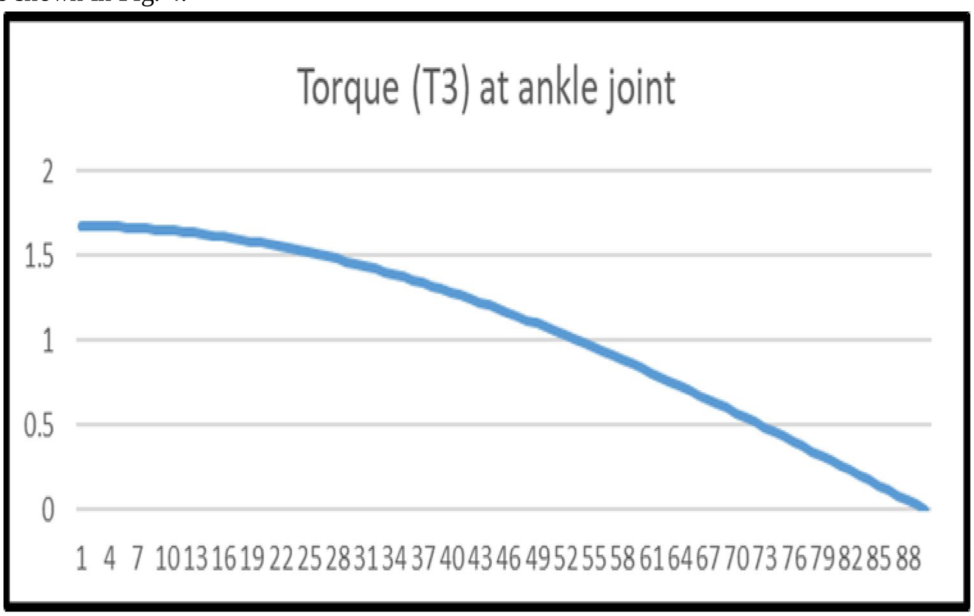


Fig. 4 Torque at the ankle joint in Nm vs theta (Ө) in degree

This is the graph for torque analysis at each at a different angle for different positions of the torque. This calculation is basically to find out the torque which will give to a requirement for selection of motor and the gear assembly at each joint. After doing the calculation at each joint with different theta angle the maximum torque at different joints are at the hip joint as 71.44Nm, at the knee joint is 14.42 Nm and at ankle joint is about 1.677 Nm.

©IJRASET: All Rights are Reserved

C. 3D Modeling

The lower limb exoskeleton device is made to support the human weight with human motion, so it is divided into three sub-assemblies that are hip assembly for supporting the weight, knee which is going to provide motion between hip and ankle assembly which support the whole assembly at the ground. The requirement for an exoskeleton is for military personnel of about 79kg, 1.79m, and need to carry weight about 50kg and with a speed of 1.54m/s is given in [14]. The weight is going to attach at the backside of the hip assembly as it is the best position to carry weight which is considered in the previous studies of the gait cycle [15].

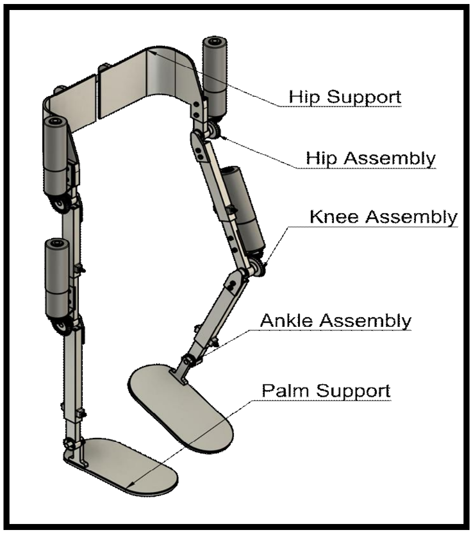


Fig. 5 Assembly of the Lower limb exoskeleton

According to the torque calculation, there are different torque and speeds needed to produce at each joint. The hip joint has the highest torque is 71.44 Nm which can be driven by the motor Crouzet Brushless Geared DC Geared Motor, 125 W which can produce a torque of about 31 Nm at a speed of 40rpm with help of bevel gear which is having speed ratio of 5:2 which will increase torque at joint up to 77.5 Nm with a speed of 16rpm as shown in Fig. 5. At the Knee joint the torque required is about 14.42 which can be produced by RHINO 24V 30 rpm 100w ig52 extra heavy-duty planetary geared dc motor 380kg*cm which can produce a torque of about 16 Nm at a speed of 30 rpm with the help of bevel gear having speed ratio of 2:1 will produce the torque at the joint about 32 Nm with a speed of 15 rpm as shown in Fig. 5. The ankle joint requires very little torque as it does not contain any heavy assembly, the torque is about 1.677 Nm which can be easily produced by any human leg, so these spring back assemblies are used to control the motion of the ankle joint.

