DESIGN AND ANALYSIS OF WHEELCHAIR IN TERM OF DAILY USAGE

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IN TERM OF DAILY USAGE

AHMAD MUHAIMIN BIN ISMAIL

Thesis submitted in fulfillment of the requirements
for the award of the degree of
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FACULTY OF MECHANICAL ENGINEERING

I certify that the project entitled "*Design and Analysis of Wheelchair according to Human Factor Engineering*" is written by *Ahmad Muhaimin bin Ismail*. I have examined the final copy of this project and in my opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. I herewith recommend that it be accepted in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering with Manufacturing Engineering.

MrAzim bin Arshad ....

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"I hereby declare that I have checked this project report and in my opinion this project report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Manufacturing Engineering."

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STUDENT'S DECLARATION

I hereby declare that this report entitled "*Design and Analysis of Wheelchair in Term of Daily Usage*" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Dedicated truthfully for supports,
encouragements and always be there during hard times, to
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ABSTRACT

Manual wheelchair propulsion in daily life is increasing day to day. So, preliminary study of human factors engineering is important in designing the wheelchair to be more ergonomics for them in doing daily activities. The main objective of this project is to improve the existing wheelchair in term of daily usage. It is focus on the use of simulation in analyzing the critical parts of the wheelchair model and evaluates it in term of daily usage. Evaluate the critical part of stress on the wheelchair which consists of seating support and wheel caster. In this steps, applying the knowledge gathered from the questionnaire is use to make a design refers to case data that suitable for the project. Several sketches were made and only three were selected based on suitability of the design. Three sketches being draw into SolidWorks software and then go through to simulation process by using FEA tools that is ALGOR software, the three designs was analyzed using constant force with three different materials. From the analysis, the Stress Von Misses was used to calculated safety factor. The result showed that, design 3 have highest value of safety factor with material E-Glass fiber which is 2.77, followed by Steel ASTM A36 is 2.44 on design 3 and 1.95 on design 2 with material E-Glass fiber. The highest number of safety factor is E-glass Fiber on design 3. So, the best selection of material is E-Glass Fiber for the Design 3.

ABSTRAK

Penggunaan kerusi roda dalam kehidupan harian semakin meningkat. Dengan itu , kajian dalam faktor kejuruteraan manusia amat penting untuk menjadikan kerusi roda lebih ergonomik untuk pengguna dalam melakukan aktiviti harian. Objektif utama projek ini ialah untuk mengubahsuai kerusi roda yang sedia ada menjadi lebih sesuai untuk kegunaan harian. Selain itu, memfokuskan penggunaan simulasi untuk menganalisis bahagian-bahagian kritikal kerusi roda dan menilainya untuk kegunaan harian. Menganalisis bahagian kritikal pada kerusi roda iaitu tempat duduk dan juga roda. Pengetahuan yang diperoleh daripada boring soal selidik digunakan untuk membuat beberapa lakaran.dan hanya tiga lakaran dipilih berdasarkan kesesuaian reka bentuk. Tiga lakaran akan dilukis dalam perisian SolidWorks dan kemudian proses simulasi dengan menggunakan perisian ALGOR, tiga jenis kerusi roda yang berlainan dianalisis menggunakan daya tekanan yang sama dan tiga jenis bahan berbeza. Dari analisis, Stress Von Misses akan digunakan untuk mengira faktor keselamatan.Hasil menunjukkan bahawa, reka bentuk 3 mempunyai nilai faktor keselamatan yang tinggi dengan bahan E-Glass dengan nilai 2.77, diikuti oleh Steel ASTM A36, 2.44 dan 1.95 pada reka bentuk 2 dengan bahan serat E-Glass. Jumlah tertinggi faktor keselamatan ialah E-glass Fiber pada reka bentuk 3. Jadi, pilihan terbaik bahan ialah E-Glass Fiber untuk Design 3.

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LIST OF ABBREVIATIONS

ADL	Activity daily life
ANOVA	Analysis of variance
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
ATD	Anthropomorphic test dummy
CAD	Computer-aided drafting
EPW	Electric powered wheelchair
FEA	Finite element analysis
FIPFA	The Federation Internationale de Powerchair Football Associations
FWORS	Fixed wheelchair occupant restraint system
HIC	Head injury criteria
RESNA	Rehabilitation Engineering and Assistive Technology Society of North America
SAE	Society of Automotive Engineers
WHMD	Wheeled mobility device
WIRS	Wheelchair integrated restraint system

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Wheelchair is a transportation device used by people who have difficulties in walking due to illness or disability. It is moved either by the handles or by turning the wheels. Today there are many options and many different types of wheelchairs such as manual wheelchairs, powered wheelchairs, and transport wheelchair. Wheelchair consists of mechanical components basically such as the hand rims, armrests, footrests, castors, seat and back upholstery. However, the existing wheelchair has weakness such as not ergonomics enough to meet the users needed. Ergonomics can be defined as the application of knowledge of human factor to the design of systems (Taylor & Francis, 2008). The first wheelchair was made for Phillip II of Spain. Later on in 1655 a disabled watchmaker called Stephen Farfler built himself a three-wheeled chair to help himself get about on. In 1881 the 'push rim' was invented which meant no more dirty hands for wheelchair users; they could use the push rim to move the wheels and not get covered in mud. From here wheelchairs have developed more and more over the years including easy use, more options, lightweight options, and adjustable seats and so on.

1.2 BACKGROUND OF STUDY

Ergonomics addresses the problems of human comfort, activity and health in environments. Selection of the proper seat width is important to comfort and stability. A seat too narrow is not only uncomfortable, but access to the chair is made difficult. In addition, a seat wider than is necessary makes propulsion more difficult (Kotajarvi et al, 2005). A seat that is too deep or longer than it should be, can restrict circulation in the legs, and causes the patient either to sit with his legs extended or to slide forward in the chair. The backrest of the basic chair is made of a flexible material stretched between the two side frames which are fixed with respect to the seat (Veeger et al., 1992). The backrest should be high enough to provide support without inhibiting motion and avoid discomfort. Armrest is providing support for the patient's arms in a resting attitude, and also provides lateral support. The function of the footrests is to keep the feet off the floor.

1.3 PROBLEM STATEMENT

Existing wheelchair are limited in its function, such as it needs human force to move it. The user need to move the wheel by hand and may getting tired using it in a longer period. Besides that, existing wheelchair have weaknesses. It is not safety enough and it is also not very comfortable as the shape and position cannot be fixing the user's body. This project is about to redesign existing wheelchair to be more ergonomic that is important element of human factor engineering. In this project, the first requirement is to evaluate the existing wheelchair in term of daily usage. The questionnaires are distributed to the wheelchair user and the guidance to make a market survey to collect a necessary data. Analysis of the questionnaires and adequate in study of designing objects are important to make sure the new design fulfill all the criteria of desirable design of wheelchair. Wheelchair design must be comfortable and safety for the user. It is also should preventing from the serious problem occurred which may lead to accident. The ergonomic desirable design of wheelchair which offers an appropriate variable features and other elements which can be changed by the user that need come out with a few designs and evaluate it according to human factor engineering and material selection.

1.4 OBJECTIVES

The objectives of this project are to:

i. Improve the existing wheel chair in terms of daily usage.
ii. Analyze the wheelchair according to human factor engineering and material selections.
iii. Simulate the prototype of the product using SolidWorks and ALGOR software.

1.5 SCOPES

This project is confined to the following scopes of study:

i. Selected the suitable manual wheelchair in terms of human factor engineering.
ii. Redesign of wheel chair drawing using SolidWorks software.
iii. Analysis the strength of the redesign drawing using ALGOR software.
iv. Simulate the prototype of product by SolidWorks software.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter provides the detail description literature review done according to the title of "Design and Analysis of Wheel Chair in Term of Daily Life Usage". Since the aim of this project is to redesign the wheel chair using Solid Works software and ALGOR software. Thus literature review related definition of design, wheel chair and handicap. Obviously literature review related with definition of human factor engineering, wheel chair and ergonomic. This literature review will give an overview or a brief introduction of the techniques that are suitable to be used in this project.

2.2 DESIGN

Design is an innovative and highly iterative process. It is also a decision-making process. Decisions sometimes have to be made with too little information, occasion ally with just the right amount of information, or with an excess of partially contradictory information (Richard G. Budynas and J. Keith Nisbett, 2010). Design is a communication-intensive activity in which both words and pictures are used and written and oral forms are employed. Engineers have to communicate effectively and work with people of many disciplines. Design is the human power to conceive, plan, and realize products that serve human beings in the accomplishment of any individual or collective purpose. It is a creative activity whose aim is to establish the multi-faceted qualities of objects, processes, services and their systems in whole life cycles. Therefore, design is the central factor of innovative humanization of technologies and the crucial factor of cultural and economic exchange.

2.2.1 Principle's Of Design

Design is a complex iterative creative process that begins with the recognition of a need of desire and terminates with a product or process that uses available resources, energy and technology to fulfill the original need within some set of defined constraints.

2.2.2 Design Guidelines

A set of guidelines developed to ensure that a product is designed so that it can be easily and efficiently manufactured and assembled with a minimum of effort, time, and cost. There are some guidelines in design:

i. Aim For Simplicity
ii. Standardize
iii. Rationalize Product Design
iv. Use The Widest Possible Tolerances
v. Choose Materials To Suit Function And Production Process
vi. Minimize Non-Value-Adding Operations
vii. Design For Process
viii. Teamwork

2.2.3 Design Process

The design process is an iterative, complex, decision-making engineering activity that lead to detailed drawings by which manufacturing can economically produce a quantity of identical products that can be sold. The design process usually starts with the identification of a need, and decision to do something about it. After many iterations, the process ends with the presentation of the plans or satisfying the need. Depending on the nature of the design task, several design phases may be repeated throughout the life of the product, from inception to termination (Richard G. Budynas and J. Keith Nisbett, 2010).

2.3 WHEELCHAIR

Wheelchairs are a type of medical device that is used to improve accessibility for people who are mobility challenged. Wheelchairs are used by people for whom walking is difficult or impossible due to illness like physiological or physical, injury or disability. In some form or another, wheelchairs have been used for many thousands of years, but it would not be until the beginning of the twentieth century that a standard wheelchair design would be developed. There are a number of different wheelchair designs and models available, but they are basically classified as either manual or electric.

2.3.1 Types of Wheelchair

Nowadays, there are many types of wheelchair that is available in the market. It is design based on different shapes and functions. Beside its main usage, wheelchair is also use for exercise activities. The types of wheelchair are manual wheelchair, electric powered wheelchair, sport wheelchair and cross-braced wheelchair. Each wheelchair has difference system and function.

2.3.1.1 Manual Wheelchair

Manual wheelchairs are the oldest type of wheelchair available and are either classified as self propelled or attendant propelled. One of the first self propelled wheelchairs was developed by a blacksmith over 300 years ago and used a hand crank to move the wheelchair. Today, there are a number of different types of self propelled manual wheelchairs, which are classified by their uses, but the most common type of manual wheelchair is the conventional wheelchair. A conventional wheelchair has hand rims which are attached to the outside of the rear wheels, which allow the user to turn the rear wheels. The rear wheels are much larger than the front wheels and are typically 24 inches in diameter (Martel et al., 1991). The Conventional wheelchair usually offers a folding design, so it can be easily transported, and has a steel tubes frame. However, to reduce weight aluminum and titanium frames are also used. The seat is typically made of vinyl, which is easy to clean (Martel et al., 1991). Attendant propelled wheelchairs, or transport chairs, often look very similar to a self propelled wheelchair; however they do not have hand rims on the rear wheels. Instead they are designed to be pushed by someone walking behind the wheelchair. Often the rear wheels will be much smaller than traditional wheelchairs.

2.3.1.1.1 Advantages and Disadvantages of Manual Wheelchairs

Manual wheelchairs do provide great advantages over power ones that many people overlook. For starters, lightweight wheelchairs are almost always manual. This can be a huge selling point for someone who does not possess a lot of body strength. They are easier to maneuver and even though power chairs do not have to be pushed, there is always the chance that the battery could die. Another advantage of manual wheelchairs is the fact that they can go almost anywhere. A person does not have to worry whether or not the terrain is bumpy or uneven, like they would with a power wheelchair. One of the main disadvantages of using manual wheelchairs has to do with the upper body. Yes, the exercise is good for those who push themselves, however, over time this same motion can lead to injury; something that wheelchair users try to avoid whenever possible. Other disadvantages of a manual is having to inflate the tires and keeping the body of the chair in line. Manual wheelchairs may not have all the bells and whistles that power ones offer to handicapped individuals, but they can prove to be cheaper and more efficient than the bulky power chairs.

Figure 2.1: Manual wheelchair

Source: Simmons et al. (2000)

Figure 2.2: Seating position of manual wheelchair

Source: Panero & Zelnik (1979)

2.3.1.2 Electric Powered Wheelchair

Electric wheelchairs, which are also called power chairs, were first developed during the middle of the twentieth century. Early electric wheelchairs were simply manual wheelchairs that had been outfitted with an electric motor. Today, most power chairs feature a molded plastic base, which contains the electric motor and batteries

(Veeger et al., 1991). A chair is attached to the base and resembles a high quality office chair, but usually has a higher back, more padding, and a headrest. The range varies, but most power chairs can travel up to 10 miles on a single charge (Veeger et al., 1991). However, environmental factors, such as hills and the rider's weight, play a role in the wheelchairs range. Most use a joystick control, which can be mounted to either the left or right armrest. There are also a great deal numbers of alternate controls, such as breath control. A remote control system is also available, to offer attendant propelled functionality. Portable power chairs are also available, which closely resemble a conventional folding wheelchair.

Indoor and outdoor powered wheelchairs and mobility scooters are for use by disabled people who cannot propel a manual wheelchair. There are criteria for using some types of electric wheelchair. There are four types of powered wheelchair offered because a user cannot propel or use a manual wheelchair:

i. Electric Indoor Chair - user controlled
ii. Electric Outdoor Chair - attendant controlled
iii. Electrically Powered Indoor/Outdoor Chair - user controlled
iv. Dual Purpose Chair - user controlled indoors, attendant controlled outdoors

Outdoor powered wheelchairs and mobility scooters are grouped into two categories, class 2 and class 3:

i. Class 2 wheelchairs and scooters must have a maximum speed of four miles per hour (6.4 kilometers per hour) and are for pavement use only
ii. Class 3 wheelchairs and scooters must have a maximum speed of eight miles per hour (12.8 kilometers per hour) and can be used on roads

Figure 2.3: Electric wheelchairs

Source: Simmons et al. (2000)

2.3.1.3 Sport Wheelchair

The most popular type of wheelchair for everyday use for a person with good upper body mobility is the lightweight manual wheelchair, which also called sport wheelchair. Lightweight chairs provide maximum independence of movement with a minimum of effort. Many active wheelchair users also prefer the sportier look of the lightweights compared with the more standard looking everyday chair. It should be noted, however, that heavy or obese persons may be unable to use these types of chairs because the lighter weight of the frame results in a reduced user capacity as compared to standard everyday chairs. Once used primarily by wheelchair athletes, the lightweight chair today is used by people in virtually all walks of life as a preferred mode of assisted mobility (Mike Savicki, 1998). Three-wheeled chairs, also developed for such sports as tennis and basketball, are also an everyday chair alternative. As the popularity of wheelchair sports and recreation has increased, manufacturers have developed wheelchairs offering speed, mobility and durability, allowing users to participate in several different activities. The basketball wheelchair and the rugby wheelchair are examples of sport-specific wheelchairs. The racing wheelchair comes with three wheels to increase speed and aerodynamics. The tennis wheelchair comes with an extended frame for quickness and maneuverability.

