جامعة الأمير محمد بن فهد
PRINCE MOHAMMAD BIN FAHD UNIVERSITY

College of Engineering

Department of Mechanical Engineering

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Senior Design Project Report

Project Title

Design and manufacturing of a lower limb prosthetic

In partial fulfillment of the requirements for the Degree of Bachelor of Science in Mechanical Engineering

Team 17
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Project Advisors:

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Abstract:

The hydraulic technology of the ankle was unknown in the past because people were not interested or thought that anything could replace the original limbs. However, with the advancement of technology, scientists can improve the function of the original leg replacement surgery lost in the accident, and the number of people who need replacement for many years, especially those who have not had leg disease for many years, is increasing. The idea started with a simple design that tried to make prosthetic legs out of parts to make them more durable and significantly reduce costs. In the future, this technology will help many people, including those born without limbs. In this project, the goal is to develop a simple hydraulic steering knuckle. In TFA, a hydraulic ankle joint is required to support the optimization of prosthesis design and the selection of prosthetic components. Using statistical models, the current ankle prosthesis model is related to the walking of the amputee. This leads to a better balance, which is reflected in an average 25% reduction in the center of pressure, a lower risk of failure and an 18% increase in overall pressure. Hydraulic ankle, fixed foot.

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Acknowledgments:

First of all, we would like to thank our advisor Dr. Megdi Eltayeb for his continuing support and encouragement. Also, we would like to thank Dr. Mohammed Saleh for answering to our problems and fixing them. Finally, I would like every member our team for working so hard till this moment.

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Chapter 1: Introduction

1.1 Project Definition:

This project is about Creating and manufacturing Hydraulic Ankles that will help people that lost their legs and work as a perfect replacement for them. As it will be able to provide assistance to the patient while walking on slopes by adapting to it and decrease the chances of pressuring the healthy limb as the load will be distributed equally. The goal of the Hydraulic Ankle is to provide the assistance that the original limb provided using the latest technology of bringing carbon fiber elements as it was lighter and stiffer than most materials which will be able to absorb shocks just like the original ankle muscles.

1.2 Project Objectives:

Our goal is to provide prostheses for patients with lower limb amputations so that users can restore (or even overcome) mobility before the amputation. In terms of appearance, lower limb prostheses are difficult to design and deliver. Mobile phones, cars and children's toys are expected to revolutionize prosthetics, but they are rare in the industry. After the introduction of this technology, it is unreasonable to increase the cost by 10 to 100 times compared with traditional solutions, so its popularity is limited. We believe this technology can provide advantages at a reasonable cost, but new design and synthesis technologies are new technologies. In this article, new methods will be shown to solve these problems. These methods should help speed up the rotation of the robot and enable people with disabilities to work in a shorter area. Liquidity level. Show how the prosthesis can be designed to stimulate the gait of patients with unilateral amputations. A new experimental method was developed to solve the problem of foot prosthesis in treadmill gait experiments with lightweight and powerful robots-powered external prostheses and steerable prostheses. Device behavior and interesting results.

1.3 Project Specifications:

The Hydraulic Ankles is a lightweight part that will be provided to those who need it and in table 1.1 will be the specification of it such as weight and max user's weight and the size range and height.

Table 1.1 Product measurements

Max users' weight	Size range	Component weight	Waterproof	Heel height	Build height
125 kg	22cm-30cm	688g	yes	10mm	Sizes 22-24 -115mm Sizes 25-26 - 120mm Sizes 27-30 - 125mm

1.4 Applications:

The purpose of this product is to do what the original limb did, and it is targeted towards people who have lost their foot up to their knees whether it was during accidents or deformation since birth, so essentially it will be used in hospitals to hopefully help those who need it.

Chapter 2: Literature Review:

The ankle anatomy of a healthy individual is an indispensable part of the complex network of joints, muscles and limbs, which can function effectively at the same time while walking. People stand and walk. The calf joint can be rotated in three stages, so it can provide a variety of mid-stride options, including amazing delay, foot support space and the convenience of foot movement in mid-stride. Swing and encourage the body to move forward. People whose lower limbs have been removed usually have far fewer prosthetic feet installed than anatomically, which is likely to make slower walking easier. It is composed of 26 bones to ensure homeostasis. More than one hundred bones, ligaments and muscles. Provides balance to the body on various surfaces. Today, the feet have been replaced by prostheses to support the body with simpler designs. Energy absorption and recovery are achieved through carbon spring elements on the feet. In any case, in such a plan, the lower part of the leg is usually seated. Ensure vigorous communication. It shows that they trust in the ability of these arise components to accommodate to different whether. Past thinkers figured out that the need for adjustment is a disadvantage of traditional prosthetics, so most prosthetic wearers will encounter some problems. Walking on uneven ground. In previous developments, it was found that walking was problematic due to uneven energy transfer when going up and down the mountain. Analyzing the uphill and downhill walking of unilateral amputees, it was found that the flexion of the hip and knee was improved during the first contact, and the prosthetic leg improved the flexion of the hip. Posture and swing when descending. When amputees walk uphill and downhill, they cannot improve the curvature of the knee prosthesis. Compared with this ingenious design, the hydraulic steering knuckle provides a variety of options, making the model more bionic. This design integrates the heel and toe springs, but does not have a hinged calf, but a hinge. Human muscles. Tasheka Kobayashi and others. The effect of orientation change on the nested reaction moment is studied.

Changes in the coronary arteries and sagittal position show the orderly consequences of the cup reaction time. When the slope changes, the reaction force changes. This effect is reduced in the hydraulic ankle joint. They are designed to push forward, increase hip joint movement and cause increased hip joint wear. In a hydraulic ankle joint, it will stick to the surface and flatten, thereby reducing the force acting on the hip joint. The ankle consumes very little energy, which has been identified by G Askew et al. The metabolic exercise cost of the hydraulic ankle joint is reduced by 20%, which greatly improves the efficiency of the locomotive. Mobility in terms of pace and gait speed increased by 8%, and progress was the most stable during the gait cycle. Through the natural selection of amputees, better energy management can be achieved. Putting it in healthy shoots also has multiple advantages. The most famous reason to cancel the lower process It is vascular diseases such as diabetes. Investigations show that in the United States, these conditions can lead to up to 82% of extremity cases. The value of prostheses and compliance rates-how each shopper perceives prostheses or the idea of their movement-has expanded significantly, in particular when Avalon customers announced a 42% increase. Because users don't have to worry about ankle arise, accelerating downhill with the prosthetic saves power and fewer laborious. By analyzing the oxygen and carbon dioxide in the lower respiratory tract, how much energy does an amputee consume when going downhill? Eleven patients were told to go downhill along various ramps and firmly fix the ESR foot and 17% of the Blatchford Echelon foot to improve the load symmetry between the limbs. For the biological ankle joint, Tendons use parallel and irregular contractions to regulate the speed that the body makes when walking, avoid impact and control the speed of movement of the legs and other parts of the body. Reverse elastic behavior "Thanks to the valve adjustment, it can adjust the rotation of the ankle and the power saved by the springs of the Talus and toes. The research also showed the amount of power the disabled will consume when wearing the same two shoes. The prosthetic feet are level. Walk at different speeds on the ground. On the hydraulic ankle joint, they consume a median of 12% fewer power at diverse hiking velocities, which means that subjects can walk up with the same energy on the hydraulic ankle joint Mm. When walking, choose your own pace, increase the speed to 8-14, and the gait cycle will proceed more smoothly; The edge of the hydraulic ankle indicates that the prosthesis has better force management. Walking briskly will naturally increase your body's strength, but if you take into account this increased walking speed, has shown that due to calculation errors, hydraulic ankles can significantly reduce the workload of healthy limbs on average. Diabetes and other diseases and studies have shown that these diseases account for over 80%of the surgical removal of legs in the United States. They are usually caused by pressure ulcers under the feet, which have not been noticed or treated. For patients with tartar problems who have undergone amputation, one in ten must have their contralateral limb amputated within 12 months. Compared with rigid or elastic prostheses, the maximum pressure when wearing a hydraulic ankle joint is reduced by an average of 24%, which significantly improves the health of the contralateral limb. People with insufficient amputations also have limbs at risk. Under these conditions, soft tissues are more prone to injury and they heal less than healthy tissues. And can be overwhelmed by incidental neuritis, muscle destruction. The person that has diabetes can develop soreness which could result in the removal of the leg. First, for prosthetic wearers, pressure sores in the residual limb represent a major problem. If the patient suffers from vascular disease at the same time, it must be operated again or higher within one year after the first operation, with 24% tibial amputation and 14% femoral amputation18. Therefore, stump protection is very important. During the movement with prosthetic feet and ankles, the pressure on the edge of the stump was checked. Control is needed in the rotation point; the result is to secure the foot nicely to not pinch the toes. For the amputee, falling is a serious problem, which is resulted by equal sacrifice of equilibrium and stumbling. The lack of tendon action of bottom limbs and proprioception means that the toe gap (the gap starting from the toes to the ground in the rotation point) will be destroyed post removal, which increases possibility of the toes being stuck by the toes and causes the user to stumble. The stance phase ends and remains unchanged throughout the swing. As a result, the minimum toe space of a hydraulic ankle increased by an average of 18% compared to a fixed foot.

