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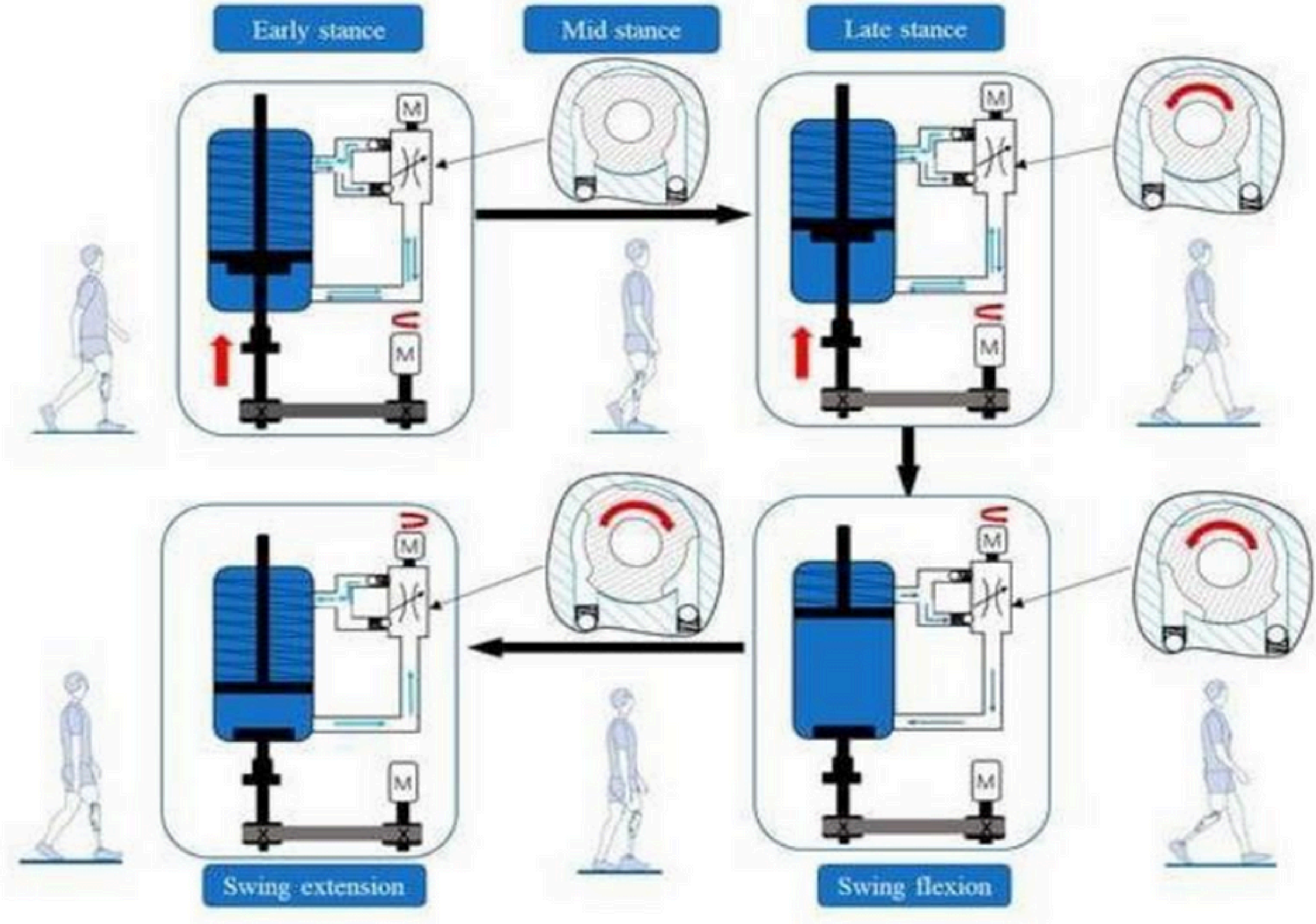
DEVELOPMENT OF THE PROSETHSIS USING SMART DAMPER



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ABSTRACT

This study focuses on the development of a semi-active type prosthesis utilizing a smart damper for improved functionality and comfort for amputees. The integration of smart damper technology allows for real-time adjustment of damping characteristics based on the user's movement patterns and external conditions, contributing to enhanced adaptability and efficiency during various activities.

The prosthesis is designed to mimic the dynamic behavior of a natural limb through the utilization of sensors to collect data on the user's gait, speed, and terrain. The smart damper responds to these inputs by modulating the damping force, providing optimal support and stability while reducing fatigue and strain on the residual limb.

Furthermore, the use of semi-active technology in the prosthesis offering a customizable and adaptable solution for users with varying needs and preferences. The potential benefits of this development include improved comfort, reduced energy consumed, and enhanced overall mobility and quality of life for prosthetic users.

Keywords (DEVELOPMENT … PROSETHSIS… SMART DAMPER)

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CHAPTER ONE

INTRODUCTION

Chapter One

Introduction

1.1 INTRODUCTION

Gait of each person varies depending on the condition and its physical characteristics. Human gait includes simultaneous work of muscles, limbs and central nervous system (CNS). Therefore, despite the fact that most people have the general dynamics of movement, gait of each individual is unique. In recent years, a large number of models of prostheses that mimic the human gait developed, thousands of people lose their lower limbs due to circulatory and vascular problems, diabetes complications, cancer, or trauma, every year. Among them, some people lost part or all of their lower limbs and the ability to walk need to be restored by lower limb prosthesis.[1]

1.2 HUMAN GAIT CYCLE ANALYSIS

Gait cycle is the series of movements that the body makes while walking. The gait cycle includes different phases such as support, transition, elevation and sinking. Understanding the gait cycle is important in the field of sports medicine and physical therapy as this knowledge can be used to help evaluate and improve performance or treat movement injuries.[2]

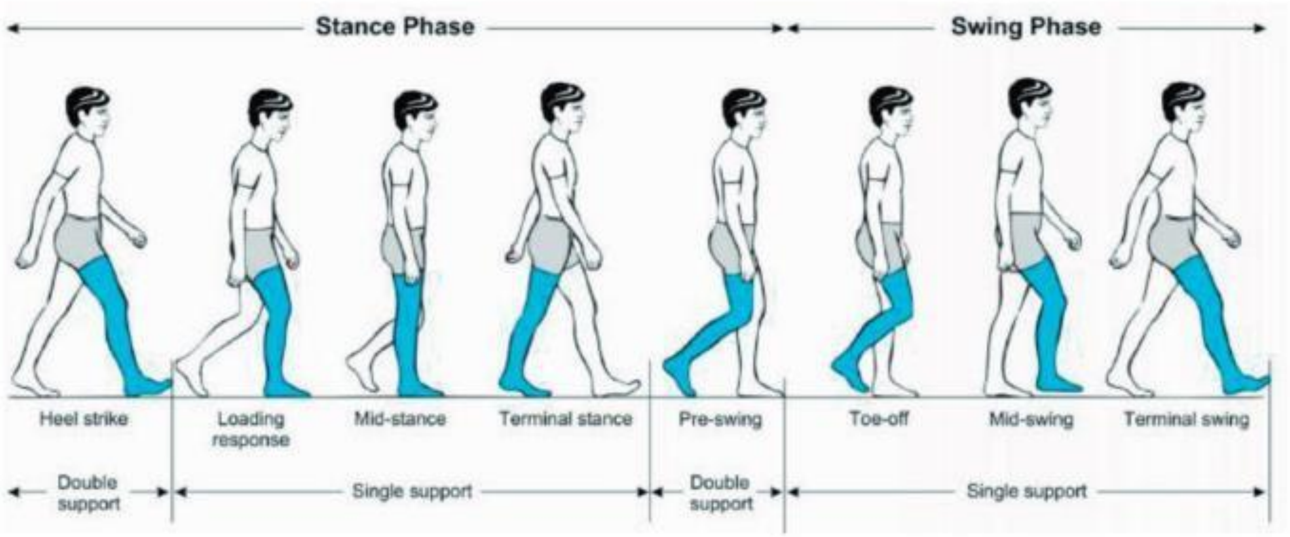


Figure (1.1)Human Gait Cycle[3]

1.2.1 Component of gait cycle

The gait cycle, or walking cycle, consists of several key components that describe the phases of walking. These components include:

1. Stance Phase: This is the period when the foot is in contact with the ground and bears the body's weight. The stance phase is further divided into five sub-phases: initial contact, loading response, mid stance , terminal stance, and pre swing.

2. Swing Phase: During this phase, the foot is not in contact with the ground and swings through the air in preparation for the next stance phase. The swing phase includes the subphases of initial swing, mid swing, and terminal swing.

These components help to describe the intricate sequence of movements involved in human walking. Each phase plays a crucial role in supporting efficient and coordinated locomotion.

The Stance Phase and the Swing Phase are two important parts of the gait cycle, as joints and muscles work in harmony to achieve harmonious movement during these phases.

1. **The balance phase:** begins when the foot touches the ground and ends when the foot rises again. During this period, the body balances on the foot, allowing weight to be transferred and preparing for the next transfer.
2. **The swing phase**: begins when the foot is lifted off the ground and ends when the foot touches the ground again. During this phase, the foot is brought back forward in rhythm with the foot in the air.

