DESIGN AND ANALYSIS OF WHEELCHAIR ACCORDING TO HUMAN FACTOR ENGINEERING

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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 concentrate the use of simulation in analyzing the critical part of the wheelchair modeling and evaluating the wheelchair design based on human factor. 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 have been made and only three have been selected based on the suitability design. Based on the sketches, material needed in this project was listed and suitable design being selected. Next the sketches being draw into SolidWorks software and then go through to simulation process by using FEA tools that is ALGOR software, the design was analyzed using constant force. Improvement of critical parts such as seating support and wheel caster 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. The report writing process will be guided by the Universiti Malaysia Pahang final year report writing guide.

ABSTRAK

Laporan ini dimulakan dengan kajian pendahuluan tentang kejuruteraan faktor manusia dan kajian ergonomik bagi rekabentuk kerusi roda. Objektif utama projek ini adalah untuk menumpukan penggunaan simulasi dalam menganalisis bahagian penting dari model kerusi roda dan menilai reka bentuk kerusi roda berdasarkan faktor manusia. Kemudian mengkaji dengan lebih lanjut mengenai bahagian yang penting dikenakan tekanan pada kerusi roda. Dalam langkah ini, menerapkan pengetahuan yang dikumpulkan dari soal selidik yang digunakan untuk membuat reka bentuk merujuk kepada data kes yang sesuai untuk projek. Beberapa lakaran telah dibuat dan hanya sebilangan yang telah dipilih berdasarkan kesesuaian reka bentuk. Berdasarkan pada lakaran, bahan yang diperlukan dalam projek ini disenaraikan dan reka bentuk yang sesuai dipilih. Kemudian, kesemua lakaran yg dipilih itu dilukis semula di dalam perisian Solidwork bagi mendapatkan lukisan dalam bentuk 3 dimensi sebelum dimasukkan ke dalam program FEA ALGOR untuk proses analisis daya tekanan. Seterusnya, penambahbaikan bahagian penting seperti pelapik tempat duduk dan tayar depan kerusi roda dikaji berdasarkan kekuatan tekanan Von Mises bergantung kepada jenis-jenis bahan yang digunakan dan dipilih mengikut spesifikasi yang terbaik. Akhir sekali, laporan lengkap akan dirangka dan ditulis mengikut garis panduan yang ditetapkan oleh Universiti Malaysia Pahang.

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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 consists of a seat supported on two large wheels on an axle attached towards the back of the seat and two small wheels near the feet. Though there are often small additional features to prevent toppling or to assist mounting curbs. These disable person moves the wheelchair by pushing both the circular bars on the outside of the large wheels with a diameter that is slightly less than that of the wheels or by actuating motors usually with a joystick. Electric powered wheelchairs (EPWs) appear to be evolving faster than manual wheelchairs. Increased computing power, low cost microcontrollers, and a greater variety of sensors have produced a very complex interaction between electric powered wheelchairs and their users (Cooper, 1999). Disabled athletes use streamlined sport wheelchairs for racing, basketball and other sport activities.

Electric wheelchairs can be used as part of adapted sports such as Wheelchair Soccer. Adapting the built environment to make it more accessible to wheelchair users is one of the key campaigns of disability rights movements. There have been several studies conducted using the ANSI/RESNA (American National Standards Institute/Rehabilitation Engineering and Assistive Technology Society of North America) wheelchair standards. The most relevant study was conducted in 1993 when ten different EPWs were tested by the National Rehabilitation Hospital. The National Rehabilitation Hospital tested ten EPWs from seven manufacturers according to the ANSI/RESNA wheelchair standards that were sanctioned in 1990 (Barnicle, 1993). The

results showed that none of the wheelchairs were ideal for every environment and that the advantages of each unit could be carefully considered when choosing an EPW.

