جامعة الأمير محمد بن فهد
PRINCE MOHAMMAD BIN FAHD UNIVERSITY

College of Engineering

Department of Mechanical Engineering

Fall 2020-21

Senior Design Project Report

Design and Manufacturing of Prosthetic Hand

In partial fulfillment of the requirements for the

Degree of Bachelor of Science in Mechanical Engineering

Team Members

	Student Name	Student ID
1	Faisal AlAnazi	201302718
2	Moath Alahmadi	201500426
3	Saad Aldoulab	201100671
4	Mohanned Algoseyer	201502646
5	Abdullah Alshehab	201401877

Project Advisor: Mohamed Elmahdi Saleh

Abstract

Human hand is an important organ at the end of upper limb used for communication, sensation and function of prehension. A lot of work has been done in this area but most of the methods used are conventional and do not have much mechanical functionality. This paper focuses at the designing and manufacturing of a prosthetic hand with multiple fingers. Conventional prosthetic hands currently in the market have less degree of freedom and limited mechanical functionality. Although in most of the cases, this performance is enough for the amputees as it serves their purpose but there is a lot of area for improvement in the design of prosthetic hand. The main aim of this paper is to design the prosthetic hand which can grasp and confirm the shape of the object. Also, the paper describes the design phase of the prosthetic hand and preliminary analysis of the protype.

List of figures

Figure 1 TBM hand, dorsal view 7
Figure 2 Full hand view 9
Figure 3 Forearm Design 10
Figure 4 Wrist Design 10
Figure 5 Fist Design 11
Figure 6 Links of fingers 11
Figure 7 Prosthetic Hand Assembly 12

Table of Contents

Abstract 2

List of figures 3

Chapter 1: Introduction 6

1.1 Project definition 6

1.2 Project Objectives 6

1.3 Project specifications 6

1.4 Applications 6

Chapter 2: Literature Review 7

2.1 Project background 7

2.2 Previous work 7

2.3 Comparative study 8

Chapter 3: System Design 8

3.1 Design Constraints 8

3.2 Design Methodology 9

3.3 Product Components 9

3.3.1 Forearm 9

3.3.2 Wrist 10

3.3.3 Fist 10

3.3.4 Finger links 11

3.4 Implementation 12

Chapter 4: System Testing and Analysis 12

3.1 System testing and Results 12

4.1.1 Adaptive Grasp Mechanism Design 12

4.2 Analysis and Discussion 13

Chapter 5: Project Management 13
5.1 Project Plan 13
5.2 Contribution of team members 13
5.3 Project Execution Monitoring 14
5.4 Challenges and Decision Making 14
5.5 Project Bill of Materials and Budget 14
Chapter 6: Project Analysis 14
6.1 Life-long Learning 14
6.2 Impact of Engineering Solutions 15
6.3 Contemporary Issues Addressed 15
Chapter 7: Conclusions and Recommendations 15
7.1 Conclusions 15
7.2 Future Recommendations 15
References ..... **Error! Bookmark not defined.**

Chapter 1: Introduction

1.1 Project definition

The project aims at designing and manufacturing of a prosthetic hand that can grasp and sense the shape of the object with multiple degrees of freedom and additional mechanical functionality. The project is useful in the industry and also targets the amputees who are searching for the prosthetic hand with high degrees of freedom. The prosthetic hand will be designed and will be passed through the preliminary analysis. The project can also be utilized in the automation industry where the robotic hands are being used to perform different tasks like grabbing the changing positions of the objects.

1.2 Project Objectives

The main objectives of this project are given below.

- Analyzing the previous research done on the passive prosthetic hand.
- Designing a prosthetic hand with multiple degrees of freedom.
- Manufacturing the prosthetic hand with additional mechanical functionality.
- Initial analysis of the prototype of prosthetic hand.

1.3 Project specifications

The specifications of the project include its design, measurements and the targeted market etc. The Prosthetic hand consists of 4 fingers and 1 thumb. The size of the prosthetic hand is more or less same as that of human hand. The project is much economical and energy efficient. The prosthetic hand is also light weight and portable. Project targets the industrial market as well as common amputees who need a prosthetic hand.

