Simulation and Kinematic Analysis of Exoskeleton for Index Finger

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Abstract - *Exoskeletons are outer support to human body organ. It is a device that provides movement to defective or injured body organ or enhances the capabilities of human organs. Exoskeletons are one of the sought after area of research nowadays. This work involves the simulation of an index finger exoskeleton and its kinematic analysis using SOLIDWORKS. The exoskeleton, based on a four bar linkage, provides movement to the index finger. Two different phalanges or links of exoskeleton perform the job of rotating the phalanges of finger. One link rotates the proximal phalanx and the other one rotates intermediate and distal phalanges. SOLIDWORKS was used to draw the 3D representation of the exoskeleton and perform motion analysis for different kinematic parameters like angular displacement, angular velocity etc. The results obtained from simulation suggests that the exoskeleton is suitable for fabrication. The range of motion of link EDF was found to be 44^0 and range of motion of link CD was found to be 20^0 .*

Key Words: Exoskeleton, Index finger, Simulation, Kinematic analysis, SOLIDWORKS.

1. INTRODUCTION

Exoskeleton, as the name suggests, is a device that works as external support to any human organ. Biologically, an exoskeleton refers to the strong outer covering of an insect which provides support and protection. In general terms, nowadays, an exoskeleton is considered to be some device that augments the human organ's ability to do tasks [1]. For designing an exoskeleton, complete biomechanics of the human finger must be considered. The design of the system largely depends upon the manner in which the human organ functions and responds to signals received by the brain. Exoskeletons have been one of the major area of research from a long time because of its ability to enhance the abilities of human hands. Earlier, the researches that happened were mainly for military application in order to augment the human power [2].

Movement of the exoskeleton can be achieved through different ways, some use cable to transfer motion from actuator to the exoskeleton whereas some use mechanisms for movement of exoskeleton [3], [4]. For actuation purpose, both linear and rotary actuators can be used depending upon the overall design. For linear actuation, hydraulic and pneumatic actuators are used. For rotary actuation, electric motors are used [5], [6].

The index finger is the first finger in the human hand. Like all other fingers, it has three phalanges and three joints. The three phalanges are: Proximal Phalanx, Intermediate phalanx and Distal Phalanx whereas three joints are: Metacarpo-Phalangeal (MCP) joint, Proximal Interphalangeal (PIP) joint and Distal Interphalangeal (DIP) joint. Flexion and extension describe movements that affect the angle between two parts of the body.

This work includes the simulation and kinematic analysis of an index finger exoskeleton. Firstly, the simulation was done using SOLIDWORKS and then kinematic analysis was performed. This work considers the flexion of Proximal and Intermediate Phalanges of index finger. The exoskeleton provides rotating motion to the MCP and PIP joints of the finger.

2. MECHANICAL ASPECT

The design of the exoskeleton is primarily based on a four bar linkage which is further connected to supporting links to provide rotating motion to MCP and PIP joints of the index finger. All the links were drawn individually in SOLIDWORKS. The individual links were then assembled to make a single exoskeleton. The assembly design feature of SOLIDWORKS allows the mating of different parts to make an assembly. Fig-1 shows the assembled 3D representation of the exoskeleton. Link S_1ABS_2 is the four bar linkage that provides forward movement to the joining links and bending movement to link EDF. Link CD rotates the proximal phalanx of the index finger whereas link CDE provides movement to the intermediate and distal phalanges of the index finger. After 3D assembly of the exoskeleton, simulation was performed in SOLIDWORKS Motion Analysis environment.

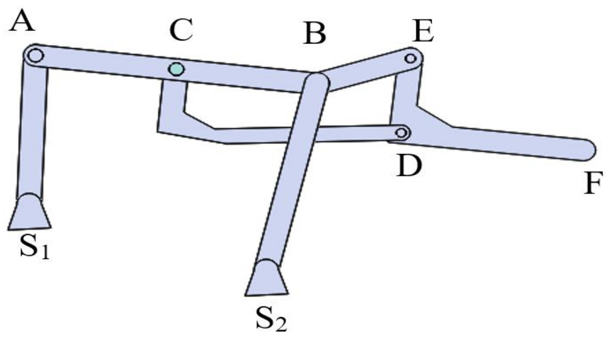

Fig-1: 3D representation of exoskeleton

2.1 Actuation

Actuation is the major part of exoskeleton. For this work, two rotary actuators were used and point S_1 and point C for movement of link S_1A and link CD. For rotary actuation, dc motor was used. As the requirement for exoskeleton is low rpm and light weight, small geared dc motor are best suited for application. A 12V, 10 rpm dc motor was selected to be best suited for application. A controller circuit is also required for control of dc motor for movement of index finger. Motor 1 and Motor 2 provide angular movement and torque to link S_1A and link CD respectively.

3. SIMULATION RESULTS

The results obtained from simulation of exoskeleton in SOLIDWORKS is discussed in this section. The kinematic parameters like angular displacement, angular velocity etc. of the motors and links were obtained in graphical form as result of the simulation. The time set for simulation was 4 seconds. Fig–2 and Fig-3 shows the angular displacement vs time graph of Motor 1 and Motor 2. Fig- 4 and Fig-5 show the graph for angular velocity of Motor 1 and Motor 2.