Rolling resistance problem is the first thing to overcome to make a wheelchair roll easy. Overall, innovations in vehicle mechanics have changed the specification of the daily use and sports wheelchair dramatically in the light of load reduction, stability and endurance. As indicated in various aspects of wheelchair design and technology have a major impact on rolling resistance (Van der Woude et al., 2001). Drag force is the major opposing force in daily life and heavily influenced by relatively straightforward aspects of 'bicycle technology', such as wheel and tire characteristics, frame design, overall load and other features. The change in frame construction material from the original steel into other materials (aluminum, titanium and carbon fiber reinforced materials, chrome alloy), has had a strong impact on the design, mass, stability, strength and endurance of the wheelchair (Cooper, 1995).

Aspects in the wheelchair itself influencing the maneuverability and rolling resistances are weight, hand rim, camber angle, the seat, back support and castors. The weight of wheelchair and user influence the amount of rolling resistance the user had to overcome. Mass distribution is also an important aspect. The total weight could lie over the rear wheels, yet not as much as causing the wheelchair to tip backwards. An optimal configuration of the wheels is an important factor in overcoming rolling resistance. A larger distance between rear wheels and castors decreases the pressure on the castors, resulting in a lower rolling resistance (Van der Woude et al., 2001). It is also important to prevent toeing in and out of the rear wheels. Another factor is the type of tires around the wheels. Special attention could be given to internal friction of the wheelchair caused by, for example, loose bolts and nuts, sliding joints and non-elastic connections.

1.2 BACKGROUND OF STUDY

Wheelchair consists of mechanical components basically such as the hand rims, armrests, footrests, head supports, castors, seats and backs. The hand rim is an essential part of a wheelchair for it is used to propel, brake, steer, negotiate obstacles and maneuver. Important aspects in finding the optimal power transmission from hand to hand rim are shape, size, diameter, material and profile of the hand rim, anthropometry, squeezing force of the hand, disabilities and special wishes of the user. It could be noted that propelling a wheelchair using hand rims is physiologically the least efficient way of propelling a wheelchair. A large diameter of the hand rim results in a relative high mechanical efficiency and effective force (Veeger et al., 1992). In case of propelling a wheelchair over a long distance, it is energetically favorable to use a hand rim with a smaller diameter. The way of grabbing the hand rim when propelling influences the mechanical efficiency greatly. Also the friction coefficient is of great influence (Van der Woude et al., 1988). It could be as low as possible in order not to brake the wheels while propelling, but it could be high enough to make it possible to transmit a certain amount of power from hand to hand rim. A camber angle has a positive influence on the stability sideways, the power transmission from hand to hand rim and the maneuverability. When using a camber angle, more pressure on the rear wheel axle and the complete wheelchair becomes wider. In general is the camber angle for an Activity Daily Life (ADL) wheelchair 2 to 4 degrees and for a racing wheelchair between 4 and 12 degrees (Van Drongelen et al., 2005)

The most important aspects of the seat of a wheelchair are the horizontal and vertical position of the user, because they greatly influence the energy needed to propel the wheelchair (Kotajarvi et al., 2005). In general it is best to position the centre of mass right above the rear wheel axle (horizontal position). In the vertical direction the user could be positioned in a way that he can just touch the rear wheel axle with his fingertips. The position of the seat influences the accessibility of the hand rim, and therefore the efficiency of power transmission from hand to hand rim and the mechanical efficiency (De Groot et al., 2002).

Castors are sensitive to forces exerted sideways. It can cause them to shimmy. When castors are positioned in a vertical position it is the easiest to make turns. Each user has his own characteristics influencing the efficiency of propelling a wheelchair and his own idea of comfort (Bertocci et al., 1999). These characteristics are age, gender, figure, physical health and disabilities. In general it can be said that wheelchair users don't have much muscle mass in their arms and shoulder girdle, which makes it extra hard to propel a wheelchair. Still, a wheelchair cannot keep a user from being mobile and of his social life.

