LEVER-CHAIN MECHANISM DESIGN FOR ALL TERRAIN WHEELCHAIR

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A project report submitted
in fulfilment of the requirements for the degree of
Bachelor Mechanical Engineering (with Honours)

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2019

DECLARATION

"I hereby declare that this report is the result of my own work except for quotes as cited in the reference".

Signature: ……………………………………………….

Author: ……………………………………………….

Date: ……………………………………………….

SUPERVISOR’S DECLARATION

I hereby declare that I have read this report and in my opinion this report is sufficient in terms of the scope and quality for the award of Bachelor of Mechanical Engineering

Signature :...................................

Name of Supervisor :...................................

Date :..................................

DEDICATION

بسم الله الرحمن الرحيم

I would like to dedicate my project to my beloved mother, father, and my family members who gave me never ending affection, love, encouragement and pray of day and night throughout this Final Year Project.

ACKNOWLEDGEMENT

بسم الله الرحمن الرحيم

First of all, I would like put the highest of praises and gratitude to Allah SWT for allowing me to complete this project with manageable complications. I am grateful and would like to express my sincere appreciation to Mr. Wan Mohd Zailimi Bin Wan Abdullah for providing tremendous technical guidance, advices, continuous encouragement, constructive criticisms, suggestions and glorious knowledge throughout the completion of this project. I would also like to express my sincere gratitude towards my parents Ghazali Bin Johan and Shamshihar Binti Mohd Ibrahim for their love, dream, and sacrifice throughout my life. Special thanks to my brothers and sisters for support and motivation. Next, I would like to thank my friends and classmates as their comments and suggestions were crucial for the completion of this project. Finally, I would like to thank to my beloved faculty, Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka for give the chance to this valuable experience throughout this project.

ABSTRAK

Makalah ini merangkumi reka bentuk dan kajian pergerakan pada reka bentuk mekanisme rantaian tuas untuk kerusi roda semua rupa bumi. Kerusi roda konvensional dilaporkan bertanggungjawab terhadap kesakitan muskuloskeletal di bahagian atas badan. Oleh itu, terdapat pelbagai teknik dan mekanisme yang digunakan dalam peningkatan kerusi roda konvensional. Penyelidik atasan telah mencipta dan fabrikasi kerusi roda yang dimajukan oleh tuil dan menjual kerusi roda mengikut keperluan pasaran. Segelintir Orang Kurang Upaya (OKU) yang tinggal di kawasan luar bandar tidak mampu untuk memiliki kerusi roda untuk mereka melakukan aktiviti dan keperluan asas mereka. Kertas penyelidikan ini bertujuan untuk mengembangkan kerusi roda rantai berkuasa oleh tuil yang mempunyai kos mekanisme yang terendah dari segi penyelenggaraan yang memudahkan kerusi roda diperbaiki di mana-mana di kedai basikal. Selain itu, kajian gerakan melalui Solidworks telah dilakukan untuk memastikan kerusi roda rantai tuil berkesan dalam kelebihan dan kecekapan mekanikal. Oleh itu, dalam reka bentuk ini tuil digunakan untuk menghantar daya untuk menggerakkan kerusi roda dan bukannya menggunakan daya pada menolak rim tayar. Kerusi roda ini di reka bentuk untuk melakukan daya yang terendah untuk pergerakkan yang lebih. Ia juga untuk mengurangkan kos daripada kerusi roda yang canggih dan maju seperti kerusi roda elektrik dan kerusi roda bermotor. Bahagian asas dalam basikal digunakan dalam kerusi roda ini untuk memastikan pemancuan mekanisme asas seperti gegancu dan gegancu berkunci yang memancarkan pemacu kuasa melalui rantai yang berputar sepenuhnya dimanfaatkan. Mekanisme merupakan mekanisme yang paling murah, mudah dijaga dan juga diperbaiki.

ABSTRACT

This paper includes design and motion study on lever-chain mechanism design for the all-terrain wheelchair. The conventional wheelchair is reported to be responsible for musculoskeletal pain in the upper limbs. Therefore, there are various technique and mechanism utilized in the improvement of a conventional wheelchair. A researcher has developed a lever propelled wheelchair and fabricated the wheelchair according to the market needs. Some of the Person with Disabilities (PWD) who lived in rural areas cannot afford to own a wheelchair. This work aimed to develop a lever chain wheelchair that has the lowest cost mechanism and easy maintenance which the wheelchair can be repaired anywhere in the bicycle shop. Moreover, motion study through Solidworks has been done to ensure the lever chain wheelchair are purposely efficient in mechanical advantage and mechanical efficiency. So in this design, the lever is used to transmit the force to move the wheelchair instead of applying the force on push rim. This wheelchair is designed in such a way that requires less effort for more movement and it cheaper than the advanced wheelchair such as an electric wheelchair or motorized wheelchair. Basic part in a bicycle is used in this wheelchair to ensure the basic mechanism sprocket and freewheel that transmit the power drive through rotating chain are fully utilized. This mechanism is far most the cheapest mechanism and easy to maintain and repaired.

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LIST OF ABBREVIATION

WHO	World Health Organisation
PWD	Person with Disabilities
VR	Velocity Ratio
QFD	Quality Function Deployment
HOQ	House Of Quality
PDS	Product Design Specification

LIST OF SYMBOL

N = Number of teeth

D = Pitch diameter

ρ = Chain pitch

C = Centre distance

L = Chain length

θ = Angle of contact

ω = Angular speed

v_c = Chain speed

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Disability can represent different meanings to different individuals. Generically, in Malaysian Person with Disabilities Act 2008 defines disability as having long- term physical, mental, intellectual or sensory impairments that may impede their full and effective participation in society in interaction with various barriers.

World Health Organization (WHO) statistics stated that it is estimated that 5–10% (1.3–2.6 million) of the world's population are Person With Disabilities (PWD). Department of Statistics Malaysia reported that the total population of Malaysia was 26.64 million people in 2006. From the total population, PWD is around 1.3–2.6 million. However, only 220 to 250 PWDs were registered with the Social Welfare Department in December 2007. Due to the increasing number of population, lifespan, and the total number of road and industrial accidents, the number of PWD also predicted to be increasing. The total number of the elderly population in Malaysia is estimated to increase from 1.73 million (6.6%) in 2005 to 3.8 million (11.3%) in 2020. Because of that, the number of people will use a wheelchair reportedly to be increasing. (Rahim, Amirah, and Samad, 2010).

There are types of wheelchair exist in this world which has been done by the researcher day by day. They inventing advancement in every sector that possible bring ease to the patient. Improvement were made to the wheelchair with various design which lead to a conventional wheelchair to an advanced wheelchair for easier use and without burden the disable person more often.

Figure 1.1 : Normal wheelchair

Figure 1.2 : Electric wheelchair


Figure 1.3 : Voice controlled wheelchair


Figure 1.4 : Lever-chain wheelchair

This priority of this paper is to introduce the wheelchair which not required any external assistance to be moved. The patient must be able to operate the wheelchair using his/her comfortably and independently. The patient will require less effort but more efficient to move than conventional wheelchair. This paper included a wheelchair that is affordable and versatile to be used. The wheelchair also can be used in varies terrains and hence accessible to a complex diversity.

1.2 PROBLEM STATEMENT

Wheelchair propulsion has been reported to responsible for musculoskeletal pain on the upper terminus. A wheelchair is one of the most efficient tools to help the patient lead normal lives by enabling them to carry out their daily activities. However, musculoskeletal problems are often associated with conventional manual wheelchair propulsion. (Sarraj and Massarelli, 2011). Rough terrain such as rocky, sand, grass and also uphill road are the major problem facing in the countryside such as India and Africa. The conventional wheelchair will burden the patients that require more effort for more movement to that kind of terrain. Hand rim wheelchair propulsion will not adapt these rough terrains normally. This paper will solve all terrains problem to give more efficiency with less effort on the wheelchair to ease the patient to move and perform their daily activities. This project is rarely seen in Malaysia due to unawareness from the villages or rural areas. This might help the poverty in Malaysia to be able to buy a cheap but efficient wheelchair to lighten the burden and make life easier.

1.3 OBJECTIVE

The objectives of this project are as follows:

1. To design a mechanism to use in all terrain wheelchair by using a lever-chain mechanism.
2. To analyse lever-chain mechanism wheelchair.

1.4 SCOPE OF PROJECT

The scopes of this project are:

1. This project will design, develop, and analyse an assistive mechanism to assist a person with a disability to be able move the wheelchair on all terrain.
2. To analyse the mechanical efficiency of mechanism used in lever-chain mechanism wheelchair.
3. To design and study the motion analysis using CAD software which is Solidworks.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION TO LEVER CHAIN WHEELCHAIR

Lever-chain wheelchair propulsion has been proposed worldwide since quite a while. These wheelchairs have helped many disabled person in terms of financial and physical mobility to do daily activities especially in India. Typical design consisted of two sprocket-connected levers that rotate freewheel connected to the wheelchair rear wheels, similar to the one used in the steam engine. In addition, lever- propelled wheelchairs are designed with manually operated push levers from the patient himself, which transfer force through the transmission mechanism to the wheels. Hence, the patient requires healthy upper limbs and strong musculoskeletal to operate this lever-propelled wheelchair.

The wheelchair designed used in this study is three-wheeled lever chain wheelchair which designed for all terrain purpose. The main purpose of this study is lever mechanism is to carry maximum load in minimum efforts. Furthermore, the patient will require less effort for more movement of the wheelchair. By using lever, it increases the velocity of the wheelchair with less force needed.

2.2 COMPARISON BETWEEN CONVENTIONAL AND LEVER CHAIN WHEELCHAIR

2.2.1 Conventional Wheelchair

Over the past several years, there has been increasing interest in wheelchair among the inventers and designers. This is due to significant high demand from the customer as the increasing of disable person in this worldwide. People are aware about conventional wheelchair with hand rim propulsion but in advanced technology, people began to demand a futuristic design with new technology for ease people lifestyle. Conventional wheelchair are widely used in hospital because of sturdy, durable and comfortable, accommodate long period of sitting. Moreover, manual wheelchair light in weight for easier to move and carry. In propulsion aspect, conventional wheelchair has good indoor portability and it is easy to steer in forward and backward direction but for turning it requires high initial force to move. (Bhende *et al.*, 2017).

In general, conventional wheelchair propulsion is divided into two phases which completed one full cycle: drive phase and recovery phase. These propulsion techniques become most important issue to the user because they wanted to reduce the incident occur in upper extremities. The disadvantages for manual wheelchair that it cannot use for outdoor due to inefficiency for rough terrain like grass, sand surface, rocky places and ramps. (Bhende *et al.*, 2017). Due to that, hand rim wheelchair is an ineffective form of human movement. The hand rim wheelchair will result in relatively high tension on cardiorespiratory and musculoskeletal systems, as well as high energy consumption, high heart rate and low mechanical performance. (van der Woude *et al.*, 1997). Figure 2.1 shows the effect on upper body from hand rim wheelchair locomotion.

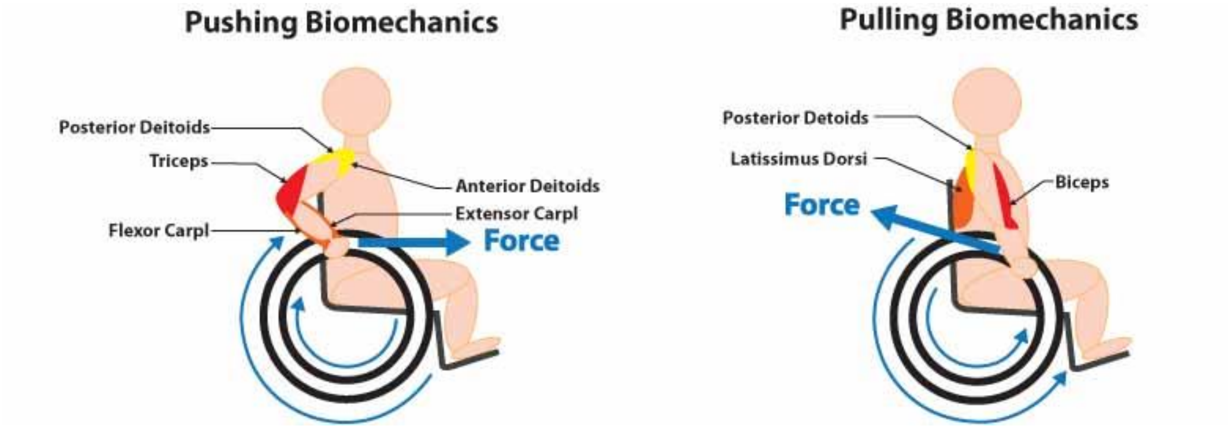


Figure 2.1 : Effect on upper body from hand rim wheelchair locomotion (Jameslacchian aresearch, 2012)

From figure 2.1, forward propulsion seems to propel in wrong movement in upper body. Soon, the upper body will permanent damage that lead to worsen shoulder. Upper body areas are not designed for heavy activity especially for long time period. Musculoskeletal problem issue are commonly related to biceps and triceps muscle which often damage the muscle due to extreme force given to the wheelchair.

It is actually pulling the wheel backward motion give less damage to your body with certain angle of hand position because the muscle can tolerate greater tension and have the ability to develop to cope with strong activity.

Shoulder damage does not simply end only in the wheelchair but the damage continues when the patient wants to perform their daily life such as reaching or grabbing things. Shoulder injuries can be harmful to user and their independence.

2.2.2 Lever-Chain Wheelchair

Lever propelled wheelchair is introduce to solve mechanical advantages and mechanical efficiency problems faced by conventional wheelchair. Lever chain wheelchair operates using two levers that connected to the sprocket as the mechanism to push the force to rotate the chain and generate the freewheel that connected to rear wheel. Figure 2.2 below shows simplified 2D depiction on how lever chain wheelchair operates.

Figure 2.2 : 2D depiction on lever chain wheelchair operates

The advantages of lever chain wheelchair are the propulsion of moving the wheelchair. According to (Lui *et al.*, 2013), the study conclude that lever-propulsion mechanism are more efficient in term of mechanical advantages compared to conventional wheelchair. Particularly, study found that higher mechanical efficiency on lever-propelled wheelchair compared to hand rim wheelchair. (van der Woude *et al.*, 1997). Figure below shows LFC which is lever-chain prototype mechanical advantages that taken for research purpose.

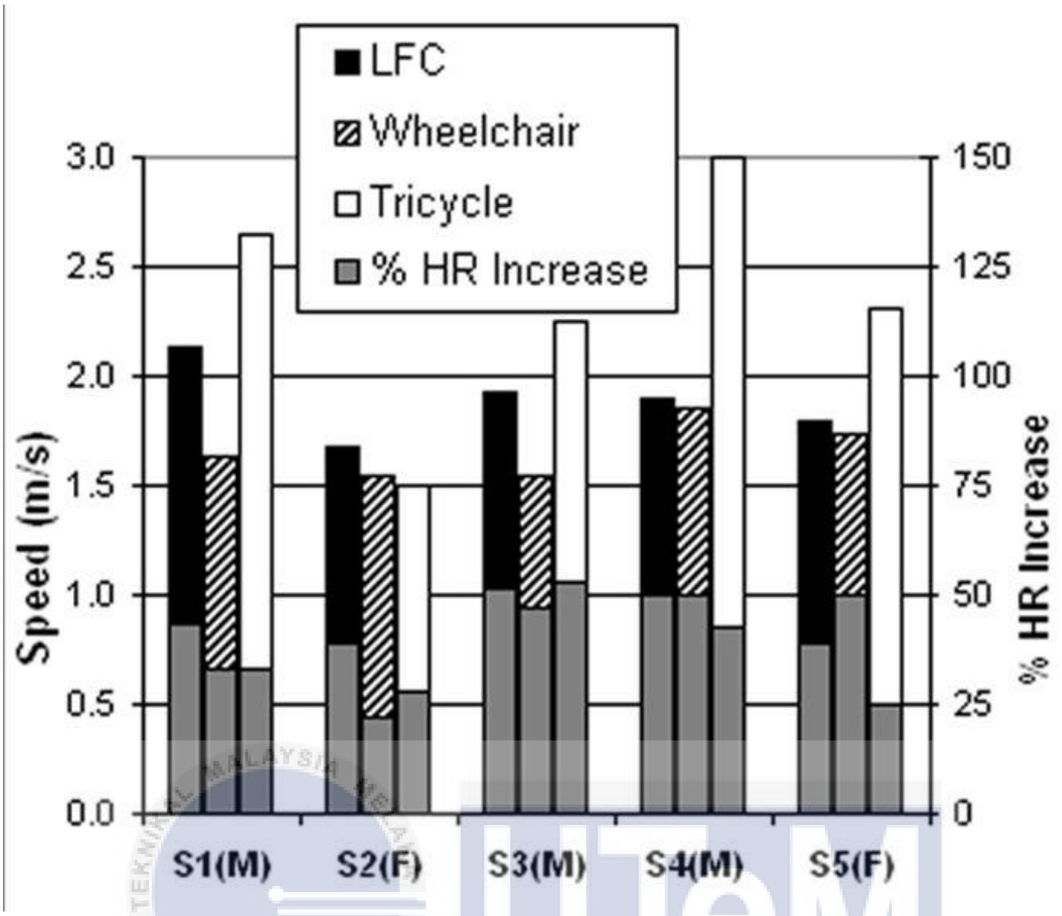


Figure 2.3 : Bar graph on mechanical advantages

In aspect of terrain effectiveness, disadvantages for conventional wheelchair that is it cannot use for outdoor due to inefficiency for rough terrain like ramps, rocky places, sand surfaces, and grass because it need more force to push the rim. Lever chain wheelchair shows that force needed to move on rough terrain is less and smooth. Most of these cases are suitable for people living in rural areas especially in India.