1) *Ankle Assembly:* The given assembly is the weight of the whole exoskeleton and carrying weight for the foot assembly is applied on this part. It contains one degree of freedom which is rotational joint and needs to be access in the range of -20 to 20 degrees [16]. As the above calculation has shown that this part requires maximum torque of about 1.677 Nm which can be easily controlled by the human power and spring back mechanism. For grip at the bottom, a rubber plate is attached for use in the different fields as shown in Fig. 6.

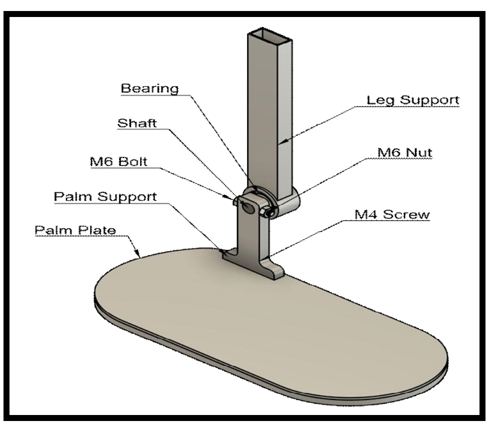


Fig. 6 Assembly of Ankle joint

2) *Hip Assembly:* This is a hip assembly shown in the figure having two degrees of freedom. One is rotational which is used to drive the motion of the thigh portion and another one is also rotational, which is used for swivelling of the exoskeleton around the vertical axis. The main purpose of the hip assembly is to support the load carriage system in the military, and another is to drive the thigh portion of the assembly body as shown in Fig. 7. The average speed of the military personnel is 1.54 m/s according to that, the rotational speed is required is about 12 – 16 rpm to achieve 1.54m/s speed and the maximum torque is about 71.44 Nm. A brushless DC motor is used for that purpose which is pre-installed with a planetary gear arrangement having a speed ratio of about 96:1 which is further connected to the bevel gear arrangement having a speed ratio of about 5:2. The structural assembly al 7075 is used and for the shaft and key an AISI steel 5210.

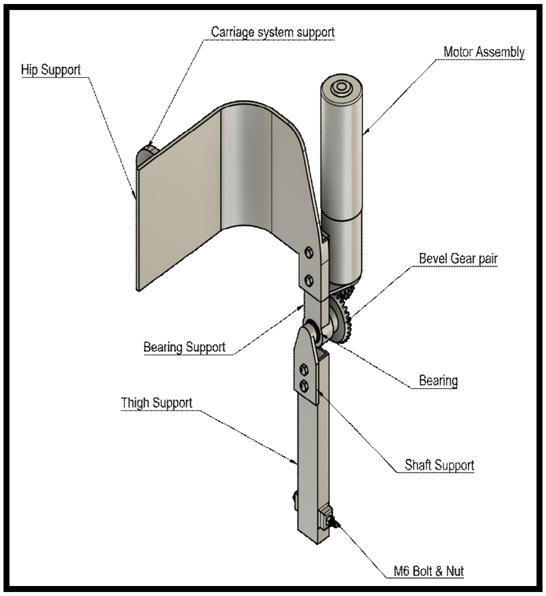


Fig. 7 Assembly of Hip Joint

3) *Knee Assembly:* This knee assembly provides motion between the thigh and the palm support having one degree of freedom as a rotational joint is driven by the DC motor and requires a torque of about 14.42 Nm which is transferred by the bevel gear pair arrangement. The structure is also provided with the vertical adjuster for the height difference between the user and the exoskeleton as shown in Fig. 8. The motor provides a torque of about 30 Nm at a speed of 15 rpm at the rotational joint. The main purpose of this joint is in the gait cycle to prevent toe scratching to the ground by swing the knee joint it can easily prevent it.

