DESIGN, SIMULATION AND ANALYSIS OF CLIMBING TROLLEY

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This report is submitted

in fulfilment of the requirement for the degree of

Bachelor of Mechanical Engineering

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DECLARATION

I hereby state that I have read through this report which the title is "Design, Simulation and Analysis of Climbing Trolley" is the result of my possess work but as cited within the references.

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Date : 11/8/2020

APPROVAL

I state that I have read this report and, in my view, that this report is adequate in term of scope and quality for the grant of the degree of Bachelor of Mechanical Engineering.

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Date : 25 August 2020

ABSTRACT

First trolley model evolved long back in eighteenth century. However, fast improvement in this field began in the middle of twentieth century. Many types of models had been designed, extending into broad range of products. That is the reason to further develop the next generation trolley. The aim of this project is developing a mechanism for easy transportation of heavy loads over stairs. The requirement for such a system arises from regular needs in our society. Devices like hand trolley are used to relieve the stress of lifting whereas on flat ground; however, these devices sometimes fail once it involves carrying the load over short fleet of stairs. In the light of this, the project makes an attempt to design a stair climbing hand cart which may carry heavy objects up the stairs with less effort compared to carrying them by manually. It is important to review the commercial viability and importance of such a product. A few designs were considered that would permit a non-industrial hand trolley to go over stairs, curbs, or uneven terrain while reducing the strain on the user. In our project, the stair climbing trolley manually is equipped with rubber excavator base wheels which enable us to carry load up and down the stairs. The rubber base set out to modify an existing product that would be east to assemble and use. The design primarily involved processes like brainstorming, creating conceptual sketches, making CAD modelling. It additionally eases movement of trolley in irregular surface like hole, bumps, etc. At the end, the design of strair climbing trolley has been produced in Autodesk 3ds Max and the result of simulation of the von mises stress,

displacement and equivalent strain on the components of the rim, handle and shaft were analyzed.

ABSTRAK

Model troli pertama telah berkembang sejak abad kelapan belas. Namun, produk ini terus berkembang dengan pesat pada pertengahan abad kedua puluh. Pada pertengahan abad kedua puluh ini, terdapat pelbagai model telah dicipta. Berikutan itu, projek ini mengambil pendekatan maju setapak lagi dalam mereka bentuk troli ini. Objektif projek ini adalah untuk mengembangkan mekanisma pengangkutan muatan berat ke tangga. Keperluan pengangkutan seperti ini diperlukan dalam kalangan masyarakat kita. Troli tangan digunakan untuk mengurangkan tekanan mengangkat semasa berada di tanah rata. Tetapi, kadang kala troli tangan ini gagal untuk mengangkat muatan apabila berhadapan dengan tempat yang bertangga. Sehubungan dengan itu, projek ini dilaksanakan untuk membina sebuah troli yang digunakan untuk membawa muatan berat ketika menaiki tangga dapat meringankan beban berbanding membawa muatan itu secara manual tanpa sebarang alat bantuan. Projek ini juga bertujuan untuk mengkaji daya maju komersial troli tersebut dan kepentingannya. Terdapat beberapa reka bentuk yang digunakan dalam bidang bukan perindustrian untuk melalui tangga, jalan, atau kawasan yang tidak rata sambil mengurangkan tekanan pada pengguna. Dalam projek kami, troli pendakian tangga secara manual dilengkapi dengan roda asas daripada getah yang membolehkan nya membawa muatan ketika naik dan turun tangga. Roda trek daripada getah telah diubahsuai untuk memudahkan penggunaan ketika dipasang dan digunakan. Reka bentuknya merangkumi proses seperti percambahan fikiran, membuat lakaran konsep, membuat

pemodelan CAD. Perkara ini juga memudahkan pergerakan troli di permukaan yang tidak sekata seperti tempat yang terdapat lubang, bonggol dan lain-lain. Kesimpulannya, projek ini telah melibatkan lakaran troli secara manual dengan menggunakan Autodesk 3ds Max, simulasi von tekanan, anjakan yang dihasilkan dan ketegangan yang setara pada komponen pelek, pemegang dan batang.

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LIST OF ABBREVIATIONS

CAD	Computer Aided Design
3D	3 Dimensional
DC	Direct Current
BS	British Standard
ANSI	American National Standards National
HOQ	House of Quality
QFD	Quality Function Deployment

LIST OF SYMBOLS

m	Meter
kg	Kilogram
%	Percentage

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CHAPTER 1

INTRODUCTION

1.1 Background

First trolley model evolved long back in eighteenth century, however fast improvement in this field initiated since middle of twentieth century. The main shopping trolley was created by Sylvan Goldman in 1937. Sylvan Goldman claimed a general store chain in Oklahoma, and Sylvan Goldman saw that the clients attempting to convey their goods in over filled, overwhelming hand baskets. With the assistance of a mechanic, Fred Young, made the principal shopping trolley model from a lawn seat, wheels, and a couple of wire baskets. The shopping trolley was not immediately effective. The men viewed pushing a trolley as womanly, while woman thought it unstylish and reminiscent of pushing an infant's surrey. In any case, they in the long run got on the grounds that they made shopping so significantly simpler, and by 1940 their prevalence had developed such a great amount of that there was a multiyear waiting list for different stores to purchase them.

In 1947, Goldman enhanced the Shopping Trolley configuration by supplanting the collapsing part with a settled design, so trolleys could be pushed into one another as it is today. Goldman likewise expanded the size of the trolleys, as understood that a bigger trolley prompts bigger purchases.

The aim of this project is developing a mechanism for easy transportation of heavy loads over stairs**.** As an understudy, Autodesk 3ds max software was used to design the

product. A trolley is a device utilized by debilitated people to upgrade their personal versatility. There are numerous kinds of trolley accessible within the market like manual or auto trolley and the decision of trolley relies on the physical and mental ability of the client. The hand trolley could be a small transport device that utilized to move heavy loads starting with one place to another place. It perhaps an exceptionally basic tools utilized by a large number of industries that transport physical items. The trolleys can secure individuals from back wounds and other medical issues that can come about because of lifting heavy loads (Alaspure *et al.*, 2016). The new concept is manually stair climbing trolley is designed to reduce burden (Raj *et al.*, 2016). Regular trolley function admirably on flat ground, yet its convenience diminishes when it becomes necessary to move an object over an unpredictable surface. The whole reason for utilizing a traditional trolley manually is to abstain from lifting and carry heavy objects around.

Lifting a trolley up the stairs direct the reason of the device, since the user give enough upward force to lift the whole weight of the trolley and its substance. Besides that, the geometry of a trolley makes it almost difficult to lift with one's legs, just like the correct shape. Extensive strain is set on the back muscles and the danger of operator injury is strongly expanded. The vibration motion may harm the things stacked on the trolley. A trolley that could climb stairs without requiring the client to lift would enhance the safety of moving heavy items over sporadic surfaces.

In this project, a task was given to design a manually-operated trolley with tracks instead of wheels with the end goal to allow the trolley to climb up or down the stairs.

1.2 Problem Statement

Based on the market, we have both auto and manual stair climbing trolley. However, for the manual stair climbing trolley, it is using tri-wheel instead of rubber track chain wheel. Stair climber tri-wheel can sometimes be problematic when trying to move on the stair, as the wheel in a rotation position will be in contact with the stair and produce vibration (Gondole, Thakre and Moon, 2016).

In this research, the purpose is to study and design the manually stair climbing trolley. The reason of choosing the manually stair climbing trolley is because of the cheaper cost compare to the automatic trolley. As a beginning, the student will refer to the existing types of trolley that has been design and look for the optimization and redesign opportunities on the way to have better quality of the body structure design. The manually stair climbing trolley can be made from different types of materials – such as tube steel, aluminium tube and high impact plastics. Most commercial trolley that are used for service deliveries are very light weight. The mechanism of the pressing hand paddle can completely eliminate the automatic ship of carrying objects upstairs. It is light weight means that it can be easily transported. It should be easy to move around and to lift too. It also has the ability to reduce or even eliminate the health problems that can arise by using conventional had trolley that still require a lot of manual labour.

A lot of people who live at the apartment are facing difficulty in lifting heavy loads to their house especially to people who live at the higher floors with no lift facility provided. In order to overcome this problem, a new invention of a trolley complete with many useful mechanisms such as stair climbing mechanism can be invented.

1.3 Objectives

The objectives of this project are as follows:

1. To design and select the final design of for manually stair climbing trolley.
2. To find the value of von mises stress, resultant displacement, and equaivalent strain through simulation.

1.4 Scope of Project

The scopes of this project are:

1. Low cost product base on manually concept system.
2. The performance parameters consider are of von mises stress, resultant displacement, and equaivalent strain.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In the part of the report, details and information collected from reading journals, books, papers, articles and other sources that written by the researchers. The idea of this is to have a clear understanding of the key elements involved in this project. The ideas are originally taken from the authors; took the information from time to time sure the project is precise however, it is all written in own words by synthesizing and paraphrasing.

Most studies that were conducted were done with the consumer in mind. Several factors have been taken in order to make sure this project is excellent in terms of safety, cost and suitability income consumers. The study of the materials and basic components used in the project has also been taken into account.

From the results that have been obtained in the studies, certain weaknesses in the project has been carefully managed to further enhance the project performance.

2.2 The Basic Components

The specification is as follows:

BODY:

The body of the manually stair climbing trolley separate into three parts, that is handle make of mild steel, strengthening piece make of steel and the base shelf make of sheet steel which join with the rubber track chain wheel.

HAND PADDLE:

The hand paddles are very important, which will help to apply extra force to move the manually stair climbing trolley up and down the staircase by continuously squeeze for few times.

SPROCKET:

The sprocket is what powers other sprockets to rotate, for the rubber track chain wheel to move by the squeeze the hand paddle.

RUBBER TRACK CHAIN WHEEL:

The rubber track chain wheel is what look like caterpillar shape, it will move the trolley up and down the staircase. This function enables the project to get grip on the edge of the staircase.

BEARING:

The bearing use for rotating two bar of shafts place at in front and back of the trolley base, which join with the rubber track chain wheel.

2.3 Hand Paddle Choosing

Hand paddle is most suitable in this project, which attached at the end of the handle that have been studied. The studies that make on as long as the chain is on the sprockets for rotate the rubber track chain wheel, it can apply a bit of force for gentle acceleration, or more force to move faster by squeeze with the hand paddle and the paddle should be adjusted so that the rubber track chain wheel can skid if necessary.

Among the factors that contributed to the selection of hand paddle is the readily availability of the idea in the mini hand fan concept. This is very important as it can saves time where moving the manually stair climbing trolley for up and down of the staircase. This type of hand paddle which are easily available in the market will also able to acquire the hand paddle needed easily. In addition, hand paddle is selected as this type requires no maintenance cost and is not complicated to install. Besides that, a hand paddle is lighter and easy to handle.

Taking all that into consideration for decided to choose two hand paddles in order to achieve the project scope which is to be climb at least five steps of stair.

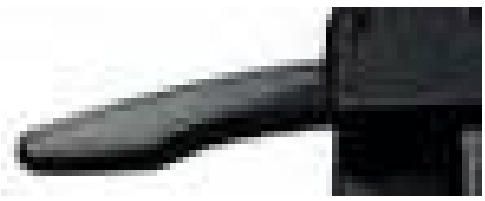


Figure 2.1 Hand paddle

Based on the previous study on the journal of "Design and Finity Element Analysis of a Stair Case Material Handling System", says that this topic be able to explain about the fabrication and analysis of the staircase lift, which able to use as Material Handling System. A staircase lift is a mechanical device for lifting individuals and wheelchair all over on the stair, who may discover trouble in doing as such themselves. This trolley keeps running on electric power and comprise of a motor, decrease sprocket box, rope drive, two rails a sliding seat. In this system, DC motor for changing the extremity of the power supply which will make the motor workers reverse direction join with the before, while the later will arrange to form the entire assembly run to descending direction, with the assistance of toggle switches and push buttons (Gerdemeli and Kurt, 2013).

2.4 Shaft

2.4.1 Introduction

Shaft is used to connect the rubber track chain wheel, few sprockets and bearing. This concept is inspired by a lawnmower. Shaft is used to rotate the rubber track chain wheel and the few sprockets that join on the shaft surface need to be direct contact of the grease thus ensuring the sprockets has a longer lifespan. This improves the Manually Stair Climbing Trolley performance more.

Shaft is used to transfer power from the transmission to differential. Transmission is usually mounted on a chassis frame, while the rear differential or axle is supported by the wheel at the front and back. Therefore, differential position relative to transmission changes at the time of operation. Shaft are usually circular shaped which is attached to elements such as sprockets, pulley, flywheel, sprocket and other elements of transfer. Shaft

usually receive bending loads, pulling loads, compressive load or load-round self-employed or a combination with one another.

There a number of different types of shafts like:

I. Axle shaft

II. Spindle shaft

III. Flexible shaft

Axle shaft is a device which is used for transmitting rotary motion between two objects relative to one another. It consists of a rotating a bar which is solid but has some torsional stiffness. It transmits considerable power.

2.4.2 Shaft Choosing

The are several factors that contributed to the selection of axle shaft which is easy to maintenance. This can be proved by a comparison of flexible shaft and axle shaft. Axle shaft does not require complicated installation, it just requires careful tacking on top of the bottom row only. In addition, the cost of installation of this shaft is also low as these shafts are available in stores where the cost of an axle shaft is only around RM50 to RM85 only. In addition, axle shaft is also the most appropriate for the project. The manually stair climbing trolley requires a shaft that can be solid to channel energy from the hand paddle to the rubber track chain wheel. Lastly, the selection of the axle shaft will increase the performance Manually Stair Climbing Trolley to operation.

Figure 2.2 Axle shaft

2.5 Bearing

2.5.1 Introduction

A bearing is an element that reduces friction between moving parts. Bearings likewise facilitate the desired motion however much as could be expected, for example, by minimizing friction. The bearings are classified comprehensively according to the type of process, the motions permitted, or to the directions of the loads (forces) connected to the parts.

2.5.2 Bearing Usage

The project decided to use bearing to reduce the friction between the shaft and the rubber track chain wheel thus increasing the projects lifespan. It also serves as a housing unit for the rubber track chain wheel.

Thus, it is found that the ball bearing possibly is the best bearing type that can be used in this project. Ball bearing is a conventional bearing that has been provided with balls on its sides so that the bearing can be used for longer periods without greasing.

This type of bearing is suitable for use in this project as there is a seal that protects the lubricant (grease) in a bearing against the entry of foreign objects. This makes the bearing an ideal bearing that can be exposed to water and dirt.

Figure 2.3 Ball bearing

2.6 Sprocket

2.6.1 Introduction

A sprocket is the portion of a machine component with teeth are cut around cylindrical shaped surface that is designed with equal spacing. The drive chain discussed in the earlier two lessons keeps running on sprockets which are designed to coordinate the roller diameter and pitch of the chain. The sprockets are associated with the shaft by one of a few accessible methods. Besides that, connection by a keyway and grub screw is normal. Sprockets give a similar drive speed, accelerated drive speed or decelerated drive speed. This is achieved by varying the number of teeth in every sprocket. A similar number of teeth gives a similar speed to the driven shaft. On the off chance that the driven sprockets teeth are less, the speed increases and if the driven sprockets teeth are more, this will decelerate the speed of the driven shaft. The sprocket standards of the sprockets for roller

chain are British Standard and American National Standards Institution. Furthermore, the other types of sprockets are conveyor, metric, double pitch, and duals (two single chains). Next, the materials of the sprocket are steel, cast steel, plastic, and stainless steel. There are four types of hubs as illustrated in the figure below:

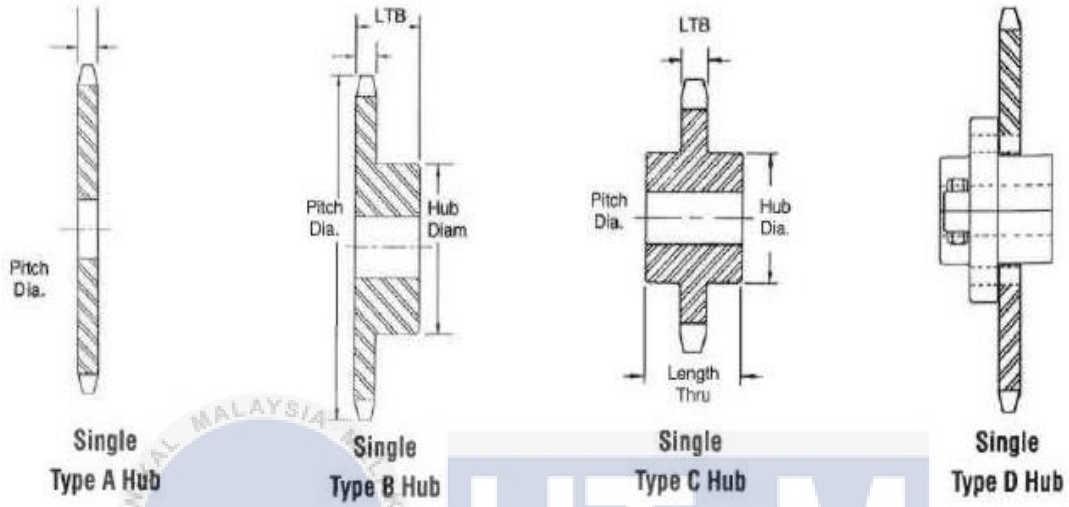


Figure 2.4 Type of hubs

The Part numbers for sprockets are like the coordinating chain part numbers and hence, will be simple to get understand it. A sprocket is recognized by the type and pitch size of chain it acknowledges, the technique for holding onto the shaft and the number of teeth.

Table 2.1 Part number data

EG. Boss Type Sprocket 08B17	**08** **B** **17**	- 1/2 inch pitch BS - Bossed - 17 Teeth
EG. Tapered Bush Entry 50BTB57*	**50** **BTB** **57**	- 5/8 inch pitch ANSI - Boss Tapered Bush - 57 Teeth
* Tapered Bushes are normally fitted through the hub of the sprocket. Flange (Face) entry are made to order.		

Most sprockets have a part number on the face, so that it can be identified by taking the measure of the pitch, the plate thickness and by description of the type. The pitch can be estimated by assessing the middle point of the teeth as illustrated in this figure. The measuring point ought to be roughly 1/3 of the path down every tooth. Since every sprocket is designed to carry a specific size chain, the situation of the pins in the space between the teeth.

