2019 4th International Electrical Engineering Conference (IEEC 2019)
Jan, 2019 at IEP Centre, Karachi, Pakistan

Modeling and simulation of robotic finger using gear train mechanism

Nomia Nouman[1*], Dr. Saifullah Samo[1] and Dr. Tanweer Hussain[1]

[1] Department of Mechanical Engineering, Mehran University of Engineering and Technology, Jamshoro, 76020, Pakistan (nomianouman089@gmail.com)

Abstract: In this research paper, a mechanism of an anthropomorphic robotic finger is being developed. The developed finger with proposed mechanism can mimic the motion of human finger as each joint can be controlled individually. The proposed mechanism has 3 degrees of freedom, which is based on gear mechanism. The gears are operated by a single servo motor and joints are controlled by solenoid pins. The presence of motor in the palm helps in reducing the total weight of the finger. The gear mechanism adds up to the dexterity of the finger. The engaging mechanism (linear solenoid) ensures the required movements of the joints of the finger. The locking mechanism holds and keeps the finger intact at a position. The equations were mathematically modelled and the CAD model of the finger is developed. The robotic finger is simulated for various positions using the CAD design in Creo and the simulations are verified by the MATLAB. The robotic finger of the suggested design can conveniently be used at 'pinch points' of an industry to carry out intricate operations while ensuring safety of the workers.

Keywords: Robotic finger, mimicking finger, hands,

I. INTRODUCTION

Over the last few decades there have been great treads in the development of robotic finger and terminal devices that take advantage of the latest technological advances, moving towards more dexterous, realistic finger devices. Robotic finger is playing an important role in manufacturing and other applications that require precision and dexterity. However, there is still a great gap between the current method of the art and devices that have ideal combination of being highly functional, durable, cosmetic and inexpensive. In order to minimize this gap, a better understanding of the performance needs of robotic finger need to be achieved.

Nowadays, robots are playing an important role in industries of the world. An example of the industrial robot is the construction of an artificial hand or finger able to reproduce the functions of the human hand/finger.

Typically, robotic hands are the automated devices which are basically used for the gripping of the objects. Numerous designs of the robotic hands which are mainly classified by the design of the robotic fingers. The design may be based on series of rigid links and motor-driven robotic joints. Some presented robotic fingers are also classified by number of degrees of freedom. Industrial robotics arms with two fingers are widely used [1] but can not mimic human finger. Multi-finger robotic grippers are also widely investigated [1-6] to increase functionality and mimicking of mimic human finger. Dynamic model of anthropomorphic robotics finger mechanism for the gripping of the target objects, it uses langrangian method [1]. A tendon-drive robotic finger and rearranged its tendons according to the moment arm of the robotic finger change linearly according to the joint angle also develop a solution for the lumbrical muscle situated between the tendons [2]. Biomimetic robotic finger for the grasping of objects, actuated with hybrid mechanism and for the integration tactile sensor is developed, hybrid mechanism includes a DC micro motor and a shape memory Alloy Wire [3]. Wearable robotic extra finger is proposed for human grasping. The guidelines given by three prototypes with both fully actuated and under actuated systems [4].

II. FINGER ANATOMY

A robotic finger is a type of mechanical finger usually programmable with similar functions to a human finger. Usually the robotic finger is made up of three joints, metacarpophalangeal (MP) joint, the proximal interphalangeal (PIP) joint, and distal interphalangeal (DIP) joint. The PIP and DIP joints are collectively called IP joints. The end of the finger is connected to the end effectors. The end effectors may be a gripper or an electromagnet to perform work. The work is about the mathematical modelling and simulation of robotic finger kinematics which has three degrees of freedom. Robotic finger modelling is done by the gear train and controlled by a single motor. At each joint there is an actuator that will engage or disengage the joints with the actuator to produce required movement of the robotic finger. The size of the robotic finger is almost same as that of the human finger.

The proposed robot finger uses gear train for its power transmission at each joint, single motor and gear mechanism can be used to make possible movements of the joints of the robotic finger. Actuators are used at each joint of the finger for controlling its angular movement according to the required position. The locking mechanism at each joint also used to holds and keeps the finger intact at the position. The moving parts and joints are developed in order to achieve high precision and accuracy.

Three sections of the frame for the robotic finger are carefully designed in 3D CAD software creo as to enable the three joints to depict movement along all their prescribed angular positions and to leave enough space for the gears to be installed within and to maintain the physical anthropomorphic shape.

Length of section 1 (MP - PIP Joint), L_1=5 cm

Length of section 2 (PIP - DIP Joint), L_2=3.5 cm

Length of section 3 (DIP Joint - Tip), L_3=3 cm

Width of the finger, w=2 cm

Height of the finger, h=2 cm

Thickness of the frame, t=0.1 cm.