For some cases, moving the lever chain wheelchair on rough terrain consist the right way of handling the lever. This fundamental mechanics of position the hand lever divided into two ways: High gear and Low gear. This advantage for lever chain wheelchair because it can operate the freedom lever with suitable force and speed. This can be seen in Figure 2.3.

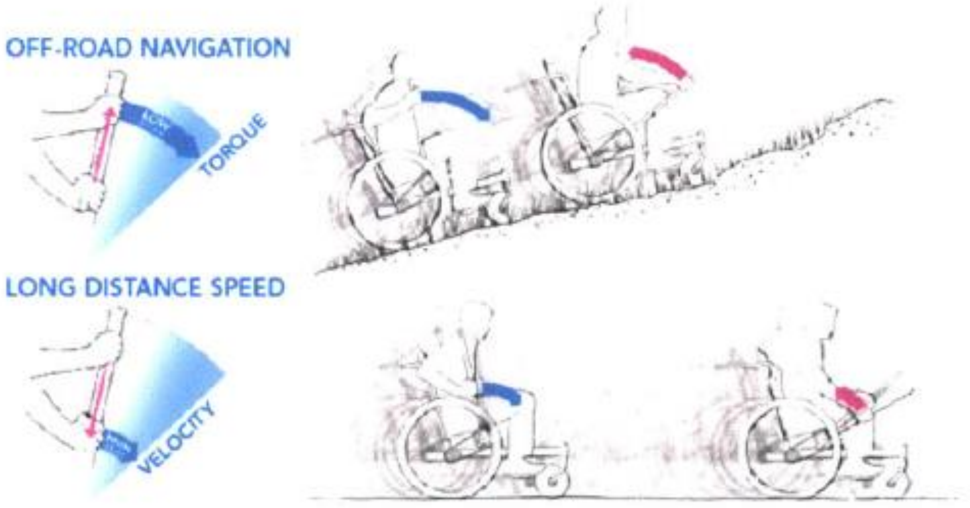


Figure 2.4 : Variable mechanical advantages drivetrain (Walton, 2011)

The action above shows high torque if hand placement is on high gear due to off-road navigation. This is suitable for incline road because distance between hand and origin point of the lever create more force and high torque to complete the cycle. The energy from upper limbs helps to push the lever to give more power. Whereas, high velocity produce if hand position is on low gear for straight or decline road which need to push forward and backward faster to create greater velocity.

2.2.3 Summarize Between Conventional and Lever Chain Wheelchair

Table 2.1 : Summarize of wheelchair

CONVENTIONAL WHEELCHAIR		LEVER CHAIN WHEELCHAIR
High impact on upper body	comparison	Low impact on upper body
Hard to propel and turning		Easy to propel and turning
Unstable on rough terrain		Stable during rough terrain
Low mechanical efficiency and advantages		High mechanical efficiency and advantages
Hands dirty when propel		Clean hands when propel

2.3 TYPE OF MECHANISM FOR ALL TERRAIN WHEELCHAIR

Nowadays, many inventions have been created to facilitate the lives of the community. One of them is wheelchairs that need to be improved to please patients for them to start their lives like ordinary people. The wheelchair has its own mechanism created by inventors who are experts in the world. This diverse mechanism has its own advantages and disadvantages. To facilitate this presentation, below shows varies types of wheelchair with its own mechanism.

2.3.1 Lever-Chain Mechanism

Figure 2.5 : Lever chain wheelchair side view

A multi-linked gear and chain type bicycle connects freewheel to the chair's rear driving wheels. Movement works when the rod changes gears in its horizontal position and the handle attached to the top of the push rod assembly allows the chair to move directly to the bike chain. A connection between the push rod box and the front caster wheel enables the patient to move the caster wheels by turning the push rod handle connected to the its housing.

2.3.2 Clutch Mechanism

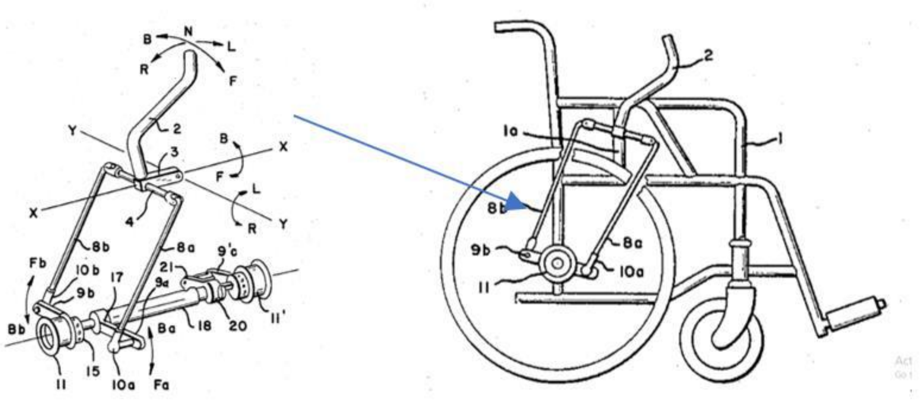


Figure 2.6 : Clutch mechanism wheelchair

A lever-operating chair includes a differential connecting mechanism connected to an operational lever, a pair of forward/backward clutch mechanisms connected to the connecting system and an enlarged connecting mechanism between the connecting mechanism and one between the clutch mechanisms. The lever- operated type chair of this invention has greater operational capacity for single- hand operation due to a pin and a knob of the operational lever organized to facilitate its operation.

2.3.3 Four-bar Mechanism

Figure 2.7 : Four-bar mechanism wheelchair

Four-bar mechanism wheelchair used lever as mechanism to propel the system. It can be classified in few types which are crank-rocker, double-rocker, and double-crank. Each type of four-bar mechanism consists of different moving mechanism. However, the mechanisms still have four link bar that involved but different angle in each type. Four bar mechanism also known as planar mechanism can be defined as rigid body that are in parallel planes or one plane for all of the relative motion. Planar mechanisms are principally two dimensional figures. (Zhang *et al.*, 2014)

An idea has been suggested to combine two mechanisms in one wheelchair. The idea was to fabricate in PSM 2 and analyse between lever chain mechanism and four-bar mechanism to compare its efficiency on all kind of terrain. The design must be able to engage and disengage the lever between two mechanisms that has been connected. The comparison of efficiency and advantages can be done after fabrication process are made and being tested.

2.4 CHAIN AND SPROCKET THEORY

2.4.1 Chain

Lever chain mechanism consists of gear drive mechanism for transmitting the power between the rotating shafts. It can be transmitting in varies type of gear drive such as chain and belt. However, the use of gears drive becomes impractical if the distance between gears is large. Chain drives are used to transfer rotational motion from one gear to another smoothly and efficiently. Chain drive can transmit in slow speed but high torque and in large distance due to tension. These are the advantages of using chain drives:

- They are less expensive in market.
- They have no slippage and provide a more efficient power transmission.
- They are more effective at lower speed than belts.
- They have lower loads on the shaft bearings because initial tension is not required.
- They have a longer service life and do not decay with factors such as heat, oil, or age.

2.4.2 Type of Chain

Chains are made mostly from plain carbon, alloy steel or stainless steel. Chains are made from a series of interconnected links. Many type of chain designs are commercially available:

1) A roller chain is shown in Figure 2.7. This is the most common type of chain used for power transmission. The roller chain design provides quiet and efficient operations. Generally use in bicycle and motorcycle.

Figure 2.8 : Roller chain

2) A multiple-strand roller chain is shown in Figure 2.8. This design uses multiple roller chain and built it into parallel strands to increase the power capacity of the chain drive.

Figure 2.9 : Multiple-strand roller chain

3) An offset sidebar roller chain is shown Figure 2.9. This is less expensive than a roller chain but slightly less power capability in transmitting the power. These chain often used on construction equipment.

Figure 2.10 : Offset sidebar roller chain

4) An silent chain is shown in Figure 2.10. Silent chain is the most expensive chain to manufacture. It can be used in application that require high speed and quite power transmission. Commonly in machine tools, pumps, and power drive units.

Figure 2.11 : Silent chain

2.4.3 Sprocket

Sprockets are the toothed wheels that mate with the chain and connected to the shaft. The functions of teeth on sprocket are designed to conform to the chain pin and link. It varies with the size of the chain and the number of teeth from the shape of the teeth. Figure 2.11 below shows a sprocket designed to mate with a roller chain that used in lever chain wheelchair.

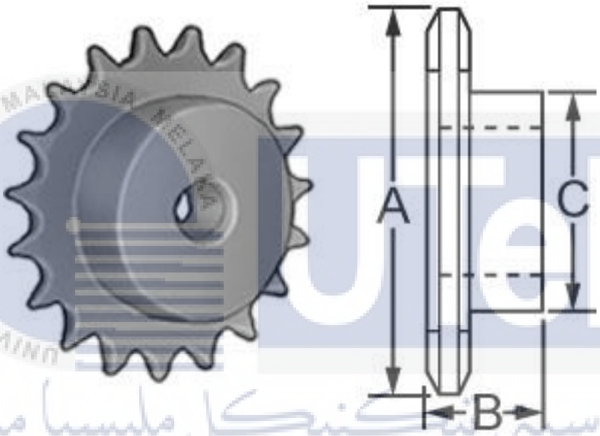


Figure 2.12 : Roller chain sprocket

From the Figure 2.11, A represent pitch diameter, D while B is the thickness of the sprocket and C is maximum hub diameter with a hole of bore diameter. Sprockets are commonly corresponded to chain size and number of teeth.

2.4.4 Freewheel

Freewheel also known as overrunning clutch are mechanism that rotates the rotation in one direction (idle) but support against or transfer torque in the opposite direction. (N.d., 1908). Freewheel can disengages when the driven shaft rotates faster than drives shaft. Mostly in used in bicycle transmission. If there is no freewheel, simple propulsion could be exhausting due to never stop to propel. It also can be dangerous if going downhill which the lever propulsion go faster than one could keep up with them. Figure 2.12 and figure 2.13 below shows the freewheel mechanism.

Figure 2.13 : Freewheel mechanism

Figure 2.14 Inside of freewheel

Freewheel works is depending on ratchet and pawls system. Ratchet give only one rotary motion in one direction and Figure 2.13 shows the ratchet rotates on clockwise direction. If paddling in backward motion on the lever chain wheelchair that is not moving, the teeth will rotates clockwise which allows the pawls and axle to be in static motion. If paddling in forward motion which is moving the wheelchair, the teeth will rotates in anticlockwise direction which engaging with pawls and axle which drive the lever chain wheelchair forward.

The advantages of using freewheel mechanism are:

- Long service life
- High level of riding comfort
- Optimized efficiency
- Efficient force transfer
- Can stop paddling for resting
- Low cost mechanism
- Easy to maintain and service

The disadvantages of using freewheel mechanism are:

- No coasting backward
- Prone easy to wear and become weaker because of pawls and teeth contact.
- High degree of engagement (slow)

2.4.5 Chain Drive Geometry

The number of teeth, N in the sprocket should usually have 17 teeth, unless if the motor operates at very low speeds. The larger sprockets usually have 120 teeth maximum.

As stated, the pitch diameter, D of the sprocket is equal to chain pitch, ρ divided by degree of number of teeth, N.

$$D = \frac{\rho}{\sin(\frac{180°}{N})} \tag{2.1}$$

Noted that the centre distance, C is the distance between the centres of the roller chain sprocket and freewheel as shown in Figure 2.14. In typical applications, the centre distance should be following range:

$$30\rho < C < 50\rho$$

The chain length, L is the total length of the chain. Due to that, the chain consist of interlinked links, the chain length must be integral multiple of the pitch. It is better to have odd number of teeth in sprocket and even number of chain. The total length, L of chain expressed in number of pitch, links, can be computed as

$$L = \frac{2C}{\rho} + \frac{(N1+N2)}{2} + \{\frac{\rho(N_2-N_1)}{4\pi^2 C}\} \tag{2.2}$$

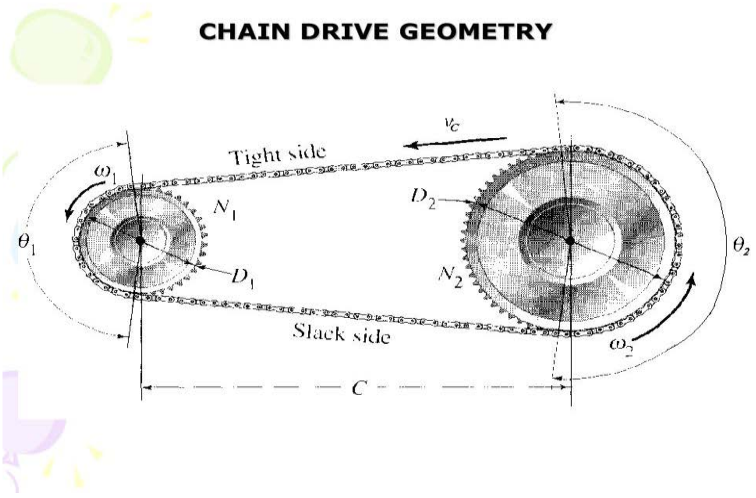


Figure 2.15 : Chain drive geometry

The centre distance, C for a given chain length can be written as

$$C = \frac{\rho}{4}[L - \frac{(N_2+N_1)}{2} + \sqrt{\left\{L - \frac{(N_2+N_1)}{2}\right\}^2 - \frac{8(N_2-N_1)}{4\pi^2}}] \qquad (2.3)$$

The angle of contact,θ is a measure on each sprocket of the chain of the angular management. It can obtain by

$$\theta_1 = 180° - 2\, sin^{-1}\{\frac{\rho(N_2-N_1)}{2C}\} \qquad (2.4)$$

$$\theta_2 = 180° + 2\, sin^{-1}\{\frac{\rho(N_2-N_1)}{2C}\} \qquad (2.5)$$

2.4.6 Chain Drive Kinematics

Velocity ratio, VR is defined as the angular speed of the sprocket (driver) divided by the angular speed of freewheel (driven). The velocity ratio computes as

$$VR = \frac{\omega_{driver}}{\omega_{driven}} = \frac{\omega_1}{\omega_2} = \frac{D_2}{D_1} = \frac{N_2}{N_1} \tag{2.6}$$

In equation 2.6, VR unit can be defined in term of revolution per minute, radians per time or any other convenient rotational velocity units. In term of magnitude, the magnitude of this velocity corresponds to the magnitude of the linear velocity of each sprocket point on the pitch diameter. The magnitude of chain speed can be given as

$$v_c = \frac{D_1}{2}\omega_1 = \frac{D_2}{2}\omega_2 \tag{2.7}$$

From the equation 2.7, the unit must be stated as radians per unit time.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

Methodology is defined as the specific procedure in order to obtain information and knowledge. This chapter will be covered all the process and method that will be involves in this project.

The detail explanation on problem formulation in this project will be covered in section 3.2. Product design specification focuses on solving the conflict between the selection of a process to make it, the choice of material and the conflict shape of a product. Next, in section 3.3, quality function deployment (QFD) is used to translate customer requirements into the design. It is powerful as it incorporates with voice of customer and house of quality (HOQ). Furthermore, conceptual design forms in early stages of design process which allows manipulate the concept and idea of improving the product. Morphological chart can help to choose the suitable and perfect part of design to the product. Finally, pugh method is used to evaluate the best design following the customer need to satisfy the customer requirement and the final product specification.