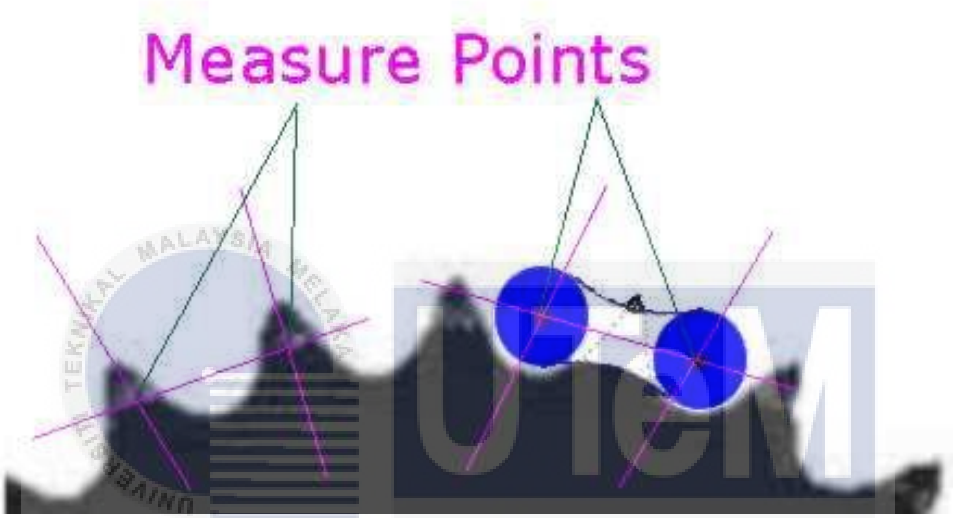


Figure 2.5 Measuring the pitch

2.6.2 Choosing the Sprocket

Some aspects have been considered in the selection of the sprocket and in the end, decided to choose stainless steel sprocket as stainless steel does not readily corrode, rust or stain with water as ordinary steel does. Stainless steel's resistance to corrosion and staining, low maintenance and familiarity makes it an ideal material for many applications. Stainless steel is also chosen as it is easy to obtain in market. Moreover, stainless steel has a high structure rigidity which ensure that the sprocket does not break when rotate with the help of chain forces.

As a rule, the sprocket must be made of a substance which is as hard as or harder than the material it is intended to rotate. If this is not the case, the sprocket will either be unable to rotate, or the teeth will wear away very quickly while damaging the chain only slightly.

Figure 2.6 Sprocket

Based on the previous study on the journal of "Design and Manufacturing of a Stair Climbing Vehicle", says that trolley can climb stair or move along rough surface. The specialized issues in structuring of the trolley are that steadiness and speed of the trolley while climbing stairs. The usages of this special trolley are in the continuous lift of products, for example, books, medicines for hospital and transportation any material for industries. Utilizing of this trolley, the Labour cost can be lessen and in addition as huge amount of loads can be exchanged consistently with less power consumption (Chowdhury, Linda and Akhtar, 2010).

2.7 Chain Drive

Chain drive an instrument in which mechanical energy is transmitted over a distance by a chain that join with sprockets. Unlike belt drives, there is no slip in chain technology. Nevertheless, the chain drive for the most part suited for small centre distance, ordinarily up to 3 meters. In some special condition, chain drives can even cover a distance of up to 8 meters.

Chain drives are characterized by different criteria: the structure of the chains utilized, the number of sprockets (simple drives with two sprockets and complex drives with at least three sprockets, including at least one driven and idler sprockets for tensioning), the way of rotate of the drive sprockets (clockwise and anti-clockwise), the spatial arrangement of the chain will be vertical circles, flat circles, and sprockets with crossed axes, the disposition of the line joining the sprocket centres at vertical, horizontal and slanting), the disposition of the main or working strand (above or under), the change method of the rotational speed of the drive shaft (decrease or stage up), the number of chain forms in parallel, the methods used to alter chain strain, the methods used to protect the chains from corruption. This chain drive technology is utilized for performing three basic functions, that are:

1) Transmitting power: It can transfer the power in the of speed and torque from one element then onto the next element by methods for a connected chain and sprockets. Chain drives can transfer a large among of torque even inside a compact space.
2) Passing on materials: It can move, carry, slide, push, and pull different materials by joining buckets, frames, pockets, or meshes to the chains. It utilized for turning rollers to move a conveyor belt.

3) Timing purposes: Many enterprises utilize it to synchronize or time movements.

Figure 2.7 Chain drive

2.8 Rubber Track Chain Wheel

2.8.1 Introduction

The rubber track chain wheel section of said type is known from WO 2012/142705 A1, which is gathered from multiple rubber track chain section, has, on the central longitudinal pivot of its internal wheel contact side, a variety of guide horns orchestrated one behind the other. Thought the guide horns formed a semi quasi continuous edge which fits into the furrows shaped in the drive wheel, in the tensioning wheel and the running wheels. The fit of the guide horns as for the furrows makes it workable for the crawler chain to be guided during the movement of the rubber track chain wheel vehicle. Moreover, the rubber track chain wheel of WO 2012/142705 A1 has a multiplicity of projections which are alluded to as traction lugs and which are set along each side of the rubber track chain wheel. The traction lugs are structured in order to involve in with fitting activity into corresponding cavities in the drive wheel. Furthermore, therefore need to

ensure the transmission of power from the engine of the rubber track chain wheel vehicle to the rubber track chain wheel. Between the guide horns and the traction lugs there is located a plane running surface, on which the running wheels of the rubber track chain wheel vehicle run and which support by the heaviness of the rubber track chain wheel vehicle. The rubber track chain wheel sections of WO 2012/142705 A1 are fragments reinforced with tensile members, which section are each furnished with conclusion focuses at the both ends. It is workable for a section to be joined with different section. Each section composed of alternating flexible and less flexibility districts, whereby right off the flexibility of the rubber track chain wheel as it circulates, and the stability of the rubber track chain wheel, are guarantee.

2.8.2 Rubber Track Chain Wheel Usage

The rubber track chain wheel section, which can be quickly swapped, is a special crawler device with both the attributes of tyres and tracks. It is utilized to solve the issue the vehicle confronted while traversing rough and troublesome terrain, for example, beaches, marshes, deserts, snow and gravel. Contrasted with the regular track, rubber track chain wheel system can adjust to difficult terrain better and it likes a smaller turning radius. With more contact part and less ground pressure, the rubber track wheel system enjoys evident superiority over the normal tyres.

The rubber track chain wheel must be custom made as it should be smaller compares to the regular size of the track wheel. This is because the rubber track chain wheel must place at the base of the trolley and it need to have grip went climb up or down the staircase with the accurate dimension of the length. It also must be rigid enough to support the weight of the trolley and the things at inside the trolley to carry at that time.

The rubber track chain wheel must be spacious enough to make the wheels which connect each on other for rotate the rubber track chain wheel.

Figure 2.8 Rubber track chain wheel

Based on the previous study on the journal of "Stair Climbing Hand Truck", says that the electrical stair climber is designed for everyday dispersion, so it tends to be utilized much of the time. This specific item was structured as a compact and lightweight stair climber with the capacity a weight of up to 150 kg. It contains two basic techniques that allow the trolley to climb and down a set of stairs:

Figure 2.9 Teeth-shaped wheels

1) It will move step-by-step.
2) The trolley being laid level on the surface of the stairs and sitting on at least two steps.

This specific trolley was designed for single operations. The structure of this trolley is fundamentally the same as the wheels of a tank or digger with its teeth-shaped wheels it can gripping the edges of the stairs, allow the trolley to climb the stairs.

CHAPTER 3

METHODOLOGY

3.1 Introduction

To make a project there must be techniques that is utilized to do the project, so the project can be complete within the time specified and the project can be finished with a neat and flawless and accomplishes the set-out objectives.

The methodology is the methods to finish the project. These measures are very important in project to ensure that the project is effectively finished in an opportune way. These steps should be taken with the most extreme exactness with the end goal to produce quality projects. The following description will explain the methodology.

Methodology flow:

1) Process Gantt Chart
2) Project Flow Chart
3) Technical Drawing

3.2 Process Flow

There are numerous viewpoints that must be viewed as when planning a trolley. These exposures must be considered painstakingly with the goal that the device works that would be an advantageous to the project. A trolley height of 1400 mm or less permits most clients a sensible perspective of the zone in front of the trolley. Trolley length ought to be somewhere in the range of 1.5 and 2 times its width in such a case that it is too long, the trolley is hard to direct, or fit into lifts or other little spaces and if it is too short, operators tend to control the trolley by curving their spine. The most extreme load needs to convey is 60 kg. The wheels which are conceivable to use with this trolley are rubber track chain wheels.

3.3 Project Implementation Flow Chart

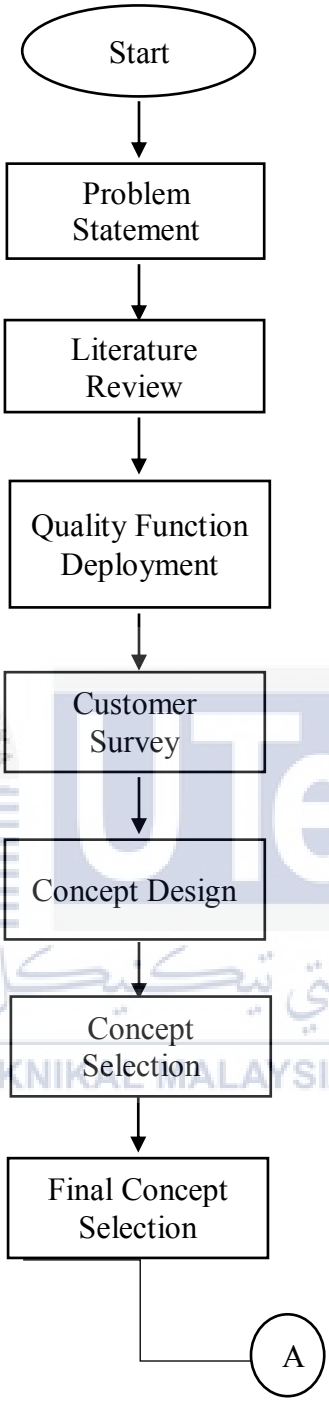
3.3.1 Gantt Chart

Gantt chart utilized for the arrangement of plan and the time taken to complete the project. The Gantt chart below shows that the how many periods taken for complete the project.

Table 3.1 Project planning schedule using Gantt chart

PROJECT ACTIVITY		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Problem Statement	Plan															
	Actual															
Literature Review	Plan															
	Actual															
Survey and Discussion Problem	Plan															
	Actual															
Project Requirement Components	Plan															
	Actual															
Improvements Project Ideas	Plan															
	Actual															
Testing and Analysis	Plan															
	Actual															

3.3.2 Flow Chart



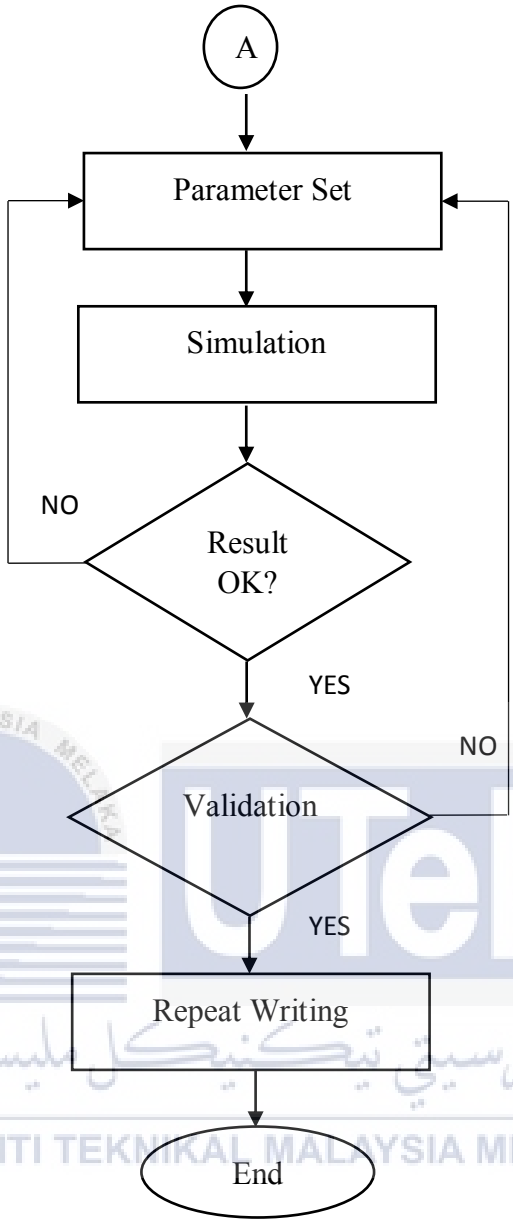


Figure 3.1 The summarized flow chart of methodology

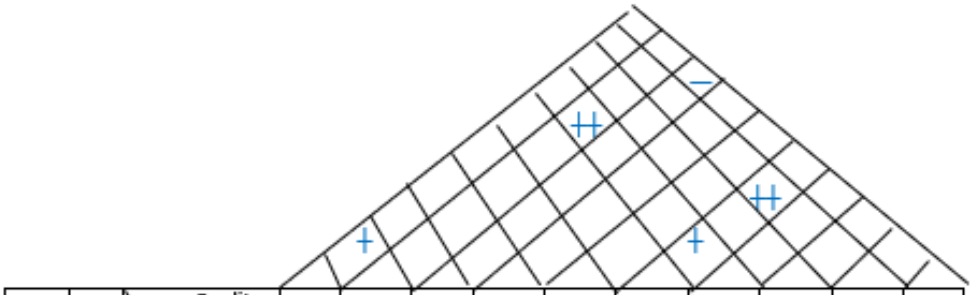
3.4 House of Quality

3.4.1 Introduction

The House of Quality (HOQ) is an important tool of Quality Function Deployment (QFD). The main function is to interpret customer necessities, market surveying and benchmarking information into organized engineering targets to be met by another product design. There are a few important elements in HOQ that ought to be a worry which relates the customer necessities with designing qualities. Customer necessities can be obtained from overview survey form analysis.

Figure 3.2 The symbol of legend

Table 3.2 The House of Quality (HOQ)



Relative Weight	Weight / Importance	Quality Characteristics (Functional Requirement) / Demanded Quality (Customer Requirements)	Weight	Strength	Stability of product	Material	Type of wheel grip	Function of mechanism	Force	Rotation	Material of mechanism	Friction, N
10.0	4.0	Easy to use			O		Θ	O	O	O		
10.0	4.0	Comfortable when using	▲		O	O	O	Θ				O
10.0	4.0	Waterproof				O						
10.0	4.0	Easy to carry things	O				Θ		Θ	Θ		▲
12.5	5.0	Safety feature		O		Θ					Θ	
10.0	4.0	Affordable prices				O	▲					
12.5	5.0	Anti-rust				O	O				Θ	
7.5	3.0	Easy to maintenance		▲		Θ						
10.0	4.0	Long life span		▲			▲					
7.5	3.0	Durability		Θ		O			O		Θ	
		Max relationship Value in Column	3	9	3	9	9	9	9	9	9	3
		Weight / importance	40.0	122.5	60.0	330.0	267.5	120.0	142.5	120.0	292.5	40.0

3.4.2 Concept Evaluation using Pugh's Method

The method that was used to choose the best concept design is Pugh method. This method looks at every concept in relative to a reference or datum concept. Pick one of the concepts as the datum then alternate concepts will be compare with the datum. The concept

that being analysed will be scored utilizing (+) sign, (-) sign or (=) sign. (+) sign shows positive score, (-) sign shows negative score and (=) shows no different score.

Table 3.3 Conceptual design evaluation using Pugh's Method

Criteria	Relative Weight (%)	Concepts			
		1	2	3	4
Easy to use	10	+	-	+	D
Comfortable when using	10	-	-	+	A
Waterproof	10	=	+	=	
Easy to carry things	10	+	-	+	T
Safety feature	12.5	+	+	+	U
Affordable prices	10	=	=	=	M
Anti-rust	12.5	+	+	+	
Easy to maintenance	7.5	+	=	=	
Long life span	10	-	=	+	
Durability	7.5	-	+	=	
PLUSES		5	4	6	0
MINUS		3	3	3	0
TOTAL SCORE		2	1	3	0

In view of the Pugh method for the evaluation purpose, the best concept design for the manually stair climbing trolley is concept design 3. It has the highest score as shown in the table above. Concept design 3 is picked as the final design for the further discussion in this PSM project.

3.5 Survey's Result

From Appendix A of this survey, female is the most. Female have the highest percentage by 56.7% and the average age of 20 to 35 years old is the highest percentage that answered the survey form. Most of the respondent never heard about the manually stair climbing trolley with the percentage of 60% because there are not many industries who develop the manually stair climbing trolley.

90% of the respondent's face problem in climbing the staircase while carrying loads. The respondent carrying a lot of loads in their daily life that cause a back pain or other. Most of the respondent are looking forward for a machine or an invention that may ease to the respondent in carrying loads via staircase to help respondent ease in carrying the loads.

46.7% of the respondent estimate that the possible cost of inventing the manually stair climbing trolley around RM 100 to RM 150, which are affordable to the society. Almost all the respondent hoping that the manually stair climbing trolley to be very effective and helps the respondent in carrying loads.

From the pie chart in Appendix A, the respondent demand for a low maintenance where the respondent can afford to pay the maintenance for the manually stair climbing trolley. The respondent also demands a fold-able where the manually stair climbing trolley is easy to handle and storage.

For modifying the manually stair climbing trolley, many respondents suggest adding another use for the facility for handicap by invent an invention a stair climbing for the wheel chairs.

Figure 3.2 Survey make at school area

Figure 3.3 Survey make at house area

3.6 Morphological Chart

Morphological chart is one of the techniques to create thoughts in a logical and orderly way. The primary capacity of this project is taken as a beginning stage, to make manually stair climbing trolley to climb up and down the staircase via conveying load in an assortment of circumstances. The components that sketches with some intuitive design. In this morphological chart, it gives different options in contrast to chosen design criteria. There is no material decision in this chart list.

There are different existing manually stair climbing trolley item in business sectors, nowadays that should be thought about and considered on their quality, safety factor of the system, type of the wheel and how the wheel can help the trolley to climb up and down the staircase. This is the initial step on the best way to coordinate the ideal of the mechanism into the project for better performance. The concept design has been placed in a morphological chart before concept design are made. The morphological chart is appeared in Figure 3.5.

