University of Southern Queensland

Faculty of Health, Engineering & Sciences

Power Assist Add-on for Manual Wheelchairs

A dissertation submitted by

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Abstract

Power assist devices can be a very useful tool for wheelchair users. Through research it was identified that a large issue with manual wheelchairs was difficulty in traveling on certain terrains along with difficulties on inclines, and repetitive strain issues on the body. With the occasional use of a powered device and help maintain better health throughout one's life. That is why it is important to make these devices as accessible as possible for those who desire this technology. The pupose of this project is to design a cost-effective power assist attachment for manual wheelchairs that promotes self-sufficiency for manual wheelchair users, and to gain better understand how a power assist attachment changes the loading conditions of a wheelchair frame. A conceptual design of an electric handcycle was created in an attempt to create a cost-effective and user-friendly method of manual to electric wheelchair conversion. The design provides a solution to this and to further aid in the limitations of movement, and the discomfort and long-term strain damage that comes with long term manual wheelchair propulsion. The concept design stage was semi successful at producing a design with potential for manufacturing.

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Certification of Dissertation

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

Jesse Batterham

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Chapter 1

Introduction

1.1 Background

The role of a wheelchair is to enhance the quality of life for those with difficulties walking. The regaining of independence, and community participation is important to this goal. Though wheelchairs do help enhance the quality of life of those who use them it is important to address the barriers to a person's mobility that still occur with the use of wheelchairs.

Manual wheelchairs are a mobility assistance device that is propelled by the user or can be pushed by another person. Manual wheelchairs have been used for centuries to allow for movement of the mobility impaired. The manual wheelchair is one of the most used assistive devices for improving personal mobility (Armstrong, Borg, Krizack, Lindsley, Mines, Pearlman, Reisinger & Sheldon 2008). There are multiple types of manual wheelchairs that have been developed in order to accommodate the diverse needs of the users. These differences can come in the form of the method used to propel the wheelchair.

The propulsion of the wheelchair is integral in the facilitation of community participation and independence for people with mobility impairments (Cowan, Boninger, Sawatzky, Mazoyer & Cooper 2008). This means that understanding the mechanics of wheelchairs in important in the aim of enhancing one's quality of life. Push rim wheelchairs work through the use of force produced by the motion of one's arms and shoulders when pushing the rim of the rear wheels of the wheelchair (Bourassa, Juarez, McMann, Schwartz & Wood 2019). It is estimated that about 1 % of the world's population in developed countries use wheelchairs and 90 % of those are manual push rim propelled wheelchairs (Flemmer & Flemmer 2016). Being the most common form of propulsion push rim propulsion has been the most studied form of manual wheelchair propulsion. A large number of studies that have been done involve the biomechanics involved in the propulsion. In these studies there is often discussion about the impact that push rim propulsion can have on the health of the users. It has been found that prolonged use of manual wheelchairs have been linked to repetitive strain issues. This was found to be as a result of the repetitive motion that is required to propel the wheelchair (Holloway & Morgado-Ramirez 2017). These issues with push rim manual wheelchairs can result in a reduction of quality of life for the people who use them. Other forms of manual wheelchairs do exist however there has not been that much research into them. The research that has been done however concludes that though in some elements there is a reduction in the negative effects of long-term use, these problems still remain along with added issues such as worse indoor navigation (van der Woude adn Annet J. Dallmeijer, Janssen & Veeger 2001).

Alongside manual wheelchairs there are electrical wheelchairs. Electric powered wheelchairs are based on the traditional manual wheelchair. Electric power wheelchairs however are equipped with power driving devices, batteries, and an electric control system (Wang, Zhao, Hu & Yang 2018). There are three different drive types, front, mid and, rear wheel drive. There is a diverse range of wheel types in electric powered wheelchairs. These wheels can be coupled to the motors through exposed or concealed chains or gear systems (Dudgeon, Deitz & Dimpfel 2014). These different wheel configurations exist to accommodate for the different needs of users. Another area these accommodations happen is in the drive controls. The most common controller designed for electric wheelchairs are joystick controllers but there are others such as switches (Hildebrand 2014).

When it comes to the effects of an electrical form of propulsion it mitigates the effects that occur in manual wheelchair use. Due to the little effort required in electrical wheelchair use, there is no connection to the use of electrical wheelchair use and repetitive strain issues (Kairy, Rushton, Archambault, Pituch, Torkia, Fathi, Stone, Routhier, Forget, Demers, Pineau & d Richard Gourdeau 2014). Though the electric wheelchair does improve aspects of the manual wheelchair there are some ellements that can impact the quality of life of the users. Electrically powered wheelchairs are large and heavy which can make them more difficult to manoeuvre in small spaces and can make it more difficult for vehicular travel (Dudgeon et al. 2014). They can also be costly.

In between the manual wheelchair and electrical wheelchair there are mobility add-ons. Mobility add-ons are an accessory that attaches to a manual wheelchair and is used to help wheelchair users reduce the effort required to propel a wheelchair. The general benefits of this device is that they are able to improve a users ability to navigate rough terrain, and increase distance travelled. There are three main types of power assist attachments being made for manual wheelchairs. There is a front attachment rear attachment, and motorised wheel replacement. These can be further categorised as passive devices, manually powered devices, and power-assist devices. Passive devices typically are something that assists in movement without changing the way in which the chair is propelled, manually powered change the propulsion method into a different form on manual power, and power assist converts the manual wheelchair into an electrical one by adding motors and batteries (Ogilvie 2019).

There has not been much study into mobility-assist attachments. What has been done conclude that like electric wheelchairs, the power attachments have similar benefits in terms of mitigated repetitive stress (Liadis 2006).

When it came to wheelchair propulsion all sources agreed that push-rim manual wheelchair propulsion was problematic. All studies related to this described how repetitive use of one's push-rim manual wheelchair can lead to strain issues in the user's body. They also all described the issues related to navigating rougher terrains and long distances. The literature related to electric wheelchairs discussed how their use helped to mitigate the issue with strain however having their own issues with their weight and size.

There was not much information available in relation to mobility attachments for manual wheelchairs. Most sources discussed their use in aiding manual wheelchair users with propulsion, but none discussed any effect the attachment would have after long term use on the wheelchair such as loading condition. What information there was however did describe that power attachments were beneficial in mitigating repetitive strain issues and help with peoples needs of travelling on harder to navigate areas.

1.2 Outline of Study

The most important element of wheelchairs is of the regaining of independence, and community participation for people with mobility problems. Though for years wheelchairs have been able to help there are still problems with current designs. From the background information it was identified that a large issue with manual wheelchairs was difficulty in travelling on certain terrains along with difficulties on inclines, and repetitive strain. It was found that one solution to this was by using a power system in replace of a mechanical one. A power system provided more force and allowed more users to be able to travel more easily and mitigated repetitive strain. However, powered wheelchairs had the issue of often being too costly and harder to navigate in tighter spaces. From this a need for a cost-effective power device for wheelchairs can be derived.

For this project there will be an investigation into another of the solutions to the issue of manual wheelchairs the power assist attachment. There has not been much research into power assist devices. The current market of power assist devices is costly. This report will work toward designing a power attachment device that is accessible to the wide arrange of wheelchair users. The process of this will involve identifying the main problems associated with wheelchair design and outlining the requirements that need to be met within the design the try and solve these problems.

1.2.1 Dissertation Outline

The dissertation will be outlined as follows:

Chapter 1 (introduction): Information into mobility add-ons alongside the aims and objectives of the report

Chapter 2 (Literature Review): A review of the relevant studies available and an overview of the available Australian standards for wheelchairs.

Chapter 3 (Methodology): An overview of the engineering methodology that will take place for the design a description of the design problems and requirements and relevant information into the testing and evaluation methods.

Chapter 4 (System Design): Conceptual designs of the wheelchair attachment with analysis on effectiveness of problem solution.

Chapter 5 (Finite Element Analysis): Final design will be modelled and, in this chapter, the FEA will take place in order to get the final results.

Chapter 6 (Conclusion and Future Direction): Summary of the results of this dissertation and direction of research, and limitations summarised.

1.3 Project Aim

The ultimate aim of this project is to design a cost-effective power assist attachment for manual wheelchairs that promote self sufficiency for manual wheelchair users. With the identification of the need for a better cost-effective manner of manual wheelchair propulsion this project's purpose will be do investigate the use of current power assist devices and analyse which methods of solution best suit the aim of this project.

1.4 research Objectives

From the aim the following research objectives were formed.

1. Investigation into the current use of wheelchairs and issues faced when using a manual wheelchair.
2. What mobility attachments are available.
3. Review information into the standards relating to wheelchairs and wheelchair add-ons.
4. Determine a design criterion based on the information gathered.
5. Design a prototype that meets the design criteria outlined
6. Model the final design and conduct an FEA testing the presided stress point,
7. Analyse the data and evaluate based upon the design criteria and relevant standards.

Chapter 2

Literature Review

2.1 Introduction

This following chapter reviews and provides background information into literature around manual wheelchairs and power assist attachments for manual wheelchairs. The review will initially aim to provide background into the use, design, and mechanics of manual wheelchairs. As the aim of this project is to design a power assist aid for a manual wheelchair this section will also outline why this project is needed. The review will outline in what situations using this attachment would be needed and what wheelchair users want out of a power assist attachment. Following this there will be a review of the information surrounding the current designs of power assist wheelchair attachments. The literature will review the current designs and usage of the attachments and evaluate the positives and negatives of the current technology. Finally, a number of documents relevant to the design of the power assist wheelchair shall be reviewed including appropriate Australian Standards.

2.2 Manual Wheelchairs

This section aims to investigate the literature relating to the basics of manual wheelchair design and use. Topics covered will include manual wheelchair propulsion and manoeuvrability, and the benefits and issues faced by manual wheelchair users. Manual wheelchairs are a mobility assistance device that is propelled by the user or can be pushed by another person. Manual wheelchairs have been used for centuries to allow for movement of the mobility impaired. The manual wheelchair is one of the most used assistive devices for improving personal mobility (Armstrong, Borg, Krizack, Lindsley, Mines, Pearlman, Reisinger & Sheldon 2008). Flemmer & Flemmer (2016) estimated that about 1 % of the world's population in developed countries use wheelchairs and 90 percent of those are manual push rim propelled wheelchairs. Wheelchair designs can vary greatly accommodate for the diverse needs of the users. The ability to customize or adjust a wheelchair to meet users physical needs will vary. To accommodate for the diversity many wheelchair designs allow for attachments and modifications to be easily made (Armstrong et al. 2008).

The most commonly used manual wheelchair is push-rim propelled. The main parts of the push-rim manual wheelchair are shown below in figure 2.1.

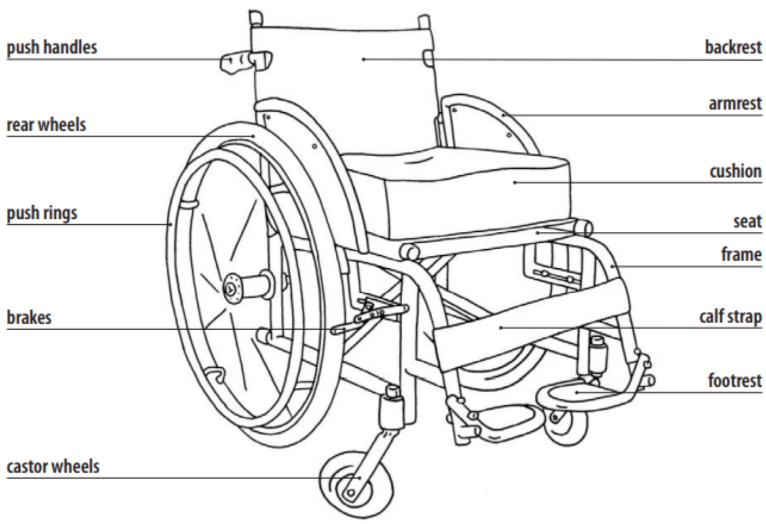

Figure 2.1: Diagram labelling the components of a push rim manual wheelchair (Armstrong et al. 2008).

The most used manual wheelchairs are collapsible push-rim wheelchairs, for their ease of use and better travel capabilities (Bourassa, Juarez, McMann, Schwartz & Wood 2019).

2.2.1 Manual wheelchair propulsion and manoeuvrability

Cowan, Boninger, Sawatzky, Mazoyer & Cooper (2008) describes wheelchair propulsion as a form of mobility that can facilitate community participation and functional independence for people with mobility impairments. To accommodate for diversity of needs there are a variety of propulsion methods for manual wheelchairs. Wheelchair biometrics is the study of the ways in which wheelchair user powers the wheels for propulsion. This propulsion is usually measured in laboratories using stationary ergometers, roller systems or treadmills (Flemmer & Flemmer 2016). There are many other factors that can affect the components on the effectiveness of the propulsion method including an injury, the environment, and the fitness level of the user. The results to measure propulsion of a wheelchair is often talked about in order of mechanical efficiency. As mentioned previously the most common form of propulsion is the push-rim. Other forms of manual propulsion include hub crank propulsion, and lever propulsion.

2.2.2 Push rim propultion

Cowan et al. (2008) describes wheelchair propulsion as a form of mobility that can facilitate community participation and functional independence for people with mobility impairments. In a study by Misch, Huang & Springle (2020), into energy loss during wheelchair propulsion describes that the motion that the range of motion of wheelchairs can be broken down into three aspects. Straight movement, fixed wheel turn, and zero-radius turns as shown in figure 2.2. The study explains that these movements will rarely be individually performed but rather consists of bouts of combinations of these motions. These motions were simplified this report in order to examine the motion loss in wheelchair use.

In a report on alternates to wheelchair propulsion Bourassa et al. (2019) review the information on the mechanics of the body during hand rim propulsion. During wheelchair propulsion Bourassa et al. (2019) explain that the motion of the arms, shoulders, and chest are what is used to create the force that pushes the wheels. The typical push rim propulsion cycle is broken into a working phase, when the force is applied, and a rest phase, when the arms release the wheel and return to the original position. This cycle combined takes one second.

Rice (2010) explains the population from a more biomechanical view. In this report it states that when manual wheelchair users move, they are will often be propelling forces routinely over 70 Newtons. All of this combined leads to the propulsion of push-rim manual wheelchairs having a very low manual efficiency. Flemmer & Flemmer (2016) discuss how having this low mechanical efficiency can lead to even the more physically strong users can have difficulty travelling up ramps and on rough surfaces. This results

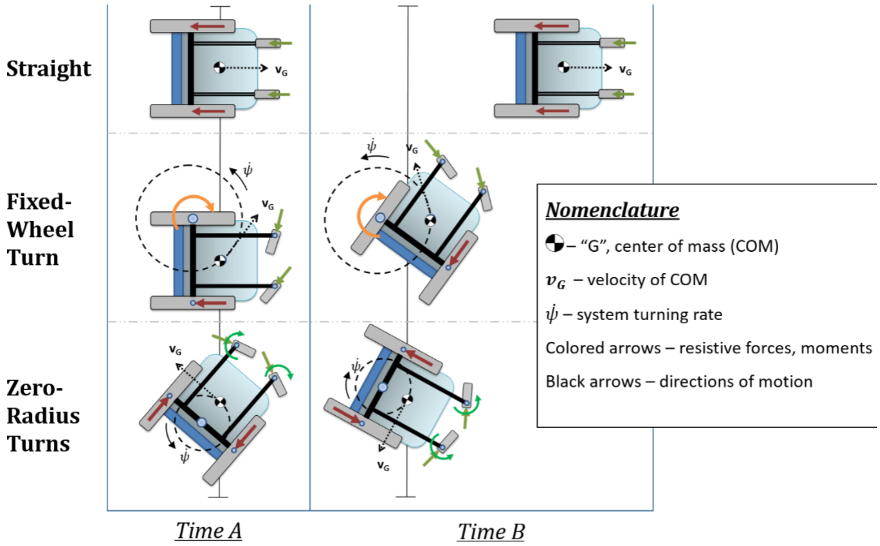

Figure 2.2: Graphical depictions of the 'canonical maneuvers' used to embody the most common features of MWC motion. (Misch et al. 2020)).

in the push-rim mechanical wheelchair ultimately only being beneficial at travelling in indoor spaces.

2.2.3 Hub Crank Propulsion

An alternative to push-rim propulsion is a hub crank. Hub cranks consist of two cranks connected to the wheel hub that allows the hands to move continuously around the hub of the wheel. Compared to the push-rim which requires the force to be applied in stages the hub crank provides a steady force to be exerted of the wheels.

Hub cranks are not a widely used form of manual wheelchairs propulsion. van der Woude adn Annet J. Dallmeijer, Janssen & Veeger (2001) states that the main use of the hub crank is in racing and athletics in the 1980s. In this study they found that the hub crank wheelchair had greater mechanical efficiency than that of the push-rim. They found that at that time there was a difference of about 4.6% (7.6%vs. 12.2%) between the chairs tested. In the report the linked most of this difference to of mechanical efficiency to the propulsion technique. They continue in saying that the continuous circular motion reduces the idle period compared to that of the push-rim. The continuous motion was found to better spread the load of power transfer over more muscle groups and thus reduced the amount of work per unit muscle mass. However, compares to the push-rim manual wheelchair was found to not be as practical. Users don't find It practical for everyday use and also lists hub cranks as being harder to steer and of having a more complicated breaking method. There hasn't been much study into the hub crank style of manual wheelchair outside of that performed by van der Woude adn Annet J. Dallmeijer et al. (2001).