Chapter 3: System Design

3.1 Design constraints and design methodology:

- **Weight Constraints:** When we started design and plan for our project, the one of challenge is to minimize the weight of our product.

- **Sustainability:** The hydraulic design of the ankle includes toe springs, but instead of rigid ankles, it uses hinges and hydraulic damping to affect the movement of the joints.

- **Energy Expenditure:** A normal foot will consume more energy, and when running on a slope, the energy consumption of the hydraulic ankle will be reduced by 20%.

- **Safety of lower flexibility artificial leg users:** over 70% of those who have lower leg removals are almost 70 years old, which may further restrict mobility.

- **Manufacturability:** one of the problems that occurred in manufacturing the parts was how to make a mold to cast aluminum and how to clean test of ammonium to make it match or component and finally how to tap iron to receive screw Bolt.

3.2 Engineering design standards:

Biognosis of the talus: Biognosis is the capability of a device to imitate the original actions of the limb that it will replace. Current ESR prosthetic feet (power saved and given back) are based on heel deflection and carbon fiber springs in the toes to create a locking mechanism for the foot while walking.

Self-alignment: When installing the flange, the ankle joint must also be adjusted to the ground. The repairer can install the prosthesis on the level floor to reduce the force acting on the joints of the lower limbs. The weight vector can be applied to the front of the ankle, the front of the knee, the upper or the back of the thigh. For the ESR foot, the ankle cannot be adjusted, so it is often necessary to compensate for movement when standing on a slope.

Hiking on ramps: It doesn't occur only when standing that foot becoming used to it is helpful. When jogging at the bottom of the hill, it is preferable to have the foot stuck on the floor quickly, in the right moment, to have a secure ground of backup. In a classic prosthetic foot, the talus is configured such that it pushes the user upfront, that causes the calf to shift forward fast as the talus pulls the user toward the toes.

Energy Expenditure: Since the user does not have to work hard for the foot arise, speeding downhill wearing a prosthetic ankle saves power and fewer laborious. patients were required to speed up on various hills of ramps with strongly connected prosthetic leg. With prosthetic ankles, a median of 20% fewer power was used around the various ramps.

Better mobility: The fact that amputees can instinctively choose higher walking speeds through the use of hydraulic ankles indicates better control over the performance of the prosthesis. On average, the load on the healthy limbs is reduced through a median of 17%, thereby improving the load proportion between them. By decreasing the pressure on healthy limbs when walking, the risk of osteoarthritis (a common disease in amputees) can be minimized.

Reducing Fall Risk: Charging and energy management are very important in the style design process. During the slap point, the objective is to place your base properly minus pinching your toes. Tumbling is a big problem due to lack of balance and tripping in similar quantities. Lack of tendon control and sense of location in the bottom extremities means that the separation of the toes (the distance between the toes and the ground during the slap point) is destroyed after amputation, which increases the risk of toe entanglement and movement of the user.

Principal Parts:

Frame: Aluminum Alloy, Brass, Stainless Steel, Steel. Carbon steel c45

Knee head: Aluminum Alloy, Stainless Steel.

Knee control: Various materials principally Aluminum Alloy, Stainless Steel, Poly Urethane Copper.

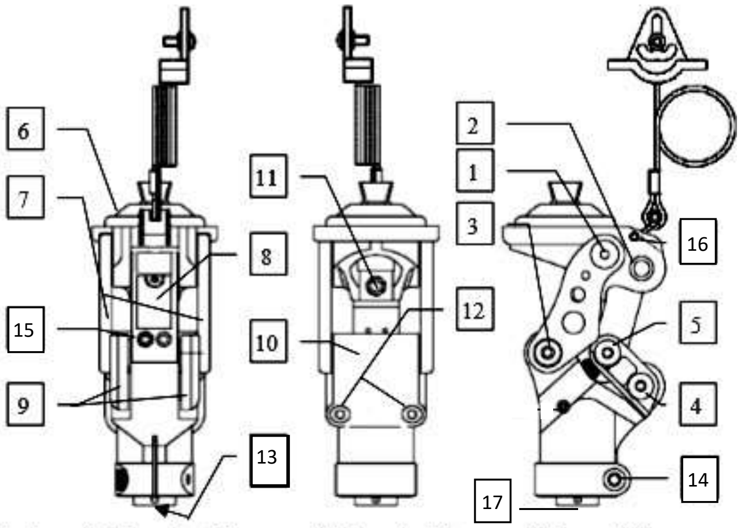


Fig. 1 (a) Posterior View (b) Anterior View (c) Lateral View

1- The Primary Axis 2- The Second Axis 3- The Third Axis 4- The Fifth Axi 5- The Fourth Axis 6- Knee Head 7- Side Bars 8- Back Linkage 9- Fifth Axial Bars 10-Knee Body 11-Knee Head Level Adjusting Screw 12- Flexion Control Adjusting Screw 13- Extension Assist Adjusting Screw 14- Tube Clamp Screw

15-Friction Swing Resistance Adjustment Screw 16- Manual Lock Disable Screw. 17- Lock Screw for Extension Assist Adjusting Screw.

