Mechatronic Hand Designing with an Integrated Mechanism in Palm for Finger Efficiency Improvement

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Abstract

One of the most important cases in humanoid robot designing is hand, which is considered as any country's development. High percentages of robot work quality depend on hand capability. A robot function increases with hand movement. One of important movements in artificial hand capability is related to fingers' lateral movement. This case has more effects on taking special objects such as round shapes or moving the taken objects. The present research investigates robotic hand designing in humanoid patterns based on embedding motor in palm and also a new mechanism was presented for finger's lateral movement. The proposed mechanism was simulated in Solid works' software and static and dynamic analyses were done on it. Appropriate size and shape for finger's lateral movement was considered as the major aim in this research.

Keywords: Humanoid Hand, Multi-link Finger, Non-back drivable Actuator.

1- Introduction

Throughout history, it was assumed that robots can mimic human behavior and they act as human in tasks' management. Nowadays robotics' industry is developing rapidly. Research, designing, and building new robots are administrated in medical, commercial, and military services [1]. According to kind of robots, we can notice the communication with external environment in order to have a responsible administration.

This communication has different qualities regarding existing conditions. Every robotic system needs sensors and other tools to understand the surrounding world in order to impose demands on the environment. Force, pressure, bending, number of rotations, linear, and angular positions are kinds of sensors used for robotics systems. Also special sensors such as gyroscope, camera, finger print and color sensors are applied in robots. With the help of sensors and after obtaining necessary information needed to an organ in surrounding environment, a robot can manipulate objects in order to carry objects with different shapes and dimensions [2]. In this case various techniques are applied for humanoid robots arisen by human hands. Developing robot's hand is one of the most important problems in robotics' technology and many researches have administrated projects for usual functions and human hand's different shapes [2]. But, robotics' science can't accomplish general features of human hand such as grace and dexterity and fine movements in fingers, relatively fast moves, high understanding with thin and light structures [3].

If a hand is designed with the capabilities mentioned, it can do physical works beside non-physical works such as gesture establ ishment [3,4]. Other possibility plans in mentioned robots relate to using it for artificial hands. This case is very desireable, because a suitable and light artificial hand will be connected to human arm through it [5]. Hand robot's designing was administrated by Steven Davis and et.al in 2008. This robot has 5 fingers (Fig. 1). Fingers are composed of 3 phalanxs and they have 2 DOFs [6].

Fig.1. Low cast 5 finger rodot [6]

A robot with human hand shape is shown in Fig. 2. This shape was proposed by Chan Sen Chen in 2012. This robot has 4 fingers and the second and third fingers of it are combined with each other. This pattern leads to the reduction of the robot's total weight [7].

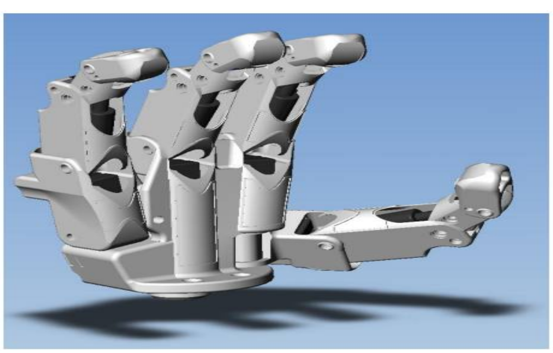

Fig.2. CAD view of a multifinger hand [7]

The robotic hand presented by Yoichi Corita in 2010 was similar to human hand and it has had 5 fingers (Fig. 3). Movement motors were located in separate parts of hand [8].

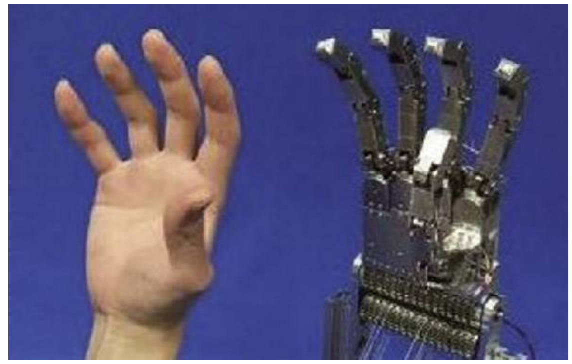

Fig.3. Anthropomorphic hand: NAIST2[8]

The designed robotic hand has had a similar appearance with human hand and it has had 5 fingers (Fig. 4). This robot was presented by Takeshi Kakaki and Turo Omata in 2011. Metals were used to construct more pieces of robots mentioned. Fingers formed with 3 phalanxs were similar to human hand and they could be closed naturally like a real hand based on its' size and dimension [3].