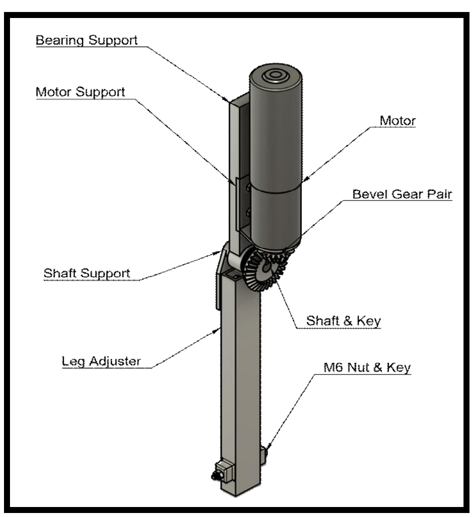


Fig. 8 Assembly of the Knee Joint

©IJRASET: All Rights are Reserved

IV. STRUCTURAL ANALYSIS

The lower limb exoskeleton 3d model is designed in the fusion 360 software and further analysed in the same software for structural analysis to find out will be able to carry a weight of about 50kg without any failure. The structural analysis is done on the three different parts of the exoskeleton that is hip assembly, knee assembly, and ankle assembly. The structural analysis is carried out to find whether the exoskeleton can withstand 50 kg of load.

Table II: Mesh Criteria in fusion 360

Average Element Size (% of model size)	
Solids	-
Scale Mesh Size Per Part	No
Average Element Size (absolute value)	2 mm
Element Order	Parabolic
Create Curved Mesh Elements	No
Max. Turn Angle on Curves (Deg.)	60
Max. Adjacent Mesh Size Ratio	1.5
Max. Aspect Ratio	10
Minimum Element Size (% of average size)	20

For the structure of the exoskeleton aluminium 7075 is used also AISI steel 5210 is used for bearing of the various joint as shown in Table III. These two-material have proven the best quality material in the material selection based on the different selection considerations. For structure aluminium rectangular tubes are used as it will reduce the weight of the overall assembly. Meshing is carried out by selecting the mesh size as 2mm in fusion 360 as shown in Table II.

Table III: Material Properties

Sr. No.	Properties	Aluminum 7075	630 Stainless Steel	Steel AISI 5210	Unit
1	Density	2.81E-06	8.061 E-06	7.81E-06	kg / mm^3
2	Young's Modulus	71700	197000	207000	MPa
3	Poisson's Ratio	0.33	0.29	0.33	-
4	Yield Strength	434	1415	1922	MPa
5	Ultimate Tensile Strength	572	1520	2011	MPa
6	Thermal Conductivity	0.15	0.0184	0.0466	W/(mm*C)
7	Thermal Expansion Coefficient	2.34E-05	1.08E-05	1.19E-05	/ C
8	Specific Heat	718	460	475	J / (kg C)

A. Hip Joint Assembly

The hip joint assembly is used to support the load at the top of 110 lb force and fixed constraint is applied at the bottom part of the assembly.

Table IV: Results of static analysis of hip assembly

Sr. No.	Name	Minimum	Maximum	Unit
1	Safety Factor (Per Body)	3.869	15	-
2	Von Mises Stress	1.512E-05	364.8	MPa
3	Total displacement	0	6.842	mm
4	Total Reaction Force	0	19.1	N
5	Equivalent Strain	2.658E-10	0.003331	-

The minimum factor of safety is about 3.869 at the contact of hip support and bearing support and having a maximum total displacement 6.8 mm at the upper portion of a hip support of aluminium plate. The maximum stress is about 364.8 MPa which acting at angular shaft support which is less than the material used which is Al7075 with a maximum strain of 3.331*10-3 as shown in Table IV and Fig. 9.