3.3 Theory and Theoretical Calculations:

On a flat ground, you can walk smoothly and overcome obstacles. Since no other nodes are connected to the force plate, the Z GRF coordinate is always 0. When walking on a flat surface under normal conditions, the physical method of Tx or Ty.Tx = Ty = 0 is not used. Calculate CS coordinates

:

$$x' = \frac{-M_y + F_x \times Z_0}{F_Z}$$

$$y' = \frac{M_x + F_y \times Z_0}{F_Z}$$

$$z' = Z_0$$

And the free moment of Z axis is:

$$T_z = M_z + F_x \times y' - F_y \times x'$$

Since the top of the ladder is horizontal and there is no physical method using Tx or Ty, climbing a ladder is the same as walking on a flat surface. The z coordinate of GRF is a constant distance H, that is, the height of the stair section in the negative direction of the Z axis. Therefore, the formula used to calculate the COP coordinates should be:

$$x' = \frac{-M_y + F_x \times (Z_0 - H)}{F_Z}$$

$$y' = \frac{M_x + F_y \times (Z_0 - H)}{F_Z}$$

$$z' = Z_0 - H$$

The calculation of the free moment is the same as the plane state. In the state of walking along the inclined slope, the inclination direction of the slope is parallel to the walking direction of the subject. Curved walking motion in this analysis, the positive Y direction of the LCS force plate corresponds to the positive direction of motion.

$$\frac{T_y}{T_z} = \tan\theta = \frac{H_{high} - H_{low}}{L}$$

$$z = -\left[\frac{y + 0.5L}{L} \times (H_{high} - H_{low}) + H_{low}\right]$$

$$y' = \frac{F_y \times [(H_{high} - H_{low}) \times (Y_0 - 0.5L) - L \times (H_{low} - Z_0)] + M_x \times L}{F_z \times L + F_y \times (H_{high} - H_{low})}$$

$$z' = -\left[\frac{y' - Y_0 + 0.5L}{L} \times (H_{high} - H_{low}) + H_{low}\right] + Z_0$$

$$x' = \frac{-M_y + F_x \times z'}{F_z}$$

The calculation for the camber ramp is similar.

$$z = -\left[\frac{x + 0.5W}{W} \times (H_{high} - H_{low}) + H_{low}\right]$$

$$x' = \frac{F_x \times [(H_{high} - H_{low}) \times (X_0 - 0.5W) - W \times (H_{low} - Z_0)] - M_y \times W}{F_z \times W + F_x \times (H_{high} - H_{low})}$$

$$z' = -\left[\frac{x' - X_0 + 0.5W}{W} \times (H_{high} - H_{low}) + H_{low}\right] + Z_0$$

$$y' = \frac{M_x + F_y \times Z'}{F_z}$$

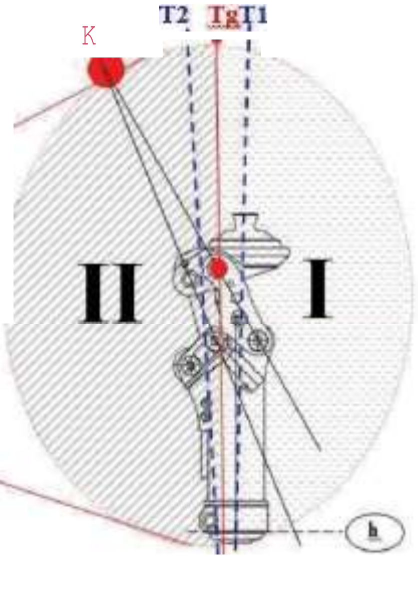
The free moment T_z can be solved using the same equation as the level ground condition after obtaining the coordinates of the COP'.

3.4 Product Subsystems and selection of Components

L1324 Knee:

1. Health KNEES HAVE A NEW Quality.
2. This isn't your grandfather's friction-braking knee. This system's geometric alignment ensures that it is still stable.

Fig. 2



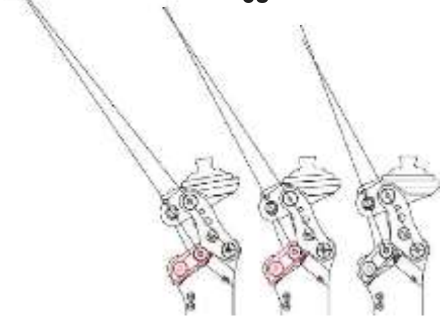
Gravitational Line

Fig. 3

Fig. 4

Stance Flexion Control (SFC)

SFC applies to L1324, 1324 & es



P/N	L1324AP Pyramid Adapter	L1324AL Lotus Adapter
Weight Limit	125kg / 275lbs	125kg / 275lbs
Build Height	112mm	118.3mm
Knee Center to Mid Dome	23.5mm	29.8mm
Knee Flexion	135 Degrees	135 Degrees
Product Weight	848g	861g
Material	Aluminum	Aluminum
Warranty	2 years	2 years

Table 3.4 Project specification

L1324 is a multi-center resting and flexing knee with a manually operated handle. When the patient opens the toes to release the knee while swinging, the posture flexion mechanism pushes the geometry to a very stable position. The knees can be bent while maintaining a stable posture. ...Elegant and simple tailoring ensures stability. The knee is still in a comfortable and well-aligned position to give the patient confidence.

3.5 Manufacturing and assembly (Implementation):

- Adjustable stance flexion varies from intense stability with up to 12 degrees of stance flexion to a very fast response with low stance flexion.
- Swing phase resistance can be adjusted with constant friction.
- Swing step extension assistance that can be modified.
- Pulling at the lanyard related to the knee lock mechanism manually unlocks the lock.

- - The lock mechanism may be disabled at any time, allowing the knee for use as a loose swing knee.
- - It may be used for disarticulation above the knee or beneath the knee.
- - Best applicable to be used with K2.
- - The 5-bar linkage is product of plane alloy, and the body is product of superlight aluminum alloy.
- A-P slide and Rotation adjustment is to be had at the proximal attachments

3.6 Economic evaluation:

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Capital Costs											
Equiprment	4200 SAR	2000 SAR	2000 SAR	2000 SAR	2000 SAR	4200 SAR	2000 SAR	2000SAR	2000 SAR	2000 SAR	4200 SAR
Construction	1000 SAR	500 SAR	500 SAR	500 SAR	500 SAR	1000 SAR	1000 SAR	1000 SAR	1000 SAR	1000 SAR	1000 SAR
Total	5200 SAR	2500 SAR	2500 SAR	2500 SAR	2500 SAR	5200 SAR	2500SAR	2500SAR	2500SAR	2500SAR	5200 SAR
Operating Cost											
Energy	0.5 kWh	0.6 kWh	0.8 kWh	0.8 kWh	0.8 kWh	1 kWh	1 kWh	1.1 kWh	1.1 kWh	1.2 kWh	1.5 kWh
Electrcitiy	400 SAR/M	500 SAR/M	700 SAR/M	750 SAR/M	750 SAR/M	900 SAR/M	900 SAR/M	1000 SAR/M	1000 SAR/M	1100 SAR/M	1500 SAR/M
Labour	600 SAR/M	800 SAR/M	1200 SAR/M	1200 SAR/M	1200 SAR/M	1500 SAR/M	1500 SAR/M	1700SAR/M	1750SAR/M	1900 SAR/M	2300 SAR/M
Insurance	500 SAR	500 SAR	500SAR	500SAR	500 SAR	800SAR	800SAR	850SAR	900SAR	1050SAR	1300SAR
Taxes	300 SAR	300 SAR	400SAR	400SAR	400SAR	600SAR	600SAR	500SAR	550SAR	700SAR	900 SAR
Total	12800 SAR	16400 SAR	23700 SAR	25500	25500	29800 SAR	29800	33750	34500	37750	47800
Revenues											
Product 1	9000 SAR	11000 SAR	15000 SAR	17000 SAR	185000 SAR	27000 SAR	27000 SAR	29000 SAR	31000SAR	36000 SAR	42000 SAR
Product 2	8500 SAR	9000 SAR	13000 SAR	15000 SAR	16000 SAR	24000 SAR	24000 SAR	28000 SAR	30000 SAR	33000 SAR	39000 SAR
Product 3	7500 SAR	8500 SAR	12000 SAR	13500 SAR	15000 SAR	23000 SAR	23000 SAR	26000 SAR	28500 SAR	34000 SAR	41000 SAR
Total	25000 SAR	28500 SAR	40000 SAR	45500 SAR	49500 SAR	74000SAR	74000SAR	83000 SAR	88500 SAR	103000 SAR	122000 SAR
Profits	7000 SAR	9600 SAR	13800 SAR	17500 SAR	21500 SAR	38600 SAR	41300 SAR	46750 SAR	51550 SAR	62750 SAR	69000 SAR

System Testing and Analysis (Chapter 4)

4.1 Sensors and data acquisition system: the experimental setup pictures showing sensor setup and location

List the sensor's specifications and justify why you choose it.
List the research criteria and describe the strategy in detail.