1.3 PROSTHETIC KNEE

A prosthetic knee is a device designed to replace a natural knee joint that has been lost or become non-functional due to injury, disease, or other medical reasons. It is a vital component of a prosthetic limb, typically part of a lower limb prosthesis used to restore mobility and functionality for individuals with limb loss or limb deficiency. Prosthetic knees are engineered to replicate the complex movements and functions of the natural knee joint as closely as possible. They are designed with various mechanical and technological features to provide stability, support, and flexibility while walking, running, climbing stairs, and performing other activities. Advanced prosthetic knees often incorporate components like microprocessors, sensors, hydraulic systems, and adjustable mechanisms to adapt to different walking speeds, terrains, and user movements. The goal is to enhance the user's comfort, safety, and overall quality of life by enabling natural and efficient movement.[4]

The selection of the prosthetic knee is based on the individual's specific needs, lifestyle, and functional abilities, and is often determined in collaboration with a healthcare professional specializing in the design, fitting, and customization of prosthetic limbs. Overall, prosthetic knees play a crucial role in restoring mobility and independence for individuals who have experienced limb loss, enabling them to engage in daily activities and pursue an active lifestyle.[4]

1.3.1 The design of a prosthetic knee

The design of prosthetic knee is crucial in ensuring the functionality, comfort, and overall effectiveness of the device for the user. Here are some key aspects of the design of a prosthetic knee:

1. Anatomical compatibility: The prosthetic knee should be designed to closely mimic the natural movement and alignment of a human knee joint. This includes considerations such as range of motion, flexion, extension, and stability.
2. Materials: Prosthetic knees are typically made from lightweight and durable materials such as carbon fiber, titanium, or aluminum. These materials are chosen for their strength, flexibility, and longevity, while also minimizing the weight of the prosthesis.
3. Articulation: The design of the prosthetic knee should allow for smooth and natural articulation during various activities such as walking, running, climbing stairs, and sitting down. Articulation mechanisms may include hinges, pneumatic systems, or electronic Components.
4. Adjustability: Many prosthetic knees offer adjustable features to accommodate individual preferences and needs. This can include adjustable alignment, stance control, damping settings, or resistance levels.
5. Safety features: Prosthetic knee designs often incorporate safety features such as locking mechanisms to prevent buckling or collapsing during weight-bearing activities, enhancing the user's confidence and stability.
6. Cosmetic: The aesthetic design of the prosthetic knee is also important to many users, as it contributes to their self-image and confidence while wearing the device. Some prosthetic knees are designed to be discreet and easily concealable under clothing.

1.4 TYPE OF PROSTHETIC KNEE

The prosthetic knee can be divided into three categories according to structures and knee torque realization methods:[5]

1. passive prosthetic knee
2. active prosthetic knee 3. semi-active prosthetic knee

1. Passive prosthetic knee:

Passive prosthetic knees are mechanical systems that do not have an active power source or electronic components. They rely on the user's body movements and weight shifting to provide stability, support, and mobility. Some of the advantages of passive prosthetic knees include simplicity, durability, and lower cost compared to active prosthetic knees. Passive knees may also require less maintenance and be easier for some users to adjust. Additionally, passive knees may not offer features such as variable cadence control or automated stance phase locking, which can impact the user's overall gait and stability.[5]

-Advantages of Passive Prosthetic Knees:

1. Simplicity: Passive prosthetic knees are often simpler in design and function, making them easier to use and maintain.
2. Durability: They may be more robust and have fewer moving parts susceptible to wear and tear compared to active prosthetic knees.
3. Cost: Passive prosthetic knees are generally more affordable than their active counterparts, which can make them more accessible to a wider range of users.
4. Stability: Passive knees can provide reliable support and stability for walking on level surfaces and performing everyday activities.

-Disadvantages of Passive Prosthetic Knees:

1. Limited Functionality: Passive prosthetic knees lack the advanced features and adjustability found in active prosthetic knees, which can limit the user's ability to navigate uneven terrain or adjust to changes in speed and incline.
2. Lack of Adaptability: Passive knees do not actively respond to the user's movements, which can affect the user's gait pattern and overall mobility.
3. Less Dynamic Response: Passive prosthetic knees may not offer the same level of energy return or support during activities such as running or climbing stairs.
4. Impact on Mobility: Users of passive prosthetic knees may experience more challenges with activities that require precise control and coordination.

2. Active prosthetic knee:

An active prosthetic knee is a specialized artificial knee joint that is designed to mimic the movement and function of a natural knee. These advanced prosthetic knees use sensors, microprocessors, and other technologies to provide more natural movement and better support for the wearer. They can adjust their resistance and movement patterns based on the user's activity level, walking speed, and terrain. Active prosthetic knees help users walk more comfortably, efficiently, and with improved stability.

-Advantage of active prosthetic knee:

1. Improved Functionality: Active prosthetic knees are designed to provide a more natural range of motion, making daily activities such as walking, climbing stairs, and navigating uneven terrain easier for the user.
2. Enhanced Stability: The advanced technologies in active prosthetic knees offer better control and stability, helping users feel more confident and secure while moving around.

3. Adaptability: Active prosthetic knees can adjust their resistance and movement patterns based on the user's activity level, walking speed, and terrain, allowing for a smoother and more natural gait.
4. Energy Efficiency: By mimicking the function of a natural knee joint, active prosthetic knees help reduce the amount of energy expended during walking, making it less fatiguing for the user.
5. Customization: Active prosthetic knees can often be customized to better suit the individual user's needs and preferences, leading to a more comfortable and personalized fit.

Overall, active prosthetic knees can significantly improve the quality of life for amputees by providing better mobility, stability, and comfort in their daily activities.

-Disadvantage of active prosthetic knee:

1. Cost: Active prosthetic knees can be more expensive than passive prosthetic knees, making them less accessible to individuals with limited financial resources.
2. Maintenance: Active prosthetic knees may require more frequent maintenance and adjustments compared to passive prosthetic knees, which could result in higher ongoing costs and inconvenience for the user.
3. Learning Curve: Using an active prosthetic knee may require a period of adjustment and training to fully understand and optimize its functionality, which could be challenging for some users.
4. Weight: Some active prosthetic knees may be heavier than passive prosthetic knees, which could lead to increased fatigue and discomfort for the user, especially during long periods of wear.

5. Technical Issues: Due to the complexity of the technology involved, active prosthetic knees may be more prone to malfunctions or technical issues that could affect their performance and reliability.

Despite these potential disadvantages, many users find that the benefits of using an active prosthetic knee outweigh the drawbacks, leading to improved mobility, function, and quality of life

3. Semi-active prosthetic knee:

These types of prosthetic knees use sensors and microprocessors to adapt to different walking speeds and terrains, providing a more natural gait for the user. They offer increased stability and improved control compared to traditional prosthetic knees.

-Advantage of semi-active prosthetic knee:

There are several advantages of semi-active prosthetic knees compared to traditional prosthetic knees:

1. Improved adaptability: Semi-active prosthetic knees use sensors and microprocessors to adjust the knee joint in real-time based on the user's movement and walking speed.
2. Enhanced control: The advanced technology in semi-active prosthetic knees allows for better control over the knee joint.
3. Increased comfort: These prosthetic knees offer a smoother and more comfortable walking experience .
4. Reduced energy expenditure: By providing a more natural walking pattern and improved stability.

-Disadvantage of semi-active prosthetic knee:

1. Reliance on technology: As semi-active prosthetic knees rely on sensors and microprocessors to function optimally, there is a risk of technical malfunctions or electronic failures that may impact the user's mobility and safety.
2. Difficult to control: It is difficult to control this type of prosthetic knee, but despite that, if this type loses control, it turns into the active type.

1.5 THE AIM OF STUDY

The main aim of the study is to design the semi- active type damping prosthesis for amputees who are wearing mechanically passive damping prosthesis. Semi-Active type prostheses can improve swing phase gait ،◌َwhen choosing between a passive, active and semi –active prosthetic knee, it's essential to consider factors such as your lifestyle, mobility goals, comfort, overall, semi-active prosthetic knees can significantly improve the quality of life and mobility for individuals with lower limb amputations by offering better functionality, control, and comfort.

CHAPTER TWO

SEMI-ACTIVE PROSTHETIC

2.1 Design of the Semi-Active Prosthetic Knee:

The active and passive structures of the prosthetic knee are shown in Figure (2.1). The thigh connector is connected to thigh socket in the upper side. The lower side is connected with the four-bar linkage. The upper piston rod is connected with the four-bar linkage by a drive link. For the variable damping control, the provided hydraulic system (Figure 2.1.b) had one fan rotation valve, namely designed throttle valve, to generate joint resistance for the flexion and the extension movement. The position of the fan valve plate was controlled by the motor 1. The flow resistance could be continuously adjusted from low to high values by the rotation of the fan valve plate. When the piston rod moved down during knee flexion, the oil flowed through the throttle valve and one-way valve 1a in the flexion channel. The oil could not flow through the extension channel due to the unidirectional cutoff characteristic of the one-way valve 1b. The knee flexion damping could be regulated by the position change of the fan valve plate. The steel spring was stretched during knee flexion by the displacement of the upper piston. For the knee extension, the piston rod moved up and the oil flowed through the throttle valve and one-way valve 1b in the extension channel. The oil could not flow through the flexion channel due to the unidirectional cutoff characteristic of the one-way valve 1a. The knee extension damping was also adjusted by the position change of the fan valve plate. The energy stored by stretch of steel spring was released. This could provide assistance for knee extension. For the powered mode, the throttle valve is completely open. This means the passive hydraulic damping is free. The lower piston rod is driven by the ball screw. The vertical displacement of the ball screw is controlled by the synchronous belt connected to the motor 2. When the lower piston moved up, the upper piston was pushed up and the active knee torque was provided by the four-bar linkage.[6]