©IJRASET: All Rights are Reserved

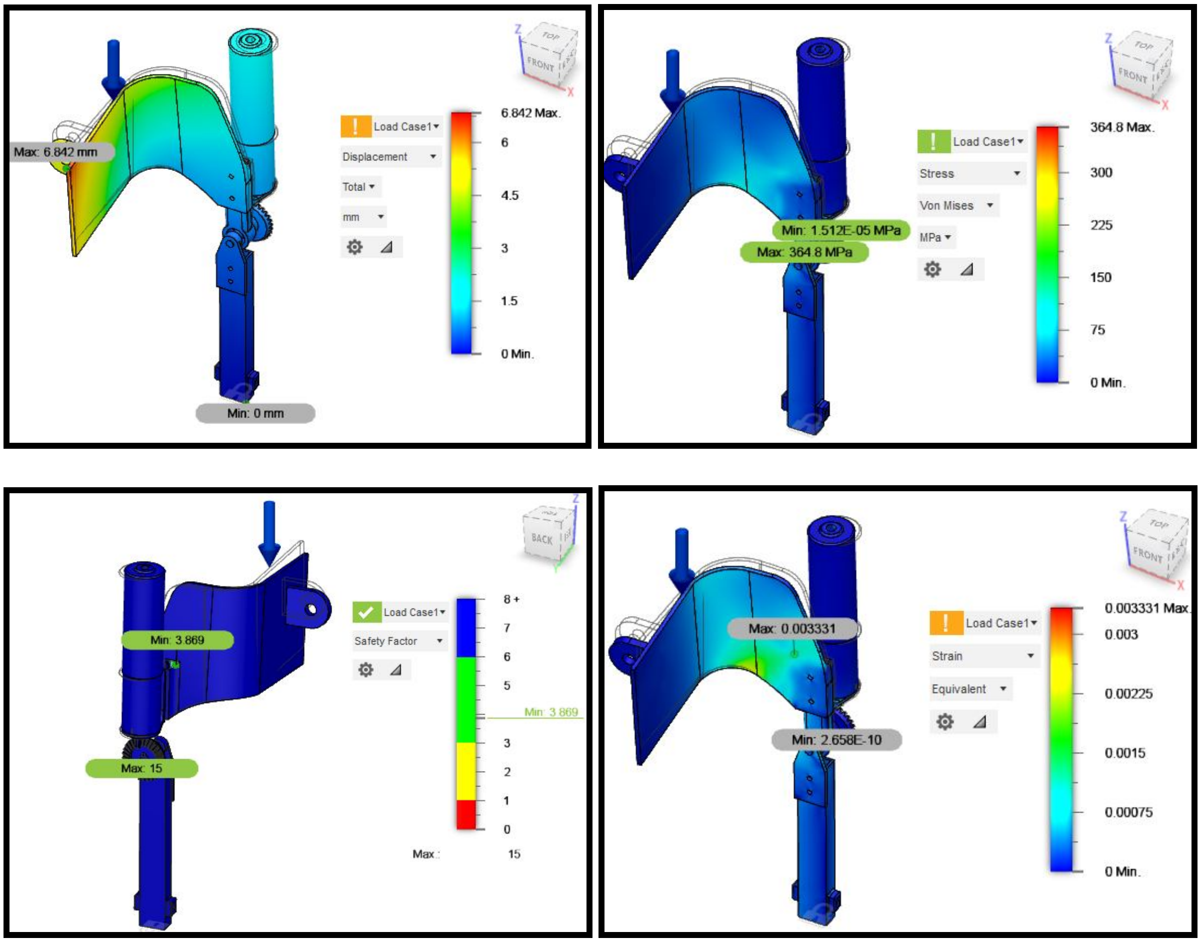


Fig. 9 Analysis of Assembly of the hip Joint in Fusion 360

B. Knee Joint Assembly

A 110 lb-force of the load is applied for analysis with standard gravity to determine whether the assembly fails or not. The solution includes factor of safety, von-misses stress, total deformation, and strain. This assembly contains materials for structure as AL7075 and for various other parts as AISI 5210 steel.

Table V: Results of static analysis of knee assembly

Sr. No.	Name	Minimum	Maximum	Unit
1	Safety factor	8.924	15	-
2	Von-mises stress	1.664E-06	73.29	MPa
3	Total displacement	0	0.1462	mm
4	Total reaction force	0	18.75	N
5	Equivalent strain	3.573E-11	7.971E-04	-

©IJRASET: All Rights are Reserved

The minimum factor of safety is about 8.924 at the intersection of motor shaft and key and having maximum total deformation 0.1462mm at the shaft support. The maximum stress is about 73.29 MPa which acting at angular shaft support which is less than the material used that is Al7075 with maximum strain of $7.97*10^{-4}$ as shown in Table V and Fig. 10.