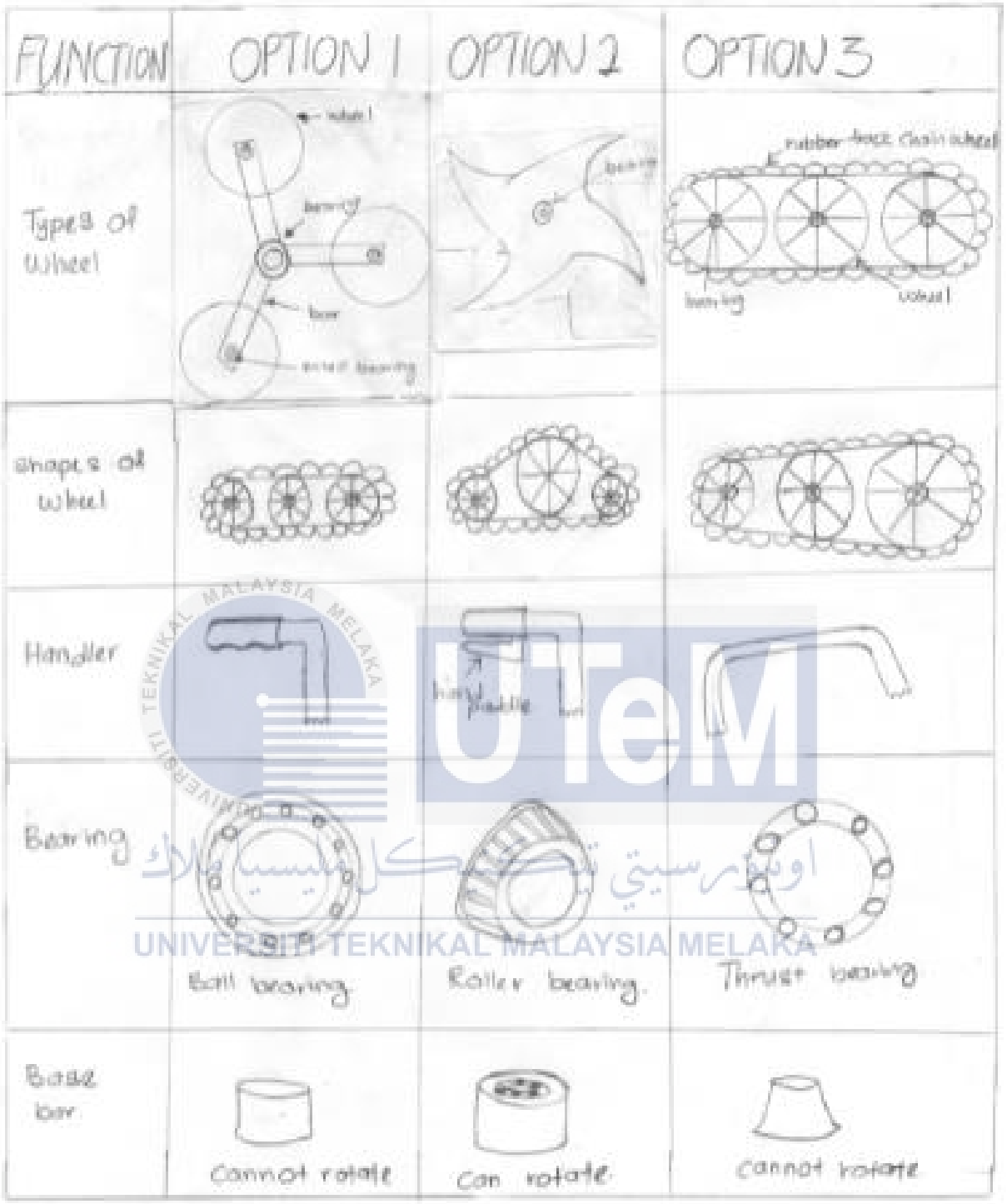


Figure 3.4 Morphological Chart

3.7 Concept Generation

CONCEPT 1	
Type of wheel	**Option 1**
Handler	**Option 3**
Bearing	**Option 3**
Base bar	**Option 1**

Figure 3.6 Concept 1

In Figure 3.6, the tri-wheel concept is designed as a rotation wheels which can exchange the wheels on 360 angles went hit the edge of the staircase. This type of wheel will make high pressure at the wheel and need more force to push the trolley climb up the staircase. The handler uses full bar join with the body of the trolley, so that it can apply at any place at the full bar to push the trolley. The bearing the use thrust bearing will apply axial force colinear with the shaft. The base bar use of a straight cylinder tool to swot the shaft, so that the shaft wheel will not move from the constant position.

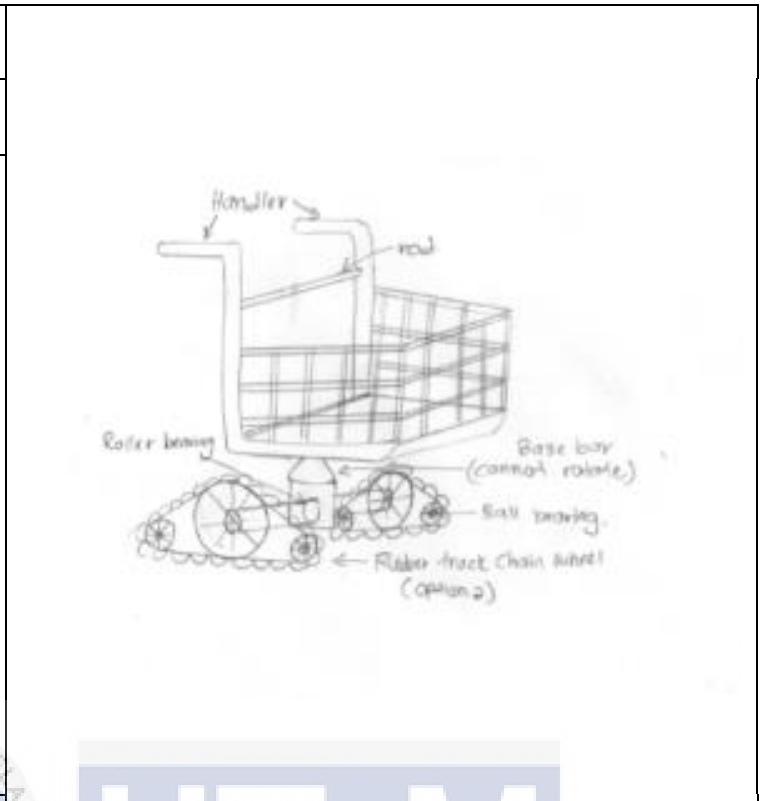
CONCEPT 2		
Type of wheel	**Option 3**	
Shape of wheel	**Option 2**	
Handler	**Option 1**	
Bearing	**Option 3**	
Base bar	**Option 1**	

Figure 3.7 Concept 2

In Figure 3.7, the shape of the wheel is triangle rubber track chain wheel arrangement concept is design to move the trolley in any situation place. But it needs a high force to rotate the middle wheel so that the other two wheels can rotate, because the middle wheel size is quite big that the two wheels. The handler that use is L shape without cover a sponge layer for hand holder. The bearing that use is roller bearing to rotate the shaft and the ball bearing at the wheel of triangle rubber track chain wheel to rotate, move one to another place. The base bar use of cone cylinder shape tool which have hole, for that shaft to place so that the middle wheel of the triangle rubber track chain wheel can be rotate.

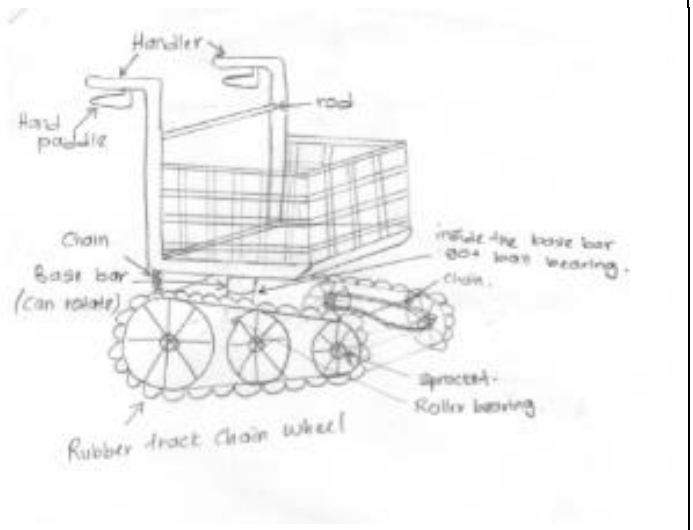
CONCEPT 3		
Type of wheel	**Option 3**	
Shape of wheel	**Option 3**	
Handler	**Option 2**	
Bearing	**Option 1 and Option 2**	
Base bar	**Option 1**	

Figure 3.8 Concept 3

In Figure 3.8, the shape of wheel is rubber track chain wheel arrangement concept is design to climb up and down the staircase, at the same time it can move the trolley in any situation place because it only will play that the edge at the teeth of the wheel. The handler has a cover of sponge at the hand holder and has hand paddle. The bearing that use is ball bearing roller bearing. The base bar uses the hollow cylinder for place the ball bearing to rotate the rubber track chain wheel went climbing up and down from the staircase.

3.8 Concept Selection

In this section**,** the concept 1 tri-wheel design shows that the wheel can be rotate 360 angle if the wheel hit at the edge of the staircase, it will produce a pressure in the tire and need high energy from the user to carry the trolley went climbing staircase. The handler of full bar join with the body of the trolley is not suitable, because at the middle of the bar will have bending state so that the user will apply more force on it, at last it has chance to break. Besides that, the concept 2 triangle rubber track chain wheel arrangement concept is not correct to use in the design because the design concept needs to push harder so that the shaft can be rotate to help the wheel move and no extra components will help the user to carry things using the staircase. The base bar shape is in cone shape, so that in chance the weight of the trolley cannot be support went climbing the staircase. Last but not least, the concept 3 is a good design because it has cover sponge layer for hand holder and at same time the important is it have hand paddle which can help to produce extra force by squeeze many times. The rubber track chain wheel is best to use for getting a better grip went climbing up and down the staircase. The roller bearing use for the heavy load and the ball bearing use in wheel and hard drives. As a conclusion, the suitable concept is concept 3 that will help the user in future use for carrying things in manually stair climbing trolley.

3.9 Manually Stair Climbing Trolley Modelling

The 3D modelling is constructed utilizing Autodesk 3ds Max software. The modelling procedure is begun from zero by utilizing point coordinates taken from past created model. Alter process isn't done on the earlier model document yet remake the model from zero. Hence, the model is fixed utilizing earlier point coordinates and improved the old model utilizing current point coordinates to make the neighbouring structure of the trolley with rubber track chain wheel. The 3D modelling process is done on the wireframe and surface design of select object by command panel as appeared in Figure 3.9.

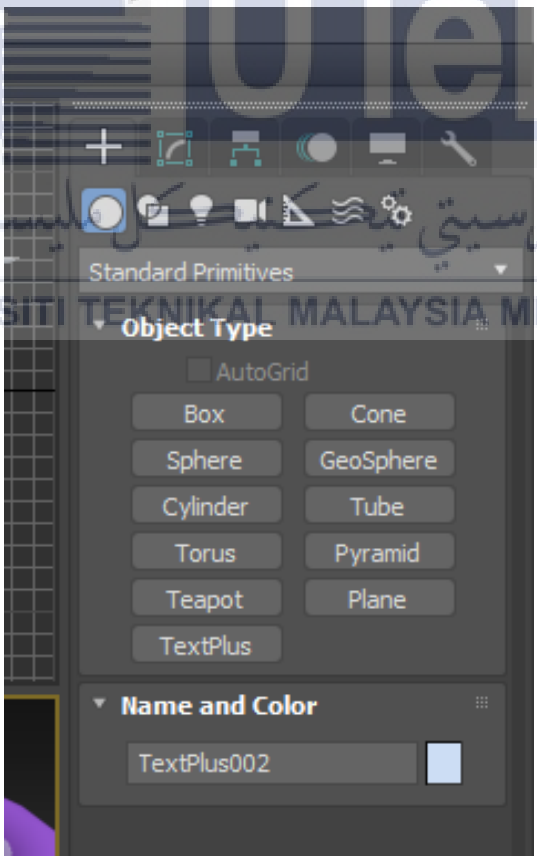


Figure 3.9 Wireframe and surface design of select object by command panel in Autodesk 3ds Max

The first step of the modelling procedure is made a circle, then extrude to make a cylinder so that can be insert ball bearing in the middle of the slot. After that, draw a cone shape for the base bar between the trolley basket and the rubber track chain wheel utilizing point by embeddings their coordinates as appeared in Figure 3.10.

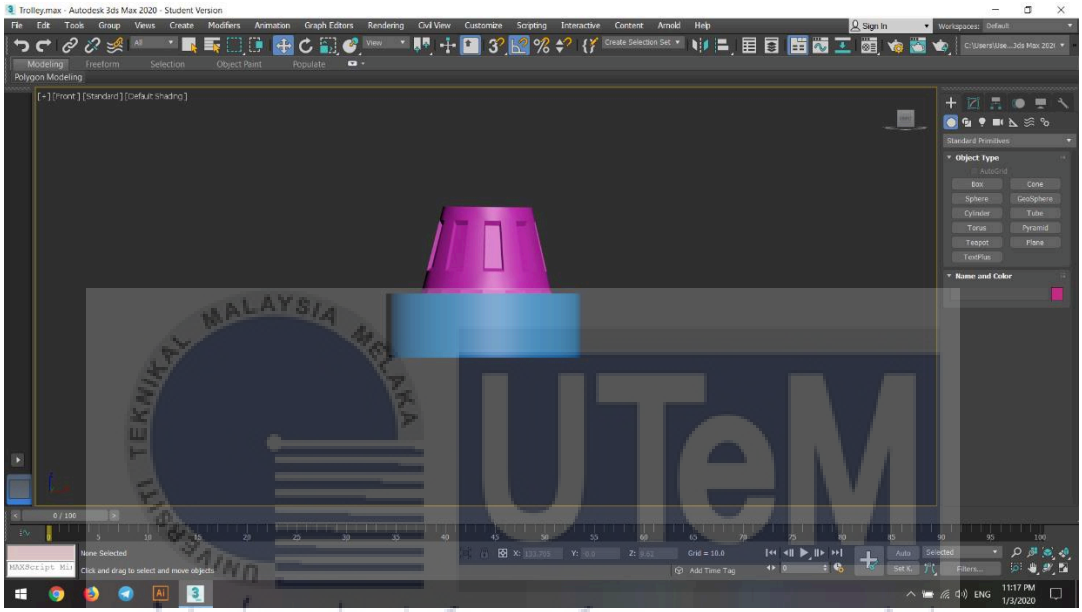


Figure 3.10 Modelling base bar (can rotate)

The second step is modelling hand paddle, by choose the create of shapes (line, rectangle, and arc) to complete the 3D modelling of the hand paddle as shown in Figure 3.11.

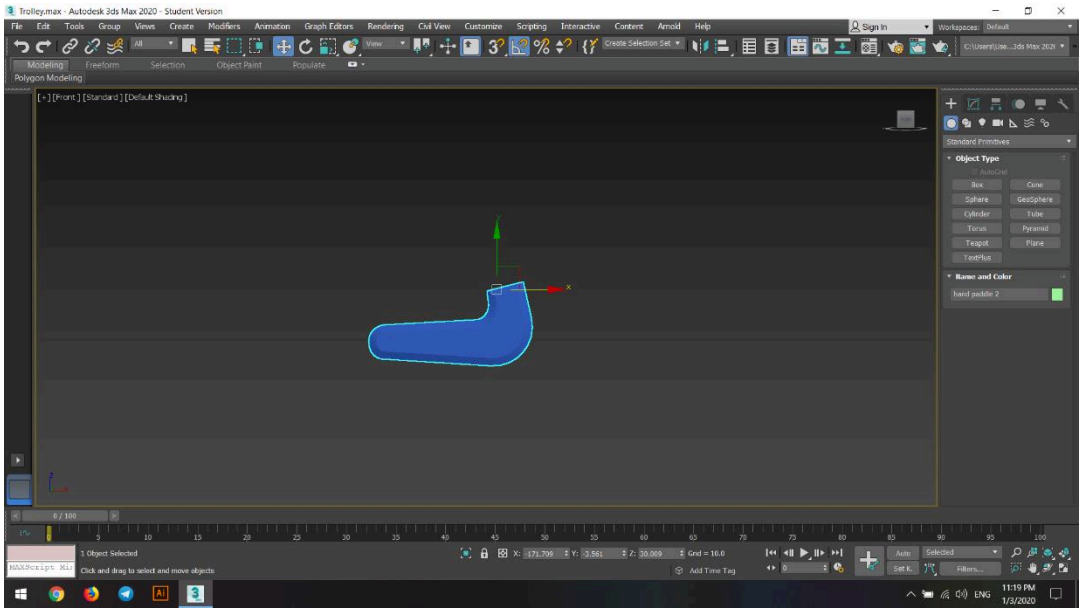


Figure 3.11 Modelling hand paddle

The third step is to create three wheels which is different diameter. The drawing started by choosing circle for the round surface and line for support the wheel, then extrude the drawing as shown in Figure 3.12. Additional, draw the rubber track chain wheel choosing extended primitives of plane and C-extrusion as shown in Figure 3.13.