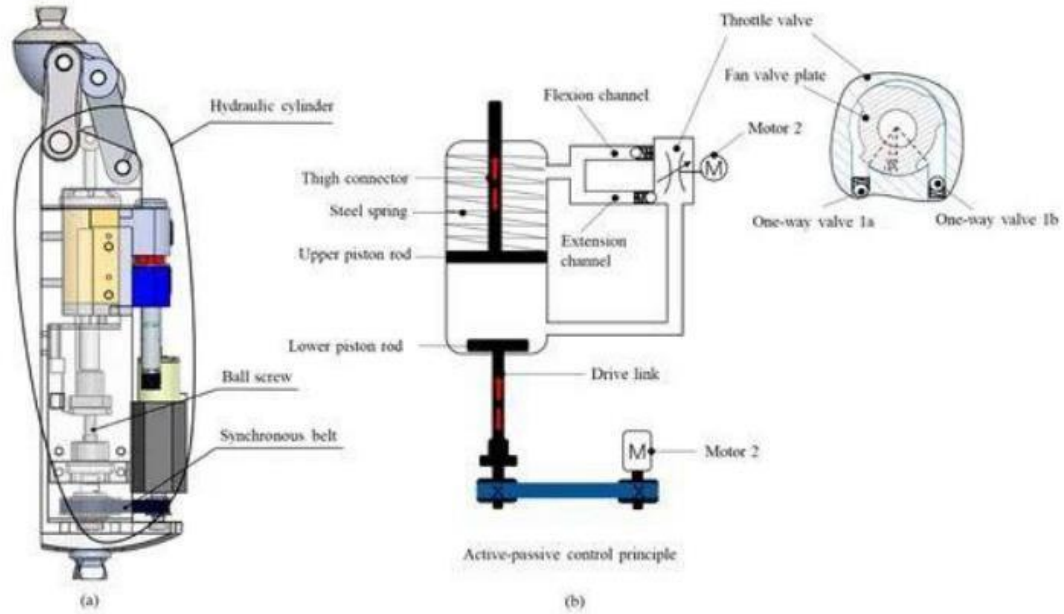


Figure 2:1 The active and passive structures of the prosthetic knee. (a)The 3D model of the prosthetic knee;(b) The active and passive work principle [6]

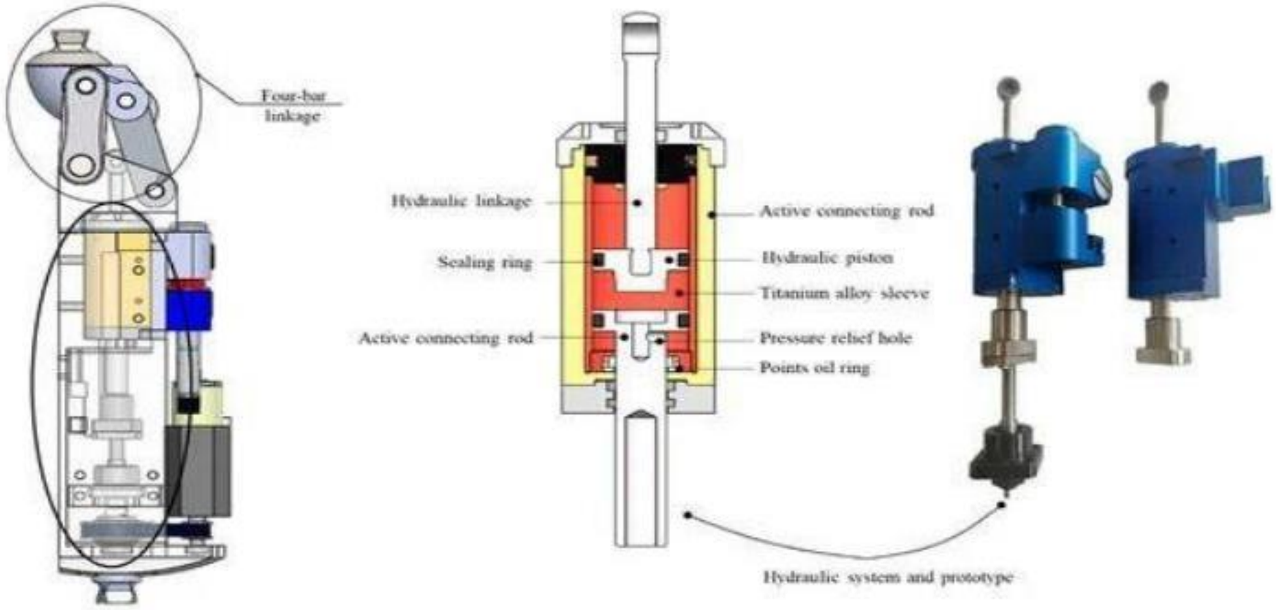


Figure 2:2 The detailed structure of the semi-active system and the prototype[6]

2.2 The work scheme of the semi-active prosthetic knee

The work scheme of the semi-active prosthetic knee is shown in Figure(3.2). At the beginning of stance in the human gait, the heel touches the ground. The calf quadriceps need to concentric contraction to increase the center of gravity and prevent the lateral foot in the swing phase from touching the ground. The knee joint provides positive work. We connect the motor 2 with the synchronous belt to output the active torque and transfer it to the ball screw. The transmitted torque of the ball screw is controlled by adjusting the speed of the motor 2.Therefore, the torque needed by the human body to do positive work is outputted by the motor 2. When the knee joint enters the swing flexion phase, the side leg touches the ground and the hip joint begins to flex. At this time, the hydraulic damping cylinder works. The pressure between the upper and lower oil chambers of the hydraulic cylinder is changed by the position change of the fan valve plate. The real-time damping torque was provided by this operation. During the swing extension phase, the extension damping torque was provided to slow the foot movement to the initial velocity of contact with the ground. Due to the fact that the prototype is currently in the processing state, the sensor system is not completely determined. In terms of control, the design mentioned in this paper will mainly use angle sensor, IMU, and force sensor to identify the gait cycle and control the position of the rotating valve. The sensor system can consider our previous work.[7,8]

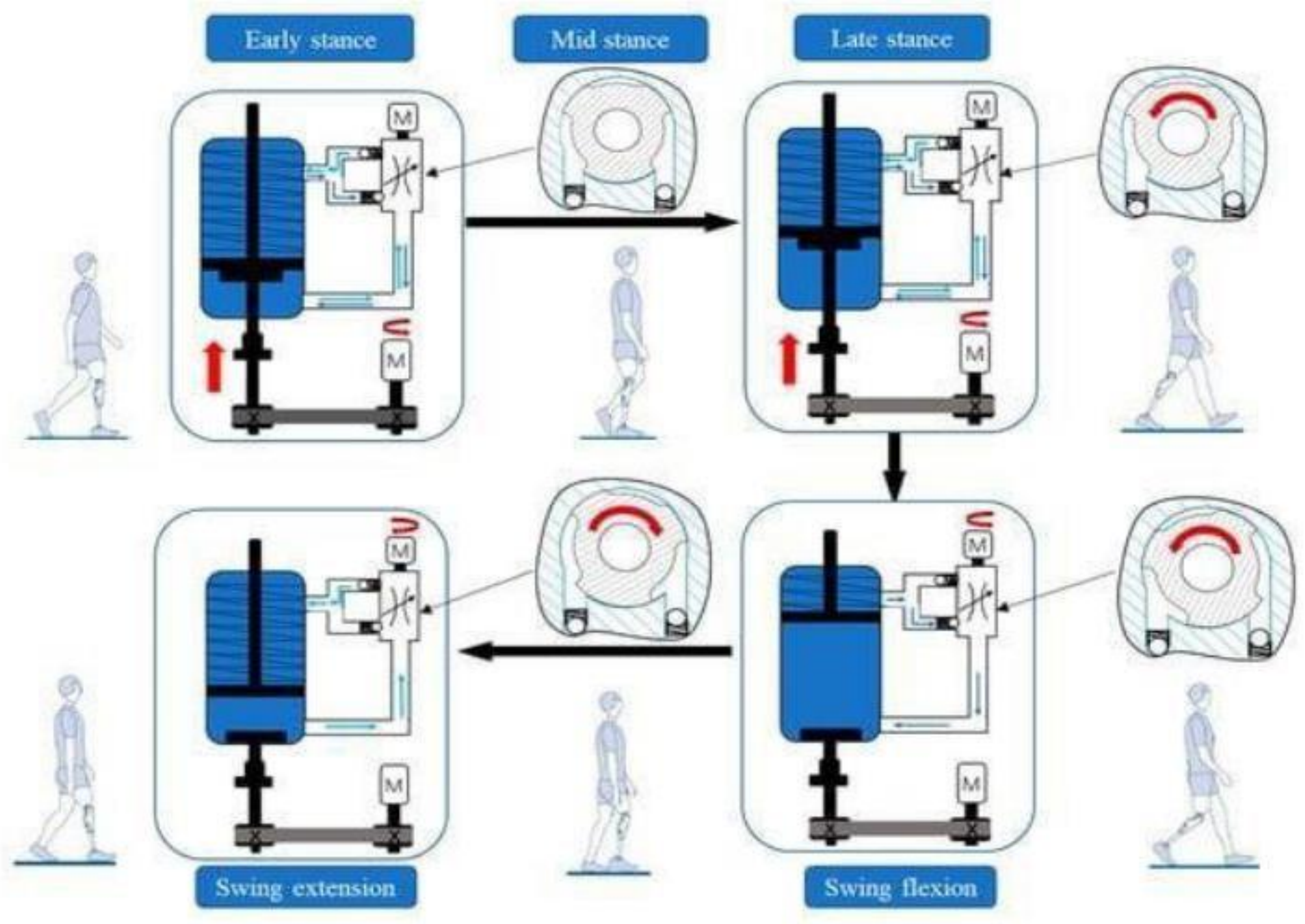


Figure 3:2 The work scheme of the semi-active prosthetic knee[7]

2.3 Characteristics of semi-active prosthetic knee:

There are several advantages of semi-active prosthetic knees compared to traditional prosthetic knees. Some of the key benefits include:[9,5]

1. Improved adaptability: semi-active prosthetic knees use sensors and microprocessors to adjust the knee joint in real-time based on the user's movement and walking speed. This adaptability enables a more natural gait and better stability on various terrains.
2. Enhanced control: the advanced technology in semi-active prosthetic knees allows for better control over the knee joint, making activities such as going up and down stairs, ramps, and uneven surfaces easier and more efficient.
3. Increased comfort: these prosthetic knees offer a smoother and more comfortable walking experience due to their ability to adjust to changing conditions, reducing strain on the user's residual limb and improving overall comfort.
4. Reduced energy expenditure: by providing a more natural walking pattern and improved stability, semi-active prosthetic knees can help reduce the amount of energy expended during walking, leading to less fatigue and increased endurance.