3.2 FLOW CHART

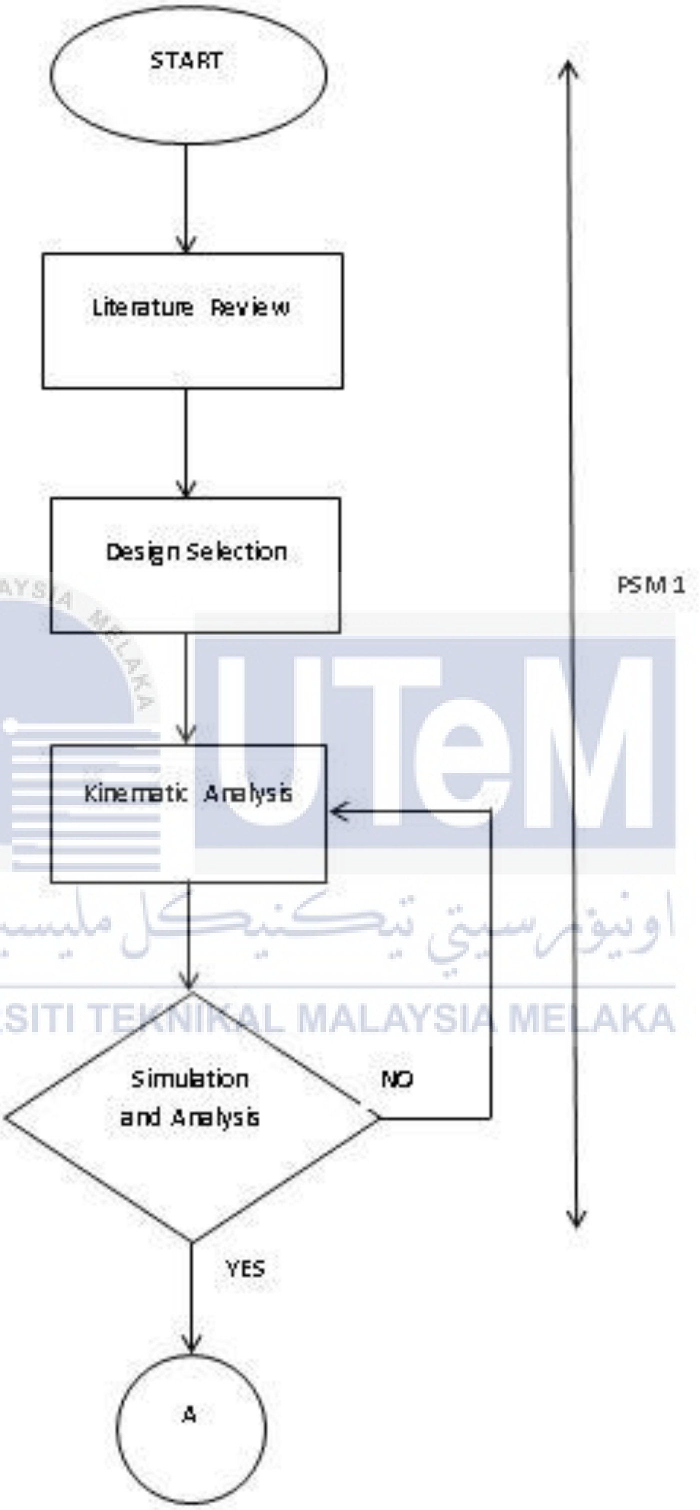


Figure 3.1 : Flow chart for PSM 1

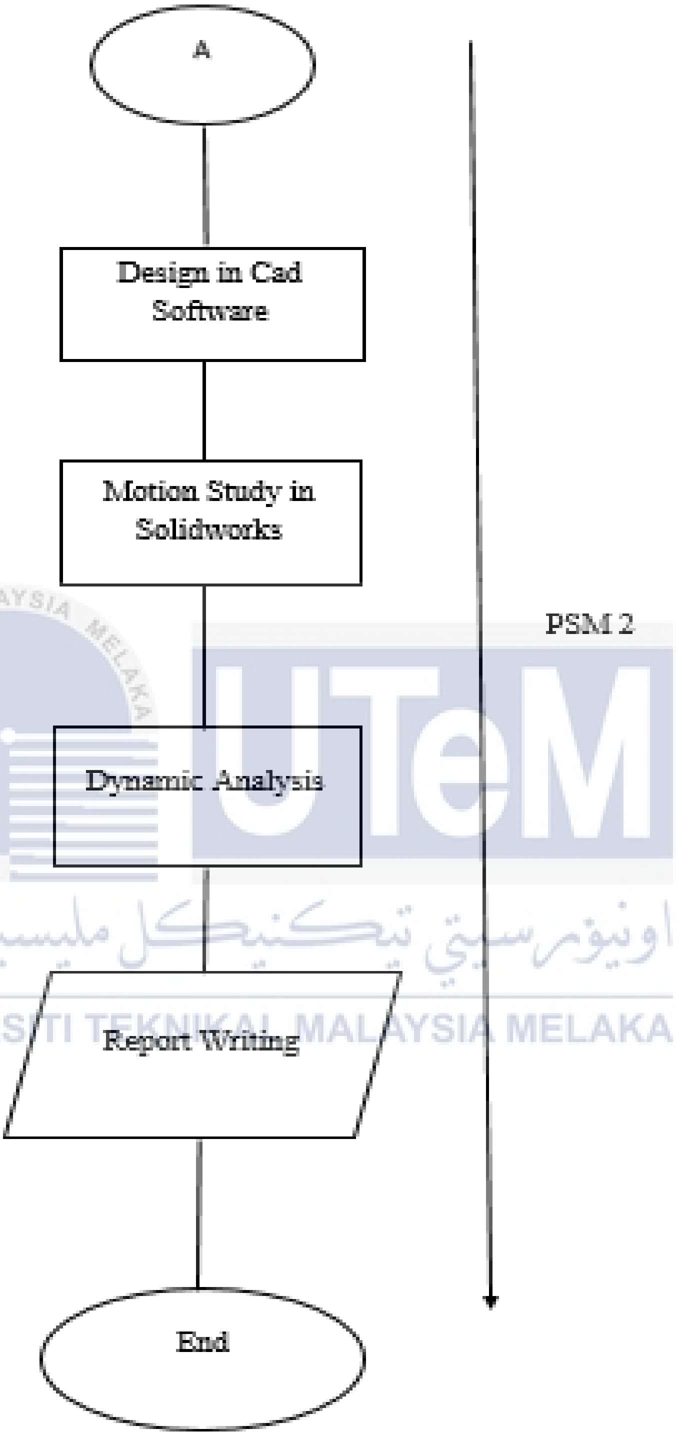


Figure 3.2 : Flow chart for PSM 2

3.3 GANTT CHART

Table 3.1 : Gantt chart PSM 1

No	Task	Week											
		3	4	5	6	7	8	9	10	11	12	13	14
1	Received and discuss title with supervisor	■											
2	Internet and library search	■	■	■									
3	Preparation of progress report			■	■								
4	Consultation				■								
5	Submission of progress report					■							
6	Consultation					■							
7	Preparation chapter 1						■	■					
8	Preparation chapter 2							■	■				
9	Preparation chapter 3							■	■				
10	Consultation								■	■			
11	Design selection with group members								■	■			
12	Theoretical calculation										■		
13	Edit Psm 1 report										■	■	
14	Submission Psm 1 report												■

Table 3.2 : Gantt Chart PSM 2

No	Task	Week											
		3	4	5	6	7	8	9	10	11	12	13	14
1	Design parts in Solidworks	■											
2	Assembly in Solidworks	■	■	■									
3	Motion study on the mechanism			■	■								
4	Preparation of progress report				■								
5	Submission of progress report					■							
6	Motion study on full assembled wheelchair					■							
7	Preparation chapter 3						■	■					
8	Preparation chapter 4							■	■				
9	Preparation chapter 5							■	■				
10	Motion analysis on full assembled wheelchair and roadtrack								■	■			
11	Result and Data analysis								■	■			
12	Consultation										■		
13	Edit Psm 2 report										■	■	
14	Submission Psm 2 report												■

3.4 DESIGN PROBLEM SPECIFICATION

3.4.1 Product Design Specification (PDS)

Product design involves several processes to gain a successful benchmarking in early stages of producing a product. By that, product design integrates with the creation of product design specification (PDS). PDS document must be complied with the new design that required all the needed requirements and constraints. PDS outlines demand for the product from the market and frequently involves detailed market research. By referring PDS, solution and concept design can be generated successfully. (N.d., 2007)

1. **Material**

- Material selected should be light weight for transportable
- Material selected must be rigid because rigidity can give stability to the wheelchair structure.
- Material selected must not easily damaged or fracture by impact.
- Material selected should be durable, strong and long lasting.

2. **Performance**

- The mechanism should be easy maintenance and easy operation.
- The mechanism must be easily engaging and disengage.
- The mechanism efficiency can handle for all terrain.
- The mechanism should follow the safety requirement and local legislation.

3. Weight

- Maximum weight not more than 20 kg.

4. Cost

- Manufacturing cost including labour cost not more than RM 200.

5. Size

- The wheelchair should be able to move through door.
- The wheelchair must able to withstand maximum 85 kg load.
- The wheelchair can fit in narrow place for storage.

6. Manufacturing process

- High cost of machining process will effect to the fabrication cost.
- Manufacturing is carried out using the material selected and tools in the workshop.

7. Assembly

- The product will assembled after process of cutting, drilling and welding are finished.

8. Service life

- Estimated minimum 5 year or longer of service.

3.4.2 Data Collection

In this project, data collection was used to obtain information on lever chain wheelchair problem. The collection data includes a review of articles, journals, books, and internet citation.

3.5 QUALITY FUNCTION DEPLOYMENT

Quality Function Deployment (QFD) is a process that integrates to defining customer requirements into the design and development of product. It is a structured approach, customer oriented process, for determining, assessing and prioritizing systems requirement. Quality is defined as meeting customer requirement and need to implement “the voice of the customer” term. The voice of customer describe as the spoken and unspoken, the stated and unstated of customer need and requirements. Source of information gather from requirements report, interviews, surveys, focus group, field report, observation and warranty data. Successful application in QFD to summarized in term of house of quality (HOQ) or planning matrix. (N.d., 2016)

3.5.1 Customer requirement

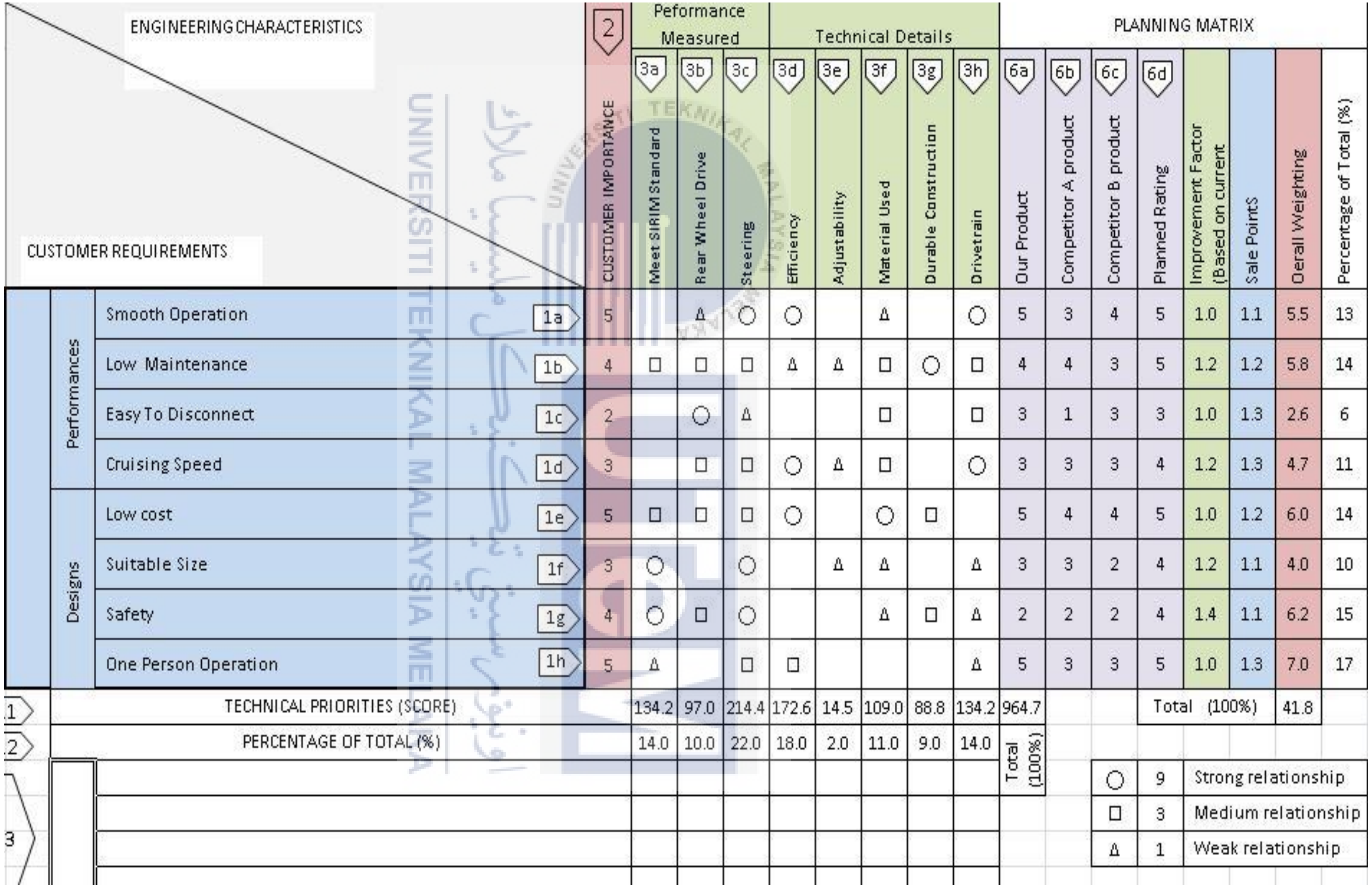
Fundamentally, products are made to satisfy customer requirement. A client demands are the specification that come from customer who are in conflict with the internal stakeholder. Products, services and experience may embrace functional and non-functional requirements. From the design team point of view, customer demand can be consider as function, performance, quality of the product, operating environment and satisfaction to the product. In aspect of lever chain wheelchair, customer requirement are taken from varies type of source from the study made from other university about lever chain wheelchair.

3.5.2 Pugh Method

Pugh method can be defined as a matrix to determine the best solutions for which items are more important to the product development. It is applies after voice of customer (VOC) is produced. This method is fairly simple to use and it is in simplicity. By performing pugh method, the design for lever chain mechanism can satisfy the customer need that relates to the technical performing. It includes all the criteria such as reliability, efficiency, costing, maintenance, and also operation of the mechanism. The highest score of matrix are used for the concept selection in which options are assigned scores relative to criteria. Best option can be select from this tool. (ISixSigma, 2000)

3.5.3 House of Quality (HOQ)

HOQ is also known as QFD relatively. It is a tool to convert the customer need into technical description in most convenient way. House of quality also called Quality Matrix because the matrix give detail about customer requirement, technical report, priority description relationship and target values for each description. It evaluate between various product and current product. HOQ below was taken from a journal that has been studied about rear wheel drivetrain wheelchair in January 27, 2009. This HOQ was just a benchmark and guideline for this project. The customer need was taken from the journal as this project neglect survey and questionnaire. (Bergmeier, 2009) Figure 3.3 below shows HOQ for lever chain mechanism design.



ENGINEERING CHARACTERISTICS / CUSTOMER REQUIREMENTS			2 CUSTOMER IMPORTANCE	Peformance Measured 3a Meet SIRIM Standard	3b Rear Wheel Drive	3c Steering	Technical Details 3d Efficiency	3e Adjustability	3f Material Used	3g Durable Construction	3h Drivetrain	PLANNING MATRIX 6a Our Product	6b Competitor A product	6c Competitor B product	6d Planned Rating	Improvement Factor (Based on current	Sale PointS	Overall Weighting	Percentage of Total (%)
Performances	Smooth Operation	1a	5		Δ	○	○		Δ		○	5	3	4	5	1.0	1.1	5.5	13
	Low Maintenance	1b	4	□	□	□	Δ	Δ	□	○	□	4	4	3	5	1.2	1.2	5.8	14
	Easy To Disconnect	1c	2		○	Δ			□		□	3	1	3	3	1.0	1.3	2.6	6
	Cruising Speed	1d	3		□	□	○	Δ	□		○	3	3	3	4	1.2	1.3	4.7	11
Designs	Low cost	1e	5	□	□	□	○		○	□		5	4	4	5	1.0	1.2	6.0	14
	Suitable Size	1f	3	○		○		Δ	Δ		Δ	3	3	2	4	1.2	1.1	4.0	10
	Safety	1g	4	○	□	○			Δ	□	Δ	2	2	2	4	1.4	1.1	6.2	15
	One Person Operation	1h	5	Δ		□	□				Δ	5	3	3	5	1.0	1.3	7.0	17
1	TECHNICAL PRIORITIES (SCORE)			134.2	97.0	214.4	172.6	14.5	109.0	88.8	134.2	964.7			Total (100%)			41.8	
2	PERCENTAGE OF TOTAL (%)			14.0	10.0	22.0	18.0	2.0	11.0	9.0	14.0	Total (100%)							
3																			

