IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 7.105 ⋇ Vol. 9, Issue 4, April 2022

DOI: 10.17148/IARJSET.2022.94117

Design and Topological Optimization of Exoskeleton Arm

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Abstract: Exoskeleton may seem to be a very futuristic device. But it's been in use since a long time. In early stages of development of such exoskeleton, there were many challenges faced by the designers. Also, there was limited technology advances in field of electronics and motors. Also manufacturing processes were not much developed. As a result of all these, the exoskeletons developed were not feasible to use extensively. They were heavier in weight and also their load carrying capacity was less. Moreover, they were not comfortable too for use. This resulted in shift of focus from exoskeleton and its potential uses. But today, there are a variety of light weight material and composites, which solves the problem of heavy weight of the device. Also, there are compact and lightweight motors and actuators available which made us possible to make a compact and ergonomic design. Our exoskeleton will play important role in lifting heavy loads on frequent basis. During long operations, doctors and attendants can use exoskeleton for carrying out the operations. Also, they can prove beneficial for handicapped persons or army personnel for carrying heavy loads on battlefield. To serve all those aspects our team has designed a similar exoskeleton, who's design and process is explained further.

Keywords: Flat Plate section, DC motor, Forearm section, Actuator,

INTRODUCTION:

The purposed model has an anthropomorphic external mechanical structure which enables the mechanical power transfer from exoskeleton structure to the human arm. The energy for the limb movement delivered to the person is a system of outer framework this device is powered by mechanical muscle Excelsior's exoskeleton suit, also known as powered exoskeleton, exoframe or exosuit, is a mobile machine. Due to this device the user will no longer feel any dizziness or fatigue in carrying heavy loads for long period of time. Purposed device is recyclable, light, and enduring. The main function of the exoskeleton suit is to assist the wearer by boosting their strength, endurance and durability. Our purposed model lifts up to 78% of object weight and remaining 22% weighted weight is carried by the human arm. Exoskeleton is an externally wearable robot with joints and limbs corresponding to those in the human body. Exoskeleton transmits torques to human joints by means of Directional Control Valve's allocated in its mechanical structure.

As we know that the shoulder is the most important joint in the human body. While this joint is normally modelled as a single ball-and-socket connection, in reality it is a complex series of joints packaged in a compact volume. The rotation and translation of the shoulder is contributed by the following system of joints such as clavicle, scapula, and humours.

This device has huge implication in the field of medicines and medical as it will help the medical staff to assists during the important surgery and enhance the precision

The previous model and architecture of Exo Skeleton arm are heavy and bulkier in nature due to this problem previous arms where not used in large scale to overcome this problem we have designed a model which is light weight in nature and is easier to maintain and is affordable.

The kinematics of the model is designed in such a way that force is evenly distributed regardless of the different type of limb configuration.This design will reduce the human effort without diverting from the normal unassisted motion trajectory. To validate the proposed approach and hypothesis, we have performed the following study.

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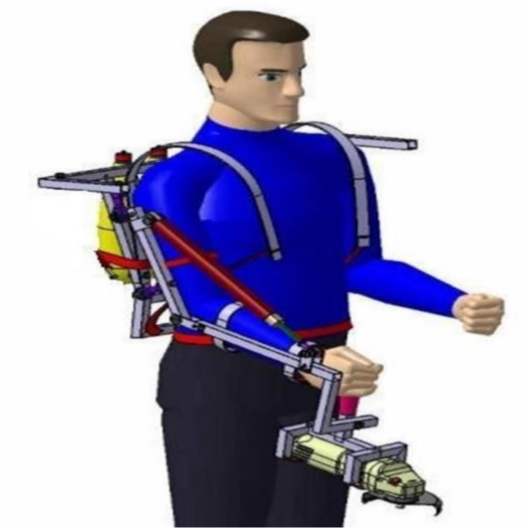

Fig 1: Exo Skeleton arm [3]

In these systems, a mechatronics structure is attached to different members of the human body, and while the wearer commands the mechanical system using physical signals the mechanical system does the hard work, like carrying heavier objects or helping the movement of handicapped members of the body.Frame that can be worn to support the body, either to help a person overcome an injury or to enhance their biological capacities.