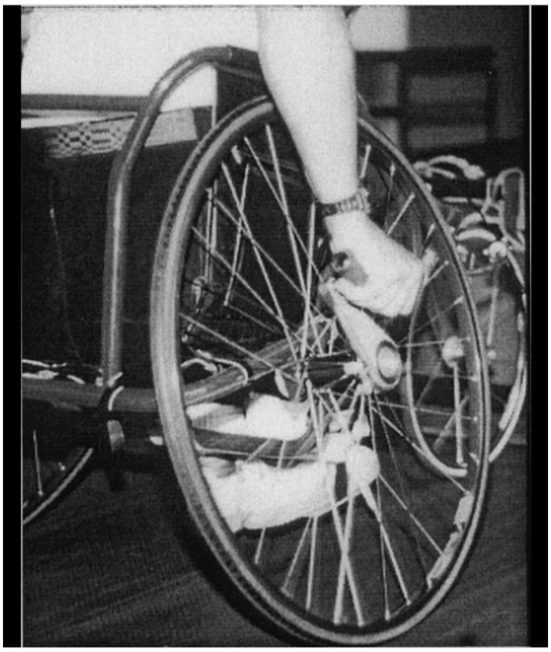

Figure 2.3: Hubcrank use in a racing wheelchair on a motor-driven treadmill (van der Woude adn Annet J. Dallmeijer et al. 2001).

2.2.4 Lever Propulsion

lever propulsion involves the hands pushing a lever in synchronous and asynchronous way working in a perpendicular plane vertical to the user. The force produced by this is what moves the wheels. Flemmer & Flemmer (2016) in their review of manual wheelchairs that there are two main types of lever propulsion that are on the market. One of the designs has the lever fitted directly to the push-rim of a standard manual wheelchair. They explain that this style of lever is mainly to the benefit of those who lack the dexterity to grip a normal push-rim. This type of push-rim was generally found to have a 3% better mechanical efficiency than that of the push-rim. The other type was the ergonomic hand drive (EHDM) that uses a cam pawl and ratchet mechanism that engages with thy tyre for the push stroke and disengages for the recovery phase. In this review it was found that users preferred this style of propulsion compared to the push-rim but the EHDM was found to have a lower mechanical efficiency. Even with this both forms of lever propulsion were found to be better at navigating outdoor environments when compared to the push-rim.

Bourassa et al. (2019) found that as was also discussed by Flemmer & Flemmer (2016) lever propulsion has a 3% greater efficiency that of a push-rim. This was found to be as a result of the forward motion generated through the push-pull mechanism of the front of the body rather than reaching horizontally to rotate the wheels to propel forward. Compared to push-rim propulsion as the force is closer to the centre of the shoulders it reduces the torque in the shoulder. There hasn't been that much information into the lever propultion style of manual wheelchair propulsion beyond those explored within this section. With this however in the in Flemmer & Flemmer (2016) review on manual wheelchair it discusses an increase of commercially available lever style of wheelchairs at the time of the study.

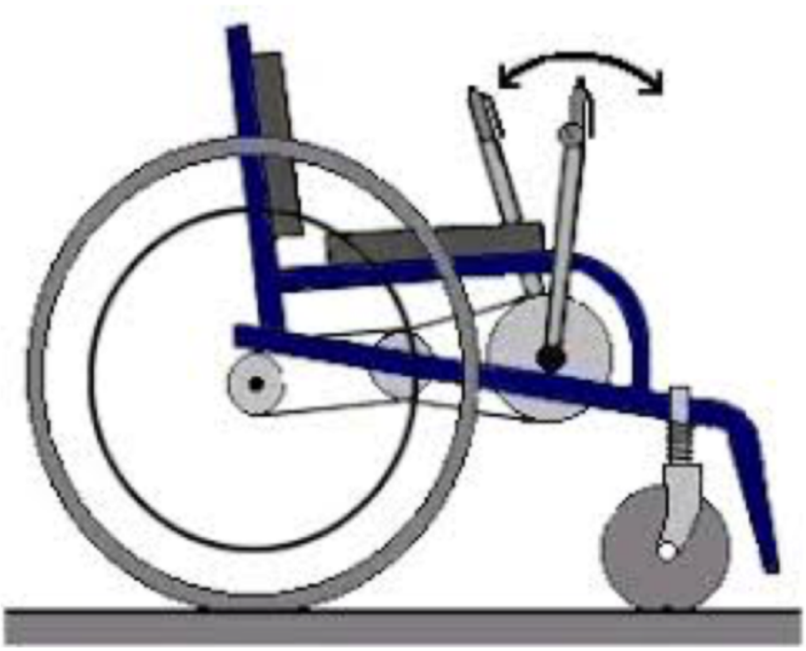

Figure 2.4: Drive Mechanism of a Lever Propelled Wheelchair (Bourassa et al. 2019).

2.2.5 Crank Propulsion

Crank-propelled manual wheelchairs or handcycles, use bicycle propulsion technology (sprocket, chain, gearing, handles, and pedals) to propel a manual wheelchair. For the crank-propelled wheelchair the handles work as the peddles and allows the user to pedal the wheelchair using their hands. Flemmer & Flemmer (2016) states that there are two types of handcycle, one that is designed into the chair and one that is an attachment to an existing push-rim chair. They describe that most commonly the handcycles are front wheel driven but some, that are mostly used for track sport are rear-wheel driven. van der Woude adn Annet J. Dallmeijer et al. (2001) and Flemmer & Flemmer (2016) both found that the mechanical efficiency of handcycle wheelchairs to be around 11-15% meaning it has a greater mechanical efficiency compared to that of the push-rim. Both of these reports also mentioned that the handcycle was one of the most popular manual propulsion outside of push-rim but is still often not regularly used due to it not being very appropriate for indoor use.

Figure 2.5: Dragonfly handcycle attachment mechanism (Dragonfly 2008).

2.2.6 Benefits and Negatives of Manual Wheelchair Use

Manual wheelchairs have been found to have more benefits than just mobility. *Can Physical Activity Improve the Health of Wheelchair Users? A Systematic Review* (2019) in a review into the benefit of wheelchair user's physical health has found they provide a way for users to perform some level of aerobic exercise. *Can Physical Activity Improve the Health of Wheelchair Users? A Systematic Review* (2019) explains that aerobic exercise is well known to have many health benefits and an improved sense of well-being. As discussed throughout the discussion of manual wheelchair propulsion many of the styles of manoeuvrability have been used for sporting activities. The hand cycle especially has been advertised as a way for manual wheelchair users to outdoor exercise. Bhambhani (2002) in a study about the physiology in wheelchair racing describes the testing methods that are don to characterise the wheelchair user's aerobic and anaerobic fitness. These tests included taking measurements of oxygen uptake, heart rate, push frequency and the oxygen uptake per distance travelled. All the studies discussed have indicated that manual wheelchair propulsion is beneficial to the physical health of wheelchair but the degree will depend because of the range of disabilities found in manual wheelchair users.

Though manual wheelchairs have been found to help in some health areas studies have found that there have been more negative health implications of long-term manual wheelchair use. Holloway & Morgado-Ramirez (2017) in a study into power assist devices for manual wheelchairs discussed that one of the main health issues faced by those who use manual wheelchairs are repetitive strain issues, usually in the shoulders. The report suggests that this is from the repetitive motion that is required to propel a manual wheelchair. Bourassa et al. (2019) describe this pain as coming from the difference in the effective force angle and the actual force direction. When people propel themselves, a downward and forward force is applied. Only the component of the force tangential to the wheel, about 40 percent of the total propulsion torque contributes to propelling the wheel. The repetitive high force that is applied is the main cause of carpal tunnel syndrome in wheelchair users. In the shoulders and joint, similar strains are produced.

Other issues are that Holloway & Morgado-Ramirez (2017) discussed manual wheelchair users will often require assistance in getting around as strength is needed to propel oneself. There is also the disadvantage of finding it more difficult for travelling long distance and in climbing inclines. Cooper, Quatrano, Axelson, Harlan, Stineman, Franklin, Krause, Bach, Chambers, Chao, Alexander & Painter (1999) in a study into the health among people with disabilities went into further detail and explained the linked manual wheelchair use to various upper limb disorders such as, rotator cuff tendonitis, cubital tunnel, and carpal tunnel neuropathies. Medola, Elui & Santana (2014) in a study on the ergonomics of wheelchairs found that though manual wheelchairs are meant to be an assistive device they have been cited by many users as the main factor in the reduction of their community participation. Medola et al. (2014) and Misch et al. (2020) state that manual wheelchair propulsion exposes the upper limbs to a harmful combination of load and repetition, which can lead to the health issues discussed earlier. Rice (2010) when discussing that 70 Newtons of routine force goes above the 39 N which is considered to be a high force to operate under. Though manual wheelchair use does have its benefits beyond being a mobility assist device there have been links to negative health implications with long-term use.

As mentioned previously manual wheelchairs have low levels of mechanical efficiency. Bourassa et al. (2019) has connected the low mechanical efficiency to both the difficulties in navigating rough environments and long-term strain issues. In the report it was explained that the low mechanical efficiency leads to needing more force and more pushes to be made which will increase movement difficulty and risk of strain. In these studies the information was gathered from push-rim propelled manual wheelchair users. Flemmer & Flemmer (2016) discuss briefly the comparison of these issues in the different styles of manual wheelchair. In their review the explain that the handcycle and lever wheelchairs are less straining modes of propulsion but they do ultimate still have an effect on the long term health of the user. They are both also better at navigating rougher surfaces and ramps but are usually found to be worse outdoor.

2.3 Electric Power Wheelchair

Electric powered wheelchairs are based on the traditional manual wheelchair. Electric power wheelchairs however are equipped with power driving devices, batteries, and an electric control system (Wang, Zhao, Hu & Yang 2018). Dudgeon, Deitz & Dimpfel (2014) in a report on the elements of wheelchair selection. Power wheelchairs have a power base design. There are three different drive types, front, mid and, rear wheel drive. There is a diverse range of wheel types in electric powered wheelchairs. They describe that these wheels can be coupled to the motors through exposed or concealed chains or gear systems. To accommodate for each person's disabilities there is a diverse range of drive control systems for electric wheelchairs. The most common controller designed for electric wheelchairs are joystick controllers but there are others such as switches (Hildebrand 2014). The electric wheelchair has been developed in order to help aid those that have a more difficult time navigating society solely in a manual wheelchair. Though the electrical wheelchair does have some advantages over the manual wheelchair there have been discussions on the negative of electric wheelchair use. Mrabet, Rabhi & Fnaiech (2018) discusses that 40 percent of regular electric wheelchair users find it hard to control in tasks such as going through a door without assistance.

2.3.1 Front Wheel Drive

Front wheel drive (FWD) power wheelchairs have the drive wheels located at the front of the wheelchair. Dudgeon et al. (2014) describes the strengths and weaknesses of using a FWD. In the report it exclaims that FWD powered wheelchairs are the most beneficial in areas of obstacle control and of being typically better suited in obstacle climbing such as curbs. A FWD also is also explained to have more stability, and because of this are able to perform well over many different terrains. The weaknesses of FWD include was said to be its speed and turning radius. A FWD because of the speed issues can have trouble going uphill and can lead to the loss of control of the back end of the wheelchair. Dudgeon et al. (2014) and Chavan & Deodeshmukh (2015) both describe that FWD power wheelchairs are most commonly used for smaller framed power wheelchairs for indoor use. Chavan & Deodeshmukh (2015) specify that FWD have four wheels and is the most flexible wheel configuration.

Figure 2.6: 2019 F5 Corpus front wheel drive electric wheelchair (Permobile 2019).

2.3.2 Mid Wheel Drive

Mid wheel drive (MWD) power wheelchairs have the wheels located in the middle of the chair, positioned typically bellow where the user sits. Dudgeon et al. (2014) explains that the main advantage of a MWD is that it is more able to manoeuvre in tight spaces. The MWD also has e good turning radius being able to complete a full circle on the spot. Dudgeon et al. (2014) and Chavan & Deodeshmukh (2015) both exclaim that because of the wheels location it has good stability and can be good on rougher surfaces, but it has also been found to be less manoeuvrable while navigating them.

Figure 2.7: Glide Centro Bariatric Power mid wheel drive electric wheelchair (GLIDE 2019).

2.3.3 Rear Wheel Drive

Rear Wheel Drive (RWD) power wheelchairs have the drive wheels located at the back of the chair. Dudgeon et al. (2014) explains that a RWD is advantageous for its speed and that compared to the other wheel drive the RWD is able to be controlled well when driving at faster speeds. (Chavan & Deodeshmukh 2015). The RWD is also beneficial over obstacles and rough terrain. The main disadvantage of the RWD is its turning radius. A poor turning radius leads this wheelchair to be not the best at navigating more confined spaces.

Figure 2.8: Q500 H rear wheeldrive electric wheelchair (Quickie 2021).

2.3.4 Drive Control

As with all elements of wheelchair design, to accommodate for the diversity of needs there are many different types of drive controls. The cost common drive control used in wheelchairs is the contactless inductive joystick. a contactless inductive joystick works be using several electromagnetic coils to measure the joystick position. There are 5 coils, the primary coil is indices a current that is picked up by the secondary coil and is located at the internal end of the joystick handle. The secondary coils are mounted in each fixed position on the joystick base. Joysticks are proportional controls in that the driving speed and direction is determined by the joystick handle position. Another type of joystick that has been used is a resistive joystick. This joystick uses a pair of potentiometers to measure the joystick position on each axis (Dudgeon et al. 2014). Hildebrand (2014) states that the resistive joystick is more prone to dust build up and wear with excessive use compared to the inductive joystick which lasts much longer. Using a joystick requires the ability to move one's hand with gradual force and thus has not been found to be appropriate for those with abnormal muscle tone. Though this is one the most common type of control system for the electric wheelchair Dudgeon et al. (2014) explains that it can be difficult for people overcome the initial difficulty in learning how to effectively control the chair.

Another type of electric wheelchair control are switches. Depending on the need wheelchairs will have a variety of switch functions and placements. Switches work through the simply by activating the switch through a movement and deactivating through another. Switches on wheelchairs will turn on the wheelchair at a pre-programed speed and other switches can be used to determine forward and backward movement and turning. Switches are a form of non-proportional control in that they only require the need to move a body part in two directions one to activate and one to deactivate the switch. Switches are used when one does not have the fine motor control to move a proportional device. Depending on the users needs there are various types of activation force are available (Hildebrand 2014). Dudgeon et al. (2014) explains that compared to the joystick people find the switches to be easier to learn however can impact the precision on movement.

The switch and the joystick have been the two more widely used for electric wheelchair for years however, there has been studies into trying to further develop this technology to aid with the diversity of needs. Rabhi, Mrabet, Fnaiech & Gorce (2018) is an investigation into the use of touchscreen technology to control electric wheelchairs with a smart joystick.

In this research they found that users found that users were faster with the smart joystick as there was less muscle effort required to control it. The found other benefits such as the increase of device speed and the stability of the movement. However there where some people in their testing that reported that the technology was initially too confusing for them.

(Dudgeon et al. 2014) in an informational document on wheelchair selection explains that when it comes to controller type it really depends on the user of the wheelchair.

2.3.5 Scooter

Another power mobility device is the scooter. Scooters typically have three wheels and may have a front or a rear wheel drive. Scooters typically have tiller controls. This leads to scooters having a larger turning radius and by extension lower manoeuvrability compared to other devices. Dudgeon et al. (2014) describes scooters as being appropriate for a marginal walker, but not suitable for those who may have marginal control due to the chairs control system. Though most scooters work on a battery system there are fuel powered systems that have been manufactured in the past. Scooters are typically used in place of other electric scooter models for those who might not need constant aid with movement. The electric scooter typically uses a lever to determine the forward and revers motion and speed of the device. There is also a speed dial that can be used to tweak the speed further. Mortenson (2016) explains in a review of the knowledge of motorised scooters that scooters eliminate many of the problems that manual wheelchairs have such as the strength needed to use them however, they have their own issues. One issue sited is that the user must sit upright and have the shoulder and hand strength to steer the device. Another issue comes from the longer length of the device. The length can make it more difficult to move about.

2.3.6 Benefits and Negatives of Power Wheelchair Use

Kairy, Rushton, Archambault, Pituch, Torkia, Fathi, Stone, Routhier, Forget, Demers, Pineau & d Richard Gourdeau (2014) discusses that using an electric powered wheelchair has multiple benefits. It increases mechanical efficiency of mechanical wheelchair propulsion, helps decrease repetitive strain and injuries and enables users to propel their wheelchair.

Figure 2.9: A90 Deluxe Mobility Scooter (Active Scooters 2021).

