DESIGN AND ANALYSIS OF MODULAR WHEELCHAIR FOR USAGE OF HANDICAP PEOPLE

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Date : 22 JUNE 2012

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

The report begins with a preliminary research of human factor engineering and ergonomic study for the design of wheelchair. The main objective of this project is to select the best conceptual design using Pugh selection method also use of simulation in analyzing the critical part of the wheelchair modeling and evaluating the wheelchair design. The projects begin with make a questionnaire survey to the respondent'. From the survey, a total of 35 respondents' has taken part. The survey consists of several parts such as personal information, general information of using wheelchair, and the ergonomic of wheelchair. The stress evaluation was carried out at lower back, buttock and knee; the gathered information through survey was applied in the redesign process. Three sketches have been sketched. Based on the sketches, Pugh selection concept has been used to select the best design. Next the sketches being draw into SolidWorks software and then go through to simulation process by using FEA, the design was analyzed using constant force. Improvement of critical parts such as seating support design was compared based on material used analysis on Stress Von Mises. At the end, when all the process mentioned above is done, the result for report writing is gathered.

ABSTRAK

Laporan ini dimulakan dengan kajian awal kejuruteraan faktor manusi dan kajian ergonomic bagi reka bentuk kerusi roda. Objektif utama projek ini adalah untuk memilih konsep reka bentuk yang terbaik dengan menggunakan kaedah pemilihan Pugh dan juga menggunakan simulasi dalam menganalisis bahagian kritikal pemodelan kerusi roda dan menilai reka bentuk kerusi roda. Projek ini bermula dengan membuat soal kaji selidik kepada orang awam. Daripada kaji selidik ini, sebanyak 35 peserta telah mengambil bahagian. Kajian ini terdiri daripada beberapa bahagian seperti maklumat peribadi, maklumat umum menggunakan kerusi roda, dan ergonomik kerusi roda. Penilaian tekanan telah dijalankan dibahagian bahagian belakang, punggung dan lutut; maklumat yang dikumpul melalui kaji selidik telah digunakan dalam proses rekaan semula. Tiga lakaran telah dilakarkan. Berdasarkan lakaran, konsep pemilihan Pugh telah digunakan untuk memilih reka bentuk yang terbaik. Lakaran seterusnya akan dibuat secara detail dengan menggunakan perisian SolidWork dan kemudian akan melalui kaedah proses simulasi dengan menggunakan FE, reka bentuk telah dianalisis dengan menggunakan daya yng tetap. Peningkatan bahagian kritikal seperti reka bentuk sokongan tempat duduk berdasarkan analisis terpakai bahan di Stress Von Mises. Pada penghujungnya, apabila semua proses yang tersebut di atas dibuat, hasil untuk penulisan laporan dikumpulkan.

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LIST OF ABBREVIATIONS

3D	Three Dimensions
AISI	American Iron and Steel Institute
CAD	Computer Aided Design
CAE	Computer Aided Engineering
EPW	Electric Powered Wheelchair
FE	Finite Element
FEA	Finite Element Analysis
F.S	Factor of Safety
PMA	Pugh Method Analysis
PSJ	Position Sensing Joystick
SAE	Society of Automotive Engineers
WHO	World Health Organization
σ	Stress
N/mm^2	Newton per Millimeter Square
MPa	Mega Pascal

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Disable people are really needs the wheelchair in their daily life. This is because a wheelchair can be use to move from one place to another place. The wheelchair is designed for the disable people to make them easy to move around independently. It contains wheels that can be controlled by hand in case of manual wheelchair. Manual wheelchairs can also be pushed by another person from behind.

Interest and participation in wheelchair sports has grown over the years and there is an ongoing effort amongst different organising bodies to popularise these events further at an international level (Burton, 2010). Many researcher has done the research, there have been lots of modifications on the purposes of wheelchairs and created the sport wheelchair. The design of special sport wheelchair for sport activity must be emphasised accuracy in order to ensure comfortable while using it. There are many types of wheelchair has been designed, but not at all are fulfil the suitable or comfortable for both user and usage, that is the target of this project to design the modular wheelchair for the handicap people in the sport activities.

1.2 PROBLEM STATEMENT

Like a normal person that needs the leg to walk around, same goes to the handicap people to move from one destination to the other destination. The handicap people need devices to meet the needs of people with various types of mobility limitations. These include for example; various types of manual wheelchairs for people with insufficient strength and function too independently. It has some limitation function on the wheelchair that need a force to move it, and the user feel not comfortable on the seat and feel tired when used the long period wheelchair. That was because the seat comfortable and the posture position are not in the good condition. This are involve on the ergonomic that need on the designing the wheelchair to give more comfortable to the users. A review of wheelchair research within the scope of the wheelchair as a means of daily ambulation is presented. The relevance of a combined biomechanical and physiological research approach is advocated for enhancing the body of knowledge of wheelchair ergonomics, that is, the wheelchair or user interaction in relation to aspects of vehicle mechanics and the user's physical condition.

The main problem of the existing wheelchair for handicap people who went to participate in the sport activities is, the existing wheelchair is not really suit to the body shape for those who are involves in the sport activity.

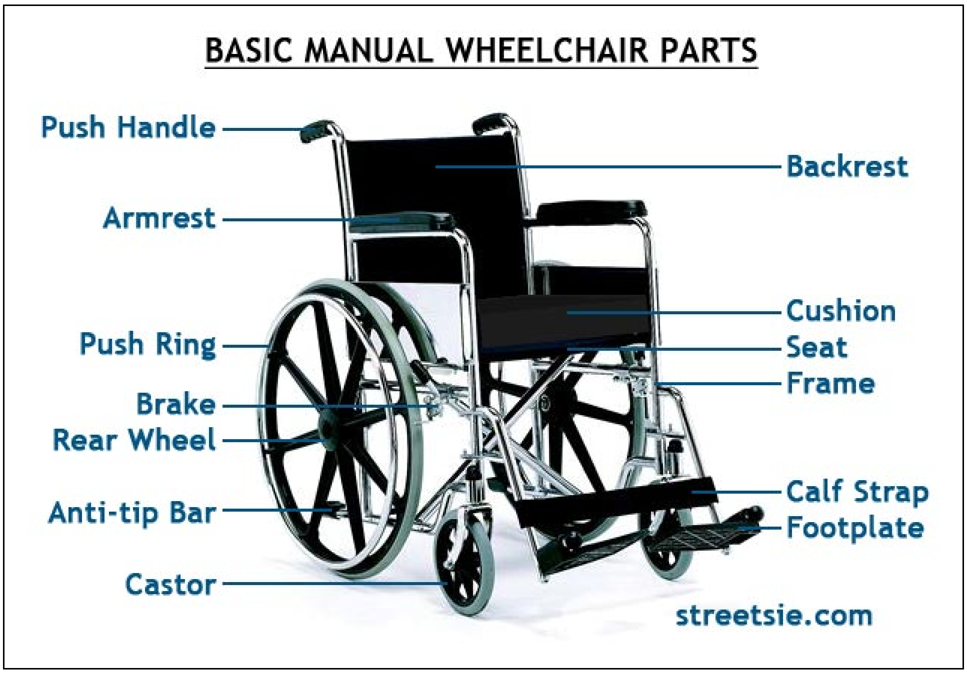

Figure 1.1: Standard wheelchair and their main components

1.3 OBJECTIVES

The aims of this project are:

i. To determine criteria required by the wheelchair.

ii. To improve and analyze the product to optimize the usage for handicap people.

iii. Simulate the altered design using CAD software and CAE software.

1.4 SCOPES OF STUDY

The scopes of this project are:

i. Maximum weight of handicap people is between 100 kg until 120 kg.

ii. Design the wheelchair using CAD software (SolidWork).

iii. Select the best design based analysis using Pugh selection concept and simulation using Algor.

1.5 EXPECTED OUTCOME

The expected outcomes for this project are:

i. To come out with project design concept.

ii. To produce the 3D modelling type and analysis

iii. To come out with project presentation

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter will discuss about the engineering design, analysis of wheelchair, a wheelchair, handicap people including the anthropometry data and the previous journal, conferences paper, and thesis similar and related with this objective in this final project report.

2.2 DESIGN

2.2.1 Definition of Design

Design is the idea to plan or to improve the object or system to get the target or goal. The design is that area of human experience, skill, and knowledge which is concerned with man's ability to mould his environment to suit his material and spiritual need (Archer, 1973). A simple design is that everyone involved with its production and use sees nothing that looks complicated from his own perspective or convention (Skakoon, 2008). The designers should identify the specific problem that are facing and then develop a solution that addresses the challenge. This challenge create the designers should be creative process to develop a product or system that meet some criteria.

2.2.2 Mechanical Engineering Design

Most engineering designs can be classified as inventions-devices or systems that are created by human effort and did not exist before or are improvements over existing devices or systems (Khandani, 2005). The innovations or design are not suddenly appearing from nowhere, but they are the result of bringing together technologies to meet human needs or to solve problems. Mechanical engineering design involves all the disciplines of mechanical engineering and design problems are open ended in nature, which means they have more than one correct solution.

2.2.3 The Engineering Design Process

The engineering design process deals with basic operation that are repeated every process with a view to seeking opportunities to turn the ideal into reality. The engineering design process is usually performed with a view to producing the item needed in the shortest time for the highest reliability. The design of a wheelchair depends on a number of factors: the physical needs of users; the way and the environment in which the wheelchair will be used; and the materials and technology available where the wheelchair is made and used.

2.2.4 Design Principles

Design principles have focused on the technical scientific rules, like in the engineering field. Indeed, good engineering design involves many parameters upon which the success of the project depends, each of which has its own subset of laws, standards, practices, codes and regulations.

2.3 ANALYSIS OF WHEELCHAIR

2.3.1 Definition of analysis

The analysis process is the process of breaking up a concept, proposition, linguistic complex, or fact into its simple or ultimate constituents (Audi, 1999). Analysis is the evaluation of the relevant information to select the best course of action from among various alternatives.

2.3.2 Pugh Selection

Pugh method analysis (PMA) is useful as a method for determining a course of action as well as gaining consensus with a project team (Cervone, 2009). Pugh concept selection is a quantitative technique used in engineering for making design decisions but can also be used to rank investment options, vendor options, product options or any other set of multidimensional entities (Stuart, 1990). Conceptual design is an early stage of the product development process which involves the generation of solution concepts to satisfy the functional or design requirement of a design problem (Hambali, 2009). Generally, the main goal of conceptual design stage is to select the most suitable concept from a number of possible options and concern of conceptual design is the generation of physical solutions to meet the design specification (Hsu and Woon, 1998)

2.3.3 Software/Equipment

To complete this project other than use Pugh selection concept, one of the methods is used software includes SolidWork® and Algor. SolidWork® 3D CAD software is intuitive and enables to develop better products by allowing design. A SOLIDWORKS model consists of 3D solid geometry in a part or assembly document. Drawings are created from models, or by drafting views in a drawing document.

Figure 2.1: The solidworks®

The Algor software represents a very powerful tool to perform a finite element analysis. It allows to perform mechanical or structure analysis with basis on the finite element method and to arrive to diverse results. Algor analyses are based as mentioned in the finite element method. This method helps to predict how an element is going to behave under wide variety of conditions can be simulated. Divide the work to a real object into millions of small elements which have almost the same shape. Then, the behaviour of each element is analyzed by mathematical equations to see how it going to behave. Then, the computer joins each of small analyses made to each element, and simulates how they are going to behave as a whole element.

Figure 2.2: The algor

2.4 WHEELCHAIR

2.4.1 Definition of Wheelchair

Wheelchair is a chair with wheels designed to transport a sick, injured, or otherwise handicap person from one place to another place. Wheelchair is a most important device used for mobility by people for whom walking is difficult or impossible, due to illness or disability. Wheelchair designs vary to enable users to safely and effectively use their wheelchair in the environment in which they live and work (Armstrong, et al. 2008). Wheelchairs are used by those people for whom walking is difficult or impossible due to illness like physiological or physical, injury or disability used in sports field. In the case of manual chairs, people need to develop upper body strength to control the chair, and they also develop techniques for navigating the environment, including methods for wheelchair mobility on rough surfaces and inclement conditions. During the injury time, the athletic also can do daily activities and doing light exercises to continue their stamina and skills.

2.4.2 Types of Wheelchair

In the world today, that has many types of wheelchair available in the market. The wheelchairs come with different type, function, and shape. Basically the types of wheelchair in the market are manual wheelchair, electric powered wheelchair and sport wheelchair. Every types of wheelchair have their own function and system. There are standard (folding) wheelchairs that fit most general needs and then there are custom (rigid) built wheelchairs.

2.4.2.1 Manual Wheelchair

Manual wheelchairs are wheelchairs that are powered either by the wheelchair user or by somebody pushing the wheelchair. Manual wheelchairs that are lightweight are easier to manage. Standard wheelchairs are your standard self-propelled option with two large wheels in the back and have smaller wheels in the front. A standard manual wheelchair has a cross-brace frame, a mid-to-high-level back, built-in or removable armrests and swing-away footrests. Some people still prefer this type of wheelchair.

Figure 2.3: The manual wheelchair

2.4.2.1.1 Standard (Folding) Wheelchairs

The folding frame types of wheelchairs are just that, a folding X style frame. Most frames fold when the locking mechanism is released for folding. Folding wheelchairs also have removable foot rests which allow for easy folding. As with anything with moveable parts, the folding wheelchair is not as durable as the rigid frame wheelchair. Therefore maintenance is required more frequently to keep all parts in good working.

Figure 2.4: The standard (folding) wheelchairs

2.4.2.1.2 Custom (Rigid) Built Wheelchairs

A rigid frame wheelchair consists of a welded frame on which the individual sits. The back of the chair is able to fold down and the wheels can be removed with a quick release mechanism to enable easy storage and transportation of the wheelchair. The advantages of these types of wheelchairs are that they have fewer moving parts, which means they are generally stronger and last longer than the folding wheelchair.

Figure 2.5: The custom (rigid) built wheelchairs

2.4.2.2 Electric Powered Wheelchair (EPW)

Electric powered wheelchair is simply manual wheelchairs that had been outfitted with an electric motor. Power or electric wheelchairs provide the benefits of a manual wheelchair without the need of carer assistance, greatly improving your independence. Nowadays, EPW has many types or style rear, centre, front wheel driven or four wheels driven. Each style wheelchair has particular handling characteristics.

The user typically controls speed and direction by operating a joystick on a controller. Conventional position sensing joysticks (PSJ's) provide access to EPW's for many individuals with disabilities, but some people do not have the motor skills to effectively operate a PSJ (Cooper, 2000). For the forward movement, the users can control easily, but when driving the wheelchair backward many users of electrical-powered wheelchairs encounter difficulties. The EPW reverse instability may be caused by a number of factors including the user, environment, speed, and front caster orientations (Ding, 2004)

Figure 2.6: The electric powered wheelchair

2.4.2.3 Sport Wheelchair

These types of wheelchairs were designed in order to be used in sports, such as tennis, basketball and athletic. These chairs may be used by people with good upper-body mobility. However, there are some devices that help people with an upper extremity paralysis use a sport wheelchair as well. Sport wheelchairs are not generally for everyday use and are often a second chair specifically for sport use (Kulig et al., 1998).

The design of a sport wheelchair varies between the purposes it is used for. There are specialized lightweight wheelchairs, such as court, races, tennis, skiing, hand-cycle or beach chairs. They are highly specialized equipment built for exclusive use in a particular sport. Depending upon the activity, the wheelchair might be geared for speed or strength. Sports wheelchairs are streamlined in design and must be rigid for strength and stability. They are adjustable, but since they do not fold up, they can be difficult to transport. Their lightweight properties make them responsive and easier to propel, which also helps athletes avoid wrist and shoulder injuries.