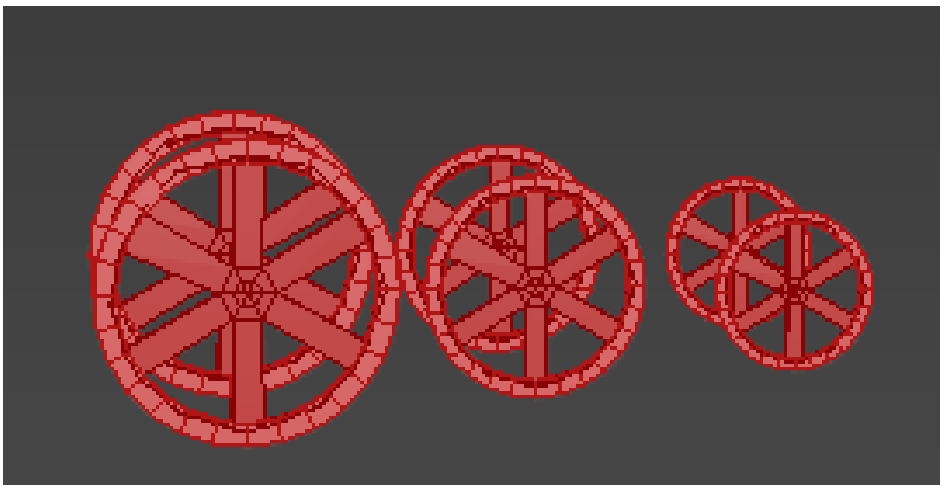


Figure 3.12 Three wheels different diameter

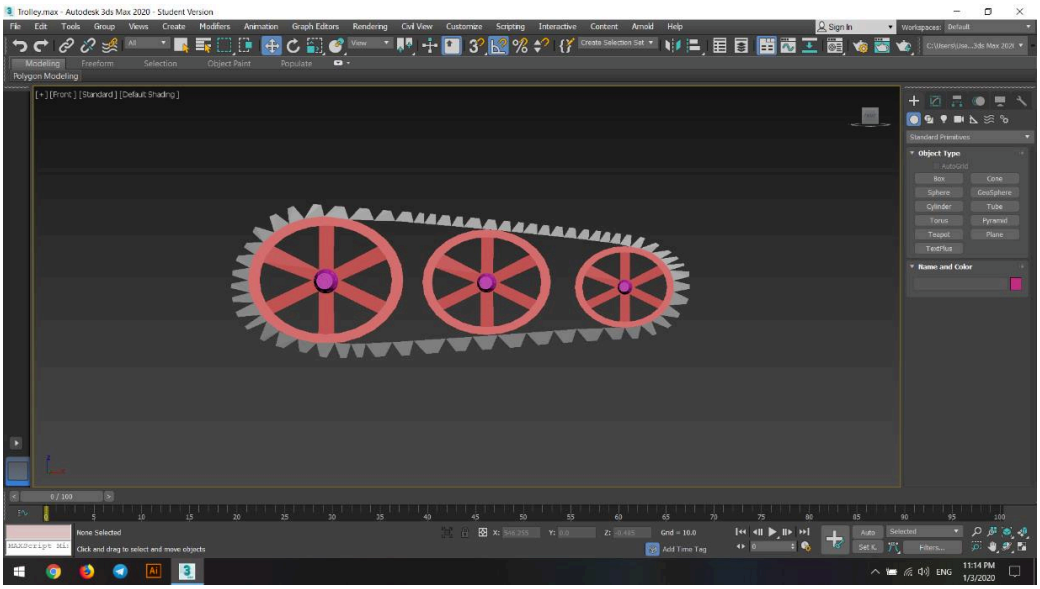


Figure 3.13 Rubber track chain wheel

The fourth step is to create panel, line and tube to model the trolley basket as shown in Figure 3.14. The trolley basket is modelled because they are the support of the loads when climbing up and down the staircase which play important role in determining the strength of the trolley.

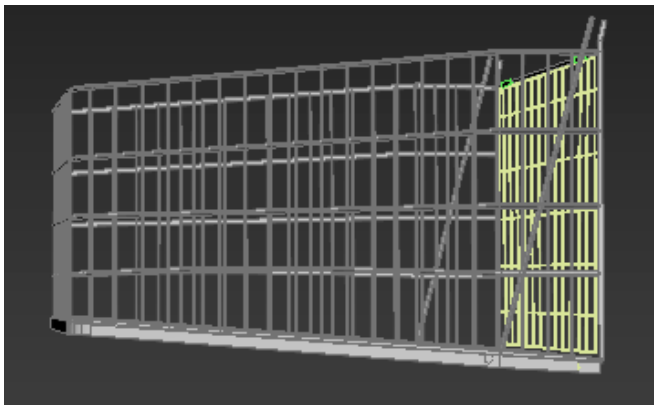


Figure 3.14 Modelling trolley basket

In Figure 3.15, it shown the fifth step which modelling handler. It created by choosing circle and line in 2D, then revolve it to make in 3D.

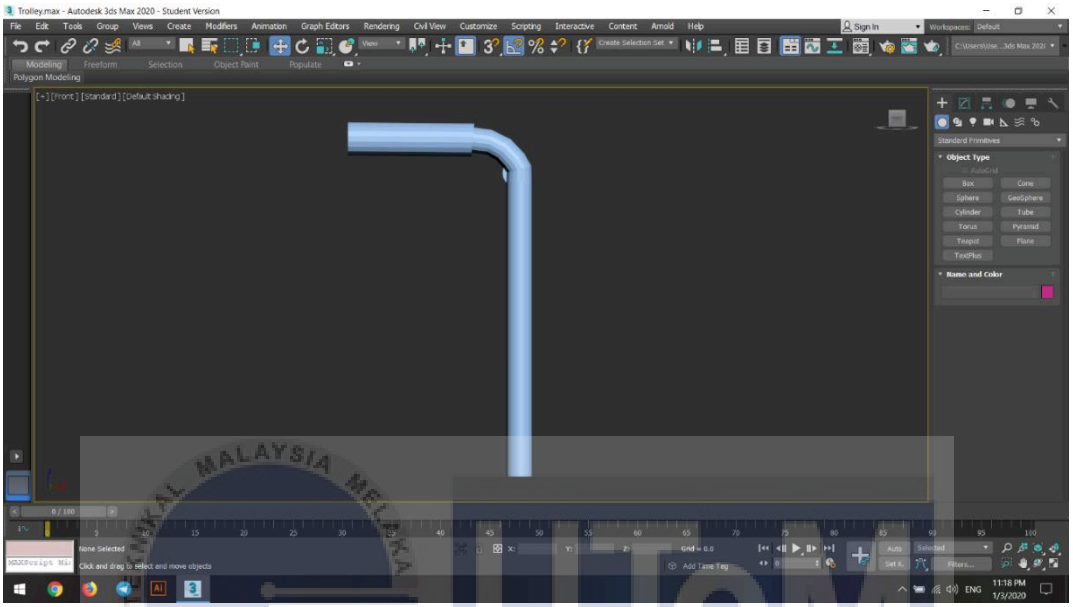


Figure 3.15 Modelling handler

Lastly, combine all the modelling parts that was drawn will be assembly together to complete the final product that shown in Figure 3.16.

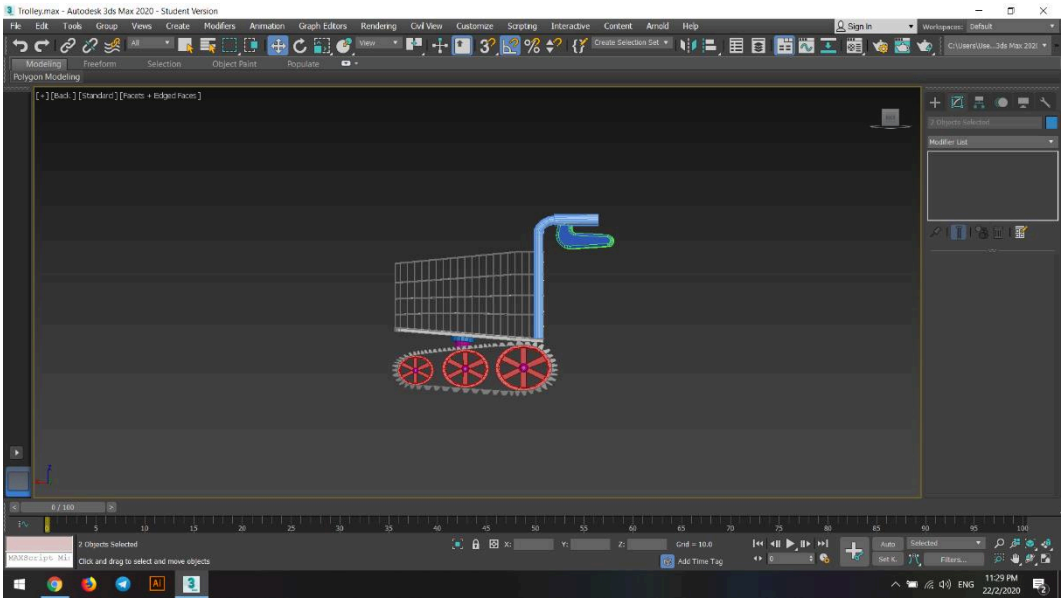


Figure 3.16 The assembly product

The final design concept is chosen from the concept 3 as shown in Figure 3.8. The design have the most appropriate and advantageous design that can assist with fulfilling the customer necessities and help to take care of the problem. The final concept design shown have all the parameters for the components of the manually stair climbing trolley. It is the best design for the things to carry at stair compared to the other two concept design. Figure 3.18 showns the view of the final product design.

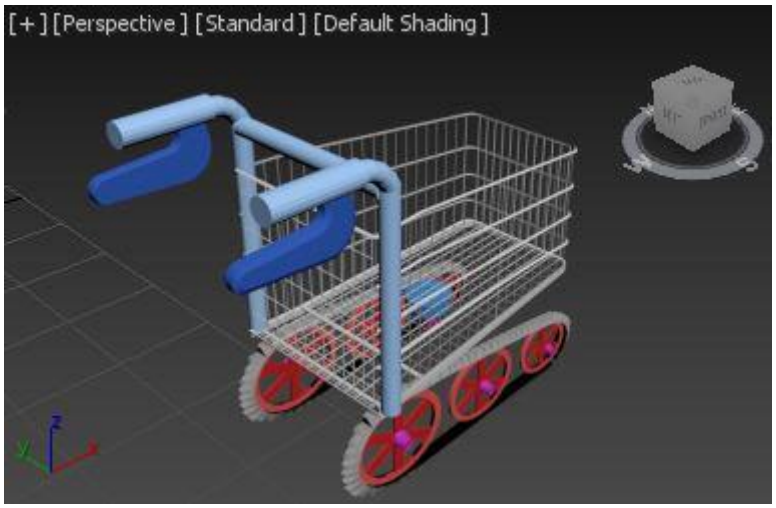


Figure 3.17 Drawing 3D

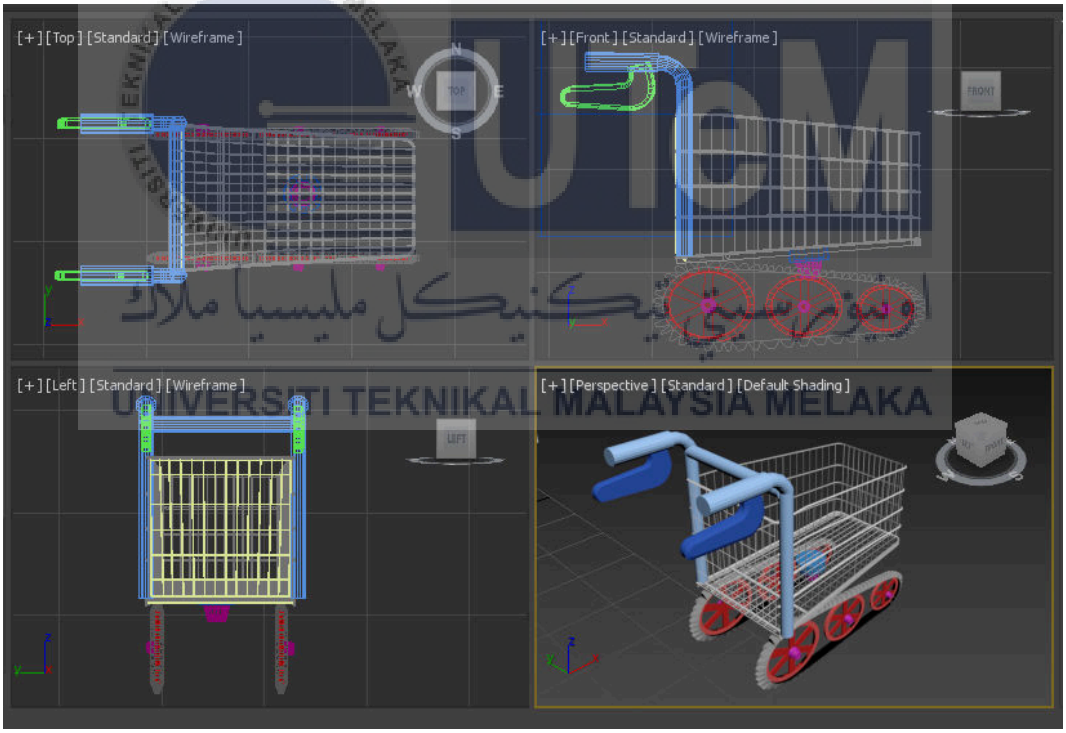


Figure 3.18 Orthographic

CHAPTER 4

SIMULATION AND RESULT

4.1 Introduction

There are a few pieces of segments that have being isolated to be examine for the advancement of bending moment and material testing part of stair climbing trolley manually. The motivation behind finding the structural analysis of this testing mechanical assembly is to decide the consequence of deformation, Von Mises stresses, and factor of safety of the project plan. Those outcomes are imperative to be known before building up this stair climbing trolley manually, as it can assist with identifying any failure that may be happen on the item structure.

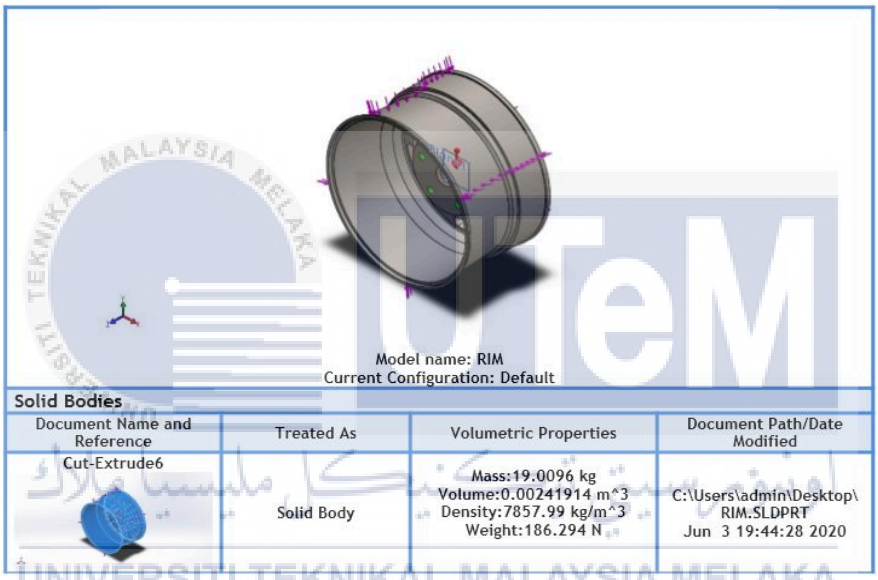
The important of performance parameter are,

- Von mises stress- The von mises stress is utilized to foresee yielding of materials under complex stacking from the consequences of uniaxial elastic tests. The von mises stress fulfills the property where two stress states with equivalent distortion energy have an equivalent von mises stress.
- Resultant displacement- Change in area of a point expressed as distance and heading of the vector estimated along a straight line from the initial position to the last position.

- Equivalent strain- The estimation of equivalent strain agrees to characterize at the estimation moment the basic condition of the material that was framed because of the previous loading.

4.1.1 Analysis on the Rim

Table 4.1 Model information of the rim



The rim in the testing is appoint to the bottom base of the product design. It has a mass at 19.0096 kg and the load that is support by the rim weight at 186.294 N. The rim supports all the components and parts that present as the testing function. The Table 4.1 shows the rim model information.

Table 4.2 Study properties of the rim

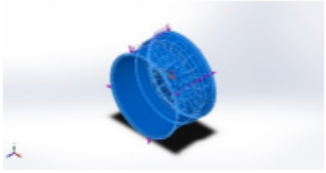
Study name	Static 1
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	FFEPlus
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SOLIDWORKS document (C:\Users\admin\Desktop)

Base on the Table 4.2, the solver type that use in the study properties is FFEPlus. FFEPlus is an iterative solver that utilizes certain combination technique. Every cycle the arrangement is accepted and blunders are assessed. Emphasis proceeds until blunders are sufficiently little. In this way, when all is said in done, if the examination contains more than 100,000 DOF, it is progressively effective and increasingly exact to utilize FFEPlus.

Will fizzle or be less precise if there is:

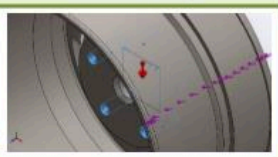
- Incongruent work and any local bonded contact sets not consequently secured by worldwide bonded contact
- Gravity or outside powers in a recurrence examination
- Base excitation in a straight unique investigation
- An enormous distinction in moduli of flexibility between parts
- Imported weight or temperature results from different examinations
- Round/cyclic balance limit conditions
- Nonlinear investigation

Table 4.3 Material properties of the rim

Model Reference	Properties		Components
	Name:	1023 Carbon Steel Sheet (SS)	SolidBody 1(Cut-Extrude6) (RIM)
	Model type:	Linear Elastic Isotropic	
	Default failure criterion:	Max von Mises Stress	
	Yield strength:	2.82685e+08 N/m^2	
	Tensile strength:	4.25e+08 N/m^2	
	Elastic modulus:	2.05e+11 N/m^2	
	Poisson's ratio:	0.29	
	Mass density:	7858 kg/m^3	
	Shear modulus:	8e+10 N/m^2	
	Thermal expansion coefficient:	1.2e-05 /Kelvin	
Curve Data:N/A			

The analysis result of the rim, which have 1023 carbon steel as its material. The steels containing carbon as the fundamental alloying component are called carbon steels. They can have up to 1.2% manganese and 0.4% silicon. Components, for example, chromium, nickel, aluminium, copper, and molybdenum are likewise present in little amounts. Choosing a galvanized or plated carbon steel is a suitable alternative to forestall corrosion. Alternatively, adding oil or paint to the surface of a carbon steel is a good way to help prevent iron oxidation from occurring. It has the elastic modulus is 2.05e+11 N/m^2 and shear modulus 8e+10 N/m^2 that show in Table 4.3. At Table 4.6 shows the maximum stress of the rim is 5.073e+06 N/m^2 and its minimum value is at 1.814e+04 N/m^2. The result show that the rim stress value is in the range that do not exceed its yield strength, which is 2.82685e+08 N/m^2.