We used two separate experimental setups in this section. The first was for calculating the angular velocity of the shaft connecting to the alternator pulley, and the second was for calculating the angular velocity of the shaft connecting to the alternator pulley.
Calculating the voltage and current values. We used a pick-up car for the first setup.
and there were three of us at the freight, two of us carrying the machine and one calculating angles
utilizing a tachometer, the tachometer has a leaser that was guided to the pulley, and we placed the sticker on the pulley so that the tachometer could read the pulley's speed

4.2 Discussion, Analysis, and Results:

Sample Table and Figure for Analysis: The caption for the chart appears below the figure, but the caption for the table appears above it.

Discussion: Discuss your findings.

Table 4.2 discussion

Distance [cm]	Photocurrent [uA]
d	Iph
0	130
20	32
30	15
50	5

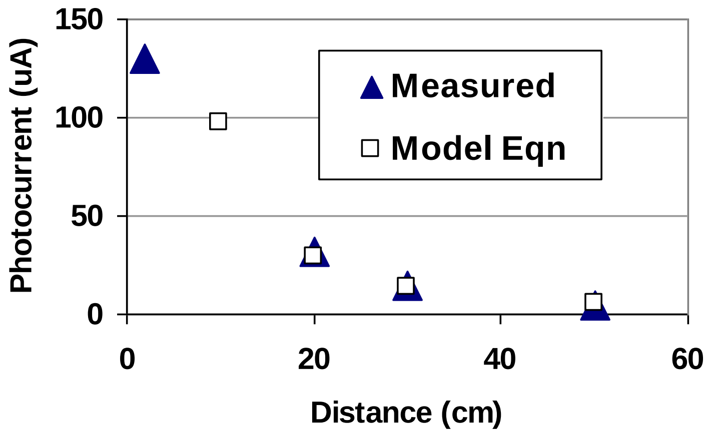


Figure 4.2 shows the output current of a Si photodiode measured with a 1mW laser.

The following must be emphasized during testing activities:

Determine the objectives of the experiment/test and the resources available (instruments, setup, etc.).

Carry out the experiment procedure and collect data Analyze the data and interpret the findings in light of the objectives

Report the findings (tables, plots, etc.) and explain any mistakes before concluding with any challenges.

Chapter 5: Project Management

5.1 Project Plan: In our project the tasks were distributed among group members and some tasks required the work of all group members and some did not. Here you can find all the information about the project.

Table 5.1: Tasks and their durations

#	Tasks		Start	End	Duration
1	Chapter 1: Introduction		14/2/2021	20/2/2021	6
2	Chapter 2: Literature Review	Project Background and comparative study	14/2/2021	20/2/2021	6

3	Chapter 3: System Design	Design Constraints and Design Methodology Engineering Design standards Theory and Theoretical Calculations Product Subsystems and selection of Components Manufacturing and assembly / Economic evaluation	1/3/2021	25/3/2021	24
4	Chapter 4: System Testing & Analysis	Experimental Setup, Sensors and data Results, Analysis and Discussion	16/4/2021	20/4/2021	4
5	Chapter 5: Project Management	Project Plan Contribution of Team members Project Execution Monitoring Challenges & Decision	16/4/2021	204/2021	4
		Making Project Bill of Material & Budget			
6	Chapter 6: Project Analysis	Life Long Learning Impact of Engineering Solution Contemporary Issues Addressed	16/4/2021	20/4/2021	4
7	Chapter 7: Conclusion &	Conclusion	16/4/2021	20/4/2021	4

	Recommendation	Future Recommendation			
8	Design of Prototype	Foot shape	15/2/2021	20/2/2021	5
		Knee shape			
		The length of the pipe			
9	Parts Purchase	Parts for foot	21/2/2021	10/3/2021	16
		Parts for knee			
		The pipe that connects the foot and knee			
10	Manufacturing	Casting	5/4/2021	18/4/2021	13
		Connecting the parts			
		Mixing the materials			
11	Testing	Making some changes	27/3/2021	29/3/2021	2
		Adding extra material	30/3/2021	3/4/2021	4

Table 5.2: Tasks and assigned members

#	Tasks	Assigned Members
1	Chapter 1: Introduction	All
2	Chapter 2: Literature Review	Faisal Alahmed
		Mohammad Alhalal
		Hadi Alhalal
3	Chapter 3: System Design	All
4	Chapter 4: System Testing & Analysis	Faisal Alahmed
5	Chapter 5: Project Management	Abdulaziz Almutairi

6	Chapter 6: Project Analysis	Mohammad Alhalal
7	Chapter 7: Conclusion & Recommendation	Hadi Alhalal
8	Design of Prototype	Hadi Alhalal
		Mohammad Alhalal
9	Parts Purchase	All
10	Manufacturing	Mohammad Alhalal
		Hadi Alhalal
11	Testing	All

5.2 Contribution of Team Members:

This table shows the tasks and participants as well as the percentage of each member's contribution.

Table 5.3: the contribution of the members

#	Tasks		Assigned	Cont. %
1	Chapter 1: Introduction		All	100%
2	Chapter 2: Literature Review	Project Background and comparative study	Faisal Alahmed	33%
			Mohammad Alhalal	33%
			Hadi Alhalal	34%
			Mohammad Alhalal	34%
			Hadi Alhalal	33%
3	Chapter 3: System Design	Design Constraints and Design Methodology	Abdulaziz	30%
			Faisal Alahmed	30%

			Mohammad Alhalal	30%
			Hadi Alhalal	10%
		Engineering Design standards	Abdulaziz	50%
			Ali	50%
		Theory and Theoretical Calculations	Faisal Alahmed	50%
			Mohammad Alhalal	30%
			Hadi Alhalal	20%
		Product Subsystems and selection of Components	Ali	30%
			Mohammad	40%
			Faisal	30%
		Manufacturing and assembly / Economic evaluation	Abdulaziz	100%
4	Chapter 4: System Testing & Analysis	Experimental Setup, Sensors and data	Faisal	100%

		Results, Analysis and Discussion	Faisal	100%
5	Chapter 5: Project Management	Project Plan	Abdulaziz	100%
		Contribution of Team members		
		Project Execution Monitoring		
		Challenges & Decision Making		
		Project Bill of Material & Budget		
6	Chapter 6: Project Analysis	Life Long Learning	Mohammad	100%
		Impact of Engineering Solution		

		Contemporary Issues Addressed		
7	Chapter 7: Conclusion & Recommendation	Conclusion	Hadi	100%
		Future Recommendation		
8	Design of Prototype	Foot shape	All	100%
		Knee shape and length of pipe		
9	Parts Purchase	Parts for foot	All	100%
		Parts for knee		
		The pipe that connects the foot and knee		
10	Manufacturing	Casting	Hadi Alhalal Mohammad Alhalal	100%
		Connecting the parts		
		Mixing the materials		
11	Testing	Making some changes	All	50%
		Adding extra material	Hadi and Mohammad	50%

5.3 Project Execution Monitoring

During our project, we carried out many activities related to improving our project. These events include important meetings and events related to our high-level projects. Table 5 lists the conferences and other activities of our project in the 2021 spring semester.