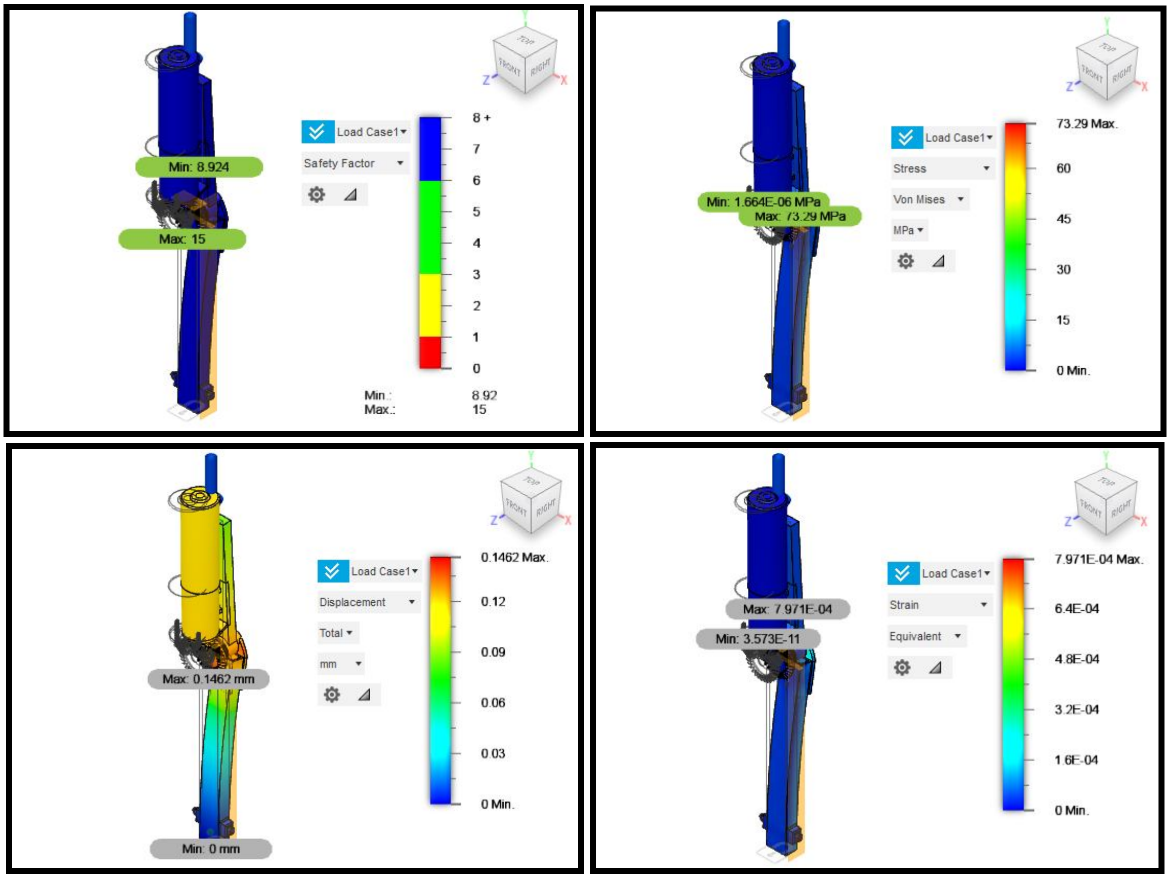


Fig. 10 Analysis of Assembly of the Knee Joint in Fusion 360

C. Ankle Joint Assembly

The ankle joint does not contain many parts, but the load and weight of the exoskeleton are applied to this assembly. The analysis is carried out in the fusion 360 software with 110 lb-force of application on the upper edge.

Table VI: Results of static analysis of ankle assembly

Sr. No.	Name	Minimum	Maximum	Unit
1	Safety factor	3.56	15	-
2	Von mises stress	7.455E-12	139.2	MPa
3	Total displacement	0	0.2068	mm
4	Total reaction force	0	2.49	N
5	Equivalent strain	0	0.003312	-

©IJRASET: All Rights are Reserved

The minimum factor of safety is about 3.56 at the bearing and having a maximum total displacement of 0.2068 mm at the upper portion of an aluminum tube. The maximum stress is about 139.2 MPa which is acting at the angular shaft support which is less than the material used which is Al7075 with a maximum strain of 3.312*10-3 as shown in Table VI and Fig. 11.