Holloway & Morgado-Ramirez (2017) have also found that the use of electric power wheelchairs can help improve user's self-esteem and increase activity levels and social participation. The benefits as described from **?** and Holloway & Morgado-Ramirez (2017) help alleviate the negatives of manual wheelchairs outlined in the works of Medola et al. (2014) and Misch et al. (2020) and Cooper, Baldini, Boninger & Cooper (2001). However, with this it also means that the benefits of manual propulsion are not given to those of powered propulsion. Kairy et al. (2014) states that people who use electric powered wheelchairs are often not provided with enough opportunities for daily exorcise, which can negatively impact one's health. Dudgeon et al. (2014) also lists that the fact that electrically powered wheelchairs are large and heavy which can make them more difficult to manoeuvre in small spaces. They find it can also make it more difficult for vehicular travel.

2.4 Mobility add-ons for manual wheelchairs

A mobility add-ons are an accessory that attaches to a manual wheelchair and is used to help wheelchair users reduce the effort required to propel a wheelchair. The general benefits of this device is that they are able to improve a users ability to navigate rough terrain, and increase distance travelled. There are three main types of power assist attachments being made for manual wheelchairs. There is a front attachment rear attachment, and motorised wheel replacement. These can be further categorised as passive devices, manually powered devices, and power-assist devices. Passive devices typically are something that assists in movement without changing the way in which the chair is propelled, manually powered change the propulsion method into a different form on manual power, and power assist converts the manual wheelchair into an electrical one by adding motors and batteries (Ogilvie 2019).

2.4.1 Front wheel attachment

Generally, a front attachment is an attachment that connects a wheel to the front of a manual wheelchair. Typically, these devices lift the wheelchairs front caster wheels and replace the front contact surface with a larger centred wheel (Ogilvie 2019). This can come in the form of the manual handcycle which was discussed earlier in the report as shown in figure 2.5. There is also the power-assist form of the handcycle which converts the wheelchair into a trike or a scooter. Another front attachment is a third wheel which essentially replaces the caster wheels with a third that is better for navigating tougher terrain. There have not been many studies done into the front attachments. One study by Ogilvie (2019) done was on the change in loading condition on the manual wheelchair when a passive wheel attachment. In this report they concluded that the addition of mobility aids was beneficial, but there addition changed the location and magnitude of stresses on the wheelchair frame. Though this experiment was done on a front wheel attachment they state that this change of load would also impact the loading conditions in other types of attachments.

Another report by Bourassa et al. (2019) explored the designs of manual handcycles. In the report it was explained that most manual handcycles use chains which could cause problems as they are susceptible to propensity derailment, and discussed the need for chainless handcycles along side the need for cheaper options for mobility add-ons.

2.4.2 Rear wheel attachment

Rear attachments push or stabilise the wheelchair from behind. Similar to the front attachment this can be a passive system which is in the form of an extra wheel for stability or a power assist device which also has attached a drive system. As discussed for electrical wheelchair the drive control for the attachment can change depending on need. There have not been that many studies into the use of rear-drive add-ons for manual wheelchairs. A study that was done Munakata, Tanaka & Wada (2013) explored the design of an active caster-drive system for light weight travel. The active caster-drive wheelchair was controlled by using a conventional 2DoF joystick. The wheelchair add-on works by attaching the active-caster drive mechanism to the support centre frame on the wheelchair. The wheelchair was able to achieve the fundamental control of motion of manual wheelchairs. Most designs on the market are of a similar configuration.

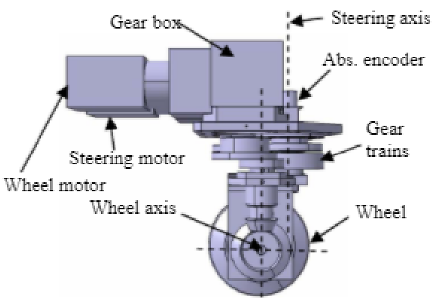

Figure 2.10: Rear-drive caster add-on

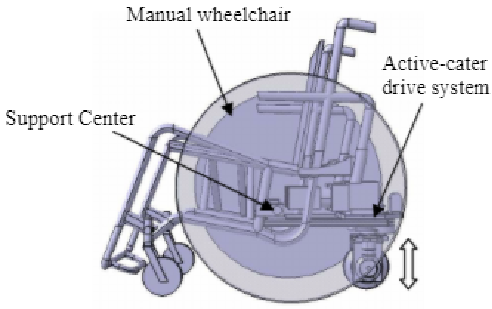

Figure 2.11: Rear-drive add-on attached to chair

2.4.3 Push-rim Activated Power Assist Wheelchair

A push-rim activated power assist device consists of a hand-rim wheelchair that has an electro-motors embedded in the wheels or wheelchair frame (Kloosterman, Snoek, van der Woude & Buurke 2012). The embedded wheels have sensors located in the push-rim of the wheel that determine the force that is exerted by the beneficiary on the wheel. Additional propulsive and breaking force is then provided by motors in each wheel (Ogilvie 2019). Push-rim activated power assist wheels have been a topic of rehabilitation research for about two decades. The transition to power assist wheelchairs has been found to influence the arm function of the users, the performance of daily activity and social participation. van der Woude, de Groot & Janssen (2006) has found that due to the heavier wheels it can impact their normal vehicle transportation. In addition, they also reported that because of the differing controls, the additional power, and the possible delay of application of the additional power can influence the control over the wheelchair. Kloosterman et al. (2012) went over studies of push-rim power assist wheelchair to report on the advantages

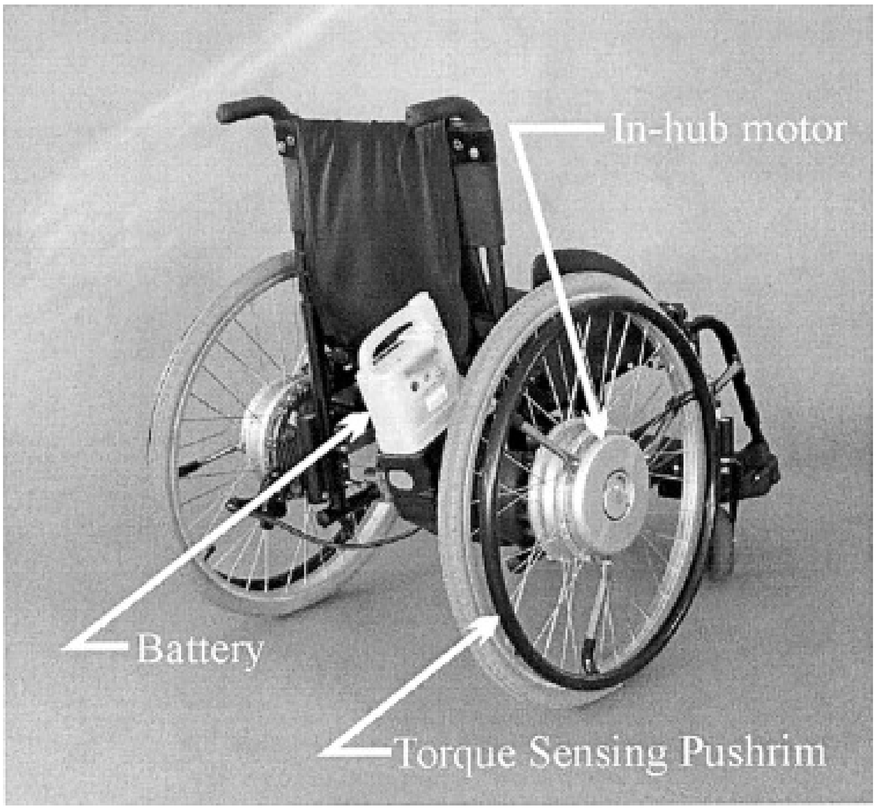

Figure 2.12: Diagram labelling the components of a push rim power assist wheelchair (van der Woude 2006).

and disadvantages of their use. Kloosterman et al. (2012) and a similar article by Levy & Chow (2004) found that power assisted propulsion reduced strain on the arms and cardiovascular system compared to when hand-rim propulsion was used. Kloosterman et al. (2012) continued that tasks that required more torque speed where easier with the power assist however precision tasks were easier on the manual wheelchair. Levy & Chow (2004) noted the benefits that push-rim power assist also includes the ability to navigate multiple environments (carpets, steep inclines, grass, etc.) that are often inaccessible to manual wheeling, while still providing the exercise challenge of manual wheelchairs.

2.5 Motor's

Motors are used to power electric powered wheelchair, and power assist attachments. Chavan & Deodeshmukh (2015) in a journal discuss all the parts of electric powered wheelchair and goes through the pros and cons when using them in powering a wheelchair. It lists the most common motors for electric wheelchairs to be a continuous DC, stepper, and R/C servo. In comparison citeasnoungua report that DC motors are the most widely used for their ability in handling variable speed, frequent start/stop, reversing, and braking. They continue by discussing the use of brushless DC motors for their advantage of having electric switches, and to produce larger torque. The brushless motor could then be separated into two subsystems sensored and sensorless brushless motors. Sensorless brushless motors use EMF voltage, instead of position sesors, to detect rotor magnet position. citeasnoungua claim that the position sensor are beneficial as the reduce the size and cost of the motor but also increase the reliability of the whole system.

Both Chavan & Deodeshmukh (2015) and citeasnoungua discuss that one of the disadvantages when using a DC motor for electric wheelchairs they need the assistance of a gear reducer as the efficiency of DC motors are low at low-speed region, and this can increase the weight and reduce energy efficiency.

Saharia, Bauri & Bhagbati (2017) in a report about joystick-controlled wheelchairs explains that in wheelchairs two DC motors are used to move wheelchairs in their different directions, and that a microcontroller is used to control these motors.

2.6 Batteries

Electrical wheelchair motors are typically powered 12V or 24V rechargeable deep-cycle lead-acid batteries. Some designs however may use Li-ion batteries. citeasnoungua in a study on wheelchair motors and batteries explained that the advantages that lead acid had was their low cost, however li-ion batteries were better in terms of energy efficiency, cycle life, and charging time.

In the report they stated that the main issue with Li-ion batteries at the time of the study was the cost and the safety of the batteries but reported that as the technology got better there would be a larger use of Li-ion batteries in electric wheelchairs. In a more recent study citeasnounyuk explains that Li-ion still aren't commonly used in electric wheelchairs but there are special types of Li-ion batteries that are being specially designed for the use in electric wheelchairs and mobility scooter.

2.7 Consumer wants

Chavan & Deodeshmukh (2015) explores the ideal parts for an electric wheelchair. In this report they talk about what wheelchair users have stated are important for them in owning a wheelchair. A summary of what was most desirable in a chair was a stable chair that was easy to manoeuvre and travel with. The want for a chair that is easy to manoeuvre and travel with was represented in the earlier topics discussing. From the earlier segments regarding wheelchairs many of the disadvantages were related to one's ability to navigate an environment. From this it can be assumed that another want from consumers would be to make sure that the chair is ergonomic and would allow for reduced risk in strain. In the study by Liadis (2006) the consumer wants in power-assist devices is discussed. The main want found from this study is that the users wanted something that was simple to operate. The users tested often reported devices that required too much tech such as a touch screen or smart phone was often too complicated for easy operation.

2.8 Wheelchair Testing Standards

Standards are published guidance documents that set out specifications, procedures, and define the quality and safety criteria for a large range of products, services and systems. A number of standards are applicable to the design process of wheelchair elements. These Standards are ones that are considered applicable to this project and summarised in the following subsections. All the standards listed are parts in a series about the testing methods of wheelchairs.

2.8.1 AS/NZS ISO 7176.8:2015: Part 8 Requirements and test methods for static, impact and fatigue strengths

This Standard is intended to specify the requirements and test methods for static, impact, and fatigue strength of wheelchairs including scooters. It is applied to wheelchairs with a maximum user of one and that don't exceed a maximum speed of 15 km/h. The primary relevant information in this Standard comes from clause 8.11, 8.12, 8.13, and 8.14 which discusses forces on steering handles. Each segment uses the following forces as provided in table in different directions on the steering handles these force directions are shown in figures.

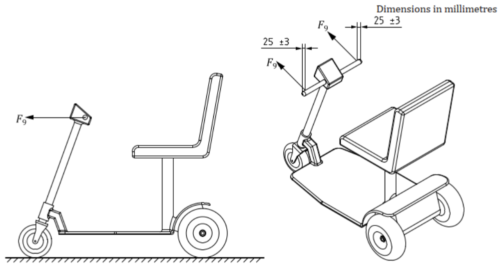

Figure 2.13: Scooter steering handles: Resistance to rearward forces

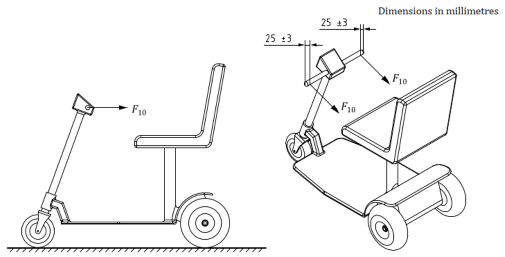

Figure 2.14: Scooter steering handles: Resistance to downward forces

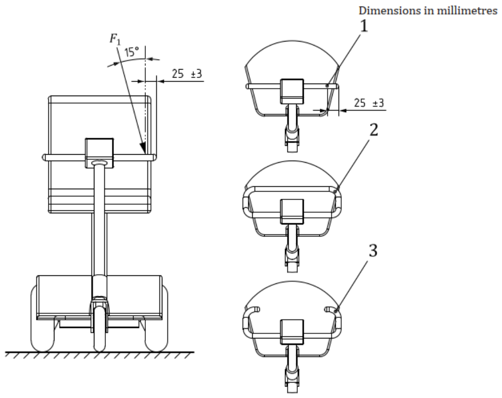

Figure 2.15: Scooter steering handles: Resistance to upward forces

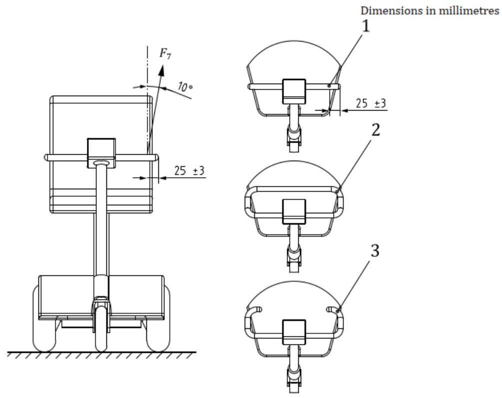

Figure 2.16: Upward forces on scooter steering handle

2.9 Gap in Literature

Though there are many areas of study that have discussed wheelchair design there has not been much research done into the ways in which mobility attachments can impact wheelchairs and wheelchair users. There have been very little studies done into how mobility attachments can impact the loading conditions of wheelchairs and there are currently no standards in regard to wheelchair attachments.

2.10 Summary

This chapter investigated the range of literature related to wheelchair propulsion and the impact that it has on their users. There has been a fair amount of research on push-rim manual wheelchairs and how it's propulsion method can impact wheelchair users. There hasn't been a exorbitant amount of research into the their forms of manual wheelchairs since 2001 however there has been an evolution into this technology. When It came to wheelchair propulsion all sources agreed that push-rim manual wheelchair propulsion was problematic. All studies related to this described how repetitive use of one's push-rim manual wheelchair can lead to strain issues in the user's body. They also all described the issues related to navigating rougher terrains and long distances. The literature related to electric wheelchairs discussed how their use helped to mitigate the issue with strain however having their own issues with their weight and size.

There was not much information available in relation to mobility attachments for manual wheelchairs. Most sources discussed their use in aiding manual wheelchair users with propulsion, but none discussed any effect the attachment would have after long term use on the wheelchair such as loading condition. There were also no standards in relation to these attachments.

Chapter 3

Methodology

3.1 Chapter Overview

The following chapter provides information into the methodology implemented to ensure the achievement of the project outcomes. First it is important to establish the design process that will be applied. Following this, will be the outline of the design problem that this report will aim to solve. Through this a criterion of importance of these design problems will be implemented based on criteria determining what is a demand and a wish when it comes to desired outcome. The manufacturing methodology will then be discussed.

After the establishment of the fundamental requirements and evaluation of the consequential issues of the report will be performed. The outcomes section will first discus safety and risk factors that are associated with the project. This will then be followed by an analysis of the environmental impact that are involved in the project and finally a discussion into the ethics.

3.2 Design Methodology

The design method for this project will be followed throughout this report in order to achieve a successful final design outcome. The design methodology that will be used for this project is derived from Pahl, Beitz, Feldhusen & Grote (2007) Systematic Approach.

This methodology of engineering design describes a sequence of four phases, Task Clarification, Conceptual Design, Embodiment Design and Detail Design. Task clarification deals with outlining and defining the design tasks. Conceptual design is done to identify the basic designs of a design solution. Embodiment Design outlines the design into its economic and technical criteria. Detail Design finalises the design and prepares for the production of the design. Each of the phases comprise of a sequence of activities that can be executed iteratively. During the completion of each phase there is a moment of analysis that is to be done to determine if the results of each phase has been met and if the next phase can begin. As this model came to be from observing design professionals and was not intended to a prescriptive model, there is some allowance for intuitive change when it comes to completing the steps iteratively.