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LITERATURE REVIEW:

Luis I [1]. Robust Tracking of the Light–Exoskeleton for Arm Rehabilitation Tasks. It is well known that the application of advanced nonlinear control techniques enable more efficient and precise tracking than linear ones in real models. However, for some critical applications nonlinear schemes are not an option but a requirement. In this paper, they deal with the nonlinear control design of an exoskeleton performing arm rehabilitation on patients with poor neural and motor capabilities.

Rahul R [2]. Exoskeleton Model through Human Synchronization Parameters, International Journal of Bioscience, Biochemistry and Bioinformatic. This research paper deals with design solutions for aiding limb module of a powered limb exoskeleton used for handling heavy work load in work-place. This paper focuses on the various issues with human-centred approach and addressing the problems of physical human–exoskeleton interactions and dealing with everyday scenarios.

Gopal Krishna U B [3]. Design and fabrication of pneumatic powered exoskeleton suit for arm, International Research Journal of Engineering and Technology (IRJET). In this a comprehensive design and fabrication of hand exoskeleton technologies for rehabilitation and assistive engineering were made from the basic hand biomechanics to actuator technology with the involvement of pneumatic power.

Kai Liu [4]. Based Design of Exoskeleton Robot Replicating Human Arm Reaching Movements. In this paper, the reaching movements of human arm are analysed by the principal component analysis method and two most significant synergies of the joints of human arm, which can account for more than 80% of the variation, are extracted.

Abdul Malik Mohd Ali [5]. Preliminary Design of a Robotic Exoskeleton for Arm Rehabilitation. This research paper presents the design of a low-cost and easy-to use 2 degree of freedom (DOF) robotic exoskeleton for arm rehabilitation. The developed exoskeleton consists of a 2 DOF robotic arm attached on a chair.

J. W. Krakauer [6]. “Arm function after stroke: from physiology to recovery,” Seminars in Neurology. There are varying degrees of spontaneous improvement in arm paresis over the first 6 months after stroke. The degree of improvement at 6 months is best predicted by the motor deficit at 1 month despite standard rehabilitative interventions in

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the ensuing 5 months. Animal studies indicate that the loss of fine motor control, especially individuation of the digits, is due to interruption of monosynaptic corticomotoneuronal connections. Spasticity occurs because of loss of cortical modulatory control on descending brain stem pathways.

Anderson [7]. Maximum voluntary joint torque as a function of joint angle and angular velocity: Model development and application to the lower limb. Measurements of human strength can be important during analyses of physical activities. Such measurements have often taken the form of the maximum voluntary torque at a single joint angle and angular velocity. However, the available strength varies substantially with joint position and velocity. When examining dynamic activities, strength measurements should account for these variations. A model is presented of maximum voluntary joint torque as a function of joint angle and angular velocity.

Bicchi [8]. "Force and dynamic manipulability for cooperating robot systems," "Force and dynamic manipulability for cooperating robot systems," The theory of force and dynamic manipulability for general systems of multiple co-operating robot manipulators is developed. Manipulability analysis refers to the study of the performance of the system regarding to the mechanical transformation of inputs (forces and torques at actuated joints) into outputs (forces and torques exchanged with the environment or accelerations of a reference member), in relation to different configurations of the system and different directions in the input and output spaces.

Buchanan [9]. Neuromusculoskeletal modelling: Estimation of muscle forces and joint moments and movements from measurements of neural command. This paper provides an overview of forward dynamic neuromusculoskeletal modelling. The aim of such models is to estimate or predict muscle forces, joint moments, and/or joint kinematics from neural signals. This is a four-step process. In the first step, muscle activation dynamics govern the transformation from the neural signal to a measure of muscle activation—a time varying parameter between 0 and 1.

T. Nef [10]. "ARM—design of a novel arm rehabilitation robot," in Proceedings of the IEEE 9th International Conference on Rehabilitation Robotics (ICORR '05). Task-oriented repetitive movement can improve movement performance in patients with neurological or orthopaedic lesions. The application of robotics can serve to assist, enhance, evaluate, and document neurological and orthopaedic rehabilitation of movements. ARMin is a new robot for arm therapy applicable to the training of activities of daily living in clinics. ARMin has a semi-exoskeleton structure with six degrees of freedom, and is equipped with position and force sensors.