Figure 2.4: Sport wheelchair

Source: Mike Savicki (1998)

2.3.1.4 Child/Junior Chairs

Children and young adults need chairs that can accommodate their changing needs as they grow. In addition, it is important that wheelchairs for children or teens be adaptable to classroom environments and is "friendly looking" to help the user fit more readily into social situations. Manufacturers today are becoming increasingly sensitive to these market demands and are attempting to address them with innovative chair designs and a variety of "kid-oriented" colors and styles.

2.3.1.5 Specialty Chairs

Because of the diverse needs of wheelchair users, wheelchairs have been designed to accommodate many lifestyles and user needs. Hemi chairs, which are lower to the floor than standard chairs, allow the user to propel the chair using leg strength. Chairs that can be propelled by one hand are available for people who have paralysis on one side. Oversized chairs and chairs designed to accommodate the weight of obese people are also offered. Rugged, specially equipped chairs are available for outdoor activities. Aerodynamic three-wheeled racing chairs are used in marathons and other racing events. Manual chairs that raise the user to a standing position are available for people who need to be able to stand at their jobs, or who want to stand as part of their physical conditioning routine. These and other specialized chair designs generally are manufactured by independent wheelchair manufacturers who are trying to meet the needs of specific target markets.

2.3.1.6 Institutional/Nursing Home/Depot Chair

The least expensive type of chair available, an institutional chair, is designed for institutional usage only, such as transporting patients in hospitals or nursing homes. It is not an appropriate alternative for anyone who requires independent movement, as the institutional chair is not fitted for a specific individual. These types of chairs are now also used as rental chairs and by commercial enterprises (such as grocery stores and airports) for temporary use.

Figure 2.5: Nursing wheelchair

Source: T.G. Frank

2.3.2 Wheelchair Components

2.3.2.1 Frame

One of the biggest breakthroughs in wheelchair technology has been the development of new, lightweight materials for wheelchair frames. Whereas stainless steel used to be the only frame material available, wheelchair users today have their choice of stainless steel, chrome, aluminum, airplane aluminum, steel tubing, an alloy of chrome and lightweight materials, titanium, and other lightweight composite materials. The type of material used to construct the frame affects the weight of the frame, and therefore the overall weight of the wheelchair. The type of frame material also can affect the wheelchair's overall strength. The two most common types of frames currently available are rigid frame chairs (where the frame remains in one piece and the wheels are released for storage or travel), and the standard cross-brace frame (which enables the frame to fold for transport or storage).

2.3.2.2 Upholstery

Upholstery for wheelchairs must withstand daily use in all kinds of weather. Consequently, manufacturers provide a variety of options to users, ranging from cloth to new synthetic fabrics to leather. Many manufacturers also offer a selection of upholstery colors, ranging from black to neon, to allow for individual selection and differing tastes among consumers.

2.3.2.3 Seating Systems

Seating systems are sold separately from the wheelchairs themselves, as seating must be chosen on an individual basis. It is important when selecting a wheelchair or a seating system to ensure that the two components are compatible.

2.3.2.4 Brakes

"Braking" on a manual wheelchair in use is accomplished by applying the hands on the wheels. However, "parking brakes" (wheel locks) are available in several different designs, and can be mounted at various heights to maximize convenience to the user.

2.3.2.5 Wheels/Tires

Most wheelchairs use four wheels, with two large wheels at the back and two smaller ones (casters) at the front. The standard tire used for the rear wheels on most wheelchairs is a pneumatic tire. Smaller and larger sizes, however, also are available. Many manufacturers now also offer other types of tires--such as solid tires, semi-pneumatic, or radial tires--at extra cost. Mag wheels and off road wheels also is options on some chairs. Casters, too, vary in size (ranging from six to eight inches in diameter) and composition (pneumatic, solid rubber, plastic, or a combination of these).

2.3.2.6 Footrests

For rigid frame chairs, footrests usually are incorporated into the frame of the chair as part of the design. Cross-brace folding chairs often have footrests which swivel, flip up, and/or can be removed.

2.3.2.7 Armrests

Many lightweight manual chairs are designed to be used without armrests. The absence of armrests makes it easier for the user to roll up to a desk or table, and many active wheelchair users prefer the streamlined look of a chair with no armrests. However, armrests are helpful if the user has difficulty with upper body balance while seated. Armrests come in a variety of styles including desk length (to allow the user closer access to desks and tables) or full length and both types may be flip-up, fixed, or detachable.

2.4 ERGONOMICS

Ergonomics, also known as human factors, is the scientific discipline that seeks to understand and improve human interactions with products, equipment, environments and systems. Drawing upon human biology, psychology, engineering and design, ergonomics aims to develop and apply knowledge and techniques to optimize system performance, whilst protecting the health, safety and well-being of individuals involved. The attention of ergonomics extends across work, leisure and other aspects of our daily lives. (Taylor & Francis, 2008).

Ergonomics derives from two Greek words: ***ergon,*** meaning work, and ***nomoi,*** meaning natural laws, to create a word that means the science of work and a person's relationship to that work. The International Ergonomics Association has adopted this technical definition ergonomics or human factors is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance (Anon, 2007).

2.4.1 Ergonomics in Product Design

Ergonomic products are often advertised as reducing fatigue and repetitive strain, and boosting productivity. According to the U.S. National Institute for Health (NIH), an ergonomic chair should have a variety of adjustable features, including seat height, tilt, adjustable arm rests, and other specific characteristics, such a "waterfall seat pan that dips towards the floor (Anon, 2007b). The NM also emphasizes creating an ergonomic workspace and lays out guidelines for optimal monitor height, lighting, keyboard and mouse position, and so on. Along with creating a physical environment that is conducive to natural movements of the body, the NM lists some simple exercises one can perform throughout the day, while sitting at a desk, to relieve fatigue. The goal of ergonomic products or environments is to interface with humans in the most natural way possible. In buying products and creating environments with ergonomic design at home and at work, one should be able to enjoy one's work or play with added ease and reduced stress (Anon, 2007b).

2.5 ANTHROPOMETRY

Anthropometry is the study of the measurement of the human body in terms of the dimensions of bone, muscle, and adipose (fat) tissue. Measures of subcutaneous adipose tissue are important because individuals with large values are reported to be at increased risks for hypertension, adult-onset diabetes mellitus, cardiovascular disease, gallstones, arthritis, and other disease, and forms of cancer. Combined with the dietary and related questionnaire data, and the biochemical determinations, anthropometry is essential and critical information needed to assist in describing the data collected from persons in the NHANES III sample.

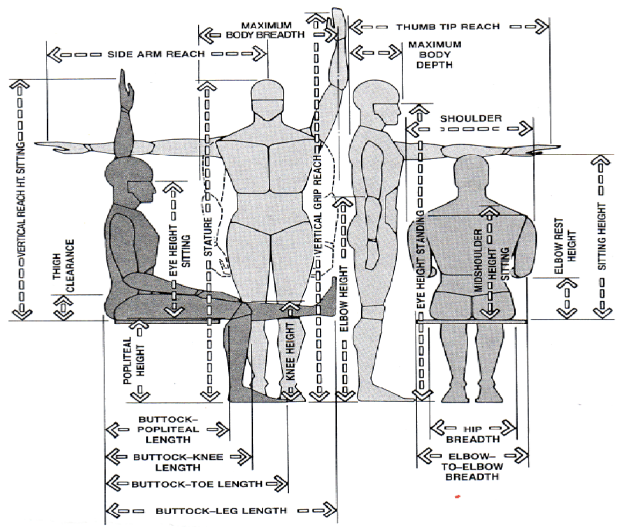

Figure 2.6: Anthropometric body measurement

Source: Panero & Zelnik (1979)

2.5.1 Malaysian Anthropometric Database

Human being plays an important role in the functioning of socioeconomic system such as in developing equipment, machinery, workstation, and objects. The most important criteria which have been suggested in ergonomic were the system must fit anthropometrically, comfortable and safe to use. Therefore the designer must ensure those important criteria such as the anthropometric data were applied before the system could be use by the user. Several literatures were presented in this paper to show the importance of incorporating anthropometric concern in designing processes. Even though the importance of anthropometric database is recognized, a published anthropometric database for Malaysian population is still not available. This paper presents a summarized data of a Malaysian population anthropometric study. The objective of the study was to develop an anthropometric database for Malaysian population. The study was conducted using anthropometric data of 1,007 Malaysian consisting of 516 males and 491 females. The equipments used in this study were measuring tools comprised of Human Body Measuring Kit and Anthropometer for body dimension measurements. A total of 40 anthropometric dimensions were measured in this study. The data collection was for both standing and sitting postures. The database comprised of the important values such as the mean and the standard deviation, the 5th and 95th percentile. The study had successfully produced a detailed and comprehensive anthropometric database for Malaysian population which can be used in the future by all designer and engineers in designing process. The results obtained from the anthropometric database collection of 1,007 Malaysian citizens in this study are shown in Table 1 below. The anthropometric data has been summarized to the mean value, standard deviation value, and the 5th and 95th percentile value.

Table 2.1: Anthropometric data for the overall Malaysian citizen, all units are in mm

No	Anthropometric Dimensions	Mean	SD	5th Percentile	95th Percentile
1	Stature	1565.00	59.58	1466.69	1663.31
2	Eyes Height	1451.15	100.52	1285.29	1617.01
3	Shoulder Height	1288.09	105.54	1113.96	1462.23
4	Elbow Height	984.44	95.69	826.55	1142.34
5	Olectron Height	995.95	72.60	876.16	1115.73
6	Waist Height	959.27	371.37	346.52	1572.03
7	Knee Height	436.81	59.36	338.87	534.76
8	Shoulder Breadth	438.97	55.88	346.77	531.17
9	Chest Breadth	317.82	50.80	234.00	401.64
10	Chest Depth	215.06	48.28	135.40	294.72
11	Hip Breadth	378.34	70.98	261.22	495.45
12	Chest Circumference	843.74	132.42	625.24	1062.24
13	Wrist Circumference	160.86	84.17	21.98	299.75
14	Waist Circumference	751.30	127.98	540.14	962.47
15	Thigh Circumference	504.72	74.16	382.36	627.09
16	Calf Circumference	345.93	48.41	266.05	425.81
17	Sitting Height	792.86	76.20	667.12	918.59
18	Sitting Eyes Height	679.08	72.69	559.14	799.01
19	Sitting Shoulder Height	515.84	62.66	412.45	619.23
20	Popliteal Height	424.80	42.68	354.38	495.21
21	Cervicale Height	597.42	76.39	471.38	723.46
22	Buttock Popliteal Length	448.60	48.93	367.87	529.33
23	Buttock-Foot Length	940.35	96.04	781.89	1098.81
24	Sitting Knee Height	470.36	65.94	361.56	579.15
25	Forearm Hand Length	421.53	33.05	366.99	476.06
26	Shoulder-Elbow Length	340.51	50.62	256.99	424.03
27	Sitting Elbow Height	224.66	56.82	130.91	318.41
28	Thigh Clearance	196.62	49.82	114.41	278.83
29	Hand Length	173.37	15.24	148.22	198.52
30	Hand Metacarpal Breadth	79.40	32.49	25.79	133.00
31	Palm Length	97.52	40.40	30.87	164.17
32	Grip Diameter	48.56	15.79	22.52	74.61
33	Foot Length	225.68	26.76	181.52	269.83
34	Foot Breadth	101.90	65.10	-5.52	209.31
35	Shoulder Grip Length	651.03	56.17	558.36	743.71
36	Weight	60.40	52.41	-26.07	146.88
37	Head Length	194.94	33.67	139.38	250.49
38	Biacromial Breadth	365.46	53.27	277.55	453.36
39	Crotch Height	789.30	105.02	616.02	962.59
40	Upper Arm Length	325.55	50.86	241.63	409.47

Source: Panero & Zelnik (1979)

From Table 2.1, it is shown that the average stature of Malaysian citizen is 1565.00 mm with 90 percent of stature lies between 1466.69 mm and 1663.31 mm. The anthropometric database from Table 2.1 can be used for all various design purposes. For example, the value of 5th percentile and 95th percentile of standing elbow height for Malaysian population is 826.55 mm and 1142.34 mm. This means that if the designers need to construct an ergonomic standing workstation, the height of the workstation table between 826.55 mm and 1142.34 mm should be able to fulfill the height of 90 % Malaysian population.

2.6 PREVIOUS RESEARCH

2.6.1 Systematic Design Customization of Sport Wheelchairs Using the Taguchi Method (Burton M, Subic A, Mazur M, Leary M, 2010)

This paper describes a systematic approach developed for customisation of wheelchairs for court-based sports, such as wheelchair rugby. Novel predictive models and reference to prior experimental work has identified pertinent wheelchair design parameters, including horizontal and vertical seat position and wheel camber. A purpose-built adjustable wheelchair frame has been developed to experimentally assess the effects of these parameters on the performance of individual athletes. The paper proposes a novel approach to determining optimal design parameters for a specific athlete based on the Taguchi method. This approach is superior to traditional testing as it enables efficient characterisation of the effect of design variables on wheelchair performance, including error checking to quantify the effect of noise variables such as muscle fatigue.

2.6.2 Wheelchair, a Motorized Wheelchair with Stair Climbing Ability (Walter Franco, Riccardo Oderio, 2010)

This thesis employs with Wheelchair, a concept for a stair climbing wheelchair capable of moving in structured and unstructured environments, climbing over obstacles and going up and down stairs. The design of the wheelchair, consisting of a frame, a seat and a four-bar linkage mechanism that connects frame and seat, is presented. The four-bar linkage moves and rotates the chair to prevent the wheelchair from overturning and to guarantee a comfortable posture to the passenger during different operations. The kinematic synthesis of the linkage mechanism is discussed using an algebraic method. When the wheelchair faces an obstacle such as a step or a stair, it can passively change locomotion mode, from rolling on wheels to walking on rotating legs, thanks to its self-adaptive locomotion units. The function of the locomotion unit is described and modelled using kinematic equations. The locomotion unit requires only one motor, for both wheeled and legged locomotion. Tests on a scale prototype were conducted in order to evaluate the effectiveness of this locomotion.

2.6.3 The Effect of Knee-Flexion Angle on Wheelchair Turning (A.H. MacPhee, 2001)

The increasingly popular hyper flexed knee-flexion angle was evaluated to determine its effects on wheelchair turning. Twenty able-bodied subjects were tested comparing the effect of full knee extension and full knee flexion on a number of parameters. We empirically measured the angular velocity of subjects spinning 720° in place, subjects' perceived ease of wheelchair turning, and the overall length of the wheelchair, the anteroposterior position of the center of mass (COM), rolling resistance, turning resistance and rear-wheel traction. The combined moment of inertia of the wheelchair and system was modelled. We found that, in comparison with full extension, fully flexing the knees increased angular velocity by 40 % and were perceived to be 66 % easier by subjects. Overall length decreased by 39 %, COM moved rearward 38 %, rolling and turning resistance decreased by 21 % and 17 % respectively, rear-wheel traction increased by 12 % and moment of inertia decreased by 42 %. All empirically tested parameters were statistically significant (*p*_0.007). We conclude that the knee-flexion angle has a significant effect on wheelchair turning. The implications of these findings for wheelchair design and prescription will need to be validated on actual wheelchair users and for smaller increments in knee-flexion range.