1.4 Applications

The applications of the project are given below.

- Prosthetic hand can be used to grasp and confirm the shape of the objects.
- The project finds wide range of applications in the automation industry.
- High degrees of freedom make it very demanding in the market for amputees.
- The design of the prosthetic hand replicates the natural human hand.

Chapter 2: Literature Review

2.1 Project background

A lot of research has been done in the area of prosthetic hand but most of them have limited functions. Also, the main problem is the degree of freedom. In most of the cases, the amputees are compatible with the functionality of the prosthetic hand because it serves their purpose. Increasing degrees of freedom also increases the cost and the research required. The project design gets more complex. This project aims at the design of the prosthetic hand with increased degrees of freedom and mechanical compatibility.

Many challenges come in the design phase of the project like mobility and angle of deflection, load bearing limit etc. Sensors were used to sense the shape of the object. The project also passes through the preliminary analysis of the protype where the hand is tested for its different constraints.

2.2 Previous work

A research [1] had been carried out for the experimental prosthetic hand being designed for the seven to eleven years age group. The prosthetic hand was used to grasp the object between fingers thus confirming its shape so the hand was able to perform Passive adaptive grasp. The design did not require any sensors and no actual electronic processing was done. The dorsal view of the prosthetic hand is given below

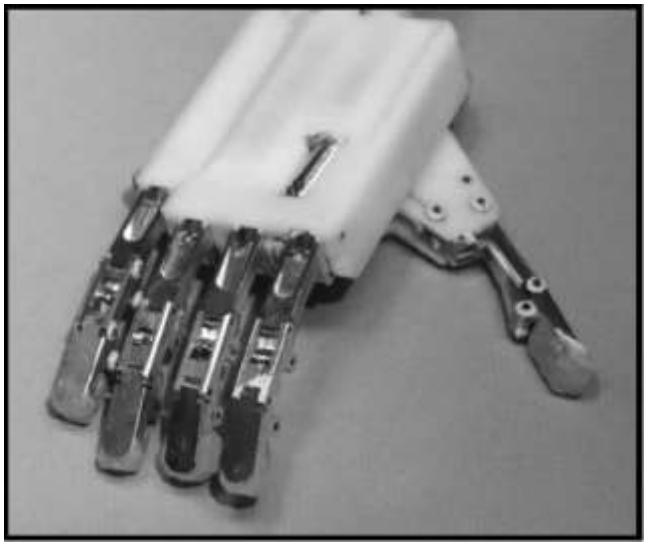

Figure 1 TBM hand, dorsal view

Conclusions showed that the opening and closing of the hand was too slow and the hand pinch force was low. The TBM hand had increased mechanical functionality.

2.3 Comparative study

Another paper [2] gave more insight in the realization of cybernetic hand. In this research, a three-hand prototype was designed and manufactured. The first one uses micro actuators which were entrenched in the structure of fingers. Second and third prototypes exploit the micro actuation which in turn increases the handiness of the hand. The results were quite interesting. The created models were compared with the natural human hand and some important design goals were stated in the paper.

A research [3]on the prosthetic hand based on the underactuated mechanisms was carried out. It is important to note that the prosthetic hands are mainly designed to grasp things and very much complex tasks can not be done using prosthetic hands. Conventional hand prostheses have one or two degrees of freedom which are often acceptable by the amputees because it serves their purpose. The paper showed that the current prosthetic hands had low cosmetic, low functionality and low controllability. The degrees of freedom result in the low grasping ability of the hand. The paper focused on an innovative approach which were based on the underactuated mechanisms which were used to solve the above problems of low controllability and low functionality etc.

Chapter 3: System Design

The main objective was to design a prosthetic hand that replicas the natural human hand with enhanced functionality. Some of the particulars of the system design are given below.

3.1 Design Constraints

There are different types of constraints that include economic constraints, sustainability constraints, safety and manufacturability constraints. One of the major constraints is the accuracy of the prosthetic hand. More accuracy and finishing bring more finances and the manufacturing of the prosthetic hand becomes more costly.