This report will implantation of this design methodology will be as such. The clarification will be outlining the essential problem that is being addressed for this report that is finding a more cost efficient and user-friendly power attachment for a typical manual wheelchair. Upon analysing this issue the next step is the conceptual design. Through this segment the task will be broken down into its essential problems and these will be expanded into exploring design elements that will try and solve the essential problems. The embodiment phase will involve the concept being drafted and compared to the design requirements outlined in the previous segments. The detail design will happen once an appropriate design has been formed. In this section a model will be created in CREO where the design will be assembled. An FEA will be done to the relevant stress points taken from the Standards and other stress points that will have been derived and compared to the desired results. Other calculations will be done to determine other criteria that requires analysis. Refer to figure 3.1 to view relevant design stages.

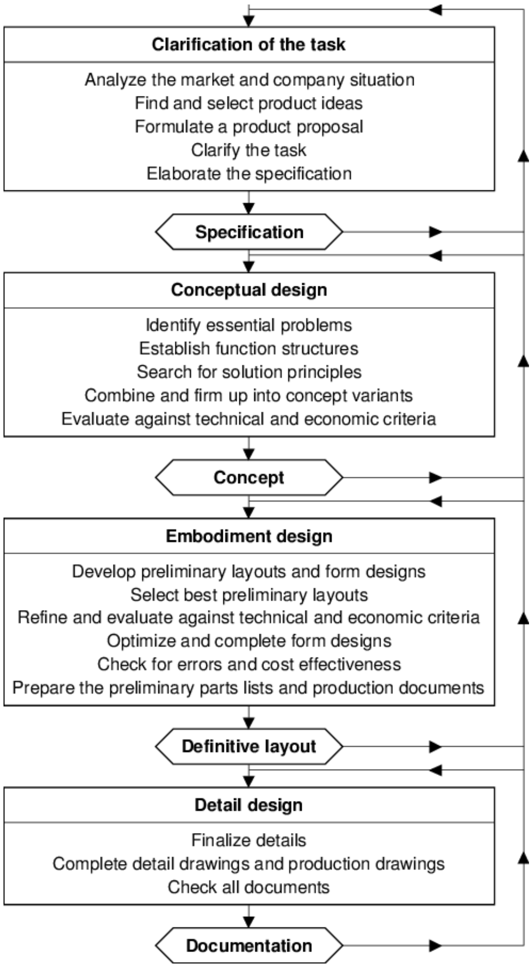

Figure 3.1: Design stages of engineering design systemic approach (Pahl et al. 2007).

3.2.1 Design Problem Statements

Design Problem 1 It is hard on manual wheelchair users to move at long distances and to navigate certain terrain without exerting large amounts of force on their arms which can lead to it being harder to participate in elements of society.

Design Problem 2 Manual Wheelchair users due to repetitive motion experience strain in their upper body.

Design Problem 3 Electric wheelchairs and power assist technology is often expensive.

3.2.2 Primary design objectives

Design objective for problem 1

The root objectives for design problem 1 have been examined:

Motorised drive wheel

Why? - Manual wheelchair users often report having difficulties navigating long distances and certain terrain due to the amount of force is required from the user. In Chapter 2.2.2 it was discussed that the main reason for this was the inefficiency of push-rim manual wheelchair propulsion. In order to achieve a solution to this problem a different form of wheelchair propulsion is needed.

How? - From the results of Chapter 2.2 multiple different types of manual wheelchair propulsion were explored. These other forms of propulsion did have a higher mechanical efficiency compared to the push-rim still did not solve the issue of navigation. Another method explored was in Chapter 2.3 way that this can be through the use of an electric wheelchair or a power assist device. Power wheelchairs have a good propulsion efficiency that will help solve the navigation problem. The overall aim of this report is to design a power assist attachment for manual wheelchairs. A power assist device will help as with the help of motors it will require less force to move on the part of the user. This could further be achieved in a variety of ways. In chapter two various types of power assist devices were discussed. They included front wheel drive, rear wheel drive and push-rim activated wheels. In general, all the devices work by adding a powered drive wheel and electric control system to help with wheelchair propulsion. This will help as a motorised drive will require less power on the users end.

What? -The problem stems from increasing the mechanical efficiency and power output during the propulsion of the wheelchair. Improving their ability to manoeuvre through society.

Lightweight system

Why? -As power wheelchair attachments are often used in travel it is important that the device be easily transportable. It is also important that the device does not greatly impact the loading condition of the original manual wheelchair. A lightweight device will make for easier manoeuvrability of the system.

How? -Appropriate selection of material in both the frame, connection attachment, battery, motor etc. An appropriate selection of material will involve outlining the weight of this material as one of the selection conditions for the design of the device. As well as making sure the design is as simple as possible. Minimising the design will ensure that only the required amount of material is used and thus minimising the total weight of the device.

What? –A lightweight system provides higher functionality in travel and can enable more travel.

40 km distance allowance

Why? -The average distanced travelled per day (combined vehicle and walking) is around 30-50 km. If the goal is to ensure that longer distance travel is possible having a desired battery life is needed. By having the system be able to travel a 40 km distance per charge it allows the user to be able to travel the average distance daily.

How? -This will be done through the selection of the battery and the motor of the system. Through calculations it can be determined if the system is able to travel the 40 km distance.

What? -Ensuring a 40km distant battery life ensures reliable daily travel.

Design objective for problem 2

The root objectives for design problem 2 have been examined:

Make the device motorised to reduce repetitive movement

Why? -Manual wheelchair often report strain after extended use. From Chapter 2.2.6 this was found to be due the repetitive movement involved in manual wheelchair propulsion. By motorising the drive of the wheelchair, it will reduce the amount of effort required on the users end thus reducing the strain over time.

How? -As mentioned in the previous section this would be achieved through the power attachment.

What? -The problem stems from increasing the mechanical efficiency of the propulsion of the wheelchair. Improving their ability to manoeuvre through society.

Ensure that the drive control is appropriate.

Why? -Along with manual wheelchair propulsion the type of drive controller can have an impact on the strain of the users. As discussed in chapter 2.3.4 certain types of controllers are not appropriate for everyone.

How? - For this project, the type of controller that will be considered are those that can be used by people with upper mobility as that those are the type of users who will be using a manual wheelchair. The type of controls that are often used are joystick controls, or handlebars. The simplicity of the controls is also important. For this project handlebars will be used. As this device is not intended to be used all the time a switch-controlled handlebar are the most easy controls to get used to using. Further analysis can be done to determine the best type of drive control. This further analysis would be done to test forced required to switch the device and to turn the handlebars when turning.

What? – An appropriate drive control will help reduce strain in the body from the lesser repetitive movement required to propel the wheelchair.

Make sure the control configuration is ergonomic

Why? –An important part of reducing strain is to make sure they system is ergonomic. As the system will be involving a scooter adjacent system it is important to make sure that the handlebars are an appropriate distance and height to ensure ease of use.

How? -This will be done by reviewing the design based upon information regarding the ergonomics of design elements such as the distance of handlebars to the user.

What? – An ergonomic design will provide strain reduction.

Easy application of attachment

Why? -Though this step may be less applicable to the person using the wheelchair it is still important to ensure that applying the power assist device is as ergonomic as possible.

It is likely that initial installation of the device of the wheelchair will be done by someone other than the wheelchair user. This will mean that what is how the thing is applied will need to be made with this in mind.

How? -There are two ways installation could happen, that is having the whole device needed to be put on in one go or having a permanent base on the frame and the rest of the device connecting to that. To try and make the device more accessible to the users, the second component the attachment itself could be applied by the wheelchair user themselves.

What? – Reduces effort required in attachment.

Design objective for problem 3

The root objectives for design problem 3 have been examined:

Use cheap frame, battery, charger, wheels, controller, ect.

Why? -Most electric wheelchairs and power assist attachments can be very costly and thus become inaccessible to a lot of people. This can be due to the type of material used. Making sure that the electrical components are sourced in a

How? -This can be achieved by making sure that the material and parts can be easily sourced. For the frame and attachment an analysis on material selection and making sure that the system is design is simple to reduce the amount of material used.

What? – Reduce cost through material selection.

3.2.3 Design Requirements

Design Problem 1

Manual wheelchair users have reported that they are limited in the way they can navigate society. For this design it is required for it to be driven electronically. The design of this system needs to be easy to use. The controls need to be intuitive and easy for the general user to operate. For people to want to use this attachment is beneficial that is easy to attach. It will be difficult to be able to produce a product that can initially attached by the average wheelchair user. It is likely that a relative or assistant will be attaching the system so it is important that the attachment process isn't too complicated or strenuous. It is desired that the system is light weight. A lightweight system will allow for it to be easily transportable and if can aid in the attachment process.

Table 3.1: Design requirments demad/wish of design problem 1.

Requirements	Demand/Wish
Electronic System	Demand
Easy to operate	Demand
East to attach	Wish
Lightweight	Wish
Speed (6km/hr)	Demand
Braking (3 seconds)	Demand
Durable	Demand
100kg Capacity	Demand

Design Problem 2

To reduce the strain, it is a requirement for the system to be electrical. To help reduce other types of strain it is desirable for the system to be light weight and easy to attach. For the system to reduce strain in other manners the configuration and use of the controls is important. It is required for the system to for the controls to be ergonomic and easy to use. To help reduce strain in the wider wheelchair population it is desired that this attachment can be used by a wide variety of users. To accomplish this, it is desired that the system has 100 kg capacity allowance and is able to be attached to a variety of wheelchairs.

Table 3.2: Design requirements demand/wish of design problem 2.

Requirements	Demand/Wish
Electronic System	Demand
Easy to operate	Demand
East to attach	Wish
Lightweight	Wish
Ergonomic	Demand
100kg Capacity	Demand
Diverse attachment	Wish

Design Problem 3

In order for this goal to be accomplished it would be desired that the parts for the system can be easily sourced. Another desire is for the system to be lightweight and have a simple design. For this design though it is important to reduce the total cost of this technology it is still mandatory for the design to be durable and accommodate with all the standards that have been placed for these types of systems.

Table 3.3: Design requirements demand/wish of design problem 3.

Requirements	Demand/Wish
Electronic System	Demand
Easy material sourcing	Wish
East to attach	Wish
Lightweight	Wish
Durable	Demand

3.2.4 Design Subsystem

In order to solve the design problems this report aims to build a power assist device. As discussed, this device is aimed to be a front wheel drive with handlebar control. The aim design of this project has been broken down into two subsections. These subsystems are the frame and the connection attachment.

Design Subsystem 1 -Frame The design of the frame will involve designing a suitable base for the handlebar section of the system. This section of the system is what controls the device. It will be what the wheelchair uses to propel and control the wheelchair. This system will have attached to it a wheel as well as the drive control device and will need a way to connect to the connection attachment. The design work of this will mainly subsist of the material selection and configuration of the system.

Design Subsystem 2 -Connection Attachment The connection attachment will involve designing a device that attaches the handlebar system to the wheelchair. This design work will focus on the material and in what way the system is able to connect to wheelchairs. Alongside the design subsystems there are elements of the design that are not being designed that will be incorporated into these designs. The other sections of the device such as the wheels, the drive control, battery and motor will be based upon already manufactured devices available on the market.

Testing and Evaluation Methodology

Finite Element Analysis Methodology

The finite element analysis will be done on the final design of the system. The power attachment is to be modelled in CREO 6.0 with an appropriate mesh, material properties, boundary conditions, and loading conditions will be specified in the model. Along side this a basic wheelchair frame will be modelled so that an FEA analysis can be done with the appropriate loading conditions. The frame modelled will be based on the Quickie Nitrum as shown in 3.2.

This wheelchair frame is made from Aluminium alloy 1100-H14. The properties for this material are displayed in the table

After the full system is modelled in CREO an FEA can be done using the CREO simulate. First an analysis will be done to test how the addition of a mobility attachment can have on the loading conditions of a wheelchair frame by comparing the stresses before and after a device is attached. In this program the load bearing sections will be analysed based on an appropriate loading condition. The von mises stress will be recorded. And the analysis will be based on the yield strength of the section's material. Another FEA will be done on the handlebars to test the tipping and back and forward motion conditions outlined in the Australian Standards discussed in chapter 2. Once these tests have been done the final design will be compared to the other design requirements.

Figure 3.2: Quikie Nitrum (Quikie 2019)

3.2.5 Manufacturing Methodology

The detailing of manufacturing aspects is beyond the scope of this project. With this however, it is important to consider the manufacturing and assembly of products during the design phase. During the design phase elements such the material selection, handling and processing, quality control and the specification of purchased components and assembly.

3.3 Consequential Effects

The following section evaluates the potential issues that are associated with the undertaking of this project. This section will focus on the safety, ecological and ethical issues in order to identify areas of concern and mitigate potential harm.

3.3.1 Safety Issues

When considering safety in designing a wheelchair attachment one of the elements needed to be considered is the risk to the user. This can come about due to a failure of components in the device, the user becoming standard, and changes to the user's stability. So when designing the attachment have an understanding of these risks and how to miti-

Table 3.4: Aluminium alloy 1100-H14 properties.

Property	Al 6061-T6
Young's modulus	68.9 GPa
Poisson's ratio	0.33
Tensile yield stress	276 MPa
Ultimate tensile strength	310 MPa
Elongation at break for 12.7mm (1/2 in.) diameter	17%
Brinell hardness	95
Fracture toughness K_{Ic} (T-L orientation)	29 MPa$\sqrt{m}$

gate them. Health and safety are especially critical considerations in engineering design. When designing there are methods that have been produced to ensure the elimination and minimisation of risks and injuries throughout the life of a product. As this assessment involves designing a product that is made to be used by the public it has a large number of safety and hazard issues to be considered. As this project involves designing an object it is important to discuss what safety and risk considerations need to be considered in the design process. Safety work Australia (20155) talks about one method of incorporating safety called safe design. Safe design begins in the concept stage where designers are to consider how safety can be best achieved in each of the lifecycle phases. Safe design has five principles:

Principle 1: Persons with control—those who make decisions affecting the design of products, facilities or processes are able to promote health and safety at the source.

Principle 2: Product lifecycle—safe design applies to every stage in the lifecycle from conception through to disposal. It involves eliminating hazards or minimising risks as early in the lifecycle as possible.

Principle 3: Systematic risk management—apply hazard identification, risk assessment and risk control processes to achieve safe design.

Principle 4: Safe design knowledge and capability—should be either demonstrated or acquired by those who control design.

Principle 5: Information transfer—effective communication and documentation of design and risk control information amongst everyone involved in the phases of the lifecycle is essential for the safe design approach.

Beyond that there is the stages of design which derive safety design further into three core stages that effect the design process. The stages of design is a process that has been made to ensure that risk identification has been done at each stage of the process to eliminate or reduce risk.

Stage 1: concept design -Identification of critical health and safety risks that may affect the viability of the project.

Stage 2: Functional deign -Identification of reasonably foreseeable safety risks associated with the construction/manufacture, installation, commission/use, maintenance/repair and demolition/disposal of the infrastructure.

Stage 3: Detailed design -Focusing on ways in which a design can be modified to eliminate or reduce issues that may affect the ongoing safety of persons involved in engineering projects.

Safety is an important consideration in engineering design from this it can be seen that during this project safety is something that needs to be taken into account for every decision made during the design project. Though constructing is out of the scope of this project, for this project it is still important to review the impact that the product will have over its perceived lifecycle.

For the project a risk management Plan has been conducted and is demonstrated in Appendix B. Project Planning.

3.3.2 Ecological Considerations

When undertaking a project EngineeraAustralia (2010) specifies that it is important to take into account the environmental factors. Peter O. Akadiri (2012) provides information into designing for environmental sustainability. In this educational kit id describes environmental sustainability to its relationship between the requirement of materials and cost to the environment in attaining and using them and to the waste and end of life of the materials. When designing for ecological sustainability Peter O. Akadiri (2012) gives some concept to consider when designing for ecological sustainability.

Material Choice: When designing something it is important to try and select ecologically sensible materials. When choosing a material, the considerations should include the natural availability of the material and the processing or manufacturing of it. When designing it is important to look at the lifecycle of the material an assessing the positive and negative values when using a particular material or method.

Designing for disassembly: Designing for disassembly involves taking into consideration the ability to take apart the different elements of the design so that all the material can be properly recycled, reduced or disposed of. This idea is to try and help reduce waste and energy in production. This can also improve the ability to replace or update components which can increase the overall lifespan of the object.

Design for durability and a long working life: This design advice is to help increase the lifespan of the object and reduce waste. This would involve engaging in the previous concepts such as material selection and designing for disassembly.

Manufacturing process: It is important to make the manufacturing process as ecologically sensible as possible. This can help reduce energy production, pollution, and efficiency of material usage. When considering the manufacturing process, it is also recommended to try and source local availability to further minimise ecological harm.

3.3.3 Ethical Issues

EngineersAustralia (2010) provides a code of ethics that is important to review through all stages of the engineering process. The values and principles outlined in the code is what is meant to shape the decisions made. The guidelines cover integrity, competence, leadership and sustainability. The main area that it is important that this assessment covers is the promotion of sustainability.

Practice engineering to foster the health, safety and well-being of the community and the environment.

EngineersAustralia (2010) suggests that health, safety and environmental considerations are important to consider in the engineering task. As this assessment requires making a device that is intended to be used constantly and because of that it is very important the final design follows the required safety standards and that the safety elements of all parts of the design are considered. This in part has been considered in some of the design elements discussed earlier in the report. As mentioned in earlier segments the task a major part of this assessment to is try and better the long-term health of wheelchair users be reducing strain. Other considerations come from the environment. When exploring material selection as well as the sourcing methods for the electronic part it is important that the environmental sustainability of these sourcing is taken into account.

