International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 04 Issue: 05 | May -2017 www.irjet.net p-ISSN: 2395-0072

A Review Paper on Designing of Assistive Upper Limb Therapeutic Device for Medical Rehabilitation

Shah Divya

Shah Divya-Student, Dept. Of Biomedical Engineering, Government Engineering College, Sector-28, Gandhinagar, India

---***---

Abstract - *Physiotherapy is the best way to treat paralyzed patient or patients who have joint fracture. The main aim of the physiotherapy is to optimize someone's range of motion and functions. The main aim of this device is to provide rehabilitation training to weak muscle. In this paper, the designing of light weight upper limb device is described which is used for medical rehabilitation. This device is light in weight and wearable. This device is used for the physiotherapy purpose.*

Key Words: Upper Limb, Rehabilitation, Physiotherapy

1.INTRODUCTION

Because of the injuries like sport injuries, personal injuries, sudden attack, there are many reasons for loss of the function of upper extremities. Because of these injuries the person is not be able to do his/her ADL. Personal injuries are bodily resulting for working. While many methods are set in place for the prevention, still injuries occur due to the poor ergonomics, handling of heavy loads manually, failure of equipments, exposure to general danger, and inappropriate safety training. During athletic activities or exercising, sports injuries may occur. These injuries can due to accidents, poor training technique in practice, faulty equipment, and repeated use of a particular body part. In hand or upper limb injuries may occur due to poor training in basket-ball and valley-ball.

Due to sports injuries, personal injuries, and sudden attacks full or partial loss of function in the upper limb is common. Treatment for these conditions depends on some extent of manipulative physiotherapy procedure. To reduce the task load for the professionals by the use of assistive orthotics could have more benefits in terms of the overall healthcare provided. At the same time it also provide greater access to effective rehabilitation. Therapeutic therapy results shows that medical benefits can gained in the hemiparetic arm using active assistive therapy. Indication suggest that robot based rehabilitation therapy have a positive effect on the reduction of impairment of the human brain. Robot allow that how much amount of exercise delivered to the patient and give a patient's performance measuring tool. There are some assistive devices available for shoulder and clavicular orthosis. These devices are used to assist only shoulder joint not full hand. In clavicular fractures to allow for tissue healing and bone remodeling, the clavicular braces are used to restrict motion. To keep the humeral head in the glenoid cavity, the shoulder sling is used to restrict shoulders and the restriction of shoulder is done by providing humeral cuff and chest straps. For patients with proximal arm paralysis or weakness to allow hand or arm use when the muscles are at least antigravity in strength, overhead sling suspension is used. Hemi-arm sling is used for shoulder movement. The main use of the hemi arm sling is to immobilize the hemiplegic shoulder which help to decrease the shoulder pain and subluxation.

Fig. 1. Hemi Arm Sling

Some other orthosis is also used for the plegic and paralyzed patient. For the high level tetraplegia or severe proximal arm paralysis, Balanced forearm orthosis is used. The support can be provided to the forearm by Balanced forearm orthosis against gravity. May be it is attached to the table or wheelchair. The tabletop activities can be performed by the patient. It is required as a prior condition for use of the device include a power source. In Arm orthosis arm sling is used. Arm sling is used for scapular or humeral fractures, rotator cuff injury, bicipital tendinitis, and hemiparesis with subluxation. It also includes cuff sling and glenohumeral support. Patient with proximal arm weakness involving the shoulder and arm, the functional arm orthosis is used. Functional arm orthosis is used in patient with arm weakness. Arm weaknesses considered as the result of spinal cord injury(SCI) or peripheral nerve lesions. Elbow orthosis is used to treat the elbow fracture or the injuries related to elbow. Just like shoulder sling, elbow splints are used to treat elbow. For elbow immobilization in subject who have had recent elbow surgery and inflammation. For prevention or correction of contractures, serial cast is used. To increase or maintain elbow extension, air splint is used. In air splint, the high pressure air is passing through it and make it rigid with the help of air. This will help for the elbow extension. For the elbow flexion means for the 90 degree movement of the elbow Dynamic elbow flexion orthosis is used. For the forearm and wrist, the available othosis are volar or dorsal. Ideally, the wrist extension should be positioned at 15- 30 degree, when the wrist should be maintained at neutral to minimize median nerve compression. Example of forearm- wrist orthoses include the following:

- Wrist Cock Up Splint
- Wrist Extension Splint
- Ulnar Gutter Splint

Fig.2. Ulnar Gutter Splint

For immobilization of patient with side or central epi- condylitis, sudden twist in wrist, wrist or forearm fractures, after operation wrist functions, and arthritic conditions.