Figure 2.7: The sport wheelchair

2.4.3 Materials Used

In generally, the selection of materials for wheeled mobility products impacts both the manufacturer and endures. Materials impact characteristics such as durability, strength, cost, appearance, design and manufacturing flexibility, and weight. Materials have been the basis of major evolution in wheelchair products.

The alloys of these aluminium and titanium are the most common materials used for making ultra lightweight and lightweight frames. Carbon fibre and magnesium are the other two material used for high-end wheelchairs. Frames made from these two materials are very expensive. Standard wheelchairs are made from steel. A wheelchair with titanium frame costs more than one made from aluminium. It is also lighter. Besides, titanium does not need to be painted. Scratches can be polished off with steel wool pads. In addition to improvements in the frame, both manual and power chairs stand to benefit from better materials for wheels, tires, and seating.

2.5 HANDICAP PEOPLE

2.5.1 Definition of Handicap People

A handicap is limitations either are present from birth or result from injury, disease, or aging (Gibson et al., 1982). A handicap people is often used to refer to individual functioning, including physical impairment, sensory impairment, intellectual impairment, mental illness, and various types of chronic diseases.

People with disabilities in Malaysia can be considered as one of the most vulnerable of the minority group in the Malaysian population. According to WHO, 7% of the population in any country suffers from disability and around 2% would need some form of rehabilitation services. According to the statistics from the Department of Social Welfare, the registered number of disabled people stood at 197,519 (Department of Social Welfare, 2006) and the breakdown according ethnic groups (Kamaruddin, 2007).

Figure 2.8: The handicap people

Table 2.1: Number of people with disabilities according to ethnic group 2003-2006

Ethnic Group	2003	2004	2005	2006
Malays	79.837	91,162	105,163	123,245
Chinese	28.956	32,408	35,104	39,519
Indians	12.396	14,246	15,995	18,346
Pribumi Peninsular	246	283	317	354
Pribumi Sabah	7.515	8,266	9,130	10,240
Pribumi Sarawak	3.226	3,617	4,037	4,682
Others	479	635	709	1,133
Total	**132,154**	**150,617**	**170,455**	**197,519**

Source: Department of Social Welfare 2006

Source: Department of social welfare (2006)

Table 2.2: Number of registered people with disabilities in malaysia 2002-2006

Types of Disabilities	2002	2003	2004	2005	2006
Visually Impaired	14,738	14,154	15,364	16,211	18,258
Hearing Impaired	21,981	22,728	24,712	26,470	29,522
Physical Handicapped	41,311	45,356	51,090	58,371	66,250
Mentally Impaired	43,042	49,340	-	-	-
Learning Disabilities	-	-	57,483	66,906	76,619
Cerebral Palsy	-	-	34	623	887
Miscellaneous	1,017	1,077	1,934	4,335	5,983
Total	**122,089**	**132,655**	**150,617**	**172,916**	**197,519**

Source: Department of Social Welfare 2006

Source: Department of social welfare (2006)

Table 2.3: Number of people with disabilities according age, types of disabilities and gender 2006

Age (years)	Visual		Hearing		Physical		Learning Disabilities		Cerebral Palsy		Misc	
	M	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
19 - 25	162	100	246	192	708	315	532	400	53	34	115	113
26 - 35	172	97	246	183	889	475	429	369	37	29	91	82
36 - 45	192	124	180	155	945	401	264	219	23	22	119	50
46 - 59	267	163	249	189	1161	552	279	270	72	40	110	79
Above 60	116	94	128	86	492	208	69	46	12	4	44	22
Total	**909**	**578**	**1049**	**805**	**4195**	**1951**	**1573**	**1304**	**197**	**129**	**479**	**346**
	Male (M) = 8402						*Female (F) = 5113*					

Source: Department of Social Welfare 2006

Source: Department of social welfare (2006)

2.6 ANTHROPOMETRIC DATA

2.6.1 Definition of Anthropometric Data

In ergonomic point of view anthropometric data is very important in product design and other applications. Hence, it is important that the data is representative of the target user or consumer of a product being designed. Anthropometric data is actually being utilized although sometimes the designer is unaware of it. Without using the appropriate measurements or limits, the product, layout or workspace may not function, or function but not as effective as it should be.

Anthropometric data to represent the "world population" would be ideal; nevertheless, it is not achievable due to the lack of available and up-to-date anthropometric data for populations of potential concern (Schneider et al. 1983). Malaysians' individual's efforts are ample in the health and nutrition application (Yap et al. 2001; Osman et al. 1993; Manuel & Mohd. Yusof 2005). Anthropometry is the study of the measurement of the human body in terms of the dimensions of bone, muscle, and adipose (fat) tissue.

Table 2.4: List of anthropometric data measured position.

Position					
Standing	**Sitting**			**Others**	
Stature	Crown buttock height	Buttock popliteal length	Hip breadth	Hand length	Foot breadth
Eye height	Eye height	Buttock knee length	Shoulder breadth	Hand breadth	Head length
Shoulder height	Shoulder height	Buttock heel length	Elbow breadth	Hand thickness	Head breadth
Elbow height	Elbow height	Elbow grip length		Thumb breath	Head height
Fist height	Popliteal height	Forward grip reach		Forefinger tip breath	Circumference
Vertical grip reach	Thigh thickness	Abdominal depth		Foot length	Weight

Source: Motmans (2005)

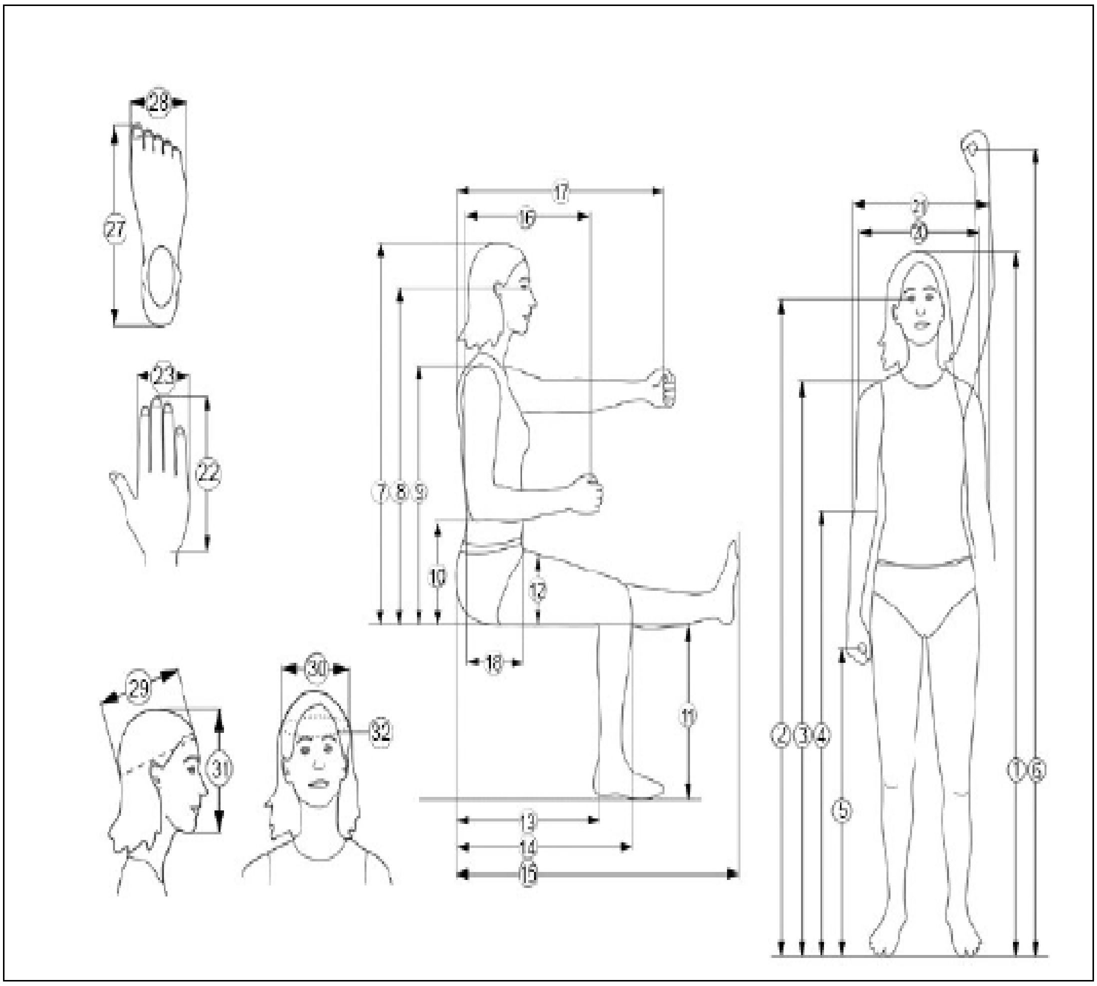

Figure 2.9: The illustration of the measured anthropometric dimensions

Source: Motmans, 2005

2.6.2 Ergonomics

Ergonomists study human capabilities in relationship to work demands. Biometrics and Anthropometrics play a key role in this use of the word Ergonomics. Ergonomics aims to avoid any misunderstanding between people and products (Kroemer et al., 1998).

In addition, ergonomics also means the application of scientific information with taking into account human factors in the design of objects, systems and environments for use by humans. Work systems, sports and recreation, health and safety must apply the principles of ergonomics in the design. Ergonomics encompasses some elements of the anatomy (the study of human body structure), physiology (human nature) and psychological (mind). Ergonomics applied to ensure that products and environments designed to comfortably, safely and efficiently for use in humans (Whitfield and Langford, 2001).

Ergonomists consider all the physical aspects of a person, such as:

i. Body size and shape;
ii. Fitness and strength;
iii. Posture;
iv. The senses, especially vision, hearing and touch; and
v. The stresses and strains on muscles, joints, nerves.

2.7 PREVIOUS RESEARCH

Design and Analysis of Packing Boxes for Flat Panel Displays (Teng, 2010)

This topic has discussed about the design and analysis for flat panel displays. Flat panel displays protected in a packing box and it might be shock when the box is bumped on the hard surface or fall into the floor, and the packing box not only designed to protect the fragile liquid crystal display from damage but also take up a volume as small as possible in order to reduce the transport cost. The objective of this topic is to minimize simultaneously the predesignated natural frequency and the mean compliance of a packing box subjected to a volume constraint. A methodology of design the packing box is based on the topology optimization technique is proposed. The target is to minimize the acceleration and the maximal stress of the panel contained in the packing box. The results show that an optimal layout of the packing box not only occupies a smaller volume, but also reduce the maximal acceleration of the panel.

Design and Analysis of an Automobile Bumper with the Capacity of Energy Release Using GMT Materials (Mortazavi Moghaddam, 2011)

This thesis has discussed about the design and analysis of an automobile bumper with the capacity of energy release using glass material thermoplastic (GMT). The target of this thesis is to design a bumper with minimum weight by employing the Glass Material Thermoplastic (GMT) materials. This bumper either absorbs the impact energy with its deformation or transfers it perpendicular to the impact direction. To get the target a mechanism is designed to convert about 80% of kinetic impact energy to spring potential energy and release it to the environment in the low impact velocity. This thesis, modelling, solving and result’s analysis are used in CATIA, LS-DYNA, and ANSYS V8.0 software respectively. Finally, steel bumper (as a conventional material) was compared with the GMT and the results showed inappropriate weight increase of about two times of the GMT bumper with the same safety factors.

Anthropometric Study among Adults of Different Ethnicity in Malaysia (Karmegam, 2011)

This paper is study about an anthropometric study among adults of different ethnicity in Malaysia. This paper is to determine the differences of anthropometry data among three ethnic populations in Malaysia. The measurements were collected among 300 males and females respondents from age 18 to 24 years. A total of thirty-three body dimensions were measured. The statistical test includes, mean, standard deviation, standard error of mean, coefficient of variation, minimum, maximum, 5th percentile, 50th percentile and 95th percentile for the various body dimension were tabulated. ANOVA F using post-hoc Scheffe test were performed to determine the significant differences between the means of anthropometric dimension and within the three ethnic's. The result shows that the significant differences ($p<0.05$) in most of the measurements taken between the three ethnics and among the different genders respectively. The post-hoc Scheffe test indicated that the Malay male's have the largest body size compared to the Chinese and Indian. In addition, the Chinese female's have the largest body size compared to the Malay and Indian population. In the male and female population, Indian and Malay have the smallest body size respectively. As a conclusion, the results suggest that there are various body dimension differences between the ethnics in Malaysian population and there is a need to consider ethnicity aspect when designing for the Malaysian population.

Systematic Design Customization of Sport Wheelchairs using the Taguchi Method (Burton, 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. This method is problematic for physical testing of athletes because of the number of experiments is very large and Experimental testing of athletes is subject to systemic errors as human performance is not precisely repeatable, and each experiment will effect subsequent trials due to muscle fatigue.

Seat and Footrest Shocks and Vibrations in Manual Wheelchairs with and Without Suspension (Rory, 2003)

This paper discussed about seat and footrest shocks and vibrations in manual wheelchairs with and without suspension. The objective of this paper is to determine differences in the shock and vibration transmitted to an occupant of a manual wheelchair with and without rear-suspension systems. The design of this paper is repeated-measures engineering testing on six manual wheelchairs. The setting is rehabilitation engineering center with a wheelchair standards test laboratory. The main outcome measures are examined by using peak acceleration and the frequency at which peak acceleration occurs for the seat and footrest. The results is the significant different were found by using peak accelerations at the seat and footrest between the wheelchairs with OEM caster forks and those with the suspension casters. There were significant differences for wheelchairs with and without rear suspension for total power per octave of seat vibrations in the octaves between 7.81 and 9.84 Hz (*P*_.01) and 12.40 and 15.63 Hz (*P*_.008). The suspension caster forks reduce the shock and vibration exposure to the user of a manual wheelchair. Rear-suspension systems reduce some of the factors related to shock and vibration exposure, but they are not clearly superior to traditional designs.

The Conceptual Design Method of Mechanical Products (Ling-ling, 2009)

This paper is study about the conceptual design method of mechanical products. The conceptual design is the first step of designing process; it decides the technology economic effect of product radically. The target of this paper is to match the product function with its structure, but the relationship between function and structure is a difficult problem in the conceptual design. This method is proposed based on the generalized concept based on product function. The function attribute not only includes technical attribute described by numerical value, which is called the semantic attribute, such as "on-off" and "protection" of electrical products. The conceptual design method is proposed with separate a product super class into several subclasses, to contra pose a certain branch node and to seek for product case of each subclass. A reasonable choice for these types of products, product design right direction, is to finally meet the design requirements of product design, which laid the foundation for the program.

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

This thesis study is about an anthropometric study of manual and powered wheelchair users. 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 (such as 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 modelling and CAD applications.

The Optimization Design and FEA Analysis in Car Sunroof Design (Xu, 2011)

In this paper the reverse engineering and software CATIA was used to create 3D model and virtual prototype of the car sunroof motion mechanism. Then the model was imported into Software ADAMS to create the virtual kinematics model. After that parameterized the model and an optimization design was carried out with sunroof motion mechanism in software ADAMS. Finally a transient dynamical FEA simulation and analysis about the motion mechanism were done with software ANSYS Workbench. The research work in this paper can not only improve the design quality and efficiency of car sunroof, and also shorten the product development period and cost.

Design of a Wheelchair with Legs for People with Motor Disabilities (Wellman, 1995)

This thesis present about design of a wheelchair with legs for people with motor disabilities. A proof-of-concept prototype wheelchair with legs for people with motor disabilities is proposed, with the objective of demonstrating the feasibility of a completely new approach to mobility. Our prototype system consists of a chair equipped with wheels and legs, and is capable of traversing uneven terrain and circumventing obstacles. The important design considerations, the system design and analysis, and an experimental prototype of a chair are discussed. The results from the analysis and experimentation show the feasibility of the proposed concept and its advantages.