S. J. Ball [11]: a rehabilitation robot with 5DOF at the shoulder complex," in Proceedings of the IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM '07. A key approach for reducing motor impairment and regaining independence after stroke is frequent and repetitive functional training. A number of robotic devices have been developed to assist therapists with the labourious task of providing treatment. Although robotic technology is showing significant potential, its effectiveness for upper limb rehabilitation is limited in part by the inability to make functional reaching movements.

M. Mistry [12]. "Arm movement experiments with joint space force fields using an exoskeleton robot," in Proceedings of the IEEE 9th International Conference on Rehabilitation Robotics (ICORR'05). A new experimental platform permits us to study a novel variety of issues of human motor control, particularly full 3-D movements involving the major seven degrees-of-freedom (DOF) of the human arm. We incorporate a seven DOF robot exoskeleton, and can minimize weight and inertia through gravity, Coriolis, and inertia compensation, such that subjects' arm movements are largely unaffected by the manipulandum. Torque perturbations can be individually applied to any or all seven joints of the human arm.

S. J. Ball [13]. "A planar 3DOF robotic exoskeleton for rehabilitation and assessment," in Proceedings of the 29th Annual International Conference of IEEEEMBS, Engineering in Medicine and Biology Society (EMBC'07). A new robotic exoskeleton for the upper limb has been designed and constructed. Its primary purpose is to act as a proof-of concept prototype for a more sophisticated rehabilitation and assessment device that is currently in development. Simultaneously, it is intended to extend the capabilities of an existing planar exoskeleton device. The robot operates in the horizontal plane and provides independent control of a user's shoulder, elbow and wrist joints using a cable-driven actuation system.

Sardellitti, E [14]. "Description, characterization and assessment of a bioinspired shoulder joint first link robot for neurorobotic applications," in Proceedings of the 71st IEEE/RAS-EMBS International Conference on Biomedical Robotics and Bio mechatronics (BioRob '06).The development of innovative exoskeletons for the upper limb requires a strong collaboration between robotics and neuroscience. The robotic system will be deeply coupled to the human user and the exoskeleton design should be based on the human model in terms of biomechanics, and control and learning strategies. This paper presents the preliminary results of the design process of the Neu robotics exoskeleton (NEUROexos).

C.-J. Yang [15]. "Different structure based control system of the PUMA manipulator with an arm exoskeleton," in Proceedings of the IEEE Conference on Robotics, Automation and Mechatronics. In this paper, we proposed a novel approach to control the famous PUMA manipulator with an arm exoskeleton which has been developed to enable force feedback teleoperation and has totally different structures and dimensions from PUMA. We presented the hardware configuration and software implementation of the whole system, and then a particular issue was associated with workspace matching, which proved to be the key step for different structure based master/slave manipulator control.

K. Kiguchi [16].
"Exoskeleton for human upper-limb motion support," in Proceedings of the IEEE International Conference on Robotics and Automation.
We have been developing exoskeletons (exoskeletal robots) for assisting the motion of physically weak persons such as elderly persons or slightly disabled persons in daily life. In this paper, we propose a 3 DOF exoskeleton and its control system to assist the human upper-limb motion (shoulder joint motion and elbow joint motion) of physically weak persons. The proposed robot automatically assists the human motion mainly based on the skin surface electromyogram (EMG) signals. Fuzzy control has been applied to realize.

T. H. Massie [17]. "PHANTOM haptic interface: a device for probing virtual objects," in Proceedings of the International Mechanical Engineering Congress and Exposition.
This paper describes the PHANTOM haptic interface-a device which measures a user's fingertip position and exerts a precisely controlled force vector on the fingertip. The device has enabled users to interact with and feel a wide variety of virtual objects and will be used for control of remote manipulators. This paper discusses the design rationale, novel kinematics and mechanics of the PHANTOM. A brief description of the programming of basic shape elements and contact interaction is also given.