However, a single motor installed in the palm and the power is to be transmitted to each of the three joints using a gear train. The diameter of the gear is in limits, so that the gear gets fit inside the frame. Diameter and no. of teeth of all gears is also same, and No. of gears in meshing determined as to maintain the same direction of motion for all the three joints.

Thus, a gear train is designed consisting of nine gears, out of which four are housed in the first section of the frame Fig. 1, three in the second section Fig. 2, one in the third section Fig. 3 and the remaining last gear became the part of the palm. The assembly with different position is shown in Fig. 4, Fig, 5 and Fig. 6.

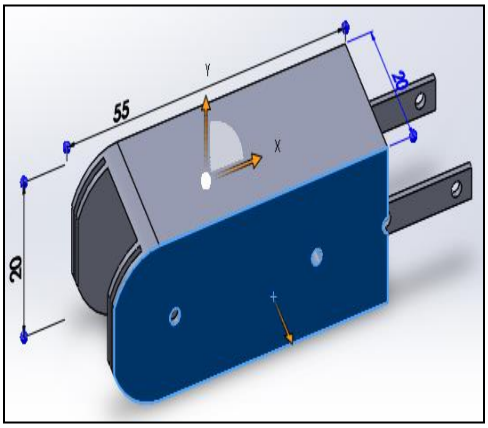


Fig. 1 Joint Name

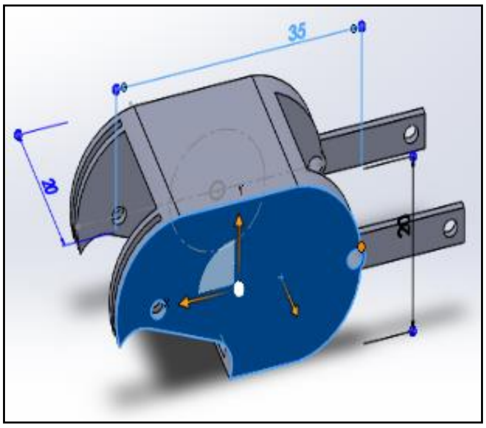


Fig. 2 Joint Name

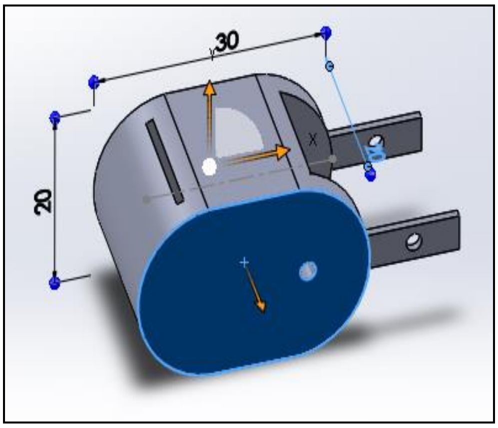


Fig. 3 Joint Name

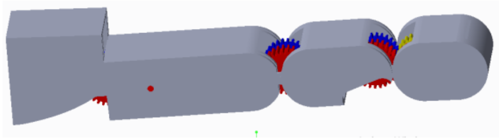


Fig. 4 Assembly with straight position

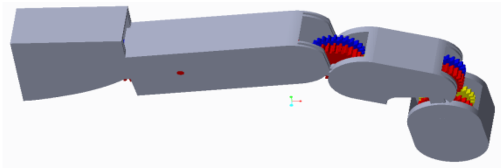


Fig. 5 Assembly with some variation position

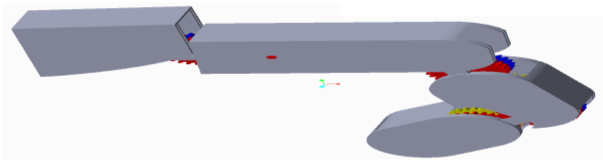


Fig. 6 Assembly with more variation position

III. MODELING

Mathematical modeling of robotic finger is being carried out to perform variety of tasks such as grasping of objects at any required position or angle at each joint of the finger. Modeled robotic finger can mimic the motion of human finger.

$$X= l_1 \cos\theta_1+ l_2\cos(\theta_1+\theta_2) + l_3\cos (\theta_1+\theta_2+ \theta_3), \quad (1)$$

$$Y= l_1 \sin\theta_1+ l_2\sin (\theta_1+\theta_2) + l_3 \sin (\theta_1+\theta_2+ \theta_3). \quad (2)$$