Redesign of a Manual Wheelchair through Concurrent Engineering Tools (Faizul, 2005)

This report describes about the implementation of redesign the manual wheelchair by using the application of concurrent engineering. The scope based on the existing wheelchair design and the appropriate application of Concurrent Engineering (CE) tools. The method used for gaining the data was from the survey done by distributing of questionnaires to several numbers of people and the wheelchair user. From the data achieved, it can be classified into several categories to be studied. Data will be analyzed by using the Quality Function Deployment (QFD) method to verify the highest rank from the people and customer requirements. The new proposed design of wheelchair was drawn using Solid works software based on the QFD result achieved. In the same time, both design and redesign of manual wheelchair were analyzed by using the Design for Assembly (DFA) tools which is TeamSET software, to compare the design efficiency to achieve the objectives of the project. Result shown that the design efficiency for redesign manual wheelchair obtained better percentage rather than the existing design. From the study, even the redesign possesses a greater number of part compared to the existing design, it still has the advantages based on the convenience functions and the percentage of design efficiency. Eventually, the improvement of wheelchair design finally will be able to meet user requirements and satisfactions.

Table 2.5: Summary of the previous research

Author	**Year Published**	**Method**	**Product**	**Results**
F. C. Teng, F. T. Wu, Chih-Chun Cheng, and Cheng-Kuo Sung	2010	The topology optimization technique	Flat panel displays	The results show that an optimal layout of the packing box not only occupies a smaller volume, but also reduce the maximal acceleration of the panel.
A.R. Mortazavi Moghaddam, M. T. Ahmadian	2011	CATIA, LS-DYNA, and ANSYS V8.0 software	An automobile bumper with the capacity of energy release using glass material thermoplastic	The results showed inappropriate weight increase of about two times of the GMT bumper with the same safety factors.

Table 2.5: Continued

K. Karmegam,S. M. Sapuan, M. Y. Ismail, N. Ismail ,M. T. Shamsul Bahri, S. Shuib, G.K. Mohana ,P. Seetha, P. TamilMoli and M. J. Hanapi	2011	The statistical test includes, mean, standard deviation, standard error of mean, coefficient of variation, minimum, maximum, 5th percentile, 50th percentile and 95th percentile for the various body dimension were tabulated.	The differences of anthropometry data among three ethnic populations in Malaysia.	The significant differences ($p<0.05$) in most of the measurements taken between the three ethnics and among the different genders respectively.
Burton M, Subic A, Mazur M, Leary M	2010	Taguchi Method	Systematic Design Customization of Sport Wheelchairs	To identify the optimal settings for design customization of wheelchairs for specific sports.

Table 2.5: Continued

Rory A. Cooper, PhD, Erik Wolf, BS, Shirley G. Fitzgerald, PhD, Michael L. Boninger, MD, Rhys Ulerich, BS, William A. Ammer, BS	2003	The design of this paper is repeated-measures engineering testing on six manual wheelchairs. The setting is rehabilitation engineering center with a wheelchair standards test laboratory.	Seat and footrest shocks and vibrations in manual wheelchairs with and without suspension.	The results is the significant different were found by using peak accelerations at the seat and footrest between the wheelchairs with OEM caster forks and those with the suspension casters.
Li Ling-ling, Duanmu yong-guang, Li Zhi-gang	2009	The conceptual design method is proposed with separate a product super class into several subclasses, to contra pose a certain branch node and to seek for product case of each subclass.	The conceptual design method of mechanical products.	Product design right direction is to finally meet the design requirements of product design, which laid the foundation for the program.

Table 2.5: Continued

Victor Paquet, David Feathers	2003	1. Participants 2. Measurement protocols 3. Variables 4. Data analysis	An anthropometric study of manual and powered wheelchair users.	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 modelling and CAD applications.

Table 2.5: Continued

Xiaoxia Xu, Zhiwu Han, Yingchun Han	2011	CATIA, ADAMS, transient Dynamical FEA simulation and analysis about the motion mechanism were done with software ANSYS Workbench.	Car Sunroof Design	The research work in this paper can not only improve the design quality and efficiency of car sunroof, and also shorten the product development period and cost.
Parris Wellman, Venkat Krovi, Vijay Kumar, and William Harwin	1995	A proof-of-concept prototype wheelchair with legs for people with motor disabilities is proposed.	Wheelchair with Legs for People with Motor Disabilities	The results from the analysis and experimentation show the feasibility of the proposed concept and its advantages.

Table 2.5: Continued

Faizul, M.	2005	Distributing of questionnaires, Quality Function Deployment, and Design for Assembly (DFA) tools which is TeamSET	Redesign of a Manual Wheelchair through Concurrent Engineering Tools	The improvement of wheelchair design finally will be able to meet user requirements and satisfactions.

CHAPTER 3

METHODOLOGY

3.1 Introductions

This chapter explains the research methodology applied as to ensure that a project running smoothly and to gather data to support the analysis of the project. To achieve the objective of this project, a proper structure of the overall methodology must be planned carefully. The project methodology has six category includes the planning of the study, project review, survey instrument, sketching, modelling and data collection and analysis process.

3.2 Overview of the Project

Final year project known as FYP start for selection the title of the project. The given title, “Design and Analysis of modular wheel chair for usage of handicap people” start with meeting with supervisor and discuss about the title that has given. During this meeting, decided the journals and reference book was decided to get the information like “Product Design and Development” by Karl T. Ulrich for Pugh selection method. Observation and questionnaire are used to collect the primary data. Secondary data are gained from paper-based and electronic sources such as journals, books and internet. Then most of the journals were taken from science direct data, IEEE *Xplore* Digital Library, springerlink and website.

Then, decided sub topic of every main chapter start with introduction, literature review, and methodology. The planning process starts from first week with the introduction included the objectives and scopes of the project.

Next, continued with literature review, a literature review is a body of text that aims to review the critical points of current knowledge, gather the appropriate information that related to this project from the previous journal, book, preliminary thesis, and other information. All of the information has related or relevant with the project title to guide to continue the progress report on this project.

The next stage is development of the questionnaire. This survey is carried out to gather right information from the users. These questionnaire were distributed to the public‘s including campus and public areas. This questionnaire was developed properly for the sport usage. These forms were distributed randomly to wheelchair user and public who are involved in sport activities. Included in this questionnaire, provide 13 questions and answer by 35 respondents. Then, the questionnaire has been analyzed taken by respondents. All the questions in the questionnaire are analyzed using Microsoft excel and the results are presented in the pie chart and next chapter.

Next, this project proceeds with sketching of conceptual design and listed down the materials that want to use in this conceptual design. Three sketches are done based on the feedback from the distributed questionnaire and the concept selection method based on existing research survey. From the selected conceptual design, the suitable concept of design could be realized by hand sketching.

3.3 Overview of Experimentation

This project conducted to design a new ergonomic wheelchair for disable peoples in Malaysia. It is carried out with the process according to the flow chart shown in fig 3.1. A flow chart is a visual a representation of all major steps in a process. Flow chart graphically presents a block diagrams that describe a process or system (Heizer, 2011). From the flow chart, the study starts with identifying the problem statement and the target on this project. Literature review was conducted in order to prepare or create the questionnaire survey and also understanding the study. Then, a survey was conducted for data collection which includes questionnaire and observations.

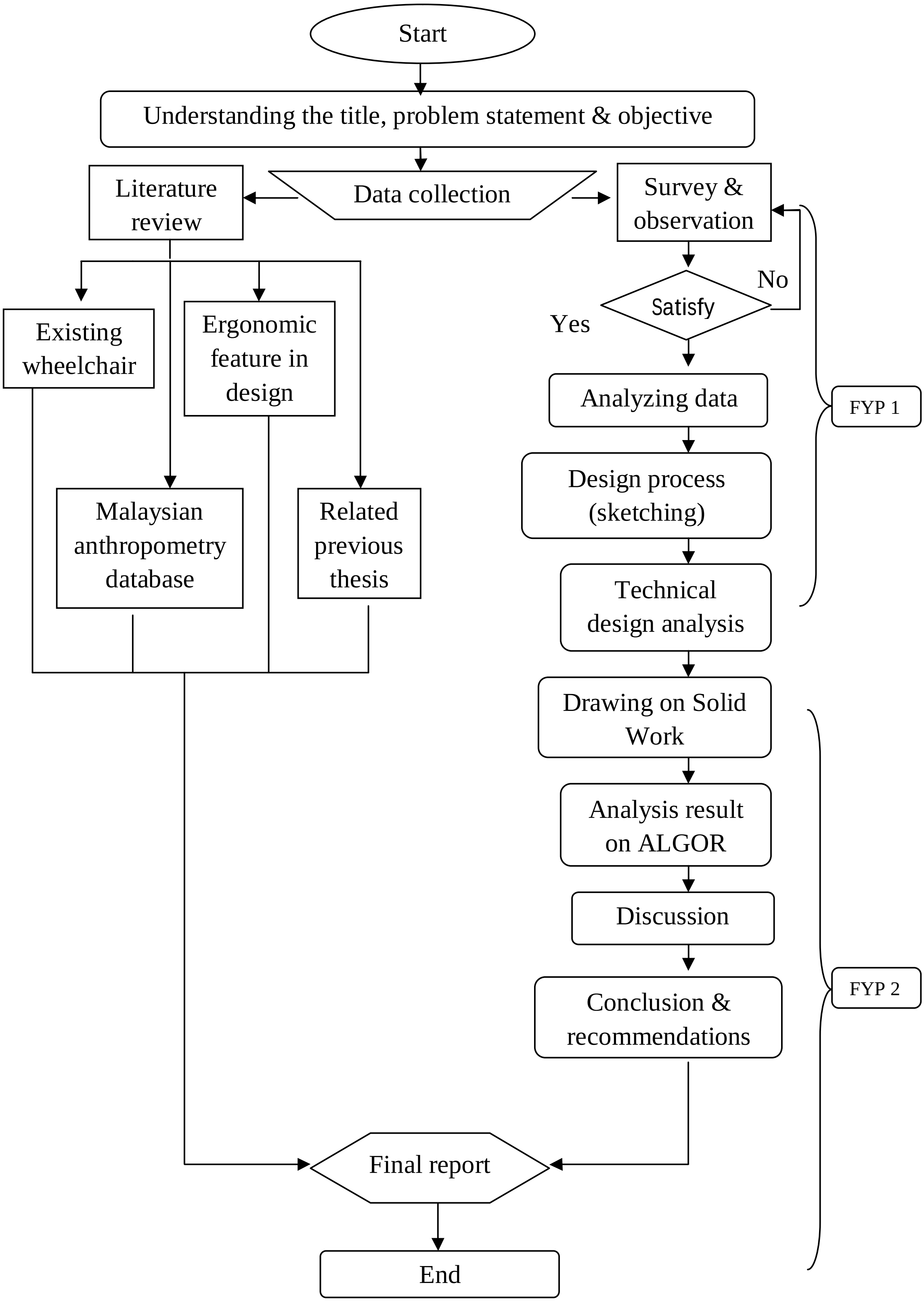

Figure 3.1: The flow chart for final year project

Data collection is an important aspect of any type of design process, in figure 3.2 showsthe front-end process for the project concept development.

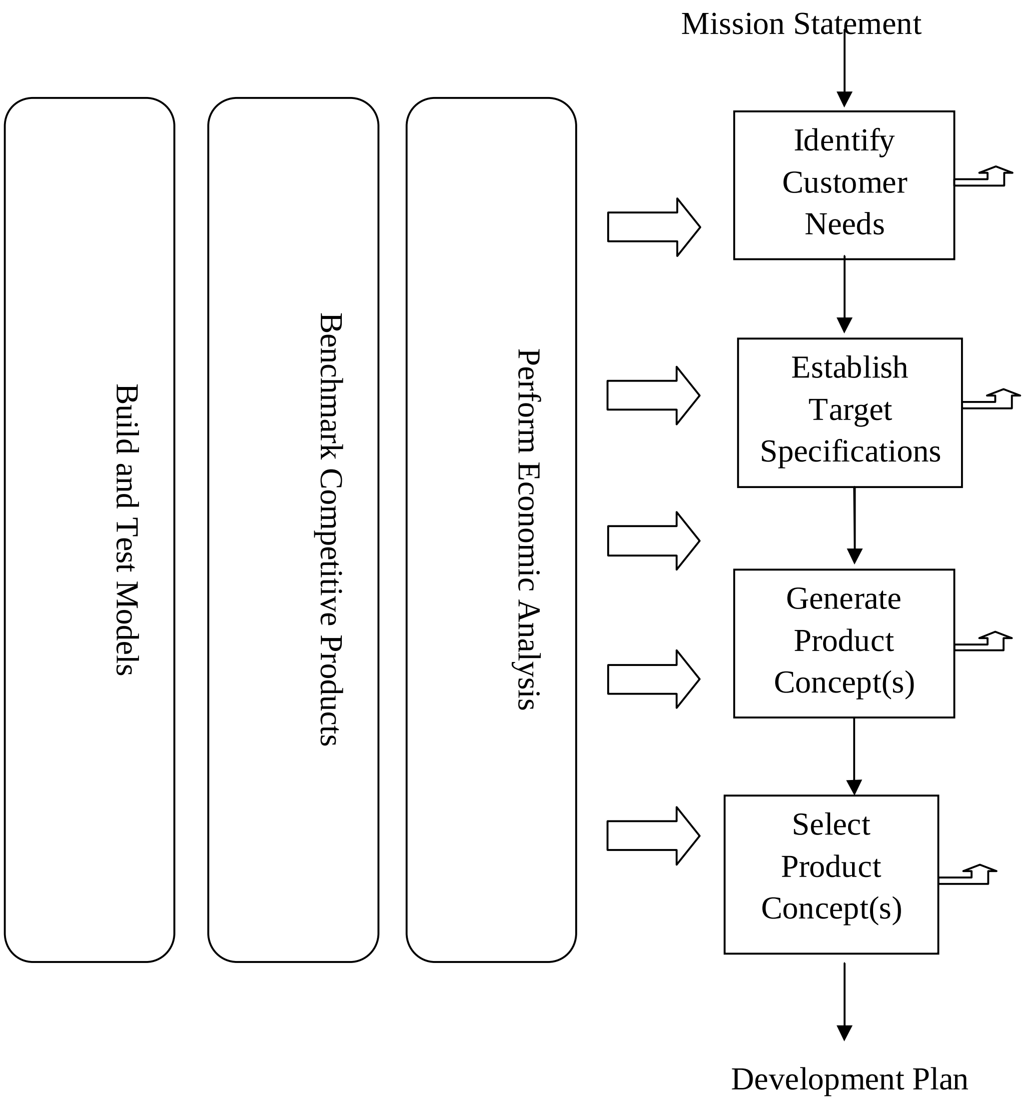

Figure 3.2: The front-end process chart

The project start with the mission target that is the goal of the objective is to understand customers' needs. The process of identifying customer needs by create questionnaire survey to gather raw data from customers. Then, continued with establish target specifications to provide a specifications description of what product has to do. In this project the target specification that need to achieves is the maximum weight and does not interfere with the injury recovery. Next to generate product concept to sketching the product concepts that may address the customer needs. These entire steps are included in the Pugh selection concept. Then, to select product concepts present two method concept selections, although the first method is using Pugh selection method and the second method is using Algor to test the product.

3.4 Material Selection

3.4.1 Titanium

Titanium is a lightweight, strong, nonferrous metal. Titanium wheelchair frames are also tungsten inert gas welded. Titanium is the most exotic of the metals used in production sports wheelchairs, and the most expensive. It requires special tooling and skill to be machined. It has very good mechanical properties and high corrosion resistance, and is resilient to wear and abrasion. A drawback of titanium, besides cost, is its tendency towards brittle fractures once worn or flawed.