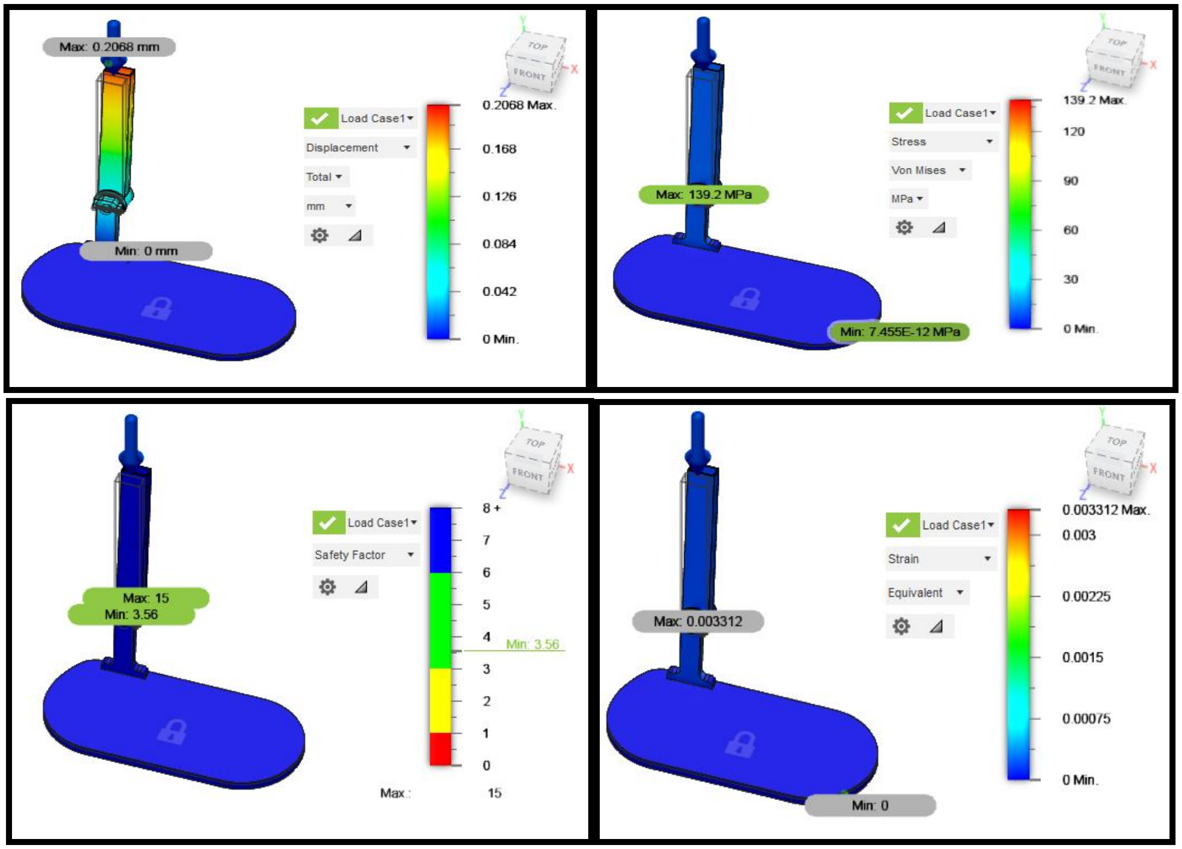


Fig. 11 Analysis of Assembly of the Ankle Joint in Fusion 360

V. CONCLUSIONS

The exoskeleton is going to develop in the different areas of manufacturing where human strength can't be used. This paper concludes the design and analysis of the lower limb exoskeleton in the military usage for carrying the load carriage system which can be used in the combat situation carrying high weight weapons like ammunition and light antitank weapon. Usually, for carrying the military load carriage system personnel are used which causes various foot injuries and loss of energy. The exoskeleton is designed to carry a weight of about 50kg and with a speed of 1.54 m/s.

The exoskeleton is designed so that it should be tough and light for that aluminum 7075 and AISI steel 5020 are selected as these materials are light having a high modulus of elasticity and also low cost as compared to other materials. The exoskeleton is designed for people, so all the human factors are considered like a range of motion and the degree of freedom at each joint. The project is designed for military usage so that it is tough, low cost, easy to handle in the field situation, and easy to disassembly and change parts.