1.3 PROBLEM STATEMENT

Wheelchair system is one of the common vehicles used by handicap or sick people are limited in its functions, such as it needs human force to move it. It is also can't be use for a long period as the user tired in moving the chair using his or her own energy. Then, the other problem is the existence wheel chair is also not really comfortable as the shape and its position also cannot be fixing to the user's body in getting comfortable seat. This project concerned about the ergonomic factor which is the important element of human factor engineering and consideration of wheelchair design are proposed after overall the criteria is appropriate with this factor. In this project, the priority requirement is to evaluate the human factor engineering of the existing wheel chair. The ergonomic need to adequate in the study of designing objects to be better adapted to the shape of the human body or to correct the user's posture. Wheelchair design could be preventing the user from sitting in positions that may have a detrimental effect on the spine. 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. Before redesign it, researcher need conduct a market survey to collect necessary data to be include in the product.

1.4 OBJECTIVES

The objectives of this thesis are to:

(i) Evaluate the existing wheel chair in terms of human factor engineering.

(ii) Redesign and analyze the product 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) Identify and selected the suitable wheel chair 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 According to Human Factor Engineering". Since the aim of this project is to redesign the wheel chair drawing using SolidWorks software and the suitable software such as ALGOR and other related software. Thus literature review related definition of optimization, 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 OPTIMIZATION

Optimization can be defined as the procedures used to make a system or design as effective or functional as possible, especially the engineering techniques involved. Means that optimization is a process or methodology of making something as a design, system or decision as fully perfect, functional and effective (Van Ryzin et al., 1993). Conclusively, it can be referring as their improvements increased the value of the property.

2.3 WHEELCHAIR

Wheelchair is a mobility device in which the user sits. The device is propelled either manually turning the wheels by the hand or via various automated systems. Wheelchairs are used by people for whom walking is difficult or impossible due to illness like physiological or physical, injury or disability. People with both sitting and walking disability often need to use a wheel bench. The earliest record of wheelchairs dates back to the 6th century, and was found inscribed on a stone slate in China (Simmons et al., 2000).

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 wheelchair is those that require human power to move them. It can be folded for storage or placement into a vehicle, although modern wheelchairs are just as likely to be rigid framed. Obviously, manual wheelchair technology has dramatically improved over the last decades; although the central concept of the most frequently employed hand propelled wheelchair in the western world the hand rim wheelchair has not clearly changed (Simmons et al., 2000). The transfer of the sling-seat chromium plated wheelchair of the 1950s towards the function-specific (all lightweight and high tech material). The majority of these people will use a form of manual wheelchair propulsion. By nature of the use of the upper body and arms, a limited age related fitness, and the impairment itself, a wheelchair confined lifestyle will hamper individual mobility and participation. Wheelchairs as mobility restraints with improving wheelchair skills with targeted intervention programs; along with making wheelchairs more 'user friendly' could result in more wheelchair propulsion with resultant

improvements in the resident's independence, freedom of movement and quality of life (Simmons et al., 2000). Although mobility is an essential element in daily life, its importance is usually only then recognized when it is for some reason as temporarily or limited, as is the case in those who are wheelchair dependent. Research clearly contributed, but many innovations originated initially from sports practice. In the context of mobility, the contemporary hand rim wheelchair has become a task specific, versatile and functional device.

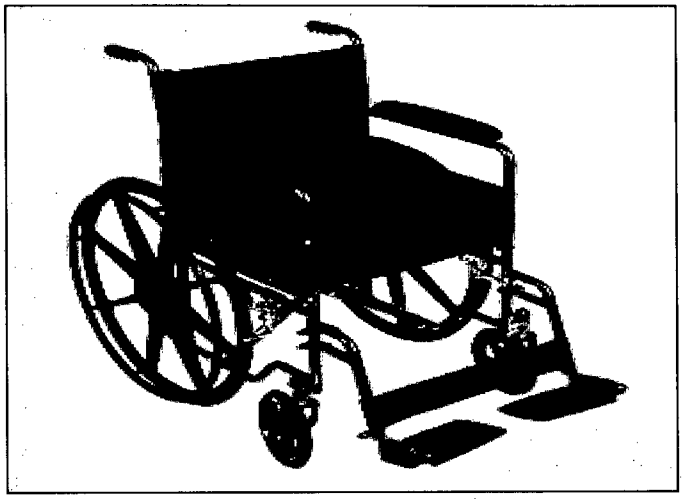

Figure 2.1: Manual wheelchair

Source: Simmons et al. (2000)

2.3.1.2 Electric Powered Wheelchair

Three general styles of Electric Powered Wheel chairs (EPW) exist: rear, center, front wheel driven or four wheels driven. Each style has particular handling characteristics. EPW are also divided by seat type some models resemble manual chairs, with a sling-style seat and frame, where as others have captain's chair seating like that of an automobile. EPW run the gamut from small and portable models, which can be folded or disassembled, to very large and heavy full-featured chairs.