3.4.2 Aluminium

Aluminium, a lightweight nonferrous metal, is welded electrically using tungsten, in an inert gas. Sometimes, aluminium tubes are bolted together using lugs (fittings made to match pieces of a joint). Most aluminium wheelchair frames are constructed of round drawn, 6061 aluminium tubing. This material is one of the least expensive and most versatile of the heat treatable aluminium alloys. It has most of the desirable qualities of aluminium, with good mechanical properties and high corrosion resistance, and annealed has good workability. It can be fabricated using most standard techniques. In the T4 condition (solution heat treated, then naturally aged), fairly severe forming operations can be performed. Full T6 properties may be obtained by artificial aging. Aluminium 6061 is available in clad, with a thin surface layer of high purity aluminium to improve appearance and corrosion resistance. Aluminium 6061 is used because of its availability, appearance, corrosion resistance, good strength, and light weight.

Aircraft grade aluminium (SAE 6061): inexpensive, versatile structural aluminium alloy which is corrosion resistant and can be welded easily. Most aluminium wheelchair frames are made of this alloy.

3.4.3 Alloy Steel

Most steel sports wheelchairs are made of chromium-molybdenum alloy (4130 or 4140) seamless tubing, commonly called chro-moly. Chro-moly is one of the most widely used steels because of its weldability and ease of fabrication. Its ability to harden is mild, and it has high resistance to fatigue. A thin section may be heat treated to achieve high strength levels, or nitride treated for increased resistance to wear and abrasion. Chro-moly is usually either tungsten inert gas welded, or brass welded. It has a high strength-to-weight ratio. Commonly, sports chairs are made of tubing 0.028 to 0.035 inches in wall thickness, and diameters of 0.25 to 1.25 inches, depending on the expected load.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

In this chapter, the result data from the research are represented. The result has been presented with the demographic data from the questionnaire that was conducted 35 respondents from the public and result from the conceptual design using Algor and Pugh Selection Concept.

4.2 ANALYSIS OF QUESTIONNAIRE

This questionnaire was distributed to the publics in the university campus. For each question, the respondents had to choose the best answer among the given answer. The questionnaire questions are shown in Appendix.

In this questionnaires, there are 13 questions include objective and suggestion question that ask to the respondents. A relevant questionnaire has been developed for individual interviews about users' needs, the functions demanded of wheelchairs, the environments in which they were used and certain user characteristics.

4.2.1 Analyze Profile of Respondents

From the pie chart in figure 4.1, the respondents' age below 20 years represent 30%, in between 21 – 25 years is 55%, 26 – 30 years is 5% and above than 30 years is 0%. This average age represented the overall student age in Universiti Malaysia Pahang.

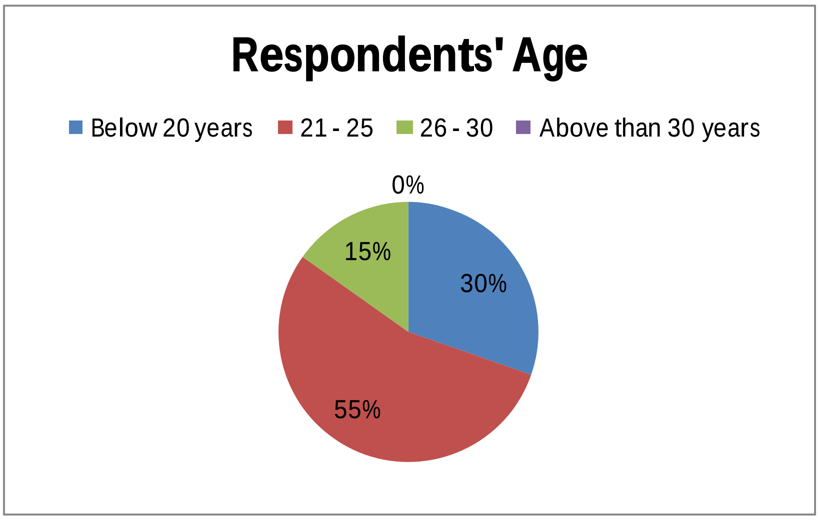

Figure 4.1: Age of respondents'

From the pie chart in figure 4.2, the respondents' race for Malay represent 82% total of the respondents'. While the Chinese and Indian race representing 15% and 3%. The majority students who are take this questionnaire is come from Malay race followed with Chinese and Indian. This shows that more Malay people use wheelchairs or are related to wheelchair users.

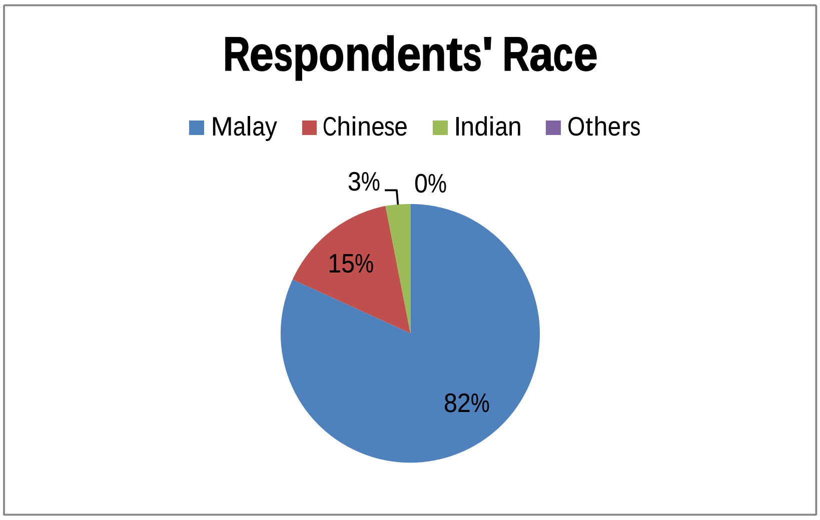

Figure 4.2: Race of respondents'

The major respondents' gender is male represented 88% and the female is 12%. This is because the major gender is give cooperation to do this survey and men are the main respondents had been surveyed. Show it in figure 4.3.

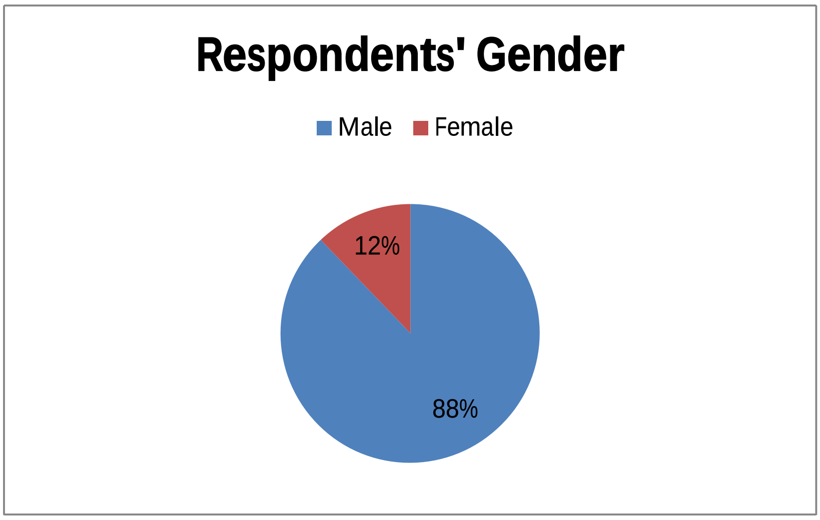

Figure 4.3: Gender of respondents'

4.2.2 Analyze the General Info of Respondents

From this pie chart in figure 4.4, the majority of wheelchair users is close contact 373%, then followed by relative and others respectively with 27% and the last is yourself with 9%. In this survey found close contact is a very large number, this is when involving self in their sports activity find out close friend had ever used. Even though respondents did not have any relationship with wheelchair users, they also must answer the survey because the study is general and to get various opinions.

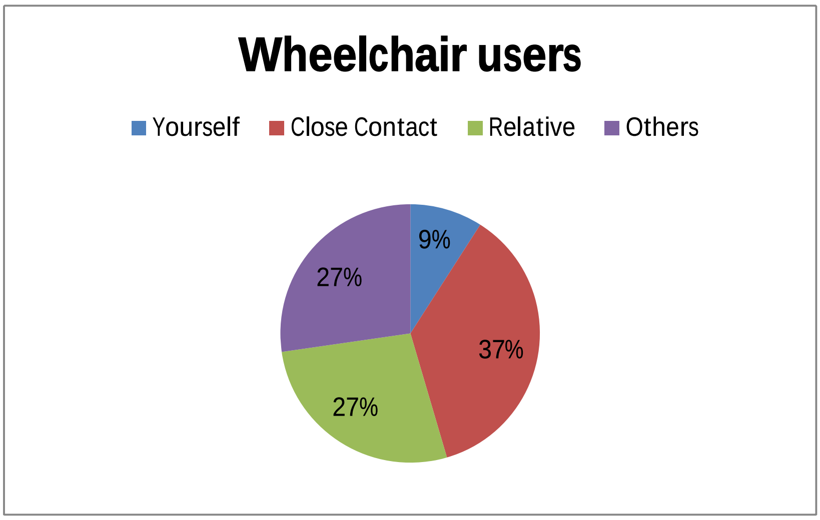

Figure 4.4: The wheelchair users

For this survey, respondents were asked to state the type of wheelchair used. This pie chart in figure 4.5 represented the types of wheelchair that respondents' used. The manual wheelchair is the highest with 88%, followed with electric wheelchair with 9% and the sport wheelchair with 3%. Most of the respondents' are friendly used a manual wheelchair compared to sport and electric wheelchair.

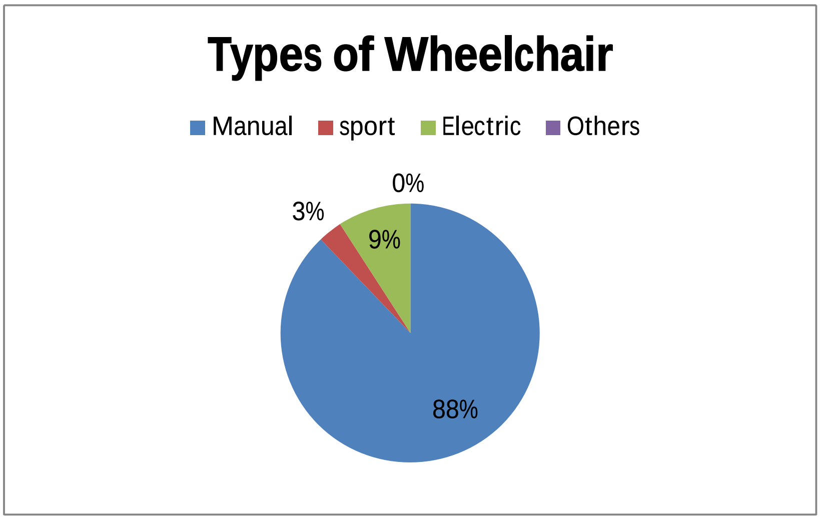

Figure 4.5: Types of wheelchair

From this pie chart in figure 4.6 represented times consume of using a wheelchair, below than 5 years represented with 85%, then others with 12% and the last is 5 – 10 years with 3%. Some of respondents' using for a while for recovery process only compared another time consumes. Even though some of users mark on other because of did not have any relationship with wheelchair users.

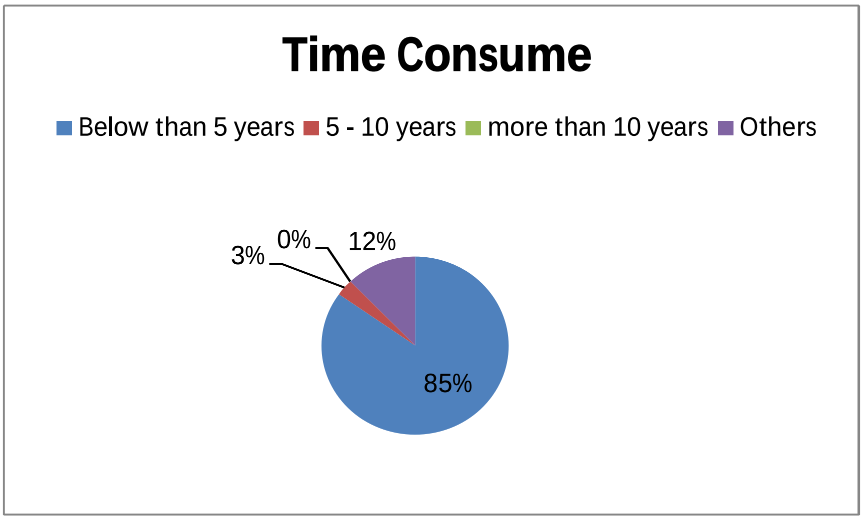

Figure 4.6: Time consume of wheelchair users

4.2.3 Analyze of the Sport and Ergonomic Factor of the Wheelchair

This pie chart in figure 4.7 represented the activities of user take part in at the moment. Basketball represented with 6%, table tennis with 9%, badminton with 9%, athletics with 15%, football with 34% and the last is others with 27%. Most of the students like to play football as their sport activities.

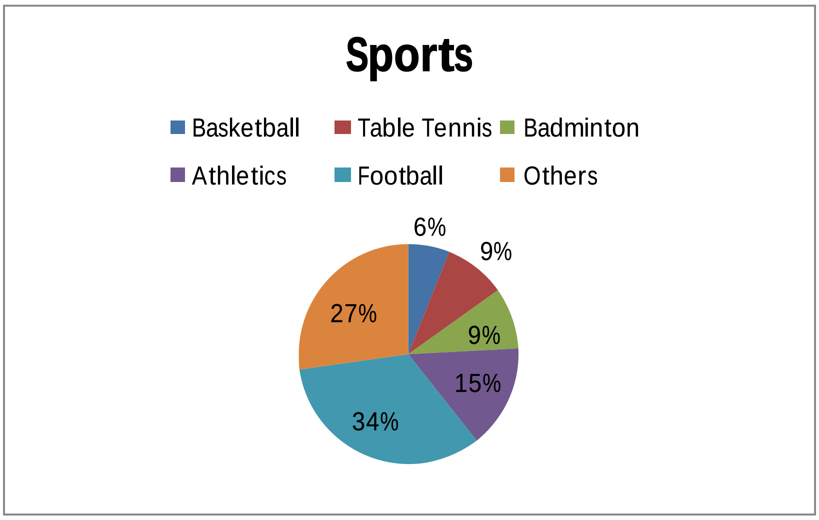

Figure 4.7: The user sport activities

This pie chart in figure 4.8 represented the feel when using a wheelchair will be affect injury recover or not. Many respondents say yes with 67% and say no with 33%. Respondents' are agreed to say that the weakness on the wheelchair that use today are the affect injury recovery when still want continue sport activities.

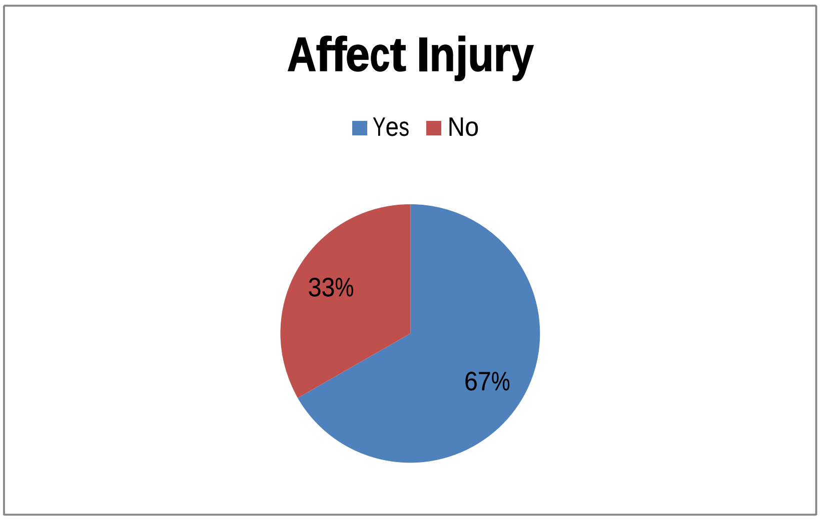

Figure 4.8: The wheelchair users affect injury

This pie chart in figure 4.9 represented the body positions that feel discomfort during using the wheelchair. The highest body position is lower back with 39%, followed with buttock, whole body, and knee respectively with 20%, 18%, and 16% and the last is back of foot with 7%. Respondents' are agreed to say that the discomfort on the wheelchair that use today are the pain on the lower back.