The equation of the velocity linear above should be square and sum of the equations to find V1, V2 and V3,

$$v_1= 1/4\, l_1^2\, \theta`_1 \quad (3)$$

$$v_2= l_1^2\, \theta`_1^2+1/4(\theta`_1^2+2\, \theta`_1\theta`_2+ \theta`_2^2) + l_1\, l_2\, C_2\, (\theta`_1^2+ \theta`_1\, \theta`_2) \quad (4)$$

$$v_3= l_1^2\, \theta`_1^2+ l_2^2(\theta`_1+\theta`_2)^2+1/4\, l_3^2\, (\theta`_1+\theta`_2+ \theta`_3)^2+2\, l_1\, l_2\, C_2\, \theta`_1(\theta`_1+ \theta`_2) + l_1\, l_3\, C_{23}(\theta`_1+\theta`_2+ \theta`_3)^2+ l_2\, l_3\, C_3(\theta`_1+\theta`_2)\, (\theta`_1+\theta`_2+ \theta`_3) + l_1\, \theta`_1^2+l_2(\theta`_1+ \theta`_2)^2 + l_3\, (\theta`_1+\theta`_2+ \theta`_3)^2 \quad (5)$$

And the link Kinetic energy,

$$(K)=K_i= 1/2\sum_{1}^{3}= (m_1v+l_i\, \omega_i^2) \quad (6)$$

The Kinematic energy

$K=0.5(A_{11}\, \theta_1^2+2\, A_{12}\, \theta_1\, \theta_2+2\, A_{13}\, \theta_1\, \theta_3+ A_{22}\, \theta_2^2+2\, A_{13}\, \theta_2$

$\theta_3 + A_{33}\, \theta_3^2)$

The potential energy is

$(p)=p_i=1/2\sum_{1}^{3}(m_i\, g y_i)$

$p_1 = 1/2 m_1 g l_1 S_1$

$p_2 = m_2 g\, (l_1\, S_1 + 1/2\, l_2\, S_{12})$

$p_3 = m_3 g\, (l_1\, S_1 + l_2\, S_{12} + 1/2\, l_3\, S_{123})$

$p = p_1 + p_2 + p_3$

$p = 1/2 m_1 g l_1 S_1 + m_2 g\, (l_1\, S_1 + 1/2\, l_2\, S_{12}) + m_3 g\, (l_1\, S_1 + l_2\, S_{12} + 1/2\, l_3\, S_{123})$ (7)

The Langrangian is computed as:

$L = K - P,$

By using the langrange-Euler Formulation, The equation of motion for three degree of freedom finger can be written as,

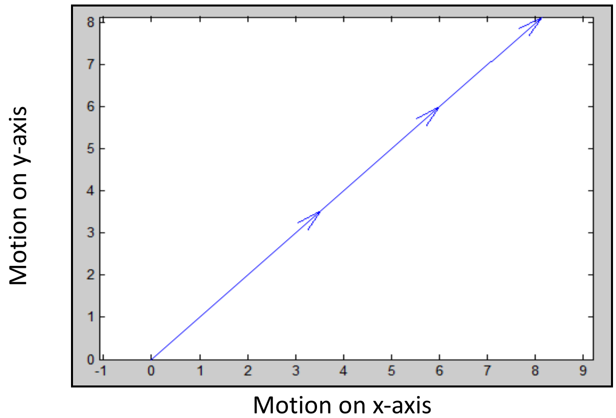
$d/dt[\delta/\delta\theta i] - \delta/\delta\theta i = \tau_I$ (i=1-3)

Thus, this completes the Dynamic modeling of anthropomorphic robotic finger mechanisms. These equations are used in the simulation of the design of anthropomorphic robotic finger mechanisms.

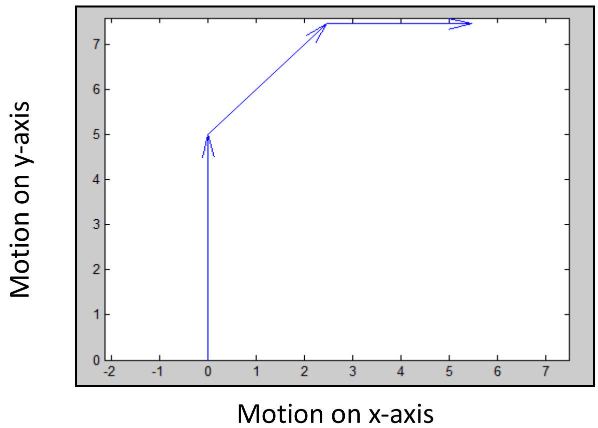
IV. SIMULATION AND RESULTS

Simulations are performed through Matlab at different engaging time as shown in Table 1.