2.1.1.1 **Table 5.4: Dates of the activates and events**

Time/Date	Activities/Events
One time a week	Assessment class
Weekly	Meeting with group members

Every 2 weeks	Meeting with the advisor
25 march, 2021	Finishing first prototype
8 April, 2021	Midterm presentation
27, March 2021	First testing of the system
18 April, 2021	Finishing the final prototype
19 April 2021	Testing the system
20 April, 2021	Submission of the report
22 April,2021	Final presentation

5.4 Challenges and Decision Making:

During the project phase, we encountered some problems that delayed the completion of the project.

The main problems were:

1) Finding the right material that fit our budget
2) Difficulties while making the final prototype

5.4.1: Finding the right material that fit our budget

While we were searching for the right material for our project, we faced some problems that included the price of these materials such as carbon steel C-45 but we put this kind of material in our project because it will help improve it but the cost was the biggest problem here because the material itself cost lots of money, so we decided to use different materials such as aluminum and stainless steel.

2.1.1.2

5.4.2: Difficulties while making the final prototype

2.1.1.3

One of the difficulties that we faced while making the final prototype is the main problem we had in the initial prototype that included how to make a mold to cast aluminum and the second problem was how to clean test of ammonium to make it match our component because we used different materials so it was a big challenge to try and mix these materials and the last thing we had was how to tap iron to receive a screw Bolt for our knee, these reasons delayed the finishing of our final prototype but it was a useful experience and we were able to finish it on time .

5.5 Project Bill of Materials and Budget:

Table 5.5 shows the materials we purchased and their cost in Saudi Riyal (SR). The manufacturing of parts is also included in the table.

Table 5.5: Bill of materials

Materials	**Costs (SR)**
Manufacturing of foot	1845
Manufacturing of Knee	3083
Casting	3500
Final prototype	2500
Total	10928

Chapter6: Project Analysis

6.1 Life-long learning:

Everyone's feet are made up of 26 bones, which account for 25% of the total human bones. The foot also has over 100 tendons, ligaments and 30 different joints. This architecture lets us walk and be stable on multiple surfaces without having to think about it. This is achieved by using a spring-shaped carbon fiber element that deforms as the weight decreases and stores energy. When the user pinches the toe, the energy returns to restore the energy that normally powers the ankle muscles. Some impetus.

However, in such layout, the ankle is normally static to have effective power transmission. It shows that it counts on the arise like components versatility to adjust to unmatched terrain. Past research has identified this absence of adjustment as a disadvantage of traditional prosthetic device, and as a result, most prosthetic patients face problems when speeding on a floor that isn't leveled.

The use of hydraulically filled ankles to solve the problem has been debatable because it contradicts modern concepts and understanding of the biomechanics of prosthetics.

How does this technology favor the consumer if it reduces the efficiency of energy return?

6.2 Impact of Engineering Solutions:

Our hydraulic technology offers users advantages that can help them increase their quality of life and maintain a healthy body Increasing the distance by 18% will reduce the chance of tripping and falling

. Long-term limb disease is less likely. Increased self-assurance while walking and navigating uneven terrain.

A. Improved Safety: An 18% rise in toenail not hitting the ground decreases the likelihood of tripping and falling.
B. Better Mechanism and Steadiness: Trust in moving and navigating difficult weather has increased.
C. Increased comfort: fork tension is reduced by 60%

D. Balanced Limb Loading: Long-term limb disease is less likely.
E. Improve energy efficiency: reduce energy costs by 10%.

6.3 Contemporary Issues Addressed:

Lower limb amputees can experience health problems long after amputation, and the consideration and treatment of these issues is critical to the patient's long-term health. Lower limb amputees have a 2-3x elevated chance of knee or hip osteoarthritis relative to the general population. Also, within two years of amputation, 61% of lower limb amputees report mild to extreme back pain. Long-time period musculoskeletal fitness, we conclude, is depending on the replica of the complicated and adaptive characteristics of herbal limb movement. Nature’s engineering is the number one supply of concept on the center of our biomimetic layout philosophy, via which the introduction of award-prevailing prostheses is centered at the long-time period fitness and wellness of each amputee.

Chapter 7: Conclusion and Future Recommendations

7.1 Conclusion:

In conclusion, the people who Suffer from amputations of the lower limbs can benefit from our project. The hydraulically regulated articulation between the prosthetic foot and shank pylon is critical for biomechanical, metabolic, and gait safety reasons, as we discussed in this article. However, it must be noted that all participants in these studies were active and safe, with at least K3 ambulatory classification from their prescribing physicians. These findings should apply to those who are healthy and active, but they may not apply to those who have other medical conditions or are less active, resulting in a slow or unstable gait. Future research might look at whether a hydraulic ankle-foot device is also beneficial to K2 ambulatory. When study participants (ankle or femoral amputees) installed the hydraulic ankle device for the first time, a small number of participants (transtibial or transfemoral amputees) showed initial movement and/or instability while standing. This is understandable given that the mechanism, once set up, allows for both plantarflexion and dorsiflexion from a neutral (standing) place. As a consequence, those with poor postural stability and/or a shaky gait can feel that using such a product is inappropriate. Finally, all the studies examined here compare the effects of using hydraulic stepped ankle-foot instruments with normal, rigid or elastically attached ESR feet on subjects.

7.2 Future recommendations:

If we have the timer resource, we can strengthen our project in the future by making all of the paths for the knee from CNC clutch parts instead of casting, as well as making shock absorbers that go inside the knee to challenge the movement for the knee. Additionally, by changing the foot's shape to make it more flexible to imitate Primal foot movement. The most important thing we do is regulate the knee and foot movement with a servo motor that receives a signal from the human brain. We would consider using pure aluminum as a commodity in the future. Even, if we want to make it lighter, we can make some of the components out of carbon fiber or fiberglass. We may also add bearings to the movement to make it smoother. Since it is readily accessible, simple to work with, and long-lasting, we chose this material for our project. We chose cast aluminum because it is simple to work with and melts at a lower temperature than iron, making it easier to work with.

