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Research Article

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Design and Analysis of a Five Fingered Robotic Hand

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Abstract

The aim of this work is to design a five fingered robotic hand and analyze the various feasible working parameters using computer software, for the betterment of the differently abled person's needs. Any person who has hand amputee, may face difficulty doing or working livelihood activities. Hence, it is very important to develop prosthetic robotic hand having greater flexibility and controllability. In this paper with the help of ANSYS and CATIA a robotic arm is designed, a material is selected for its fabrication and FEM analysis is performed, which enabled to have a working model and software prototype similar to a generalized human hand, that is competent to perform gripping and holding of objects. There are also provisions for mechanisms that would allow proper movement and precise control of the hand. Also, kinematic analysis was carried out to understand and improve certain design considerations and to ensure that the robotic hand works well within its operating limits. The paper is based on the improvement and simplifications of the design of the robotic arm which were previously developed. It is found that the material that is selected and designed is safe, and stress applied is within elastic limit.

Keywords

Amputee, Robotic hand, End-effector, Gripper, Polyethylene material

Introduction

End-effectors or grippers in robotics is basically a means of interaction of a robotic arm with the environment. End-effectors assist the robotic arm for performing various tasks in household as well as industrial activities. Robotics grippers are of various types such as two-fingered or multi-fingered which are useful for holding parts, materials, tools, etc. The design of such multi-fingered robotic grippers should signify the human hand required for seizing and also manipulating different types of items. Such robotic arms with multi-fingered grippers have been used for various pick and place operations, which are monotonous tasks for a human being [1]. Several commercially available robotic hands are being used for rehabilitation purposes e.g., development of prosthetic hands [2]. Effective design of a prosthetic hand having high degree of flexibility and dexterity is vital for assisting differently abled persons for providing functional support [3]. So, the main idea is to provide flexible and affordable robotic arm to the common people, starting within India.

The hand design, which is adept at doing human-like postures as well as activities, is of different elements. This is resolved by computing the kinematics, contact surface smoothness, accurate link sizes etc., The Okada Hand, which has two fingers and an opposable thumb, was created (1979) with eleven controlled degrees of freedom thumb with an exoskeleton structural design [4]. Another hand named as the Stanford/JPL Hand developed (1983), had three interconnected fingers and nine actuated joints. Motion position sensors and tendons were used for power transmission [5]. Utah University (1988), there is hand developed collaborating with MIT called The Utah/MIT had 4 fingers and 16 joints had the size proportional to a human hand including palm. This was designed for grasping different objects using pneumatic actuators, motors, and motion position sensors [6]. Barrett Hand (1988), another robotic hand consisting of three number of fingers, driven by a DC brushless servomotor [7]. NASA's Johnson Space Center or JSC, developed the five fingered 22 joints robotic hand named as "Robonaut" hand for space-based operation (1999) [8]. A more powerful and accurate hand named DLR I and DLR II were developed which had 4 number of fingers, 17 number of joints with 13 specific actuations. The Ultralight hand that was developed (2000) had 5-fingers, 18 number of joints with 13 number of actuated joints. It was humongous in comparison to human hand though smooth surface of contact provided frictionless performance. The Gifu Hand developed (2001), was also having 5-fingered hand containing 20 number of joints with degrees of freedom calculated as 16. It could perform agile object manipulation close to human hands [9, 10]. A robotic hand named as an anthropomorphic hand with 4 fingers containing with an opposing thumb was developed (2013) [11]. Each finger had 3 joints actuated by tendons.

A multi-fingered hand with fingers connected like a human hand has dexterity. Research using multi-fingered hands has so far deliberated on gripping and manipulation of gripped objects. Most of the clasping and synthesizing studies brought off in the last two decades have contributed to complex and widespread mechanisms. Some of it can be applied to physical applications also in unstructured environments. In addition to adroitness and manipulability, there is clearly a growing need for lesser friction with smaller volume, lightweight grippers with coherent and simple actuation and transmission systems to improve manipulator performance. Little attention has been paid to the anthropomorphic design of the hand, which is also a relevant component of hand convalescence applications. Based on the literature, a 5-fingered robotic hand is developed in this paper.