2.4 Type of semi-active prosthetic knee

There are several types of semi-active prosthetic knees that have been developed to enhance the functionality and performance of prosthetic devices. Some common types include:[10]

1. Magnetorheological (MR) dampers: these prosthetic knees use MR fluid within the damper system to adjust damping properties based on user movement and external forces. The viscosity of the MR fluid changes in response to an applied magnetic field, allowing for real-time control of the knee's response.
2. Electrohydraulic actuators: these prosthetic knees incorporate electrohydraulic systems to modulate damping characteristics and provide adjustable resistance during gait cycles. The hydraulic system can adapt to different walking speeds, terrains, and activities, offering improved stability and control.
3. Variable stiffness mechanisms: some semi-active prosthetic knees utilize mechanical mechanisms to vary the stiffness of the joint based on user input and movement dynamics. These mechanisms can adjust the knee's response to changes in walking speed, ground conditions, or inclines, improving overall comfort and efficiency.
4. Sensor-based control systems: many semi-active prosthetic knees incorporate sensors such as accelerometers, gyroscopes, and force sensors to provide feedback on user motion and load distribution. This data can be used to adjust the knee's behavior in real time, optimizing stability, balance, and energy efficiency.

Overall, these different types of semi-active prosthetic knees aim to enhance user comfort, mobility, and natural movement patterns by dynamically adjusting the knee's properties in response to changing conditions. Each type has its own unique features and benefits, allowing for personalized solutions that meet individual user needs and preferences.

CHAPTER THREE

MATHMATICAL MODEL OF SEMI-ACTIVE PROSTHETIC KNEE

Chapter Three

Mathematical Model of Prosthetic Knee

3.1 SYSTEM MODELING

The amputee's swing leg is modeled as a two-link rigid body chain representing the thigh and the shank in sagittal plane motion. The knee is modeled as a hinge joint with the damper in figure(3. 1). The ankle and the center of mass are assumed to be fixed. The subscript 1,2 denotes thigh and shank . $m_i$are mass , a_i are distance from the mass center , $I_i$are moment of inertia in the mass center, $l_i$is the length of thigh, X_h is horizontal movement of hip, and $Y_h$is vertical movement of hip. The equations of motion can be written as:

$Mh(\ddot{h}) + C(h, \dot{h}) + K(h) = Bu$ ……………………...……………………………….……….(1)

$[MM^{11}{}_{21}\, MM^{12}{}_{22}] + [hh^{1}\dot{2}\,] + [CC^{1}{}_{2}] + [KK^{1}{}_{2}] = [^{1}0 \qquad {}^{-}1^{1}]\ [uu_{h}{}^{k}]$

……………………………….……..(2) Where:

M(h)=$[mI^{1}{}_{2}+l_{1}am_{2}{}^{1}\cos a^{12}\,(+h_{1}m-{}^{2}lh^{12}{}_{2}\ ) \qquad m^{2}l^{1}aI_{2}{}^{2}+\cos m({}_{2}ha^{1}{}_{22}- h^{2})]$ …………………….……(inertial matrix)

C(h,$\dot{h}$)=[$m^{2}l^{1}a^{2}\sin(h^{1} - h^{2})h^{2\dot{2}}$] ……………………...….(centripetal and coriolis torques) $-m_{2}l_{1}a_{2}$

$\sin(h_{1} - h_{2})h_{2\dot{2}}$

K(h)=$[(m^{1}a^{1} + m^{2}l^{1})(\cos h^{1}X^{\ddot{h}} + \sin h^{1}\,Y^{\ddot{h}} + \sin h^{1}g)]$ ……………..(Gravitational torque and hip

$m_{2}a_{2}(\cos h_{2}\,X_{\ddot{h}} + \sin h_{2}\,Y_{\ddot{h}} + \sin h_{2}\,g)$

acceleration term)

h=[] h_2
h^1 ………………………………...……………(vector of the thigh and shank angles)

u^h
u=[u_k] ……………………………………………...(input vector of the hip and knee torques)

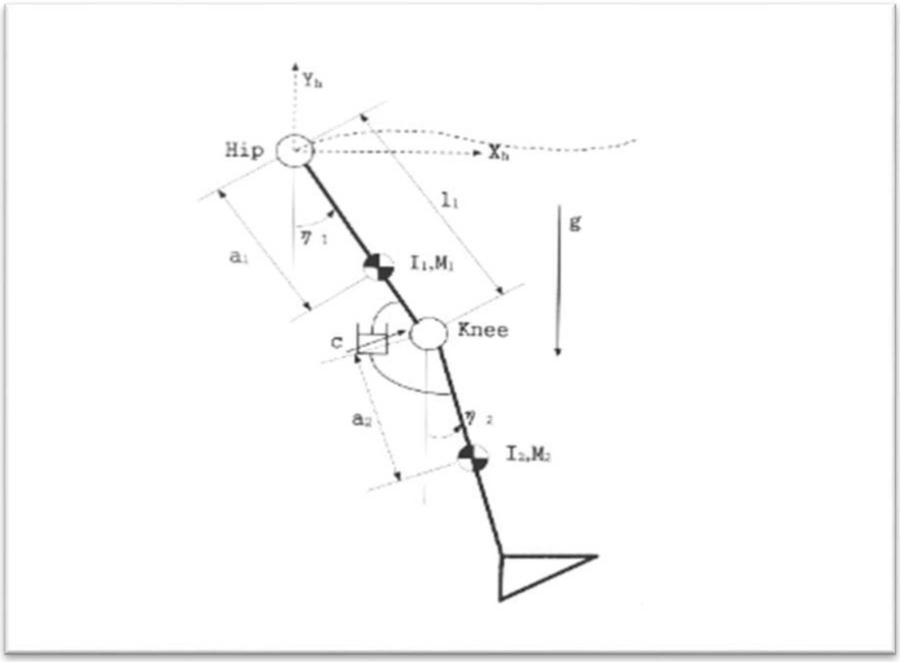


Figure 3:1 The amputee's swing leg model

If it is assumed that the hip torque and the thigh angle are accord with normal person's, all we has to consider in controlling the knee angle is 2nd equation of (1). In our experiment, leg simulator generates hip torque and thigh angle of normal person. So, the equation of motion to be considered is written as:

$u_k = M_{21}h\dot{1} + M_{22}h\dot{2} + C_2(h, \dot{h}) + K_2(h, X\ddot{h}, Y\ddot{h})$ ……………………(3)

Because we assumed that the knee is only composed of the damper, u_k is the torque acting on the damper.

2.3 SIMULINK OF THE SYSTEM BY USING MATLAB

We developed a nonlinear dynamic model based on the prosthetic device. In order to improve the spring constant of our prosthetic leg, we started by creating a nonlinear dynamic model. This involved determining the mathematical relationships between body speed and the force acting on our knee, which acts on the spring system inside the prosthesis. This was then mathematically linked to knee torque and angular velocity, resulting in a model of motion of the prosthetic knee. This model was fed into Simulink where the horizontal movement of hip(X_h), and vertical movement of hip(Y_h)became the input and the vector of the thigh and shank angles (h_1,h_2) is the output.

Within this dynamic model, an important factor was the spring constant (u_k) within the prosthetic knee. Our focus in this laboratory was to optimize the value of k in such a way as to increase the precision of each step and the mechanical efficiency of the prosthesis. We simulated our model over a range of (u_k) values and compared the resulting distance and mechanical efficiencies. After determining the optimal k, we used this in the simulation to verify its accuracy.

3.3 The Simulink of circuit control

-The model before addition of control shown in figure(3,2):

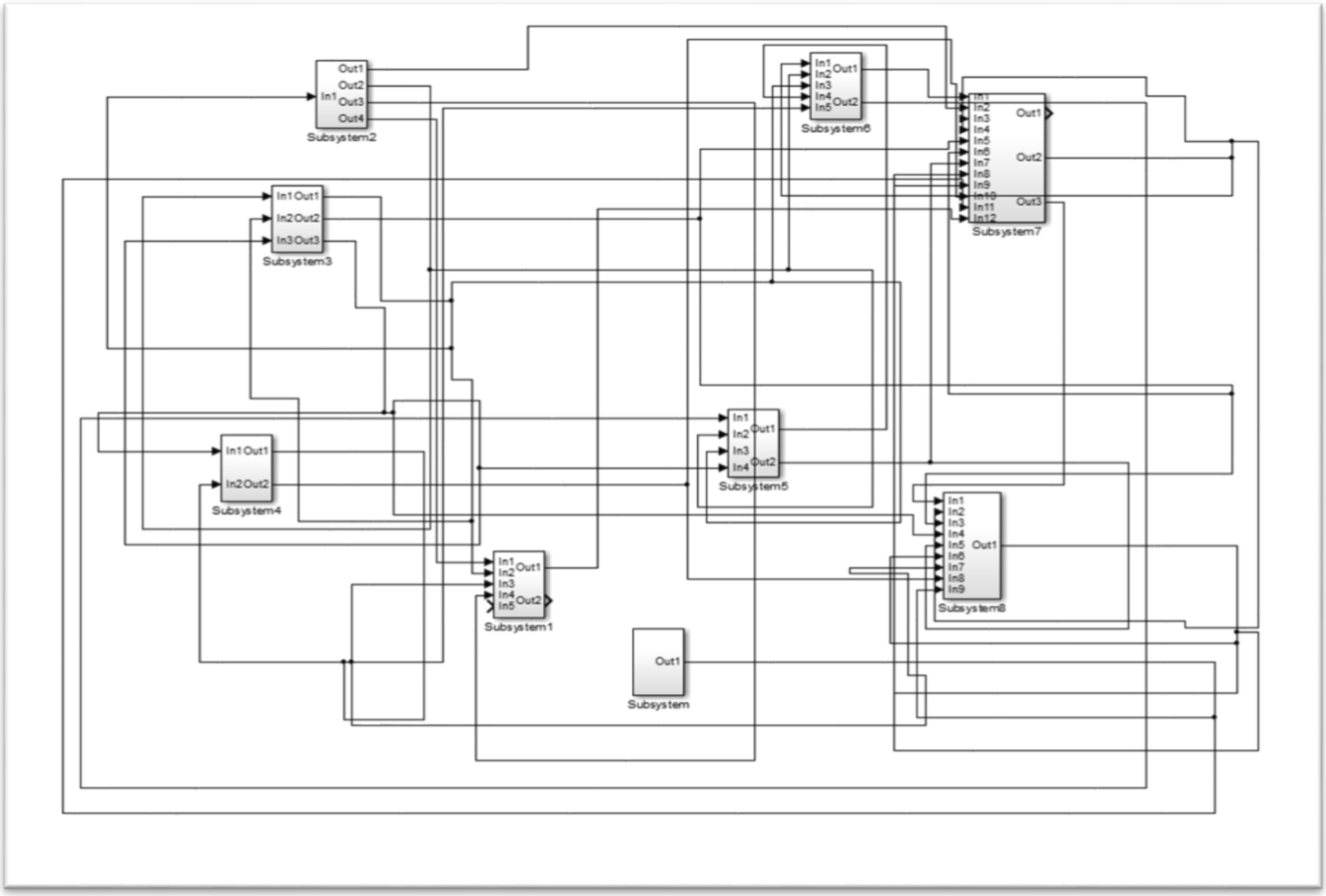


Figure 3:2 the main circuit of the prosthetic knee simulation

3.3.1 The component of this model circuit:

1. simulation the equation of the parameter $[M_{11}]$ shown in figure(3,3):