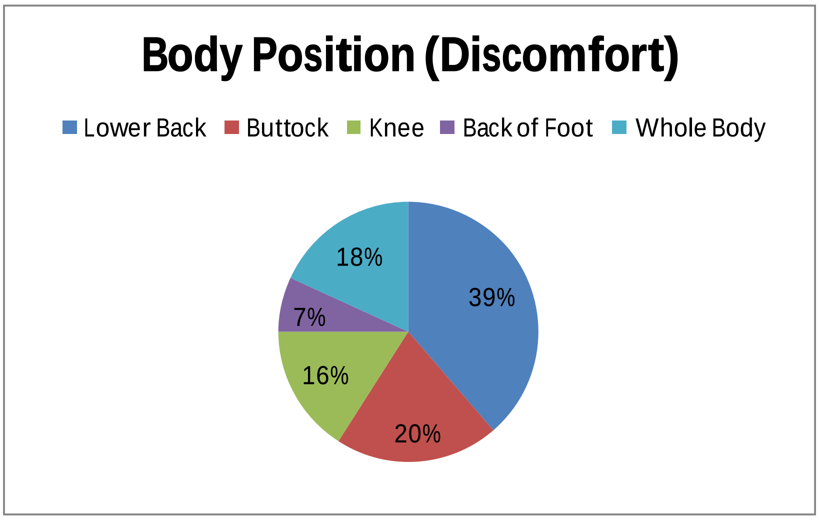

Figure 4.9: The body position (discomfort)

This pie chart in figure 4.10 represented the parts that want to modify. Much respondents says want to modified at the lower back position with 32%, at the buttock with 26%, knee with 21%, whole body with 14% and back of foot with 7%. Respondents' are agree the part of wheelchair need to change or modification is lower back, buttock and knee.

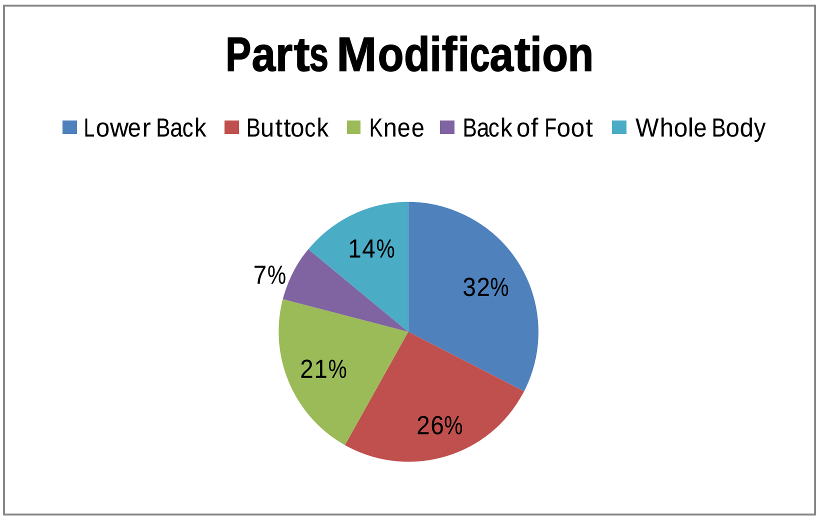

Figure 4.10: The parts modification

This pie chart in figure 4.11 represented how respondents satisfy with the wheelchair that in prepare by hospitals. Most of the respondents says fairly satisfied with 41%, then followed with neutral with 37%, fairly unsatisfied with 13%, extremely satisfied with 6% and the last is very satisfied with 3%. This satisfaction is only for the manual wheelchair that has provides by hospital or clinic.

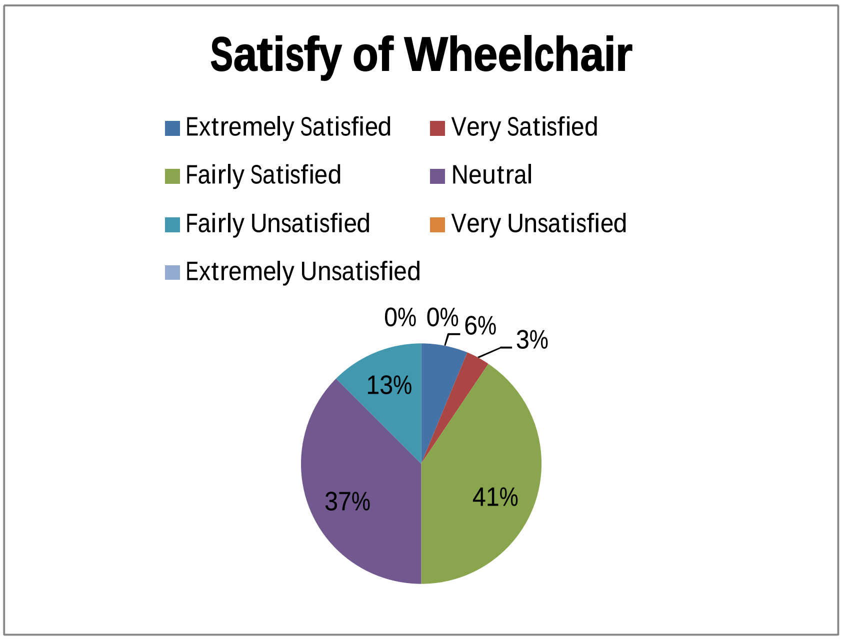

Figure 4.11: The satisfy users of wheelchair

This pie chart in figure 4.12 represented the feel of user about current effectiveness of wheelchair and need to modify or not. Most of respondents says need to modify with 94% and the others say no with 6%. Many of respondents' are agreeing that the manual wheelchair need to modification for the future application.

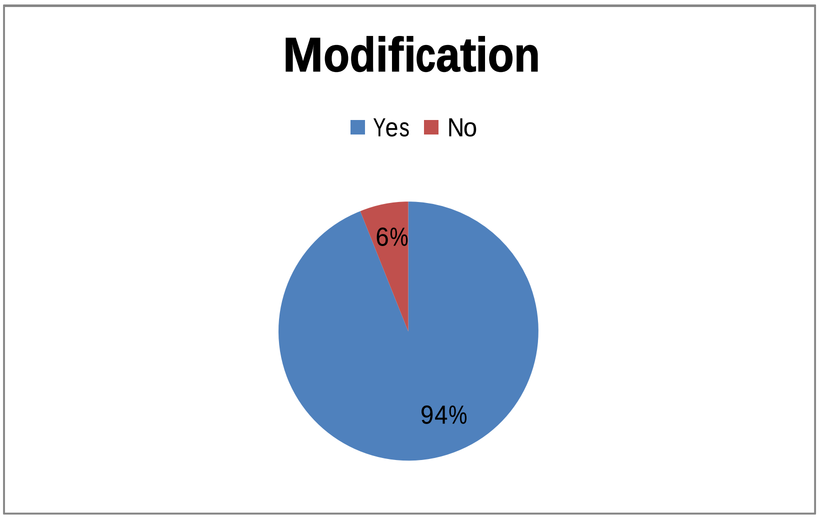

Figure 4.12: The opinion of respondents

4.2.4 Summary from the Questionnaire Analysis and Suggestion

Summary finding from this questionnaire analysis have been survey for 35 respondents due to several analysis consideration which is consisting of analysis profile of respondents, analysis of the wheelchair user, analysis of sport activities of user and analysis of the ergonomic factor of the wheelchair type. Analyze profile of the respondents is asking about general biography information about respondent that concentrate with age, race, and gender of respondents'. Analyze profile of the respondents can be conclude as majority of their age is below 20 years represent 30%, in between 21 – 25 years is 55%, 26 – 30 years is 15% and above than 30 years is 0%. The majority of them are race for Malay represent 88% total of the respondents'. While the Chinese and Indian race representing 15% and 3%. More than haft of the respondents are male (62%) and 38% of female. The major respondents' gender is male represented 88% and the female is 12%.

Analysis of the wheelchair user is asking about the general information of experience about wheelchair users with three questions. It can be conclude that the majority of wheelchair users is close contact 37%, then followed by relative and others respectively with 27% and the last is yourself with 9%. Mostly of the manual wheelchair is the highest with 88%, followed with electric wheelchair with 9% and the sport wheelchair with 3% and the last is 0% of others. The duration of users using the wheelchair that the highest period of usage is below than 5 years represented with 85%, then others with 12% and the last is 5 – 10 years with 3%.

Analysis of the sport and ergonomic factor is asking about the customer need toward their critics and comments on the existing wheelchair. Based on the sport activities, most of the respondents' like to play football 34% compare with others sports like basketball represented with 6%, table tennis with 9%, badminton with 9%, athletics with 15%, and the last is others with 27%. According to the affect injury recover when used the manual wheelchair, the respondents' agree with yes with 67% and say no with 33%. The body position that the respondents' feel discomfort is lower back with 39%, followed with buttock, whole body, and knee respectively with 20%, 18%, and 16% and the last is back of foot with 7%. According to the customer need had been surveyed state that the majority of them suggested the part of wheelchair need to make modification is on the lower back with 32% because of the pain or discomfort on the spine also at the buttock with 26%, knee with 21%, whole body with 14% and back of foot with 7%. Most of the respondents says fairly satisfied with 41%, then followed with neutral with 37%, fairly unsatisfied with 13%, extremely satisfied with 6% and the last is very satisfied with 3%. This is referring to the manual wheelchair that has provided by hospitals and clinics. While most of respondents say need to modify with 94% and the others say no with 6%.

4.3 CONCEPTUAL DESIGN

The design criteria are based on what customer needs on the survey that has done. The criteria customers want on the wheelchair are safety, comfortable, ergonomic, functional and easy to handling. After get the information from the customer needs and brain storming session, a few designs were draw with simple sketching.

4.3.1 Analysis and Metric Development

The design requirement and objectives listed the basis of goals to be achieved in the final design. These goals were determined from the wheelchair user survey mostly from the survey questionnaire. The requirements are then translated to a quantifiable metrics to be applied in the final design. The descriptions of the requirements are as follows:

- ***Comfortable:*** The design is such that the wheelchair user would feel comfortable throughout their usage for daily life activities.
- ***Safety:*** Safety is the most important aspects in wheelchair design. Complete safety considerations for the wheelchair such as there no sharp or rough edges, discomfort features and effect to wheelchair user must be look into during the design stage.
- ***Functionality:*** The design is such that it facilitates of the disability people activities on the daily life activities such as working, sport and other activities.
- ***Ease to handling:*** The design is such that it will not obstruct the movement of the wheelchair user.
- ***Ergonomic:*** Should be provided the user interface related to satisfactory customer and human need consideration through some features likes comfortable seating, easy access to adjustments and other factors.

4.3.2 Concept 1

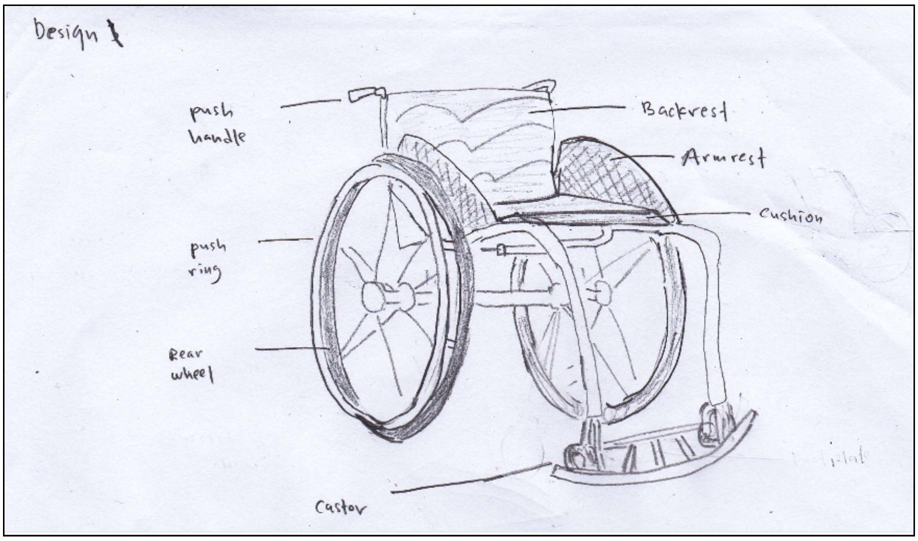

Figure 4.13: Concept 1

Figure 4.13 are shows the concept 1 that the operations functional are design working manual. The camber is design 5^0 to give more stability and lower down the gravity center of wheelchair. Design for cushion is s-shape seating to reduce pressure relief and sliding forward. The suggestion material used in this design is air cushion. Air cushion is the best mechanical performance with regard to the distribution of pressure and contact surface (Gil-Agudo, 2009). Suggestion for caster material is combinations of aluminium or steel with plastic (Bertocci, 1999). Suggestion material for frame wheelchair consists of aluminium, titanium and steel.

4.3.3 Concept 2

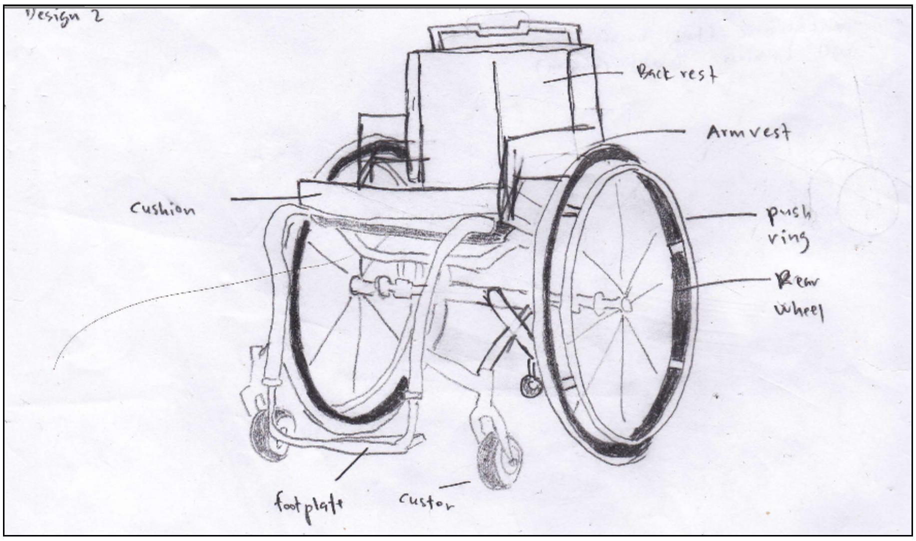

Figure 4.14: Concept 2

Figure 4.14 shows the sketches for the concept 2. The operation functional is using manual operation. Add one caster on the back to give more support of wheelchair. Design the cushion freedom seat (anatomy shape) to fit the curve of back and lower body for a comfortable seat. The air cushion is used in this design that has been suggestion by Gil-Agudo. Suggestion material for frame wheelchair consists of aluminium, titanium and steel. The combination of aluminium or steel with plastic on the caster has been used by referring Bertocci.