For the scope of this report considering ethics is going to come into the form of material and manufacturing methodology analysis to ensure that environmental issues have been appropriately addressed, and that the wheelchair attachment complies with the safety and health considerations outlined.

3.4 Chapter Summary

The main goal of this project is to produce a design for a cost-effective user-friendly power attachment for manual wheelchairs. When designing the attachment multiple design goals will be taken into consideration to ensure that the design requirements are met. Once a design is finalised a FEA will be done to test the loading conditions of the wheelchair. In the designing of the attachment along side the design requirements the consequential effects will need to be considered. The effects of the design will be considered in areas such as safety, environment, and ethics. With all this considered a design will then be finalised.

Chapter 4

System Design

This chapter will aim to document the design process of the wheelchair power attachment. The chapter will follow how each element of the design during this process plans to meet the design aims outlined in chapter 3. Finally, the concept designs will be evaluated against the criteria and evaluated based on the engineering mechanics and consequential considerations.

4.1 Design Subsystems

4.1.1 Connection Attachment

When designing the connection of the device it was identified that a wish for it to be easily attachable and detachable for the user of the wheelchair. So, for the design of the connection type, it is important to explore multiple options that can be used. For the decision of a connection type, it is important to outline the desired criteria for the best fit.

For the connection device to meet the requirements outlined in the design problems. Based upon the design problem requirements outlined in Chapter 3.2.1 the following criteria were formed.

Assembly Time: How long it would take to attach

Ease of use: How easy it would be for the wheelchair user themselves to attach the device

Manufacturing: How easy is it to manufacture the part

Adjustability: Can this be adjusted to work with multiple wheelchair frame types

Design Concept 1: Bolt

The bolt design would function by bolting a separate device to the frame of a wheelchair that would act as a permanent fixture, that would then allow the attachment of the remaining device. The way the designed device would work is by using a drop out frame. The bolted device would contain an extruding point that would then connect to a dropout that was located at the end of the attachment arm as shown in 4.1. This design is beneficial as it is a very simple design. However, as it requires to be bolted onto the wheelchair first it reduces it ease of use.

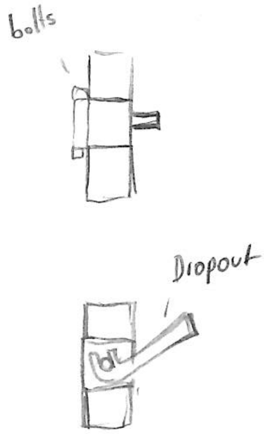

Figure 4.1: Bolt attachment concept design.

Design Concept 2: Caster Pin

The caster pin option would function by having the footplate section of a rigid wheelchair rest within a frame and fastened in using a pin as shown in 4.2. The contraption would attach by lifting the hole of the frame underneath the footplate then lifting so that the foot plate rests within. This is fast and easy to attach but does not allow for much adjustability.

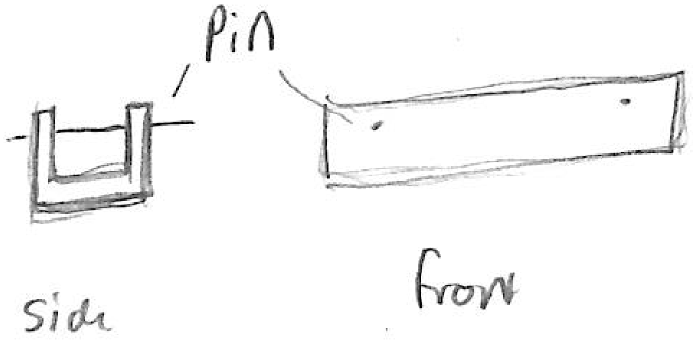

Figure 4.2: Pin attachment concept design.

Design Concept 3: Clamp

The clamp design would function by having the clamp attached to the end of the attachment arm, the clamp would wrap around the frame of the wheelchair and be locked by a lever and latch mechanism as shown in 4.3. This design is quick to use however it could end up being difficult regarding ease of use for those with less strength.

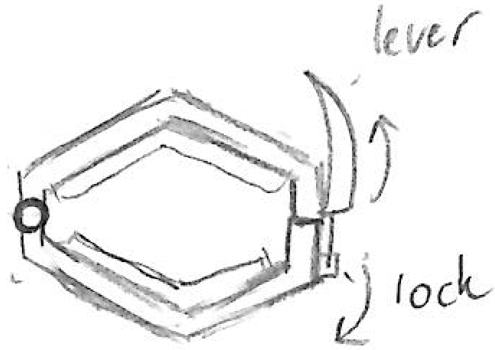

Figure 4.3: Clamp attachment concept design.

Table 4.1: weighted decision matrix for connection type.

		Clamp		Bolt		Caster Pin	
Design Criteria	Weight (%)	Rating	Weight Score	Rating	Weight Score	Rating	Weight Score
Assembly Time	20	3	0.6	1	0.2	4	0.8
Ease of use	30	3	0.9	1	0.3	5	1.5
Manufacturing	20	4	0.8	5	1	4	0.8
Adjustability	30	4	1.2	4	1.2	1	0.3
		total	3.5		2.7		3.4

Evalustion of designs

A weighted decision matrix was formed based upon the design requirements outlined.

Based off of the 4.1 the final choice in design for the attachment is the clamp.

The Final design of the clamp can be shown in 4.4.

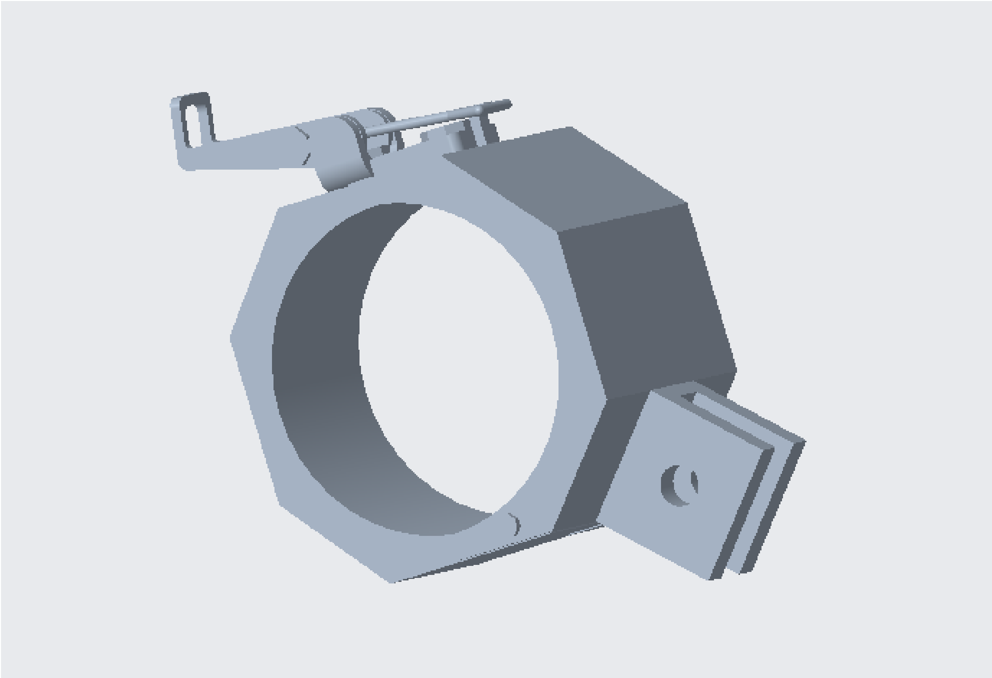

Figure 4.4: Clamp attachment 3D model.

4.1.2 Attachment Arm

For the frame of the connection attachment is what will piece the attachment from the wheelchair frame back to the electric handcycle. When designing the attachment arm, the design solutions will need to be considered to determine what would work best to solve the problem.

For design problem 1 it was discussed that it is important for wheelchair users to be able to navigate long distances and diverse terrains without large amounts of force. For this section the weight of the subsystem is what needs to be considered. With this it is also important that the subsystem is durable. This largely came down to material selection and the structure of the attachment arm.

For design problem 2 it was it was discussed that it was important that the design reduced strain. For the attachment arm of the system that would involve ensuring that the subsystem is ergonomic and easy to use.

For design problem 3 it was discussed that the device be cost effective. This would done through by ensuring that the attachment arm has a simple design and uses material that is cost effective and can easily be sourced.

Other desires as outlined in Chapter 3.2.2 is for the device to be adjustable to allow for it be usable for a more diverse range of wheelchairs. From this some design requirements can be outlined.

Ease of use: How easy it would be for the wheelchair user themselves use the system.

Manufacturing: How easy is it to manufacture the part.

Adjustability: Can this be adjusted to work with multiple wheelchair frame types.

Design Concept 1

The concept for this design consists of three main joints. The shoulder and elbow of the arm consist of joints that move along the horizontal plane, and a ball joint at the attachment end allowing full range of motion. The shoulder and elbow joint also have a screw device on them to lock them in place once positioned. The idea of the joints is to try and allow for adjustability. The main issue that comes with having them be manoeuvred and locked by screws is that it reduces the ease of use of the device as it could be difficult for those with hand mobility issues to use.

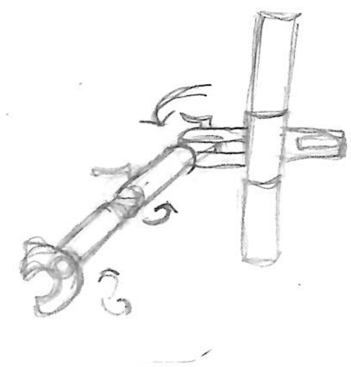

Figure 4.5: Attachment arm concept design 1.

Table 4.2: weighted decision matrix for attachment arm.

		Concept 1		Concept 2	
Design Criteria	Weight (%)	Rating	Weight Score	Rating	Weight Score
Ease of use	35	2	0.7	2	0.7
Manufacturing	25	2	0.5	2	0.5
Adjustability	35	2	0.7	3	1.05
		total	1.9		2.25

Design Concept 2

For this concept it has the arm attached to a pin that goes through the batter holder that allows for rotation at the elbow. At the elbow is also a joint that allows for the arm to move along the horizontal plane.

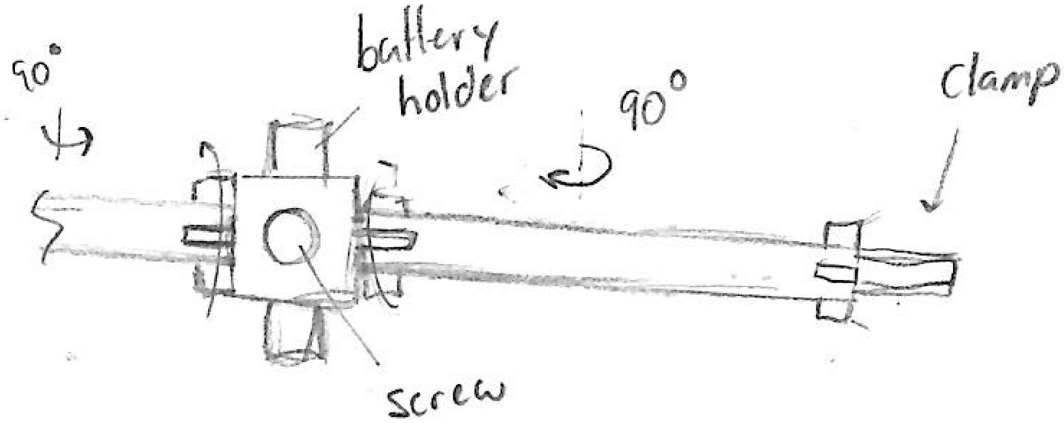

Figure 4.6: Attachment arm concept design 2.

Evaluation of Designs

A weighted decision matrix was formed based upon the design requirements outlined.

Based off of the 4.2 the final choice in design for the attachment arm is design concept 2.

Final Design

4.7 shows the 3D model for the final design of the arm attachment with the connection attachment included.

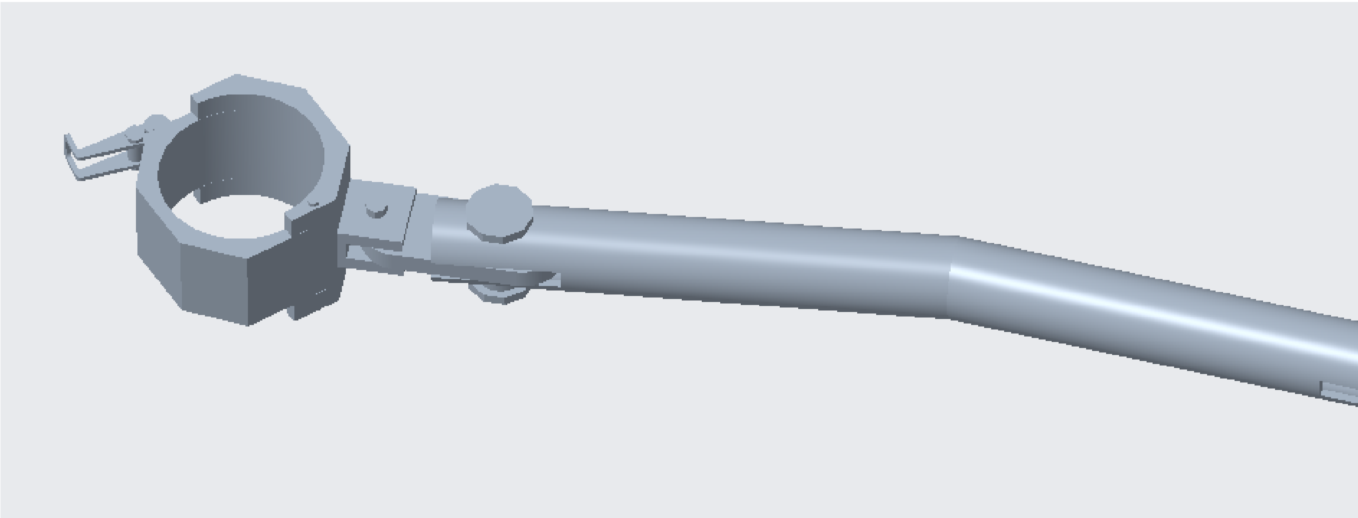

Figure 4.7: Arm attachment 3D model.

4.1.3 Design of Frame

The frame of the system involves designing the base for the handlebar section This section of the system is what will hold the controls of the device. The frame will have attached to it all the electrical components so in its design it needs to accommodate for the placement of everything. The frame is also what is going to be used to control the system so how it moves is important for the design. Alongside all this ergonomics are needed to be considered so that it is ensured that the sizing of the device allows for it to be used comfortably. To begin the design, it is important to understand what areas of designing the subsystem are integral to solving the design problems outlined in Chapter 3.2.1

For design problem 1 it was discussed that it is important for wheelchair users to be able to navigate long distances and diverse terrains without large amounts of force. For this design solution to come through in the frame the main area of thought would need to come through the weight of the subsystem. With this it is also important that the subsystem is durable. This largely came down to material selection and the structure of the frame.

For design problem 2 it was it was discussed that it was important that the design reduced strain. For the frame of the system that would involve ensuring that the subsystem is ergonomic. This involved ensuring that the system would control easily and that the dimensions of the frame were within an appropriate size for use.

For design problem 3 it was discussed that the device be cost effective. This would done through by ensuring that the frame has a simple design and uses material that is cost effective and can easily be sourced.

4.8 shows a 3D model of the frame.

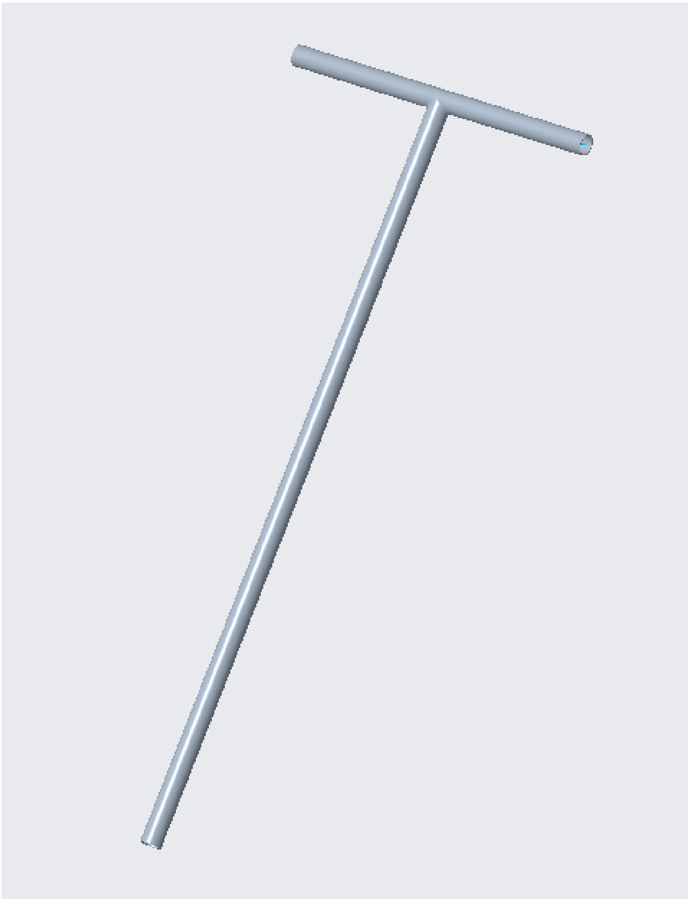

Figure 4.8: Frame 3D model.