○	9	Strong relationship
□	3	Medium relationship
Δ	1	Weak relationship

Figure 3.3 : HOQ

3.6 CONCEPT DESIGN

3.6.1 Morphological Chart

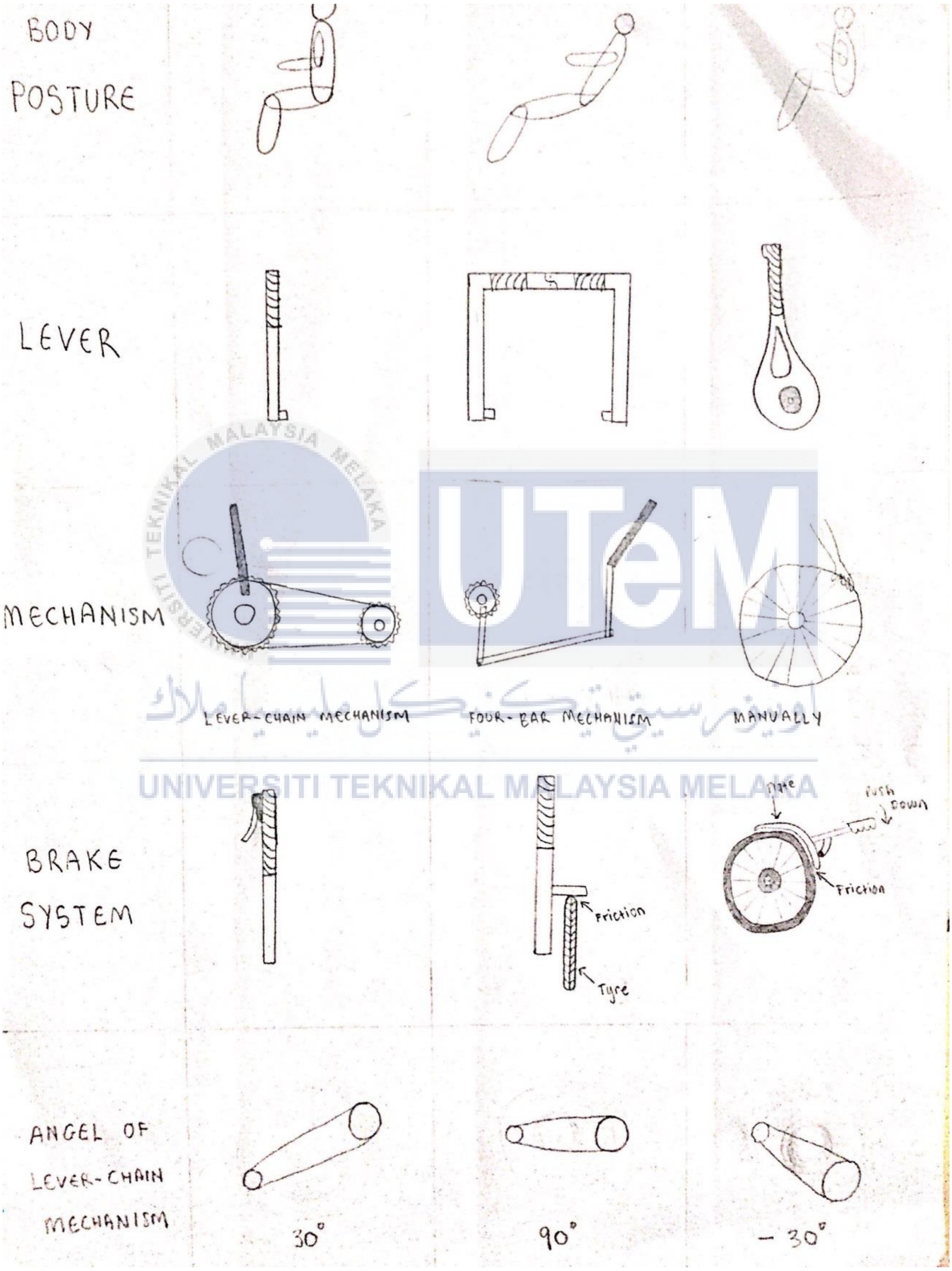


Figure 3.4 : Morphological Chart

3.6.2 Conceptual Design

CONCEPT DESIGN 1

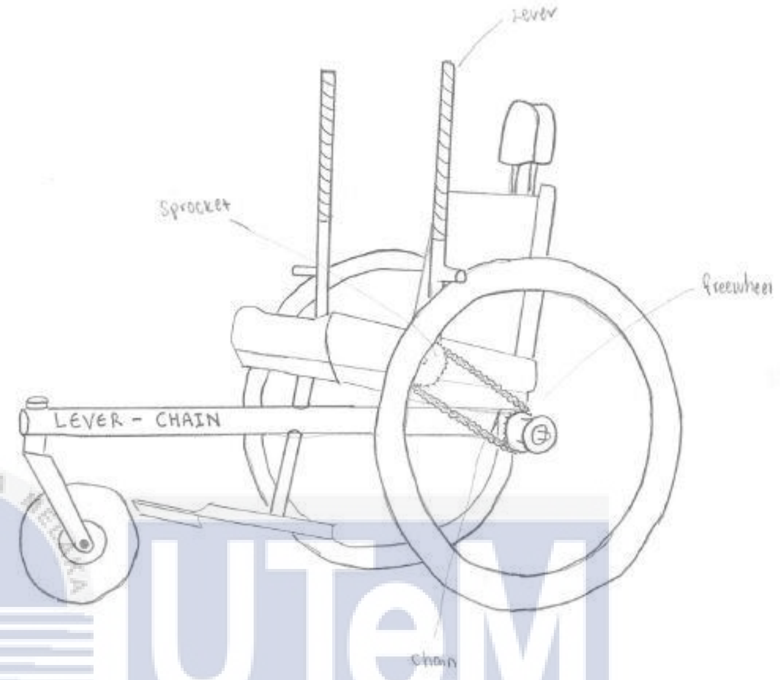


Figure 3.5 : Concept design 1

CONCEPT DESIGN 2

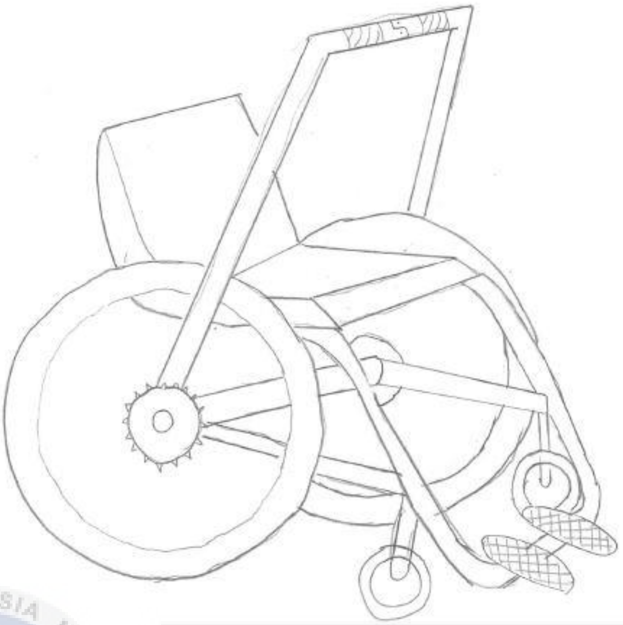


Figure 3.6 : Concept design 2

concept DESIGN 3

Figure 3.7 : Concept design 3

3.7 PRE PROCESS LEVER CHAIN WHEELCHAIR

Concept sketch design has been chosen and the process continues to design in 3D model using Solidworks. In Solidworks, there are 3 process that has been utilized to perform lever chain wheelchair. This process are called part design, assembly design and motion analysis. The final and assembly design for lever chain wheelchair are in Figure 3.8 below.

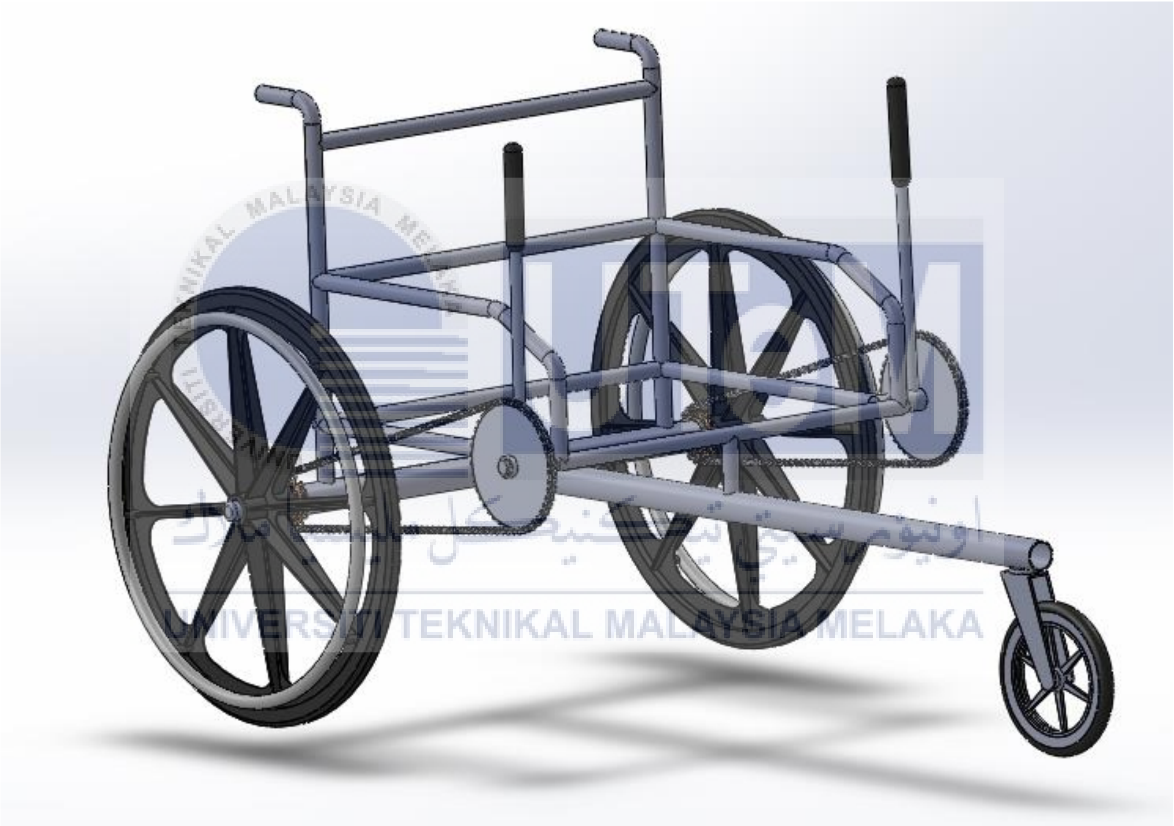


Figure 3.8 : Lever Chain Wheelchair Assembly

There are 15 parts including frame of the wheelchair for this assembly. Each part consist of sketch, dimension and mates that perform in assembly design. There are some special mate that used in this lever chain wheelchair which are in the mechanism assembly. The mechanism assembly consist of chain, sprocket and gear mate. It also required to have chain path which the chains will connected along the path.

To perform belt and chain features, select under assembly features and select belt and chain. Next, sprocket and freewheel need to be align and parallel before using belt and chain features. After align the sprocket and freewheel, select the teeth diameter of the sprocket and freewheel to create a path for chain. Belt and chain features will make the sprocket move along with freewheel.

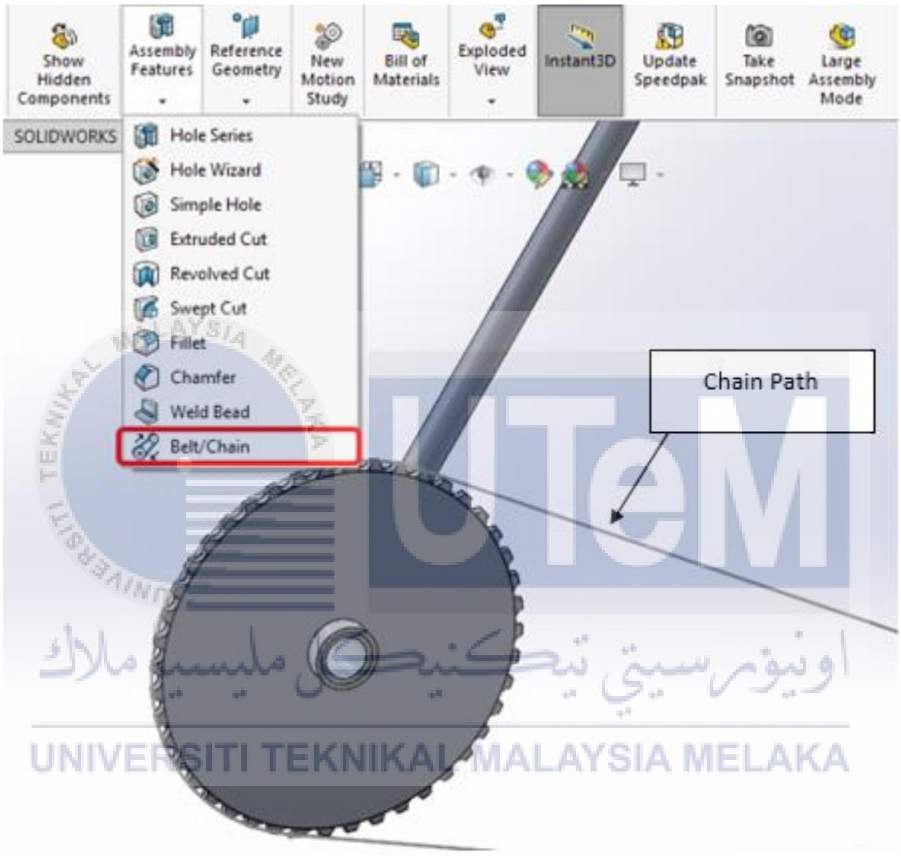


Figure 3.9 : Belt and Chain Features

Chain has two component parts which is inner link and outer link. Both need to mate to the path to engage when rotating the sprocket and freewheel. Select the middle of each inner and outer link which is mid plane and mate to the path line to ensure both link are in perpendicular state.

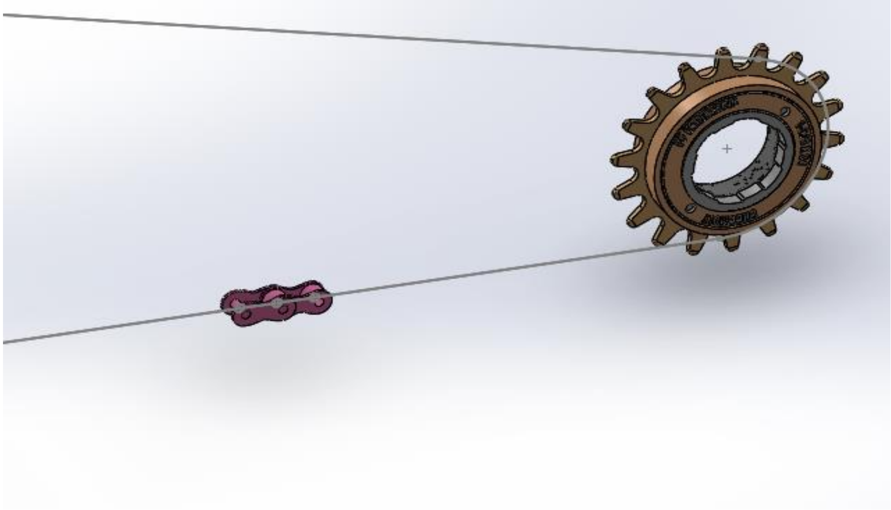
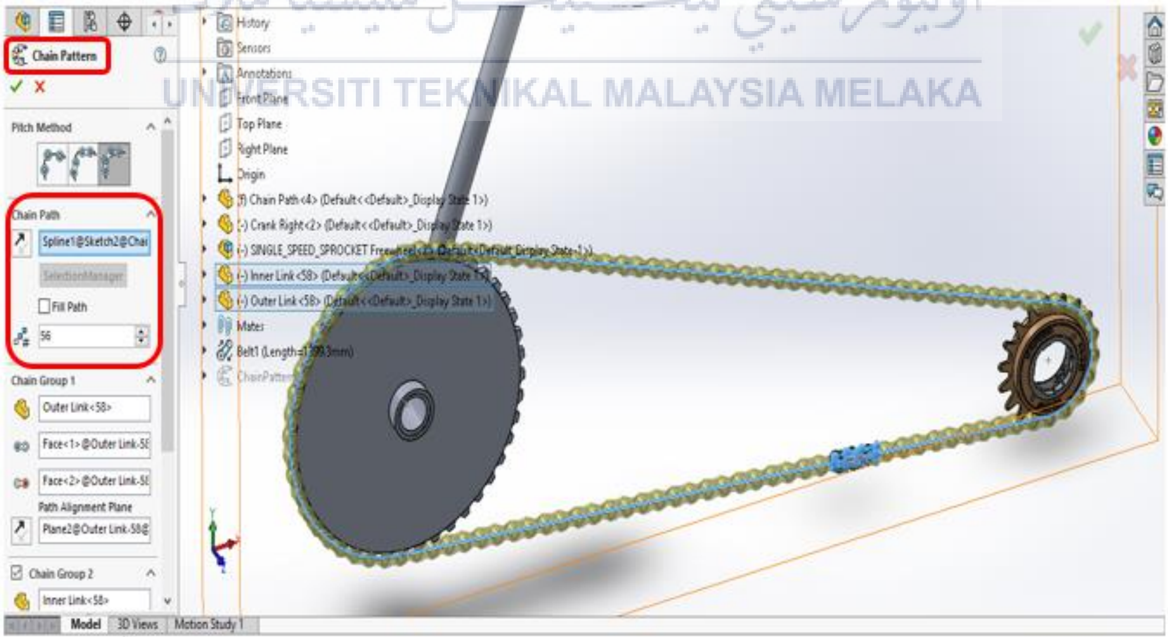


Figure 3.10 Inner and Outer Chain Mate with Chain Path

To create a full combination of chain in the path, select chain pattern under linear component pattern. Select the right pitch mode and select path that has been created using belt and chain features. To fill along the path, click fill path or use number of chain needed to fill in the path. For lever chain wheelchair needs 56 chains. Inner and outer link need to be choose to complete the chain pattern.



