DESIGN AND ANALYSIS OF WHEELCHAIR IN TERM OF DAILY USAGE

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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)

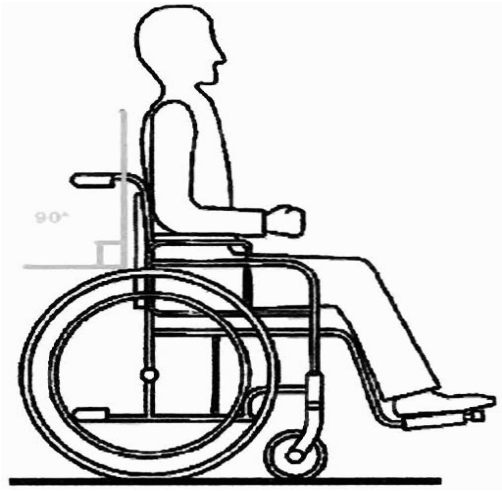

Figure 2.2: Seating position of manual wheelchair

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.