Table 4.4 Loads and fixtures for the rim

Fixture name	Fixture Image	Fixture Details
Fixed-2		Entities: 5 face(s) Type: Fixed Geometry

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	-0.0115662	186.556	-6439.39	6442.1
Reaction Moment(N.m)	0	0	0	0

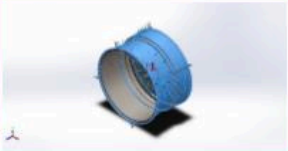
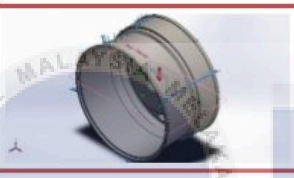
Load name	Load Image	Load Details
Force-1		Entities: 17 face(s) Type: Apply normal force Value: 132.277 lbf
Gravity-1		Reference: Top Plane Values: 0 0 -9.81 Units: m/s^2

Table 4.5 Mesh information of rim

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	0.560611 in
Tolerance	0.0280306 in
Mesh Quality Plot	High

Allegorical components can outline geometry significantly more precisely than straight components of a similar size. The mid-side hubs of the limit edges of a component are set on the real geometry of the model. In amazingly sharp or bended limits, the situation of mid-side hubs on the real geometry can bring about creating mutilated components with edges that traverse one another. The jacobian proportion of an incredibly twisted component gets negative, making the investigation stop. The jacobian proportion

check depends on various focuses situated inside every component. The product gives you a decision to put together the jacobian proportion check with respect to 4, 16, 29 Gaussian focuses.

The jacobian check is utilized when the work is a "Great" work for example allegorical second request components; which means, they have hubs toward the finish of each edge just as one mid-side hub on each edge, these mid-side hubs can fold over geometry, for example, high ebb and flow locales far superior to a straight "Draft Quality" work can precisely catch those districts of your model. This implies with "grimy" geometry like little edges or little bit faces (think for instance a V-indent sort of shape) can cause the mesher to put mid-side hubs so that they make the jacobian a negative number.

The setting of the software is in inches. From the Table 4.5, the element size value is 0.560611 in and the tolerance is 0.0280306 in.

Table 4.6 Von Mises stress of rim

Name	Type	Min	Max
Stress1	VON: von Mises Stress	1.814e+04 N/m^2 Node: 4411	5.073e+06 N/m^2 Node: 3285

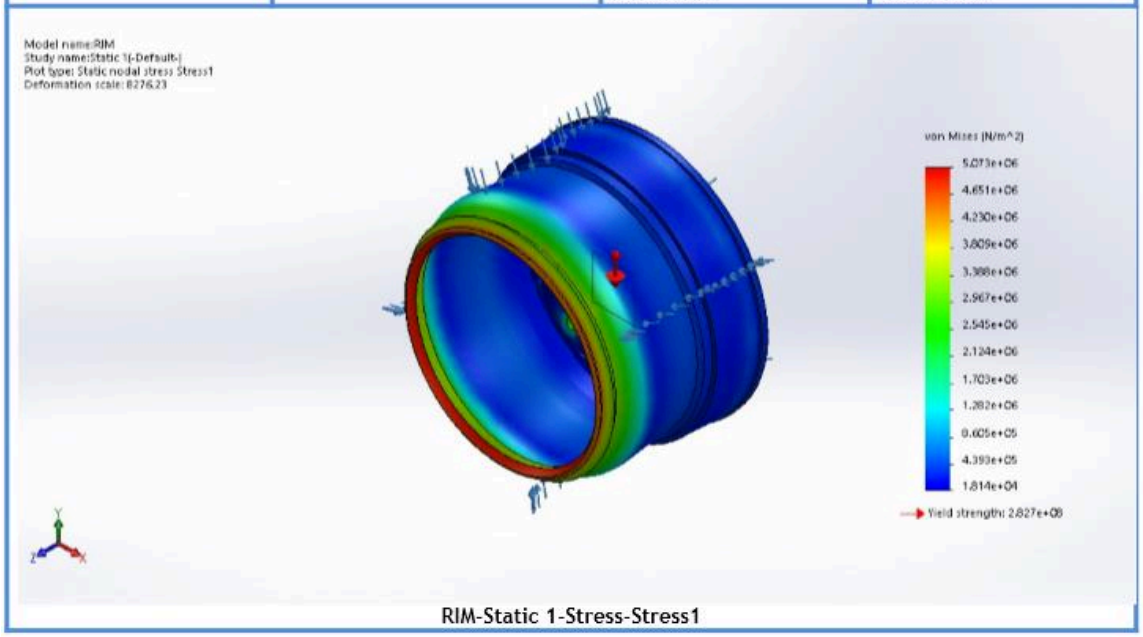
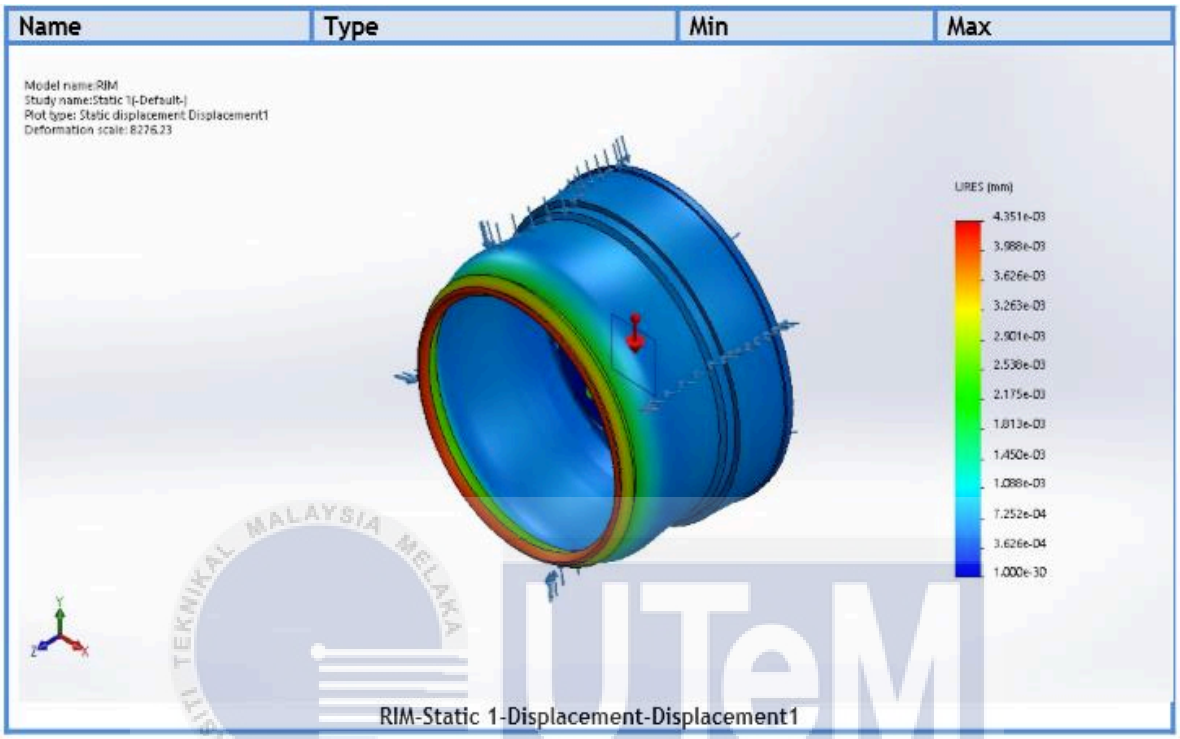


Table 4.7 Resultant displacement of the rim

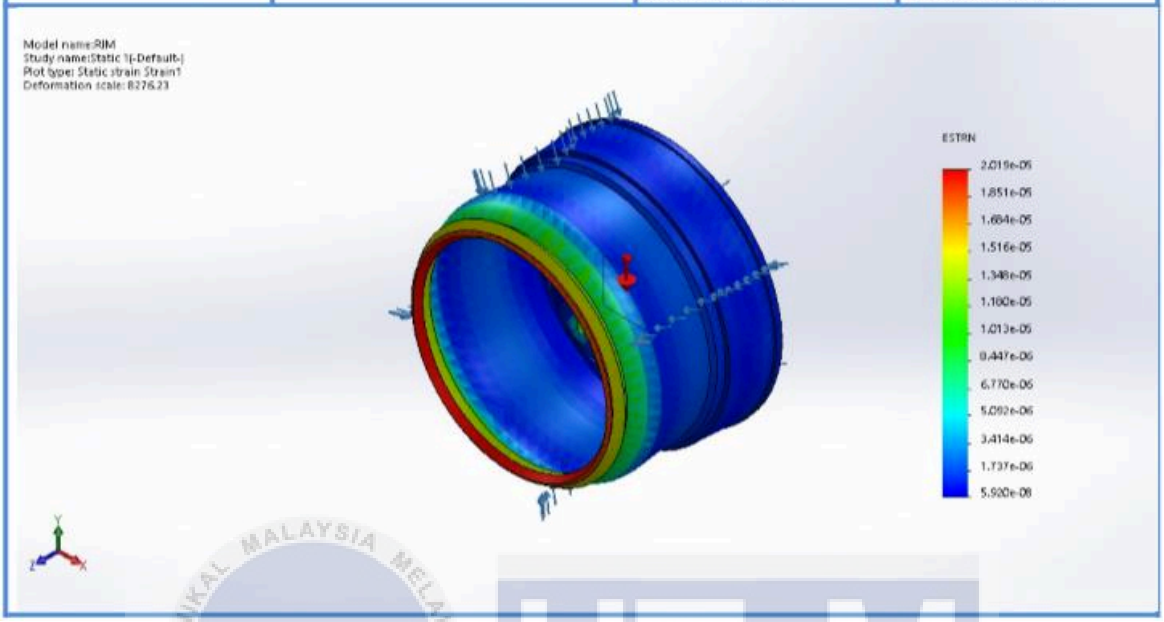
Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00 mm Node: 493	4.351e-03 mm Node: 1477



While Table 4.7 shows the maximum displacement of the rim can handle, which is at 4.351e-03 mm and the minimum displacement of the rim is 0.000e+00 mm.

Table 4.8 Equivalent strain of the rim

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	5.920e-08 Element: 6406	2.019e-05 Element: 13802

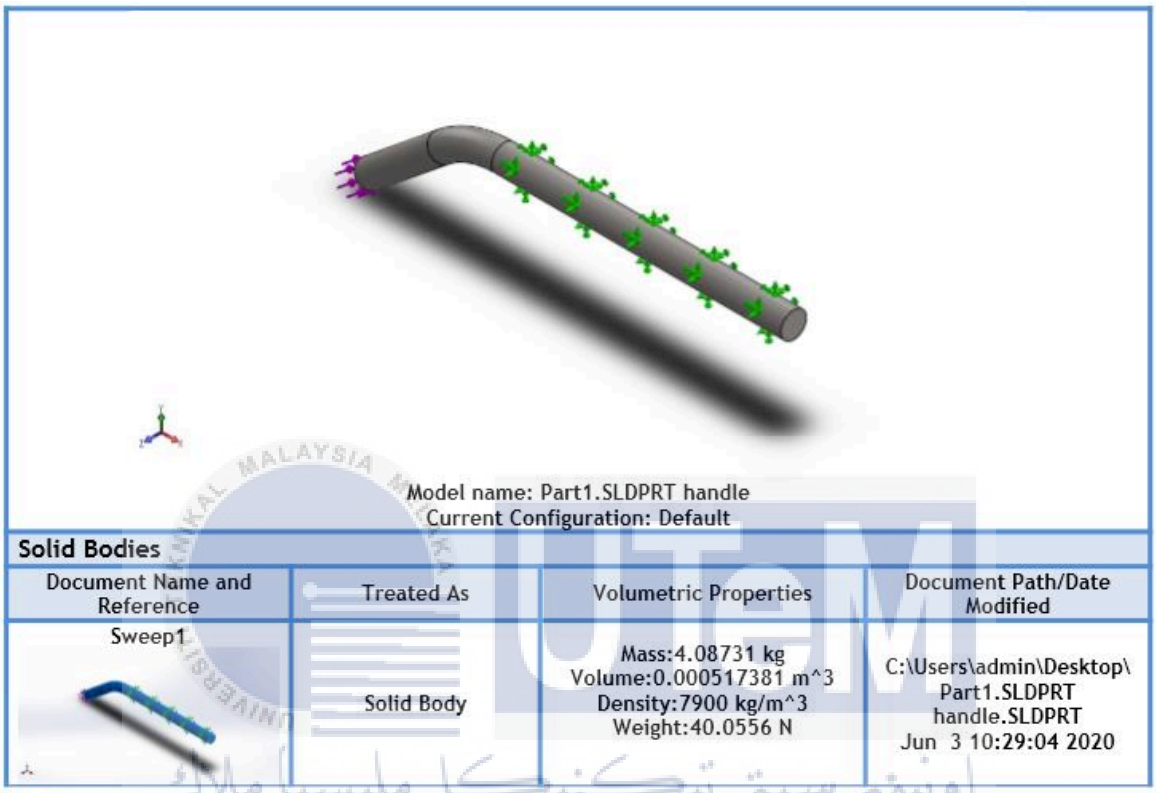


Name	Type	Min	Max
RIM-Static 1-Strain-Strain1			

The equivalent strain of the rim is as appeared in the analysis of the result on the Table 4.8. It shows that it has the maximum equivalent strain value of 2.019e-05 and the minimum equivalent strain value of 5.920e-08.

4.1.2 Analysis on the Handle

Table 4.9 Model information of the handle



Solid Bodies

Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
Sweep1	Solid Body	Mass:4.08731 kg Volume:0.000517381 m^3 Density:7900 kg/m^3 Weight:40.0556 N	C:\Users\admin\Desktop\Part1.SLDPRT handle.SLDPRT Jun 3 10:29:04 2020

As appointed in Table 4.9, the handle for the push and pull the manual trolley. The handle needs to support the load given by each of the user for the push and pull of the manual trolley when climbing the stairs. The total mass of the handle is 4.08731 kg and the handle weight at 40.0556 N.

Table 4.10 Study properties of the handle

Study name	Static 2
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	FFEPlus
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SOLIDWORKS document (C:\Users\admin\Desktop)

Table 4.11 Material properties of the handle

Model Reference	Properties	Components
	**Name:** AISI 1020 **Model type:** Linear Elastic Isotropic **Default failure criterion:** Max von Mises Stress **Yield strength:** 3.51571e+08 N/m^2 **Tensile strength:** 4.20507e+08 N/m^2 **Elastic modulus:** 2e+11 N/m^2 **Poisson's ratio:** 0.29 **Mass density:** 7900 kg/m^3 **Shear modulus:** 7.7e+10 N/m^2 **Thermal expansion coefficient:** 1.5e-05 /Kelvin	SolidBody 1(Sweep1)(Part1.SLDPRT handle)
Curve Data:N/A		

The analysis result of the handle, which have AISI 1020 mild steel as its material. AISI 1020 development steel is generally utilized as solid support and little machine parts. In any case, aside great surface properties as flexibility, hardness, and wear opposition, it is inclined to extreme erosion. As the nearness of Chromium (Cr), in overabundance of 12%-13% in Fe combinations, turns them impervious to a few destructive assaults, we attempted

to bring Cr into the outside of this steel in such sums. Cr films were saved by electron pillar on AISI 1020 surface and afterward assaulting either by nitrogen Plasma Immersion Ion Implantation (PIII), Cr iotas are pull back brought into the steel lattice. It has the shear modulus reading of 7.7e+10 N/m^2 and the elastic modulus of 2e+11 N/m^2 that show in Table 4.11.

Table 4.12 Load and fixtures of the handle

Fixture name	Fixture Image	Fixture Details
Fixed-1		Entities: 1 face(s) Type: Fixed Geometry

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	-190.353	-154.646	-0.00565088	245.255
Reaction Moment(N.m)	0	0	0	0

Load name	Load Image	Load Details
Force-1		Entities: 1 face(s) Type: Apply normal force Value: 245.25 N

Table 4.13 Mesh information of the handle

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	0.31614 in
Tolerance	0.015807 in
Mesh Quality Plot	High

From the Table 4.13, the element size value is 0.31614 in and the tolerance is 0.015807 in.

Table 4.14 Von Mises Stress of handle

Name	Type	Min	Max
Stress1	VON: von Mises Stress	4.410e-05 N/m^2 Node: 5435	2.166e+06 N/m^2 Node: 9503

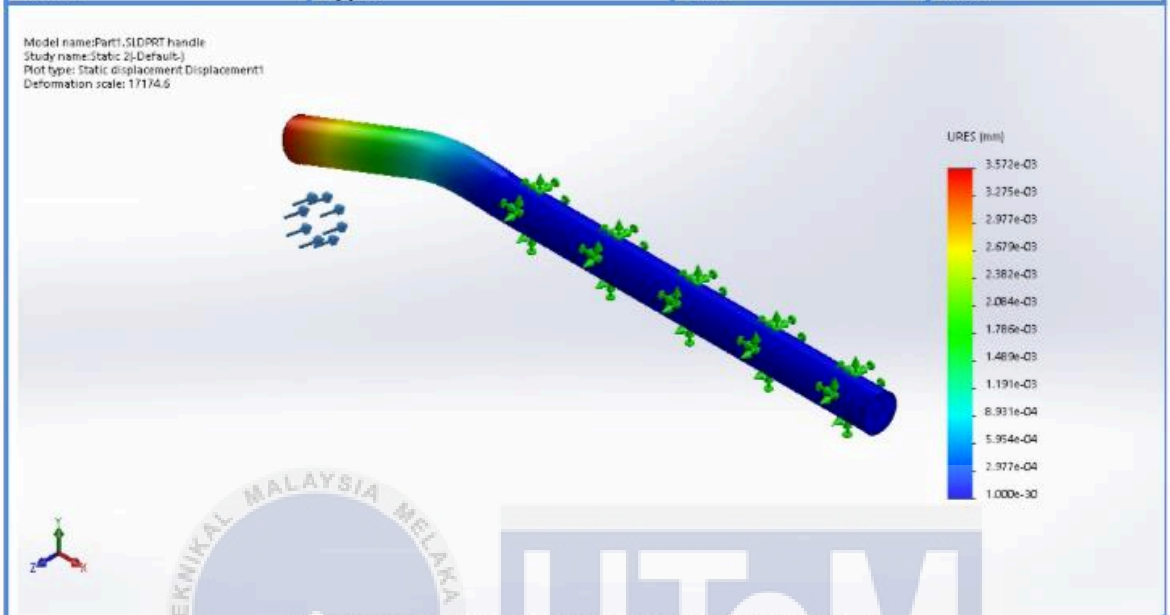
Part1.SLDPRT handle-Static 2-Stress-Stress1

At Table 4.14 shows the maximum stress of the handle is 2.166e+06 N/m^2 and the minimum value is 4.410e-05 N/m^2. It is acceptable by the result shows that the handle stress is in the range that will not exceed its yield strength value, 3.51571e+08 N/m^2.