Chain Pattern

Pitch Method

Chain Path

Spline1@Sketch2@Chai

☐ Fill Path

56

Chain Group 1

Outer Link<58>

Face<1>@Outer Link-5E

Face<2>@Outer Link-5E

Path Alignment Plane

Plane2@Outer Link-58@

☑ Chain Group 2

Inner Link<58>

Figure 3.11 : Chain Pattern

3.8 ANALYSIS PROCESS LEVER CHAIN WHEELCHAIR

To determine the kinematic and dynamic analysis in Solidworks, assembly design needs to be mate accordingly before applying motion study. Motion study or motion analysis is a time-based approach for rigid body kinematic and dynamic problems. Motion study can evaluate the wheelchair by movement into the physical calculation of the force and motions of an assembly as it moves using external or internal force. Motion study can calculate the effect of force, springs, dampers, gravity, speed, and contact between two components. In the case of study, motion study evaluates lever chain wheelchair to calculate velocity, displacement, acceleration, contact force, and reaction force.

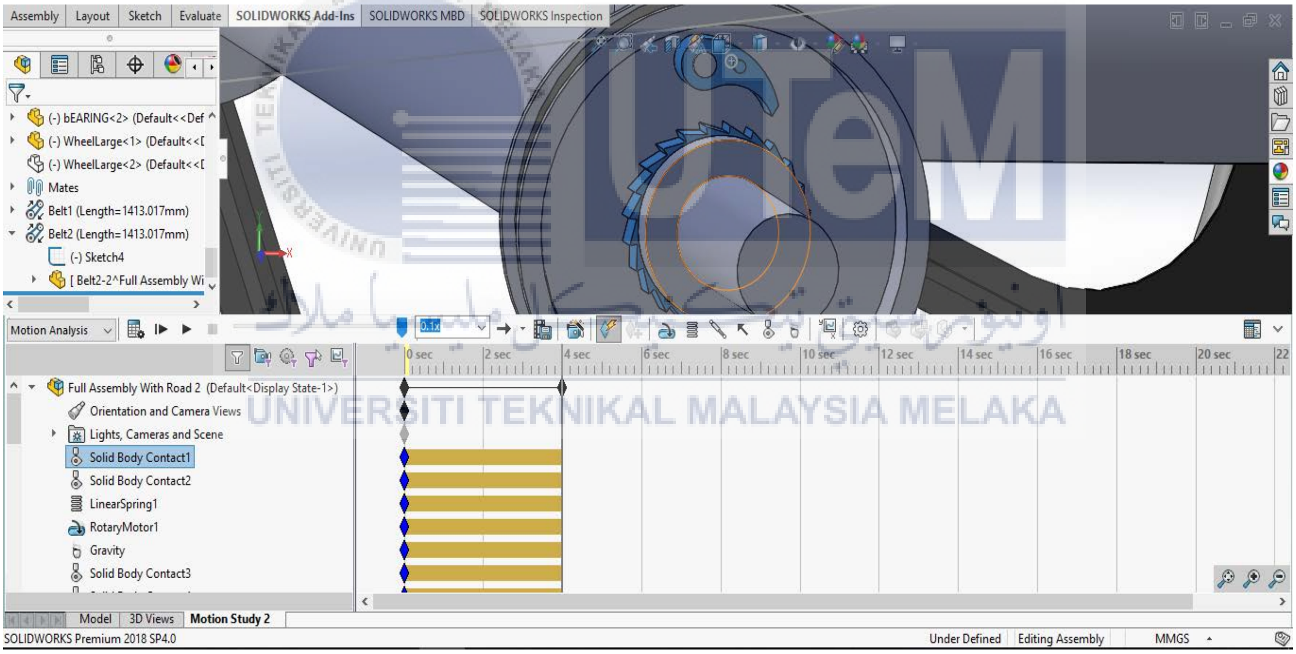
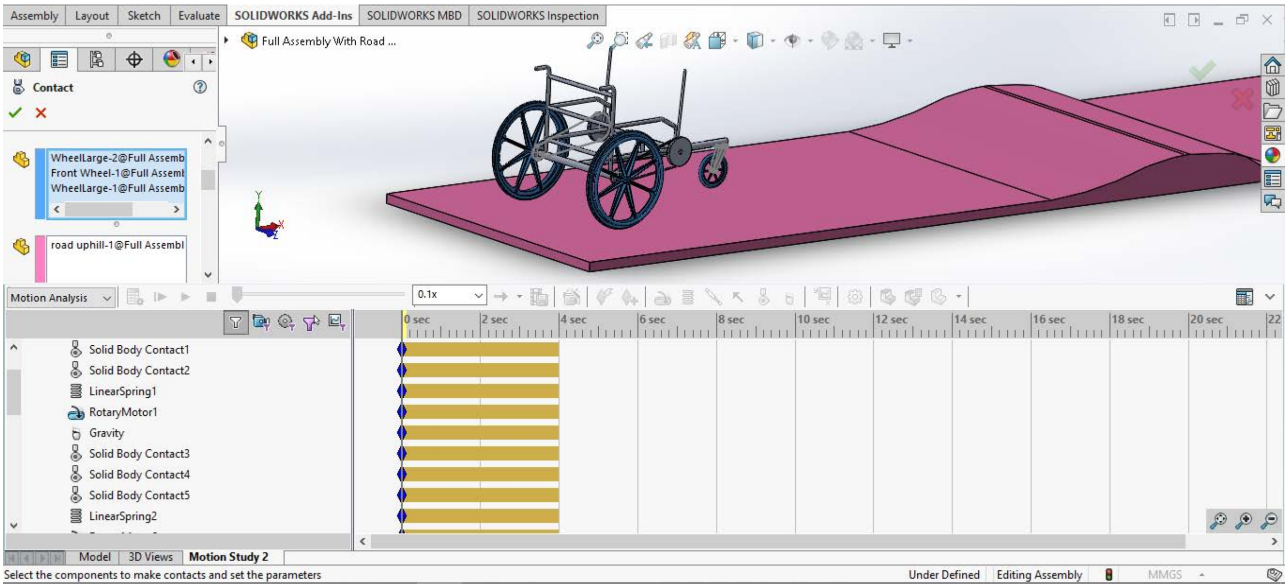


Figure 3.12 : Solid Contact Body

Figure 3.12 above shows motion study features before starting to evaluate the motion study on wheelchair. Solid contact body are used in ratchet and pawl system because both of the component need to contact to rotates into one direction and performing the ratchet and pawl system.



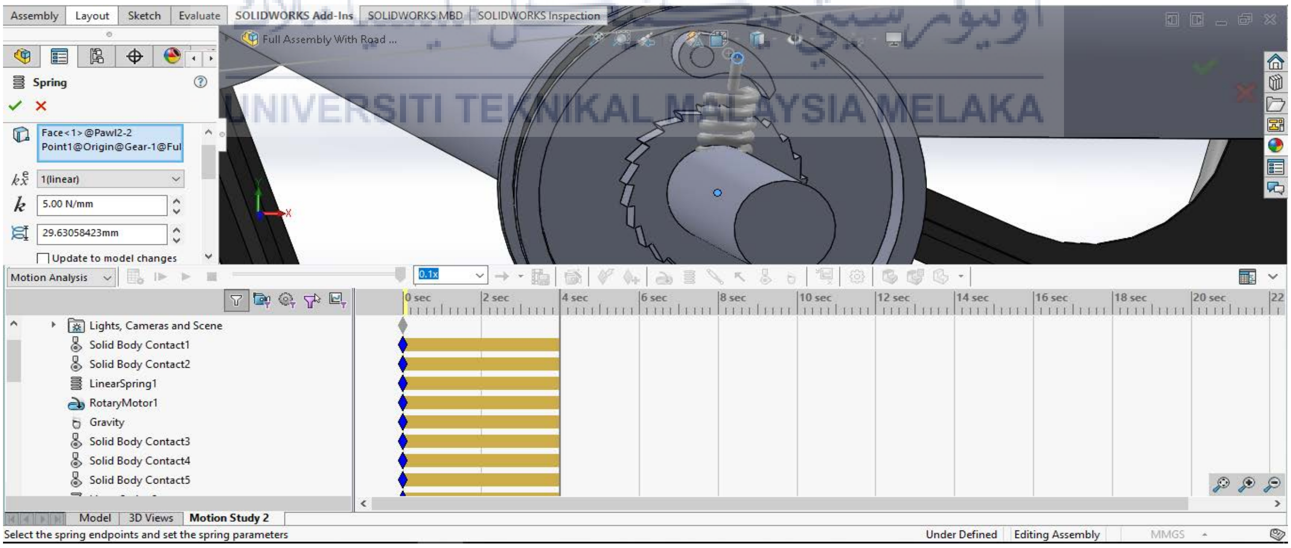
WheelLarge-2@Full Assemb
Front Wheel-1@Full Asseml
WheelLarge-1@Full Assemb

road uphill-1@Full Assembl

Select the components to make contacts and set the parameters

Figure 3.14 Solid Contact Body on Terrain

Road and tyres need to be contact so the motion study will successfully calculate the movement of the wheelchair through the terrain. By applying the gravity features on y-axis, the wheelchair will stay connect to the road until the evaluation are done.



Face<1>@Pawl2-2
Point1@Origin@Gear-1@Ful

1(linear)

5.00 N/mm

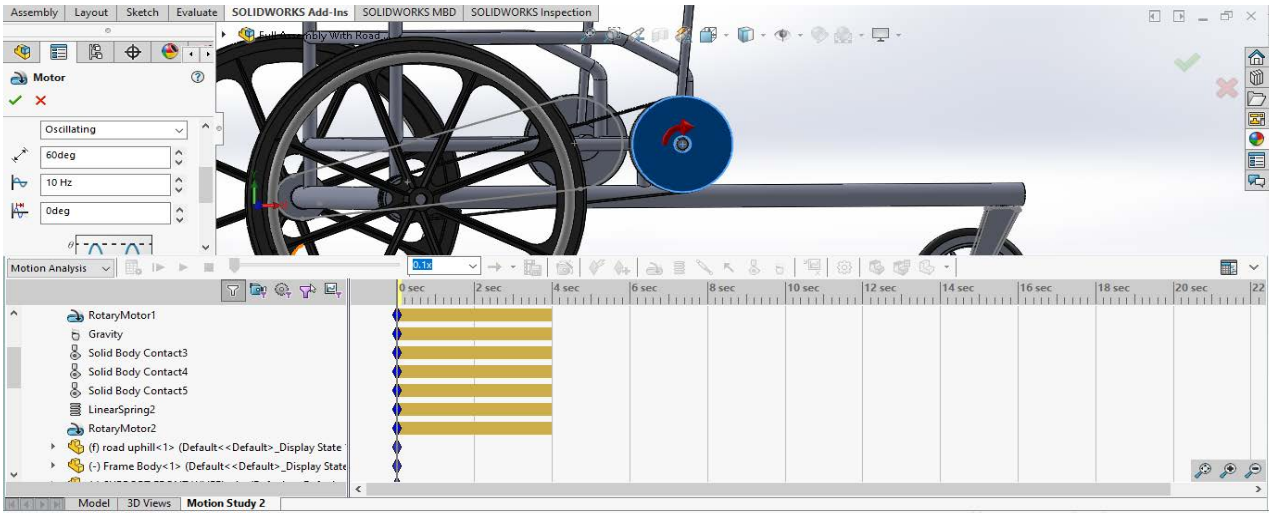
29.63058423mm

☐ Update to model changes

Select the spring endpoints and set the spring parameters

Figure 3.13 Spring Features

Spring features are used to ratchet and pawl system to avoid the pawl rotating while apply motion study. Stiffness with 5 N/mm and 29 mm length of spring for this evaluation.



Motor

Oscillating

60deg

10 Hz

0deg

Figure 3.15 Applying Motor in Motion Study

In motion analysis, motor features are one of the most important roles in evaluating the analysis in every component. The motor helps a component to move or rotates with a certain amount of speed and give the movement to the whole assembly to run. Moreover, the motor can evaluate the maximum torque and the maximum speed of the wheelchair when running on the rough terrain track. For lever chain wheelchair, only two motors are used and it is used in both of the lever sprockets. This is because the force and power to move the wheelchair come from the lever which is the human force given to the lever to generate the sprocket to move the wheelchair. Type of motor used in motion study is oscillating which has an angle of 60 degrees. This is due to the propulsion of the lever need to be repeated 60 degrees angle to move the wheelchair. Belt and chain features connects lever sprocket with freewheel when it moves, motor that apply to the sprocket with eventually rotates freewheel and ratchet pawl systems to be move. The evaluating of torque or speed can be done at the gear of freewheel.

CHAPTER 4

RESULT AND DATA

4.1 THEORETICAL CALCULATION

Length of Handle = 500 mm

Average Human Force = 500 N

Torque on Sprocket = Force on Handle x Length of Handle

= 500 x 0.5

T = 250 N.m

1. Calculation for Power

Average Velocity, V = 0.8-0.9 m/s

Diameter of Wheel = 610 mm

Therefore, V = $\frac{3.14 \times D \times N}{60}$

$$0.85 = \frac{3.14 \times 0.61 \times N}{60}$$

N = 26.63 rpm ~ 27 rpm

Power = $\frac{2 \times 3.14 \times N \times T}{60}$

P = $\frac{2 \times 3.14 \times 27 \times 250}{60}$

P = 706.5 W

2. Choose Pitch and No. Of Strands

No of Strand = Single Strand

Chain No. = 56

Pitch = 12.7 mm

3. Calculation for Centre Distance

$$C = \frac{\rho}{4}(L - \frac{(N_2 + N_1)}{2} + \sqrt{\left(L - \frac{N_2 + N_1}{2}\right)^2 - \frac{8(N_2 + N_1)^2}{4\pi^2}}$$

$$C = \frac{12.7}{4}(113 - \frac{(44 + 18)}{2} + \sqrt{\left(113 - \frac{44 + 18}{2}\right)^2 - \frac{8(44 + 18)^2}{4\pi^2}}$$

C = 505.2 mm

4. Length of Chain

$$L = (\left(\frac{T_1 + T_2}{2}\right) + \left(\frac{2C}{\rho}\right) + \frac{\rho(\, T_1 + T_2)^2}{40C})$$

$$L = (\left(\frac{44 + 18}{2}\right) + \left(\frac{2(505.2)}{12.7}\right) + \frac{12.7(\, 44 + 18)^2}{40(505.2)})$$

L = 113 number of links

5. Case 1

Torque = 250 N.m

For large sprocket,

No of teeth = 44

Diameter of sprocket = 180 mm

Therefore, Torque on Sprocket = Tension Chain Drive x Radius of Sprocket

250 = Tension Chain Drive x 0.09

Tension on Sprocket = 2777.78 N

6. Case 2

For smaller sprocket, No of teeth = 18

Diameter of Sprocket = 80 mm

Torque on Freewheel = Chain Tension x Radius of Sprocket

= 2777.78 x 0.04

Torque on Freewheel = 111.12

Based on the theoretical calculation above, it is clearly seen that the lever chain wheelchair with a chain and sprocket mechanism will increase the movement velocity. This calculation was set during smooth terrain which the calculation shows that lever chain wheelchair will give more velocity in less effort. The length of the handle was followed according to the design specification. The length will not affect the calculation as the patient will grip the lever according to its seating position and comfort handling to propel. Next, the average human force was estimated using journal. (Bhende et al., 2017). Lever chain wheelchair consists of 27 rpm number of turns with 706.5 Watts power needed. The selection of chain was according to graph selection of roller chain standard. Lever chain wheelchair used single strand chain with 56 chain number. The pitch for each chain is 12.7 mm. Figure 4.1 below shows the standard graph roller chain selection.