2. LITERATURE REVIEW

There are various exoskeletons are available. Some of them are describe below: 1) 7DOF 'soft-actuated' Exoskeleton Robot 2) 5DOF Exoskeleton Robot: L-EXOS 3) ARMin Exoskeleton Robot.

2.1 7DOF 'soft-actuated' Robot

Loss of functions of the shoulder, elbow or wrist are a common problem associated with a wide range of in- juries, disease processes, and other conditions including sports injuries, personal injuries, spinal column injuries, and sudden attacks. Treatment for these conditions re- lies to some extent on manipulative physiotherapy procedures. Nature of these procedure are extremely labour intensive and require high level of one to one attention from highly skilled medical personnel. This paper is concern with the 7 DOF exoskeleton system. It includes: 3DOF in shoulder (adduction/abduction, flexion/extension, internal rotation/external rotation), 2DOF in elbow (flexion/extension and pronation/supination), 2DOF in wrist (flexion/extension and abduction/adduction).

The mechanical arm structure is developed as per the natural 7 DOF of the human arm from shoulder to wrist except hand. The high stress joint section is fabricated with steel and the arm structure is constructed from aluminum and composite mateial. By doing this we get a light, low cost and comfortable structure with a stable platform. This 7 d.o.f arm structure is constructed for the use of typical adult by adjusting some minor changes in the set-up. Changing of arm length is easy and quick. The main importance of the device is the easiness of wearing the device which is more suitable for person with neurological disorders. Velcro attachments located at the elbow and wrist make it more easy for the mounting and detachment of the device. The nature of the drive source of the system forms a key sub- system within rehabilitation unit which making the use of the soft nature of the actuator operation. This kind of system uses braided Pneumatic Muscle Actuators (pMA). This actuators provide a clean, low cost actuation source with a high power/weight ratio and safety due to the inherent compliance. The graphical representation of the exoskeleton is as shown in fig(3).

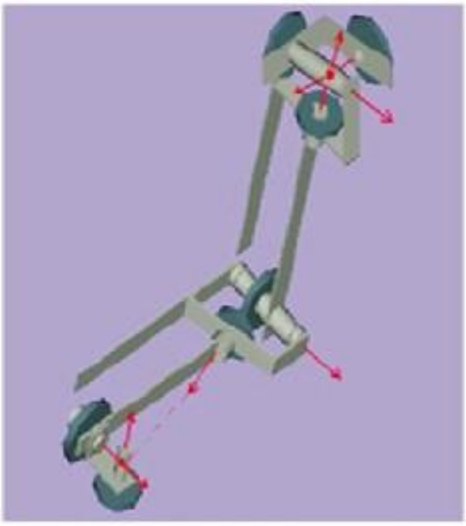

Fig. 3. The Graphical Representation of the Robot

The activation of the pMA is depends on the controlling of the airflow from and into the muscles. By producing appropriate opposite torques through the pulleys driven by the pneumatic actuators, joint motion/torque on the rehabilitation/training arm is achieved. The pneumatic Muscle Actuator is a single direction-acting element. Because of this property of pneumatic muscle actuator for bidirectional motion/force two opposal elements are needed. These two acting elements work together in opposite direction and simulate a biceps- triceps system to provide the bidirectional motion/force. For the rotation of more than 90 degree, double groove pulleys have been employed. Solid aluminium pieces is used to make pullyes. A positive or negative torque/motion at the joint generates by the force difference between the agonist and antagonist muscle. The compact actuator structure allows the overall design compact in line with the design requirements.