2.6.4 An Anthropometric Study of Manual and Powered Wheelchair Users (Paquet and Feathers, 2003)

The purpose of this study was to evaluate the structural anthropometric dimensions of adult wheelchair users as part of a larger project that involved developing a database of the structural characteristics and functional abilities of wheelchair users. Measurements were made on 121 adult manual and powered wheelchair users with an electromechanical probe that registered the three-dimensional locations of 36 body and wheelchair landmarks. Thirty-one body and wheelchair dimensions (e.g., heights, breadths, depths) were calculated from the three-dimensional coordinate data. Tests of distributional normality showed that less than 1/3 of the dimensions were not normally distributed. ANOVA showed significant differences between powered and manual chair users, and women and men for only some of the anthropometric dimensions. The results of this study provide anthropometric information for a small and diverse group of wheelchair users using new measurement methods that may have value for three-dimensional human modeling and CAD applications.

2.6.5 Wheelchairs Used As Motor Vehicle Seats: Seat Loading In Frontal Impact Sled Testing (Gina Bertocci, 2001)

Wheelchairs are not typically designed to function as motor vehicle seats. However, many wheelchair users are unable to transfer to a vehicle seat and instead travel seated in their wheelchair. ANSI/RESNA WC19: Wheelchairs Used as Seats in Motor Vehicles provides design and testing requirements, but does not provide wheelchair manufacturers with design guidance related to expected loads imposed upon wheelchair components during a crash. To provide manufacturers with crashworthy design guidance, our study measured wheelchair seat loading during 20g/48kph frontal impact sled tests with a 50th percentile male test dummy. Loading conditions were assessed using two different rear securement point positions. Results of four sled impact tests revealed downward loads ranging from 17 019 to 18 682 N, depending upon rear securement point configuration. Maximum fore/aft shear loads ranged from 4424 to 6717 N across the tests.

2.6.6 Evaluation of the wheelchair standards (Rentschler, 2002)

The results from this study provide an in depth look at the performance, safety, and general characteristics of the five different types of EPWs tested. The information gleaned from this study shows how similar looking and comparatively priced EPWs can perform quite differently. They depend on their wheelchair to function safely and reliably at all times to provide a source of independence not otherwise available. Currently, wheelchair standards are the best source of information to determine exactly how an EPW will perform and what its limitations are. Unfortunately, the results of EPW testing are not always readily available and consumers and even clinicians depend mainly on experience and word of mouth to select the best wheelchair for a given situation. This study demonstrates that the information gathered from the standards testing is essential when attempting to compare different wheelchair makes and models.

2.6.7 Determination of the Normal and Maximum Reach Measures of Adult Wheelchair Users (John W. Kozey, 2003)

The aim of the study was to determine of the normal and maximum reach measures of adult wheelchair users. Industrial workspaces intended to accommodate adults, who use a wheelchair, must consider the reach capabilities of the users. This research employed a direct anthropometric measurement approach to the study of the normal reach area (NRA) and the maximum reach envelope (MRE) of a sample of 42 male and 20 female, adult wheelchair users. A computerized potentiometric system for anthropometric measures (CPSAM) was designed, built and tested for use in this study. The CPSAM recorded the position of a movable pointer in 3-D space with respect to a table reference point. The subjects were positioned in front of an adjustable work surface and asked to produce three trials of each of their normal and maximum reach. The 3-D Cartesian coordinate values were converted to cylindrical coordinates to model the reach surfaces. Using multiple linear regression of the reach surface separate linear equations were derived to describe the 5th, 50th and 95th percentile reach boundaries for males and females, separately. The overall root mean square error of the reach equations across the males and females ranged from 4 to 17mm for the NRA and 12–39mm for the MRE.

2.6.8 Biomechanics and Physiology in Active Manual Wheelchair Propulsion (L.H.V. Van Der Woude, H.E.J. Veeger, A.J. Dallmeijer, T.W.J. Janssen, L.A. Rozendaal, 2001)

Manual wheelchair propulsion in daily life and sports is increasingly being studied. Initially, an engineering and physiological perspective was taken. More recently a concomitant biomechanics interest is seen. Themes of biomechanical and physiological studies today are performance enhancing aspects of wheelchair use and the ergonomics of wheelchair design. Apart from the propulsion technique the focus of biomechanics research of manual wheelchair propulsion is mainly towards injury mechanisms, especially phenomena of overuse to the upper extremity. Obviously, the vehicle mechanics of wheelchairs must be included within this biological framework. Scientific research is progressing, but is still hampered by methodological limitations, such as the heterogeneity and small numbers of the population at study as well as the inconsistency of employed technologies and methodologies. There is a need for consensus regarding methodology and research strategy, and a strong need for collaboration to improve the homogeneity and size of subject groups and thus the power of the experimental results. Thus a sufficiently strong knowledge database will emerge, leading to an evidence-base of performance enhancing factors and the understanding of the risks of wheelchair sports and long-term wheelchair use. In the light of the current biomechanical and physiological knowledge of manual wheelchair propulsion there seems to be a need for the stimulation of other than hand rim propelled manual wheelchairs.

2.6.9 Effect of Wheelchair Headrest Use On Pediatric Head and Neck Injury Risk Outcomes During Rear Impact (Susan I. Fuhrmana,, Patricia E. Karga, Gina E. Bertocci, 2008)

Comparative risks or benefits to wheelchair-seated pediatric occupants in motor vehicles associated with wheelchair headrest use during rear impact were evaluated using pediatric head and neck injury outcome measures. A Hybrid III 6-year-old anthropomorphic test device (ATD), seated in identicalWC19-compliant pediatric manual wheelchairs, was used to measure head and neck response during a 25 km/h

(16mph), 11*g* rear impact. ATD responses were evaluated across two test scenarios: three sled tests conducted without headrests, and three with slightly modified commercial headrests .Head and neck injury outcomes measures included: linear head acceleration, head injury criteria (HIC) values, neck injury criteria (*Nij*) values, and combined rotational head velocity and acceleration. Neck and head injury outcome measures improved by 34–70% in sled tests conducted with headrests compared to tests without headrests. Headrest use reduced *Nij* values and the likelihood of concussion from values above established injury thresholds to values below injury thresholds. Injury measure outcome reductions suggest lower head and neck injury risks for wheelchair-seated children using wheelchair-mounted headrests as compared to non headrest users in rear impact. Use of relative comparisons across two test scenarios served to minimize effects of ATD biofidelity limitations.

2.6.10 WC19: A Wheelchair Transportation Safety Standard - Experience to Date and Future Direction (Manary et al., 2010)

ANSI/RESNA WC19 is a voluntary standard that specifies design and performance requirements for wheelchairs that are suitable for use as seats in motor vehicles. The guiding principles for the standard originate from automotive crash-protection principles that are effective in reducing occupant injuries and fatalities. In addition to frontal-impact testing of wheelchairs, the standard includes tests for secure point accessibility, tie down strap clear paths, lateral stability, and accommodation of vehicle anchored belt restraints. Results from testing wheelchairs to WC19 reveal that the most common wheelchair problems include: a lack of structural integrity during frontal impact loading; sharp rigid edges; and wheelchair structures that interfere with achieving proper positioning of vehicle anchored belt restraints. Data from 8 years of experience with WC19 indicate where changes are needed to further improve transportation safety for wheelchair seated travelers. These include expanding WC19 to include wheelchairs for smaller children who require a five point harness restraint and requiring wheelchairs to achieve a minimal rating for the ease of achieving proper positioning of vehicle anchored belt restraints.

Table 2.2: Summary of Previous Research

AUTHOR	TITLE	METHOD	RESULTS & DISCUSSION
Burton M, Subic A, Mazur M, Leary M, 2010	**Systematic Design Customization of Sport Wheelchairs Using the Taguchi Method**	**Taguchi Method**	The paper proposes a novel approach to determining optimal design parameters for a specific athlete based on the Taguchi method. This approach is superior to traditional testing as it enables efficient characterisation of the effect of design variables on wheelchair performance, including error checking to quantify the effect of noise variables such as muscle fatigue.
Walter Franco, Riccardo Oderio, 2010	**Wheelchair, a Motorized Wheelchair with Stair Climbing Ability**	**Algebraic Method**	When the wheelchair faces an obstacle such as a step or a stair, it can passively change locomotion mode, from rolling on wheels to walking on rotating legs, thanks to its self-adaptive locomotion units. The function of the locomotion unit is described and modelled using kinematic equations. The locomotion unit requires only one motor, for both wheeled and legged locomotion. Tests on a scale prototype were conducted in order to evaluate the effectiveness of this locomotion.
A.H. MacPhee, 2001	**The Effect of Knee-Flexion Angle on Wheelchair Turning**		The combined moment of inertia of the wheelchair and system was modelled. We found that, in comparison with full extension, fully flexing the knees increased angular velocity by 40% and were perceived to be 66% easier by subjects. Overall length decreased by 39%, COM moved rearward 38%, rolling and turning resistance decreased by 21% and 17% respectively, rear-wheel traction increased by 12% and moment of inertia decreased by 42%. All empirically tested parameters were statistically significant (*p*_0.007). We conclude that the knee-flexion angle has a significant effect on wheelchair turning. The implications of these findings for wheelchair design and prescription will need to be validated on actual wheelchair users and for smaller increments in knee-flexion range.
Paquet and Feathers, 2003	**An Anthropometric Study of Manual and Powered Wheelchair Users**	**ANOVA**	Measurements were made on 121 adult manual and powered wheelchair users with an electromechanical probe that registered the three-dimensional locations of 36 body and wheelchair landmarks. Thirty-one body and wheelchair dimensions (e.g., heights, breadths, depths) were calculated from the three-dimensional coordinate data. Tests of distributional normality showed that less than 1/3 of the dimensions were not normally distributed. ANOVA showed significant differences between powered and manual chair users, and women and men for only some of the anthropometric dimensions.

Table 2.2: Summary of Previous Research (*continued*)

AUTHOR	TITLE	METHOD	RESULTS & DISCUSSION
Manary et al., 2010	**WC19: A Wheelchair Transportation Safety Standard - Experience to Date and Future Direction**	**WC19**	Results from testing wheelchairs to WC19 reveal that the most common wheelchair problems include: a lack of structural integrity during frontal impact loading; sharp rigid edges; and wheelchair structures that interfere with achieving proper positioning of vehicle anchored belt restraints. Data from 8 years of experience with WC19 indicate where changes are needed to further improve transportation safety for wheelchair seated travelers. These include expanding WC19 to include wheelchairs for smaller children who require a five point harness restraint and requiring wheelchairs to achieve a minimal rating for the ease of achieving proper positioning of vehicle anchored belt restraints.
Susan I. Fuhrmana,, Patricia E. Karga, Gina E. Bertocci, 2008	**Effect of Wheelchair Headrest Use On Pediatric Head and Neck Injury Risk Outcomes During Rear Impact**	**Sled Tests**	Neck and head injury outcome measures improved by 34–70% in sled tests conducted with headrests compared to tests without headrests. Headrest use reduced neck injury values and the likelihood of concussion from values above established injury thresholds to values below injury thresholds. Injury measure outcome reductions suggest lower head and neck injury risks for wheelchair-seated children using wheelchair-mounted headrests as compared to non headrest users in rear impact.
Rentschler (2002)	**Evaluation of the wheelchair standards**		The results from this study provide an in depth look at the performance, safety, and general characteristics of the five different types of EPWs tested. The information gleaned from this study shows how similar looking and comparatively priced EPWs can perform quite differently. They depend on their wheelchair to function safely and reliably at all times to provide a source of independence not otherwise available. Currently, wheelchair standards are the best source of information to determine exactly how an EPW will perform and what its limitations are. Unfortunately, the results of EPW testing are not always readily available and consumers and even clinicians depend mainly on experience and word of mouth to select the best wheelchair for a given situation. This study demonstrates that the information gathered from the standards testing is essential when attempting to compare different wheelchair makes and models.

Table 2.2: Summary of Previous Research (*continued*)

AUTHOR	TITLE	METHOD	RESULTS & DISCUSSION
L.H.V. Van Der Woude, H.E.J. Veeger, A.J. Dallmeijer, T.W.J. Janssen, L.A. Rozendaal, 2001	**Biomechanics and Physiology in Active Manual Wheelchair Propulsion**	**Biomechanics Research**	Apart from the propulsion technique the focus of biomechanics research of manual wheelchair propulsion is mainly towards injury mechanisms, especially phenomena of overuse to the upper extremity. Obviously, the vehicle mechanics of wheelchairs must be included within this biological framework. Scientific research is progressing, but is still hampered by methodological limitations, such as the heterogeneity and small numbers of the population at study as well as the inconsistency of employed technologies and methodologies. There is a need for consensus regarding methodology and research strategy, and a strong need for collaboration to improve the homogeneity and size of subject groups and thus the power of the experimental results. Thus a sufficiently strong knowledge database will emerge, leading to an evidence-base of performance enhancing factors and the understanding of the risks of wheelchair sports and long-term wheelchair use. In the light of the current biomechanical and physiological knowledge of manual wheelchair propulsion there seems to be a need for the stimulation of other than hand rim propelled manual wheelchairs.
John W. Kozey, 2003	**Determination of the Normal and Maximum Reach Measures of Adult Wheelchair Users**	**Multiple Linear Regression**	The 3-D Cartesian coordinate values were converted to cylindrical coordinates to model the reach surfaces. Using multiple linear regression of the reach surface separate linear equations were derived to describe the 5th, 50th and 95th percentile reach boundaries for males and females, separately. The overall root mean square error of the reach equations across the males and females ranged from 4 to 17mm for the NRA and 12–39mm for the MRE.
Gina Bertocci, 2001	**Wheelchairs Used As Motor Vehicle Seats: Seat Loading In Frontal Impact Sled Testing**	**Sled Tests**	To provide manufacturers with crashworthy design guidance, our study measured wheelchair seat loading during 20g/48kph frontal impact sled tests with a 50th percentile male test dummy. Loading conditions were assessed using two different rear securement point positions. Results of four sled impact tests revealed downward loads ranging from 17 019 to 18 682 N, depending upon rear securement point configuration. Maximum fore/aft shear loads ranged from 4424 to 6717 N across the tests.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

In this chapter, the discussion of the methodology is provides to conduct the project from starting until it is done completely. Besides that, a proper methodology has been planned to make sure the goals and objectives of this project can be achieve successfully. There are some categories that need to be considered in conducting this project which are research review, survey questionnaire, sketching, modeling and analysis process.

The first method is selecting the suitable product to use in this project that is manual wheelchair. Then, do research about existing manual wheelchair, include of the operational function, advantages and disadvantages, also the problems of this wheelchair. Next, appropriate variable features which can be changed by the user through conducting from a research survey to collect necessary data to be included in the wheelchair. After that, come out with 3 designs of wheelchair and sketch them by hand. Then, draw the wheelchair design using SolidWorks software. Next, analyze the strength of the redesign drawing wheelchair using ALGOR software. Lastly, calculated the safety factor and selected the best design in term of human factor engineering and material selection.

3.2 OVERVIEW OF METHODOLOGY

This project begins with meeting the supervisor to discuss about the best title to use for final year project (FYP). Weekly appointment with supervisor was fixed to make sure that the progress of project progress running smoothly according to the scheduling work and planning project progress. Then, after some discussion with supervisor, the project title is decided and given title is “Design and Analysis of Wheelchair in Term of Daily Usage”. According to the title, understanding about design and knowledge about wheelchair is very important. The journals and references books were searching to get the information and most of information was taken from science direct data, website and design and processes books.

After doing some revision from journal and references books, the subtopic of every chapter is decided. Then, the planning of progress gets started with literature review. It is about gathering the information from various sources such as articles, journal, references book, preliminary thesis and others that related to this project title. Then, do the survey questionnaire. These questionnaires are distributed to the handicapped people in some places such as hospitals, campus, and in public places. This questionnaire also distributed to the guardian and to the people whose are experience using the wheelchair. After finish distributes the questionnaires, these forms are then quoted after they finished answering. The analysis of questionnaire must be done with analyzing the entire question and the results are taken.