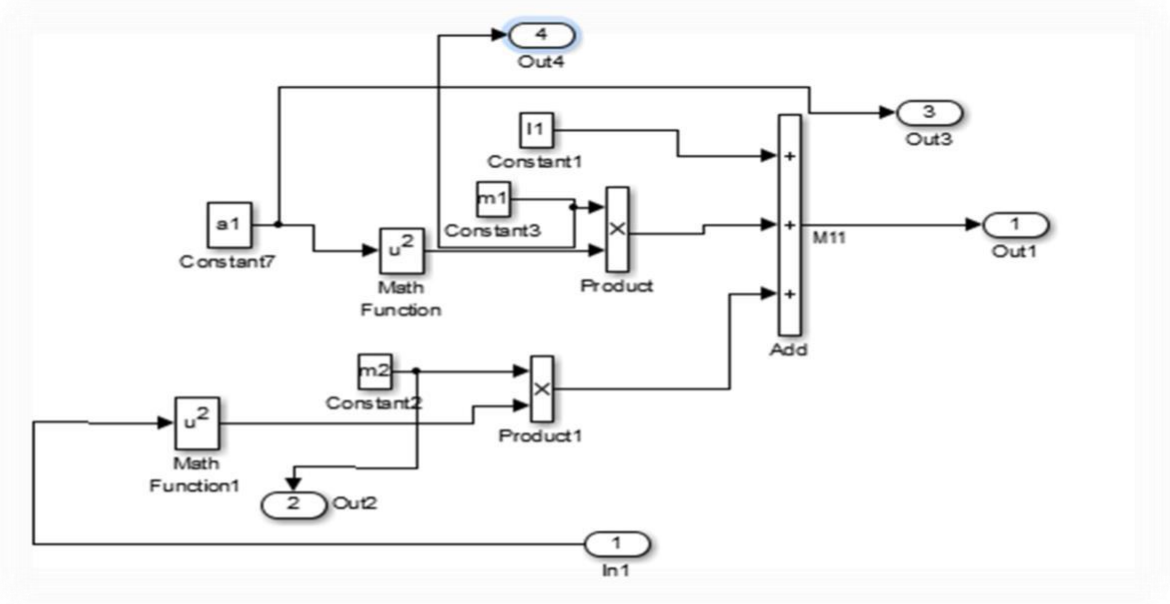


Figure 3 :3 The simulation of $[M_{11}]$

2. the simulation the equation of the parameter$[M_{12}]$ shown in figure (3,4):

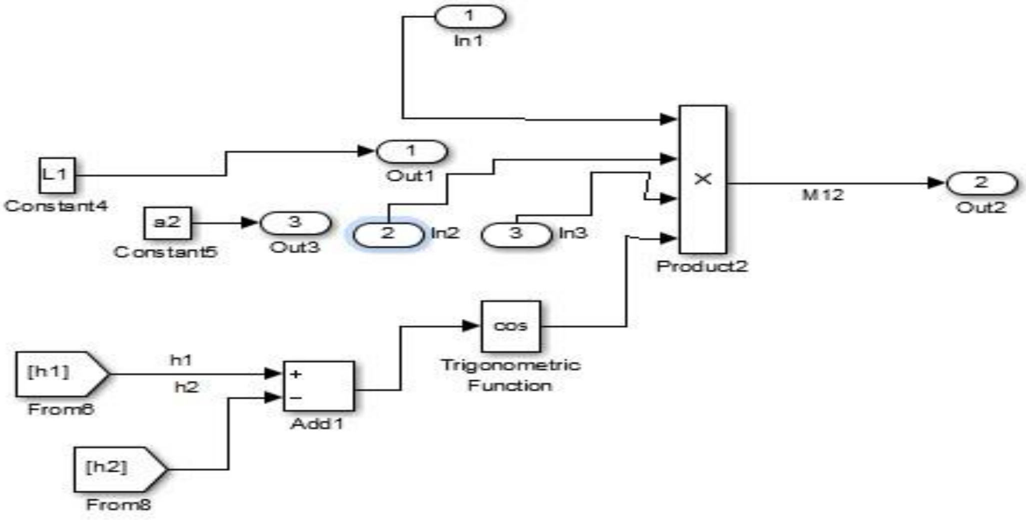


Figure 3:4 The simulation of $[M_{12}]$

3.the simulation of equation of the parameter$[M_{22}]$ shown in figure(3,5):

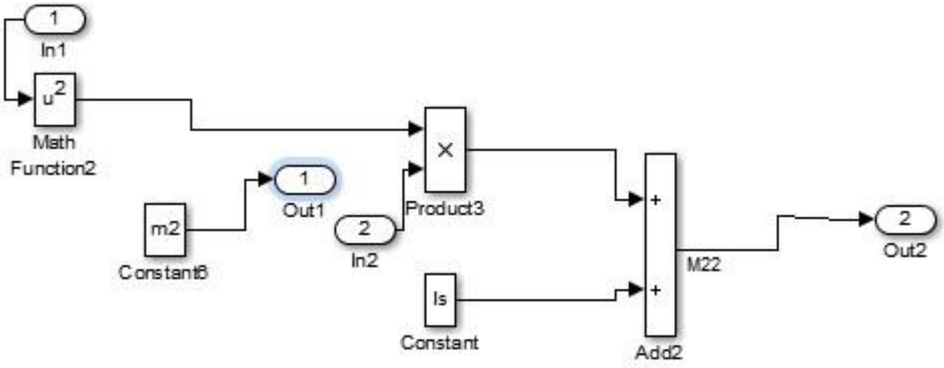


Figure 3:5 The simulation of $[M_{22}]$

4.the simulation of equation of parameter $[C_1]$ shown in figure (3,6):

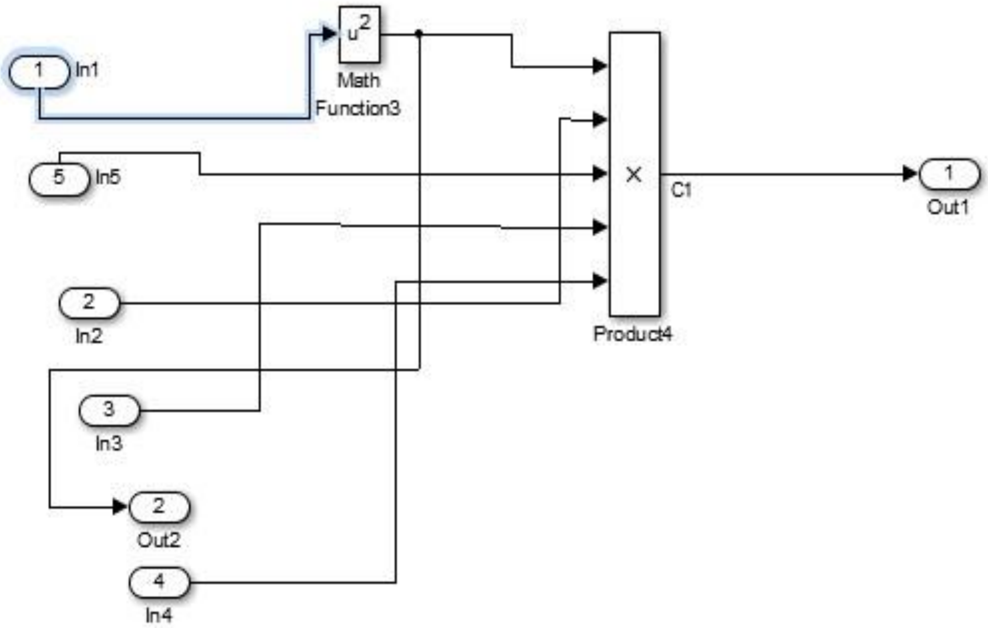


Figure 3:6 The simulation of $[C_1]$

5.simulation the equation of the parameter$[C_2]$ shown in figure(3,7):