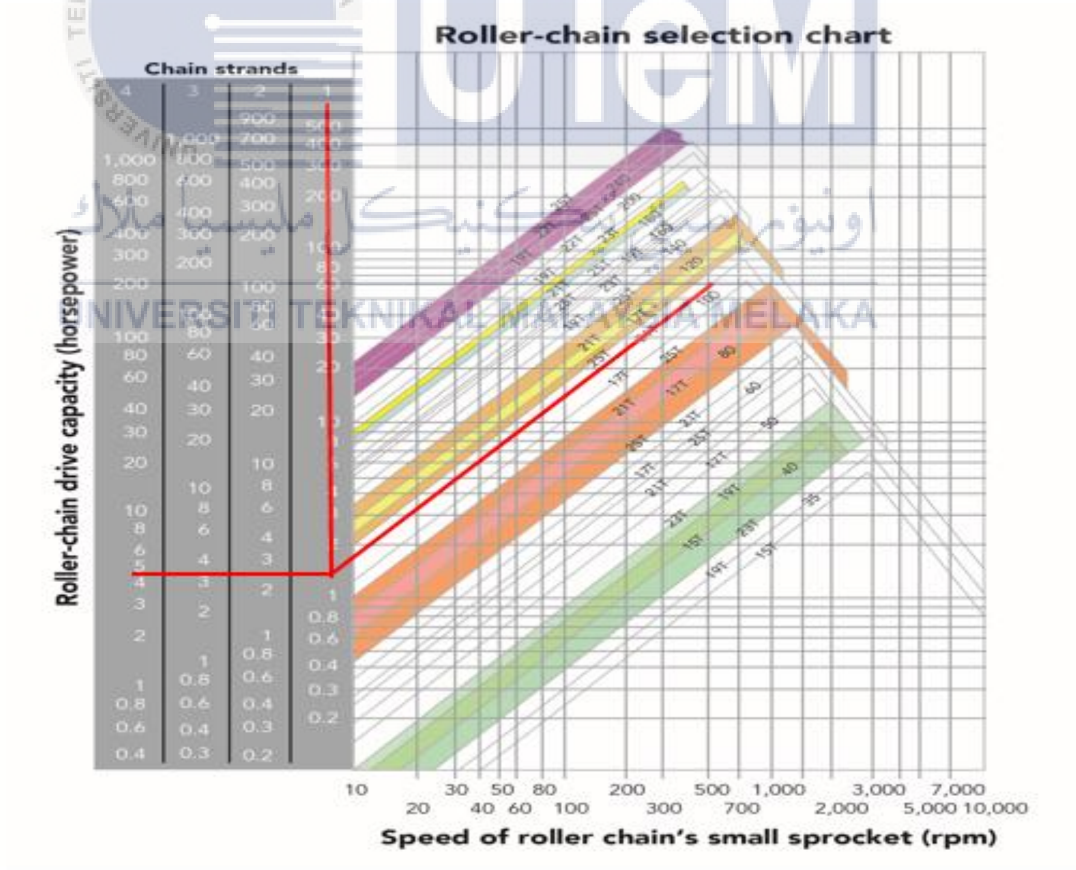
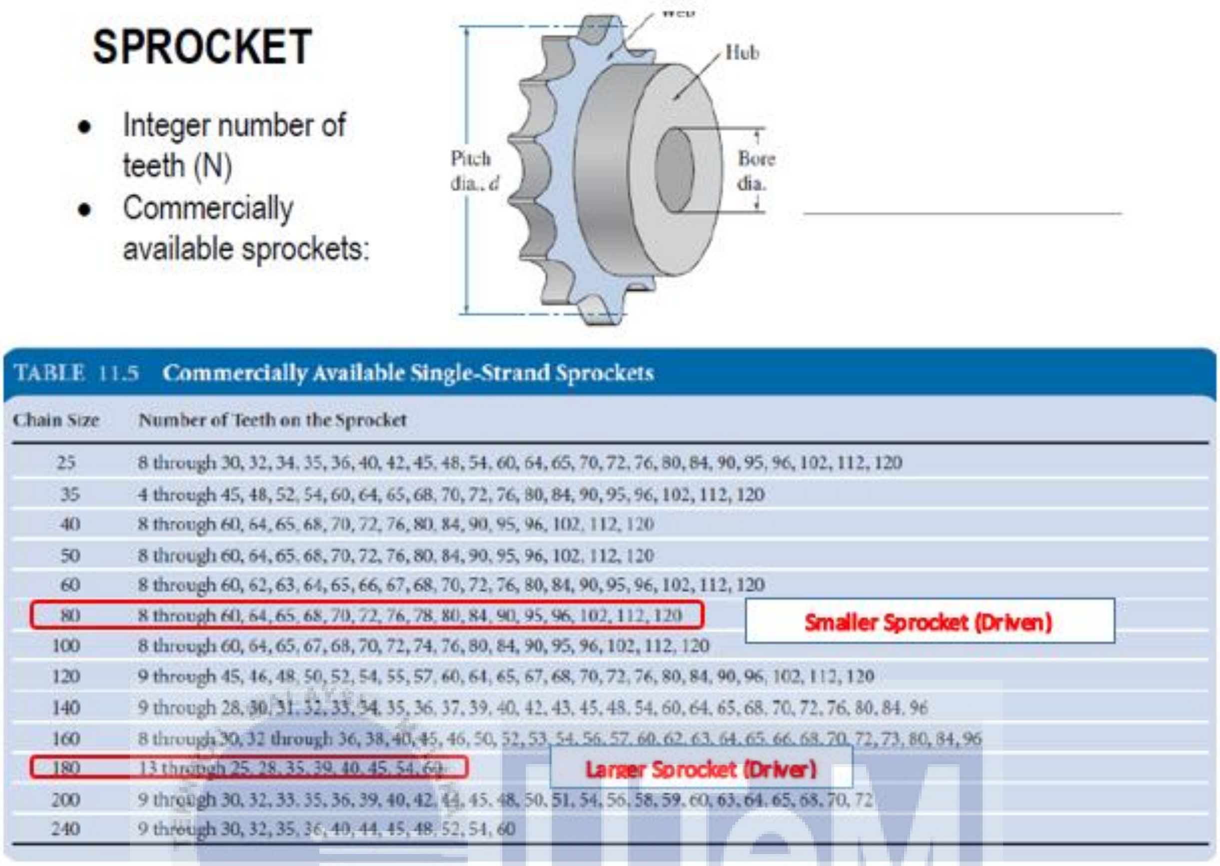


Figure 4.1 : Standard Roller Chain Selection

Centre distance is the maximum length for both sprockets to be position. The center distance can avoid excessive sag and fatigue stresses. The chain must have integers number of the total chain loop. For the calculation, the center distance for lever chain wheelchair is 505.2 mm. Moreover, the length of the chain can be determined using a simple formula. The total length of the chain can be expressed as the total number of links used. The length of the chain for this paper is 113 links.

For both sprocket, driven and driver, it can be classified in two cases. The first case, the larger sprocket consist of 44 number of teeth with a diameter of sprocket of 180 mm. The design and selection of sprocket were determined using commercially available single-strand sprocket table. The tension chain drive can be determined by dividing torque on sprocket over the radius of the sprocket. For case two, torque on freewheel can be examine using chain tension multiply with the radius of freewheel which is 80 mm. The number of teeth for freewheel is 18 which can be selected at the table. Figure 4.2 below shows single-strand sprocket selection.



SPROCKET

- Integer number of teeth (N)
- Commercially available sprockets:

TABLE 11.5 Commercially Available Single-Strand Sprockets

Chain Size	Number of Teeth on the Sprocket
25	8 through 30, 32, 34, 35, 36, 40, 42, 45, 48, 54, 60, 64, 65, 70, 72, 76, 80, 84, 90, 95, 96, 102, 112, 120
35	4 through 45, 48, 52, 54, 60, 64, 65, 68, 70, 72, 76, 80, 84, 90, 95, 96, 102, 112, 120
40	8 through 60, 64, 65, 68, 70, 72, 76, 80, 84, 90, 95, 96, 102, 112, 120
50	8 through 60, 64, 65, 68, 70, 72, 76, 80, 84, 90, 95, 96, 102, 112, 120
60	8 through 60, 62, 63, 64, 65, 66, 67, 68, 70, 72, 76, 80, 84, 90, 95, 96, 102, 112, 120
80	8 through 60, 64, 65, 68, 70, 72, 76, 78, 80, 84, 90, 95, 96, 102, 112, 120
100	8 through 60, 64, 65, 67, 68, 70, 72, 74, 76, 80, 84, 90, 95, 96, 102, 112, 120
120	9 through 45, 46, 48, 50, 52, 54, 55, 57, 60, 64, 65, 67, 68, 70, 72, 76, 80, 84, 90, 96, 102, 112, 120
140	9 through 28, 30, 31, 32, 33, 34, 35, 36, 37, 39, 40, 42, 43, 45, 48, 54, 60, 64, 65, 68, 70, 72, 76, 80, 84, 96
160	8 through 30, 32 through 36, 38, 40, 45, 46, 50, 52, 53, 54, 56, 57, 60, 62, 63, 64, 65, 66, 68, 70, 72, 73, 80, 84, 96
180	13 through 25, 28, 35, 39, 40, 45, 54, 60
200	9 through 30, 32, 33, 35, 36, 39, 40, 42, 44, 45, 48, 50, 51, 54, 56, 58, 59, 60, 63, 64, 65, 68, 70, 72
240	9 through 30, 32, 35, 36, 40, 44, 45, 48, 52, 54, 60

Smaller Sprocket (Driven)

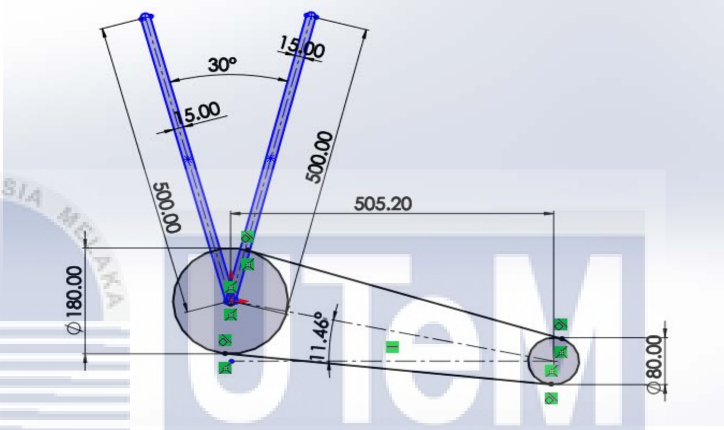
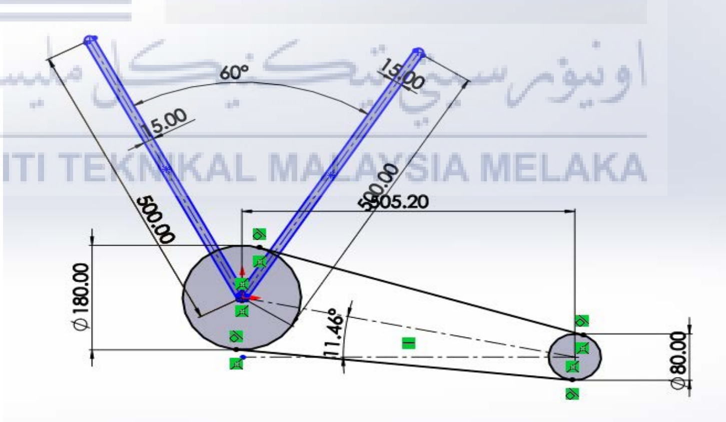
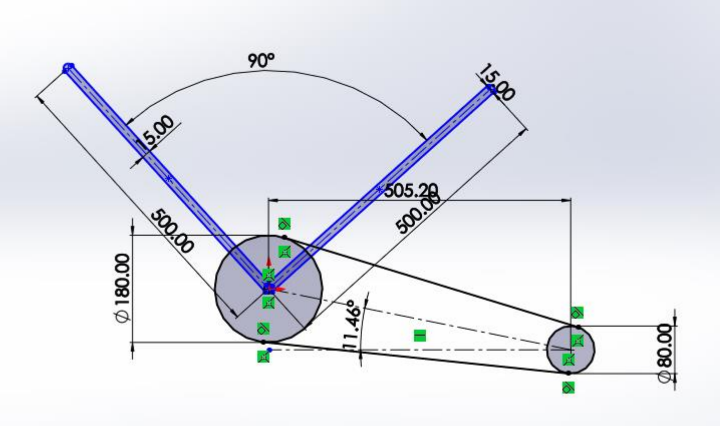
Larger Sprocket (Driver)

Figure 4.2 : Single-Strand Sprocket Selection

4.2 MECHANISM DESIGN (SOLIDWORK)

In this part, Lever-Chain wheelchair were designed and analyzed using Solidworks software. Parts were designed following the specification and measurement using standard all-terrain conventional wheelchair design and using motion study to analyze the mechanism efficiency.

4.2.1 2D SKETCH LEVER-CHAIN MECHANISM MOTION

$\theta = 30°$	
$\theta = 60°$	
$\theta = 90°$	

The table above shows propelling motion for lever chain wheelchair which consists of a different angle. Those angles can represent different terrain and different force acting on the wheelchair. For angle, θ =30 it is suitable for smooth terrain which can create high velocity due to small angle. The patient can propel faster by lowering down the hand position of the grip to create faster force. For angle, θ=60 is where patient propel the wheelchair is standard velocity. This angle can be used in smooth and rough terrain and it is the most suitable angle according to human upper body limb position. Lastly, θ=90 give higher torque compare to other angles. If hand placement is on high gear due to off-road navigation and it is suitable for incline road to create more force and high torque to complete the propelling cycle.

4.2.2 OVERVIEW OF LEVER-CHAIN MECHANISM

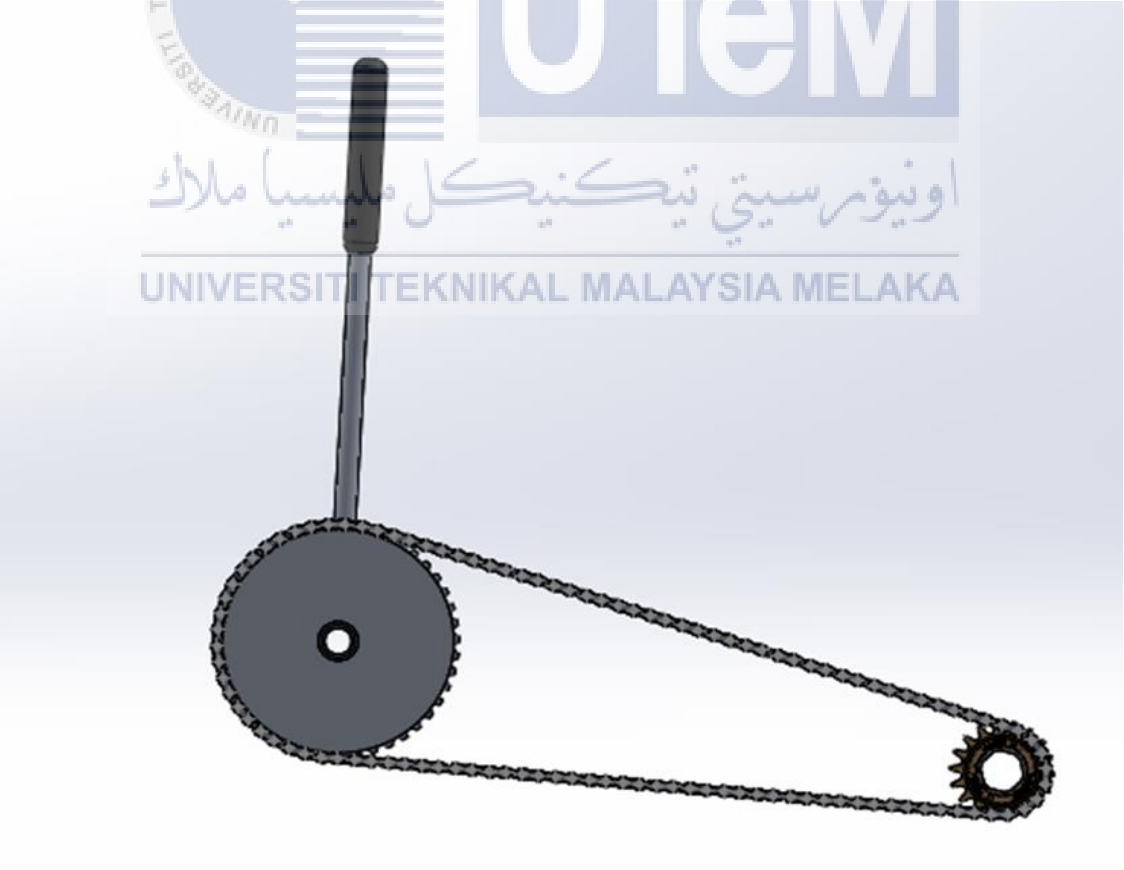


Figure 4.3 : Lever Chain Mechanism

4.2.3 OVERVIEW OF LEVER-CHAIN WHEELCHAIR ASSEMBLY

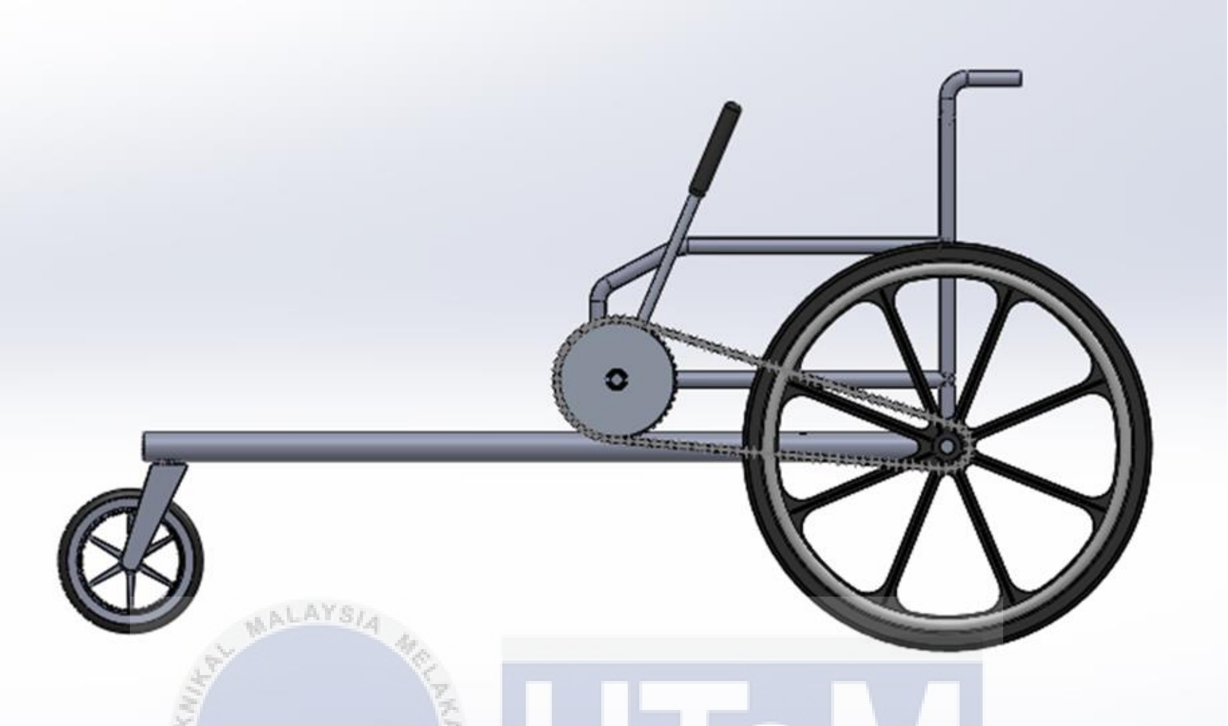


Figure 4.4 : Full Assembly Lever-Chain Wheelchair

By using Solidworks, lever chain wheelchair has fully completely designed and assembled. The process of the assembly was shown in pre-process which it uses mate command. The exterior design like seat, cushion and push handle was not concluded because of this design only for analysis purpose. Furthermore, the design is based on the all-terrain wheelchair design. This design has 3 tires due to compatible with rough road such as sand, grass, rocky and uphill road. The main frame of the wheelchair is enough as supporting member and main body for the wheels to gain weight from the seat and human body.