Next, the sketching of conceptual design takes place. Based on the results from the survey questionnaires, three sketches are done. The suitable concept of design is selected after doing several sketching. Then, this conceptual design can be converting to the modeling drawing using SolidWork software. After do sketching, this project proceeds with developing the wheelchair model using SolidWorks software. This software provides the best and easy way to make the wheelchair model. The model becomes more accurate in 3D modeling. Wheelchair model must be save in IGES format to make sure it can be used in ALGOR software to perform the nodal analysis.

Finally, ALGOR software was used to perform analysis of finite element. In this software, the stress distribution effects are analyzed on critical parts of the wheelchair. After gain the data and analyzed, do the conclusion is made if data is correct or re-do the analysis. Conclusions are made directly from the gained data.

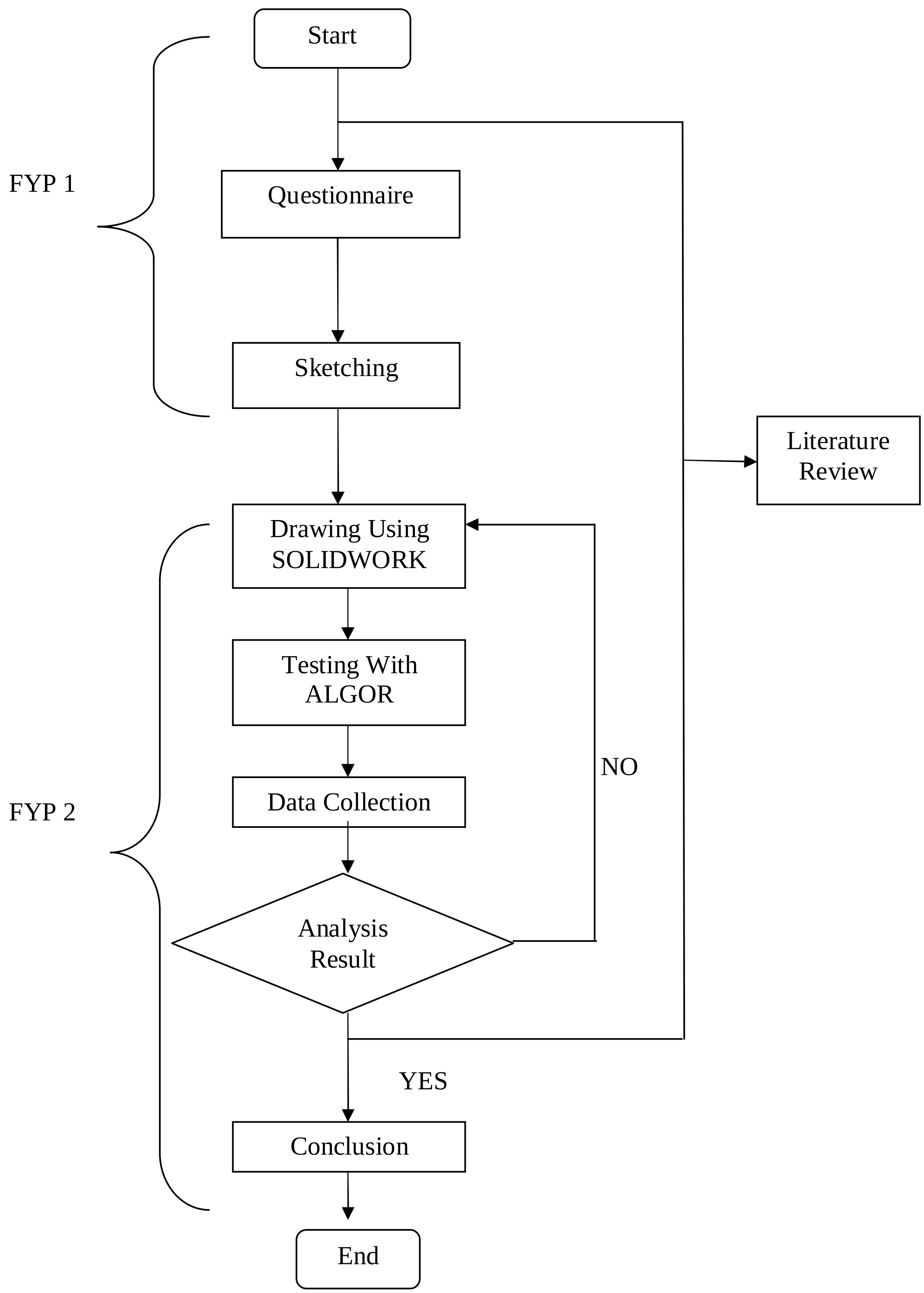

Figure 3.1: Flow Chart for Final Year Project

3.3 DRAWING OF PRODUCT (SOLIDWORKS SOFTWARE)

Solidworks is a 3-D modeling tool. SolidWorks is easy to learn, easy to use, and easy to navigate. SolidWorks Simulation allows simulating how designs will perform in the real world without having to build costly prototypes and helping to reduce costs and time to market. Unlike other 3-D modeling tools, Solidworks is not fully three dimensional. In Solidworks, one draws in a plane and then extrudes solids from the plane. Planes are used to obtain position in three dimensional spaces. It is possible to draw in three dimensional space using Solidworks, but is very difficult. Therefore the best method of creating three dimensional objects is using planes.

Figure 3.2: SolidWorks software

3.4 DEVELOP WHEELCHAIR MODEL

After done doing hand sketching, developed the wheelchair model by using SolidWorks software. SolidWorks is common design software that provides easier way to make a 3D design with an accurate measurement. In SolidWorks, the parts can be design separately and then assembled them together. The critical parts can be saving in IGES format that can be used in ALGOR software to perform the stress analysis using Finite Element Analysis (FEA).

3.5 FINITE ELEMENT ANALYSIS (ALGOR)

Finite element analysis (FEA) is a software which basically including the discipline of mathematics, physics, and engineering and computer science. The method has wide application and enjoys extensive utilization in the structural, thermal and fluid analysis areas. The main advantages of FEA are numerous and important. A new design concept may be modeled to determine its real world behavior under various load environments, and may therefore be refined prior to the creation of drawings, when any changes cannot involve any cost. Once a detailed CAD model has been developed, FEA can analyze the design in detail, saving time and money by reducing the number of prototypes required. Beside, FEA can be performed on increasingly affordable computer workstations and personal computers, and professional assistance is available.

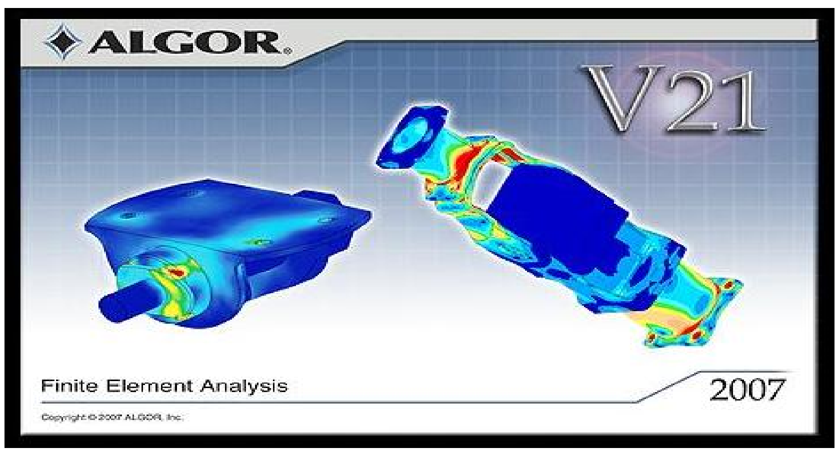

Figure 3.3: Finite element analysis (ALGOR)

3.5.1 Mesh Setting

The mesh setting that used in this analysis is only 50%, best setting that gets from the operating computer. The finer mesh size the better result is come out. But the finer mesh size needs a high performance computer to mesh the model.

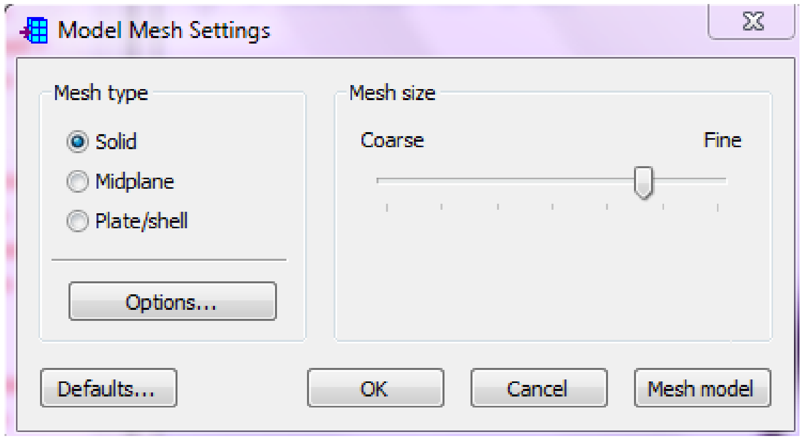

Figure 3.4: Model mesh settings

3.6 MATERIAL SELECTION

Material is the most important things that must be considered in designing the part of wheelchair. For material selection, the performance and cost indices must be considered to make thing cheaply, light weight, and increase safety. The best performance of the material very important because it determines how strong the body part can be to endure the stress when the force was apply and its must be long lasting units. The survival of many products depends on how the designer adjusts the maximum stresses in a component to be less than the component's strength at specific locations of interest. The designer must allow the maximum stress to be less than the strength by a sufficient margin so that the despite the uncertainties, failure are rare (Richard G. Budynas and J. Keith Nisbett. Three types of material were chosen for this body part which is Steel ASTM A36, Aluminium T6 and E-GlassFiber.

3.6.1 Steel ASTM A36

The Steel ASTM A36 has a density of 0.28 lbm/in³ is 7.8 g/cm³. Steel ASTM A36 almost shape in plates, bars, and with thickness of less than 8 inch or 200 mm has a minimum yield strength of 36,000 psi (250 MPa). The Ultimate Tensile Strength (UTS) of 58000 – 80000 psi (400–550 MPa). The plates thicker than 8 in have a 32,000 psi (220 MPa) yield strength and the same of Ultimate Tensile Strength (UTS). The Steel

ASTM A36 is a standard carbon steel then it’s also without advanced alloying (Smith and Hashemi, 2006). A36 steel has an elongation rating of 20 percent, meaning that when stress is applied it will stretch an additional 20 percent of its size before it breaks. This is more than twice the ductility of other types of steel. As a result, it bends much easier than other varieties, such as 1018 mild steel. This makes it useful for sheets or bars that require angles.

3.6.2 Aluminium T6

T6 temper 6061 has an ultimate tensile strength of at least 42,000 psi (300 MPa) and yield strength of at least 35,000 psi (241 MPa).In thicknesses of 0.250 inch (6.35 mm) or less, it has elongation of 8% or more; in thicker sections, it has elongation of 10%. T651 temper has similar mechanical properties. The typical value for thermal conductivity for 6061-T6 at 80°C is around 152 W/m K. The actual value of fatigue limit for an application can be dramatically affected by the conventional de-rating factors of loading, gradient, and surface finish. Aluminium is one of the lightest available commercial metals with a density approximately one third that of steel or copper. Aluminium has excellent resistance to corrosion due to the thin layer of aluminium oxide that forms on the surface of aluminium when it is exposed to air. In many applications, aluminium can be left in the mill finished condition. Whereas steel becomes brittle at low temperatures, aluminium increases in tensile strength and retains excellent toughness. Besides that, aluminium can be easily fabricated into various forms such as foil, sheets, geometric shapes, rod, tube and wire.

3.6.3 E-Glass Fiber

E-glass is electrical grade with low alkali content. It manifests better electrical insulation and strongly resists attack by water. It has nominal composition of SiO_2 54wt%, Al_2O_3 14wt%, CaO+MgO 22wt%, B_2O_3 10wt% and Na_2O+K_2O less then 2wt%. Some other materials may also be present at impurity levels.More than 50% of the glass fibers used for reinforcement is E-glass. E-Glass Fiber has an ultimate tensile strenght of 1500 MPa. E-Glass Fiber has many advantages such as low modulus, low cost, high production rates, high strength and high stiffness. Self abrasiveness if not treated appropriately leading to reduced strength. It also relatively low fatigue resistance. Besides that, it higher density compared to carbon fibres and organic fibres.

3.7 CONCLUSION

The SolidWorks software is used to make the drawing and Finite Element Analysis (ALGOR) is to analyze the critical part of the wheel chair. After that, make the evaluation of the design and select the suitable design to be optimized. Then, the material selection of the critical part wheelchair on the product is chosen. Lastly, result and discussion for the best design of critical part can be identified and discussed in the next chapter.

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CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

In this chapter, the results of the research data are presented. Profile of respondents is the first analysis had been presented to determine the demographic and background of the respondent. This presentation was forwarded to the reliability analysis to assess whether the value obtained in this research can be trusted or not. The study was conducted on 50 respondents from the public.

4.2 ANALYSIS OF QUESTIONNAIRE

The questionnaire was distributed to the public's including in the hospitals, shopping centers, campus, and in public places for three weeks. Every copies of the questionnaire were distributed to University Malaysia Pahang (UMP) students and handicap people in Pekan, Pahang for gathering information about product function for handicap. After three weeks, there are 50 respondents was responded to the survey questionnaire. For each question, the interviewee had to choose the best answer among the given answer.

In these questionnaires, there are 12 questions include general info about wheelchair, ergonomic issue and functional questions. Besides that, in this questionnaire also have 4 subjective questions for handicap people to give their opinion, in order to get some information about the handicap life. Those questions are about the most wanted tools of wheelchair, what the features of wheelchair that they need, and the important handicap to do the daily life activities.

4.2.1 Analyze Profile of the Respondents

In this study, men are the main respondents had been surveyed. Which contribute as much as 60% of respondents indicated that using a wheelchair and has a close relationship with wheelchair users while 40% are female. Figure 4.1 shows the distribution of gender involves in answering questionnaire.

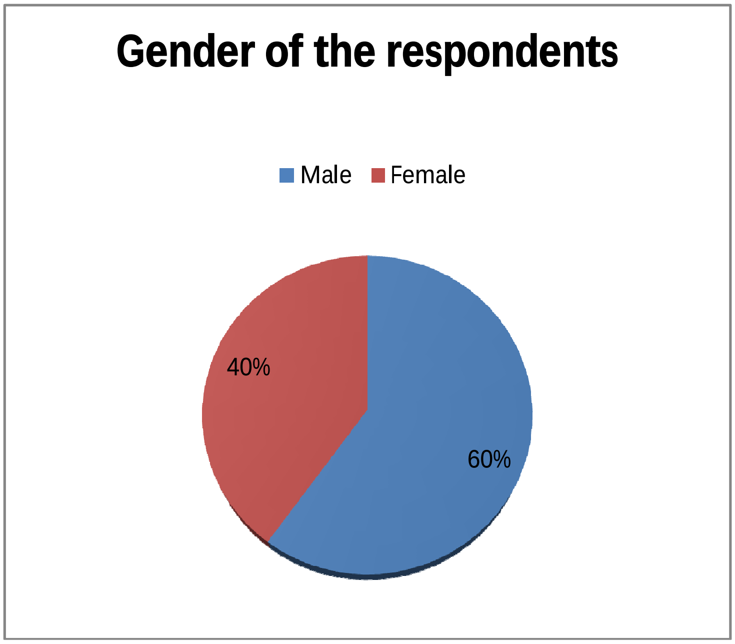

Figure 4.1: Gender of the respondents

Looking at the race, Malays had the highest percentage of 60%, Indian 23%, Chinese 17% and others 0%. This shows that more Malay people use wheelchairs or are related to wheelchair users. Figure 4.2 shows the distribution of race involves in answering questionnaire.

