Australian Journal of Basic and Applied Sciences, 5(7): 976-981, 2011
ISSN 1991-8178

Design of Human Elbow Joint Mechanism

Haider A.F. Almurib, Haidar Fadhil Al-Qrimli, Nandha Kumar

Faculty of Electrical Engineering, University of Nottingham, 43500 Semenyih, Malaysia

Abstract: In this paper, the development of an experimental procedure for human elbow joint mechanism is described. The experiment will be set up to imitate the human motion of the elbow joint. In this article, the arm supplied with micro electrical linear actuator to mimic the flexion and extension movements of the human elbow. The main component of the mechanism is the two revolute joints (passive and active) and the aluminum profile material. The CAD model and the Finite Element Analysis were developed by using SolidWorks software to determine the stresses in critical sections of the design.

Key words: Elbow Joints, Humanoid, Rehabilitation.

INTRODUCTION

There is a demand in studying human joints, and it has become extremely essential in the area of orthopedic and rehabilitation (GabrieÈ lle *et al.,* 2000; Nait-Chabane *et al.,* 2009). The main components of the human arm are bones and joints that connect the bones together. These joints allow a complex range of movements for the arm and without these joints; the human arm would not be able to carry out so various moments such as: rotating, extending and retracting (Sun Baiqing and Luo Yanjun, 2009). The tolerances and strength of the materials that will be used in the elbow and shoulder requires being significantly higher than the ones used for the wrist and fingers (Dingguo Zhang and Wei Tech Ang, 2006; Kyoungchul Kong and Masayoshi Tomizuka, 2009; Hyung-Soon Park, 2007). The fundamental of the human elbow anatomy that the elbow joint will moves by three bones: humerus, ulna and radius. The humerus is the longest bone of the upper extremity extended from the shoulder to the elbow. The forearm, connected from the humerus, which consists of the ulna and the rodius. The upper end of the ulna is rounded with the end of the humerus to allow flexion and extension at the elbow. Figure 1 shows the Anatomy of the elbow (Rafael *et al.,* 2003). The range of motion of the human elbow is about 150 degree measured from the flexion and 0 degree in the extension. The relation movements between these bones look like a revolute (hinge) joint (Rahman *et al.,* 2010; Innes Vanderniepen *et al.,* 2008).

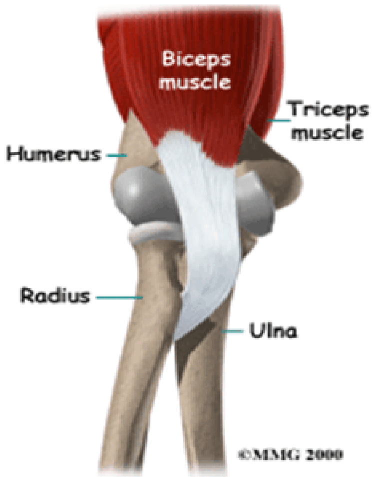

Fig. 1: Anatomy of the human elbow joint (Rafael *et al.,* 2003).

Corresponding Author: Haider A.F. Almurib, Faculty of Electrical Engineering, University of Nottingham, 43500 Semenyih, Malaysia
E-mail: halqrimli@yahoo.com

Robotics, more than ever the assistant robots for aged and disables people, have been known as one of the mainly promising areas in the robotics studies. A number of human elbow robotic prototypes have been designed for a variety of applications, such as robotic rehabilitation devices, and service robots (Meng and Lee, 2006). Previous designs attached an artificial ball and socket joint (Yang *et al.*, 2004). The joint is actuated by a lockable rod and this device is worn by the patient. Several pneumatic and hydraulic actuators are used as the muscle actuations of many other prototypes are commonly used to date. One more mechanism is by using cables but it make the design and analysis more complicated and challenging. Even though there are many prototypes possess several elementary features of the human being, for instance, the DOF, joint type, same size, and mimic the movement characteristics, their mechanism designs still fairly different from the human being. Thus, their actual performances still far from the human arm significant manipulation abilities such as light weight, high dexterity and large reachable workspace (Subrata Kumar Kundu and Kazuo Kiguchi, 2007; Huiyu Zhou and Huosheng Hu, 2008).