3.2 Design Methodology

The design of the prosthetic hand included different parts such as forearm, wrist, palm thumb and fingers. Two links were used for the fingers and thumb taking in account of the degrees of freedom of both. The Design of the prosthetic hand is shown in the figure below. [4]

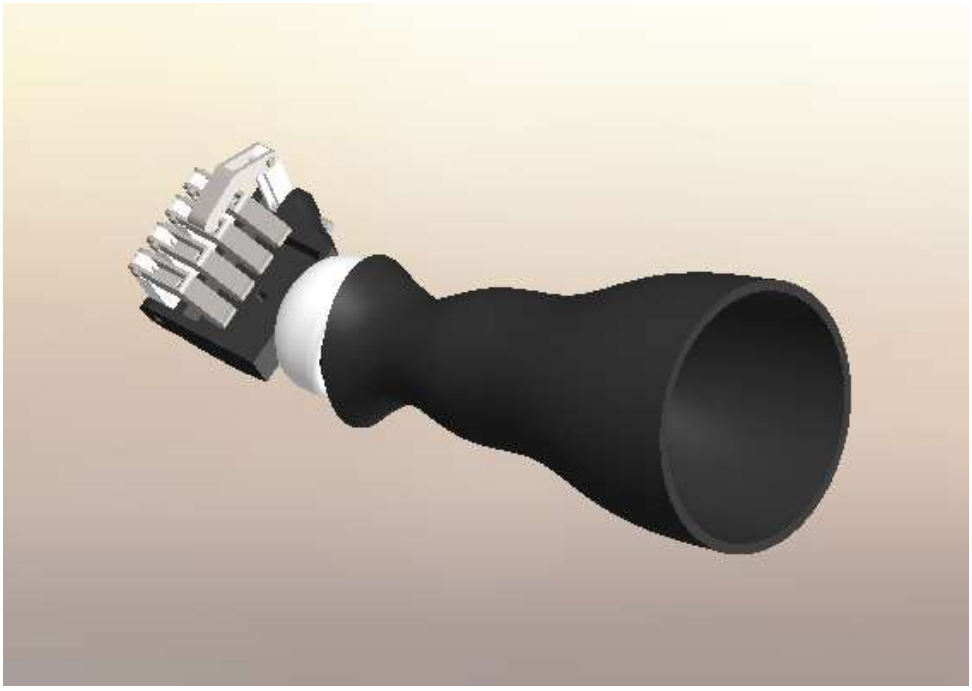

Figure 2 Full hand view

3.3 Product Components

Different components of the prosthetic hand are given below.

3.3.1 Forearm

The forearm is made with the cavity inside for fixing purposes. The design of the forearm is simple and is shown in the figure below.

Figure 3 Forearm Design

3.3.2 Wrist

The design of the wrist is rather simple and the wrist is attached with the forearm using **Ball joint**. The wrist design is shown in the following figure.