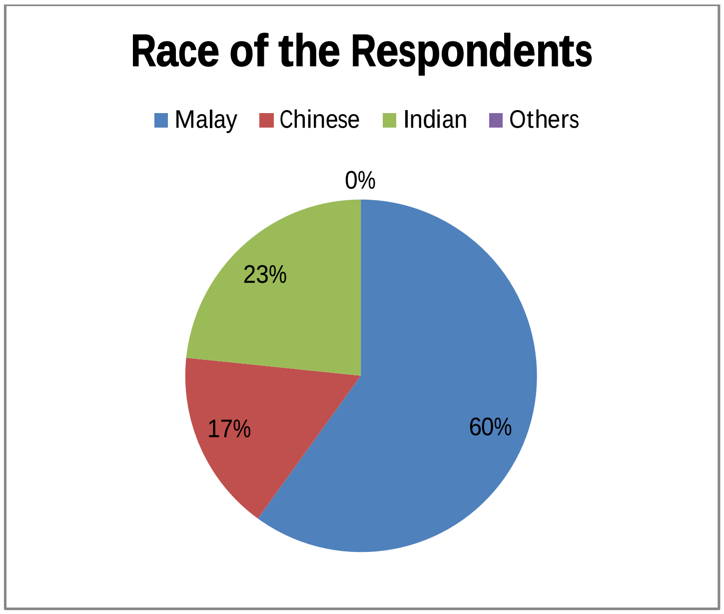

Figure 4.2: Race of the respondents

Based on the survey, the age of respondents were distributed with the questionnaire form survey are between 20 to 50 years. These are composed of 22 respondents are women and 28 respondents are men. Respondents who were age between 20-29 years have 50% followed by age 30-39 years old with 27%, 40-49 years old with 13% and 50 years old and above with 10% only. Figure 4.3 shows the distribution of age involves in answering questionnaire.

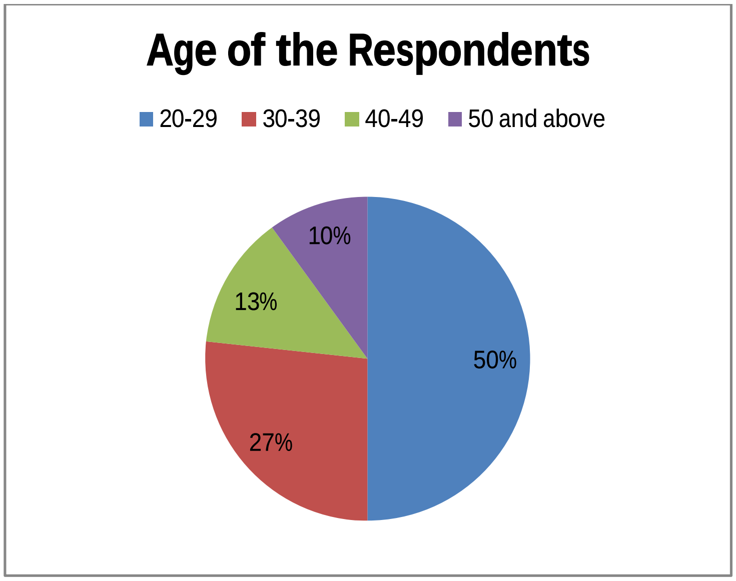

Figure 4.3: Age of the respondents

4.2.2 Analyze of the Wheelchair User

This survey was to determine how many users who use wheelchairs independently or used the guidance to help them using wheelchair. Results showed that only 37% are independently wheelchair users. While users that using guidance's help scored are 63%. Even though respondents did not have experience in using wheelchair themselves, they also must answer the survey because the study is general and to get various opinions. Figure 4.4 shows the distribution of wheelchair user involves in answering questionnaire.

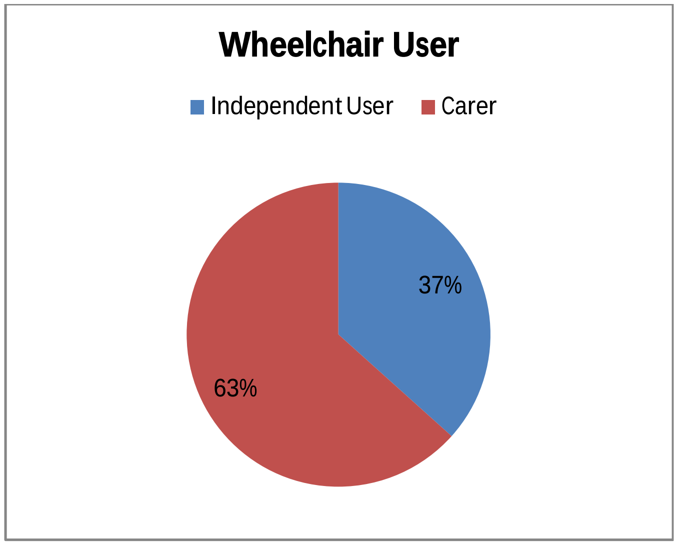

Figure 4.4: Wheelchair user

The results of the survey found that, overall wheelchair users are use 1-3 years with 34%. While the usage over 3 years scored are 33%. New user scored 10%, which are less percentage than 3-1 year user with 23%. Figure 4.5 shows the distribution of duration wheelchair users involves in answering questionnaire.

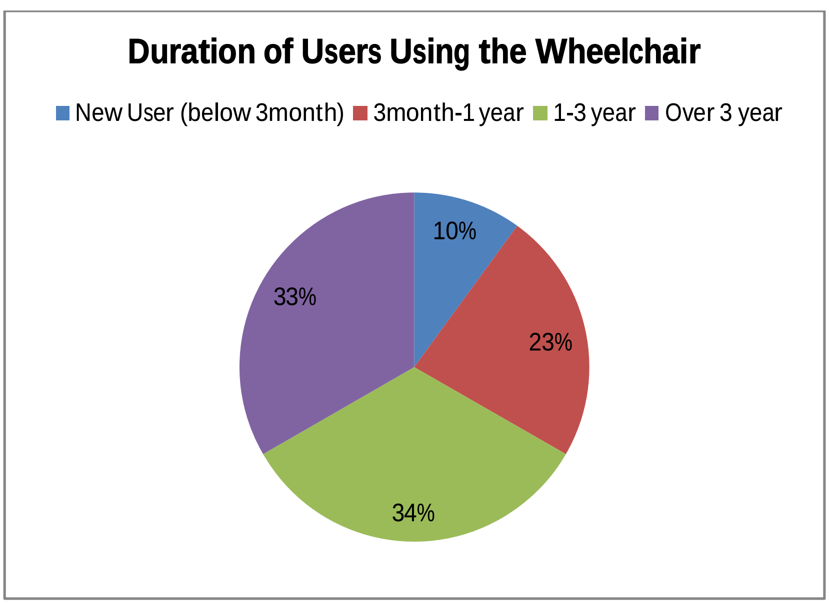

Figure 4.5: Duration of users using the wheelchair

4.2.3 Analyze of the Ergonomic Factor of the Wheelchair Type

For this survey, respondents were asked to state the type of wheelchair used. The survey had found about 77% of respondent using the type of manual wheelchair. While 10% are using the type of electric powered wheelchair. For the number of transport wheelchair type users are 10% and the remaining of users using the other types of wheelchair are 5%. Figure 4.6 shows the distribution of the type of wheelchair used involves in answering questionnaire.

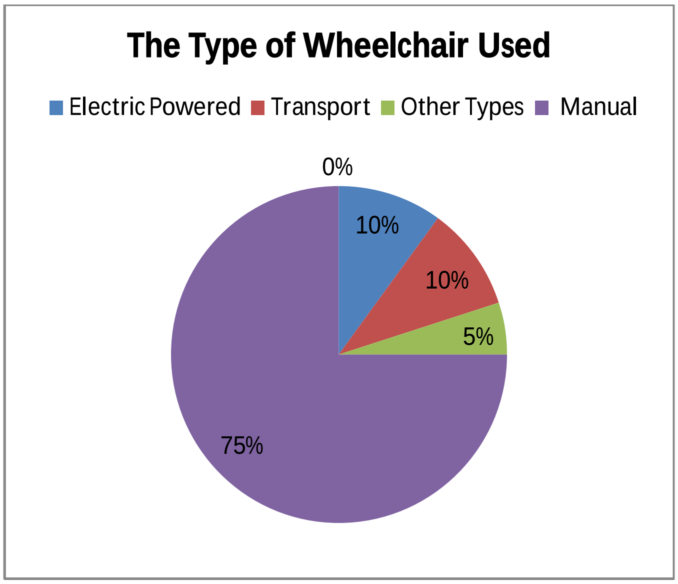

Figure 4.6: The type of wheelchair used

For this survey, about 55% of respondents agreed to say that the weakness on the wheelchair that use today is comfortable issue. While as about 32% had said the wheelchair was difficult because of the size used by different users. The rest of respondents had said they felt less safe when using a wheelchair with 13%. Figure 4.7 shows the distribution of the weaknesses on the existing wheelchair involves in answering questionnaire.

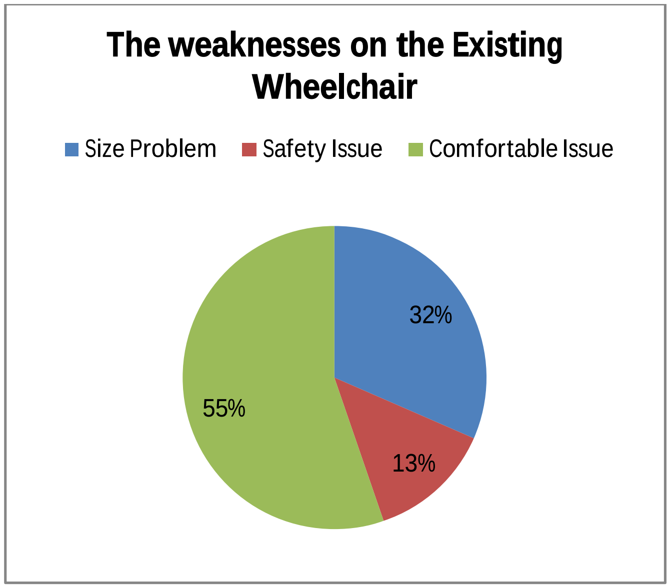

Figure 4.7: The weaknesses on the existing wheelchair

As about 25% of respondents said that the place to hold arm is the most part which make the patients uncomfortable. Also about 20% said that the back upholstery is the most uncomfortable. While, the seat upholstery is about 18%, followed by caster with 13%, footplate with 11%, handgrip with 8%, and wheels and hand rim is about 5%. Figure 4.8 shows the distribution of the wheelchair part that easily damage involves in answering questionnaire.

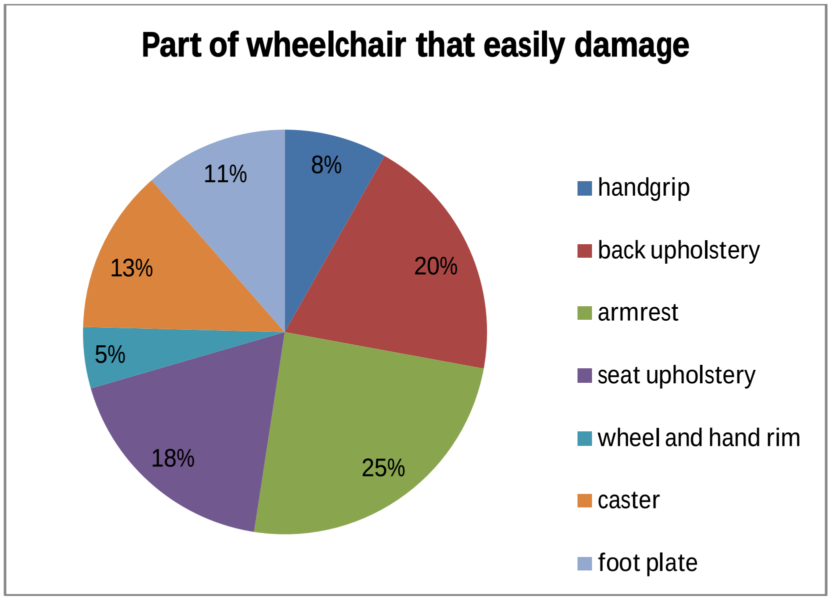

Figure 4.8: Part of the wheelchair that easily damage

The results of the survey found that, the part that needs to be modified most is seat upholstery and back upholstery are about 35%. Armrest is about 16% followed by footplate with 14%. Figure 4.9 distribution of the wheelchair part not comfortable involves in answering questionnaire.

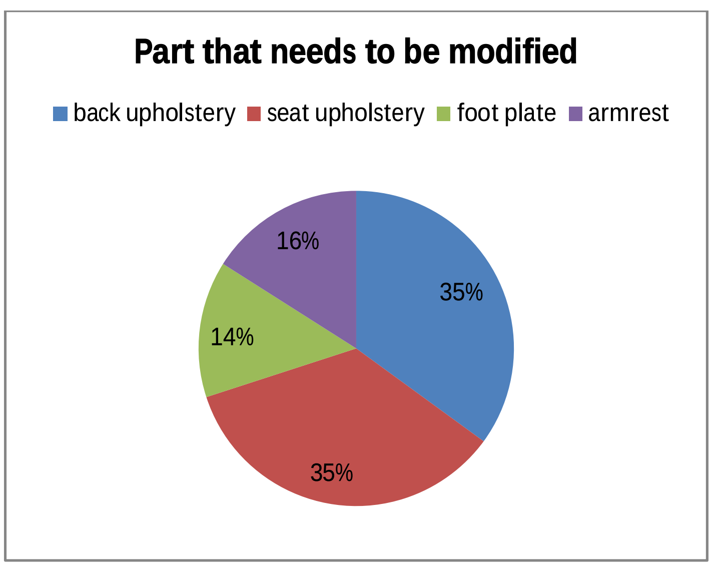

Figure 4.9: Part of the wheelchair that needs to be modified

As about 50% of respondents said that the existing wheelchair is acceptable in meet their needs. And 37% of respondents said that condition of the wheelchair is very poor and the rest are about 13% said that it is good. Figure 4.10 shows how well the existing wheelchair meets their needs.

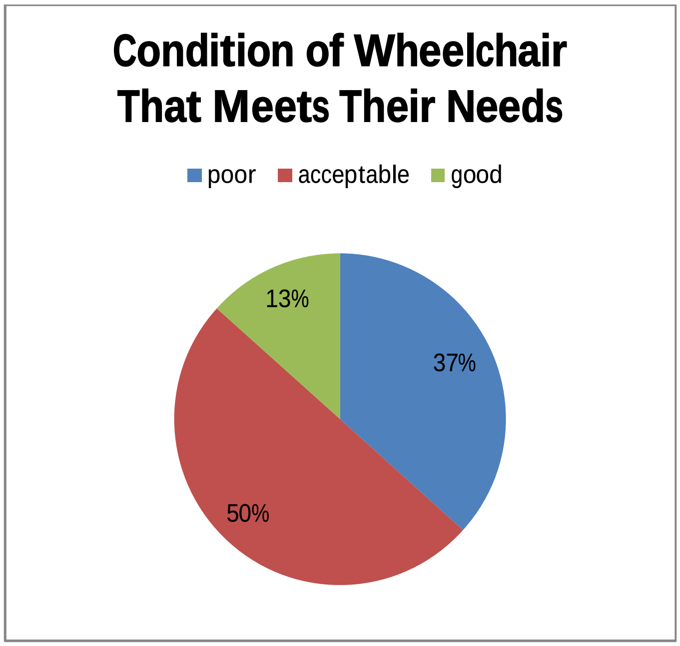

Figure 4.10: Condition of wheelchair that meets their needs

4.2.4 Conclusion from Questionnaire Analysis

Questionnaire analysis have been survey for 50 respondents due to several analysis consideration which are consists of analysis profile of respondents, analysis of the wheelchair user and analysis of the ergonomic factor of the wheelchair type. From the analysis of biography respondents, most of the respondents to my questionnaires are Malay and males in range of age are between 20-29 years old.