The actuators which helps for the movement of wrist, it is mounted on forearm. On a support structure, the fore-arm pronation/supination actuators are mounted. To direct the coupling cables to the pronation/supination joint pulley, two idler pulleys at the elbow level are used. On the upper arm, The elbow flexion extension actuators are mounted. Just like the forearm rotation actuator, the shoulder medial/lateral rotation actuators are fixed to a support structure. On each joint ,joint torque control has been implemented. A high bandwidth torque control loop can be formed around each individual joint, using the torque feedback provided by the torque sensor on each joint. Due to the mechanical structure and actuator displacement limit on the training shoulder, the motion of the exoskeleton is restricted at above the operator's head and behind the operator's body. The example of this type of exoskeleton is as shown in fig(4).

Fig. 4. Example of 7 DOF Robot

2.2 5DOF Robot: L-EXOS

In this paper, the mechanical design of the L-EXOS, a new exoskeleton for the human arm is described. The L-EXOS is a tendon driven wearable haptic interface with 5 DOF, 4 actuated ones. Some special mechanical components and carbon fiber structural parts are used to obtain the reduce mass and high stiffness. This exoskeleton is characterized by a serial kinematics which consist of five rotational joints from which first four are actuated and sensorized and the last one is only sensorized. The general kinematics of the L-EXOS is shown in below fig.(5).

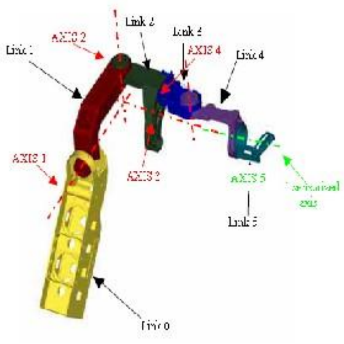

Fig. 5. General Kinematics of L-EXOS

In order to emulate the kinematics of a spherical joint with the same center of rotation of the human shoulder, the first three rotational axes are incident and mutually orthogonal. To maximize the workspace of the shoulder joint, the orientation of the first axis was optimized. The axis which is coincident with the elbow joint was the fourth axis and the fifth axis is coincident with the forearm, to allow the pronation-supination of the wrist. All the motors of the exoskeleton have been located on the fixed frame. The torque is delivered from the motor to the respective joint by steel cables. Reduction gear integrated at the joint axis for each

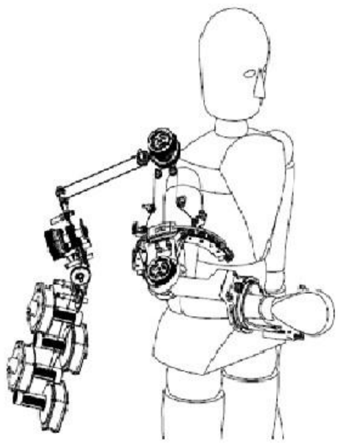

Fig. 6. CAD model of L-EXOS

actuated DOF. By fixing all the motors on the fixed frame, the mass of the moving parts can be reduced. For better torque to weight and torque to volume ratio, the electric actuators are used. To ground the motors long transmission required and it can be implemented through steel cables. Steel cables presenting low mechanical stiffness. Reduction gears with low reduction ratio were located at the joint axis to achieve a higher stiffness of a device at end effector. By reducing the tendon diameter one can reduce the mass and volume of mechanical parts. The CAD model of L- Exos is as shown in fig.(6). The structural components were made of carbon fibre, to improve the lightness and stiffness. For better conection aluminium parts were bonded on the carbon fibre. This mechanical device include some special components like: the Circular Guide, the Integrated

Planatary Reduction Gear and the Motor Group. The major drawback of this exoskeleton is higher weight which is 11kgs. around 6kgs of weight is distributed on the link 0which is the fixed part.

2.3 ARMin Robot

For the training of activity of daily living, ARMin is appli- cable. This is a semi exoskeleton with 6 DOF. It is equipped with position and force sensor. The robot must have the characteristics like low inertia, low friction and no backlash for the better performance. The motor/gear combination needs to be back-drivable. The mechanical design of the semi-structured exoskeleton is as shown in fig.(7).