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Appendix A: Progress Reports

	SDP – WEEKLY MEETING REPORT
	Department of Mechanical Engineering **Prince Mohammad bin Fahd University**

SEMESTER:	Spring 2020-2021	ACADEMIC YEAR:	2020-2021
PROJECT TITLE	Design and manufacturing of a lower limb prosthetic		
SUPERVISORS	Dr. Megdi Eltayeb		

Month: March

ID Number	Member Name
201602840	Abdulaziz Almutairi*
201402518	Hadi Alhalal
201501191	Mohammad Alhalal
201501109	Faisal Alahmed
201401857	Ali Alotaibi

List the tasks conducted this month and the team member assigned to conduct these tasks

#	Task description	Team member assigned	Progress 0%-100%	Delivery proof
	Project summary form	Abdulaziz Almutairi	100%	It was submitted on bb
	Milestone 3	1-Abdulaziz Almutairi 2- Hadi Alhalal 3-Faisal Alahmed 4-Mohammad Alhalal	100%	It was submitted on bb
	Senior project presentation	1- Abdulaziz Almutairi 2- Ali Alotaibi	50%	Still working on it

List the tasks planned for the month of March and the team member/s assigned to conduct these tasks

#	Task description	Team member/s assigned
	Monthly progress report	Abdulaziz Almutairi
	The presentation	1-Abdulaziz Almutairi 2-Ali Alotaibi

- **To be Filled by Project Supervisor and team leader:**
- **Please have your supervisor fill according to the criteria shown below**

Outcome MEEN4: an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
MEEN4A. Demonstrate an understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental and societal context	Fails to demonstrate an understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts	Shows limited and less than adequate understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts	Demonstrates satisfactory understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts	Understands appropriately and accurately the engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts
Outcome MEEN5: an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
MEEN5A: Ability to develop team work plans and allocate resources and tasks	Fails to develop team work plans and allocate resources and tasks	Shows limited and less than adequate ability to develop team work plans and allocate resources and tasks	Demonstrates satisfactory ability to develop team work plans and allocate resources and tasks	Properly and efficently makes team work plans and allocate resources and tasks

MEEN5B: Ability to participate and function effectively in team work projects to meet objectives	Fails to participate and function effectively in team work projects to meet objectives	Shows limited and less than adequate ability to participate and function effectively in team work projects to meet objectives	Demonstrates satisfactory ability to participate and function effectively in team work projects to meet objectives	Function effectively in team work projects to meet objectives
MEEN5C: Ability to communicate effectively with team members	Fails to communicate effectively with team members	Shows limited and less than adequate ability to communicate effectively with team members	Demonstrates satisfactory ability to communicate effectively with team members	Communicates properly and effectively with team members

Indicate the extent to which you agree with the above statement, using a scale of 1-4 (1=None; 2=Low; 3=Moderate; 4=High)

#	Name	Criteria (MEEN4A)	Criteria (MEEN5A)	Criteria (MEEN5B)	Criteria (MEEN5C)
1	Hadi Alhalal	3	3	3	3
2	Mohammad Alhalal	3	3	3	3
3	Ali Alotaibi	3	3	3	3
4	Faisal Alahmed	3	3	3	3

Comments on individual members

Name	Comments
Hadi Alhalal	Trying to fast-track all the task that is possible execute in parallel.
Mohammad Alhalal	Trying to fast-track all the task that is possible execute in parallel.
Ali Alotaibi	Trying to fast-track all the task that is possible execute in parallel.
Faisal Alahmed	Trying to fast-track all the task that is possible execute in parallel.

	SDP – WEEKLY MEETING REPORT
	Department of Mechanical Engineering Prince Mohammad bin Fahd University

SEMESTER:	Spring 2020-2021	ACADEMIC YEAR:	2020-2021
PROJECT TITLE	Design and manufacturing of a lower limb prosthetic		
SUPERVISORS	Dr. Megdi Eltayeb		

Month: April

ID Number	Member Name
201602840	Abdulaziz Almutairi*
201402518	Hadi Alhalal
201501191	Mohammad Alhalal
201501109	Faisal Alahmed
201401857	Ali Alotaibi

List the tasks conducted this month and the team member assigned to conduct these tasks

#	Task description	Team member assigned	Progress 0%-100%	Delivery proof

	Project summary form	Abdulaziz Almutairi	100%	It was submitted on bb
	Milestone 3	1-Abdulaziz Almutairi 2- Hadi Alhalal 3-Faisal Alahmed 4-Mohammad Alhalal	100%	It was submitted on bb
	Senior project presentation	3- Abdulaziz Almutairi 4- Ali Alotaibi	50%	Still working on it

List the tasks planned for the month of March and the team member/s assigned to conduct these tasks

#	Task description	Team member/s assigned
	Monthly progress report	Abdulaziz Almutairi
	The presentation	1-Abdulaziz Almutairi 2-Ali Alotaibi

- **To be Filled by Project Supervisor and team leader:**
- **Please have your supervisor fill according to the criteria shown below**

Outcome MEEN4: an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
MEEN4A. Demonstrate an understanding of engineering professional and ethical standards and their impact on engineering solutions in	Fails to demonstrate an understanding of engineering professional and ethical standards and their impact on engineering	Shows limited and less than adequate understanding of engineering professional and ethical standards and their impact on engineering	Demonstrates satisfactory understanding of engineering professional and ethical standards and their impact on engineering solutions in	Understands appropriately and accurately the engineering professional and ethical standards and their impact on engineering solutions in global, economic,

global, economic, environmental and societal context	solutions in global, economic, environmental, and societal contexts	solutions in global, economic, environmental, and societal contexts	global, economic, environmental, and societal contexts	environmental, and societal contexts
Outcome MEEN5: an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
MEEN5A: Ability to develop team work plans and allocate resources and tasks	Fails to develop team work plans and allocate resources and tasks	Shows limited and less than adequate ability to develop team work plans and allocate resources and tasks	Demonstrates satisfactory ability to develop team work plans and allocate resources and tasks	Properly and efficently makes team work plans and allocate resources and tasks
MEEN5B: Ability to participate and function effectively in team work projects to meet objectives	Fails to participate and function effectively in team work projects to meet objectives	Shows limited and less than adequate ability to participate and function effectively in team work projects to meet objectives	Demonstrates satisfactory ability to participate and function effectively in team work projects to meet objectives	Function effectively in team work projects to meet objectives
MEEN5C: Ability to communicate effectively with team members	Fails to communicate effectively with team members	Shows limited and less than adequate ability to communicate effectively with team members	Demonstrates satisfactory ability to communicate effectively with team members	Communicates properly and effectively with team members

Indicate the extent to which you agree with the above statement, using a scale of 1-4 (1=None; 2=Low; 3=Moderate; 4=High)

#	Name	Criteria (MEEN4A)	Criteria (MEEN5A)	Criteria (MEEN5B)	Criteria (MEEN5C)
1	Hadi Alhalal	3	3	3	3
2	Mohammad Alhalal	3	3	3	3
3	Ali Alotaibi	3	3	3	3
4	Faisal Alahmed	3	3	3	3

Comments on individual members

Name	Comments
Hadi Alhalal	Trying to fast-track all the task that is possible execute in parallel.
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Ali Alotaibi	Trying to fast-track all the task that is possible execute in parallel.
Faisal Alahmed	Trying to fast-track all the task that is possible execute in parallel.