Other Frame Connections

First connected to the bottom of the frame is what will connect the frame to the wheel. The design of this is a simple dropout frame that is commonly found to connect bike wheels. This design was chosen for its simplicity. 4.9 shows a 3D model of the design of the dropout.

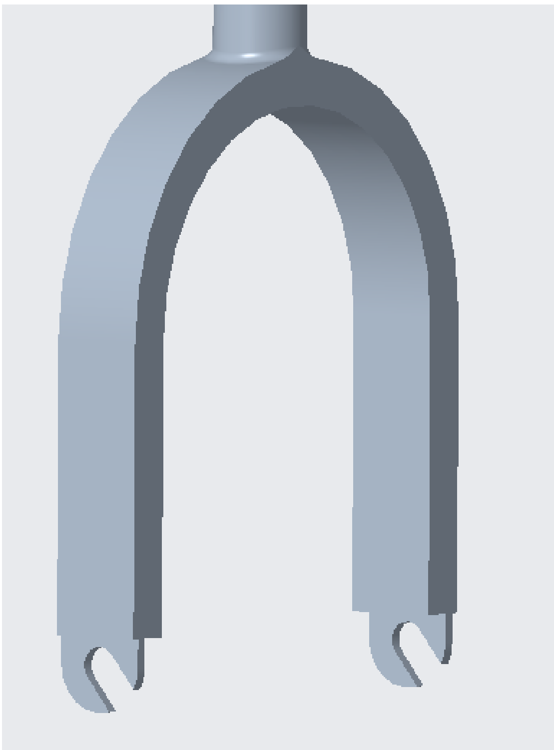

Figure 4.9: Dropout 3D model.

Another attachment is the battery holder. This will function to keep the battery stabilised to the frame but will also hold the connection arm. Finally, is the stand the stand will be used so that the device can stand on its own while so it can remain upright wile being attached to the wheelchair. 4.10 shows the 3D model of the design of the battery holder.

4.1.4 Electrical System

The electrical system of the electric handcycle will consist of parts that would be purchased from third party places. The parts of the electrical system that were used include:

- Drive control
- Battery
- Motor and wheel
- Controller

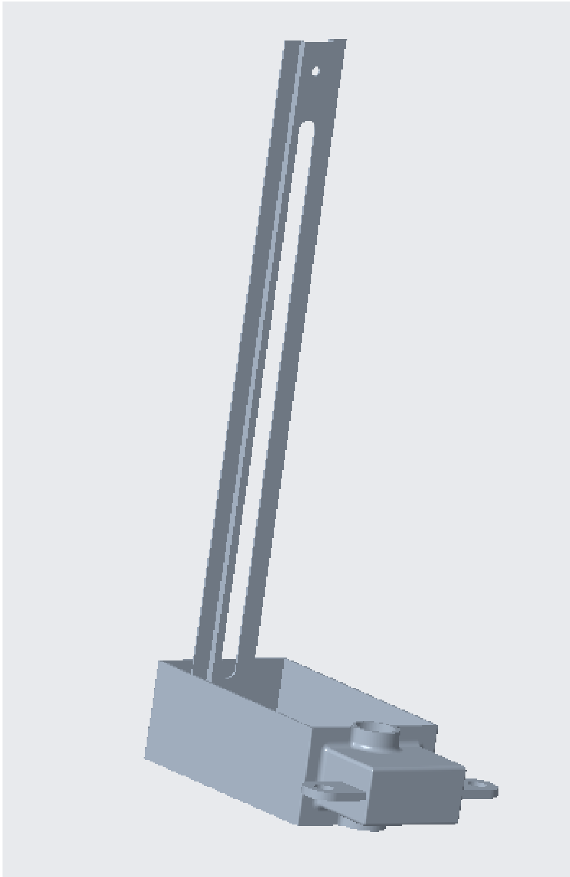

Figure 4.10: Battery holder 3D model.

As form Chapter 2.5 it was found that typically electrical wheelchair motors are typically powered at 12 or 24 volts and at around 250 wats so when deciding for the electrical system it is important for the parts to fit around this specification. When choosing the electrical parts, the availability for long-term production was also considered. In keeping with the ecological outlined in Chapter 3.3.2 elements such as trying to source locally if possible and trying to consider that the parts where easily disassembled and where replaceable. Following these considerations, a decision as to the brand of the part was chosen.

Drive Control

The final chosen drive control was the KS Westy Under Bar Remote Lever. The drive control decided on for the electric handcycle was a remote lever drive. Being a hand cycle a remote lever drive device is the most intuitive control for this type of device. This was chosen as it was it can be simply attached and removed if needed and was available locally in Australian warehouses.

Battery

The final battery that was chosen for the handcycle was a Silverfish E-bike 350 W 36 V 10 Ah amp li-ion battery. The battery being for E-bikes has already been appropriately designed for a handcycle style device. The specifications meet the requirements outlined and it is easy to buy replacements when needed.

The main downside of this battery was cost. As stated in Chapter 2.5 Li-on batteries are the more cost exhaustive type of battery for electrical devices such as a handcycle however this was outweighed by the availability of this style of battery.

Motor and Wheel

The final choice was the RisingSun hub motor and wheel (350 W, 36 V). The specs of this wheel matched with the desired specifications outlined.

For the handcycle to be driven a motor is required. As the system requires only one wheel it was decided that a hub motor would be appropriate. For the motor and wheel, it was decided that a good option was for the device to be one that was already in production for E-bikes or E-scooters as these would be readily available for production and later for replacement if required.

Controller

The final choice for the controller was a generic brand 350W 36V speed controller box. This choice was made as it met the required specifications with all the needed plugs for the system.

4.2 Cost and Weight Analysis

For the pricing of the aluminium pipe pricing was found by averaging multiple options found from websites selling the pipes. The final product was found to require 1.9 m of piping. There was no option for 1.9m so the final cost was based upon the available length

Table 4.3: Estimated cost and weight of the contraptions parts.

		Concept 1		Concept 2	
Design Criteria	Weight (%)	Rating	Weight Score	Rating	Weight Score
Ease of use	35	2	0.7	2	0.7
Manufacturing	25	2	0.5	2	0.5
Adjustability	35	2	0.7	3	1.05
		total	1.9		2.25

of 6.5m. It was difficult to find the appropriate sizing for all the parts that would require aluminium sheets to build. So, for them the cost was based upon a cost per kilogram average that was estimated by companies selling aluminium plates. This was found to be priced at $5/kg. The cost for the electronic items were based on the asking price in the store they were found at.

The final cost of the product is slightly over the desired price of under $1000. The final price of the item, however, is only a representation of the material to produce a single unit and would not be represented in a situation in which multiple products would be made. This could end up increasing or decreasing the total cost of the product depending on many factors.

The weight of the product did manage to be the desired weight of 10 kg. The results of this analysis are demonstrated in 4.3

4.3 Summary

This chapter explored the design of the power attachment. The final design of the Final material chosen for the elements of the design was Al60601-T6 due to its good strength and its weight. Overall the design was ble to incorperate all the needed elements required for a handcycles use. The design was not able to make the desired cost limit reaching over $1000.

Chapter 5

Finite Element Analysis

5.1 Analysis Overview

5.1.1 Loading Condition

In this section an FEA was performed to simulate how the loading conditions would change on a wheelchair frame when the handcycle is attached.

Stress Analysis

The first test was done on the wheelchair frame by itself. The chair was constrained with a pin joint at both where the rear wheels would be located and at the location of the caster wheels. A load of 1000N was applied on seating location.

From 5.1 it can be seen that most of the stress is concentrated at the location of the rear wheel.

With the addition of the handcycle the concentration of the stress moves from being located at the point of the rear wheel to covering the area from the wheel to where the handcycle connects to the wheelchair, as demonstrated in **??**. The max stress held was on the handcycle itself being located at the beginning of the arm. The maximum stress experienced was of 37.1 MPa which was located where the arm is connected to the handcycle as demonstrated in 5.4. This stress is below the max stress limit for both the

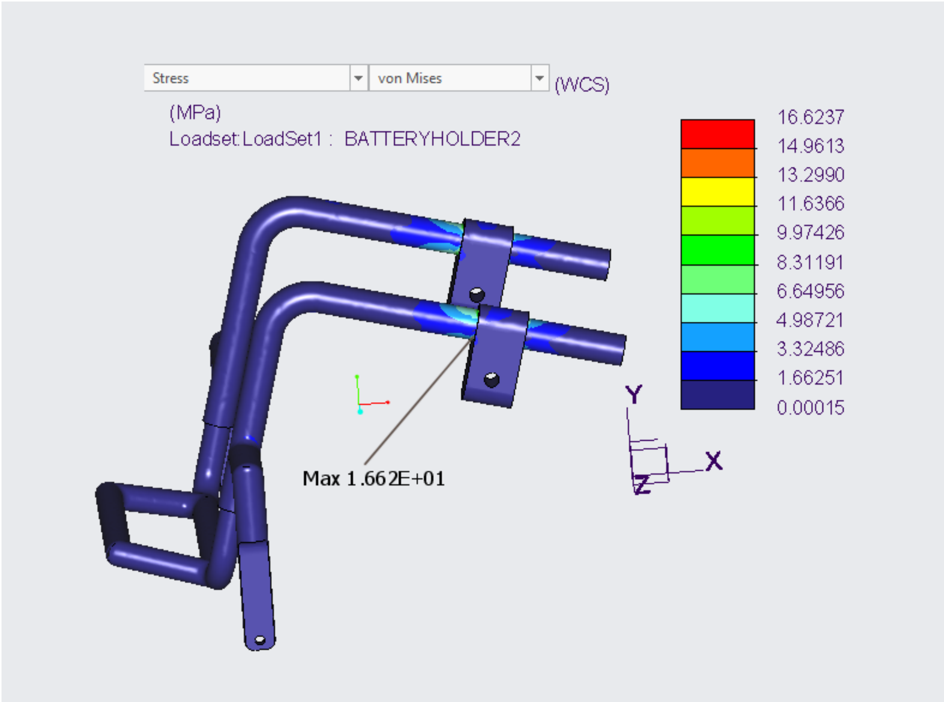

Figure 5.1: Stress analysis for loading condition of ridged wheelchair frame

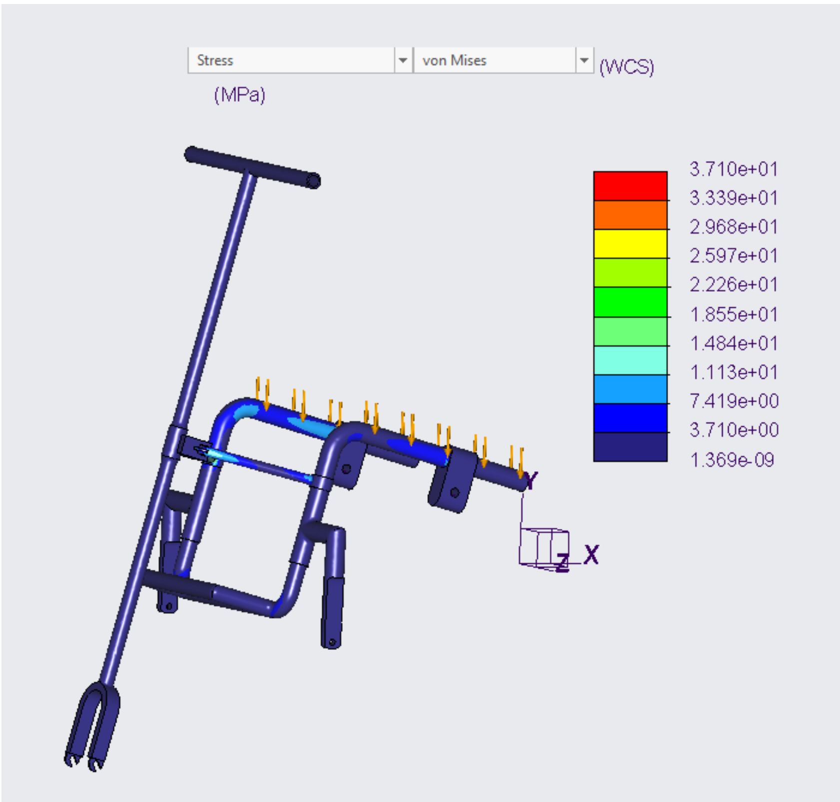

Figure 5.2: Stress analysis for loading condition of power handcycle and ridgid wheelchair frame

wheelchair frame and the handcycle so under these new loading conditions there should

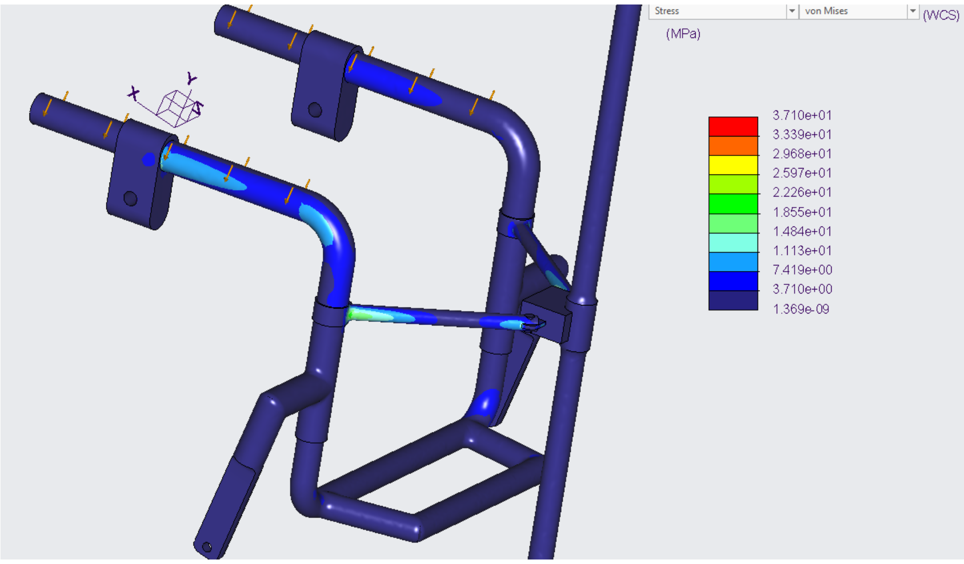

Figure 5.3: Stress analysis for loading condition of power handcycle and ridgid wheelchair frame stress concentration

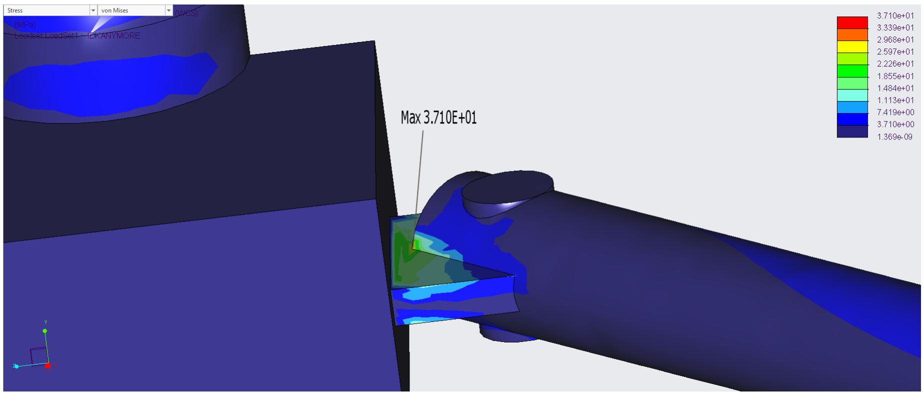

Figure 5.4: Stress analysis for loading condition of power handcycle and ridged wheelchair frame stress concentration

be no failure.

discussion

The loading condition change experienced by the frame does demonstrate a need for more information to be found in this area. With the addition of an attachment this FEA shows that not only does the area that the stresses are located changes but, in the case of the handcycle designed for this project, it increased the stress experienced by the frame.

5.1.2 Stress Bearing Area

This FEA was performed to simulate the stress bearing parts of the wheelchair while the chair is static with a person of 100 kg sitting on it.

Stress Analysis

Stand

A test was done on where the stand. The analysis was done for when the stand is in a standing position. This was to ensure that it would be okay to hold up the device when in a standing position. A constraint was put where the stand is connected to the frame of the handcycle and a load simulating the wight of the handcycle pushing down on the stand.