4.3.4 Concept 3

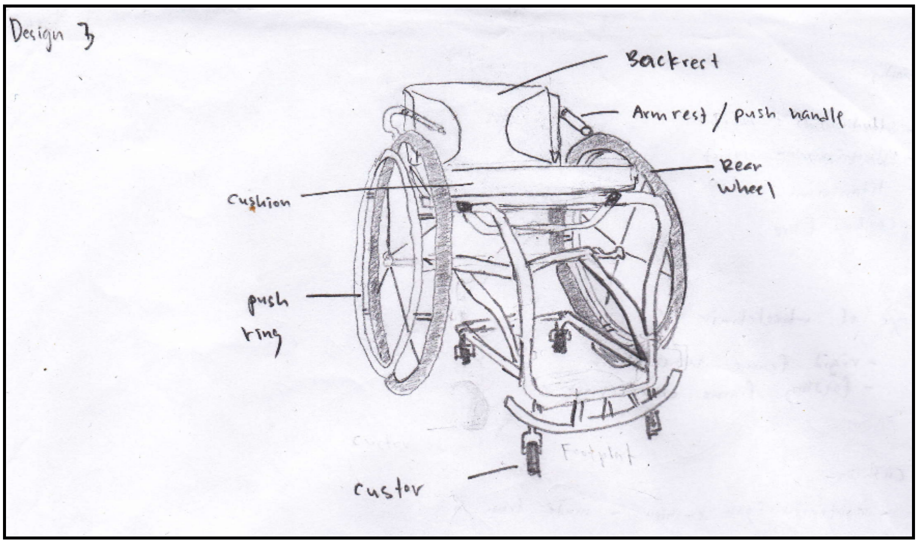

Figure 4.15: Concept 3

Figure 4.15 shows the sketches of concept 3. The operation of this wheelchair is used manual operation. Design the seat with small to give more opportunities for hand-free operation of their wheelchair. The frame design are two times from design 1 (50mm) and add more small caster on the back to give more stability. Design with versatile chamber (5^0) to give more stability. Suggestion material for frame wheelchair consists of aluminium, titanium and steel. The combination of aluminium or steel with plastic on the caster has been used by referring Bertocci.

4.4 CONCEPT SELECTION

In this stage, the concept design selection refers to the Concept Screening and Concept Scoring that was introduced by Stuart Pugh (Pugh, 1990). This method is well-establish selection methods that are common used in industries (Lu, 2008). The selection of three designs will discuss in the next subtopic. Concept selection is a process of choosing the best of concept by using different methods.

4.4.1 Concept Screening

Concept screening is based on the Pugh Matrix. The purposes of this stage are to narrow the number of concepts quickly and to improve the concepts (Ulrich, 2004). Table 4.1 shows the evaluation of concept screening that has been done by referring to the customer needs.

Table 4.1: Concept screening

Selection Criteria	**Concept**			
	Datum	**Design 1**	**Design 2**	**Design 3**
1. Safety	–	0	0	+
2. Comfortable	–	0	0	–
3. Ergonomic	–	0	–	0
4. Functional	+	+	+	+
5. Ease of handling	+	+	+	+
Sum of “+”	**2**	**2**	**2**	**3**
Sum of “ – ”	**3**	**0**	**1**	**1**
Sum of “0”	**0**	**3**	**2**	**1**
Net score	**-1**	**2**	**1**	**2**
Rank	**4**	**1**	**3**	**1**
Continue?	**Combine**	**Yes**	**Combine**	**Yes**

Rate the concept
"+" Better than
"0" Same as
"–" Worse than

After the concept screening, a decision is made to continue the design 1 and design 3 and make a combine design 2 with the datum. Whereas add some ergonomic feature on seating and add more caster at the back of design 2.

4.4.2 Concept Scoring

The concept scoring is similar with concept screening, with an extra column for criteria weights (Lu, 2008). Concept scores are determined by the weight sum of the ratings (Ulrich, 2004). Weighting alternatives for selection is not a new idea. The following is one of the earlier references for using selection matrices with weight (Alger, 1965). The concepts with the highest score are shown in Table 4.2.

Table 4.2: Concept scoring

Selection Criteria	Weight	Concepts					
		1		2		3	
		Rating	Weight Score	Rating	Weight Score	Rating	Weight Score
Safety	22	3	0.66	4	0.88	5	1.0
Comfortable	25	3	0.75	3	0.75	2	0.5
Ergonomic	23	3	0.69	2	0.46	3	0.69
Functional	13	4	0.52	4	0.52	4	0.52
Ease of handling	17	3	0.51	4	0.68	4	0.68

Total score	**3.13**	**3.29**	**3.39**
Rank	**2**	**3**	**1**
Continue?	**No**	**No**	**Yes**

Relative Performance	Rating
Much worse than reference	1
Worse than reference	2
Same as reference	3
Better as reference	4
Much better than reference	5

4.5 DESIGNED WITH SOLIDWORK SOFTWARE

The design criteria are based on what customer needs on the survey that has done. The criteria customers want on the wheelchair are safety, comfortable, ergonomic, functional and easy to handling. After get the information from the customer needs and brain storming session, a few designs were draw with the 3D drawing in SolidWork software.

4.5.1 Design 1 using SolidWork

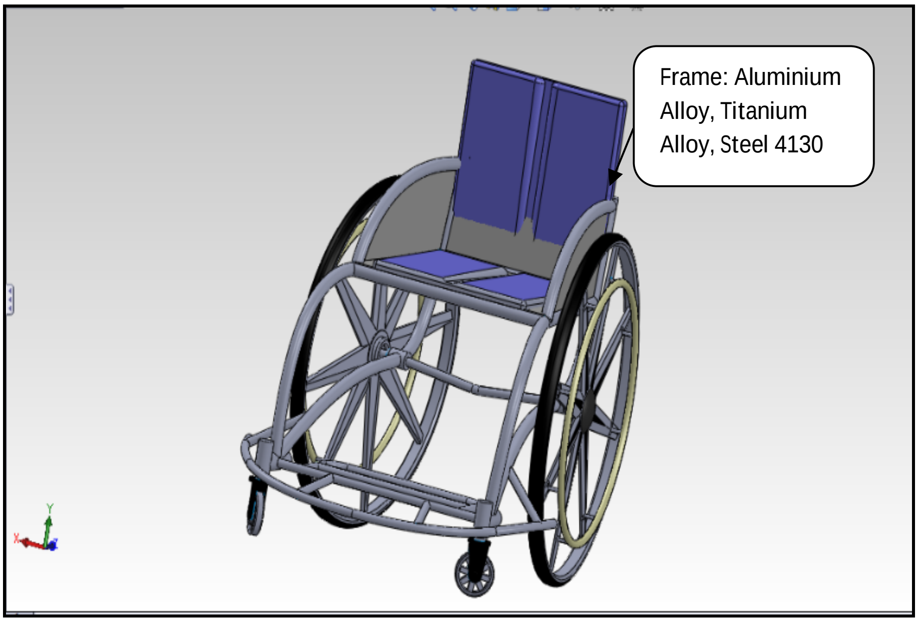

Figure 4.16: Design 1 using solidwork

Figure 4.16 shows the full design 1 using SolidWork. The dimension of the frame is 25mm, the height of wheelchair is 100mm and the width is 110mm. The materials used on frame are aluminium alloy 6061-T6; 6061-T461, titanium alloy (6Al-4V) and Steel (AISI 4130). The operation functional is working manually.

4.5.2 Design 2 using SolidWork

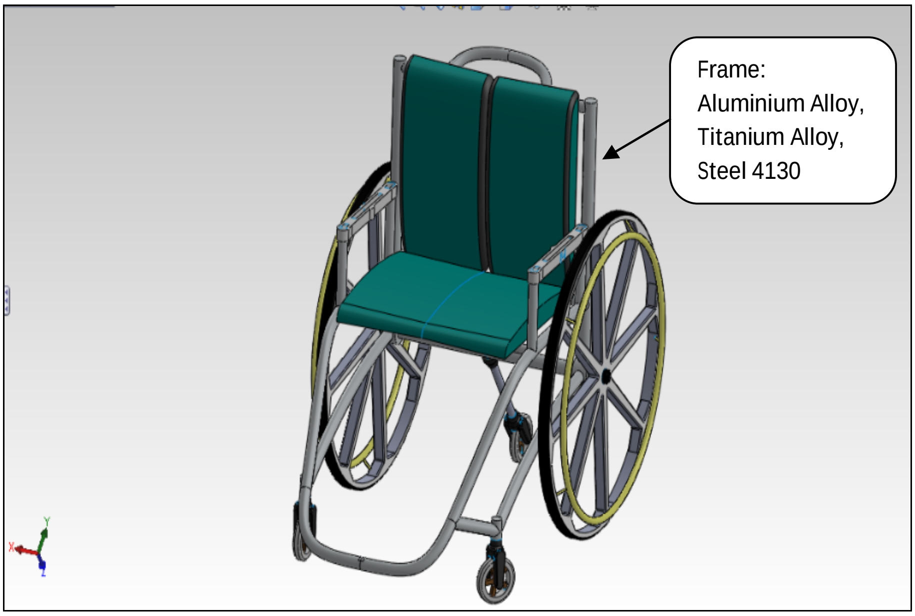

Figure 4.17: Design 2 using solidwork

Figure 4.17 shows the design 2 that has been draw using SolidWork software. The operation functional of wheelchair is working manually. The dimensional of frame is 25 mm, the height of wheelchair is 110mm and the width is 125mm. The materials used on frame are aluminium alloy 6061-T6; 6061-T461, titanium alloy (6Al-4V) and Steel (AISI 4130). The design was added the additional caster at back.

4.5.3 Design 3 using solidwork

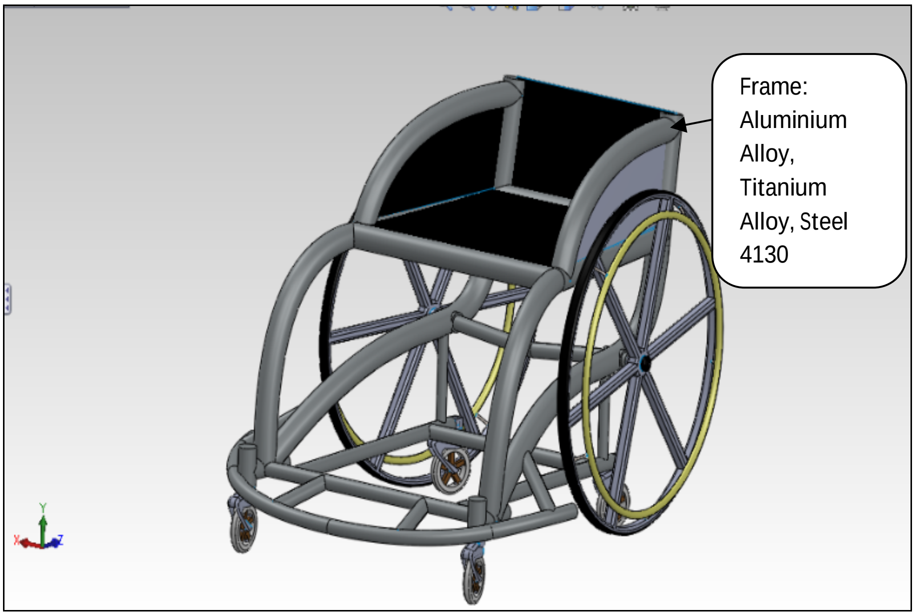

Figure 4.18: Design 3 using SolidWork

Figure 4.18 shows the design 3 that has been done draw using SolidWork software. The operation functional of wheelchair is fully manual. The dimensional frame of wheelchair is 50mm, the height is 100mm and width is 110mm. Add more caster at the back to give more stability. The materials used on frame are aluminium alloy 6061-T6; 6061-T461, titanium alloy (6Al-4V) and Steel (AISI 4130).

4.6 ANALYZE SIMULATION USING FINITE ELEMENT ANALYSIS (ALGOR)

Seating support is the critical part that are analyze on stress analysis to select the best design with the lowest stress von mises. This analysis was performed with three different designs with three different materials to study the impact loading based on static stress with linear finite element analysis.

4.6.1 Stress Distribution for Seating Support (1200N)

This analysis of finite element (FE) linear of the seating support was performed in FE software (ALGOR). Using three different materials into three different designs to study the stress distribution effects on the seating support applied load on the seating area. The target applied force on the wheelchair is 1200N approximately 120kg force on seating support. Suggestion average weight on the wheelchair is 64.8kg (Ikeda, 2008).

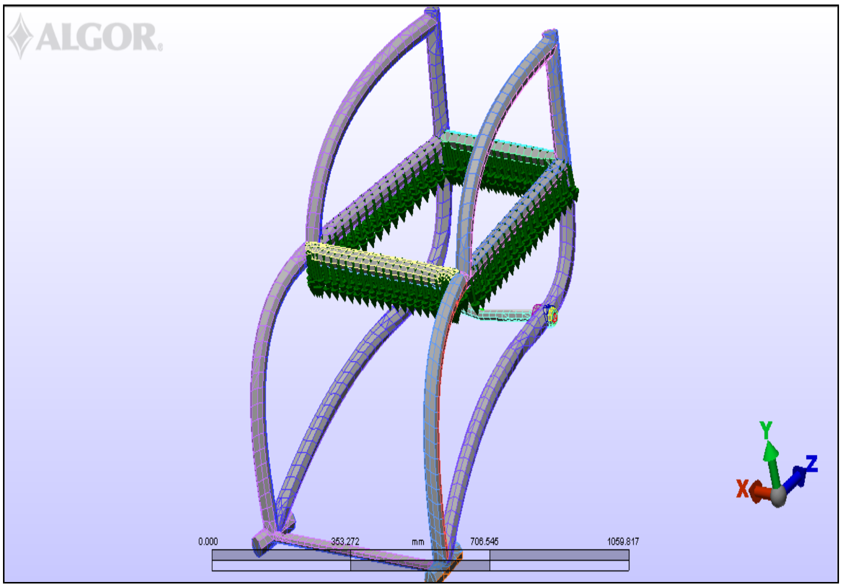

Figure 4.19: Applied Load on Seating Support

4.6.2 Analysis of Seating Support

Next, select the suitable material on the critical part with simulation using Algor. From that analysis, the best selection will be select based on the lowest stress von mises between three designs. From the table, the Steel (AISI 4130) was chosen because the lowest stress von mises on the design 3. Table 4.3 will shows the comparison between three designs with different materials.