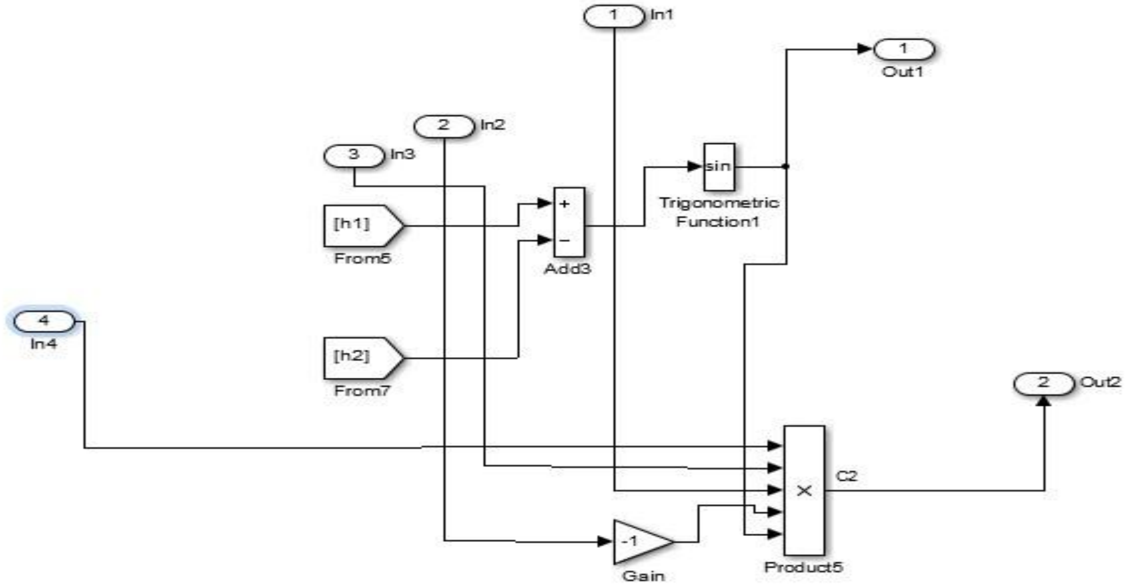


Figure 3:7 The simulation of $[C_2]$

6. simulation the equation of the parameter$[K_1]$ shown in figure (3,8):

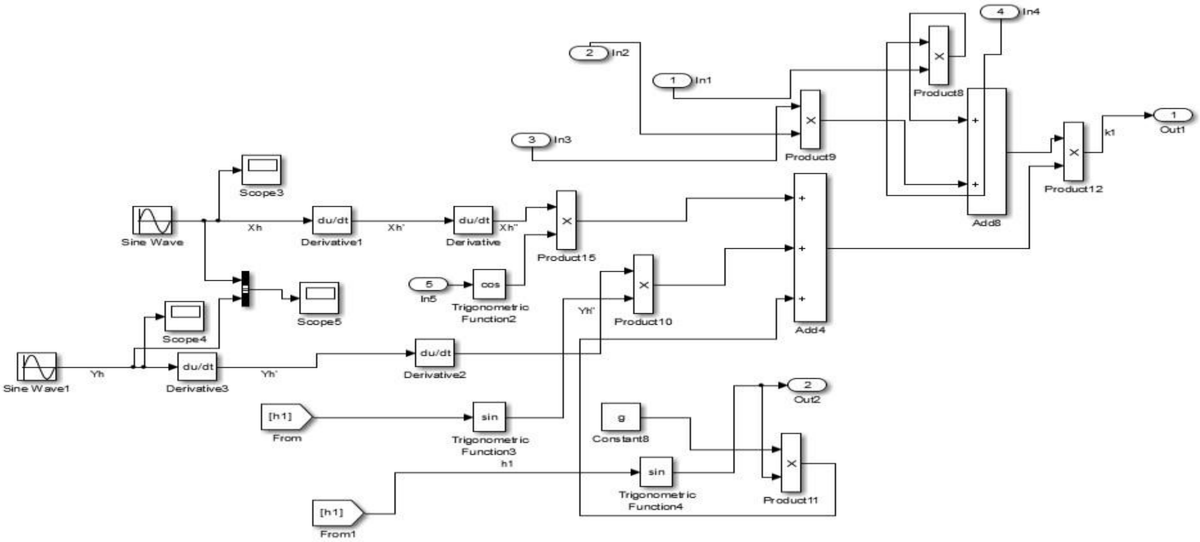


Figure 3:8 The simulation of$[K_1]$

7.simulation the equation of the parameter$[K_2]$ shown in figure (3,9):

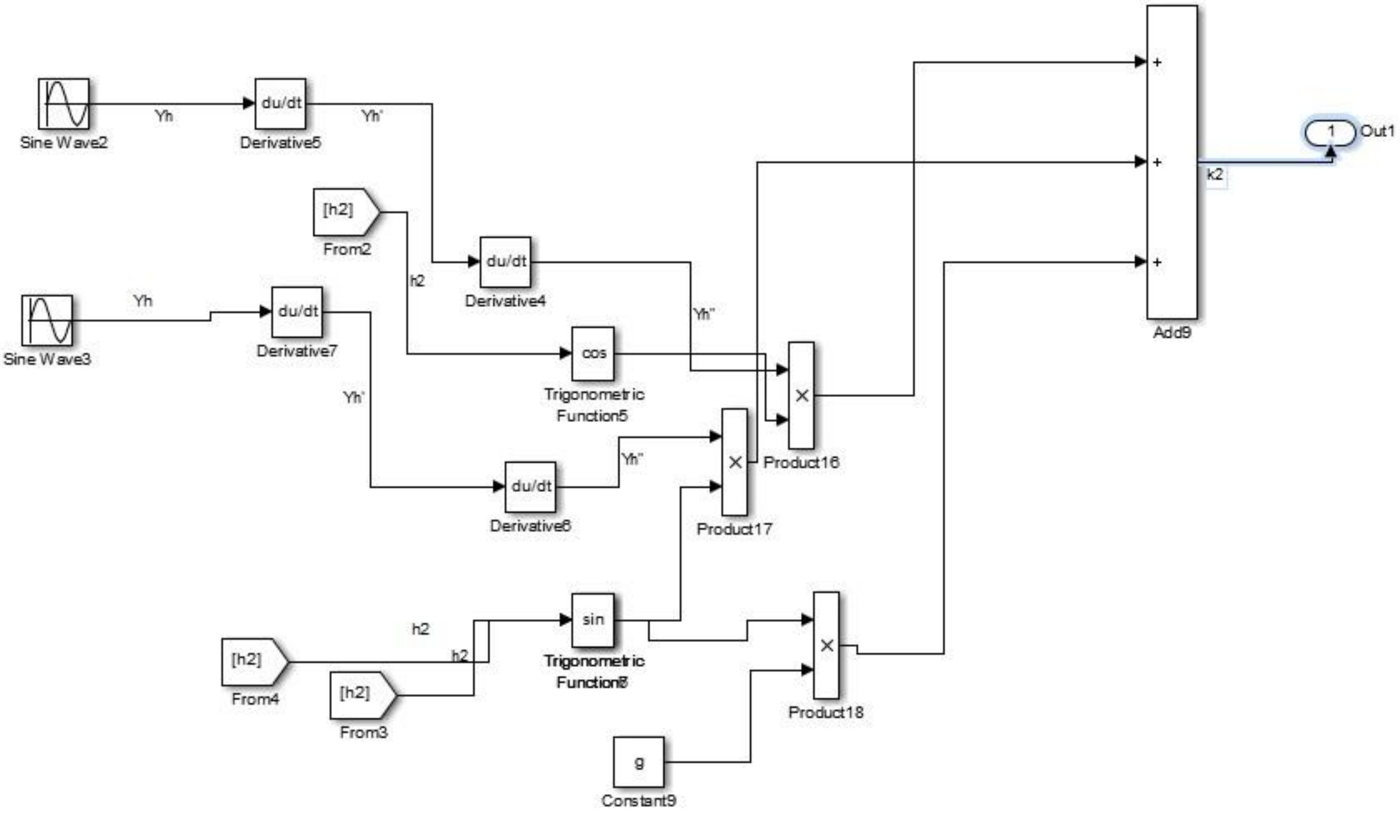


Figure 3: 9 The simulation of $[K_2]$

8.simulation the equation of the parameter $[h_1]$ shown in figure(3,10):

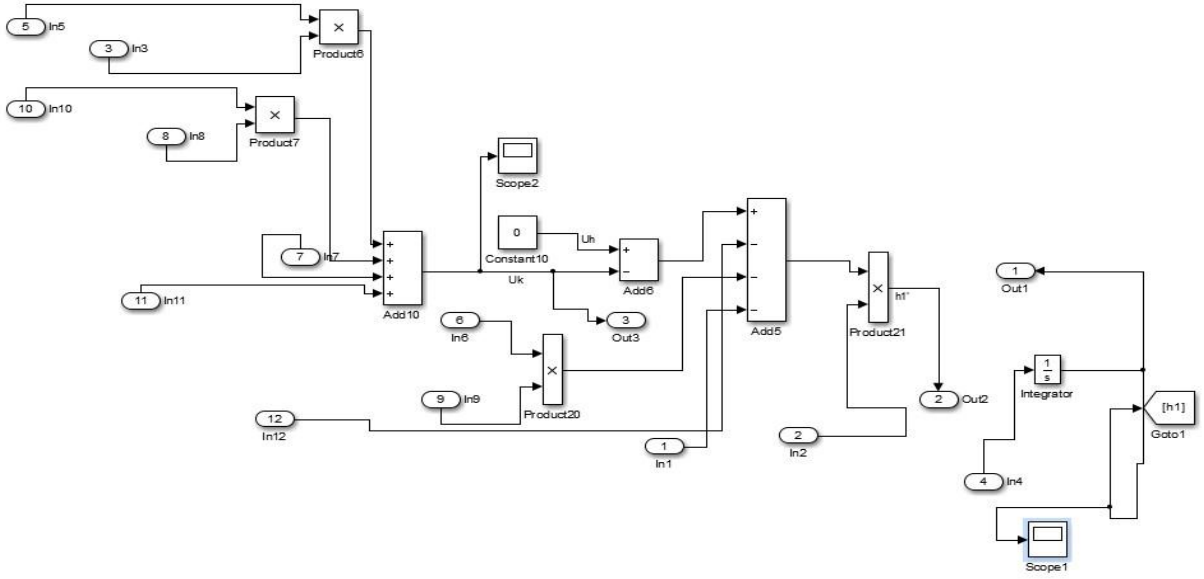


Figure 3: 10 The simulation of $[h_1]$

9.simulation the equation of the parameter $[h_2]$ shown in figure (3,11):