Notably the tasks are pick and place, throwing and catching an object, for cutting purposes with a sharp tool like knife in rapid up and down movement, holding any stressed rope with minimum friction, etc.

Since the number joints are 3 for each finger and 2 for the thumb, and there is an additional joint connecting the palm to the arm visualizing a human hand, the degree of freedom here is 12. The application of the robotic arm is specifically picking up and placing and gripping any objects.

It is observed that the previously done projects on the robotic arm topics are lacking in dimensional analysis, whereas the projects emphasis on the outstanding design abilities. Ease of operating the prototype is also concerned in the project by the suitable selection of the material type, so that the user experiences effortlessness and satisfaction rather enervated.

The manuscript is structured as follows. The proposed mechanisms of the robotic hand are described in Section 2, followed by the results and discussion which is in Section 3. The paper is concluded briefly in Section 3.

Mechanism

A robotic hand with 5 fingers and 3 joints in each finger is developed to replicate a human hand in terms of its functionality and controllability. The gripping mechanism with five fingers as well with two fingers (Thumb and index finger) is also shown with the help of simulation. A three-dimensional computer aided design (CAD) model of the hand is designed using CATIA software as shown in figure 1.

Components of the robotic hand

The robotic hand consists of 5 fingers having three links in each finger. The schematic of each link of the index finger are shown in figure 2a to 2c, for the middle figure in figure 3a to 3c, for the little finger in figure 4a to 4c, for the thumb in figure 5a to 5c and the palm design is shown in figure 6a to 6c. The dimensions are colored in different tones.

FEM Analysis

Polyethylene is basically a thermoplastic which has the highest use of component fabrications and their parts. Availability of this material is widespread, denoting to various grades and formulations. Generally, polyethylene offers commendable chemicals as well as impact resistance and electrical properties along with low coefficient of friction. In addition, polyethylene is lighter in weight, easily produced or processed and offers negligible amount of moisture absorption. In comparison to other materials, it is reliable and recyclable. So, polyethylene is preferred over any other material, for manufacturing the robotic hand. Table 1 shows the comparison among the most commonly used materials for robotic hand. Engineering properties of polyethylene used during FEM analysis are shown in figure 7.

Each link of the fingers and the palm of the robotic hand are designed in the CATIA and the stress analysis is done in ANSYS version 16. The application of force, resulting equivalent stress and strain and directional and total deformation of the palm of the robotic hand are shown in figure 8a to 8f.

The proposed model of the robotic arm is basically a scrutinized version of the anthropomorphic hand which has the same outlook of a human hand. Its degree of freedom found is 12 where in case of the anthropomorphic hand it's not properly defined, and can perform dexterous work as Gifu hand [10]. Specifically, it has higher advantages due to the selection of material (Polyethylene) which is lighter in mass/weight. The

Table 1: Comparison of different properties of the material.

Properties	Polyethylene	Mild Steel	Aluminium (Pure)
Density (kg/m^3)	930	7849.05	2710
Young's Modulus (GPa)	1.1	207	70
Poisson's Ratio	0.42	0.303	0.31
Bulk Modulus (GPa)	2.2917	160	62
Shear Modulus (GPa)	3.8732	77	25