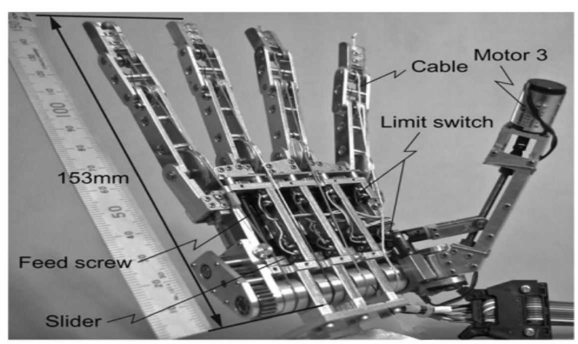

Fig.4. A human sized 5 finger hand [3]

By investigating the designed systems for taking objects according to the degree of freedom, appearance, weight and type of energy, we can conclude that, the best pattern is human hand. Human hand shows an extraordinary pattern of natural bio-mechatronics' system and it shows a criterion for robotics' designers with complex capability aims [9].

Up to now, robotics' hand development has had mimics of human hand as the main problem. In order to achieve the applicable and effective hand robots, we have considered stimuli design mechanisms because the general function of a robotic hand is restricted to mechanical structures [10,11]. The aim of the present study is to develop excellent capabilities, very light and humanoid hands in robots. By presenting new mechanisms we can achieve lateral movements in a robot hand's fingers.

2- Designing and Manufacturing Humanoid hands

2.1. Robot finger actuation mechanisms

Designed robotics' finger to move in 90 degrees range must rotate pivotally around the hinge. In the present designing method we have used a force transformation method in rotation cases to linear cases. In order to administer this project we selected converting belts as one of non-return actuator mechanisms.

According to robot finger dimensions and other pieces, linear move requirement for complete finger opening and closing must be lower than 10 mm. In order to achieve this size within a suitable time, numbers of rotation in gearbox motor per time unit, actuating screw, and connection places with fingers are considered to be the effective methods.

2.2. The mechanical design of fingers

By investigating existing samples, it was found out that the designed robotics' hands in real shape and size had the most and the best efficiencies. Robotics' hand with 5 fingers, 3 phalanxs in each finger and 90 degrees movement were the bases of the mentioned designing as it is shown in Fig. 5.

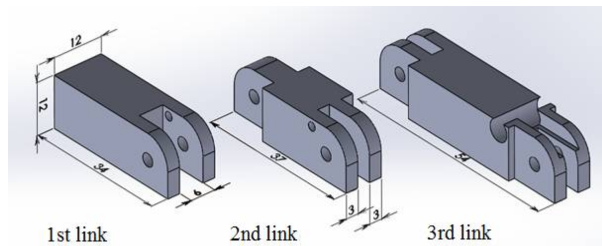

Fig.5. 3 links for first finger

2.3. Motor selection

In order to create movement in a finger, a DC electrical motor with a gearbox with 800 rotation speed per minute in output shaft was selected. According to the equations (1) and (2), the linear speed approaches 6.6 mm per sec after transformation of linear movement with 0.5 mm pitch in screw.

$$L=P.N \quad L=0.5x800 \quad L=400\ mm \qquad (1)$$

In equation (1), P is the screw pitch, N is the screw rotation and L is linear movement.

$$V=L/t \quad V=400mm/60s=6.6mm/sec \qquad (2)$$

Equation (2) shows the linear speed.

Reducing speed with high ratio causes the increase of the linear force of gearbox motor.

2.4. Linkage mechanism for the linear actuator with a finger

Fig. 6 shows 3 assumed cases for finger first phalanx angles.

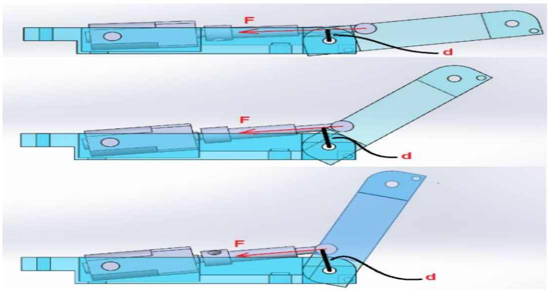

Fig.6. Exerted force from motor to the first link

Torque equation in Fig. 2 presents this case.

$$T=F.d \quad (3)$$

By increasing the amount of d, torque's amount will increase.