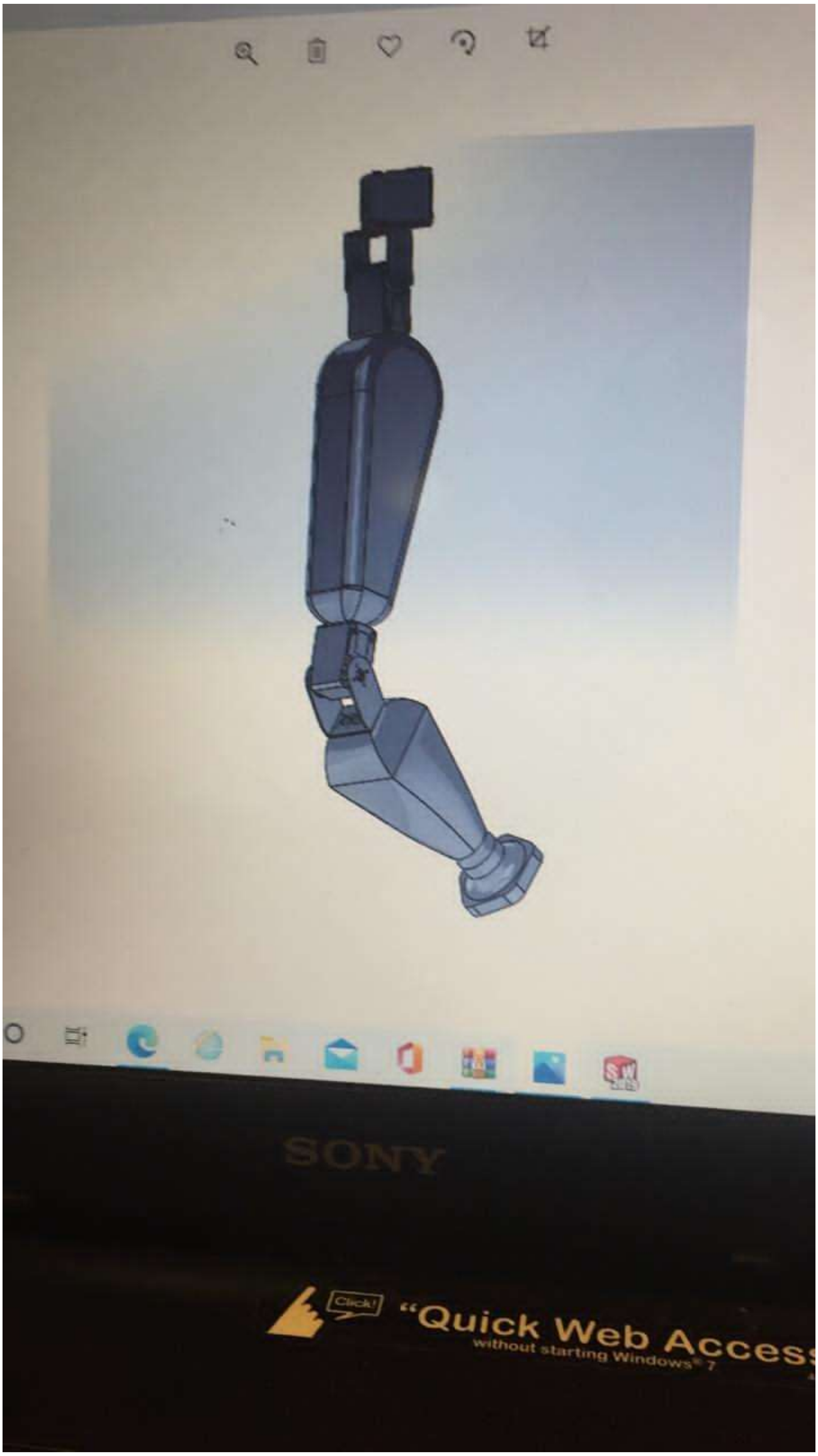
Appendix B: Engineering standards (Local and International)

Frame: Aluminum Alloy, Brass, Stainless Steel, Steel. Carbon steel c45

Knee head: Aluminum Alloy, Stainless Steel.

Knee control: Various materials principally Aluminum Alloy, Stainless Steel.

Appendix C: CAD drawings and Bill of Materials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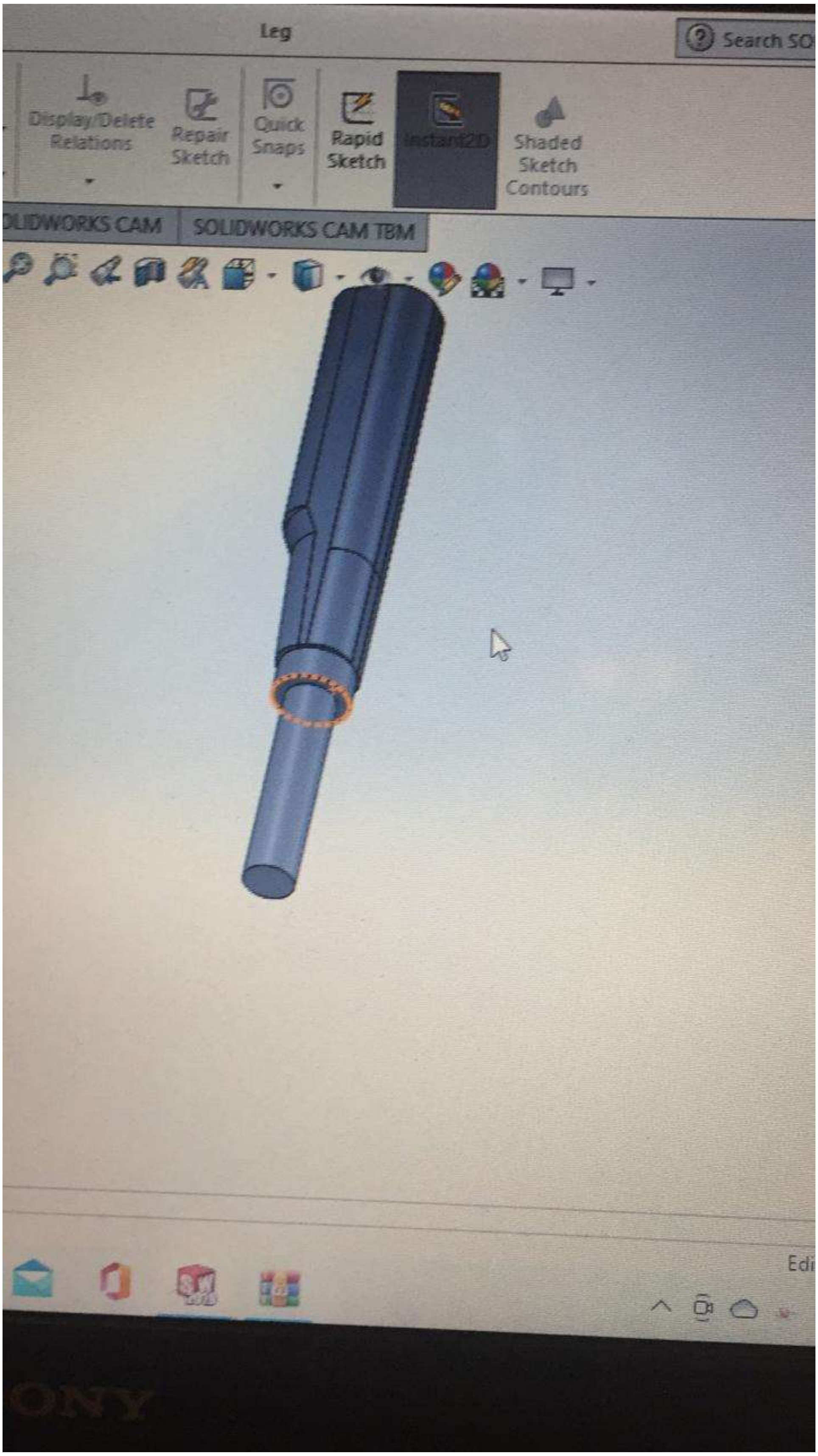
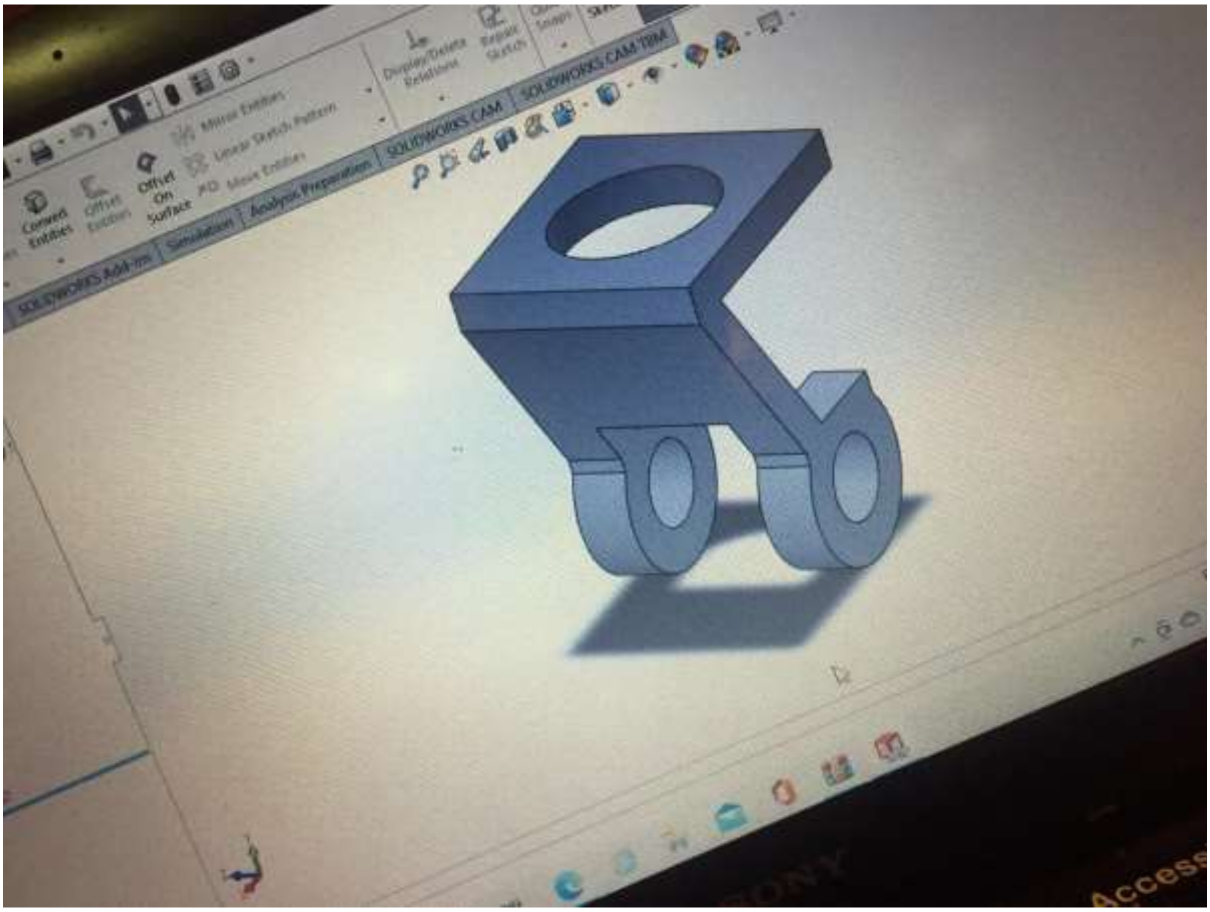