EPW may be designed specifically for indoor use, outdoor use, or both. They are generally prescribed for persons who have difficulty using a manual chair due to arm, hand, shoulder or more general disabling conditions and do not have the leg strength to propel a manual chair with their feet.

The user typically controls speed and direction by operating a joystick on a controller. Many other input devices can be used if the user lacks coordination or the use of the hands or fingers. This controller is the most delicate and usually the most expensive part of the chair. EPW can offer various powered functions such as tilt, recline, leg elevation, seat elevation, others useful or necessary to health and function.

EPWs use electric motors to move the wheels. They are usually powered by 4 or 5 amp deep-cycle rechargeable batteries, similar to those used to power outboard boat engines. These are available in wet or dry options. Currently dry cell batteries are more popular. Many EPW carry an on-board charger which can be plugged into a standard wall outlet older or more portable models may have a separate charger unit.

2.3.1.3 Sport Wheelchair

Disabled athletes use streamlined sport wheelchairs for disabled sports that require speed and agility such as basketball, rugby, tennis and racing. Each wheelchair sport tends to use specific types of wheelchairs and these no longer look like their everyday cousins. They are usually non-folding it's in order to increase solidity, with a pronounced angle for the wheels which provides stability during a sharp turn and made of composite, lightweight materials. Sport wheelchairs are not generally for everyday use and are often a second chair specifically for sport use (Kulig et al., 1998).

A new sport has been developed for power chair users called power chair football or power soccer. It is the only competitive team sport for power chair users. The Federation Internationale de Powerchair Football Associations (FIPFA) governs the sport and is located in Paris, France with country affiliates around the world.

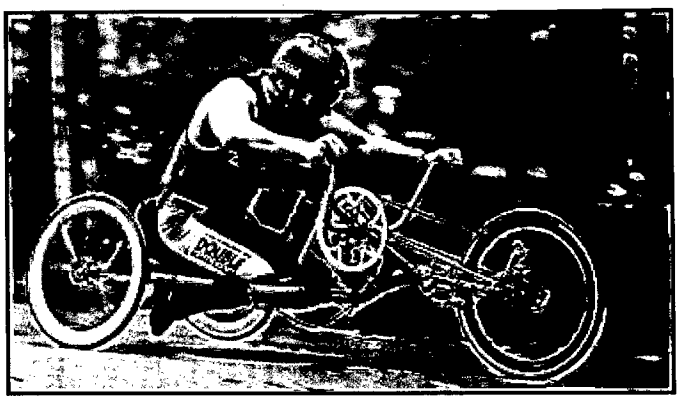

Figure 2.2: Sport wheelchair

Source: Kulig et al. (1998)

2.3.1.4 Cross-braced Folding Wheelchair

The two wheelchairs (Everest & Jennings, Custom Premier, 4203 Earth City Expressway, Earth City, MO 63045) that had used in this study were representative of those commonly used in both hospital and community settings in Figure 2.3 (Deitz and Dudgeon, 1995; Cooper, 1998). The chairs were both cross-braced, folding chairs, each weighing 17.9 kg. They were manually propelled with rear wheel drive, 60cm diameter rear wheels with pneumatic tires, 20cm diameter front casters with solid tires, high mount push to lock wheel brakes, removable desk length armrests, seat rails 48 cm from the floor and swinging detachable footrests with heel loops.