In this paper, we discussed the development of an electrical actuator technology that performs similar to a muscle for elbow joint. This novel structure is a part of an ongoing research that proposed a 7-DOF robotic arm designed with a light weight and commercial humanoid robotic arm which consists of 3-DOF in the shoulder joints, a 1-DOF elbow joint, and a 3-DOF wrist joint. The prototype has a novel structure that has been adopted by learning from the human arm anatomical structure. The elbow joint has one degree of freedom, which produces dynamic movement of the human elbow flexion and extension.

II. Prototype Development:

The material used is aluminum profile and aluminum plates that were obtained from the university lab. Aluminum profile served as the bone frame of the arm. Based on the fact that aluminum is easy to manufacture, relatively have low weight and have good characteristics than the other material such as steel, aluminum plates were selected to be used as the linking and covering material of the structure of the robotic arm. The aluminum is relatively cheap, good strength and excellent corrosion resistance, with high impact resistance properties. The electric linear actuator acts like the biceps and triceps muscles. The joint was built up on active and passive revolute joints to mimic the radius and ulna bones. Sequentially, to achieve soft movement with zero friction between the rotated parts, we attached a ball bearing for the two revolute joints. These two joints were fixed on an aluminum profile bar (forearm) to afford flexion and extension movements of the arm. Steel pins are used to join the ball bearing with revolute joints and the aluminum profile bars. Several machines have been used to achieve the required dimensions of the designed parts, namely handsaw was used to cut, milling machine was used to create flat and smooth surfaces and CNC turning machine had been used to create the round shapes. Firgelli linear actuator was used to provide the power of the system it must be aligned in a parallel way to the aluminum profile bar and the end of the Firgelli actuator must be fixed to the active revolute joint which connected to the forearm to provide smooth flexion and extension and to minimize losses in the transmission during the action.

The elbow has one degree of freedom and it allows two types of movement, which are flexion and extension. The range of the elbow flexion angle starts from zero to 140 degrees and the angle of the extension is zero degree. The main reason of using the electric actuator to mimic the movement of the human muscle. The Firgelli linear technology (L12) is used to control the arm flexion and extension to achieve similar movement of the elbow.

III. Electrical Actuator Specifacation:

The Figelli L series (L12) actuator is designed to push forward or backward loads along its complete stroke length. There is an automatic break system in the actuator so when the power is off, the actuator will automatically stop and clutch at the same position, unless the load goes over the back drive force, if that is the case the break system of the actuator will fail. This micro linear actuator design flexible and dexterous design that is combined gears, motor and the linkage in one small effective device.

The specification of the Figelli linear actuator (L12) is an axial devise with a rectangular cross section for better stiffness and weighs 43g. The maximum stroke length is 100mm and has multiple speeds that can reach maximum of 4mm /s. The gear ratio is 100:1 and the peak power point that the actuator can support the load or force is 67N. Furthermore, the input voltage will be 6V, and the maximum back drive force is 230N. Figure 3 shows the CAD model of the linear actuator and the way contacted to the active joint of the elbow mechanism and how it have been attached to the forearm.

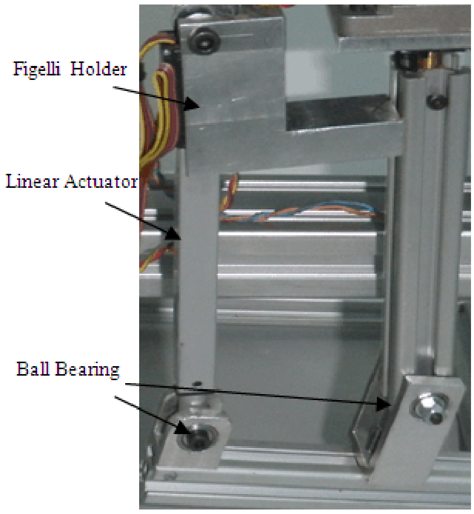

Fig. 2: Elbow joiint protype.