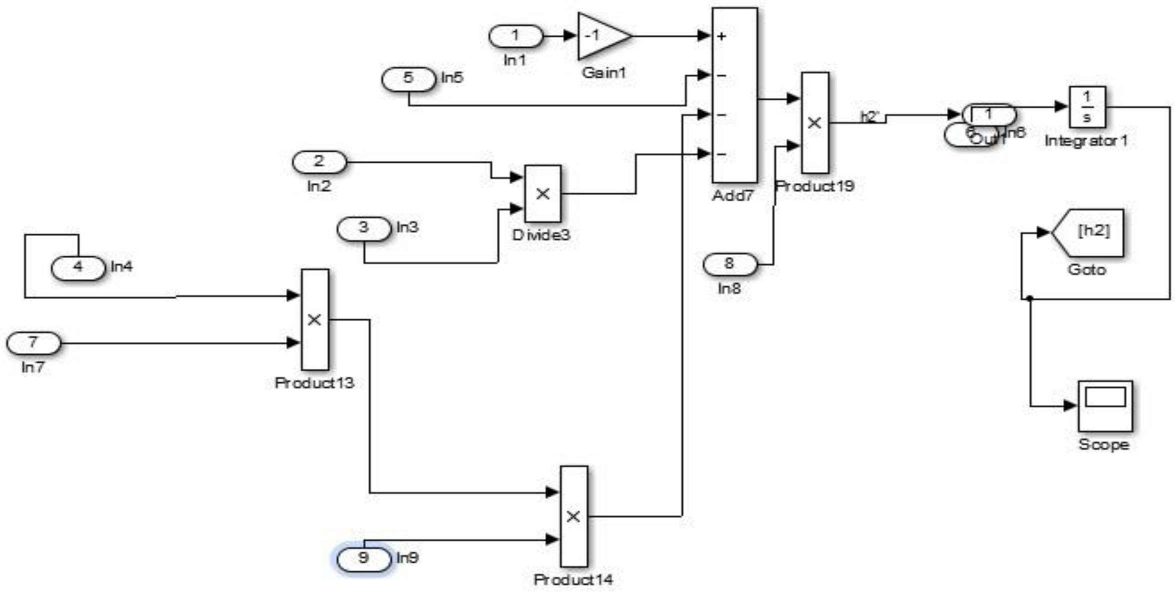
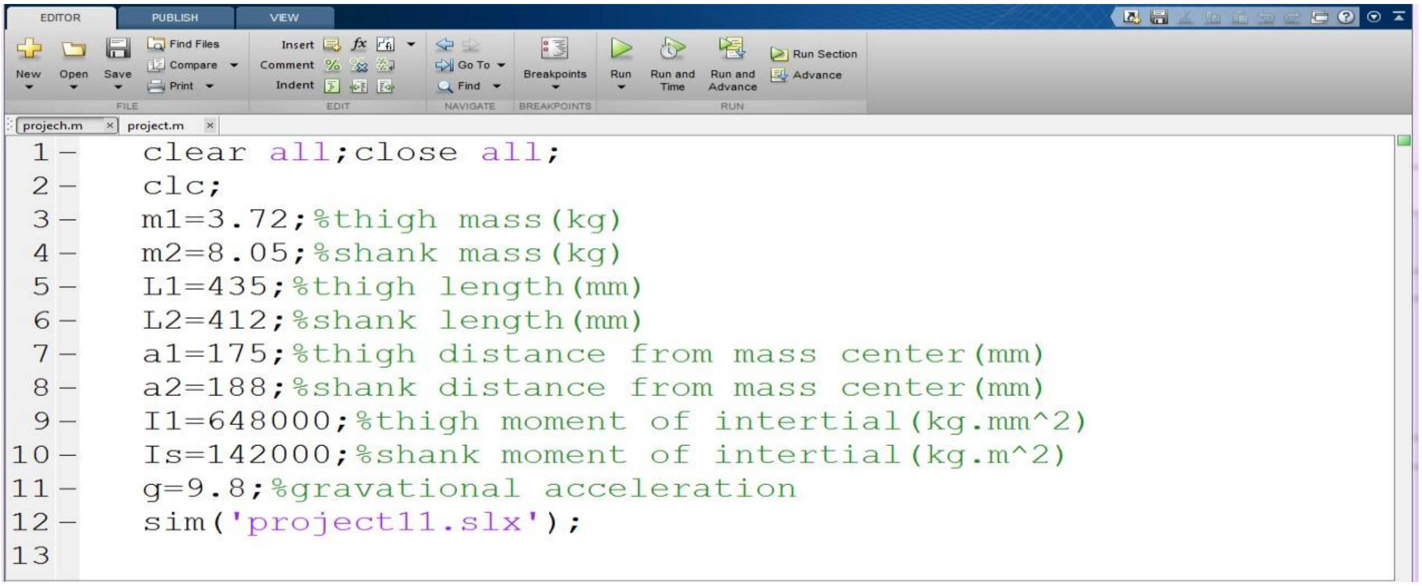


Figure 3:11 The simulation of[h_2]

-The m-file of this circuit:



```
clear all;close all;
clc;
m1=3.72;%thigh mass(kg)
m2=8.05;%shank mass(kg)
L1=435;%thigh length(mm)
L2=412;%shank length(mm)
a1=175;%thigh distance from mass center(mm)
a2=188;%shank distance from mass center(mm)
I1=648000;%thigh moment of intertial(kg.mm^2)
Is=142000;%shank moment of intertial(kg.m^2)
g=9.8;%gravational acceleration
sim('project11.slx');
```

Figure 3:12 the m-file of the simulation circuit

CHAPTER FOUR
RESULTS

Chapter Four Results

4.1 RESULT THE SIMULINK OF MODEL

After we modeled the model and we ran the circuit, the results was four signals, two input signals(X_h, Y_h) and two output signals(h_1, h_2).

The input signal(X_h,Y_h) shown in figure (4,1),(4,2):

The signal X_h is horizontal movement of the hip that we obtained through the work simulation for the model circuit ,as it represents one of the inputs of the circuit.

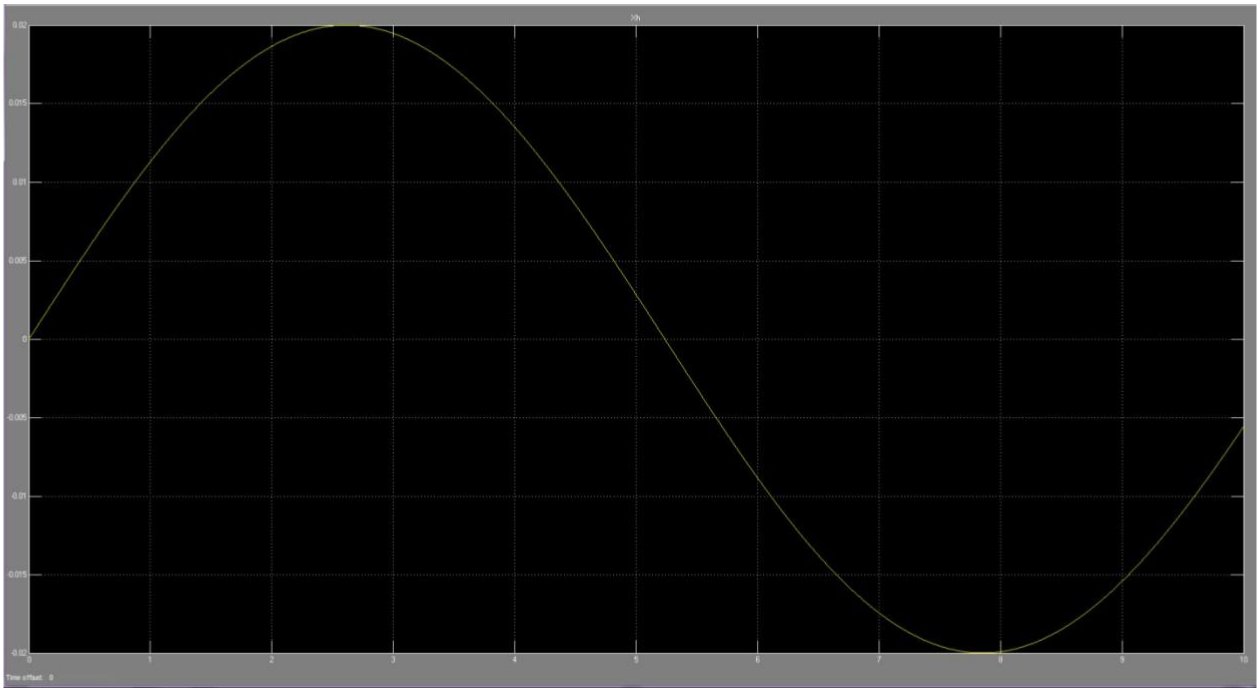


Figure 4:1 The signal of(X_h)

The signal Y_h is vertical movement of the hip that we obtained through the work simulation for the model circuit ,as it represents one of the inputs of the circuit.