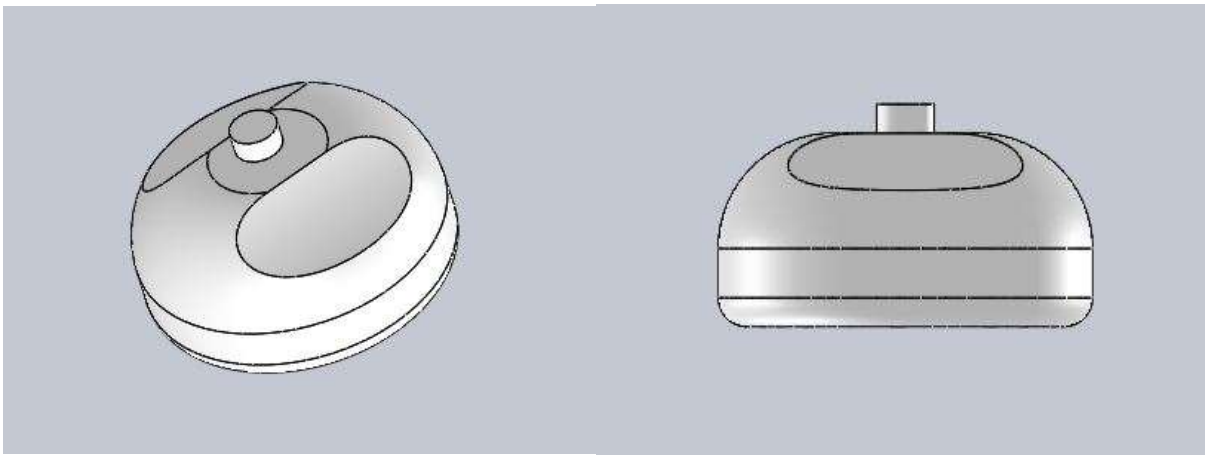

Figure 4 Wrist Design

3.3.3 Fist

The design of the fist is given below.

Figure 5 Fist Design

3.3.4 Finger links

Fingers and thumb consist of two links used to replicate the natural human fingers. The design of the all the fingers is same irrespective of the fact that there is a size difference in the human fingers. It is to make calculations easy. The design of those links is shown in the figure below.

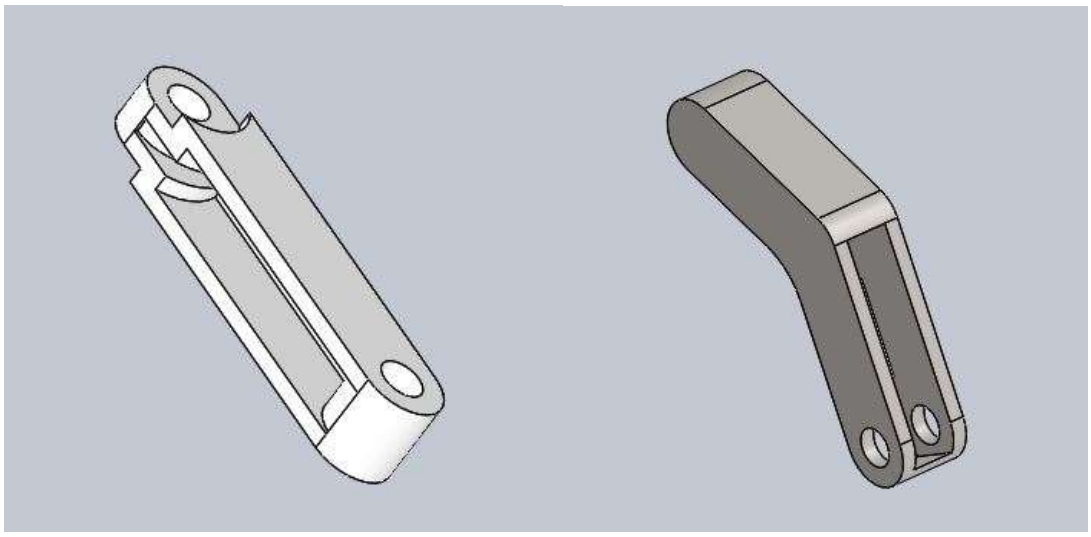

Figure 6 Links of fingers

These were some components of the prosthetic hand. Links of fingers and thumb are pin connected to the fist with constrained rotation (movement).

3.4 Implementation

All the components are connected using joints. Pin joint and ball joints are used. Thumb and finger links are directly pin connected to the palm and the rotation of the pin is also constrained according to the natural movement of the fingers and thumb. Fist is connected to the wrist which is fixed to the forearm. Total assembly of the fixed components is shown below.