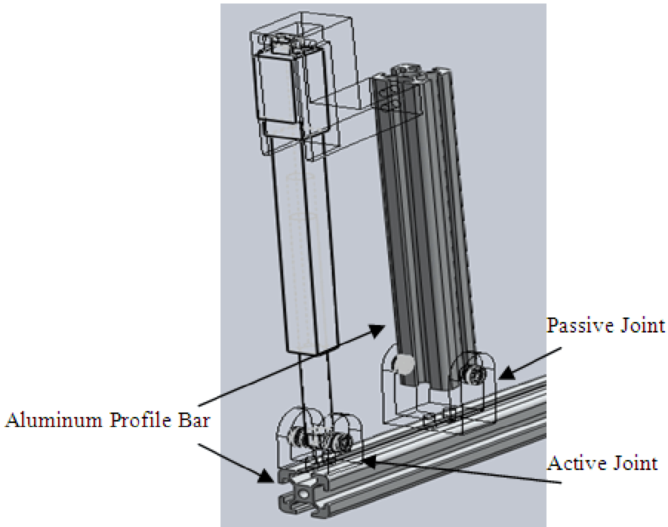

Fig. 3: CAD model of elbow joint.

Fea Simulation:

The aluminum part that is holding the micro actuator is one of the critical parts that we make analysis on. Shear will occur on the steel pins that have been used in revolute joints, especially the passive joint. So it is necessary to calculate the stress, deformation and the safety factor of the critical parts. The type of analysis is static, type of mesh is solid mesh and the aluminum material is considered as Linear Elastic Isotropic material.

SolidWorks have been chose to calculate the von misses and displacement analysis of the critical parts. The purpose of calculating the von misses is to check the maximum stress that the mechanism of the elbow can cling to. Though the displacement analysis had been carried out to calculate the deformation that can be occurred on the critical parts of the mechanism.

Figure 4 shows the Von Mises analysis. The entire arm subjected to 3kg, which is the worst case of load that the arm can hold after running the simulation the maximum Von Mises to be 46.92Mpa and this value is lower than the yield point of the aluminum. For the maximum displacement, it was found to be 0.074mm which is considered extremely small; and can be ignored and in zero scaling this deformation cannot be observed. The displacement analysis is shown in Figure 5.

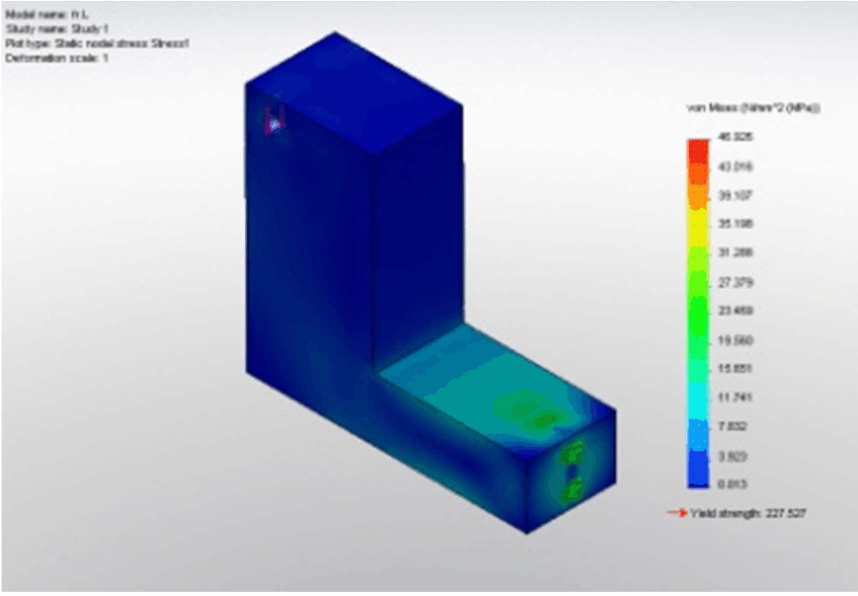

Fig. 4: Von Stress Analysis.