Analysis of the functional factor is asking about the experience from wheelchair users. It can be conclude that only 37% of respondents are the independent users, meanwhile the rest is using guidance to help them using wheelchair. The highest duration of users using the wheelchair is between 1 to 3 years, followed by user over 3 years. Majority of the respondents stated that common type of wheelchair used is manual wheelchair and only 5% of the respondents stated that the others types of wheelchair is rarely used such as sport wheelchair and lightweight wheelchair.

Analysis of the ergonomic factor is asking about the wheelchair users needs toward their comments on the existing wheelchair. According to the wheelchair users needs from the surveyed shows that the majority of them suggested the part of wheelchair need to make modification is on the seat upholstery and back upholstery because of the pain and discomfort on the spine and also at the armrest and footrest because this is the most part make the users feel uncomfortable. 55% of the respondents agreed to say that the weakness on the wheelchair that use today are the mostly in comfortable issue. While as about 32% had said that the wheelchair having size problems and difficult because of different users. Only 13% had said the wheelchair is not safe enough for them in doing daily activities.

4.3 CONCEPTUAL DESIGN WITH SKETCHING

The design criteria are based on the ease of maintenance, installation and ease of use. After go through the brainstorming session, few design was constructed with simple sketching.

4.3.1 Design 1

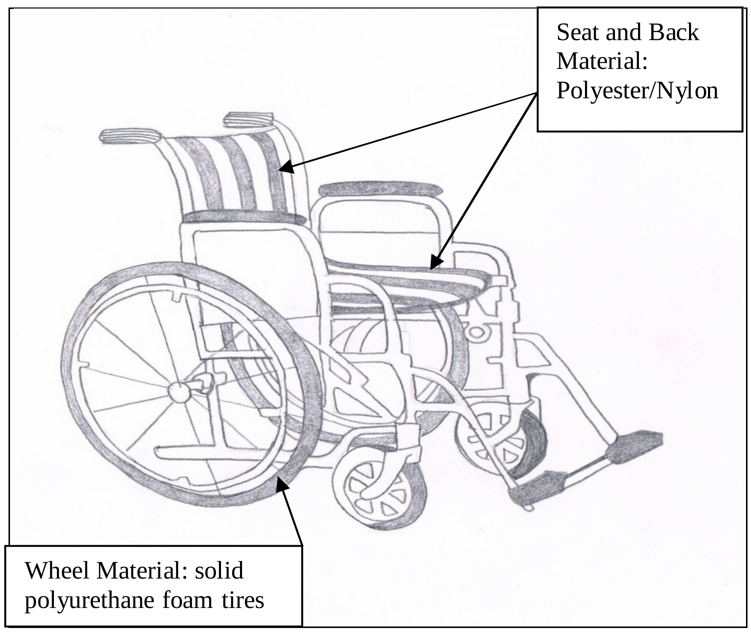

Figure 4.11: Wheelchair Design 1

Figure 4.11 shows the design 1 sketches. The operation functional is on comfortable and safer for user. This design is similar with design of manual wheelchair but certain parts in this design made to be adjustable. The armrest and footrest can be adjust manually to fit the user hands and foots. At the same time, adjustable armrest and footrest made the user feel more comfortable and reduce the feel of tired after using the wheelchair for a long period. Also, its can preventing from elbow and knee injuries occurred. Besides that, the seat upholstery and back upholstery is made from polyester cushion. This material is more comfortable and suitable for user to use it to do their daily activities. It is also provides the seat that able to be wiped clean or laundered easily for hygienic and aesthetic reasons. Finally, the disadvantages of this product are the type of wheelchair is the seat and back upholstery not designed to be adjusted.

4.3.2 Design 2

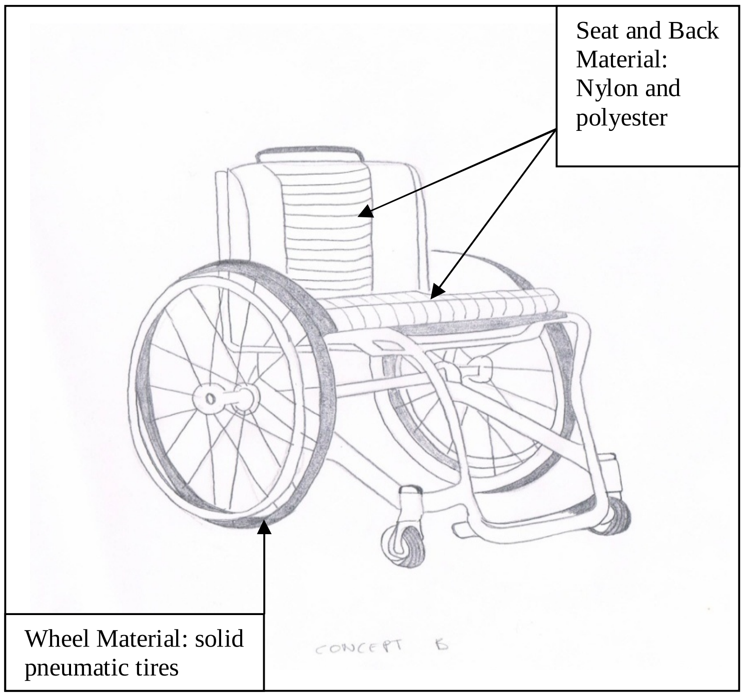

Figure 4.12: Wheelchair Design 2

Figure 4.12 shows the design 2 sketches. The operation functional is on comfortable issue and designed for handicap purpose. It is using the comfort seat and the luggage is placed on the side of wheel chair. Suggestion material for seating is using seat cushion nylon and polyester because these materials have a significant impact on cost and customer satisfaction. , allow for air circulation and provide user comfort, yet it also must be able to be wiped clean or laundered easily for hygienic and aesthetic reasons. Then, the disadvantages is about their weight of seat is so heavy because using the big and wide seat. Suggestion for wheel material is using solid pneumatic tire and caster material using solid rubber nylon tires because pneumatic tires provide great comfort to achieve the comfort level offered by pneumatic tires along with the reliability and durability offered by solid tires. Increase in durability will also provide economic relief to the users.

4.3.3 Design 3

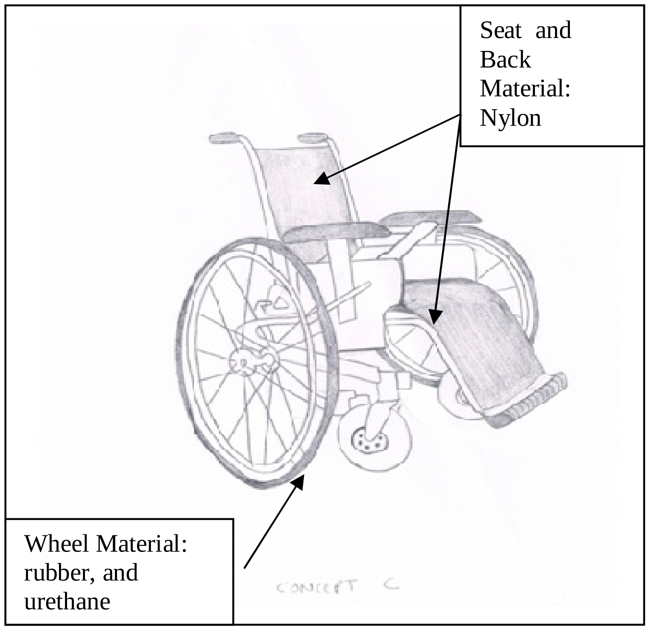

Figure 4.13: Wheelchair Design 3

Figure 4.13 shows the design 3 sketches. The operation functional is same like design 2, interested in comfortable usage for human. This design is more on comfortable usage for user in doing their daily life activities, such as go to school, go to works, sleeps and so on. Seat can be converted to bed which is it lie flat through the runner. The system is operated manually such common pneumatic adjustable height on an office chair. Suggestion material for seating is using seat cushion foam consists of nylon that has a significant impact on cost and customer satisfaction. Seating material must withstand daily use in varied weather and thus must be durable. Cushions can reduce shocks considerably Suggestion for wheel material is using rubber and urethane because these materials need for improved tire wear without compromising ride and traction. Tires must be functional on varied surfaces such as sand, rugs, snow, either smooth or rough surfaces and must be non-marking.

4.4 DESIGNED WITH SOLIDWORK SOFTWARE

The design criteria are based on the previous sketching and analyze of questionnaire. After go through the brainstorming session, few design was constructed with the 3D drawing in Solid Work software.

4.4.1 Design 1

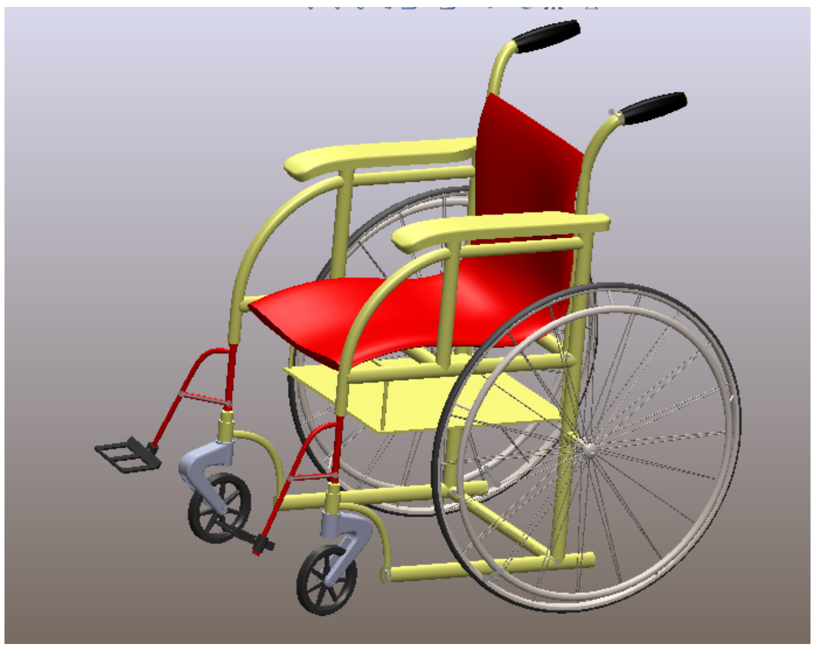

Figure 4.14: Design 1

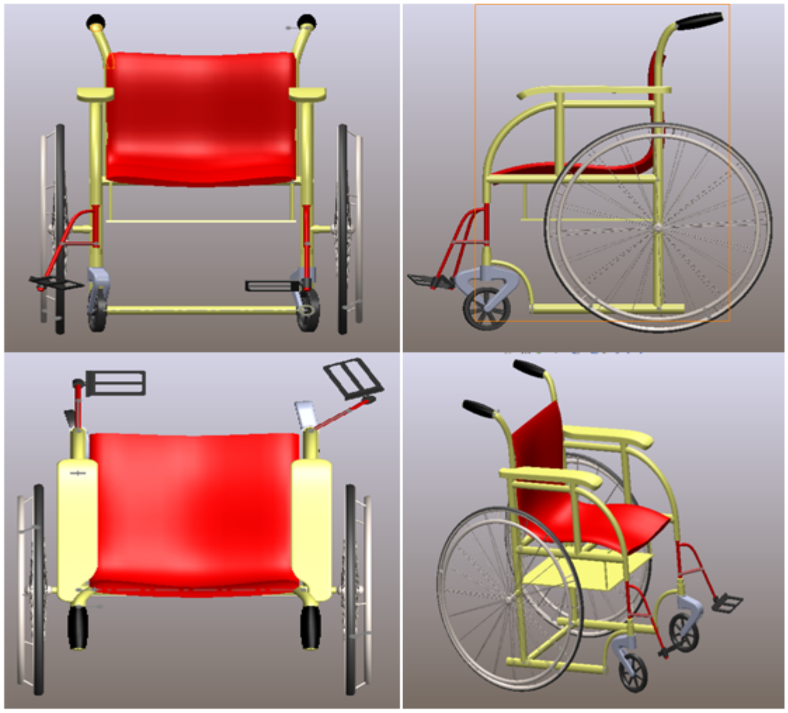

Figure 4.15: Design 1 split view

Figure 4.14 and figure 4.15 shows design 1 picture that has been draw using SolidWork software. Basically, this design not have much different than original design but the body support for this design is modified with adding compartment under the seat to store users' items. Besides that, the footrest is modified so that it can be swivel depend on the user comfortability.

4.4.2 Design 2

Figure 4.16: Design 2

Figure 4.17: Design 2 split view

Figure 4.18: Design 2 (Modification)

Figure 4.16, figure 4.17 and figure 4.18 shows pictures of design 2 that has been draw using SolidWork software. The operation functional is occasionally interested in comfortable usage for human. It is using the comfort seat and larger size. The armrest is designed to be adjustable to fulfill the needs of handicap people and to meet their comfort.

4.4.3 Design 3

Figure 4.19: Design 3

Figure 4.20: Design 3 split view

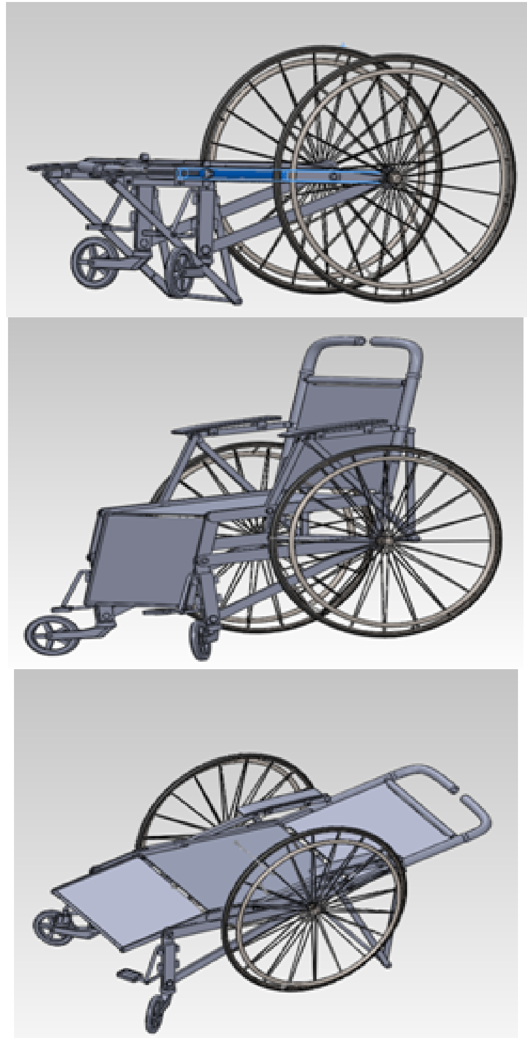

Figure 4.21: Design 3(Modification)

Figure 4.19, figure 4.20 and figure 4.21 shows pictures of design 3 that has been draw using SolidWork software. This design is more on ergonomic function features. The seat can be converted to bed that suitable for handicap people using it to rest after doing their daily activities. Besides that, the user also can lean while waiting in order to receive treatment. In addition, the adjustable back upholstery can avoid the back illness while using the wheelchair for long period. The operation functional is working principle and main structure the device is designed for handicap purpose properly.