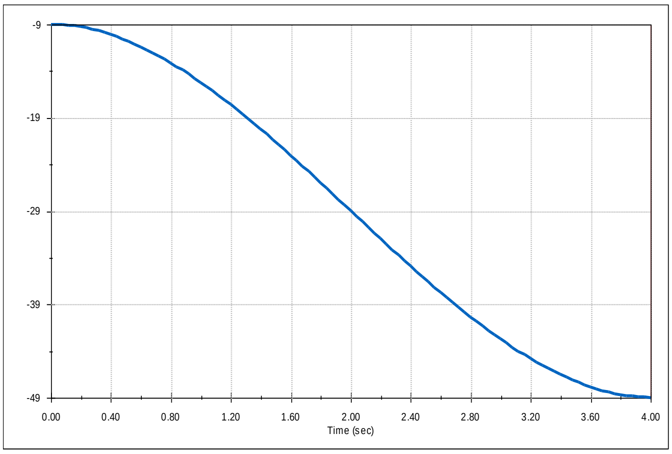

Fig-2: Angular displacement of Motor1

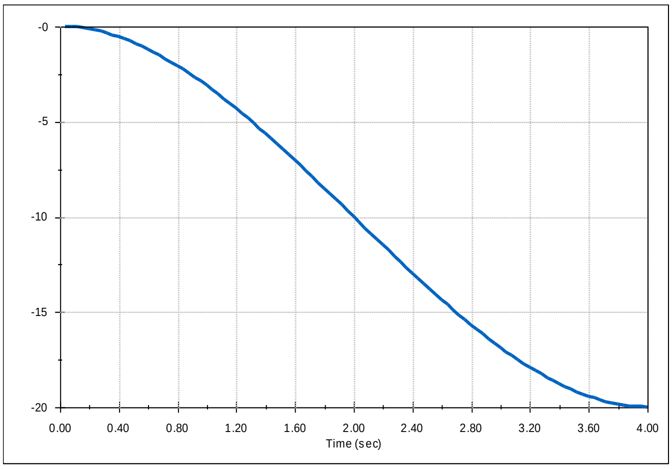

Fig-3: Angular displacement of Motor2

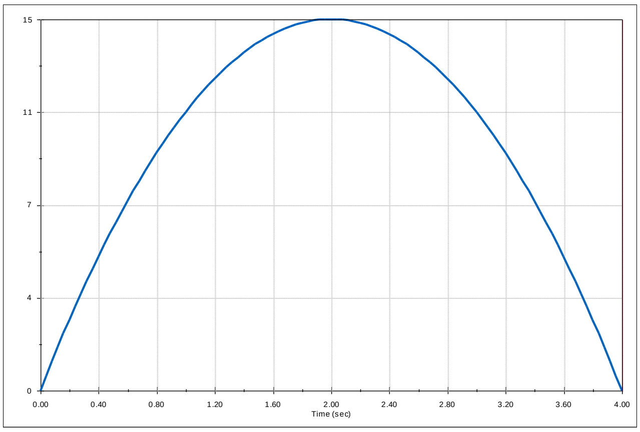

Fig-4: Angular velocity of Motor1

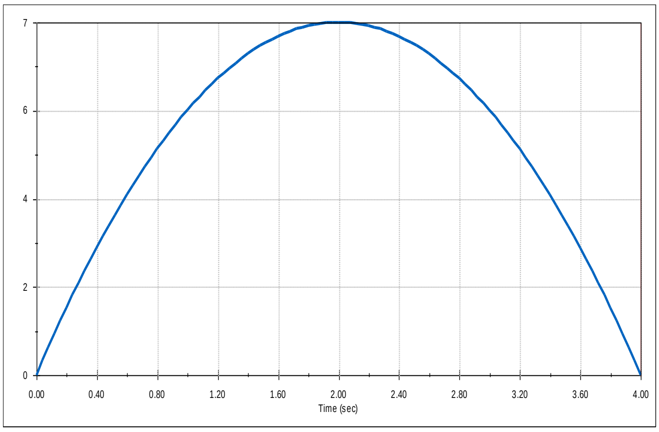

Fig-5: Angular velocity of Motor2

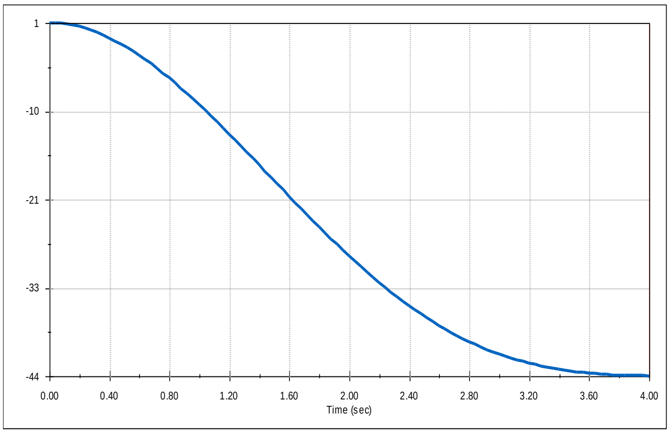

Fig-6 Angular displacement of link EDF

Fig-6 shows the graph for angular displacement of link EDF vs time of simulation. Link CDF moves the intermediate and distal phalange of the index finger. Fig-7 shows the graph of angular velocity variation of link CDF during the time of simulation. Fig-8 shows the angular displacement vs time graph for link CD. Link CD is responsible for the movement of proximal phalange of the index finger.