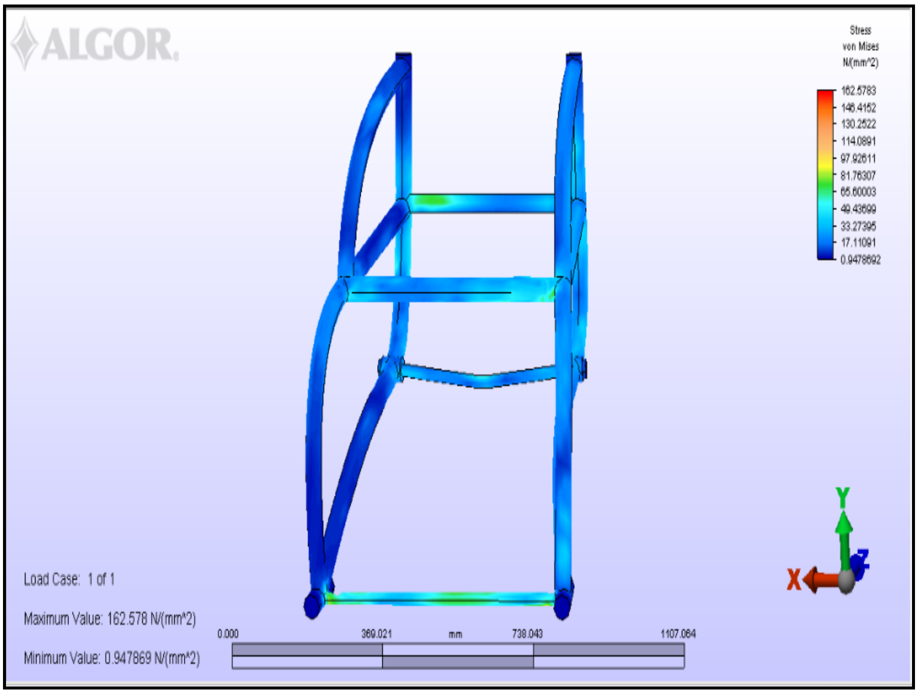

Figure 4.20: Stress von mises of aluminium alloy design 3

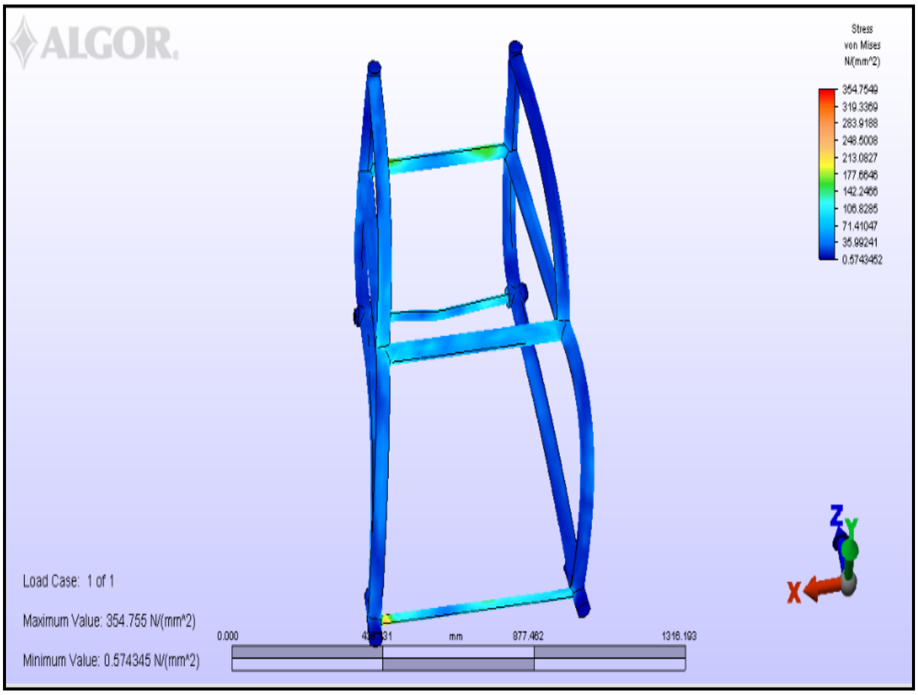

Figure 4.21: Stress von mises of titanium alloy design 3

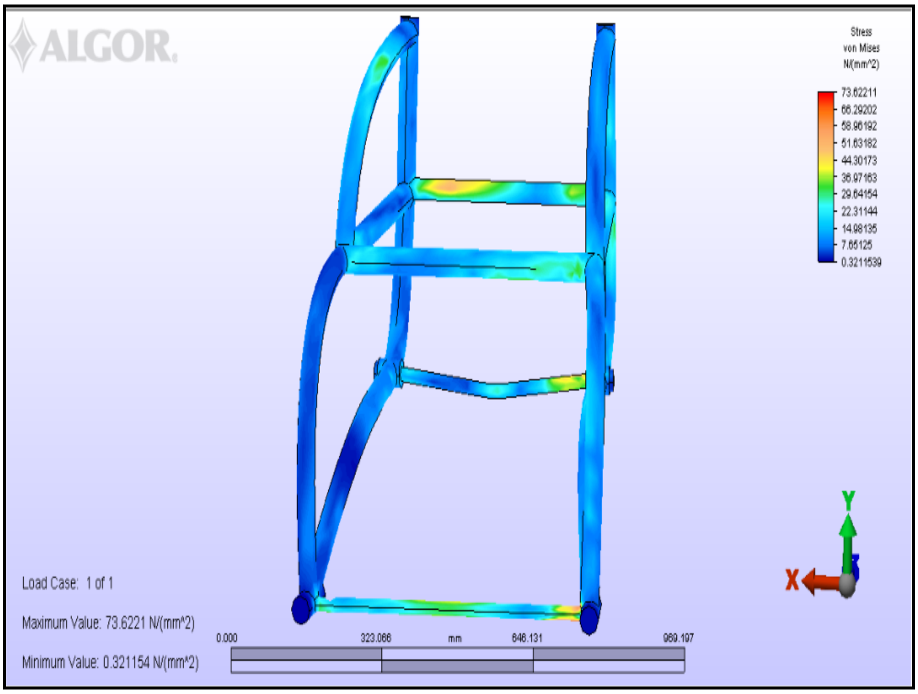

Figure 4.22: Stress von mises of steel design 3

Table 4.3: Comparison between three designs with different materials

	PART 1 (Frame)		
DESIGN MATERIAL	DESIGN 1	DESIGN 2	DESIGN 3
Aluminum Alloy 6061-T6; 6061-T461	4341.31 N/mm^2	916 N/mm^2	162.578 N/mm^2
Titanium Alloy (6Al-4V)	6898.83 N/mm^2	128.25 N/mm^2	354.755 N/mm^2
Steel (AISI 4130)	12926.6 N/mm^2	1683.83 N/mm^2	73.6221 N/mm^2

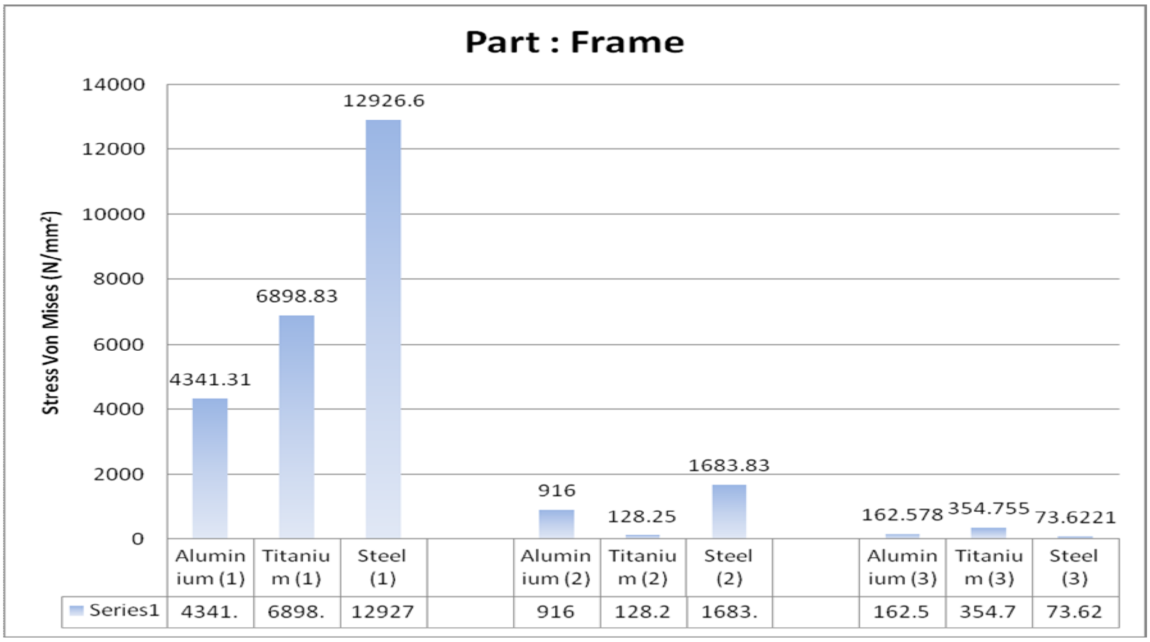

Figure 4.23: Graph comparison between three designs with different materials

4.6.3 Factor of Safety

Based on the analysis using Algor, stress von mises used to find the factor of safety. The stress field produced by FEA is used in conjunction with a conventional limit method to determine the safety factor (Farias, 1998).

The factor of safety is the ratio of the ultimate stress to the allowable stress:

$$F.S. = \sigma_{Ultimate} / \sigma_{von\ mises}$$

UTS aluminium alloy 6061-T6; 6061-T461 = 310 MPa

UTS titanium alloy (6Al-4V) = 950 MPa

UTS steel (AISI 4130) = 670 MPa

Table 4.4: Safety factor of the design

Design / Material	Design 1	Design 2	Design 3
Aluminum Alloy	0.07	0.34	1.91
Titanium Alloy	0.14	7.41	2.68
Steel	0.05	0.40	**9.10**

The factor of safety or the ratio of design with large the stress at a particular point is in comparison to the material's yield stress. A higher ratio is better. The point in the structure that has the lowest safety factor is like the weakest link in a chain – it is the most likely point of failure (Streerter, 2008).

4.7 SUMMARY

On this analysis, three type of material are choose as material for the part and the seating support suggested by Robert Vandermark (Vandermark, 1997). The materials are aluminium alloy 6061-T6; 6061-T461, titanium alloy (6Al-4V) and Steel (AISI 4130). The force are applied to the frame are the total weight that want to achieved of human being are 1200N (120kg) on the seating support. The stress von mises is the total force that acting to the surface area. The maximum stress von mises at design 3 act on the surface on the tube of Aluminium Alloy 6061-T6; 6061-T461 is 162.578 N/mm^2. The maximum value stress von mises at design 3 on the frame of titanium alloy (6Al-4V) is 354.755 N/mm^2. The maximum stress von mises at design 3 on the tube of steel (AISI 4130) is 73.6221 N/mm^2.

Compared between three maximum value of stress von mises, Steel (AISI 4130) is the lowest with the highest safety factor. This meant, the best selection of material is Steel (AISI 4130) for the design 3. The criteria are considered what customer wants on that their survey. Followed the previous research, found that select titanium ultralight rigid wheelchairs had fewer equivalent cycles and less value than select aluminium ultralight and steel wheelchairs, but proper wheelchair manufacturing and design based on the material properties are important (Liu, 2010).

Simulation result shows that the critical point of stress occurred at the seating area. The stress is critical at this point because the boundary condition was applied at that point to calculate the stress von mises. The highlight areas on the stress point are the fatigue failure and it is important to take note this area to reduce the stress magnitude at this point.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

This project was carried out successfully as classified in the objectives. The information to gather through survey had shown those users prefer a wheelchair with structures such as safety, comfortable, ergonomic, functional and easy to handling. Based on this information one of three conceptual designs was chosen. The use of Pugh selection concept to integrate matrix model proved that the selection of design concept at the conceptual stage can be performed. It is clear that use this matrix is a useful method in decision making process. Pugh concept can help the designers to evaluate and select the best design concept based on the criteria aspects of a decision. The support analysis on this project is use a FEA to perform the stress distribution effects on the wheelchair model part. Simulation result shows the magnitude of highest stress is critical because of the value of stress von mises is high. From the design concept selection and analysis using FE linear analysis, the best design can be selected are design 3 using steel (AISI 4130).

The existing wheelchair to optimize the usage for handicap people based on sport factor has been evaluated 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 seating support and make the selection best design based on design concept selection. From the above, the overall objective for this project had been achieved successful.

5.2 RECOMMENDATION

For the future work, the design of wheelchair must be modified and not to complex parts. Used advance Finite Elements Analysis software NASTRAN/PASTRAN, CATIA, and ABAQUS if the models are too complex.

In order to improve more effective and efficiency for manual wheelchair based on sport, adopt the minimal grid consisting of the selection criteria mentioned in the conclusions, i.e., manufacturing materials, pressure distribution quality, interface shape, comfort, stability, and cost. As a fast development now days, the design must consider all factor that will effects to the customer, environment and economic.

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Appendix A: Questionnaire

The main purpose of wheelchair is to support the disabled and make them feel independent walking. A relevant questionnaire has been developed for individual interviews about users' needs, the functions demanded of wheelchairs, the environments in which they were used and certain user characteristics.

Physiological characteristics of wheelchair user:
(*tick √ only one*):

1. Age (Range which in between these years):
   ( ) Below 20 years ( ) 26-30
   ( ) 21 - 25 ( ) above than 30 years
2. Race:
   ( ) Malay ( ) Chinese
   ( ) Indian ( ) Others: _____________ (*Please specific*)
3. Gender:
   ( ) Male ( ) Female

General Info

4. Who usually uses a wheelchair:
   (*Tick √ only one*):
   ( ) Yourself ( ) Relative
   ( ) Close Contact ( ) Other: ___________ (*Please state if you have others*)
5. What type that uses of wheelchair used:
   ( ) Manual Wheelchair ( ) Electrical Wheelchair
   ( ) Sport Wheelchair ( ) Other: ___________ (*Please state if you have others*)
6. How long have you/he/she been using a wheelchair:
   ( ) Below than 5 years ( ) 5 to 10 years
   ( ) More than 10 years ( ) other: ___________ (*Please state if you have others*)

Sport and ergonomic

7. Which of the following activities if any, do you/he/she take part in at the moment? (*tick √ all relevant*):
   ( ) Basketball ( ) Athletics
   ( ) Table tennis ( ) Football
   ( ) Badminton ( ) Others: ________________ (*Please specific*)
8. Do you/he/she feel that when using a wheelchair would affect injury recovery process? (*tick √ only one*);
   ( ) Yes ( ) No
   (Question 9 -10 you can mark more than 1)
9. Which body position did you feel the discomfort during riding the wheelchair? *(Please "O" mark to the number).*
   1. Lower Back
   2. Buttocks
   3. Knees
   4. Back of Foot
   5. Whole-Body
10. Which parts that you want to modified? *(Please "O" mark to the number).*
    1. Lower Back
    2. Buttocks
    3. Knees
    4. Back of Foot
    5. Whole-Body
11. Does you/he/she satisfy using your wheelchair in your current environment? *(Please "O" mark to only one number).*
    1. Extremely Satisfied
    2. Very Satisfied
    3. Fairly Satisfied
    4. Neutral
    5. Fairly Unsatisfied
    6. Very Unsatisfied
    7. Extremely Unsatisfied
12. Do you/he/she feel that the wheelchair are effectiveness and need to modified, (*tick √ only one*);
    ( ) Yes ( ) No
13. Please give any suggestion to improve the wheelchair in term of sports usage;
    ____
    ____
    ____
    ____
    ____
    ____

Thank you for your cooperation.