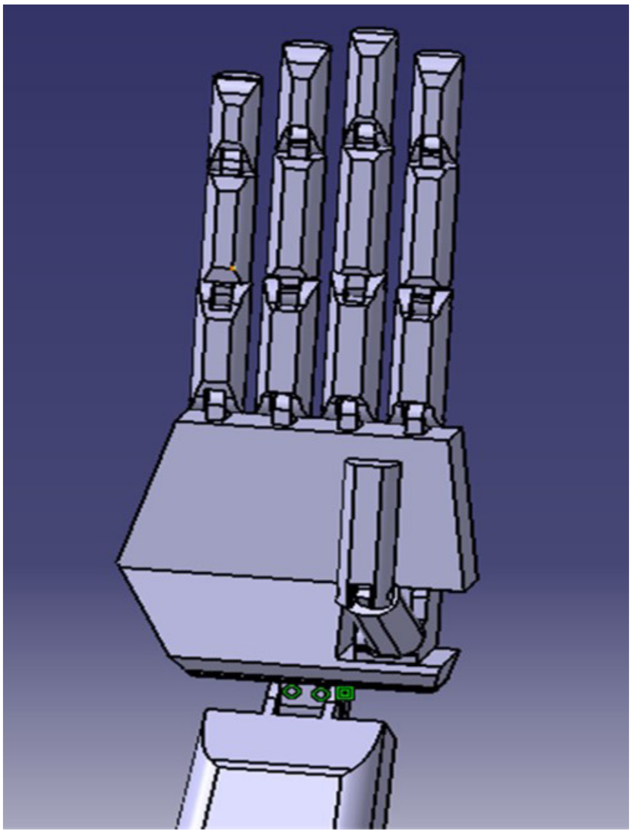


Figure 1: CAD model of the five fingered robotic hand.

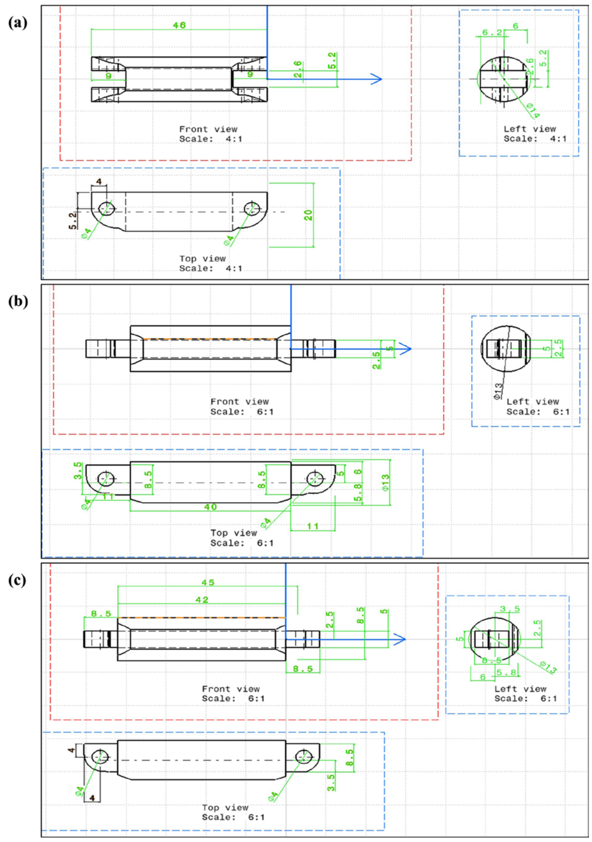


Figure 2: Dimension of the index finger **(a)** link 1, **(b)** link 2, and **(c)** link 3.