REFERENCES

[1] Giancarlo Villena Prado, Raimo Yli-Peltola and Miguel B. Castro Sanchez "Design and Analysis of a Lower Limb Exoskeleton for Rehabilitation" Interdisciplinary Applications of Kinematics. Springer, Cham, published on 2019.

[2] Baltej Singh Rupal, Sajid Rafique, Ashish Singal, Ekta Singal, Magnus Isaksson and Gurvinder Singh Virk "Lower-limb exoskeletons: Research trends and regulatory guidelines in medical and non-medical applications." International Journal of Advanced Robotic Systems 14.6 (2017): 1729881417743554.

[3] Knapik, Joseph J., Katy L. Reynolds, and Everett Harman. "Soldier load carriage: historical, physiological, biomechanical, and medical aspects." Military medicine 169.1 published on 2004

[4] Bingshan Hu, Hongyang Yu, Hongrun Lu and Yongjie Chang "Design of Mechanism and Control System for a Lightweight Lower Limb Exoskeleton." 3rd International Conference on Control, Robotics and Cybernetics (CRC). IEEE, 2018.

©IJRASET: All Rights are Reserved

[5] Vishnu Vardhan Dadi, P.V.N.S Sathwik, D. Mahesh, Dala Jaswanth, S. Karthik Kumar, M.M. Ramya and D. Dinakaran "Structural Design and Analysis of a Lower Limb Exoskeleton for Elderly." International Journal of Advanced Mechatronic Systems 8.2-3 published on 2020

[6] Kai Yang, Qing Fei Jiang, Xiu Lai Wang, Yi Wu Chen and Xue Yan Ma "Structural Design and Modal Analysis of Exoskeleton Robot for Rehabilitation of Lower Limb." Journal of Physics: Conference Series. Vol. 1087. No. 6. IOP Published on 2018.

[7] Norazam Aliman, Rizauddin Ramli and Sallehuddin Mohamed "Design and development of lower limb exoskeletons: A survey." Robotics and Autonomous Systems 95 published on 2017

[8] Zhiguo Lu, Jun Huo, Yuce Wang, Tongle Xin and Zhengbo Xie “Design and Simulation Analysis of a Lower Limbs Exoskeleton Powered by Hydraulic Drive” International Conference on Advanced Robotics and Mechatronics published on 2017

[9] Renee L. Attwells, Stewart A. Birrell, Robin H. Hooper and Neil J. Mansfield "Influence of Carrying Heavy Loads on Soldiers' Posture, Movements and Gait." Ergonomics Vol: 49 Published on November 2006

[10] Hina Najam, Burak Bal and Ramazan Unal “Material Selection for Knee Exoskeleton Frame” International Conference on Material Science, Mechanical and Automotive Engineering’s and Technology published on April 2018

[11] Rafael Rodriguez-Martinez, Julio Alberto Lopez-Amaya, Guillermo Urriolagoitia-Sosa, Beatriz Romero-Angeles, Guillermo Manuel Urriolagation- Calderon "Proposal by simple design of the lower limb exoskeleton of continuous use, provided of own mobility and body load support. Case: application due to an illness." Journal of Physics: Conference Series. Vol. 792. No. 1. IOP Publishing, 2017.

[12] N. Latif A Shaari, Ida S Md Isa and Tan Chee Jun "Torque Analysis of the Lower Limb Exoskeleton Robot Design." ARPN Journal of Engineering and Applied Sciences 10.19 (2015): 9140-9149.