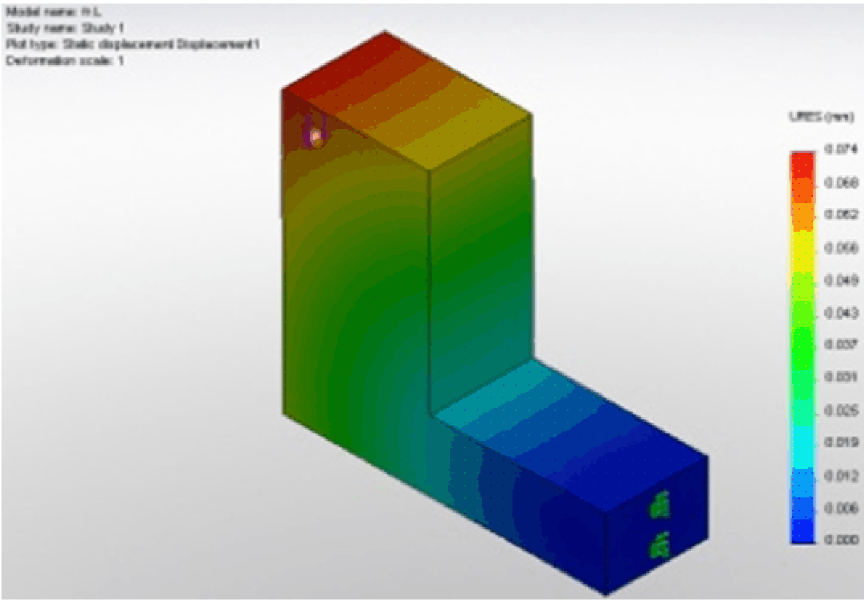

Fig. 5: Displacement Analysis.

The safety factor had been calculated for the design functions. The greater the safety factor the lower the like hood of the structure factors and more stress cycles the structure can take so the working hours or in other words, the life time will be longer. The safety factor of the mechanism is above one, and that means that the design is conceder safe. Figure 6 shows the factor of safety of the aluminum part of the micro actuator holder.

Conclusion:

Nowadays one of the challenging design issues is to develop a light weight dexterous mechanisms. In this study we developed a human like elbow joint mechanism by using a micro linear actuator which are equivalent to the human arm movement. it can be a perfect multipurpose mechanism to perform human-like operations. Two of the critical design analysis concerns have been discussed; the von misess displacement analysis. From the results it can be conclude that the aluminum is preferable for artificial elbow joint mechanism because it is cost effective material and lighter than the other materials.

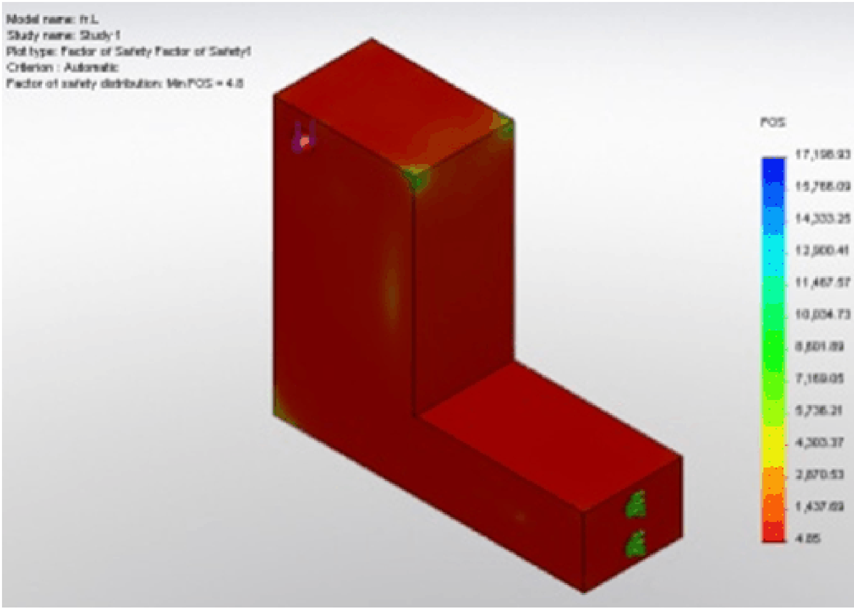

Fig. 6: Factor of Safety (FOS).