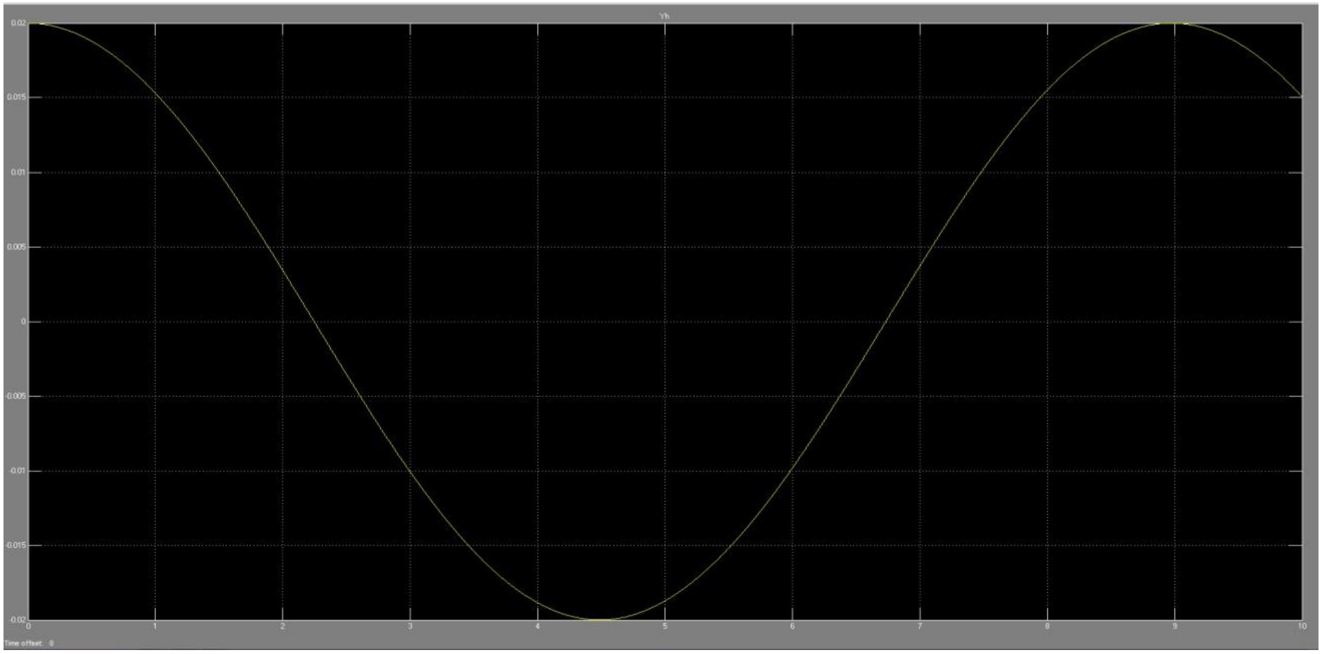


Figure 4:2 The signal of (Y_h)

The output signal (h_1, h_2) shown in figure (4,3),(4,4):

The signal $h_1$is angle of the hip that we obtained through the work simulation for the model circuit ,as it represents one of the output of the circuit.

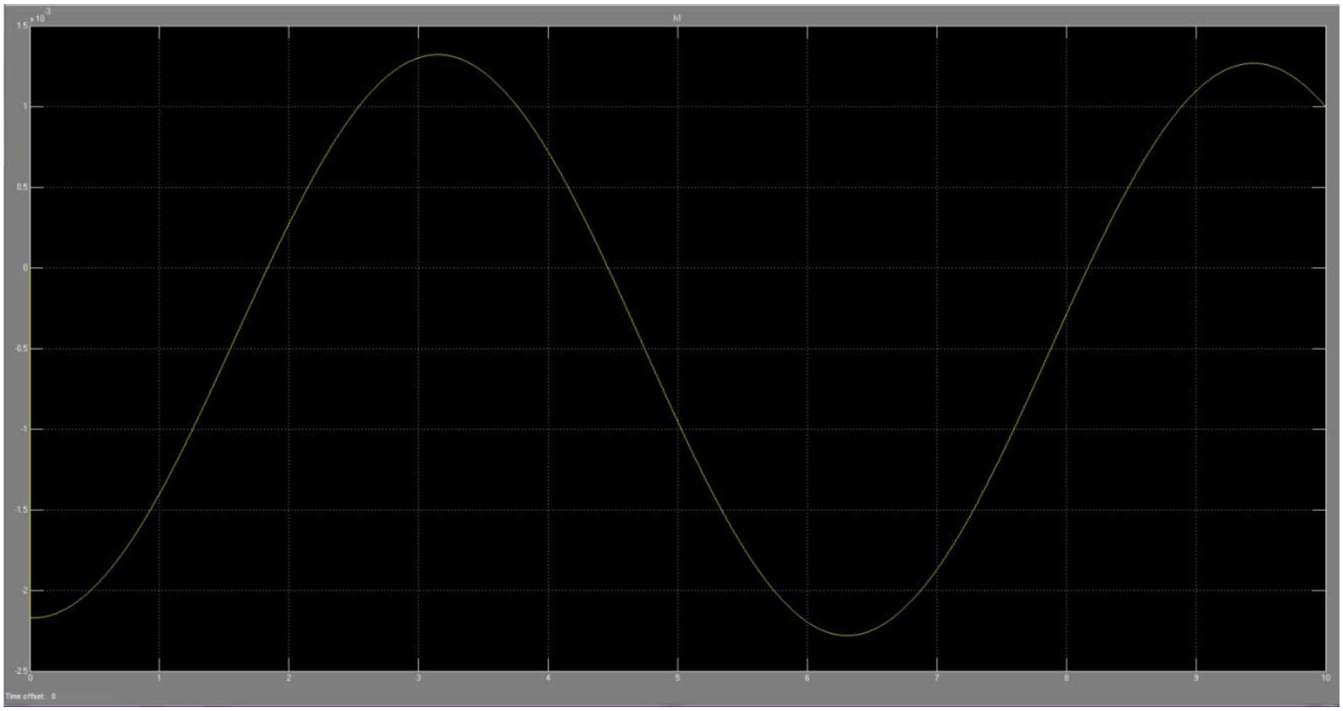


Figure 4:3 The signal of (h_1)

The signal h_2 is angle of the shank that we obtained through the work simulation for the model circuit ,as it represents one of the inputs of the circuit.

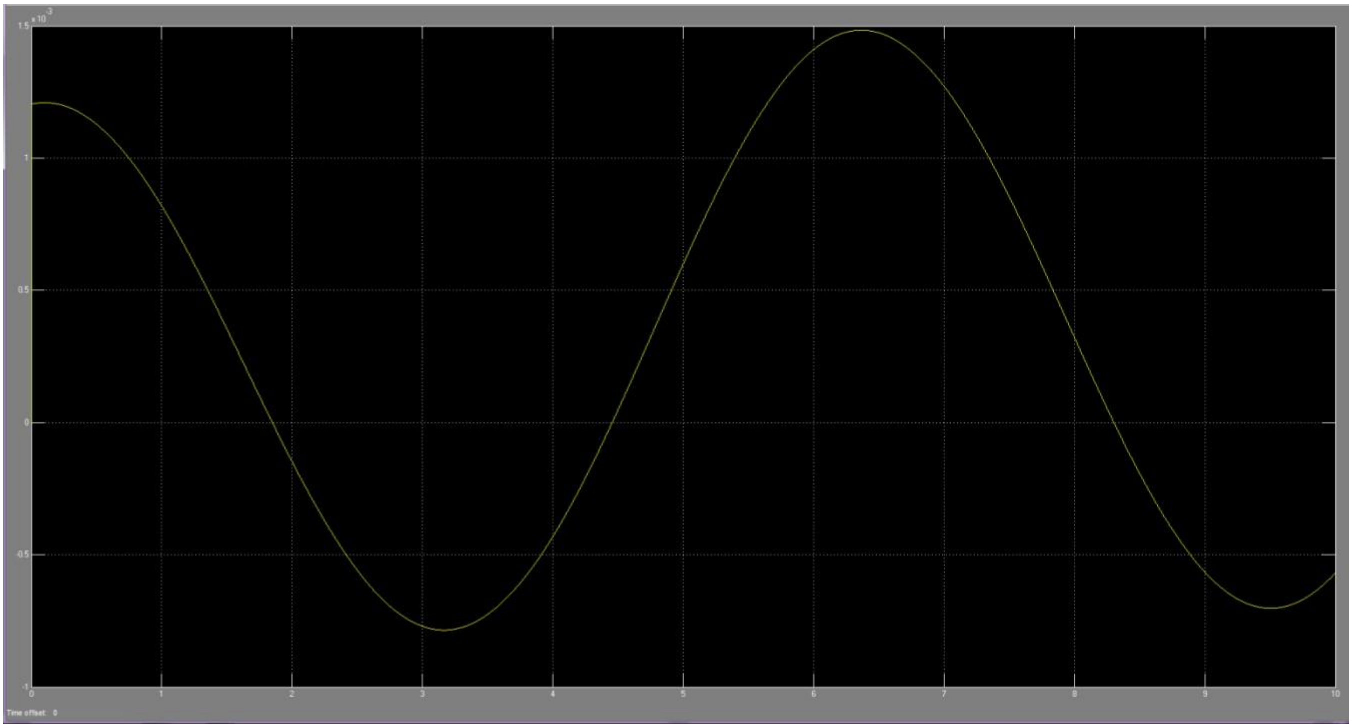


Figure 4:4 The signal of (h_2)

CHAPTER FIVE

CONCLUSION

Chapter Five

Conclusion

5.1 Conclusion

In conclusion, the development of semi-active prosthetic knees using Simulink offers a promising method for advancing the field of prosthetics. Simulink provides a powerful platform for designing, simulating, and optimizing control algorithms that can enhance the performance, functionality, and user experience of prosthetic knees.

By leveraging Simulink's capabilities, researchers can model complex biomechanical systems, design adaptive control strategies, integrate sensor feedback, optimize energy efficiency, and conduct human-in-the-loop simulations. These tools enable a more comprehensive understanding of the interactions between the prosthetic knee, user movements, and external forces, leading to improved designs and user outcomes.

The use of semi-active damper in prosthetic limb seems to be advantageous as it is able to offer a wide dynamic range of damping force. This research utilizes magnetorheological fluid (MRF) damper that is able to provide variable damping, based on the amount of magnetic field induced in the fluid. The implementation of MRF damper in prosthetic limb is aimed at reducing injuries and gives comfort to the amputees, due to its adapt ability to the ground and impact.

Overall, the use of Simulink in the development of semi-active prosthetic knees holds great potential for driving innovation, improving control algorithms, and ultimately enhancing the quality of life for individuals with limb loss .Continuing research and development efforts in this area are crucial for realizing the full benefits of advanced prosthetic technologies.

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