The robot is fixed via aluminum frame at the wall. The design comprises four active and two passive DOF in or- der to allow elbow flexion/extension and spatial shoulder movements. Vertically oriented axis 1 performs shoulder ab duction/adduction. Shoulder rotation is being realized by a backlash free and backdrivable harmonic drive module in the horizontal plane. The horizontal arm rotation drive and the upper arm rotary module connects by the interconnection module via two hinge bearings. All mechanical components are make the best with maximum stiffness and minimum weight. A special custom made rotary module, that is connected to the upper arm via an orthotic shell, is responsible for internal/external shoulder rotation. The module is made of a half cylinder for the easy access to the patient's arm. For position and velocity measurement four brushed DC motors are equipped.

The force and torque of the shoulder actuation is measured by a six DOF force and torque sensor. For the torque of the elbow actuation, a separate torque sensor is available. Two DC motors which is equipped with a digital signal processor , two MOSFET full bridges and analog electronics are controlled by two motor modules for the sensor interface, the motor module communicate via serial bus with the real time target computer system. ARMin Host which is known as the user interface runs on a windows machine and via ethernet, it is connected with the real time target. The signal to noise ratio is improved by reducing the length of the analog cables between sensors and the analog to digital converters. For safety purpose, four position sensing potentiometers are placed which allows detection of malfunction of position sensor or a controller.

The safety circuit will be cut the power of the motor drives, whenever an abnormal event has been detected. Because all drives are backdrivable, if the patient feel uncomfortable position the robot will be manually operated by the therapist. The therapists safety also considered. Therapist have to know about all the dangerous collision position with the robot because robot cannot know the position of therapist. Four different control modes are there to operate the robot. In the first prerecorded trajectory mode, the robot and the human arm is guided by the therapist while the position data is recorded. The preprogrammed standard therapy exercises are chosen by the therapist in the second predefined motion therapy mode. After display the desired position of human arm, the patient is asked to move his/her arm towards the desire position from the basic position in the third point and reach mode. In the forth patient guided force supporting mode, using mechanical model of the patient and the robot, the robot predicts required forces and torques and measure the forces and toques. Only for monitoring purpose the forces and torques are measured.

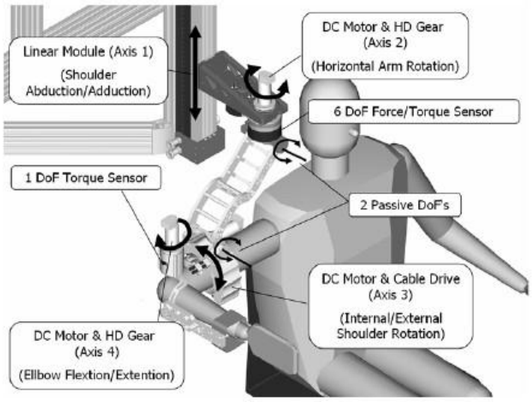

Fig. 7. The Mechanical Design of Robot

3. CONCLUSION

In this paper many techniques explained for designing of upper limb therapeutic devices. Different exoskeletons are used as a motion assistant device but they are costly and the movement of upper limb is restricted. Though ARMin robot is quit costly and not wearable it is better than other robots.

REFERENCES

[1] N. G. Tsagarakis and D. C. Caldwell, "Development and Control of a 'Soft-Actuated' Exoskeleton for Use in Physiotherapy and Training," Journal of Autonomous Robots, vol. 15, pp. 21-33, 2003.

[2] Nef, T., & Riener, R. (2005). ARMin – Design of a Novel Arm Rehabilitation Robot, 57–60.

[3] Rocchi, A. F. F., Dettori, S. M. A., Bergamasco, F. S. M., Scuola, P., & Anna, S. S. (2005). A new force-feedback arm exoskeleton for haptic interaction in Virtual Environments.

[4] A. Frisoli, F. Rocchi, S. Marcheschi, A. Dettori, F. Salsedo, and M. Bergamasco, "A New Force-Feedback Arm Exoskeleton for Haptic Interaction in Virtual Environments," in Proc. of First Eurohaptics Conference and Symposium on Haptic Interfaces for Virtual Environment and Teleoperator.