Table 4.15 Resultant displacement of the handle

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00 mm Node: 1	3.572e-03 mm Node: 9051

Name	Type	Min	Max

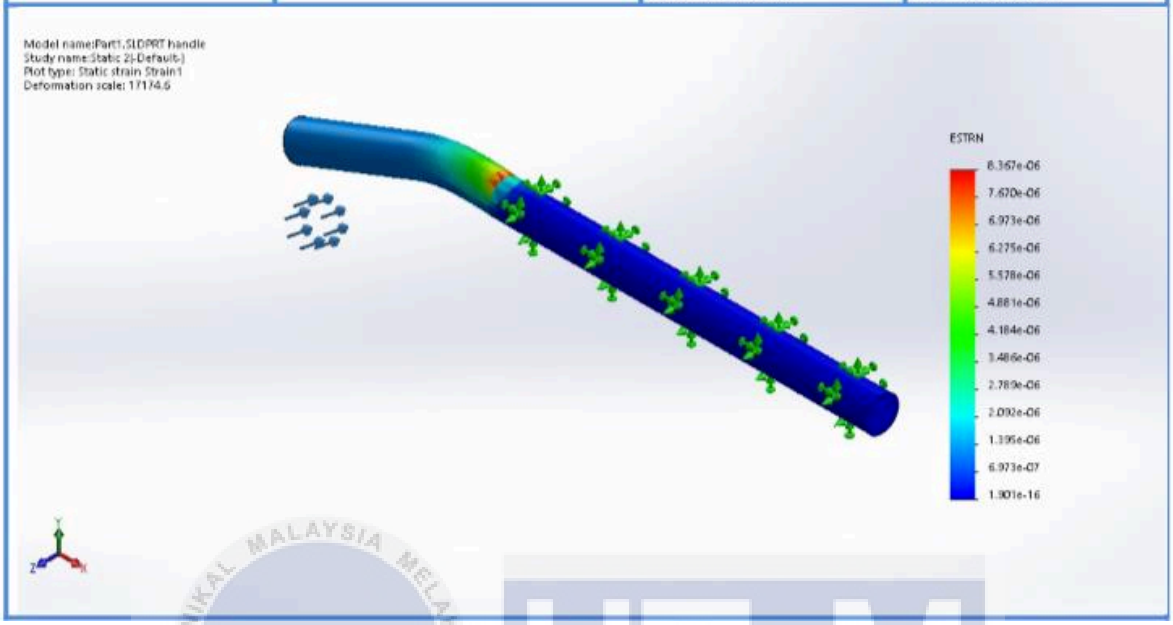


Part1.SLDPRT handle-Static 2-Displacement-Displacement1

The resultant displacement of the handle is as appeared in the analysis of the result on the Table 4.15. It shows that it has the maximum displacement value of 3.572e-03 mm and the minimum displacement value of 0.000e+00 mm.

Table 4.16 Equivalent strain of the handle

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	1.901e-16 Element: 4728	8.367e-06 Element: 2133

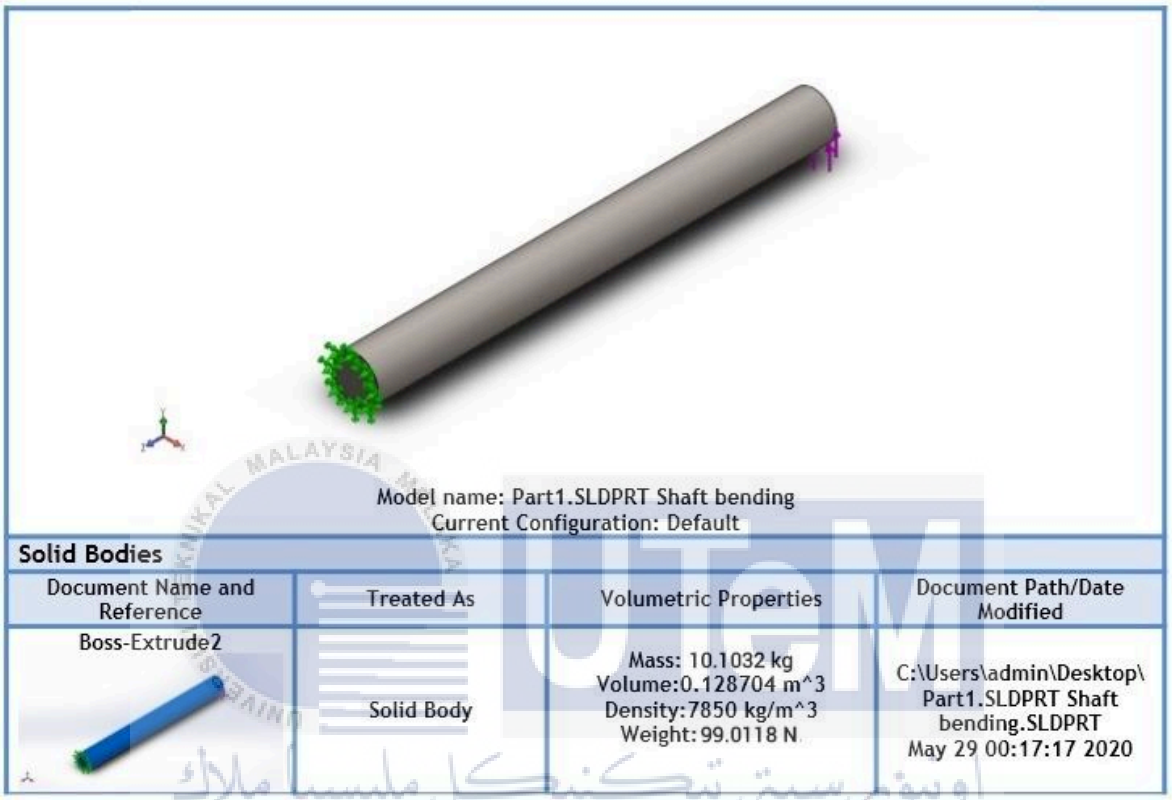


Name	Type	Min	Max
Part1.SLDPRT handle-Static 2-Strain-Strain1			

The equivalent strain of the handle is as appeared in the analysis of the result on the Table 4.16. It shows that it has the maximum equivalent strain value of 8.367e-06 and the minimum equivalent strain value of 1.901e-16.

4.1.3 Analysis on the shaft

Table 4.17 Model information of the shaft



Solid Bodies

Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
Boss-Extrude2	Solid Body	Mass: 10.1032 kg Volume:0.128704 m^3 Density:7850 kg/m^3 Weight: 99.0118 N	C:\Users\admin\Desktop\Part1.SLDPRT Shaft bending.SLDPRT May 29 00:17:17 2020

The shaft that join between (middle part) the two wheels for the manual trolley to move around as shown in Table 4.17. The total mass of the shaft is 10.1032 kg and the shaft weight at 99.0118 N.

Table 4.18 Study properties of the shaft

Study name	Static 3
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	FFEPlus
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SOLIDWORKS document (C:\Users\admin\Desktop)

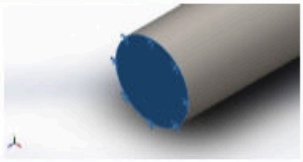
Table 4.19 Material properties of the shaft

Model Reference	Properties	Components
	**Name:** AISI 4130 Steel, normalized at 870C **Model type:** Linear Elastic Isotropic **Default failure criterion:** Max von Mises Stress **Yield strength:** 4.6e+08 N/m^2 **Tensile strength:** 7.31e+08 N/m^2 **Elastic modulus:** 2.05e+11 N/m^2 **Poisson's ratio:** 0.285 **Mass density:** 7850 kg/m^3 **Shear modulus:** 8e+10 N/m^2	SolidBody 1(Boss-Extrude2) (Part1.SLDPRT Shaft bending)
Curve Data:N/A		

The analysis result of the shaft, which uses AISI 4130 steel, normalized at 870C as its material. AISI 4130 steel is a low-composite steel containing chromium and molybdenum as fortifying operators. The steel has great quality and strength, weld ability and machinability. AISI 4130 steel is an adaptable compound with great atmospheric

corrosion opposition and sensible quality. It shows great by and large blends of solidarity, strength, and fatigue strength. It has the shear modulus reading of 8e+10 N/m^2 and the elastic modulus of 2.05e+11 N/m^2 that show in Table 4.19.

Table 4.20 Load and fixtures of the shaft

Fixture name	Fixture Image	Fixture Details
Fixed-1		Entities: 1 face(s) Type: Fixed Geometry

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	0.0664902	-588.533	0.123947	588.533
Reaction Moment(N.m)	0	0	0	0

Load name	Load Image	Load Details
Force-1		Entities: 1 face(s) Type: Apply force Values: ---, 588.6, --- N

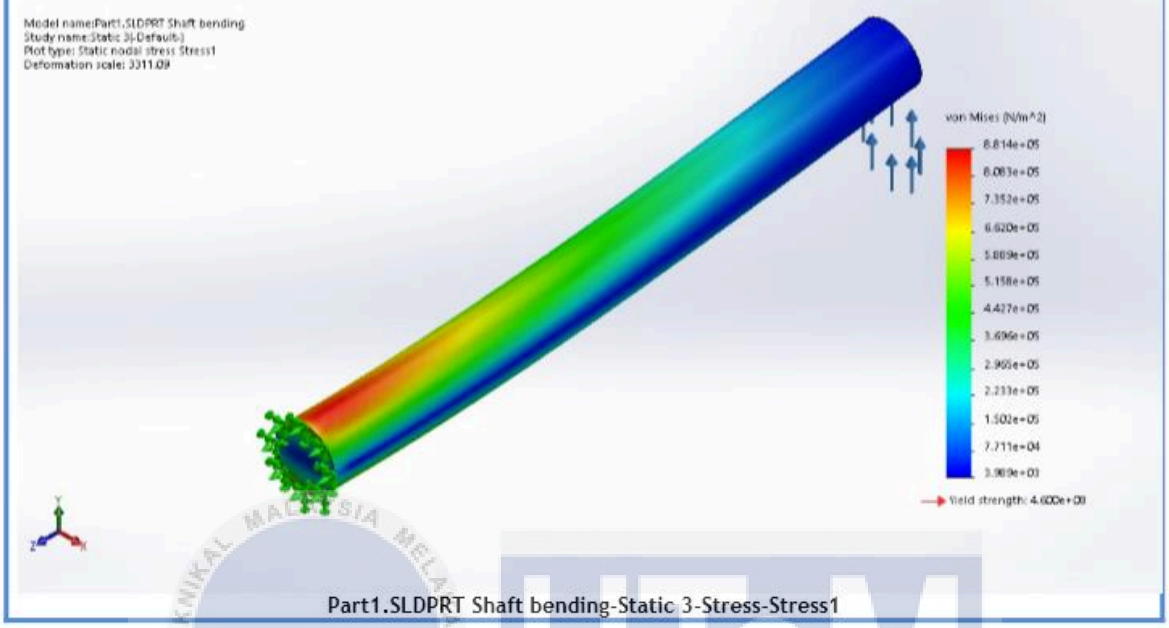
Table 4.21 Mesh information of the shaft

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	1.98789 in
Tolerance	0.0993946 in
Mesh Quality Plot	High

From the Table 4.21 mesh information, the element size value is 1.98789 in and the tolerance is 0.0993946 in.

Table 4.22 Von Mises stress of the shaft

Name	Type	Min	Max
Stress1	VON: von Mises Stress	3.989e+03 N/m^2 Node: 324	8.814e+05 N/m^2 Node: 468

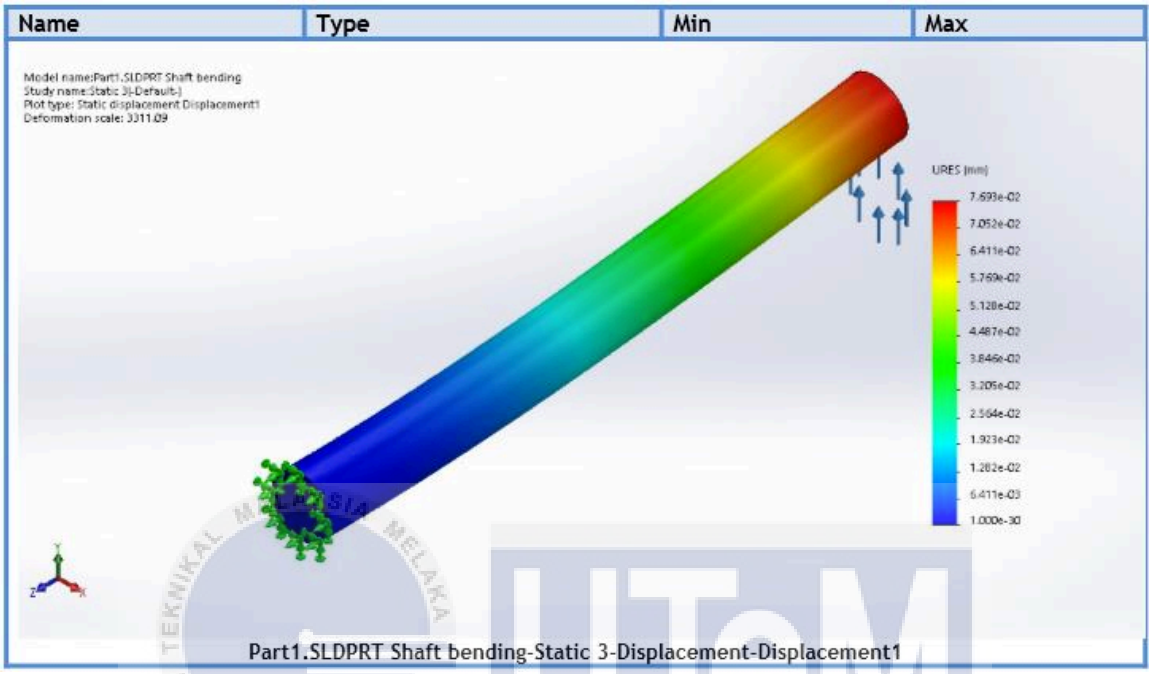


Part1.SLDPRT Shaft bending-Static 3-Stress-Stress1

At Table 4.22 shows the maximum stress of the handle is 8.814e+05 N/m^2 and the minimum value is 3.989e+03 N/m^2. It is acceptable by the result shows that the handle stress is in the range that will not exceed its yield strength value, 4.6e+08 N/m^2.

Table 4.23 Resultant displacement of the shaft

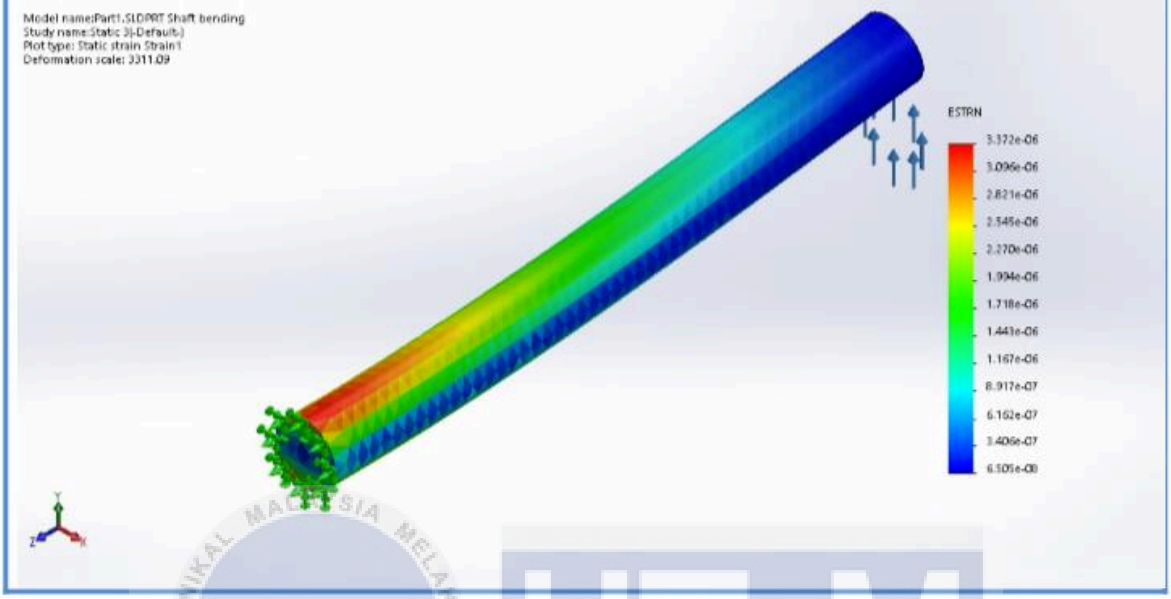
Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00 mm Node: 58	7.693e-02 mm Node: 8032



The resultant displacement of the handle is as appeared in the analysis of the result on the Table 4.23. It shows that it has the maximum displacement value of 7.693e-02 mm and the minimum displacement value of 0.000e+00 mm.

Table 4.24 Equivalent strain of the shaft

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	6.505e-08 Element: 3131	3.372e-06 Element: 2331



The equivalent strain of the shaft is as appeared in the analysis of the result on the Table 4.24. It shows that it has the maximum equivalent strain value of 3.372e-06 and the minimum equivalent strain value of 6.505e-08.

4.2 Summary of analysis

Table 4.25 Analysis summary

Characteristics	Rim	Handle	Shaft
1. Model Information	The rim is designed to be at the bottom of the product design. The rim supports all the components and parts that present during the product testing.	The handle is used to push and pull the manual trolley. The mass of the handle need to support the load given by the user.	The shaft is the element that is joined in between the two wheels for the manual trolley.
2. Study Properties	FFEPlus is one the solver type that is used to utilize certain combination technique. The examination need to contain100,000 DOF and it means that it is progressively effective and its working.	FFEPlus solver is used to get a progressive and an effective handle. A solid mesh is used.	FFEPlus solver is used to get an effective shaft model.