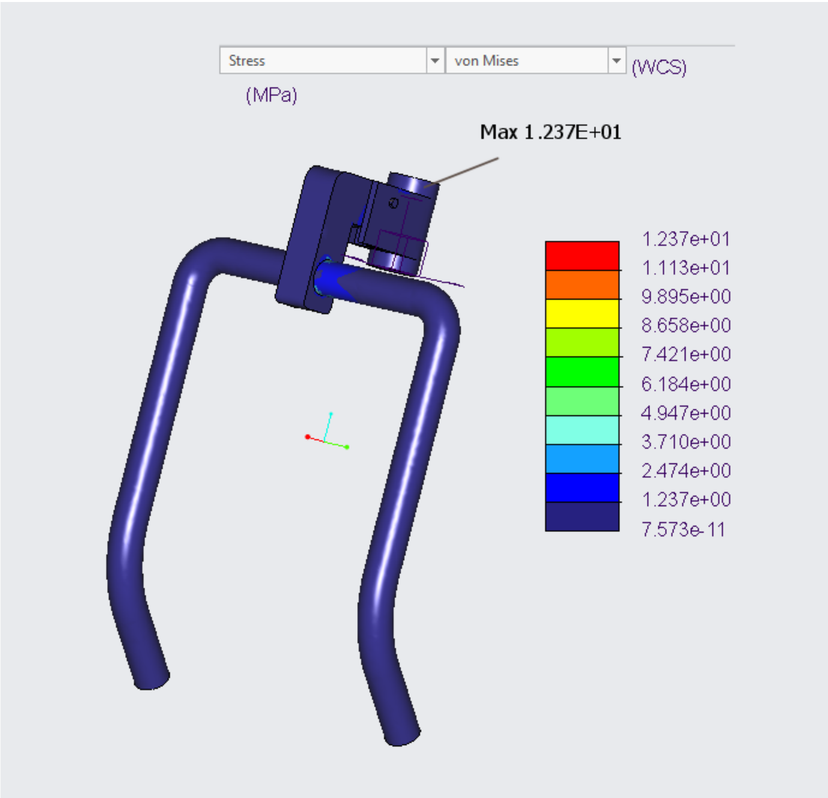

Figure 5.5: Stress analysis on stand assembly

The strain experienced by the stand was within a reasonable range. the maximum amount of stress was found to be 12.37 MPa which was located near where the stand connects to the frame.

Battery Holder

A test was done on the battery holder. A constrain was put where the battery holder connects to the frame. A load representing the battery was placed where it goes and another load was laced in the area where load would be from where the arm would be connected.

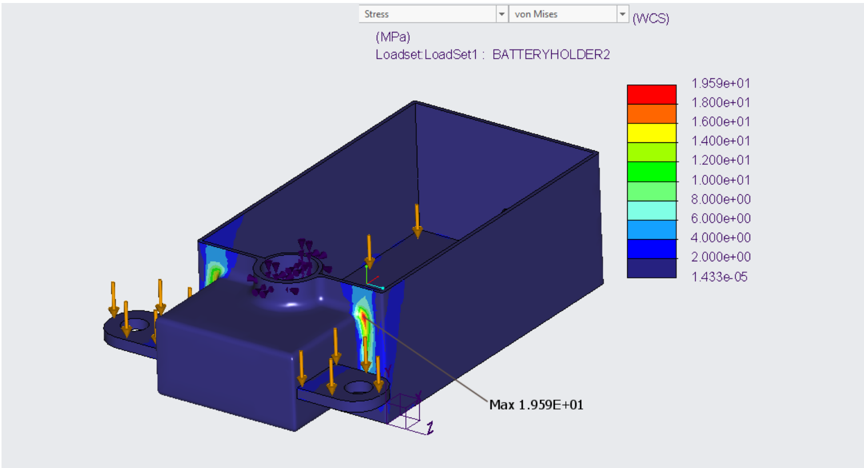

Figure 5.6: Stress analysis on battery holder assembly

This component under the loading condition would not cause yielding or deformation. The largest stress of 19.59 MPa on this part is where the arms of the power handcycle connects to the frame as shown in 5.6. Most of the stress is concentrated in this area. There is some stress inside where the battery is located but this is not enough to cause any form of deformation.

Dropout

A test was done on the dropout. A constrain was placed at the top where it would be connected to the frame and a pin constrain was placed where the wheel would be located.

The stress on the dropout is minimum. The stress on the dropout is concentrated where the wheel connects as can be seen from 5.7. The max stress is 2.983 MPa which is well within the max stress allowed for the part.

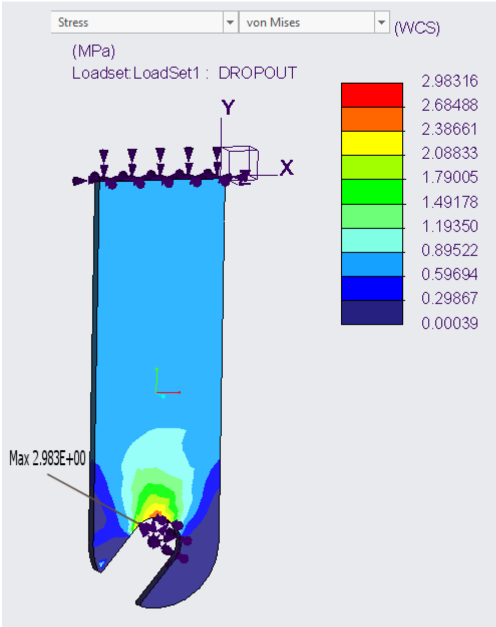

Figure 5.7: Stress analysis on dropout

Discussion

All the lead bearing areas represented did not exceed the maximum stress allowance.

5.1.3 Handlebar Resistance to Forces

This section was based upon the test methods for static stress section of Australian Standard ISO7176-8:2014. The tests are supposed to be done to test the tipping and back and forward movement of an unloaded mobility scooter.

Stress and Displacement Analysis

Resistance to forward forces

A force of 300N was placed at 25mm into each end of the handlebar facing forward and the stress and displacement were recorded.

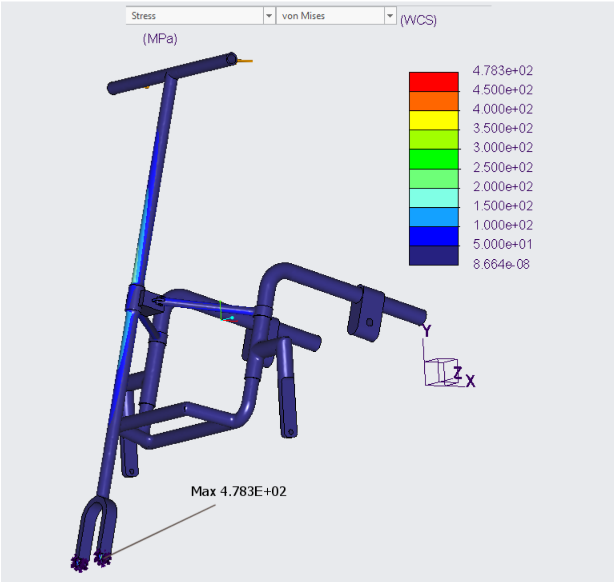

Figure 5.8: Stress analysis on forward forces

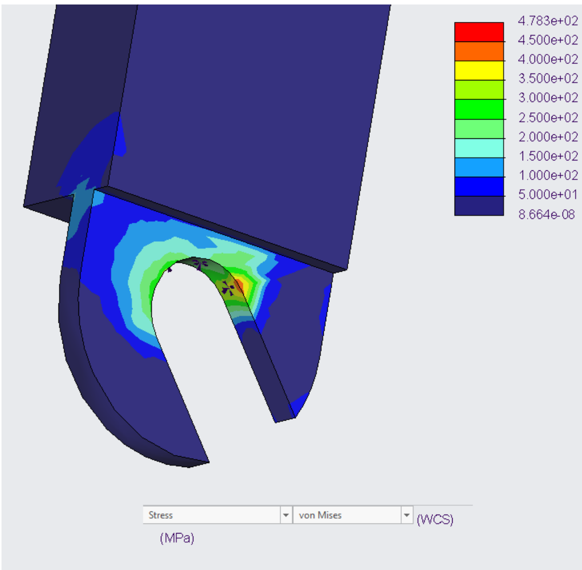

Figure 5.9: Stress analysis on forward forces, concentrated stress area

Resistance to Rearward Forces

A force of 300N was placed at 25mm into each end of the handlebar facing rearward and the stress and displacement were recorded.

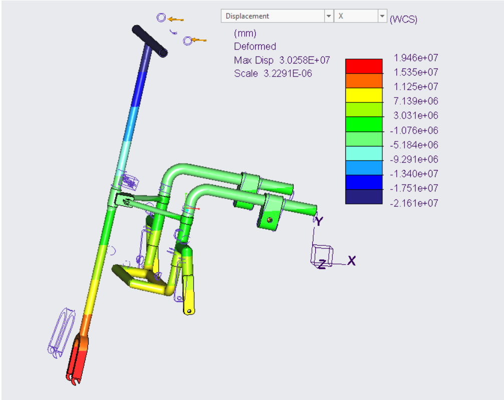

Figure 5.10: Displacement analysis on forward forces

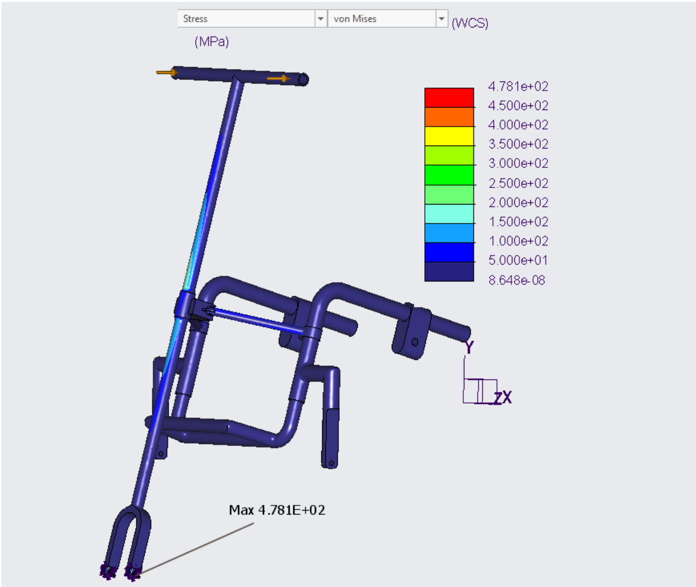

Figure 5.11: Stress analysis on rearward forces

resistance to upward forces

A force of 300N was placed at 25mm into one end of the handlebar facing up at a 15 degree angle and the stress and displacement were recorded.

Resistance to Downward Forces

A force of 300N was placed at 25mm into one end of the handlebar facing downward at a 15 degree angle and the stress and displacement were recorded.

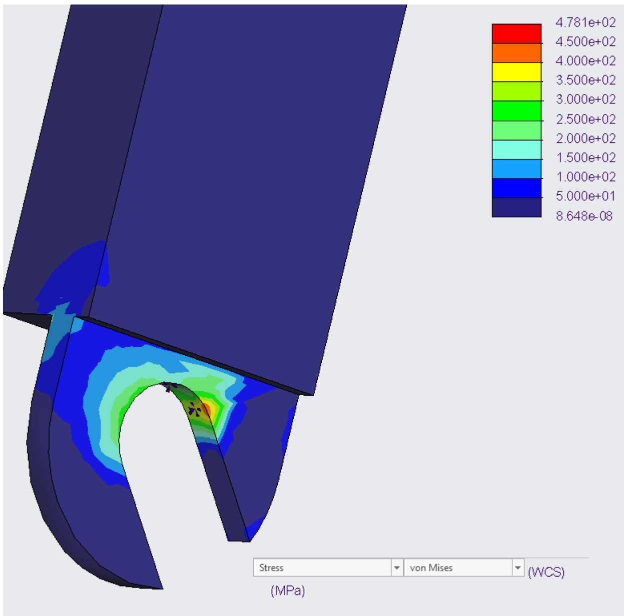

Figure 5.12: Stress analysis on rearward forces, concentrated stress area

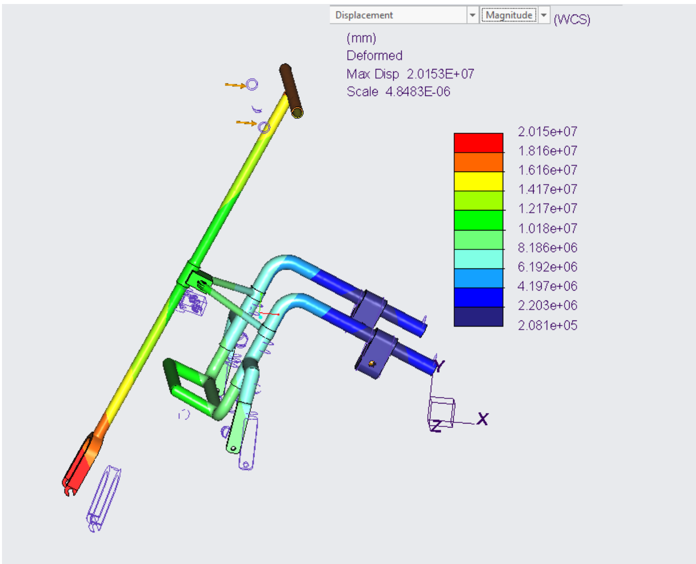

Figure 5.13: displacement analysis on rearward forces

Discussion

All the forces in these tests provide a great level of displacement and stress within the handcycle. The handlebar tests are done on scooters to as a means to prevent tipping and moving backwards and forwards. Compared to a scooter it would be reasonable to assume that a wheelchair and handcycle would not be able to handle the same amount of force before tipping or moving forward due to elements such as their difference in weight. This test does not accurately represent the tipping and moving conditions of the handcycle

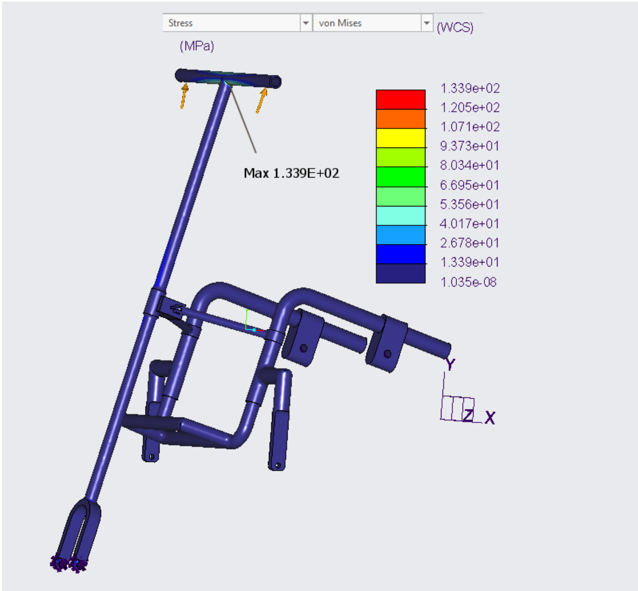

Figure 5.14: Stress analysis on upward forces

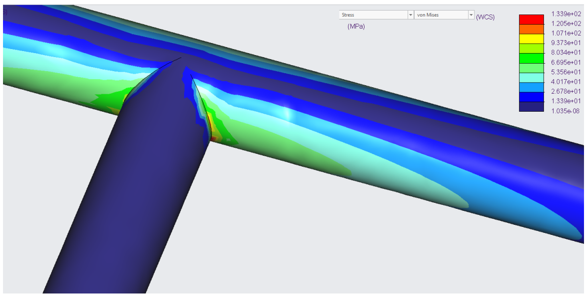

Figure 5.15: Stress analysis on upward forces, concentrated stress area

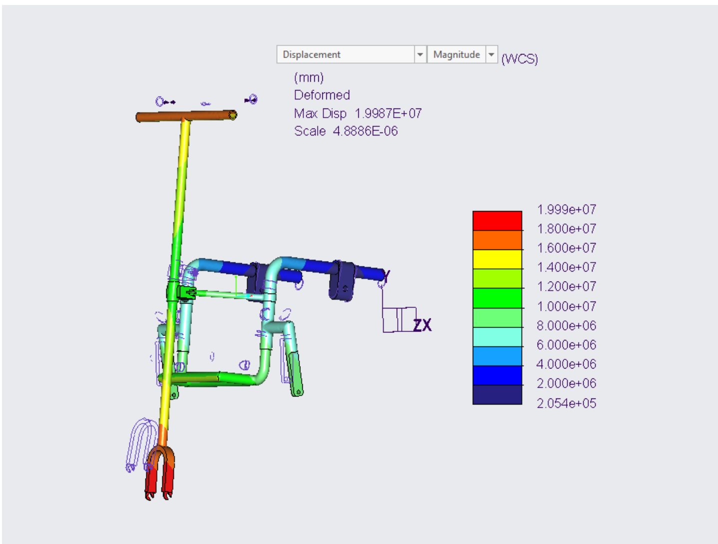

Figure 5.16: displacement analysis on upward forces

but does provide some incite into the stress conditions of the handcycle if someone were to misuse the handcycle in ways such as trying to lift or it by the handles while attached.