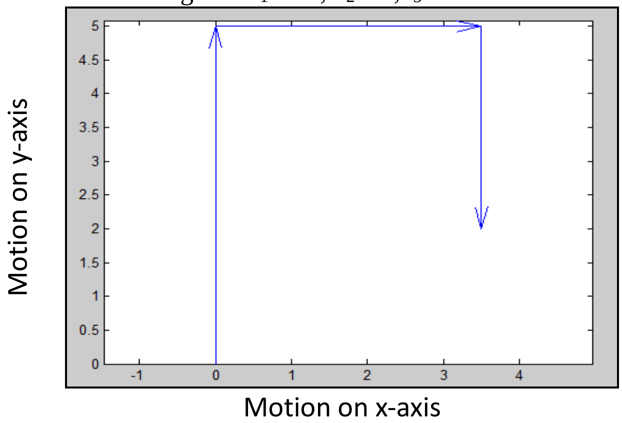
Simulation of finger at $\theta_1 = 45°$, $\theta_2 = 45°$, $\theta_3 = 45°$



Simulation of finger at $\theta_1 = 90°$, $\theta_2 = 45°$, $\theta_3 = 0°$



Simulation of finger at $\theta_1 = 90°$, $\theta_2 = 0°$, $\theta_3 = -90°$



Simulation of finger at $\theta_1 = 90°$, $\theta_2 = 0°$, $\theta_3 = 0°$

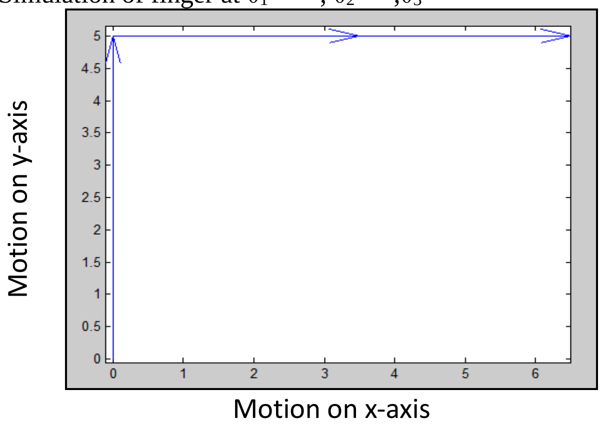


Table. 1 Engaging time of finger at each joint

θ_{123}	30°	60°	90°
t_1 (milliseconds)	63.1065	126.2131	189.3196
t_2 (milliseconds)	52.9688	105.9376	158.9064
t_3 (milliseconds)	50.4620	100.9240	151.3860

Velocity at each joint of the finger at 90°

$v_1 = 6.25$ cm/ms

$v_2 = 25$ cm/ms

$v_3 = 12.25$ cm/ms

V. CONCLUSION

This paper has considered the mechanism and control of the robotic finger for mimicking the human finger. The finger mechanism has 3 degrees of freedom and based on gear with locking mechanism. Proposed robotic finger can mimic the motion of human finger for holding the job or in empty state (space).

A gear driven robotic-finger is actuated by single motor and force is transmitted by gear train from motor to each joint. Locking mechanism is used to lock the finger joint to hold the position or unlock the finger joint to achieve new position. It requires small finger space due to simple mechanism and other system will be installed in palm. However, through this research work it is observed that the proposed mechanism for robotic-finger is fit for a robot hand to hold any shape of tool or object.

REFERENCES

[1] Giuseppe C., Antonio G., "A numerical simulation of the grasp operation by LARM Hand IV: A three finger robotic hand". *International journal Robotics and Computer-Integrated Manufacturing*, vol. 7, no, 2, pp 450-459, 2011

[2] Zaidy, A. H., Rehan, M., Quadir, A. & Parvez, M. "Dynamic Model Of Anthropomorphic Robotics Finger Mechanisms". *International Journal of Modern Engineering Research*, vol. 3, no, 2, pp 1061-1065, 2013

[3] Shirafuji, S., Ikemoto, S. & Hosoda, K. "Development of a Tendon-Driven Robotic Finger for an Anthropomorphic Robotic Hand". *The international journal of robotics research*, vol.33, no.5, pp.1-17, 2014

[4] Low, C. Y., A. Kasim, M. A., Koch, T., Dumitrescu, R., Yussof, H., Jaafar, R., Jaffar, A., Aqilah, A. & NG, K. M. 2013. "Hybrid-Actuated Finger Prosthesis with Tactile Sensing". *International Journal of Advanced Robotic Systems*, vol.10, no.10, pp 1-10, 2013.

[5] Hussain, I., Gionata, S., Malvezzi, M. & Prattichizzo, D. Design Guidelines for a Wearable Robotic Extra–Finger. *Proceedings IEEE Int. Forum on Research and Technology for Society and Industry,* vol.1, no.2, pp.1-7, 2015.

[6] Giuseppe C., Antonio G., "Design of a low-cost five-finger anthropomorphic robotic arm with nine degrees of freedom". *International journal Robotics and Computer-Integrated Manufacturing*, vol. 28, no, 4, pp 551-558, 2012.