3. Material Properties	1023 carbon steel I sued as the material for rim. A galvanized or plated carbon steel is a suitable alternative material that will prevent corrosion.	AISI 1020 mild steel is used as the material. This type of steel is used as solid support and little machine parts. It has great flexibility, hardness and wear opposition.	AISI 4130 steel is used as the material. It has two important properties which is known as chromium and molybdenum. It has great strength and fatigue strength.
4. Load and Fixtures	Apply normal force, the value 132.277 lbf (Table 4.4).	Apply normal force, the value 245.25 N (Table 4.12).	Apply force, the value 588.6 N (Table 4.20).
5. Mesh Information	The mesh quality plot must be high and a solid mesh is used. A standard mesher is used.	The mesh quality plot must be high and a solid mesh is used. A standard mesher is used.	High mesh quality plot is used. A solid mesh and a standard mesher is used.
6. Von Mises Stress	The rim stress is higher than the its yield strength value.	Handle stress is in the range that will not exceed its yield strength value.	The shaft stress is in the range that will not exceed its yield strength value.
7. Resultant Displacement	Maximum and minimum displacement of the rim is calculated.	Maximum and minimum displacement of the handle is calculated.	Maximum and minimum displacement of the shaft is calculated.

8. Equivalent Strain	Maximum and minimum equivalent strain value of the rim is in figures.	Maximum and minimum equivalent strain value of the handle is in figures.	Maximum and minimum equivalent strain value of the shaft is in figures.

In short, this stimulation validation must be conducted with the existing system itself. The result shows a maximum and a minimum resultant displacement value. Based on the result and values obtained, all the important data that has been presented met the requirement with the above validation. Thus, Von Mises Stress must be in range that will not exceed its yield strength values. These results can be used for future references.

4.3 Validation

Validation is known as a process that creates documentation that demonstrates the procedures or activity carried out in a testing. This process is needed to ensure a productive result in the end. Qualification and the equipment involved are important in the process of validation. Every part of a process needs to be validated so validation was divided into subsections. For example, computer system validation or equipment validation. Validation process was carried out initially to produce a quality and a similar product that functions and benefits the people. This could avoid major mistakes during the process of making a product.

4.3.1 Shaft

There was a previous study on the making of a shaft by Yetkin, 2018. The article is titled as stress-deformation analysis of the F16 aircraft auxiliary landing gear. The geometry auxiliary landing gear of F16 landing gear was drawn using the SolidWorks software program which is one of the computer design program. Landing gears are the important element that carries the weight of the aircraft and reduces the shock when the aircraft is moving or on the ground. Two shafts with different radius have been used that pass through the piston and connects with the rims. The radius that is used are 36 mm and 52 mm respectively.

Figure 4.1 Total deformation of the shaft part when shaft radius 36 mm

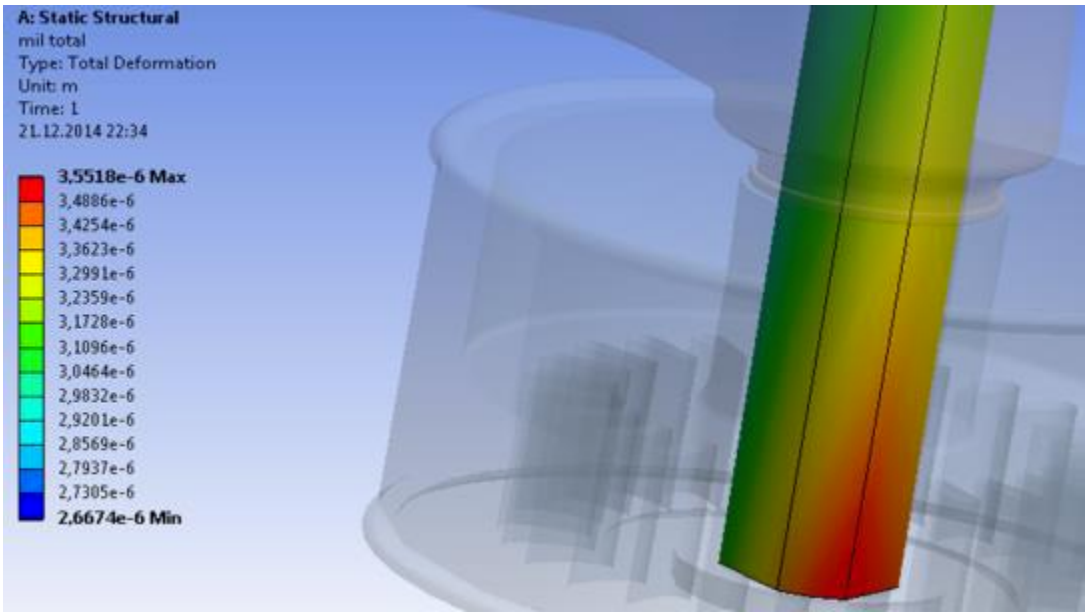


Figure 4.2 The total deformation of the shaft part when shaft radius 52 mm (first)

In one part of the landing gear, the shaft radius was changed hiked from 36 mm to 52 mm thus creating a new geometry. Then, the values were created and examined. In the 36 mm shaft, the deformation occurs mostly in the part of the rims and the average values were known as $2{,}4644.10^{-6}$ m. While in 56 mm shaft, the deformations occur in the rim parts. And the estimated value is $4{,}617.10^{-6}$ m. The maximum stress in the 36 mm landing gear that have produced at the piston part and the average figure is 2.516,105 *Pa*. In addition, the maximum stress of the landing gear with a shaft radius of 52 mm occurs at the piston and the value is 2.0989,105 *P*. The total number of deformation that have been formed in the system where the shaft diameter is hug. It is larger than the total deformation in the system where the shaft diameter is small. In this case, it is vital to reduce the shaft diameter in order to reduce the total amount of deformation.

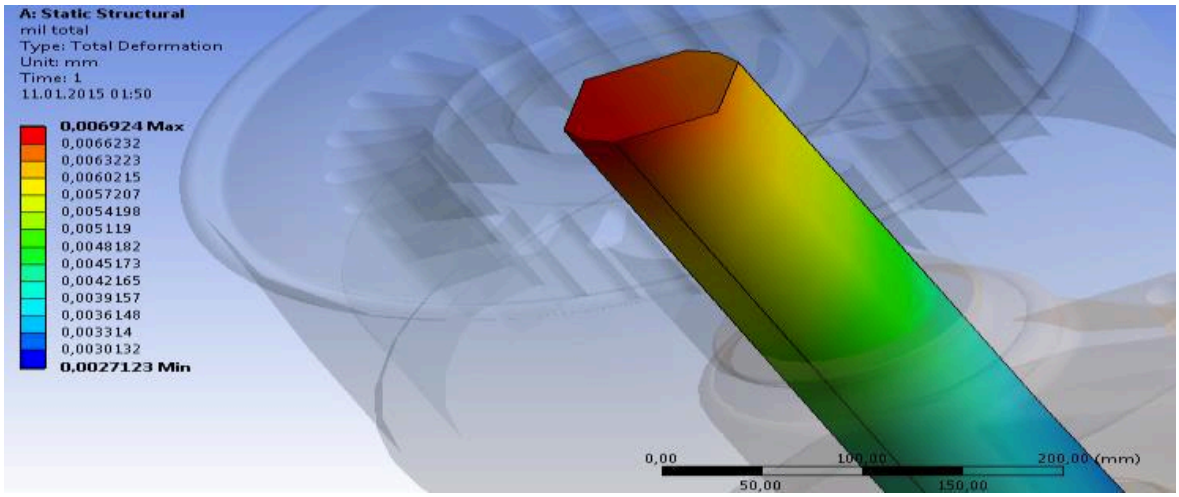


Figure 4.3 Total deformation of the shaft part when the shaft radius 52 mm (second)

While in the model shaft that have been created, the radius of the shaft is smaller than the shaft used in the landing gear as it involves two different object that is known as landing gear of an aircraft and a trolley carrying heavy load. Though the objects are different, but the purpose is to withstand a certain amount of load be it a heavy or light object (Yetkin, 2018).

The model shaft is used to join in between (middle part) the two wheels for the manual trolley to move around with a load that is shown in Table 4.17. The total mass of the shaft is estimated at 10.1032 kg and the shaft weight is 99.0118 N. It has the modulus reading value of 8e+10 N/m^2 and the elastic modulus value of 2.05e+11 N/m^2 that is shown in Table 4.19. In Table 4.21 it is shown that the maximum stress of the handle is estimated as 8.814e+05 N/m^2 and the minimum value is known as 3.989e+03 N/m^2. The result can be accepted that the handle stress is in the range that will not extend its yield strength value of 4.6e+08 N/m^2.

Thus, it is concluded that the model shaft that have been created using the SolidWorks designing program have the average value of 80% accuracy that it can handle

the load that have been imposed on the shaft. The structure and the mass of the shaft is compatible compared to the shaft that is used in the landing gear of the aircraft.

4.3.2 Rim

A previous study was found by Yetkin, 2018 on making rim parts that supports the load that is imposed on the object. According to the study, rim parts that have been created after multiple developed experimental setups seem to withstand the load that is given. The rims were created using alloy steel. The technical setups of rims and wheels are significant during take-off and landing of aircraft. Breaking rims or bursting wheels can cause serious damages to the aircraft such as the aircraft will be imbalanced during landing and take-off. Therefore, appropriate rims and wheels must be selected for a good landing gear.

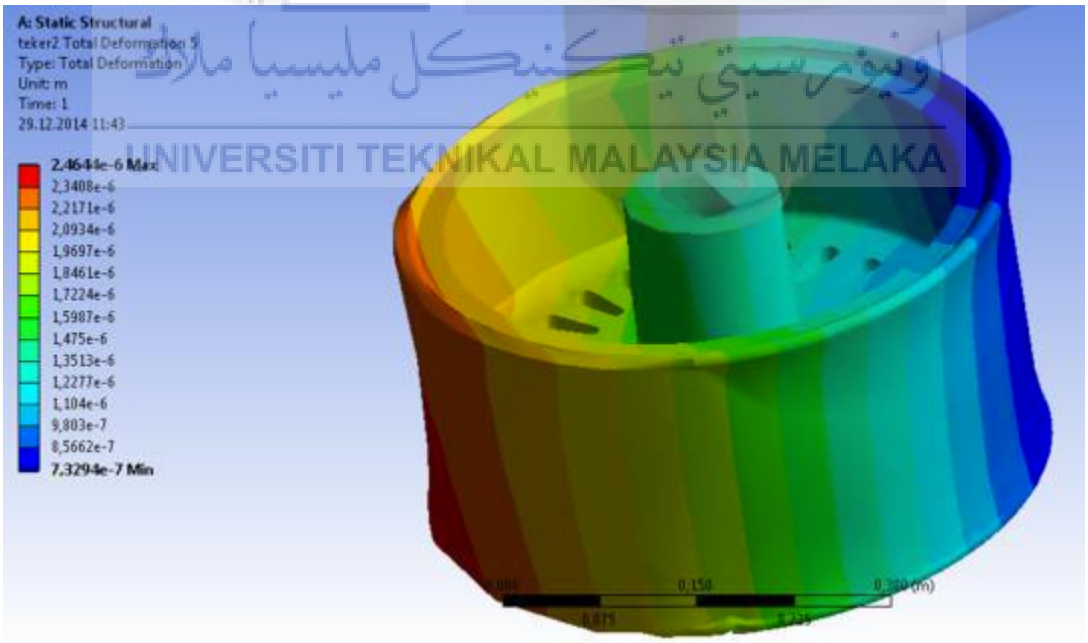


Figure 4.4 Total deformation of the rim part when shaft radius 36 mm (first)

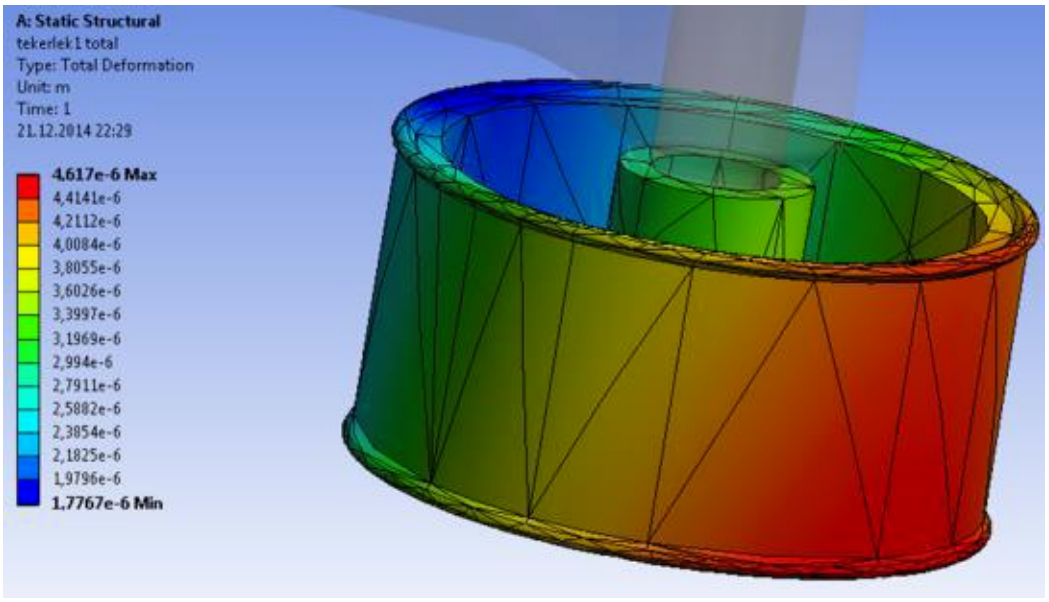


Figure 4.5 Total deformation of the rim part when shaft radius 52 mm (first)

When the previous study is examined, it can be seen that the most deformation values are found in the rim and the shafts of the landing gear. The total value deformation of the 36 mm rim part is 0.002464 mm. The figure shows the total amount of deformation in the 52 mm rim and the value is estimated as 0.004617 mm. When 100 N.m torque force is applied to the landing gear, it is seen that the total deformation amount in the rim part is 0.0083278 mm as can be seen in the Figure 4.6 (Yetkin, 2018).

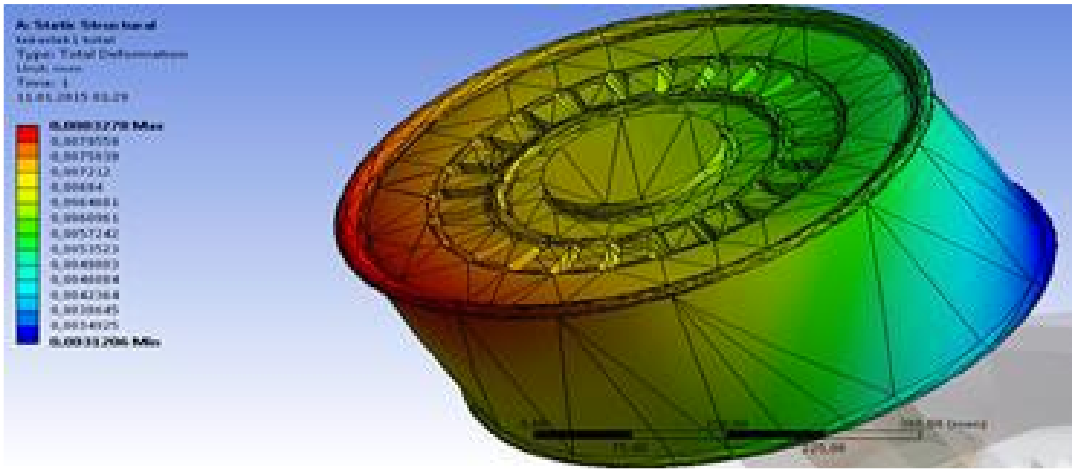


Figure 4.6 Total deformation of the rim part when shaft radius 52 mm (second)

In the model rim that have been created using the SolidWorks designing program, the rim in the testing is applied at the bottom base of the product that have been designed. It has a mass at 19.0096 kg and the load that is supported by the rim weighs at 186.294 N. The rim supports all the components and parts that have been presented during the testing function. The Table 4.7 shows the maximum displacement the model rim can handle which is at 4.351e-03 mm and the minimum displacement of the rim is 0.000e+00 mm. The equivalent strain of the rim is produced in the analysis of the result on the Table 4.8. This is shown that the rim has the maximum equivalent strain value of 2.019e-05 and the minimum equivalent strain value of 5.920e-08.

In short, it is summarised that the model rim that have been created using the SolidWorks designing program have the average value of 85% accuracy that it can handle the load that have been imposed on the rim parts. The structure and the mass of the rim is almost equivalent compared to the rim parts that is used in the landing gear of the aircraft.

4.3.2 Handle

There was a previous study on making a handle that has a complete strength and is made of high end material that will allow the handle to withstand the load and the pressure. The name of the model is known as ASTM A513 Steel and the model type is made of linear elastic isotropic. The default failure criterion is using the Max von Mises Stress and yield strength value is 53186 psi. The tensile strength value is known as 76523 psi and the elastic modulus value is at 2.90075e+007 psi while the poisson's ratio stands at 0.26. The mass density values at 0.283599 lb/in^3 and the shear modulus values at 1.15015e+007 psi (Xploder, 2016).