Colacino [18]. Subject-specific musculoskeletal parameters of wrist flexors and extensors estimated by an EMGdriven musculoskeletal model. An EMG-driven musculoskeletal model is implemented to estimate subject-specific musculoskeletal parameters such as the optimal physiological muscle length, the tendon slack length and the maximum isometric muscle force of flexor and extensor muscle groups crossing the wrist, as well as biomechanical indexes to quantify the muscle operating range, the stiffness of the musculotendon actuators, and the contribution of the muscle fibres to the joint moment.

Goljat, R [19]. "Power-augmentation control approach for arm exoskeleton based on human muscular manipulability". The paper presents a novel control method for the arm exoskeletons that takes into account the muscular force manipulability of the human arm. In contrast to classical controllers that provide assistance without considering the biomechanical properties of the human arm, we propose a control method that takes into account the configuration of the arm and the direction of the motion to effectively compensate the anisotropic property of the muscular manipulability of the human arm.

A. Schiele [20]. "Kinematic design to improve ergonomics in human machine interaction," IEEE Transactions on Neural System and Rehabilitation. This paper introduces a novel kinematic design paradigm for ergonomic human machine interaction. Goals for optimal design are formulated generically and applied to the mechanical design of an upper-arm exoskeleton. A nine degree of freedom (DOF) model of the human arm kinematics is presented and used to develop, test, and optimize the kinematic structure of an human arm interfacing exoskeleton. The resulting device can interact with an unprecedented portion of the natural limb workspace.

Design:

Overview of functions and tools used in making 3D CAD model of the exoskeleton arm. The software used for making CAD model is CATIA. It is a widely used software in the industry for 3D modelling purpose.It is very to use.There are a wide variety of tools in CATIA. Tools used for modeling are:

1] Sketch tool - to draw a 2d drawing of part to convert it to 3d later. In sketch, there are various tools like line tool, profile tool, circle tool, rectangle tool, etc.

After creating sketch,

IARJSET

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2] Tools like Pad, pocket, sweep, loft, edge fillet, etc are used for converting the 2D sketch to 3D model.Use of planes plays very important role in creating a model of varing dimensions in free form mode.

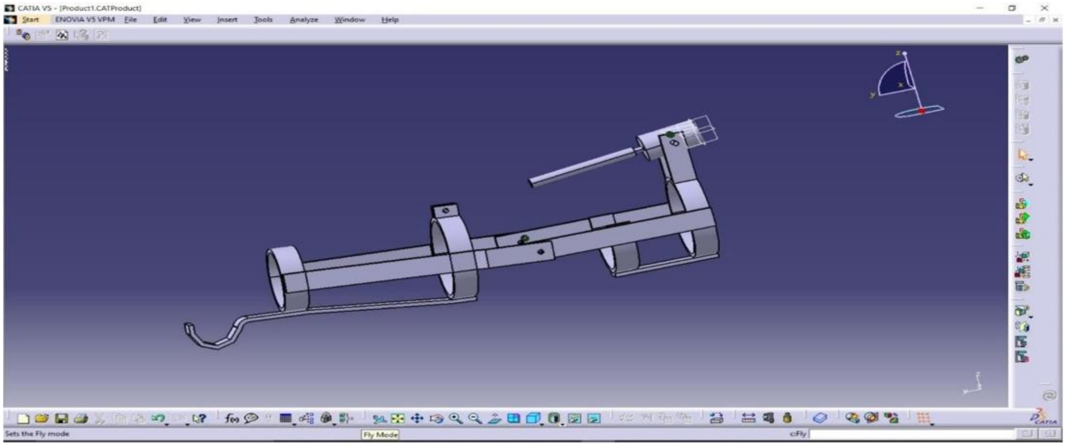

Fig 2. Side view of arm with motor attached.

After creating individual parts assembly is to be done.

For assembly there is a separate window, where different parts are to be imported and constrained with each other for final assembly.

Constraints used are: Coincidence , Surface contact , Offset , Angle.

After fully constraining the assembly, it is updated by using update tool and finally a assembled exoskeleton arm is created.