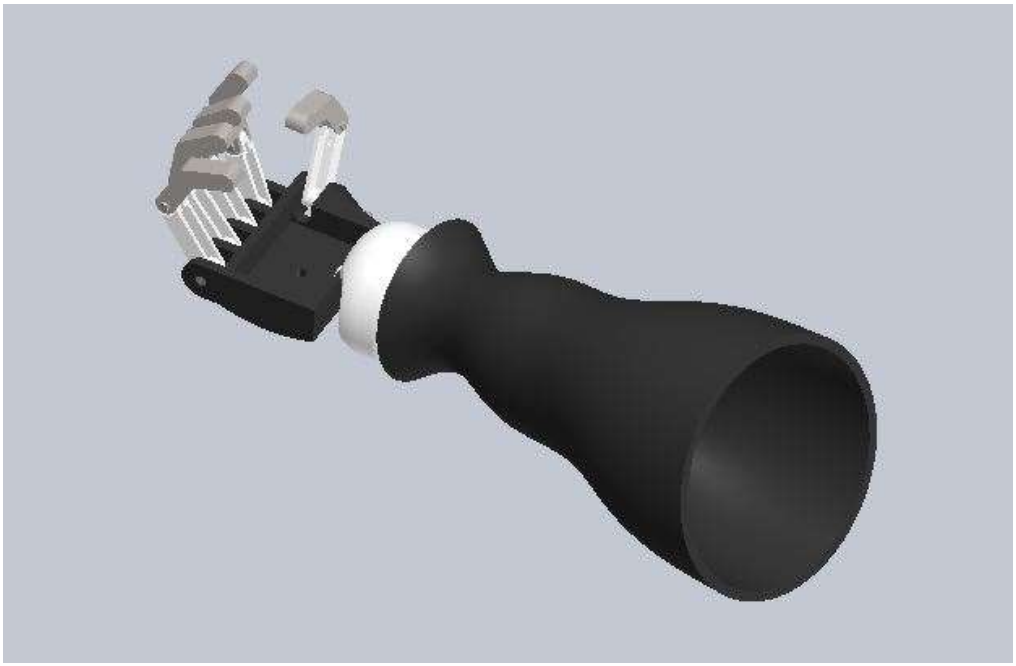

Figure 7 Prosthetic Hand Assembly

Chapter 4: System Testing and Analysis

4.1 System testing and Results

In general, for the grasping behavior of the prosthetic hand, fingers are designed for the natural wrapping of the finger movement. The design of all the fingers is same irrespective of the difference is size of human fingers.

4.1.1 Adaptive Grasp Mechanism Design

Between the fingers, adaptive grasp mechanism is introduced. Normally the index finger and the middle finger do not come in contact with the object at the same time in the normal prosthesis. When one finger touches the object, other fingers can no longer add into the grasping of the object but by the adaptive grasp mechanism, the compression of relative spring causes the slider to continue its motion and the rest of the fingers can now grasp the object.

4.2 Analysis and Discussion

Designed prosthetic hand is passed through preliminary testing phase and it was able to grasp objects. Although there are some improvements required in it but from the economic point of view, it serves the purpose as many amputees do not need much of the mechanical functionality. Also, the kinematic analysis is done on the prosthetic hand. The required grasping force needed to hold the object varies from object to object. The hand is designed in such a way that it changes the grasping force according to the need.

Chapter 5: Project Management

5.1 Project Plan

The Project plan was created and analyzed before starting the project. All the objectives of the project were set and all the potential problems were catered in the project plan. In the project plan, the scope of the project was defined and sub portfolios were created. **Project Libre** software was used to manage the ongoing flow of the project work. The project is free and has many advantages. The starting and ending time of the project was set and there was no such delay in the project. Different risks appeared but they were solved in time. The main points of the project plan are given below.

- Initial brainstorming
- Designing the prosthetic hand
- Material selection
- Budget analysis
- CAD model
- Purchasing of parts
- Fabrication process
- Assembling the parts
- Testing phase
- Technical project report etc.

5.2 Contribution of team members

The project was divided into smaller parts and the tasks were assigned to the team members. CAD modeling was done by one member while buying the material and fabrication was done mutually.

Different design ideas were put forward and they were checked against their pros and cons. The wiring was done by another team member. All the team members performed their tasks. In the end, the project report was created and the lessons learned were documented.

5.3 Project Execution Monitoring

The progress of the project was monitored on the Project Libre. The team leader made sure that all the group members are doing their tasks so that the project do not get delayed. Some potential risks arouse during the project and suitable monitoring was done unto them. Project integration was made strong so that all the team members communicate efficiently. Different meetings were arranged to discuss the progress of the project and to share new ideas.