Name	Type	Min	Max
Stress1	VON: von Mises Stress	7.79272e-007 psi Node: 33910	52690.8 psi Node: 120627

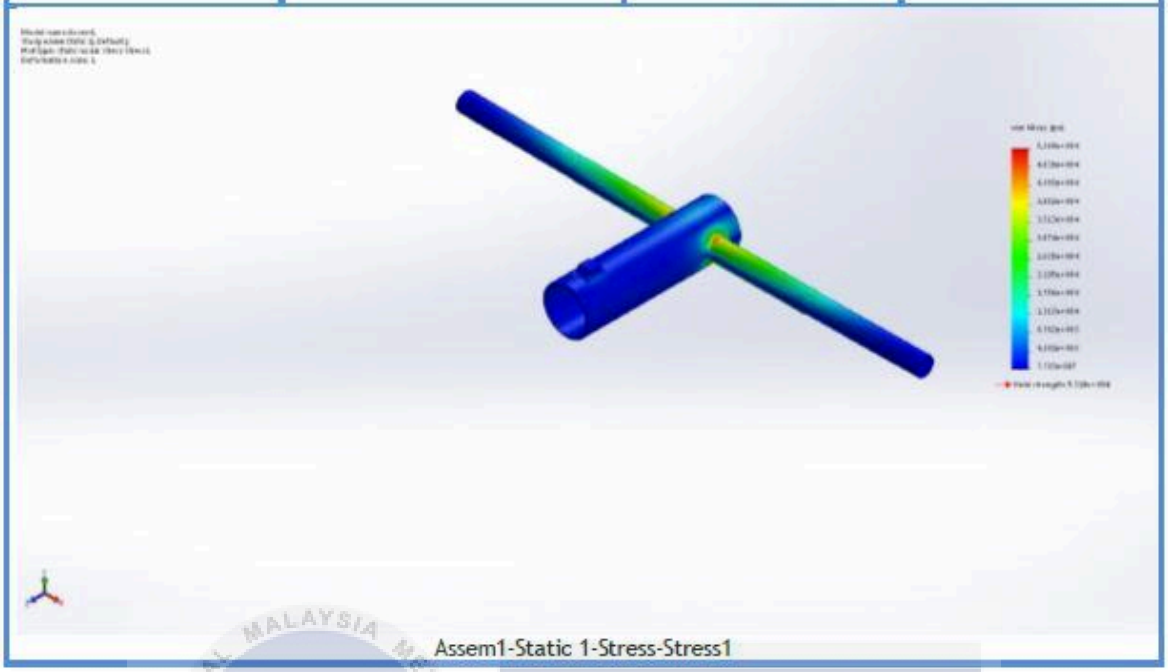


Figure 4.7 The von mises stress xploder handle

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 in Node: 1	0.132713 in Node: 123316

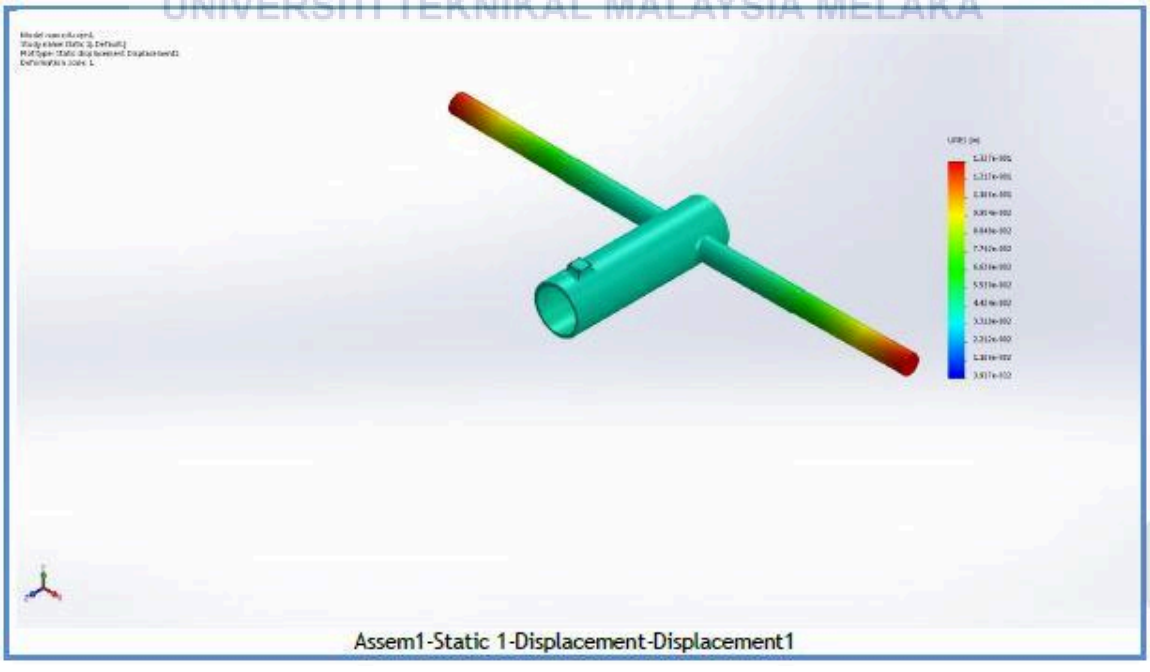


Figure 4.8 The resultant disaplacement of the xploder handle

According to the example model handle that have been created using SolidWorks, the handle for the push and pull the manual trolley has a solid strength. The handle needs to support the load that is given by each of the user for the push and pull of the manual trolley while climbing up and down the stairs. The total mass of the handle is valued at 4.08731 kg and the handle weight at 40.0556 N. In the Table 4.14, it is shown that the maximum stress of the handle is at 2.166e+06 N/m^2 and the minimum value is at 4.410e-05 N/m^2. The result shown is acceptable that the handle stress is in the range that will not exit its yield strength value which is 3.51571e+08 N/m^2. The resultant displacement of the handle is produced in the Table 4.15. It is shown that the model handle has the maximum displacement value of 3.572e-03 mm and the minimum displacement value of 0.000e+00 mm. The equivalent strain of the handle is shown in the analysis of the result in the Table 4.16. It is shown that it has the maximum equivalent strain value of 8.367e-06 and the minimum equivalent strain value of 1.901e-16.

Then, it is summarised that the model handle that have been created using the SolidWorks designing program have the average value of 80% accuracy as it can handle the load that have been imposed on the handle parts. The structure and the mass of the handle is almost equivalent compared to the handle that is used in the previous study.

In short, validation is an important process that must be conducted while producing objects that will be used by the people. Every item and the process needs to be validated to produce a product that has high quality and benefits the people. This validation process must be conducted regularly to test the quality and the steps that have been taken to create certain products. Validated product or process shows that it has been created using the instructed process and it is beneficial.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

There are three kinds of testing used in each of the component to test the properties of the assembly manually stair climbing trolley. The literature study to investigate the knowledge in designing manually stair climbing trolley has been presented in this report.

This investigation is to design and analyze on the components for the manually climbing trolley. The concept design, reverse engineering and computer simulation have been done in on the item structure. All the technique uses for structuring the item configuration is begun with the QFD such as Gantt Chart, HOQ, survey (customer requirements), product design specification, engineering characteristics, and Morphological Chart is used as the analysis technique.

This project is useful for the people who using the staircase when carrying the loads. The rubber track chain wheel in this project can help the people from getting grip went climbing up or down the staircase with accurate dimension of the teeth length which place on the edge of the staircase. The design for the project chosen by using concept design method is fully achieved.

This objective is achieved by concept 3 is chosen as the final design because it requires the less force to move by the user and it is more stable. The next work in will include modelling the final design into 3D model by using Autodesk 3ds Max software.

Besides that, simulation has also been done at Solidwork software to test the Von Mises stress, Resultant displacement, and Equivalent strain on the components of rim, handle and shaft. In view of the aftereffects of simulation analysis, it shows every one of the components included can withstand with the extraordinary load needs to pass on is 60 kg load applied. The consequences of the stress isn't surpassed to the yield strength of the 1023 carbon steel (rim component), AISI 1020 mild steel (handle) and AISI 4130 steel, normalized at 870C (shaft), as its material utilized.

5.2 Recommendations

From the investigation of design and analysis of the testing components to test the properties of the assembly manually stair climbing trolley, there are a few suggestions for the future investigations. Those are as per the following,

1) Make a simulation analysis on the component that include with the process of bending and tensile testing to components of the manually climbing strain trolley.
2) Manufacture a total testing component by utilizing the design that have being done finish with the estimations.
3) Each of the component to test the properties of the assembly manually stair climbing trolley by utilizing the Autodesk 3ds Max software and Solidwork software.
4) To use ratchet as the stop mechanism during climbing, if it goes down from the staircase the ratchet will hole it.

In short, the limitations of the research is that time is limited to conduct a test run on each material. The material is made of high quality steel and each material need to have

a certain mass that supports each other to deliver as a product. The research did not specify the material of the loads that will used on the end product. But the research is only focused on the maximum weight that is used on the product which is 60 kg. The research also did not highlight the duration on how long the trolley manual can be used. For future studies, researchers can use this limitations to create a new objective that will fulfill the limitations. Thus, being able to produce quality products that focuses on shaft, rim and handle. The research only focuses in using the staircase as the base as the topic is about manually staircase climbing trolley. As per the research, the calculations and also the free body diagram, the manually staircase climbing trolley will not be slanted or tilted while climbing up the staircase. This is because an external force in form of a human can control the trolley by holding the handle and pushing it upwards. Thus, the trolley can be controlled and it will not fall from the staircase.

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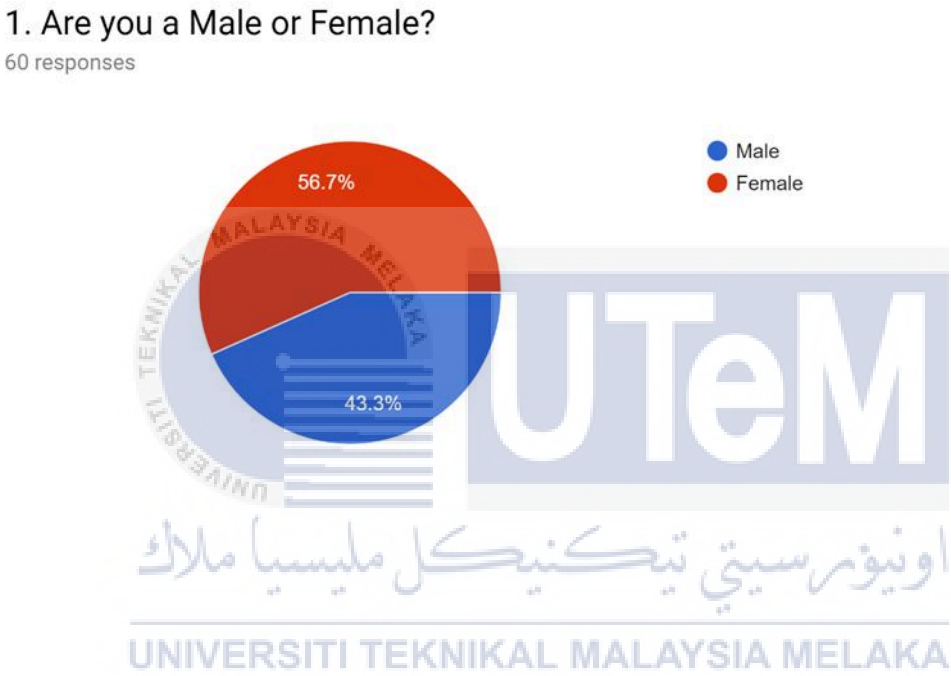
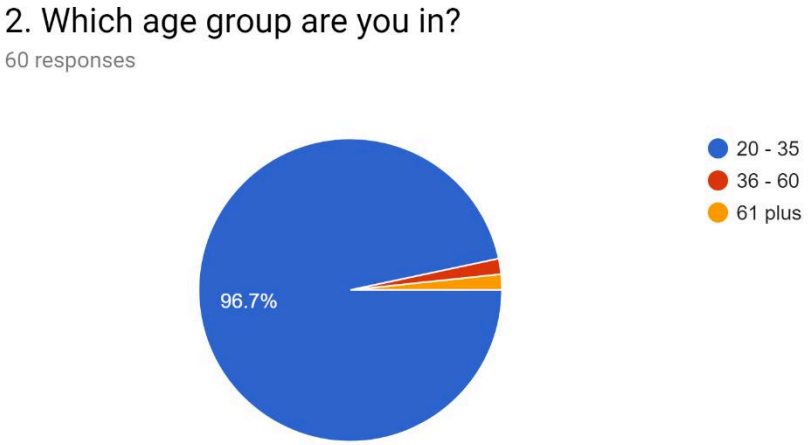
APPENDIX

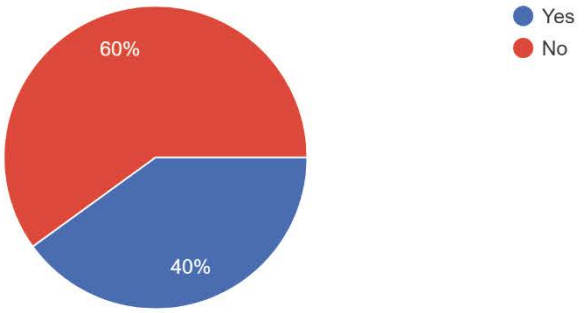
A. Survey of 60 responses in pie percentage





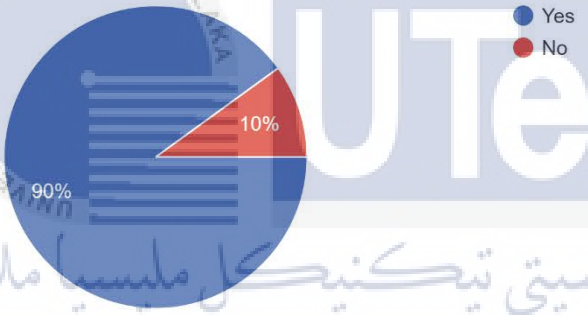
3. Have you heard about manually stair climbing trolley?

60 responses



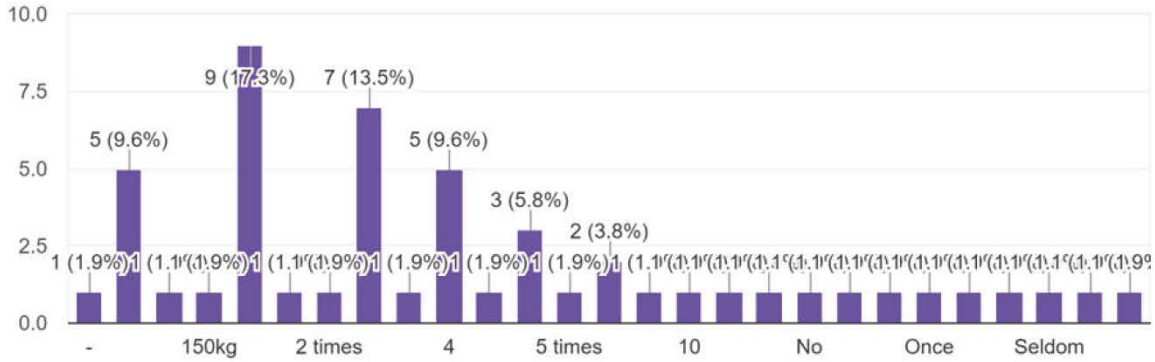
4. Do you face problem in climbing the staircase while carrying loads?

60 responses



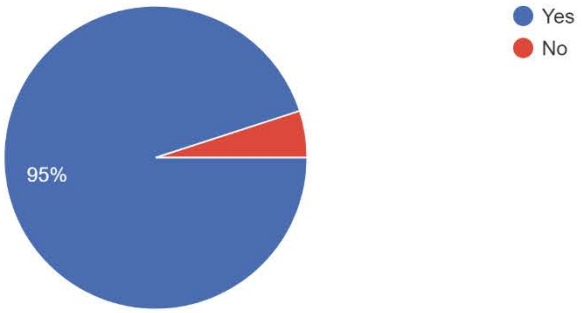
5. Frequent for carrying load per week? (time per week)

52 responses



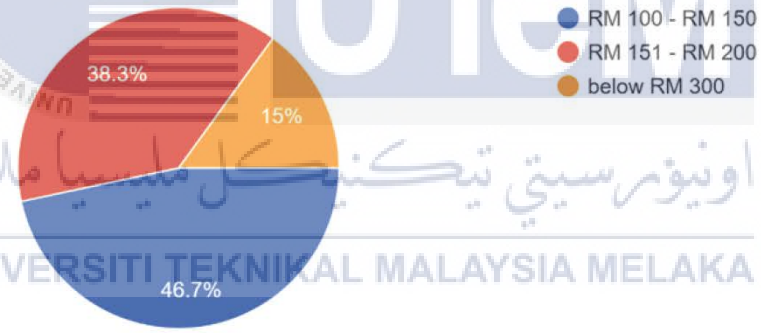
6. Are you looking forward for a machine or an invention that may ease you in carrying loads via staircase?

60 responses



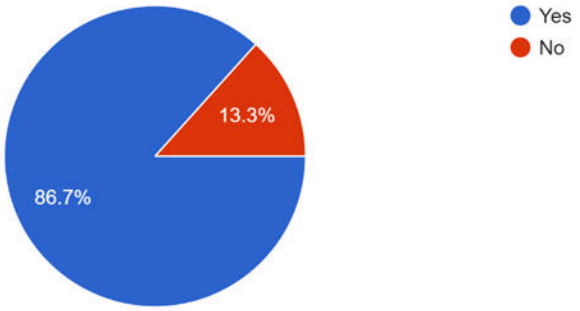
7. In your opinion, what would be the possible cost of inventing the manually stair climbing trolley?

60 responses



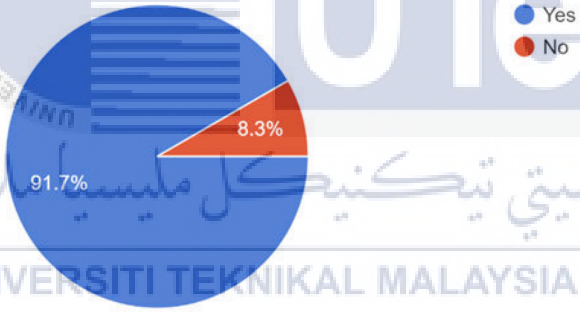
8. Do you consider manually stair climbing trolley as an effective invention and useful to carry loads?

60 responses



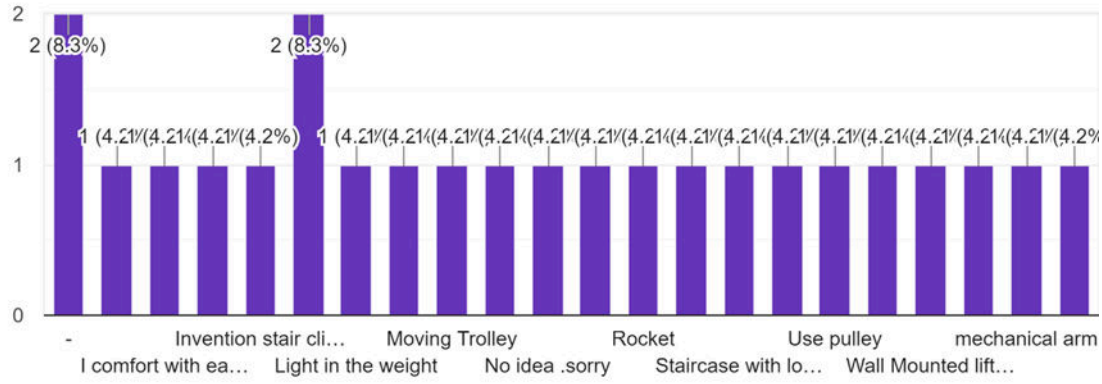
9. Do you consider low maintenance and fold-able are the important aspect in inverting manually stair climbing trolley?

60 responses



10. Suggestion a machine or an invention that may help you in carrying loads via staircase?

24 responses



Appendix A Survey question and responses