The two wheelchairs were identical except that one had a sling seat while the other had the seat removed as the no-seat condition. They included both conditions because removable solid seating bases that attach to the seat rails are increasingly being prescribed to improve sitting posture and comfort without the sling seat to grasp. The person folding the wheelchair must grasp the seat rails or cross brace to fold the wheelchair. Their chosen not to equip the no-seat wheelchair with a drop seat because they wished to focus specifically on the folding and unfolding skills. The handling of wheelchair parts (e.g., drop seat, modular backrest, and quick-release rear wheels) that sometimes need to be removed to break the wheelchair down into the smallest and

lightest components possible for transportation or storage is sufficiently problematic that were considered it beyond the scope of the current study.

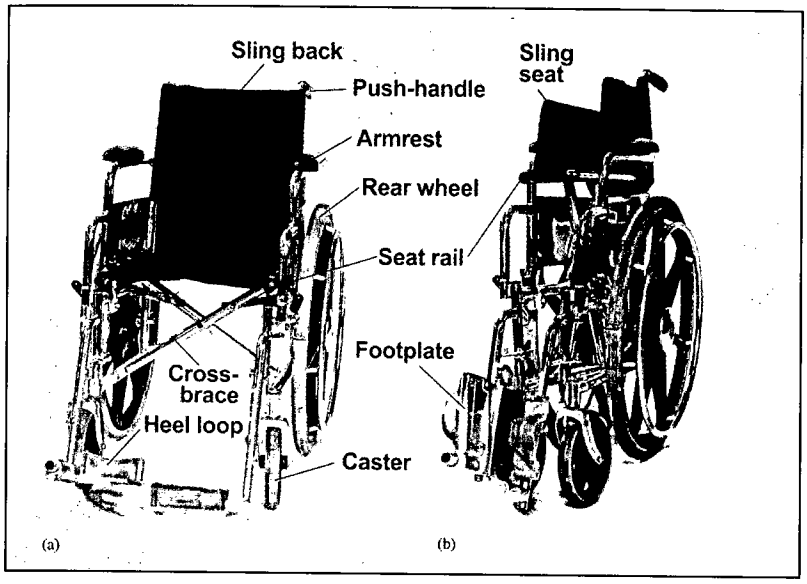

Figure 2.3: Cross-braced wheelchair, open (a) and folded (b)

Source: Deitz and Dudgeon (1995); Cooper (1998)

2.4 ERGONOMICS

Ergonomics is a systematic study of human characteristics and their relationship to the environment, equipment, procedures, facilities and products. Ergonomics aims to avoid any misunderstanding between people and products (Kroemer et al., 1998).

The emphasis in the field of ergonomics is to humans (as opposed to engineering where the emphasis is more on engineering or technical factors). In the U.S. the term ergonomics is generally known as the human factor (Sander and Ernest, 1993). It is closely related to the anthropometric, a branch of ergonomics is concerned with the size, shape and strength of the body (Rosnah and Oon, 1996).

Products that has been created, managed, installed and then to be used by humans. Because humans are an integral part of any product in the engineering, human factors must be thought in the design of a product as early as possible. Thus, designers need to think about the capabilities and limits the overall guide when designing a product. According to Kroemer et al. (1990), ergonomics means: Ergonomics is a discipline for studying human nature and produce a suitable design to life and work environment. The basic purpose of ergonomics is all types of equipment that produced by man, machine, environment and also security need to be adjusted with the man himself.

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).

But sometimes there also has confusion between ergonomics and human factors. According to Sanders and Ernest (1993), the human factor is a term commonly used in the United States and other countries, while the ergonomics are commonly used in Europe. There are some people who try to distinguish the meaning of human factors and ergonomics, but the fact remains the same meaning. Another term used is the human engineering. However, this term is less popular. Finally, the term of engineering psychology is used by some psychologists in the United States. They tried to distinguish the engineering psychology and express it as the ability and limits of human beings. Meanwhile, human factors focused on applications of information in designing a product.

Human factor is focus on the interaction between human and product that be produced, equipment, facilities, procedures and the daily environment. The purpose of human factors is concern to improve the effectiveness and efficiency, increase the value