4.3 MOTION STUDY ANALYSIS ON MECHANISM

For motion analysis, roller chain and gear mate are difficult to be done as the knowledge are limited and less knowledge about the gear and chain motion analysis. To overcome the problem with limited time, it is suggested to use another transmitted power drive which is belt drives. The result and outcome are the same where both of the drive systems is purposely to transmit power from the driver to driven. Belt and gear analysis were done to determine the result such as:

4.3.1 TRACE PATH ANALYSIS

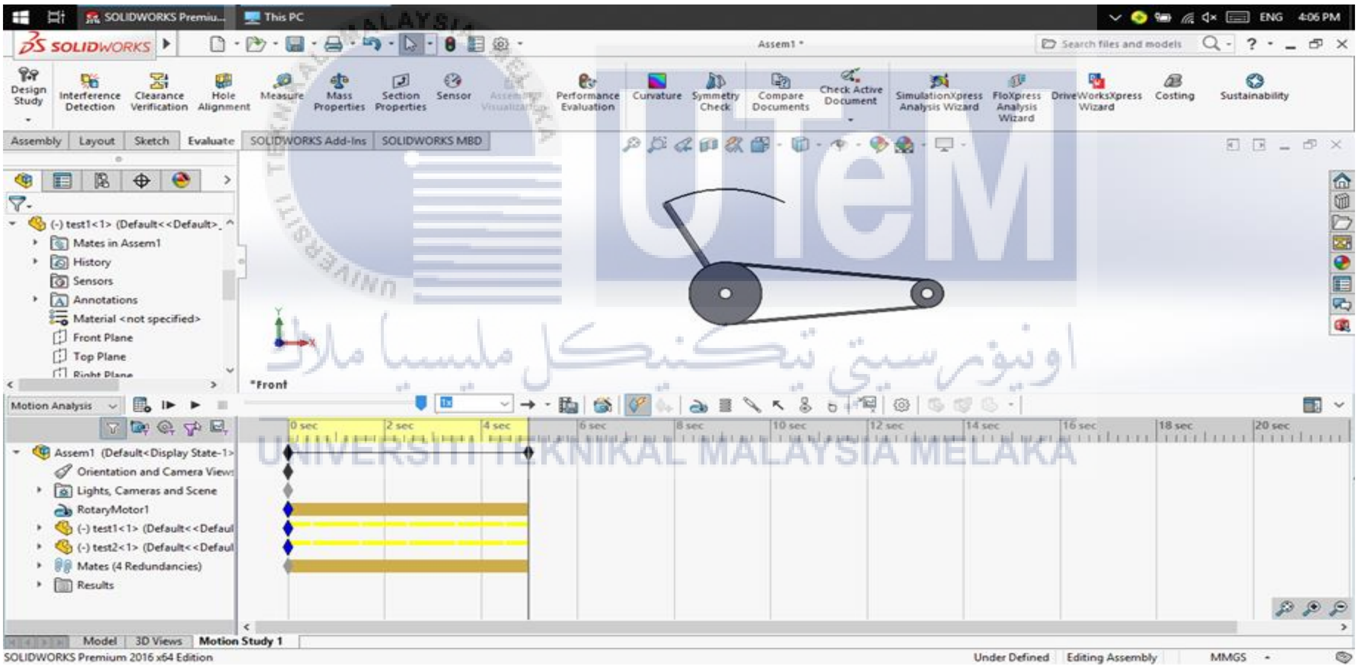


Figure 4.5 : Trace Path

Trace path is a path of motion that shows angle and movement of the lever handle. For this motion, it is 60° degree angle movement. The lever moves forward and backward with 60° angle which connected to the chain and transmit force and velocity to freewheel.

4.3.2 ANGULAR DISPLACEMENT ANALYSIS

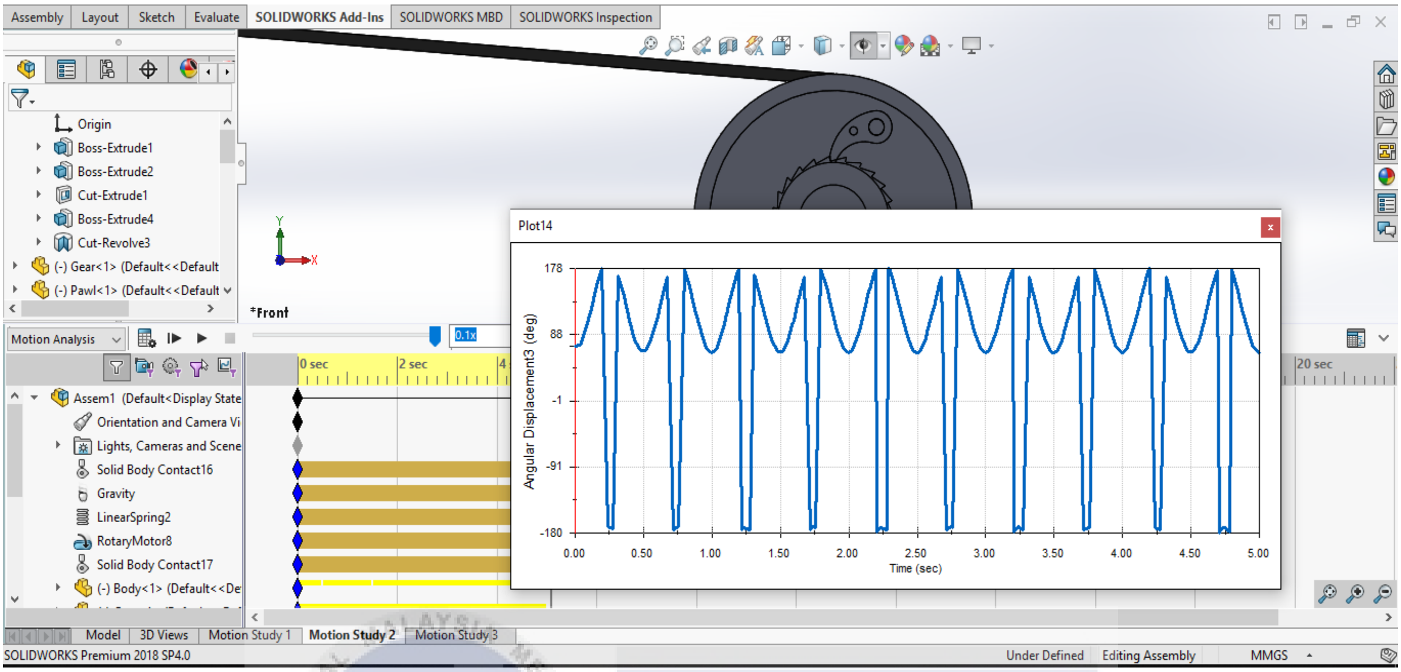


Figure 4.6 : Angular Displacement on Mechanism

Angular displacement is defined as the angle in radians (degrees, revolutions) through which a point or line has been rotated in a specified sense about a specified axis. It is the angle of the movement of a body in a circular path. For lever chain wheelchair, θ are the angle of lever handle which is 30°, 60°, and 90°. The radius, r are the radius for the drive sprocket and displacement, s is the distance between angles. This can compute in the angular displacement formula, = s/r. The unit for angular displacement is degree per seconds which is rotation per time. In the graph above, the highest value for angular displacement angle is 178 degrees/sec and the lowest value is -180 degrees/sec. The motion of the graph represents the rotating of freewheel which the displacement between one point to another has been rotated at the specified axis.

4.3.3 ANGULAR VELOCITY ANALYSIS

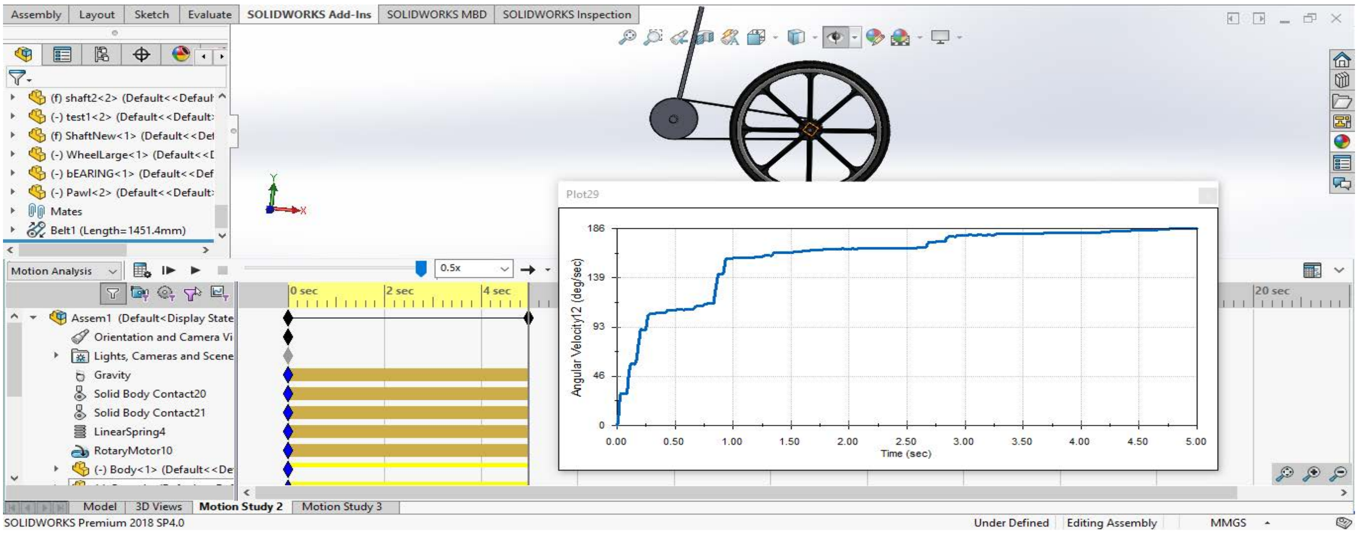


Figure 4.7 : Angular Velocity on Mechanism

Motion analysis can determine the angular velocity at specific angular parts. Angular velocity is a rate of change of angular position of a rotating body. The highest angular velocity is when the lever handle reaches at the middle of rotating motion which is the highest peak of angular velocity. The highest velocity for lever chain wheelchair is 186 degree per seconds. If we convert it to rotational per minute (rpm), it will become 31 rpm. A rotational per minute can be converted into km/hour which the unit is the basic speed units which must use the formula km/hour = wheel diameter x rpm x 0.001885. By inserting information to the formula, we can conclude that the highest velocity for lever chain wheelchair is 3.56 km/hour. This can be concluded for lever chain wheelchair has the highest velocity compared to the conventional wheelchair.

4.3.4 ANGULAR ACCELERATION ANALYSIS

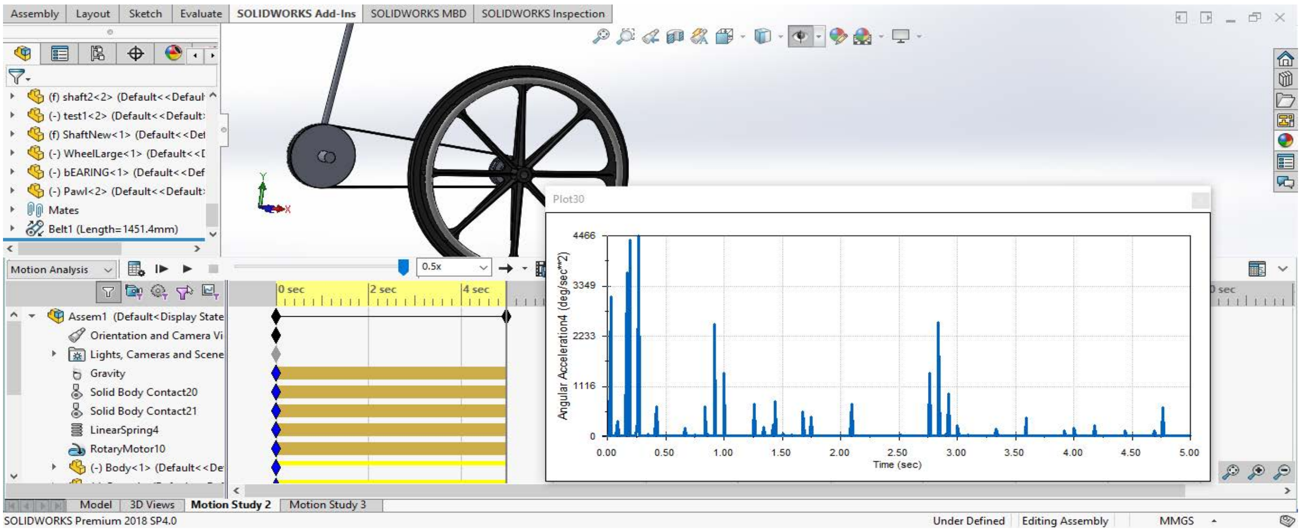


Figure 4.8 : Angular Acceleration on Mechanism

Angular acceleration is the time rate of change of angular velocity. SI units for angular acceleration are in radian per seconds squared (rad/s^2). The average angular acceleration is the change in the angular velocity, divided by the change in time. The angular acceleration is a vector that points in a direction along the rotation axis. The magnitude of the angular acceleration is given by the formula $\alpha = \frac{\Delta\omega}{\Delta t} = \frac{\omega_2 - \omega_1}{t_2 - t_1}$.

The graph above shows the highest value on acceleration is 4466 deg/sec^2. At 0 sec, the acceleration are high because of the wheelchair is about to move from stationary place. At 0.3 sec, the acceleration are maximum due to high force of propelling needed to give velocity to the wheelchair. The graph are slight skip about 2 sec each due to freewheel ratchet and pawl system. The acceleration occur when pawl are contact with the ratchet to rotate freewheel in one direction.