5.4 Challenges and Decision Making

During the project, different potential challenges arouse like, the grasping force calculations needed to be redone because of the fact that there is a lot of difference between calculation on ideal system and actual design of the prosthetic hand. The movement of the fingers was not as smooth as expected and the joint needed to be replaced.

The wrist design was not suitable and the whole design was remade. It caused extra finances and time but these challenges were anticipated during the project plan that is why it did not cause much problem.

5.5 Project Bill of Materials and Budget

The Budget allocated for the project was 1,500 SAR. The bill of project is given below.

No.	Expenses	Cost (SAR)
1	3D printing	1500
	Total	1500

Chapter 6: Project Analysis

6.1 Life-long Learning

Overall project was a success and we learned a lot of technical skills and soft skills as well. We acquired the selection criteria of the material for the device/machine/prototype we are making. Also, while manufacturing the parts, we learned of many technicalities that may come because the real-life mechanisms are different than the ideal calculations.

The project strengthened our management skills as there were a lot of challenges that we faced and managed accordingly. Time was also a constraint that was taken care of in this project and it helped us improving our time management skill. There are different ways to perform a

task, achieve a goal and we learned how to choose the best option. Some options were economical but other options were favorable in terms of quality of the product and we had to chose best option possible.

6.2 Impact of Engineering Solutions

This prosthetic hand is useful for the people who has fully or partially disabled hand and are struggling through their lives. The prosthetic hand is more functional as compared to the conventional prosthetic hand. The cost of the product is reasonable and it is imparting a huge effect on the society. Engineering solutions have always brought ease to the society and prosthetic hand is one of them. Also, the prosthetic hand can be automated and in turn, used in the industry as well.

6.3 Contemporary Issues Addressed

The country is lacking in the prosthesis field and this project opens up a new field of interest in Saudi Arabia. The project has not been carried out on a very high level but it is addressing small issues of the people and providing them with an alternate method to keep on living their lives effectively and efficiently.

Chapter 7: Conclusions and Recommendations

7.1 Conclusions

Prosthetic hand with multiple fingers and enhanced mechanical functionality was designed and manufactured. Different designs of the hand were chosen and the best design was implemented. Two links are used for finger and thumb design connected with the fist. The movement of the fingers is constrained. Fist is connected to wrist which in turn is ball jointed with the forearm. The performance of the prosthetic hand was tested in the preliminary analysis. The hand was able to grasp different objects. Conventional hands in the market have less DOF while this prosthetic hand carries high DOF. Challenges occurred during the implementation phase but they were catered and solved.

7.2 Future Recommendations

The design of the fingers can be improved and the link lengths can be changed according to the human natural fingers. It will help grasping the objects more effectively. For the smooth

movement of the fingers and fist, more sensors can be used in the future projects. The joint of the wrist is not very strong and some other type of joint can be used to strengthen the connection between the fist and wrist.

References

- W. C. S. N. N. Dechev, "Multiple finger, passive adaptive grasp prosthetic hand," 2001.
- M. Zecca, "On the development of a Cybernetic Prosthetic Hand," 2003.
- S. R. M. C. P. D. B. Massa, "Design and development of an Underactuated Prosthetic Hand," 2002.
- F. Tasnim, "GrabCAD," 27 09 2020. [Online]. Available: https://grabcad.com/library/lower-arm-prosthesis-trial-1-1.
- Authors, A., & Kate, J. (2016). 3D-printed upper limb prostheses: A review. Retrieved October 25, 2020, from
- Joseph T. Belter, M. (n.d.). Journal of Rehabilitation Research & Development (JRRD). Retrieved October 25, 2020, from
- X. Wang, Yi. Liu, L. Jiang, D. Yang, N. Li, H. Liu, H. Huang, "Design and control of a coupling mechanism-based prosthetic hand, " Journal of Shanghai Jiaotong University, 2010
- M. Bahari, A. Jaffar, C. Low, R. Jaafar, K. Roese, H. Yussof, "Design and development of a multifingered prosthetic hand" International Journal of Social Robotics 4 , 2012
- N. Dechev, WL. Cleghorn, S. Naumann, "Thumb design of an experimental prosthetic hand," Proceedings of the International Symposium on Robotics and Automation, 2000