Leg
Search SO
Display/Delete Relations
Repair Sketch
Quick Snaps
Rapid Sketch
Instant2D
Shaded Sketch Contours
SOLIDWORKS CAM TBM


Convert Entities
Offset On Surface
Display/Delete Relations
Repair Sketch
SOLIDWORKS Add-Ins
Simulation
Analysis Preparation
SOLIDWORKS CAM
SOLIDWORKS CAM TBM
Access

Appendix D: Datasheets

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Capital Costs											
Equiprment	4200 SAR	2000 SAR	2000 SAR	2000 SAR	2000 SAR	4200 SAR	2000 SAR	2000SAR	2000 SAR	2000 SAR	4200 SAR
Construction	1000 SAR	500 SAR	500 SAR	500 SAR	500 SAR	1000 SAR	1000 SAR	1000 SAR	1000 SAR	1000 SAR	1000 SAR
Total	5200 SAR	2500 SAR	2500 SAR	2500 SAR	2500 SAR	5200 SAR	2500SAR	2500SAR	2500SAR	2500SAR	5200 SAR
Operating Cost											
Energy	0.5 kWh	0.6 kWh	0.8 kWh	0.8 kWh	0.8 kWh	1 kWh	1 kWh	1.1 kWh	1.1 kWh	1.2 kWh	1.5 kWh
Electrcitiy	400 SAR/M	500 SAR/M	700 SAR/M	750 SAR/M	750 SAR/M	900 SAR/M	900 SAR/M	1000 SAR/M	1000 SAR/M	1100 SAR/M	1500 SAR/M
Labour	600 SAR/M	800 SAR/M	1200 SAR/M	1200 SAR/M	1200 SAR/M	1500 SAR/M	1500 SAR/M	1700SAR/M	1750SAR/M	1900 SAR/M	2300 SAR/M
Insurance	500 SAR	500 SAR	500SAR	500SAR	500 SAR	800SAR	800SAR	850SAR	900SAR	1050SAR	1300SAR
Taxes	300 SAR	300 SAR	400SAR	400SAR	400SAR	600SAR	600SAR	500SAR	550SAR	700SAR	900 SAR
Total	12800 SAR	16400 SAR	23700 SAR	25500	25500	29800 SAR	29800	33750	34500	37750	47800
Revenues											
Product 1	9000 SAR	11000 SAR	15000 SAR	17000 SAR	185000 SAR	27000 SAR	27000 SAR	29000 SAR	31000SAR	36000 SAR	42000 SAR
Product 2	8500 SAR	9000 SAR	13000 SAR	15000 SAR	16000 SAR	24000 SAR	24000 SAR	28000 SAR	30000 SAR	33000 SAR	39000 SAR
Product 3	7500 SAR	8500 SAR	12000 SAR	13500 SAR	15000 SAR	23000 SAR	23000 SAR	26000 SAR	28500 SAR	34000 SAR	41000 SAR
Total	25000 SAR	28500 SAR	40000 SAR	45500 SAR	49500 SAR	74000SAR	74000SAR	83000 SAR	88500 SAR	103000 SAR	122000 SAR
Profits	7000 SAR	9600 SAR	13800 SAR	17500 SAR	21500 SAR	38600 SAR	41300 SAR	46750 SAR	51550 SAR	62750 SAR	69000 SAR

Appendix E: Operation Manual

Running the prototype is easy, all you have to do is move knee and adjust the height of the pipe connecting between the foot and knee.

Appendix F: Gantt Chart

PRINCE MOHAMMAD BIN FAHD UNIVERSITY
College of Engineering
Department of Mechanical Engineering

Design and manufacturing of a lower limb prosthetic
Team 17

	Start Date	Days to complete
Task 1: Report		
Chapter 1 & 2: Introduction & Literature Review	14/02/2021	6
Chapter 3: System Design Including economic evaluation	1/03/2021	24
Chapter 4: System Testing and Analysis	16/04/2021	4
Chapter 5 & 6: Project Management & Analysis	16/04/2021	4
Final Submission	16/04/2021	4
Task 2: Design of Prototype		
Design and Planning		
Foot shape	15/02/2021	5
Knee shape	15/02/2021	5
The length of the pipe	15/02/2021	5
Parts Purchase		
Parts for foot	21/02/2021	16
Parts for knee	21/02/2021	16
The pipe that connects the foot and knee	21/02/2021	16
Manufacturing		
Casting	5/04/2021	13
Connecting the parts	5/04/2021	13
Mixing the materials	5/04/2021	13
Testing		
Making some changes	27/03/2021	2
Adding extra material	30/03/2021	4