Higher amounts of d cause the increase of exerted torque amounts in the link of objects received with higher forces.

2.5. Embedding gearbox motors in palm and creating lateral movement in fingers

By studying object's lifting, we can find that hand fingers have a stability lateral movement, and before closing hand to grab an object, stable fingers are arranged in suitable places of the arm and other fingers' movement and they could select the objects. It is important to know that this case was done in an accurate and controlled form by human's brain and hand.

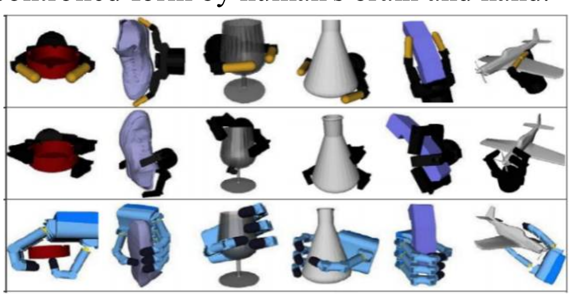

Fig.7. Taking different objects
The first row: A hand with 2 fingers.
The second row: A hand with 3 fingers.
The third row: A hand with 4 fingers [12]

For each of fingers, separate pieces were designed for separate motors and parts of movement mechanisms and fingers are separated completely from each other. Designing help to create easy lateral movements in hand fingers with its details will be presented in next section. Using separated motors to create lateral movements for each of the fingers leads to increase the degree of freedom in robot hand and it affects robot's efficiency. In robots' designing, its total weight, construct cost, and robot controlling must be considered which is hard to do regarding the increase of motors' numbers. According to the mentioned reasons, 3 DC gearbox motors were applied for 4 fingers' lateral movement.

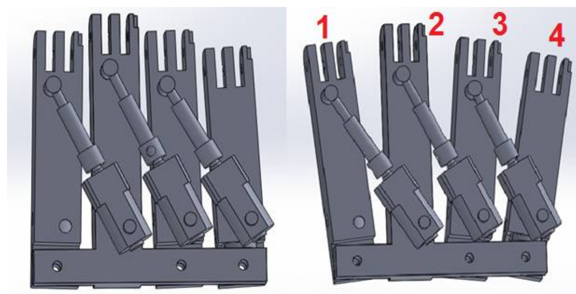

Fig.8. Embedded motors behind the palm

The firs finger (pointer finger) has the most efficiency and highest movements in taking objects. In the present study, motor connection place to finger design with large mechanical forces are represented for the movement system. Fig.9 shows motor force on the first finger palm link.

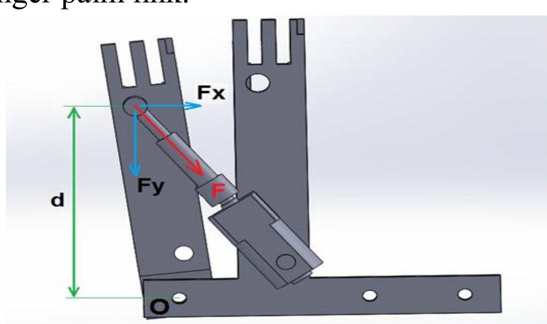

Fig.9. Exerted force to the first finger in lateral movement

According to Fig.9, torque around O point is equal to:

$$M)_o = F_x \, . \, d \quad (4)$$

In equation (4), d is vertical distance force to exert torque place with maximum designed size to reach the maximum amount of exerted torque from motor.

2.6. Investigating motor torque and consumption energy

The equation of motor torque and consumption energy (friction was avoided)

$$P_m = T.\omega \quad (5)$$

$$P_e = V.I \quad (6)$$

$$P_m = P_e \quad (7)$$

$$T.\omega = V.I \quad (8)$$

In equation (8), W and V are angular speed and electrical motor voltage, which are constant and it is known that, by reducing mechanical torque, the motor consumed will be diminished.

3- Results and Discussion

In this section, designed parts of robots were investigated.

3.1. Comparing some basic features of the designed robot with previous designs

By completing design structure and assemblage operation in all of the pieces (Fig. 10) some of parameters were investigated as a model according to designed and previous patterns.

According to aims of robot designing, main features of the system such as dimensions, degree of freedom, and fingers' movement angle were studied and some examples are shown in table 1.