APPENDIX B1: GANTT CHART FINAL YEAR PROJECT 1

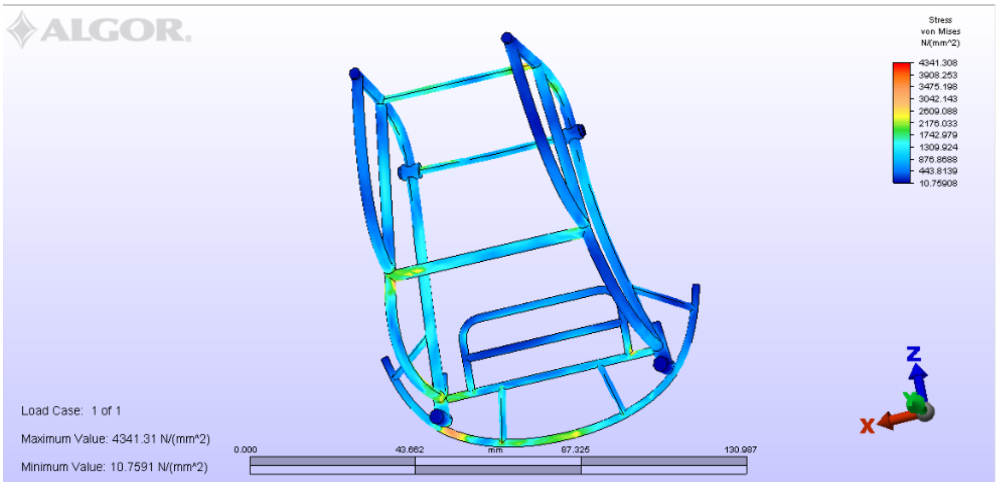
Project Progress		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
1. Get the title project and discuss with supervisor	Planning		■													
	Actual		■													
2. Learning the theory, objective, and get the information about the project	Planning			■	■											
	Actual			■	■											
3. State the objective, scope of project and background of study (Chapter 1)	Planning				■	■										
	Actual				■	■										
4. Writing thesis chapter 1 (Introduction)	Planning					■	■									
	Actual					■	■	■								
5. Build the questionnaire survey	Planning					■	■									
	Actual					■	■									
6. Review study of design and analysis (Chapter 2)	Planning						■	■								
	Actual						■	■	■	■						
7. Review study of handicap people and wheelchair (Chapter 2)	Planning							■	■							
	Actual							■	■	■	■					
8. Writing chapter 2 (Literature review)	Planning								■	■						
	Actual								■	■	■	■	■			
9. Get the data from questionnaire	Planning									■	■					
	Actual									■	■					
10. Writing chapter 3 (Methodology)	Planning											■	■	■		
	Actual											■	■	■		
11. Make a designs of wheelchair	Planning											■	■	■		
	Actual											■	■	■		
12. Submit draft thesis and log book for final year project 1	Planning														■	
	Actual														■	
13. Final year project 1 presentation	Planning															■
	Actual															■

APPENDIX B2: GANTT CHART FINAL YEAR PROJECT 2

Project Progress		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
1. Redesign of wheelchair drawing using SolidWork software	Planning															
	Actual															
2. Analysis the strength using Algor software	Planning															
	Actual															
3. Simulate the prototype by Algor Software	Planning															
	Actual															
4. State the 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. Writing chapter 4(Result and Discussion)	Planning															
	Actual															
8. Make the conclusion and provide suggestion for improvement	Planning															
	Actual															
9. Writing chapter 5 (Conclusion and Recommendation)	Planning															
	Actual															
10. Prepare the proper thesis to submit	Planning															
	Actual															
11. Final year project 2 presentation	Planning															
	Actual															
12. Submit the thesis and log book for final year project 2	Planning															
	Actual															

APPENDIX C1: ANALYSIS OF DESIGN FRAME SUPPORT 1

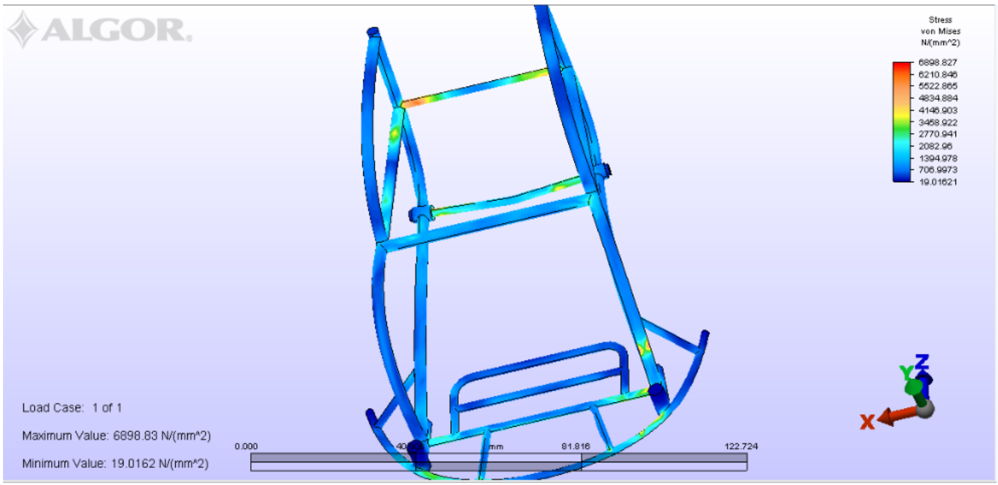
Material 1: Aluminum Alloy 6061-T6; 6061-T461



Stress von Mises;

Maximum value: 4341.31 N/mm^2

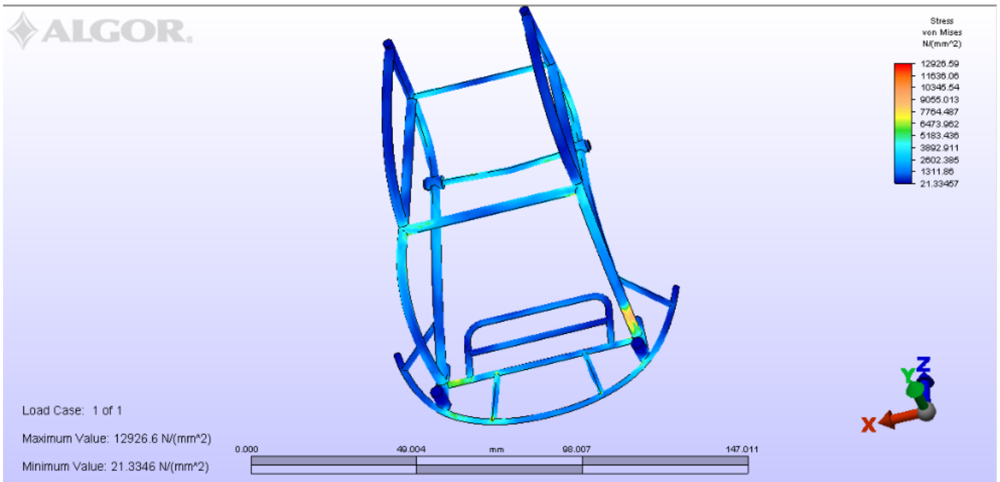
Material 2: Titanium Alloy (6Al-4V)



Stress von Mises;

Maximum value: 6898.83 N/mm^2

Material 3: Steel (AISI 4130)

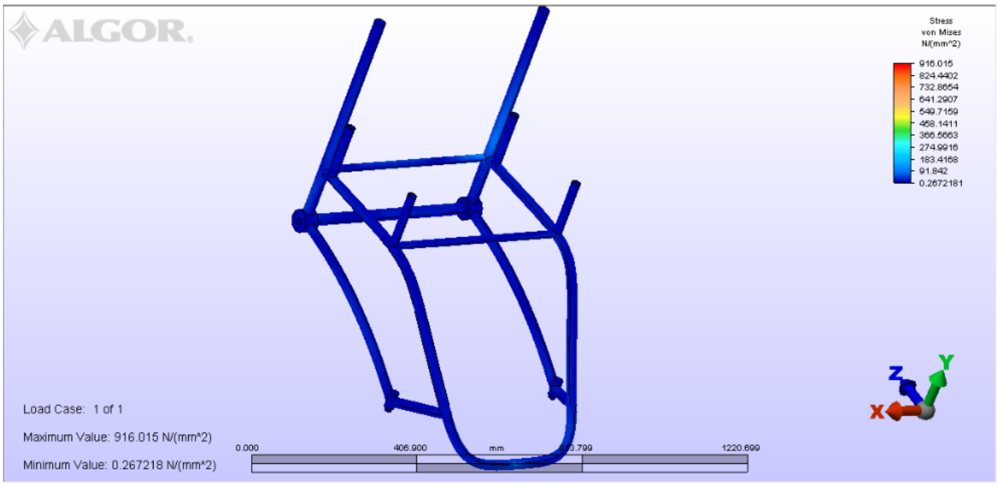


Stress von Mises;

Maximum value: 12926.6 N/mm^2

APPENDIX C2: ANALYSIS OF DESIGN FRAME SUPPORT 2

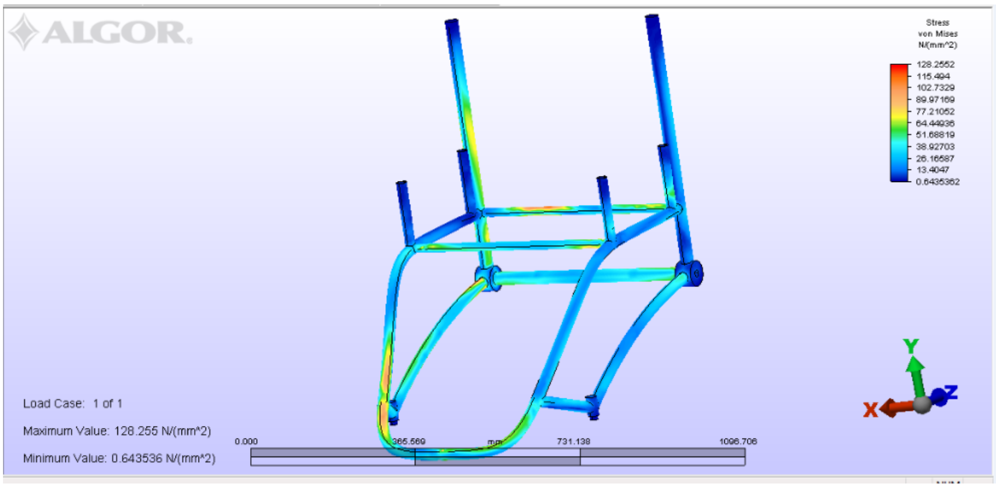
Material 1: Aluminum Alloy 6061-T6; 6061-T461



Stress von Mises;

Maximum value: 916.015 N/mm^2

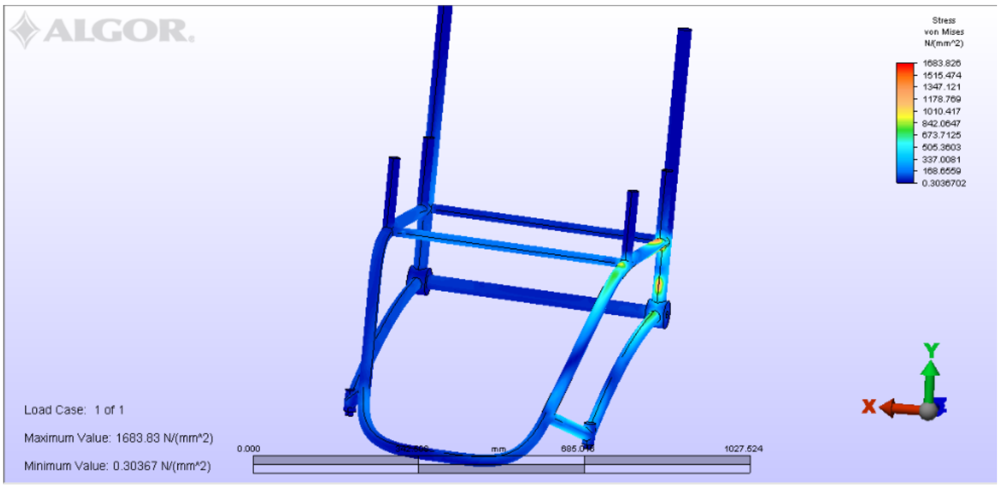
Material 2: Titanium Alloy (6Al-4V)



Stress von Mises;

Maximum value: 128.255 N/mm^2

Material 3: Steel (AISI 4130)

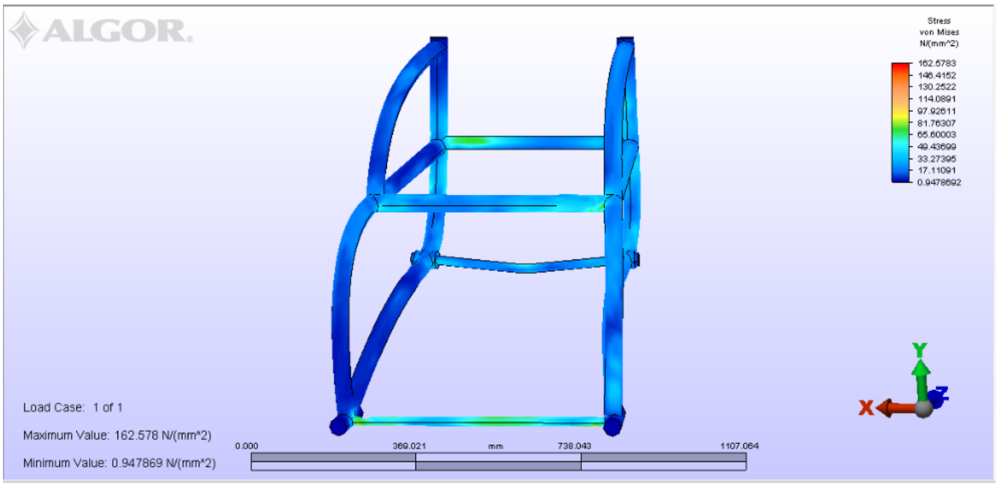


Stress von Mises;

Maximum value: 1683.83 N/mm^2

APPENDIX C3: ANALYSIS OF DESIGN FRAME SUPPORT 3

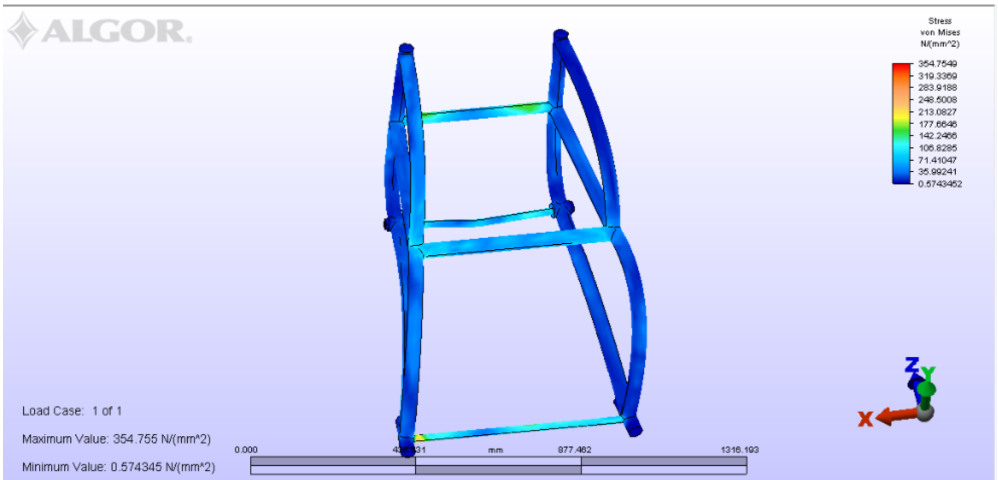
Material 1: Aluminum Alloy 6061-T6; 6061-T461



Stress von Mises;

Maximum value: 162.578 N/mm^2

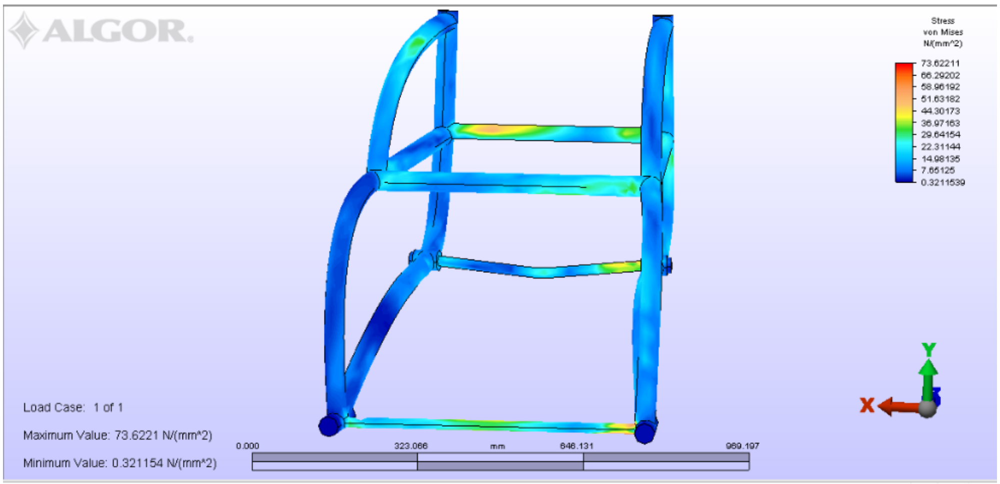
Material 2: Titanium Alloy (6Al-4V)



Stress von Mises;

Maximum value: 354.755 N/mm^2

Material 3: Steel (AISI 4130)



Stress von Mises;

Maximum value: 73.6221 N/mm^2