4.5 SIMULATION USING ALGOR (FINITE ELEMENT ANALYSIS)

There are two critical parts consists of body support and wheel caster design model that were analyze on stress analysis to select the best design. For body support, every part has three designs to compare with three different materials on stress analysis. For caster, two different materials is use for stress analysis on same design of caster. This analysis was performed by three designs to study induced stresses under impact loading by implementing finite element analysis in ALGOR software based on a static stress with linear finite element models.

4.5.1 Stress distribution for Body Support (Load 1500N)

A finite element (FE) linear analysis of the seating support model was performed in ALGOR software to study the stress distribution effects on the seating support under vertically applied load acting on the seating posture and horizontally applied load acting on the backrest of the seating support. Three different materials were utilized as the seating support material during this analysis. The force are applied to the plate are the total weight of average human being are 1500N on seating support. The total mass of the wheelchair cannot exceed 1800N which is average adult wheelchair with an occupant weight limit of 735N or more and average pediatric wheelchair with a maximum occupant weight below 735N (Schneider et al., 2009).

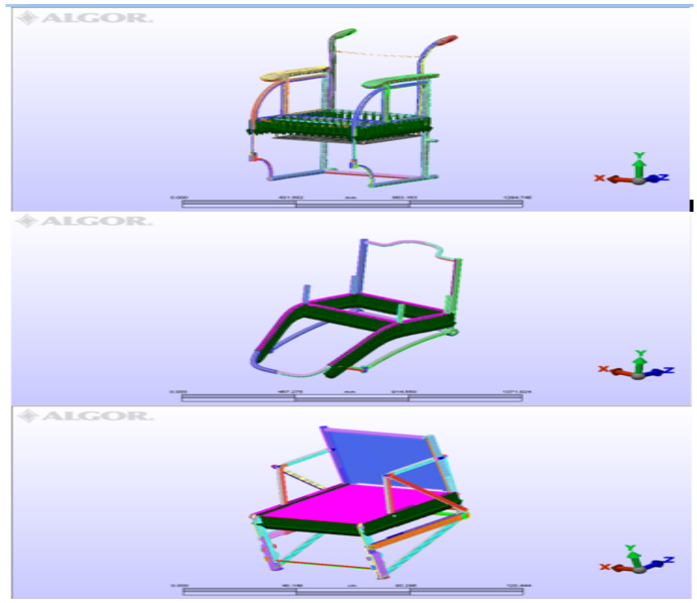

Figure 4.22: Testing on seating support

4.5.2 Analysis of Body Support

Next, obtain the suitable material to develop critical part of wheelchair. From that analysis, the Aluminium T6 have lower value of maximum value for von misses stress compare with Steel ASTM A36 and E-Glass Fiber it's depending by design 1, design 2 and design 3.

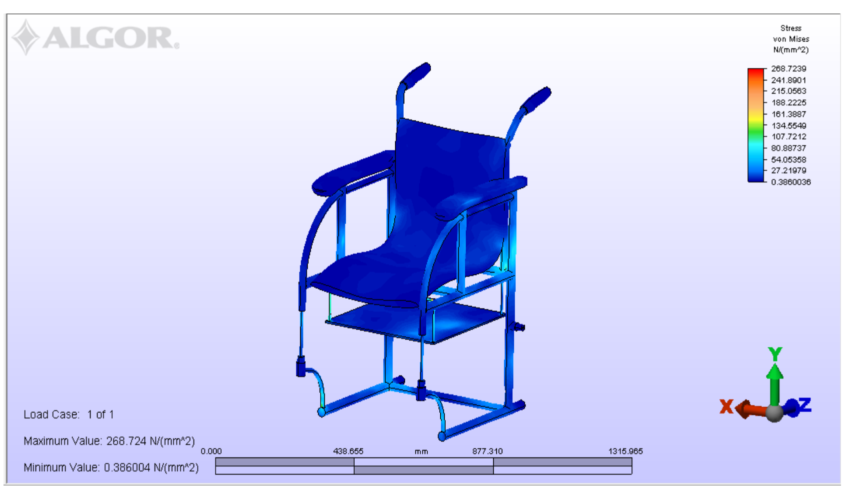

Figure 4.23: Analysis on seating support for Design 1

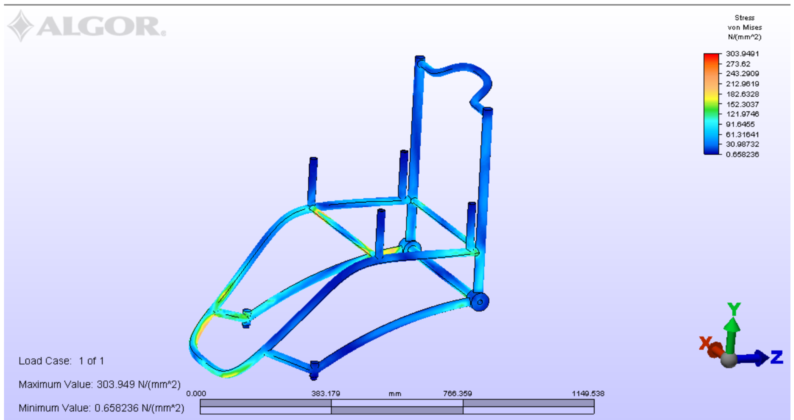

Figure 4.24: Analysis on seating support for Design 2

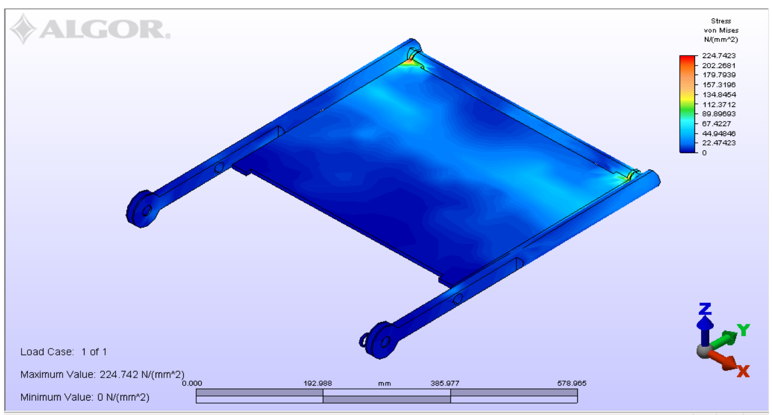

Figure 4.25: Analysis on seating support for Design 3

The finite element analysis in part 1 is concentrate on body support for Design 1, Design 2 and Design 3 using three difference materials which are Steel ASTM A36, Aluminium T6 and E-Glass Fiber. It is observed that the maximum value of von misses stress are differences between each design and material used (Table 4.1).

Table 4.1: Comparison between three designs depends on different material of body support

MATERIAL	DESIGN 1	DESIGN 2	DESIGN 3
Aluminium T6	202.856 N/mm^2	211.089 N/mm^2	153.8202 N/mm^2
Steel Ast A36	268.724 N/mm^2	303.9491 N/mm^2	224.7423 N/mm^2
E-Glass Fiber	858.35 N/mm^2	615.5144 N/mm^2	541.2099N/mm^2

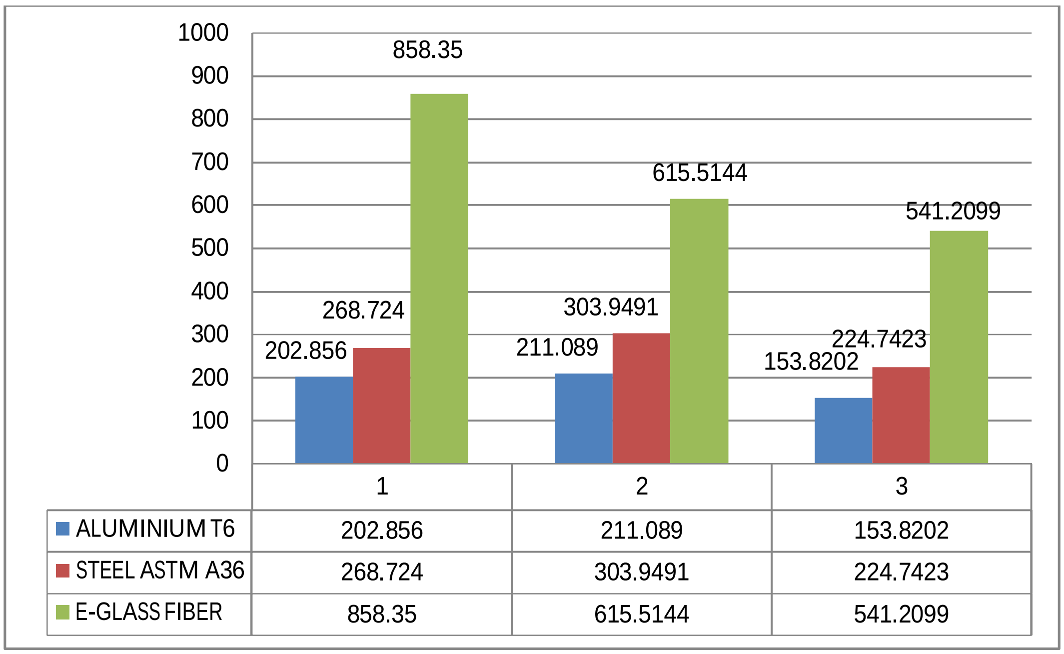

Figure 4.26: Column chart of comparison between three designs depends on different material

4.5.3 Factor of Safety for Body Support

Factor of safety, also known as safety factor, is a term describing the structural capacity of a system beyond the expected loads or actual loads. Essentially, how much stronger the system is than it usually needs to be for an intended load. Safety factors are often calculated using detailed analysis because comprehensive testing is impractical on design to carry load must be determined to a reasonable accuracy. The value of Von Mises Stress of each design and material are used to calculate the safety factor of each design. Ultimate tensile strength (UTS), often shortened to tensile strength (TS) or ultimate strength, is the maximum stress that a material can withstand while being stretched or pulled before necking, which is when the specimen's cross-section starts to significantly contract. Each material has different value of Ultimate Tensile Strength. Steel ASTM A36 has ultimate tensile strength of 58,000–80,000 psi (400–550MPa), Aluminium T6 temper 6061 has an ultimate tensile strength of at least 42,000 psi (300 MPa) and E-Glass Fiber has an ultimate tensile strenght of 1500 MPa. The safety factor for design 1, 2 and 3 was calculated and it is observed that factor of safety is differences between each design and material used (Table 4.2).

4.5.3.1 Calculation of Safety Factor

The formula to calculate safety factor is :

Factor of Safety (FOS) = $\boldsymbol{\sigma}_{\text{limit or UTS}}$ / $\boldsymbol{\sigma}_{\text{vonMises}}$

Calculation for design 1:

i. Steel ASTM A36 = 550/303.9491 = 1.80
ii. Aluminium T6 = 300/211.089 = 1.42
iii. E-Glass Fiber = 1500/858.35 = 1.74

Calculation for design 2:

i. Steel ASTM A36 = 550/268.74 = 2.04
ii. Aluminium T6 = 300/202.856 = 1.47
iii. E-Glass Fiber = 1500/615.5144 = 2.43

Calculation for design 3:

i. Steel ASTM A36 = 550/224.7423 = 2.44
ii. Aluminium T6 = 300/153.8202 = 1.95
iii. E-Glass Fiber = 1500/858.35= 2.77

Table 4.2: Comparison safety factor depends on different material of body support

MATERIAL	DESIGN 1	DESIGN 2	DESIGN 3
Aluminium T6	1.42	1.47	1.95
Steel Astm A36	1.80	2.04	2.44
E-Glass Fiber	1.74	2.43	2.77

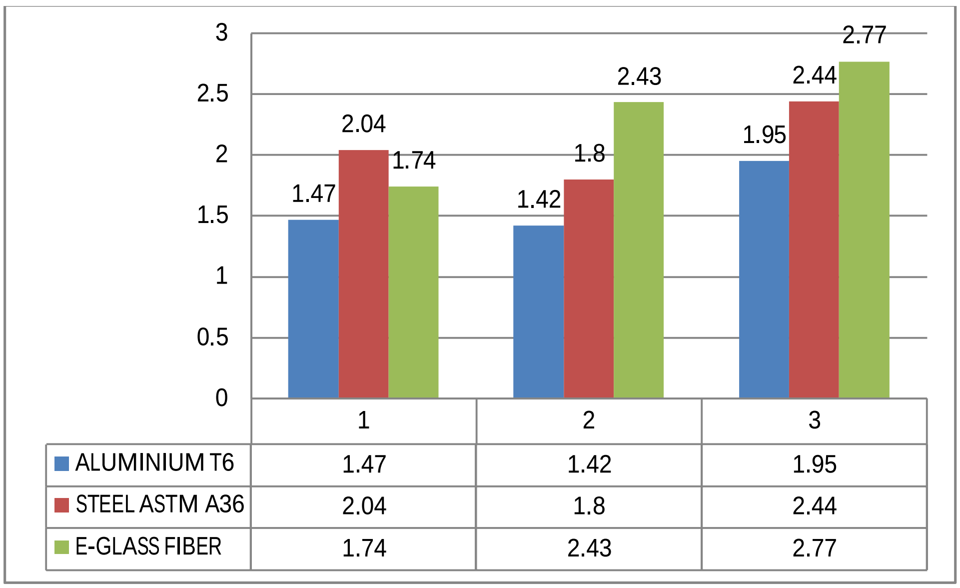

Figure 4.27: Column chart of safety factor between three designs depends on different materials

4.5.4 Stress distribution for Wheel Caster (Load 1800N)

A finite element (FE) linear analysis of the caster model (Design A) shown in Figure 4.21 was performed in ALGOR software to study the stress distribution effects of the wheel under a vertically applied load acting through the caster hub. Two different materials were utilized as the caster material during this analysis.

Additionally, the model was assumed to have no geometric or material nonlinearities. A static force of 400 lbs (1800 N) (VanRoosmalen et al, 2003) at an angle of 55° to the horizontal (representing the line of caster force application in frontal impact) was applied to the area representing the bearings in the caster hub. The FE model was restrained in three ways to prevent rigid body motion. Axial movement of the model was prevented by constraining the inner surface of the hub in the axial direction. The outer surface of the tire was constrained cylindrically, to prevent the caster from rotating. Additionally, a contact patch between the tire and the ground was incorporated into the model to represent the tire contact area during normal operation and was constrained in all directions (fixed).