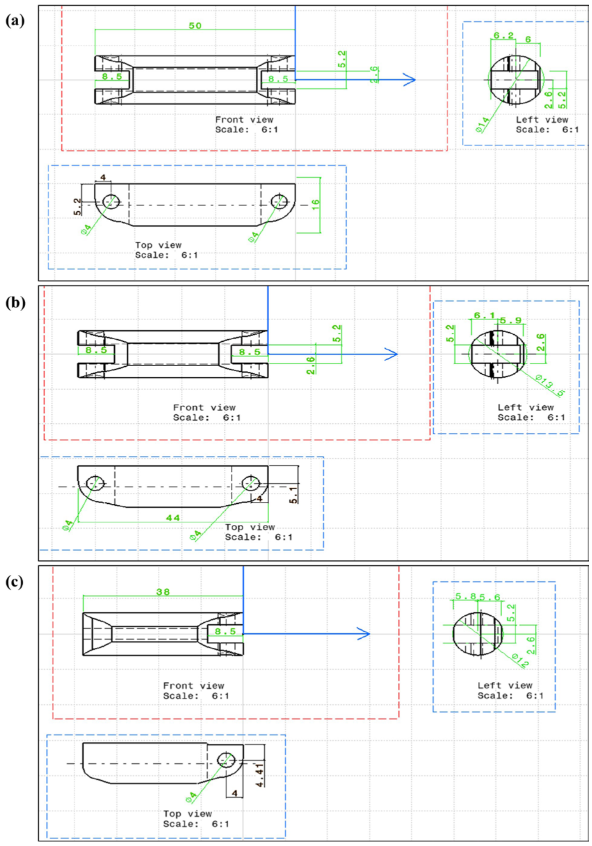


Figure 3: Dimension of the middle finger **(a)** link 1, **(b)** link 2, and **(c)** link 3.

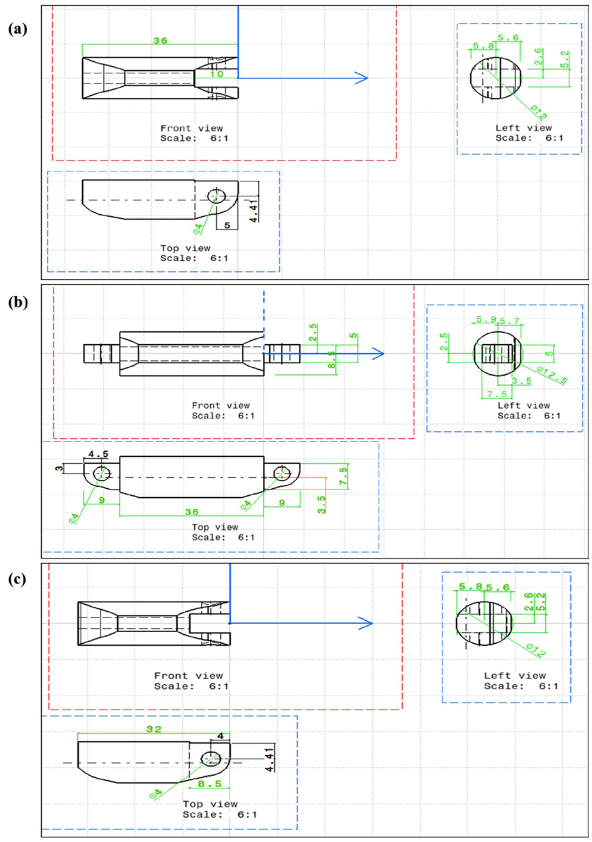


Figure 4: Dimension of the little finger **(a)** link 1, **(b)** link 2, and **(c)** link 3.

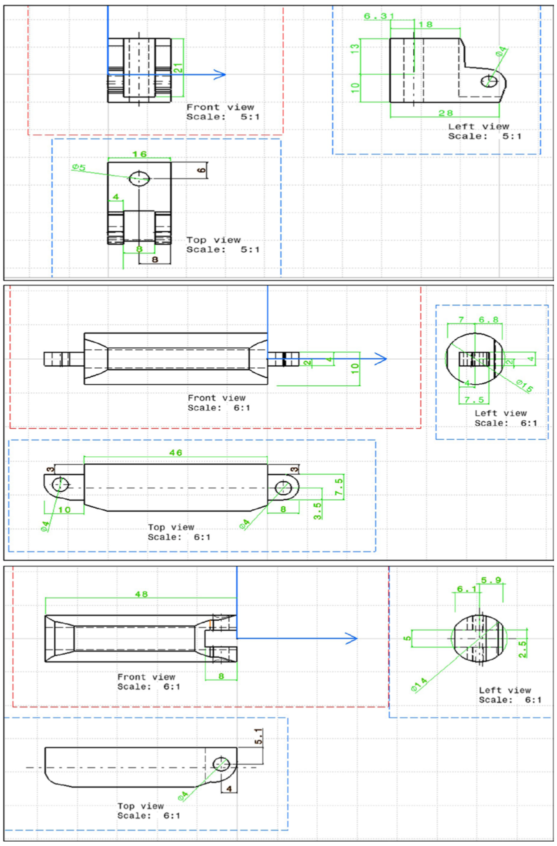


Figure 5: Dimension of the thumb **(a)** link 1, **(b)** link 2, and **(c)** link 3.