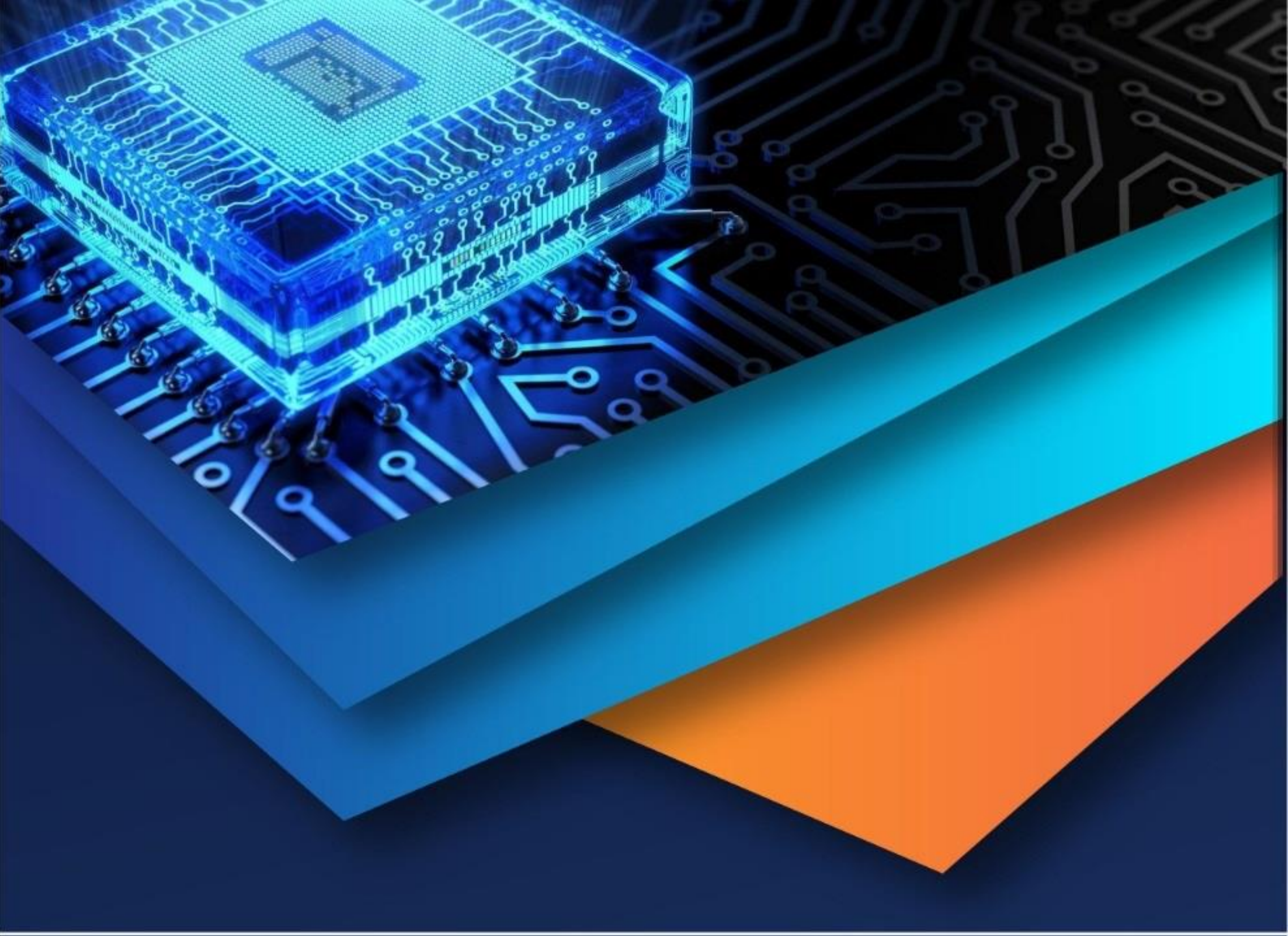
[13] Hipolito Aguilar Sierra, Wen Yu, Sergio Salazar and Ricardo Lopez "Design and Control of Hybrid Actuation Lower Limb Exoskeleton." Advances in Mechanical Engineering Volume 7.6 published on 4th may 2015

[14] Polese, Janaine Cunha, et al. "The Effects of walking Sticks on Gait Kinematics and Kinetics with Chronic Stroke Survivors." Clinical biomechanics 27.2 (2012): 131-137.

[15] Byungju Yoo, Sungdo Kim, Andrew Merryweather and Donald Bloswick “The Effect of Carrying a Military Backpack on a Transverse Slope and Sand Surface on Lower Limb During Gait” The University of Utah, 2014.

[16] Shuxiang Guo, Yibin Ding and Jina Guo "Design and Analysis of a Lower Limb Exoskeleton Robot." 2020 IEEE International Conference on Mechatronics and Automation (ICMA). IEEE, 2020.

©IJRASET: All Rights are Reserved



10.22214/IJRASET

INDEX COPERNICUS
45.98

ISRA JIF
IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL
IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089 (24*7 Support on Whatsapp)