4.3.5 TORQUE ANALYSIS

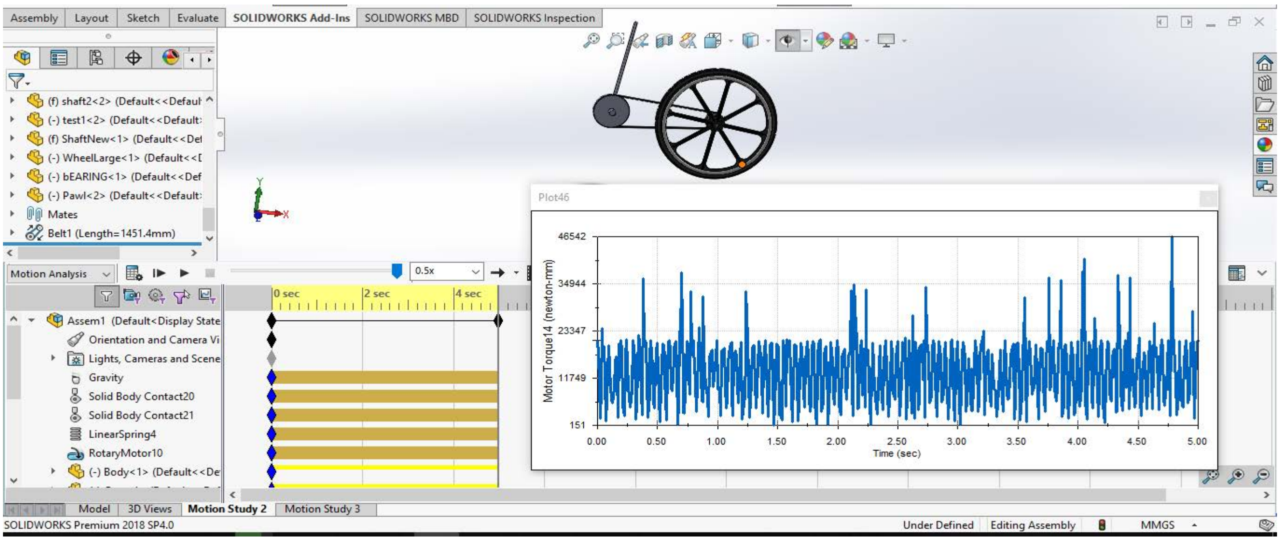
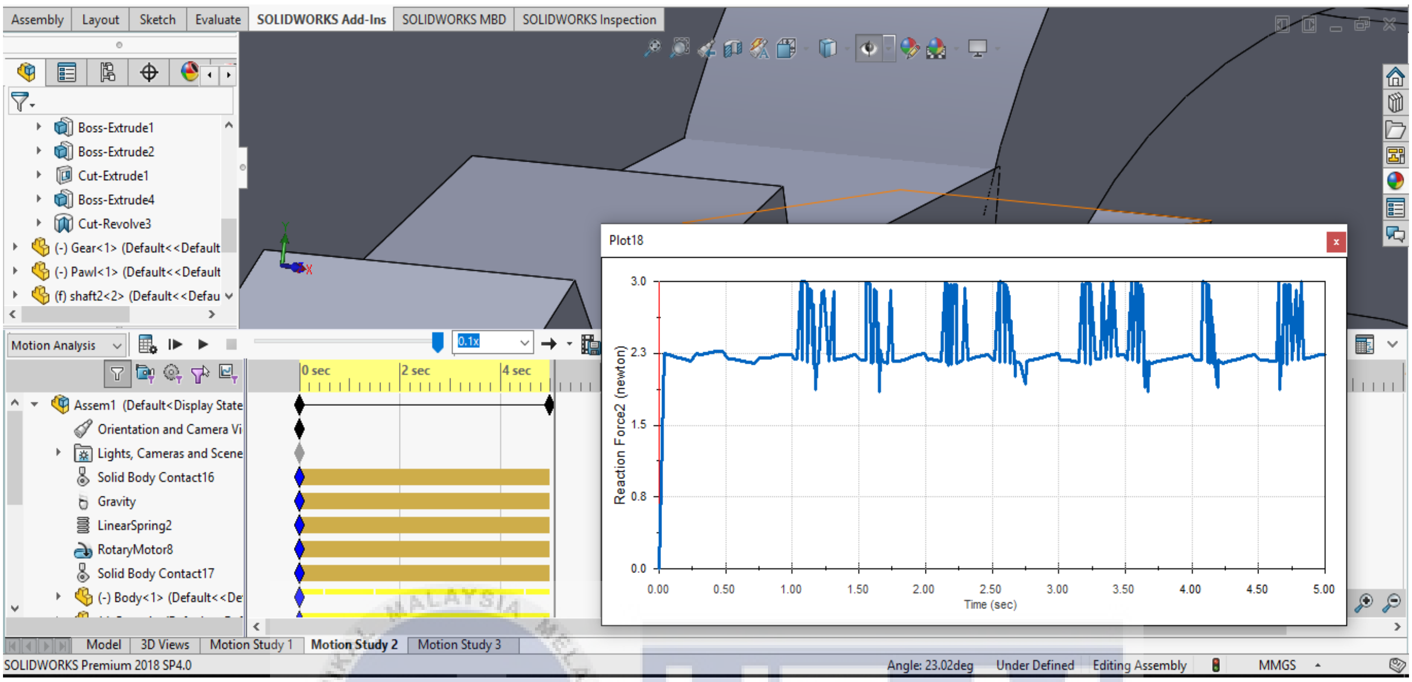


Figure 4.9 : Torque on Mechanism

Sprocket is the motor torque for this mechanism where the force is given on the handle that attached to the sprocket. The power will be transmitted to freewheel to rotate the rear wheel. Motor torque gives the simulation a graph of Newton versus time (seconds). Highest torque is 46.54 Nm also when the position of the handle is at the highest peak which is at 90° to the position of the human seat. Highest torque can be utilized when the wheelchair is going uphill road or rough terrain. The user can change the position of the hand to the tip of the lever to create more force and torque to propel. It creates high angles to complete one cycle propulsion. From the graph above, 0 sec has 23.34 torque power. This is because it takes high torque to move a stationary wheelchair. After the wheelchair has moved, the propelling force maintains and has the same torque which is approximate 20.0 Nm as shown in the graph.

4.3.6 CONTACT FORCE ANALYSIS



Freewheel also known as ratchet rotates the rotation of the transferred power in one direction but transfer torque in the opposite direction. The transfer torque gives the ratchet and pawl contact force which helps freewheel to rotate in one direction. Ratchet and pawl system has contact force which can be analysed using motion analysis in Solidworks. Ratchet consists of gearwheel and spring loaded with a pawl that engages the teeth. When the teeth from gear move clockwise, the pawl slides between the teeth. The spring force will pawl back into the depression between teeth. If the lever propels in forward motion which is the moving wheelchair, the ratchet rotates anti-clockwise direction which engaging and contact occur with pawl which drives the lever chain wheelchair forward. From the graph above, the reaction force with teeth and pawl approximately 2.3 N to 3.0 N.

4.4 MOTION STUDY ANALYSIS ON LEVER CHAIN WHEELCHAIR WITH TERRAIN

4.4.1 LINEAR DISPLACEMENT ANALYSIS

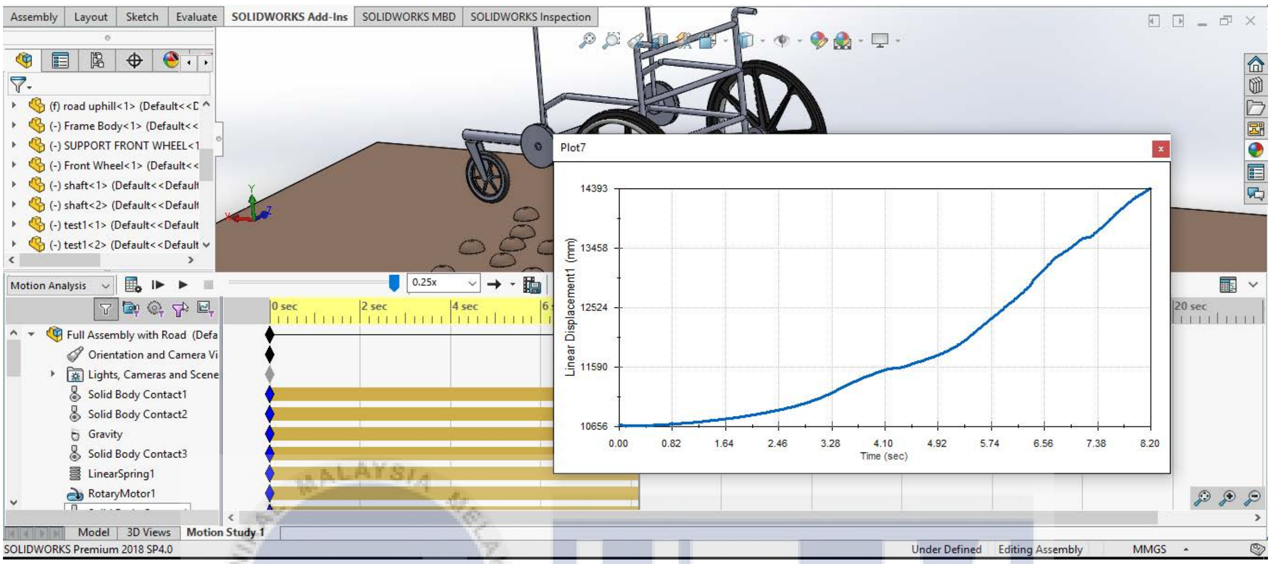


Figure 4.10 : Linear Displacement

Linear displacement can be defined as movement of an object in a linear fashion along a single axis in a straight line, for example; from side to side or up and down. Linear displacement for lever chain wheelchair are in x-axis where from starting point of 0 sec to end point 8.20 sec. Graph above shows an increasing linear displacement by the unit of mm/sec. The highest value for linear displacement is 14393 mm/sec which can be convert to 51.8 km/h while the minimum value for linear displacement is 10656 mm/sec and can be convert to 38.4 km/h. From the displacement over time graph above, it shows an accelerating graph which is increasing curve.

4.4.2 LINEAR VELOCITY ANALYSIS

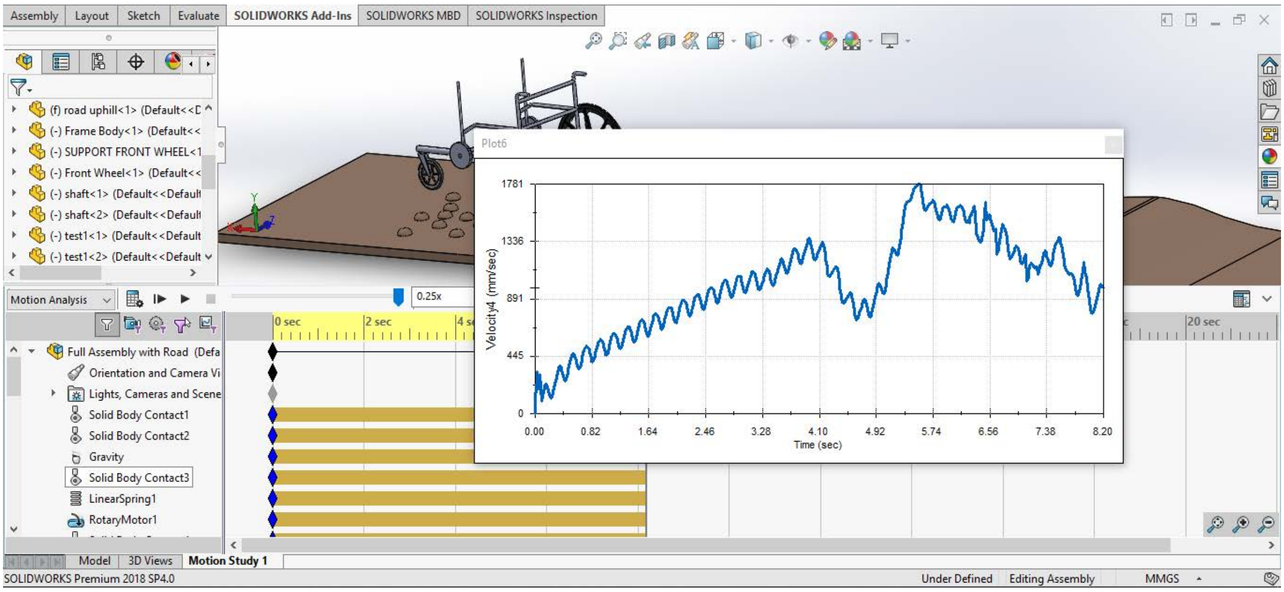


Figure 4.11 : Linear Velocity

Linear velocity graph above shows the maximum and minimum velocity of lever chain wheelchair on uphill and rough terrain. The minimum value of velocity is approximate 300 mm/sec which can be convert to 1.08 km/h and the maximum velocity for lever chain wheelchair during downhill velocity is 1781 mm/sec which can be convert to 6.4 km/h. This is because the minimum velocity achieved when the wheelchair is about to accelerates. It requires high force to start propelling the lever on the wheelchair and also uphill state. This can be seen 4.92 sec, the wheelchair at lowest velocity due to uphill road climbing and have maximum velocity during downhill speed. At 6.56 sec where wheelchair start to experience rough terrain, the velocity shows slightly decrease due to rocky terrain. The average velocity for wheelchair to move in rough terrain is 1336 mm/sec which can be convert to 4.8 km/h.

4.4.3 LINEAR ACCELERATION ANALYSIS

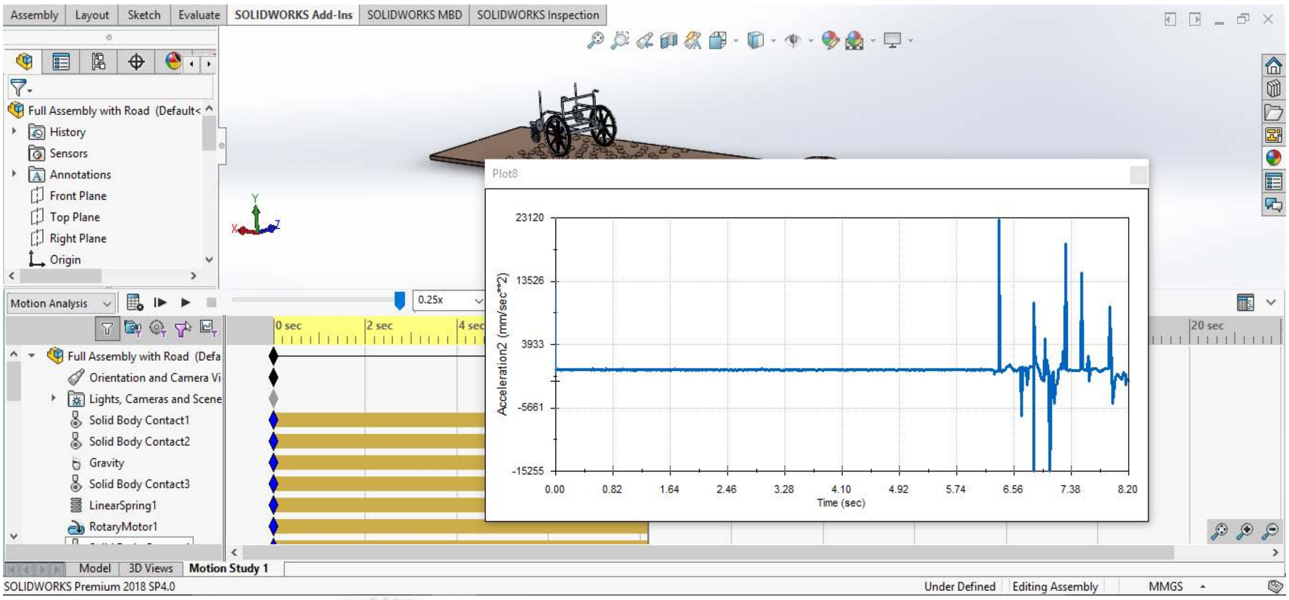


Figure 4.12 : Linear Acceleration

The acceleration graph above shows how lever chain wheelchair start to move and also when the wheelchair had to accelerates during rough terrain. Acceleration is rate of change of velocity. The acceleration graph shows at 0 sec, the acceleration is approximately 11000 mm/sec^2. This is because acceleration of the wheelchair at the starting point or about to move the wheelchair, maximum force is given to start propel the lever to move the wheelchair. At time 6.00 sec, the wheelchair experience rough terrain. The graph shows up and down accelerating due to unstable road. It shows that lever chain wheelchair can accelerates smoothly even in rough terrain and unstable road.

CHAPTER 5

CONCLUSION & RECOMMENDATION

5.1 INTRODUCTION

This chapter will summarize the results that were obtained from the testing of the composites. In this chapter, the final conclusion of the project is stated. The recommendation pertaining to the project is discussed.

5.2 CONCLUSION

Conclusively, the design and simulation of lever chain wheelchair is complete and the objective are met. The simulation and animation are run through Solidworks and has been shown to my supervisor. The design of the lever chain wheelchair are fully utilized and can be used as market developing to enhance the person with disabilities to own a cheapest wheelchair that has basic mechanism to do their daily work activities. Due to constraint during the project, the motion study on angular velocity, angular acceleration and angular displacement result cannot be valid due to insufficient time to fabricate the model to test and compare. The angular velocity for the lever chain mechanism is 186 deg/sec which is 31 rpm. By the theoretical calculation for velocity is 27 rpm which can be compared with the 31 rpm angular velocity. Due to that, the velocity for lever chain mechanism is 3.56 km/h. Next, the angular displacement value is 178 deg/sec and the angular acceleration for mechanism is 4466 deg/sec^2. Freewheel torque from the motion study is 46.54 Nm which can be compare with theoretical value of 111.12 Nm. The power required to propel the lever chain mechanism is 706.5 W according to theoretical value. Moreover, for full assembly motion study on lever chain wheelchair is observed. Linear velocity for the wheelchair speed is 1781mm/sec which convert to 6.4 km/h speed. Next, linear displacement the highest value is 14393 mm/sec which is 51.8km/h. Finally, linear acceleration highest value during motion study is 11000 mm/sec^2.

5.3 RECOMMENDATION

The recommendation of this project for future investigation is to analyse the data result with the testing result from the fabrication of the wheelchair. As a result, the data can be valid due to comparing between theoretical, motion study and testing. Finally, the data can be more accurate for future study about the mechanism.

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