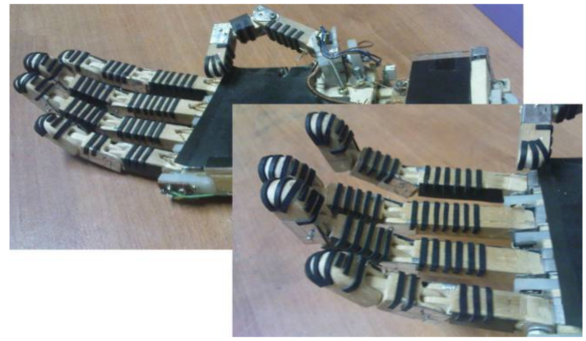

Fig.10. Prototype model of robotic hand

Table1. Features of some robots compared to the designed robot

Project denomination	Number of finger	Number of joints	Number of controlled DOF	speed
DLR hand II	4	17	13	360 deg/s
DLR-HIT-hand	4	17	13	180 deg/s
high-speed hand	3	8	8	1800 deg/s
Barrett hand	3	8	4	1.0 s (fully close)
TBM hand	5	15	1	4...5 s (fully close)
SH2	5	14	5	2.2 s (fully close)
CyberHand	5	16	6	45 deg/s
Designed Hand	5	19	9	2 s (fully close)

3.2. Investigations according to the size

Fig. 11. shows the designed 5 fingers' hand with a cable mechanism. Hand dimensions have more length and width, unlike a robotic hand.

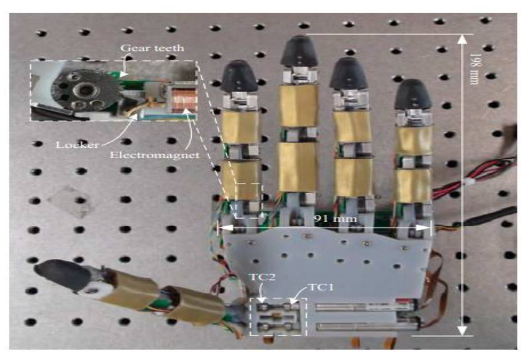

Fig. 11 . Main dimensions of robot hand [9]

Table 2 shows other compared dimensions of hand.

Table.2. Some of robot hand sizes

Components	Dimension [mm]
Overall length	153
Palm (width, length, thickness)	74×69×24
Proximal, Middle, and Distal phalanx	38, 20, and 22.5

Based on the size, main dimensions of the designed hand are 75*180 mm. This size is suitable for embedding electrical motors and pieces of movement mechanisms. So, assumed dimensions for the artificial robot hand is similar to a real hand.

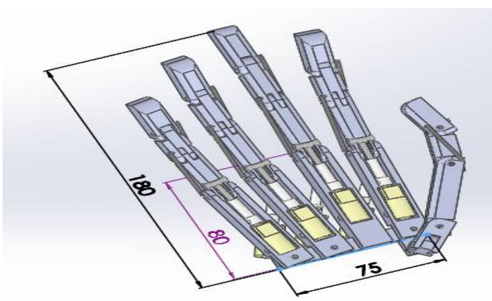

Fig.12. Schematic pattern of robot hand with general sizes

3.3. Fingers' movement angle

Fingers' movement angle is one of the most important features in a robotic hand. The most suitable amount for mentioned angle is 90 degree.

In this case, the hand can take objects with more different sizes. Most robots have 90 degree. Only in designing which finger to activate motor embedded inside, the angle is less than 90 degrees. In the designed robots, 3 movement angles in the best conditions have had 90 degrees.

3.4. Investigation of the degree of freedom

Degree of freedom in a system has a direct relationship with numbers of activate motors. According to the mentioned definition, designed robotic hand has 90 degree of freedom and it is proper against other robots.

3.5. Simulation results

Fig.13. shows the first finger lateral movement for the designed hand in software environment.

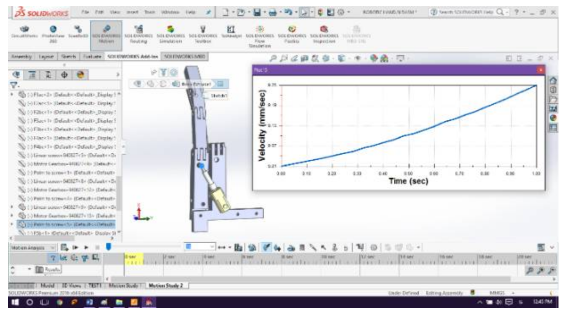

Fig.13. Schematic pattern of the first finger lateral movement in a solid work motion environment

The first finger lateral motion speed during 1 second, is shown in Fig.14.