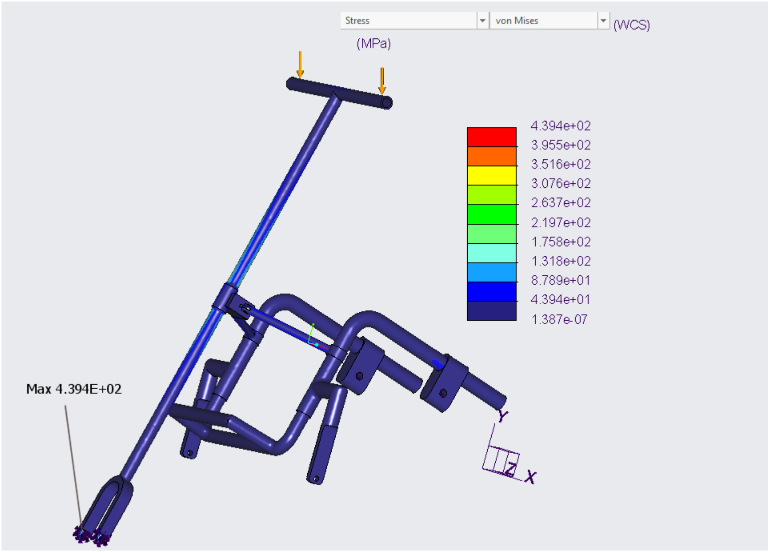

Figure 5.17: Stress analysis on downward forces

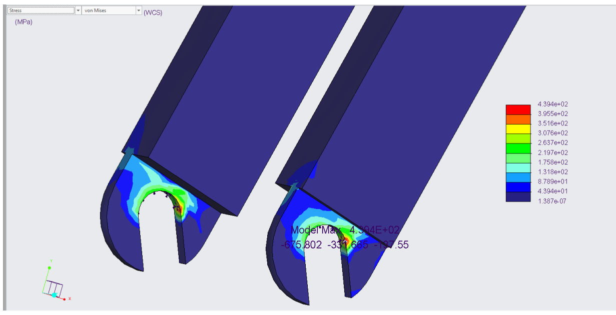

Figure 5.18: Stress analysis on downward forces, concentrated stress area

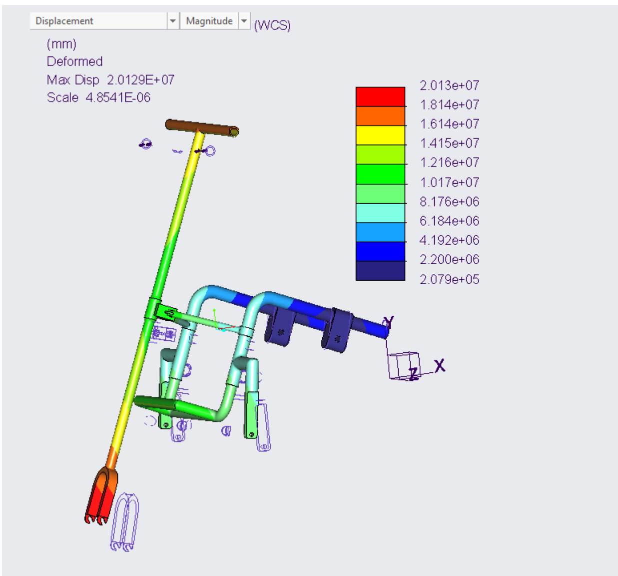

Figure 5.19: Dissplacement analysis on downward forces

From the stress and displacement, the handcycle would fail under these conditions.

5.2 Limitations

More stress testing could be done under the many conditions that wheelchairs move under. The testing done for this assessment focused on the different stresses under a static condition, however as wheelchairs are used for mobility, testing would need to be done to understand how the device would function under dynamic conditions. Under dynamic conditions it could be assumed that there would be a larger concentration of stress appearing where the handcycle and the wheelchair are connected.

As wheelchairs are an important mobility tool rigorous testing is required to ensure that they are appropriate for use. With limited testing abilities it is hard to come to any decisive conclusion about the effectiveness of the final design. Alongside this there are no standards regarding power attachments for wheelchairs. No test described in standards properly reflect how they should be tested regarding tipping, back and forward movement. And there is no information into how the stress changes in the wheelchair frame

Chapter 6

Conclusion

A conceptual design of an electric handcycle was created in an attempt to create a cost-effective and user-friendly method of manual to electric wheelchair conversion. The design provides a solution to this and to further aid in the limitations of movement, and the discomfort and long-term strain damage that comes with long term manual wheelchair propulsion. The concept design stage was semi successful at producing a design with potential for manufacturing. The design was able to meet most of the requirements however fell short in the cost analysis.

6.0.1 Achievment of Objectives

1. Investigation into the current use of wheelchairs and issues faced when using a manual wheelchair. This objective of the investigation into the current use of wheelchairs and issues faced when using a manual wheelchair was performed and completed within the literature review section of this report. Information was found into areas such as wheelchair propulsion methods, and reviews into the effects of wheelchair use on the body were reviewed for this investigation.

2. What mobility attachments are available. This objective was completed in the literature review section of this report. Information was gathered from both manual and powered mobility attachments were reviewed.

3. Review information into the standards relating to wheelchairs and wheelchair add-ons. This objective was completed in the literature review section of this report.

Standards related to wheelchair testing were found, however no information was found into the standards of the use of wheelchair attachments.

4. Determine a design criterion based on the information gathered. This was accomplished in the methodology section of the report. This section outlines demands and wishes for the concept design to accomplish.

5. Design a prototype that meets the design criteria outlined This was performed in chapter 4 of the report. A concept design of an electric handcycle was complete and compared to the design criterion outlined in the methodology.

6. Model the final design and conduct an FEA testing the presided stress point, This was accomplished in chapter 5 of this report. The concept design was modelled in in Creo and an analysis was performed on the stress bearing areas of the design, and an additional analysis was performed on the change of loading conditions on a wheelchair frame attached the handcycle.

7. Analyse the data and evaluate based upon the design criteria and relevant standards. This was accomplished in chapter 5. Though there were no standards relating to add-ons for wheelchairs there was some based upon handlebars for scooters. This criterion was evaluated in a section of chapter 5.

6.0.2 futurework

Though a conceptual design was complete more investigation can be done. For future work creating a prototype of the design and performing a physical evaluation would be the next step for this report. As there currently little information into the use of mobility add-ons for wheelchairs, there would be benefit into performing tests in a physical setting. This testing would ensure that the wheelchair is able to meet the performance requirements outlined.

Testing needs to be done to ensure that the handcycle is able to function effectively in dynamic situations. A stress test would need to be performed to ensure that bath the handcycle and the wheelchair do not fail in dynamic situations. Alongside this more information is required to better understand how mobility add-ons effect the loading condition of wheelchairs overtime.

Finally, more can be done to see if there are better ways to reduce the cost of mobility aid during the manufacturing of handcycle devices. It is important that people are able to access the tools that they need to best navigate the world.

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Appendix A

Project Specification

ENG 4111/2 (or ENG8002) Research Project

Project Specification

For:	**Jesse Batterham**
Topic:	Power Assist Attachment for Manual Wheelchairs
Major:	Mechanical Engineering
Supervisors:	Steven Goh
Project Aim:	Design an inexpensive power assist attachment for manual wheelchairs.

Program: Version 1, 17th March 2021

1. Review and evaluate initial background information into wheelchair and current power assist attachments. Gather information into the components power assist attachments, how they work, what materials they are made from.

2. Review and evaluate existing power assist attachment designs, and identify and identify and analyse usability issues and suggest design improvements.

3. Research the equations are used to determine the forces and required power in power assist wheelchair use.

4. Review the disability standards and wheelchair test standards that they need to meet for public use and sale.

5. Analyses which power assist attachment design features would be best suited to fulfil the project scope.

6. Design a frame for the power assist attachment and perform a stress analysis for it to determine if it meets the standard specifications.

7. Finalise the design of the power assist attachment and evaluate each component, how they will work and how the meet the project scope.

Appendix B

Project Planning

B.1 Risk Assesment Plan

A risk assessment plan isessential when undertaking any task. It is important to be able to identify what risks may manifest during the task and have a plan to mitigate them. The table ?? was used as the risk assessment plan index that was used to identify the severity of the risks that were identified for this project. The risk management plan covering the project is shown in table ??.

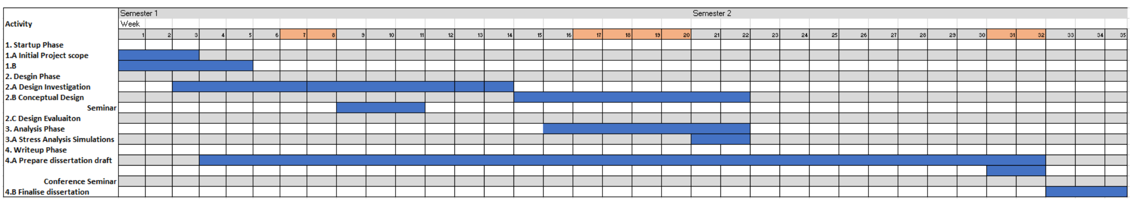
IMPACT x PROBABILITY	NOT SIGNIFICANT	MINOR	MODERATE	MAJOR	SEVERE
HIGHLY UNLIKELY	LOW	LOW	LOW / MED	MEDIUM	MEDIUM
UNLIKELY	LOW	LOW / MED	LOW / MED	MEDIUM	MED / HIGH
POSSIBLE	LOW	LOW / MED	MEDIUM	MED / HIGH	MED / HIGH
LIKELY	LOW	LOW / MED	MEDIUM	MED / HIGH	HIGH
HIGHLY LIKELY	LOW / MED	MEDIUM	MED / HIGH	HIGH	HIGH

RISK OR HAZARD DESCRIPTION	EXISTING CONTROL MEASURES	RISK PROBABILITY	RISK IMPACT	RISK RATING
Loss of Files/Computer	Saving files onto OneDrive and saving extra copy onto an external hard drive	Possible	Severe	Med/High
Conducting the FEA and design fails	Try re-evaluating and redesigning the product	Likely	Moderate	Medium
Potential for report to be used externally	Ensure the information in the report is reported accurately	Unlikely	Moderate	Low/Med
Unable to meet design criteria	Re-evaluate the design and criteria	Likely	Major	Med/High
Insufficient time to write dissertation	Make sure to follow timeline and begin writing at every stage of the project	Possible	Major	Med/High
Unable to design model in Creo	Review knowledge on Creo and seek out resources if more knowledge is required	Possible	Major	Med/High
Unable to access USQ computer lab with Creo Simulate	See if USQ has access to a license to use on at home computer	Unlikely	Major	Medium
Issues with using LaTeX in writing the dissertation	Review LaTeX Knowledge and find resources to help with needed information	Likely	Moderate	Medium

Appendix C

Project Timeline

Table C.1: Project Timeline.



Appendix D

Concept Illustrations

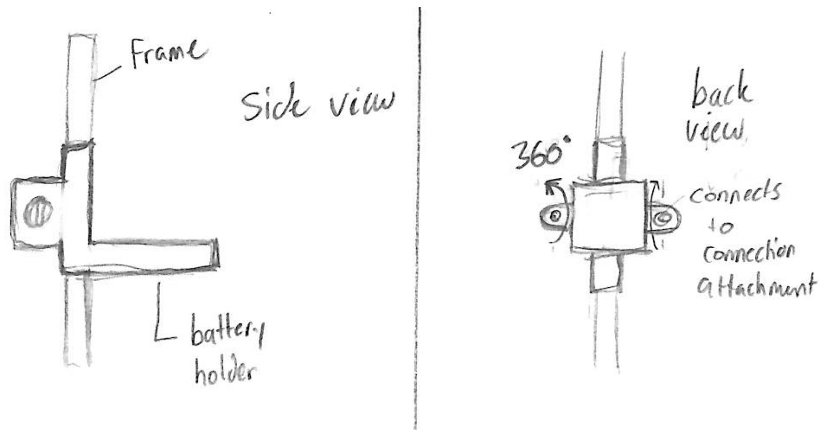


Figure D.1: Concept design of battery holder.

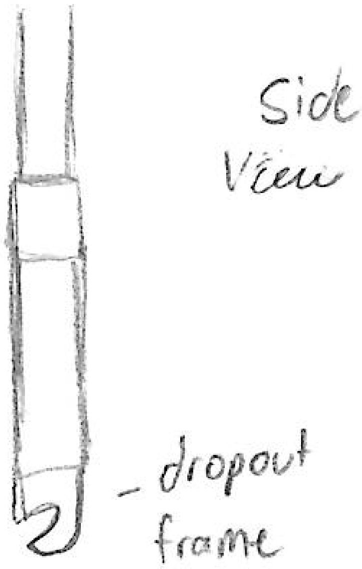


Figure D.2: Concept design of the dropout.

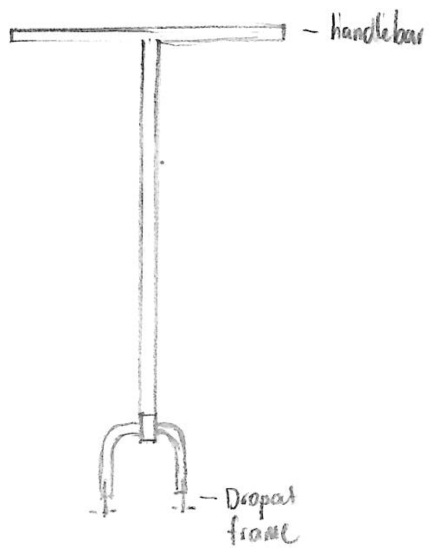


Figure D.3: Concept design of frame.

Appendix E

Drawings

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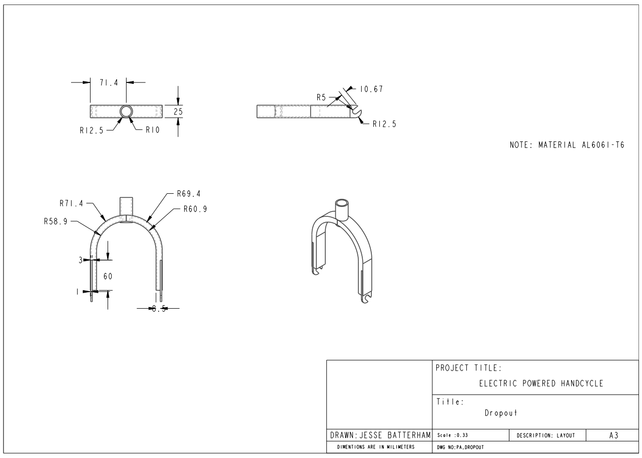

Figure E.1: Dropout drawing.

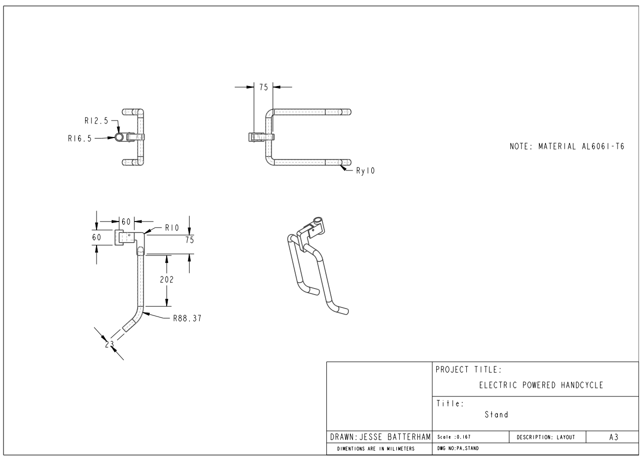

Figure E.2: Stand drawing.

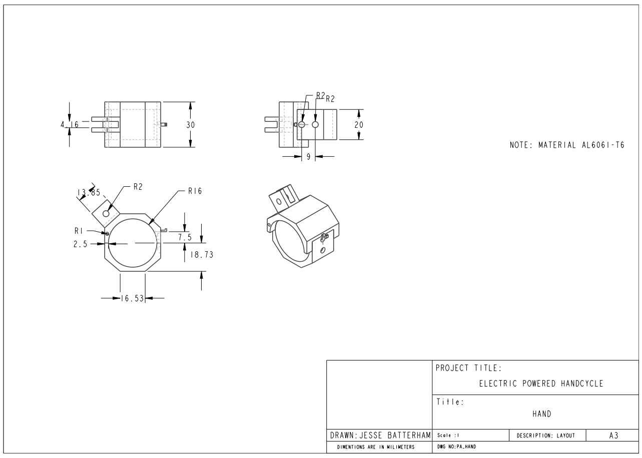

Figure E.3: Hand drawing.

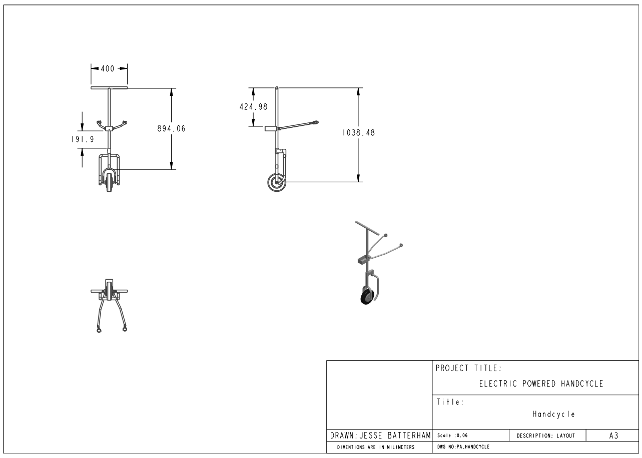

Figure E.4: Handcycle drawing.