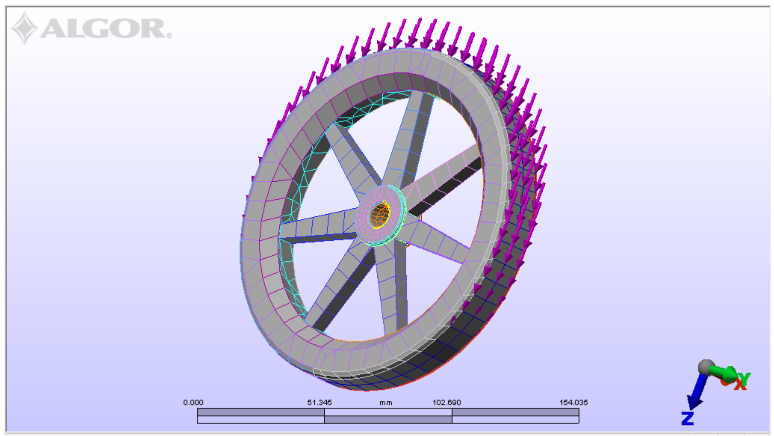

Figure 4.28: Loads and constraints as applied in ALGOR to Design 1

4.5.5 Analysis of Wheel Caster

After complete doing the finite element analysis in wheel caster, we obtain the suitable material to develop critical part of wheelchair. From that analysis, the Plastic Abs has higher value of Von Mises Stress than Plastic-Acetal.

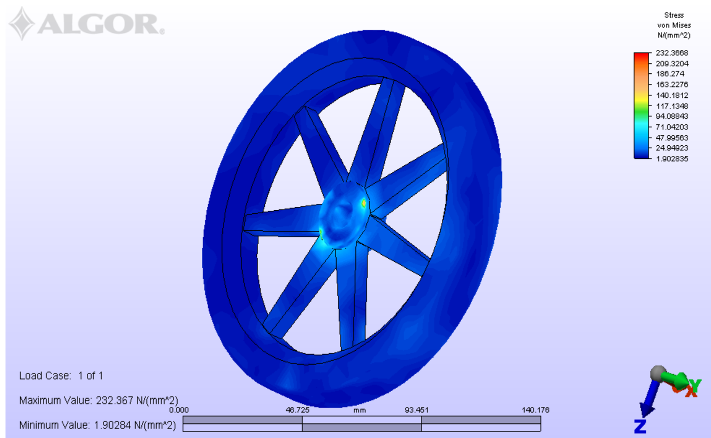

Figure 4.29: Analysis on wheel caster for Design 1

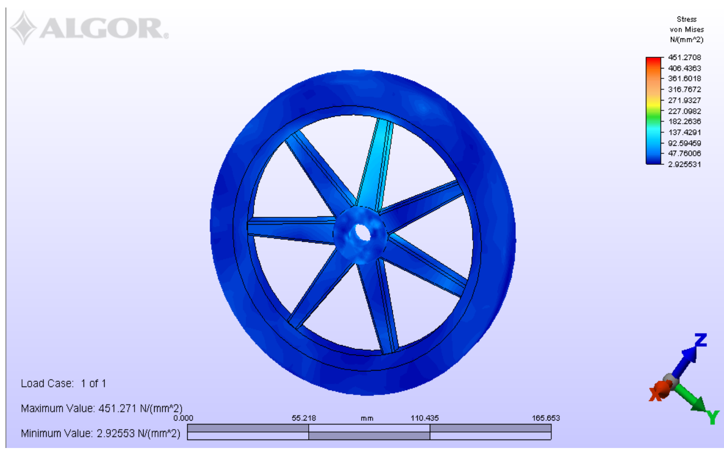

Figure 4.30: Analysis on wheel caster for Design 2

The finite element analysis in part 2 is concentrate on body caster using two difference materials which are Plastic ABS and Plastic. It is observed that the maximum value of von misses stress are differences between each design and material used (Table 4.3).

Table 4.3: Comparison between three designs depends on different material

DESIGN MATERIAL	PART 1 (BODY)
PLASTIC ACETAL	202.856 N/mm^2
PLASTIC-ABS	268.724 N/mm^2

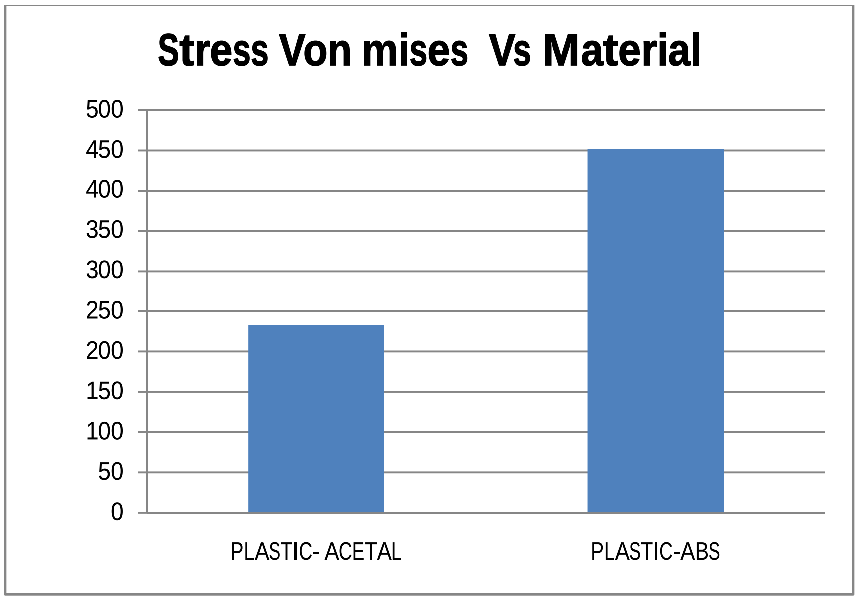

Figure 4.31: Column chart of comparison between two designs depends on different material

4.5.6 Factor of Safety (Wheel Caster)

Ultimate Tensile Strength of ABS A36 shapes and bars are 58,000 - 80,000 psi (400-550 MPa) and Ultimate Tensile Strength of Plastic-Acetal is 60Mpa. To calculate the safety factor, the value of Ultimate Tensile Strength was dividing by the value of Von Mises Stress. The results is represent in Figure 4.32

4.5.5.1 Calculation of Safety Factor for Wheel Caster:

i. Calculation for ABS

550/451 = 1.21

ii. Calculation for Acetal

60/232 = 0.25

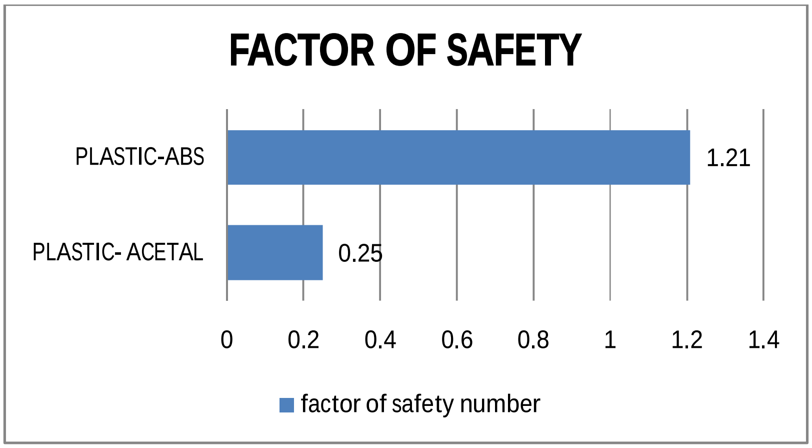

Figure 4.32: Bar Chart of comparison between two designs depends on different material

4.6 CONCLUSION

Three type of material are choosing as a material for the part and the body support. The materials are Steel ASTM A36, Aluminium T6 and E-Glass Fiber. The force are applied to the plate are the total weight of average human being which are 1500N on seating support and 1800N on wheel caster. Stress Von Misses is the total force that acting in surface area. The maximum value of stress acting on the plate of Steel ASTM A36 can support the applied load of 1500N is 303.9491 N/mm² on design 2. The maximum value of stress acting on the plate of Aluminium T6 can support the applied load of 1200N is 211.089 N/mm^2 on design 2**.** The maximum value of stress acting on the plate of E-Glass Fiber can support the applied load of 1500N is 858.35 N/mm^2 on design 1. After doing calculation to get safety factor, the design 3 have highest value of safety factor with material E-Glass fiber which is 2.77, followed by Steel ASTM A36 is 2.44 on design 3 and 1.95 on design 2 with material E-Glass fiber.

The results of analysis for stress distribution using ALGOR software shown that the wheel caster with Plastic-ABS can support the applied load of 1800N is 451.2708 N/mm^2. For Plastic-Acetal,the maximum value of Von Mises Stress is 232.6668 N/mm^2. The safety factor for wheel caster with Plastic-ABS is 1.21 that is better than Plastic-Acetal is 0.25. This is meant the highest number of safety factor is E-glass Fiber on design 3. So, the best selection of material is E-Glass Fiber for the Design 3. For wheel caster, the best material is Plastic-ABS.

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CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

Improvement on existing wheelchair is important because it help the users to do every activity which can be done by normal people. This will ensure that their daily chores are not affected by their disabilities. Improvements that have been made are on armrest, seat and adding some compartment under the seat. From this study, the existing manual wheelchair was studied. From this studied, the questionnaire was created and distribute to know the weaknesses of existing wheelchair and also the desirable wheelchair according to the users. After that, the wheelchair was drawn using SolidWorks and analyze using ALGOR software to study the stress distribution effects on the wheelchair model part. The results of von misses stress was used to calculate the safety factor.

The results showed that the design 3 is the best design than design 2 and design 1. The best selection of material is E-Glass Fiber for body support and Plastics-ABS for wheel caster. E-Glass Fiber has higher density and also high in strength. Furthermore, it also has low modulus, low cost and higher stiffness.

Overall of work done can be conclude to this final project carried out successfully and project objectives have been achieved. The existing wheelchair was improved and the analysis consideration to the critical part model has been developed. The objective and the scope of this project were focused on the stress that acting on wheel caster and seating support. From the above argument, the overall objective for this project had been achieved successful.

5.2 RECOMMENDATIONS FOR FUTURE WORK

After analyze the critical part model for the wheelchair design, some recommendation for the future work that was suggested. By modified a whole design for the wheelchair model and each detail design analysis need to consider. For the second suggested, included the detail of ALGOR simulation function that could be used to affect the effective analysis result. Nowadays, many type of simulation method that has been used can be recognizable to studying as it very helpful especially in finite element analysis such as NASTRAN, PATRAN, Hyper Mesh and etc.

In order to improve the design of wheelchair for handicap people, more features can be added to the design concept for example electric mobility devices system and other ergonomics feature of mechanism. As the engineering design areas are highly developing in nowadays, application of design software is very useful. The Finite Element Analysis (FEA) and design software such as SolidWorks, CATIA and AutoCAD could be widely emphasizing for student as it very helpful application especially in engineering design study.

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APPENDIX A1

SURVEY QUESTIONNAIRE

People with disabilities use a wheelchair as a vehicle for them to move. Nowadays, wheelchairs have been designed not only for daily use but designed for sports activities. Purpose of this survey is to refurbish existing wheelchairs for comfort and safety of wheelchair users.

Respondent Profile

1. Biography respondent *(Check* ***only one****)*

Race: ○ Malay ○ Indian ○ Chinese ○ Others

Gender: ○ Male ○ Female

Age : ○ 20 years – 29 years ○ 40 years – 49 years ○ 30 years – 39 years ○ above than 50 years

General Info

2. Do you use wheelchair independently? Or be carer to push wheelchair?

   ○ Independent User
   ○ Carer

3. How long you had been use or be guardian of a wheelchair?

   ○ New user (below 3month)
   ○ 3month to 1 year
   ○ 1 to 3 years
   ○ Over 3 years

4. What types of wheelchair that you used?

   ○ Manual wheelchair
   ○ Electric powered wheelchair
   ○ Transport wheelchair
   ○ Other types of wheelchair: ____________________ *(Please state if you have others)*

5. Why did you decide to use that type of wheelchair?

   (..) *(Please specify)*

Ergonomic

6. Identify the problem of the wheelchair which is be used nowadays?

○ Size problem
○ Safety issue
○ Comfortable issue

7. Which part of wheelchair that easily damage?

○ Handgrip
○ Back upholstery
○ Armrest
○ Seat upholstery
○ Wheel and hand rim
○ Caster
○ Foot plate

8. What suggestions do you feel is appropriate to make that part to be more comfortable?

	Comfortable	State your suggestions briefly
i. Back upholstery	○ Yes ○ No	(...)
ii. Seat upholstery	○ Yes ○ No	(...)
iii. Foot plate	○ Yes ○ No	(...)
iv. Armrest	○ Yes ○ No	(...)

Functional

9. Do you feel that the function of nowadays wheelchair is less effectiveness and should be modified?

○ Yes ○ no

10. Which part of wheelchair need to modify?

	Modification	State your suggestions briefly
i. Back upholstery	○ Yes ○ No	(...)
ii. Seat upholstery	○ Yes ○ No	(...)
iii. Foot plate	○ Yes ○ No	(...)
iv. Armrest	○ Yes ○ No	(...)

11. How well does the wheelchair that you used now meet your needs?

○ Poor
○ Acceptable
○ Good

12. What improvement would you like to see made on the wheelchair?

(………
………
……)*(Please specify)*

Thank you for your help!

APPENDIX B1: GANTT CHART FYP 1

Project Progress		W 1	W 2	W 3	W 4	W 5	W 6	W 7	W 8	W 9	W 10	W 11	W 12	W 13	W 14	W 15
1) Get the project title and arrange discussion time with supervisor.	Planning	■														
	Actual		■													
2) Do research and collect the information from various resources	Planning	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
	Actual		■	■	■	■	■	■	■	■	■	■	■	■	■	
3) State the objective, scope and background of the study. (Chapter 1)	Planning	■	■	■	■											
	Actual		■	■	■											
4) Review study of journal and thesis (Chapter 2)	Planning				■	■	■	■	■							
	Actual					■	■	■	■							
5) Study of human factor engineering (Chapter 2)	Planning						■	■	■	■	■					
	Actual							■	■	■	■					
6) Do sketching of 3 design of wheelchair and make selection	Planning									■	■	■	■			
	Actual										■	■	■			
Report Progress																
7) Do Introduction, problem statement and objectives (Chapter 1)	Planning			■	■	■										
	Actual			■	■	■										
8) Do scopes, expected outcomes and report arrangement (Chapter 1)	Planning			■	■	■										
	Actual			■	■	■	■									
9) Do Literature review, and previous research (Chapter 2)	Planning					■	■	■	■							
	Actual					■	■	■	■							
10) Do Methodology (Chapter 3)	Planning									■	■	■	■			
	Actual									■	■	■	■			
11) Submit draft thesis and log book for final year project 1	Planning													■	■	
	Actual														■	
12) Final year project 1 presentation	Planning															■
	Actual															■

APPENDIX B2: GANTT CHART FYP 2

Project Progress		W 15	W 16	W 17	W 18	W 19	W 20	W 21	W 22	W 23	W 24	W 25	W 26	W 27	W 28	W 29	W 30
1) Redesign of wheel chair drawing using Solid Works software	Planning	■	■	■	■												
	Actual	■	■	■	■												
2) Analysis the strength using ALGOR software	Planning			■	■	■											
	Actual			■	■	■	■	■	■								
3) Simulate the prototype by ALGOR software	Planning				■	■	■										
	Actual				■	■	■	■	■	■							
4) State initial summary based on simulation performed	Planning						■	■	■	■							
	Actual							■	■	■	■	■	■	■			
5) Discuss the analyzed results	Planning							■	■	■	■	■					
	Actual							■	■	■	■	■					
6) State the possible error during the simulation	Planning										■	■	■				
	Actual										■	■	■				
7) Make conclusion and provide suggestion for improvement	Planning											■	■				
	Actual											■	■	■	■	■	
8) Prepare the proper thesis to submit	Planning												■	■	■	■	■
	Actual												■	■	■	■	■
9) Final year project 2 Presentation	Planning													■	■		
	Actual														■		
10) Summit the thesis	Planning														■	■	■
	Actual																■