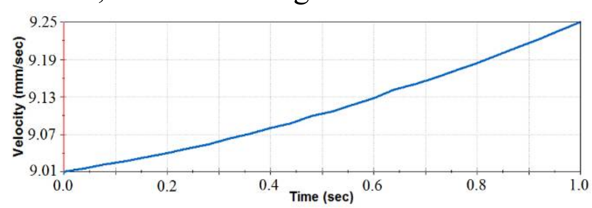

Fig.14. Linear speed of the first finger palm movement piece

It is clear that, the first finger lateral motion speed increases with constant motor rotation speed in distant with the second finger. Speed is less to recede first finger from second finger in a closing case. Lowering speed with a constant of motor speed in all times refers to increasing force in the considered finger.

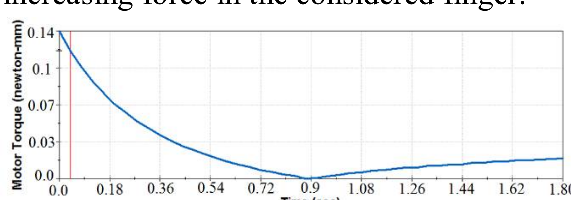

Fig.15. Exerted torque from gearbox motor

According to Fig.15. and all of parameters in previous part, if finger closes more, the motor will need less torque in order to create a constant force. Electrical motor can create a high torque by more closes of fingers and exerting high forces to considered objects.

Figures 16 and 17 show some images for the first applied finger in the designed case and they are analyzed.

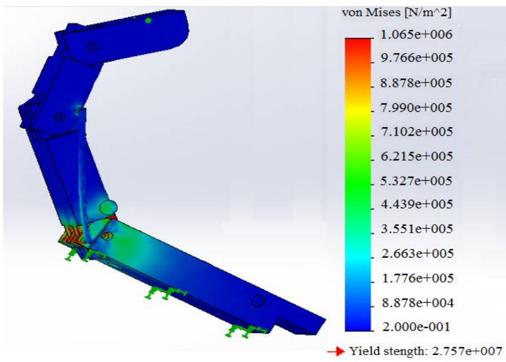

Fig.16. Critical point of finger mechanism in solid works' environment

By administrating tension analysis according to Von Mises criteria, the most amount of tension in studied mechanism is nearly 0.1066 N/ mm^2 for every 2 N exerted force. Aluminum critical tension is nearly 27 N/ mm^2 and because of light weight, high critical tension, accurate machining and it's stainless steel feature, it is proper for robot construction.

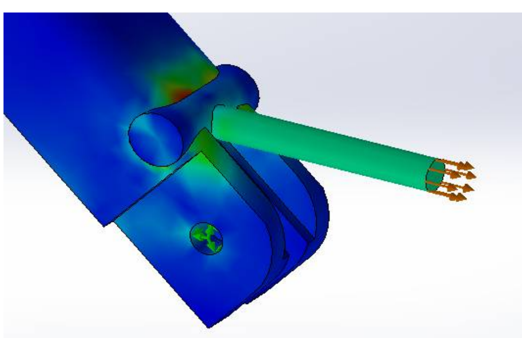

Fig.17. Exerted force from motor to connected pieces and the third strap

This piece is located in a joint case with connections to palm. Fingertip is considered as a resistance force (moving the body with object) and it is determined beforehand. Exerted force from gearbox motor was equalized on piece. Also as it is shown in the figure, critical parts were characterized. Selective material critical tension amount and analyses cases acted properly in this research.

4. Conclusion

One of the most important parts of robots is hands with most effectiveness in robot efficiency. Considered hands have 5 fingers and 3 phalanxs for each hand and it is similar with human hands in designing period. Lateral motion in robot hand fingers haven't been studied completely yet. In the present research a proper mechanism was investigated for creating motion in robotic hands and fingers.

After studying previous plans and designing, the basic parts of 5 fingers' hand were modeled. Then considered mechanisms were administrated on the system to create lateral motion in fingers. Locating and embedding motors was done with the first finger because of better efficiency and more force against other fingers.

Also motors' locating and embedding for closing fingers were investigated by this case.

If fingers close more to take objects, exerted force to objects will be more.

To optimize fingers' lateral motion, we have presented a new method with 3 gearbox motors for 4 fingers which reduce robot's final weight, simple controlling and diminishes electrical consumption.

Proper type of material was selected for designed pieces in software and they were analyzed. So, Aluminum was selected because of proper critical tension, light weight, stainless steel feature and it was used in the designing stage.

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