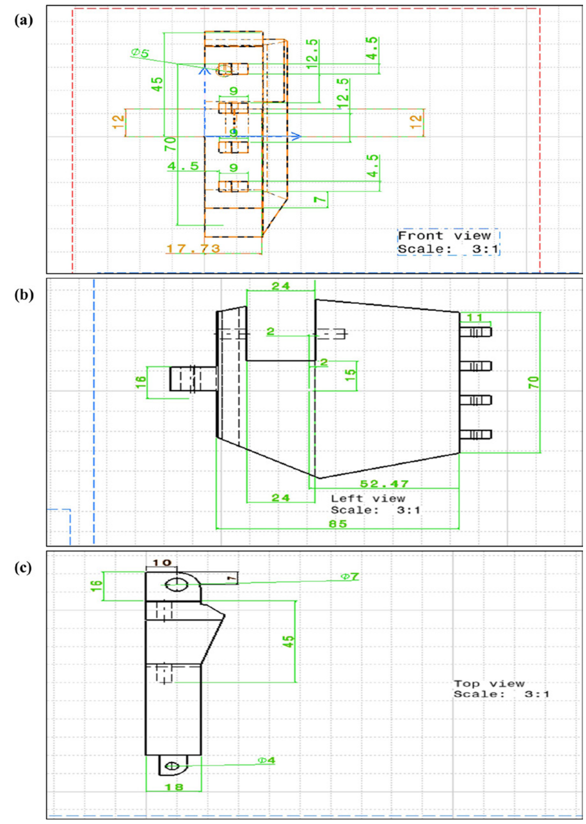
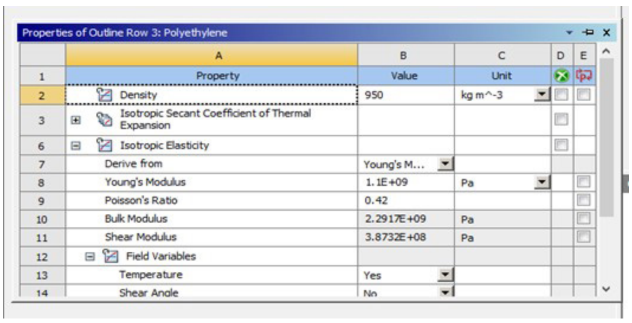


Figure 6: Dimension of the palm in **(a)** front view, **(b)** left view, and **(c)** top view.



Properties of Outline Row 3: Polyethylene

	A	B	C	D	E
1	Property	Value	Unit		
2	Density	950	kg m^-3		
3	Isotropic Secant Coefficient of Thermal Expansion				
6	Isotropic Elasticity				
7	Derive from	Young's M...			
8	Young's Modulus	1.1E+09	Pa		
9	Poisson's Ratio	0.42			
10	Bulk Modulus	2.2917E+09	Pa		
11	Shear Modulus	3.8732E+08	Pa		
12	Field Variables				
13	Temperature	Yes			
14	Shear Angle	No			

Figure 7: Engineering data of polyethylene material.

Table 2: Parts required to develop the robotic arm.

Parts	Works
Tendons	Acts as rope-pulley transmission system
DC servo and stepper motors	Electrical actuators which will help to convert the electrical energies to mechanical energies.
Force sensing resistor	A type of strain gauge act as a sensor to sense the pressure and has a very small amount to space to occupy.

components of the mechanism are listed in table 2 for its fabrication.