Some standard components are directly downloaded from the internet since their models are available free of cost.

It reduces the time taken for creating the assembly.

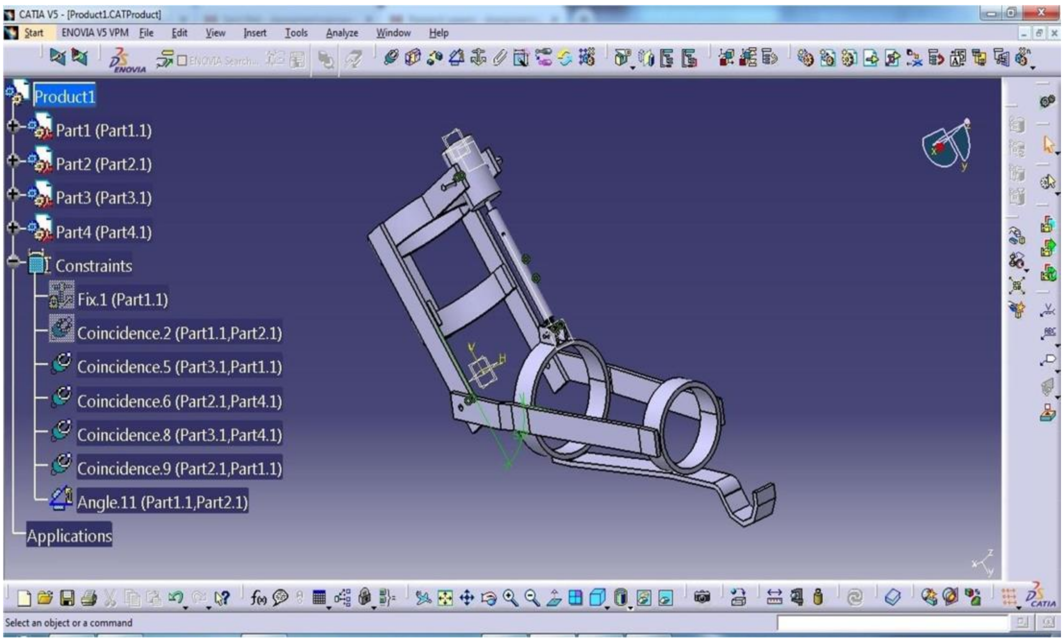

Fig 4. Arm assembly

The Exoskeleton comprises of 3 major parts

Upper Arm

Lower Arm

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MotorThe Lower Arm and the Upper Arm are connected with the help of motor and screws the back side is connected to the upper arm and the front side is connected to the lower arm.

CONCLUSION:

Surviving a stroke or debilitating injury is often the start of a very long challenge Physical therapy can be very slow and with no guarantee of recovery. Robotic exoskeletons can sometimes provide a support to a body which needs to be heal and strengthened. The idea behind this project is to develop an inexpensive and user friendly system. This project shows that it is simple in design, construction and cheap in cost also . It gives quick response and it is more flexible compared to hydraulic and electrical type exoskeleton. This can be achieved while maintaining simplicity, ease of use, implementation and maintenance. Our project is not only used to lifts weights but also is applicable in rescue operations, military and industries. There is an increasing amount of applications for an exoskeleton in military , such as decreased fatigue and increased productivity while unloading supplies or enabling a soldier to carry heavy objects (of mass 12 - 15kg) while running or climbing stairs. Not only a soldier could potentially carry more weight, but also they could wave heavier armour and weapons while lowering their metabolic rate or maintaining the same rate with more carry capacity. In civilian areas, exoskeletons could be used to help firefighters and other rescue workers surviving dangerous environment. Exoskeleton arm makes physically disabled people to carry weights in their daily life because the maximum load is carried by this pneumatic system. The exoskeleton robot can be mainly used in hospital to assist the patient to accomplish rehabilitation trainings. The proposed design method can make sure that the mechanically kinematic chain of the exoskeleton robot matches with the human kinematic chain. The tests have approved that the exoskeleton robot could effectively replicated the necessary reaching movements included in basic ADLs, which proves that the design method of the exoskeleton robot is feasible.