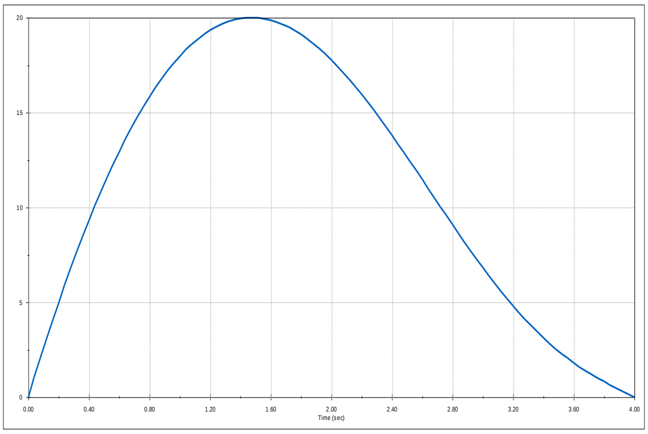

Fig-7: Angular velocity of link EDF

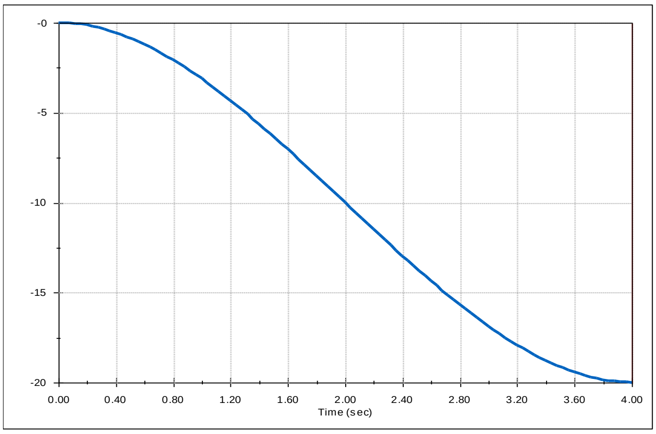

Fig-8: Angular displacement of link CD

3. CONCLUSIONS

An Index finger exoskeleton with 2 Degree of Freedom was successfully simulated and kinematic analysis of the different links was also done. The exoskeleton based on a four bar linkage provides motion to the proximal and intermediate phalanges of index finger. The 3D representation of the exoskeleton was drawn in SOLIDWORKS. The exoskeleton is found to be suitable for fabrication because of its Range of Motion and ease in fabrication. Kinematic analysis of the exoskeleton showed that the link EDF, which moves the intermediate and distal phalanges, has a Range of Motion of 44^0 whereas Link CD, which moves the proximal phalanx, has a Range of Motion of 20^0. The angular velocity of both the motor is found to be very smooth and in range. The angular velocity vs time graph is seen to be parabolic in nature.

The scope of future enhancement is that other finger can be considered for application. Also, only flexion and extension has been taken into consideration for this exoskeleton. The design can be improved by adding adduction and abduction movement to the finger which would increase the Degree of Freedom of the exoskeleton.

REFERENCES

[1] E. Guizzo and H Goldstein, "The rise of the body bots [robotic exoskeletons]", in IEEE Spectrum. vol. 42, no. 10, pp. 50-56.

[2] A. M. Dollar and H. Herr, "Lower Extremity Exoskeletons and Active Orthoses: Challenges and State-of-the-Art", in IEEE Transactions on Robotics. vol. 24, no. 1, pp. 144-158.

[3] J. Wang, J. Li, Y. Zhang, & S. Wang, "Design of an exoskeleton for index finger rehabilitation". 2009 Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 5957-5960.

[4] S. Ito, H. Kawasaki, Y. Ishigure, M. Natsume, T. Mouri, and Y. Nishimoto, "A design of fine motion assist equipment for disabled hand in robotic rehabilitation system". Journal of the Franklin Institute. Volume 348. ISSN 0016-0032. Issue 1.pp. 79-89.

[5] K. Nasilowski, J. Awrejcewicz, and D. Lewandowski, "Kinematic analysis of the finger exoskeleton using MATLAB/Simulink". Acta of bioengineering and biomechanics 16(3). pp. 129-134.

[6] M.N.A.B. Ab Patar, T. Komeda, J. Mahmud, and C. Y. Low, "Model Based Design of Finger Exoskeleton for Post Stroke Rehabilitation Using a Slotted Link Cam with Lead Screw Mechanism". Industrial Engineering, Management Science and Applications. Lecture Notes in Electrical Engineering, vol. 349. Berlin, Heidelberg.