Results and Discussion

The proposed multi-fingered robotic hand is designed in CATIA and FEM analysis is done in ANSYS version 16 software. Equivalent stress, strain, directional deformation, and total deformation under an applied load is shown in the pre-

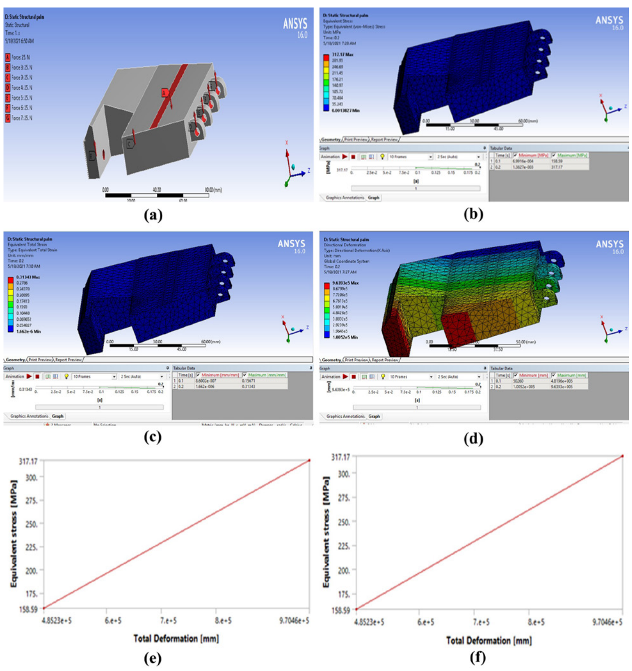


Figure 8: (a) Force direction on palm, **(b)** Equivalent stress of palm, **(c)** Equivalent strain of palm, **(d)** Directional deformation of the palm, **(e)** Equivalent stress versus total deformation, and **(f)** Equivalent stress versus directional deformation.

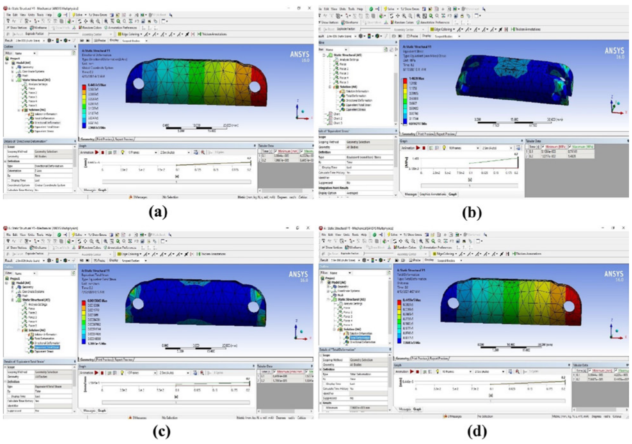


Figure 9: (a) Directional deformation of link, **(b)** Equivalent stress on link, **(c)** Equivalent total strain on link, and **(d)** Total deformation of link.

ceding section. It is observed that the material and the design is safe, and the stress applied is within the elastic limits. The thumb that the gripper is suitable for various practical applications such as pick and place operations.

Conclusions

The design of a working hand with the help of robotics is a challenge even though there are a lot of technologies today. The structure of a robotic hand is described in this paper using CATIA model and ANSYS simulation. The working of the robotic hand, from the tip of the finger of the hand to the joint has kinematics linked for its effective operation. The thumb of the hand is also contrived with the help of the same analysis. FEM analysis has also been done to visualize the regions of potential failure and thus helped in refining the design. Future research may be done on the fabrication and testing of proposed robotic hand.

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None.

Conflict of Interest

The authors declare no conflict of interests that are relevant to the content of this article.

Credit Author Statement

Zahnupriya Kalita: Conceptualization, Methodology, Writing - original draft preparation, Supervision; Sabyasachi Kashyap Mech: Conceptualization, Methodology, Experimentation, Writing - original draft preparation, Writing - review and editing; Raktim Borah: Experimentation, Writing - original draft preparation; Mukul Chandra Swargiary: Experimentation; Khandib Pao: Experimentation, Writing - review and editing. All the authors read and approved the manuscript.

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