The main goal for the use of new and improved materials will always be the same principle, to develop materials that are stronger, lighter and more durable. These future joints will be a lot more efficient. Furthermore, the joint motion of the developed mechanism is the same range of motion to the human elbow joint.

ACKNOWLEDGMENT

The researchers whould like to thank the Ministry of Science, Technology and Innovation (MOSTI) Malaysia for their financial support of this work through the e-Science Fund Project No. 06-02-12-SF0072.

REFERENCES

Dingguo Zhang and Wei Tech Ang, 2009. "Tremor Suppression of Elbow Joint via Functional Electrical Stimulation: A Simulation Study," Proceeding of the 2006 IEEE International Conference on Automation Science and Engineering Shanghai, China, pp: 182-187.

GabrieÈ lle, J.M., Tuijthof, Just L. Herder, 2000. "Design, actuation and control of an anthropomorphic robot arm," Mechanism and Machine Theory, 35: 945-962.

Huiyu Zhou and Huosheng Hu, 2008. "Human motion tracking for rehabilitation-A survey", Biomedical Signal Processing and Control, 3: 1-18.

Hyung-Soon Park, Yi-Ning Wu, Yupeng Ren and Li-Qun Zhang, 2007. "A Tele-Assessment System for Evaluating Elbow Spasticity in Patients with Neurological Impairments," Proceedings of the 2007 IEEE 10th International Conference on Rehabilitation Robotics, pp: 917-922.

Innes Vanderniepen, Ronald Van Ham, Michael Van Damme and Dirk Lefeber, 2008. "Design of a powered elbow orthosis for orthopaedic rehabilitation using compliant actuation," Proceedings of the 2nd Biennial IEEE/RAS-EMBS International Conference on Biomedical Robotics and Biomechatronics Scottsdale, AZ, USA, October 19-22, pp: 801-806.

Kyoungchul Kong and Masayoshi Tomizuka, 2009. "Realization of Fictitious Gain in Human: Experimental Verification on an Elbow Joint," IEEE/ASME International Conference on Advanced Intelligent Mechatronics Suntec Convention and Exhibition Center Singapore, pp: 439-444.

Meng, Q. and M.H. Lee, 2006. "Design issues for assistive robotics for the elderly," Advanced Engineering Informatics, 20: 171-186.

Nait-Chabane, K., S. Delarue, P. Hoppenot, E. Colle, 2009. "Strategy of approach for seizure of an assistive mobile manipulator," Robotics and Autonomous Systems, 57: 222-235.

Rafael, A. López Jr., Luis A. Miro, Lyann M. Cancel and Claudio J. Cardona, 2003. “Biomechanics of Joint Replacements: Finger to Shoulder,” Applications of Engineering Mechanics in Medicine, GED at University of Puerto Rico, Mayagüez, pp: 1-22.

Rahman, M.H., M. Saad, J.P. Kenné and P.S. Archambault, 2010. “Exoskeleton Robot for Rehabilitation of Elbow and Forearm Movements,” 18th Mediterranean Conference on Control & Automation Congress Palace Hotel, pp: 1567-1572.

Sun Baiqing and Luo Yanjun, 2009. “Dynamics Modeling of Human Elbow Joints Servicing for Rehabilitation Robots,” Industrial electronics and applications, 4th IEEE Conference, ICIEA 2009, paper 10.1109, pp: 2566-2569.

Subrata Kumar Kundu and Kazuo Kiguchi, 2007. “EMG Controlled Robotic Elbow Prosthesis as an Inner Skeleton Power Assist System,” Proceedings of IEEE International Conference on Mechatronics Kumamoto Japan, 8-10 May 2007, pp: 1-6.

Yang, G., H.L. Ho, W. Chen, W. Lin and M.S. Kurbanhusen, 2004. “A Haptic Device Wearable on a Human Arm”, in Procedings of 2004, IEEE Conference on Robotics, Automation And Mechatronics, Singapore, December, pp: 243–248.