# DESIGN AND SIMULATION OF AN EXTENDABLE WHEEL CHAIR

**BY**

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AN INDIVIDUAL PROJECT REPORT SUBMITTED TO THE FACULTY OF ENGINEERING, TECHNOLOGY, APPLIED DESIGN AND FINE ART, KABALE UNIVERSITY (KAB) IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF MECHANICAL ENGINEERING IN THE DEPARTMENT OF MECHANICAL ENGINEERING

# DECLARATION

I hereby declare to the best of my knowledge that this piece of work is my own and has never been submitted to any higher institution of learning for the award of a Degree or any other academic qualification and thus describe my involvement as a student of Mechanical Engineering.

Date: 26/04/2022

SIGNATURE ...~...............................

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# APPROVAL

This is to certify that this work was carried out under strict supervision and has been approved for submission to the Faculty of Engineering, Technology, Applied Design and Fine Art, Department of Mechanical Engineering of Kabale University in partial fulfillment of the requirement of the award of a Bachelor of Mechanical Engineering.

SIGNATURE .....................................

Mr. Isaac Ndawula

SUPERVISOR

DATE...26th/04/2022.........

# ABSTRACT

People with walking disabilities are denied the luxury of accessing elevated places in the while using their wheelchairs. Some of these people rely on attendees to access these places. Others try to access these places on their own which is tedious. In this paper, a wheelchair with a double scissor mechanism is proposed that will help wheelchair users to comfortably access elevated places, The proposed wheelchair is first conceptualized to come up with the conceptual design consisting of a chair, mobile platform and a double scissor mechanism. The proposed wheelchair components are then designed and the 3D model prepared in solid works. The designed components include; Scissor Jinks, lead screw and a nut The prepared model is then imported into ADAMS and motion analysis is carried out. The displacement, velocity and acceleration graphs are generated showing the movement of the chair in the Y axis. Finite element analysis of the model is also carried out in solid works. The static stress and static displacement graphs are also generated. All the results generated using the different CAE software's are then discussed.

# ACKNOWLEDGEMENT

First and fore most I would like to thank the Almighty God for the gift of life and opportunity to study this course and work on this project with my supervisor.

Throughout the proposal drafting, am very fortunate to be blessed with the guidance and encouragement from Mr Isaac Ndawula (supervisor).

In addition I would like to gratefully thank the administration of Kabale University, FETDAT for the provision of supervision during the drafting period.

Lastly I would like to appreciate my mother Mrs Muganzi Jenipher for the financial support she offered to me during the drafting period.

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# ABBREVIATIONS

**DOF -** Degree Of Freedom

CAE **-** Computer Aided Engineering

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# INTRODUCTION

## 1.1 Background

There are many people today who find it difficult to learn and perform day to day tasks because they are unable to move from one place to another. Their inability to walk is caused by illness, injury, old age or a disability. A disability is defined as any state of the mind or body that incrementally makes it difficult for a person to do certain exercises and integrate them in their overall environment[ 1]. **Most** of these people rely on assistive equipment to help them accomplish day to day tasks. The most used assistive equipment is a wheelchair. A wheelchair is a seat fitted with wheels. These are a variety of wheelchairs available on the market for disabled people namely; manual wheelchairs, powered Wheelchairs and smart wheelchairs. When using the above mentioned wheelchairs, the disabled person is able to reach out to items closest to him or her. This denies the wheelchair user the freedom to reach out to items that are not very close to him or her for example raised shelves. While reaching out for these items the wheelchair occupant is likely to stretch and this make it **uncomfortable.**

## 1.2 Problem statement and motivation

Wheelchair occupants are denied the freedom to access elevated places by the available chairs on the market. This leaves the occupants in need of assistance to access these elevated places. The maximum height a wheelchair occupant can access is 4.5ft (1400mm) compared to the 7ft (2135mm) accessed by a normal person.

My motivation is the discomfort incurred by a wheelchair user while accessing elevated place when using the currently available wheelchairs.

## 1.3 Objectives

### 1.3.1 **Main** objective

To design an extendable wheelchair

### 1.3.2 Specific objectives

(a) To conceptualize the proposed wheelchair (h) To
design the proposed system components

(c) To perfonn dynamics analysis of the proposed design by ADAMS.

(d) To perform finite element analysis of the proposed system by SOLID WORKS.

## 1.4 Project report outline

The rest of the report consists of five chapters namely; literature review, conceptual design, design and simulation, results and discussion, and a final chapter on conclusion and future works. The chapters are arranged in the order stated above.

In the literature review chapter different types of wheelchairs are review and referenced. The review wheelchairs are organised in ascending order beginning with the most conventional wheelchair and ending with the latest innovation.

In the conceptual design chapter all the components of the proposed wheelchair are described these include; chair, double scissor mechanism and the mobile platform. The working principle of the scissor mechanism is also explained in this chapter.

In the design and simulation chapter, the design equations used to design the different components of the wheelchair are elaborated. The components designed in this chapter include; scissor links, lead screw and nut. The chapter *also* includes procedures used to carry out simulation in both ADAMS and SOLIDWORKS.

In the results and discussion chapter the outcomes of the design equations are elaborated. The chapter also consists of the simulation graphs generated in ADAMS namely; displacement graph, velocity graph and acceleration graph. Results from the finite element analysis in SOLIDWORKS are presented and these include static stress and static displacement results. The final chapter consists of the conclusion and the future works to be done on the wheelchair.

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# LITERATURE REVIEW

The following review of literature illustrates work done by researchers in the development of wheelchairs. There are mainly three types of wheelchairs presented in previous developments and studies, namely; manual wheelchair, _powered wheel and smart wheelchair. Each type is presented in details as follows.

## 2.1 Manual wheelchairs

These are classified into two namely; manual self-propelled wheelchairs and manual attendant propelled wheelchairs.

Chen in [2] suggested an optimization design for a standard manual wheelchair consisting of a sliding seat and a reclining backrest as shown in Fig I. The suggested design made the **standard manual wheelchair more comfortable.**

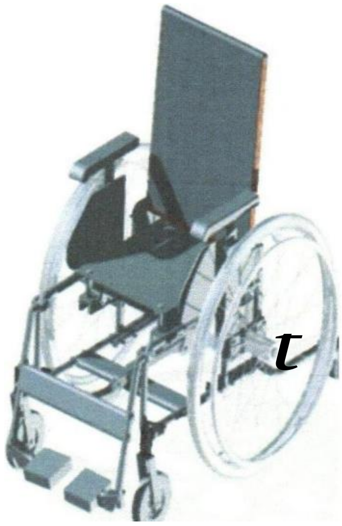

Fig 1: Optimization design for a standard manual wheelchair [4]

In [3] a foldable manual wheel chair with a swing- legged system is designed. The swinglegged system consists of a wheelchair, two chain systems, a handle wheel and a link that is rigidly fixed on the sprocket *D* as shown in Fig 2. The designed wheelchair bas obstaclecrossing capability.

Fig 2: Model of swing-legged system [5]

## 2.2 Powered wheelchairs

Electric-powered wheelchairs, also called "Motorized wheelchairs" are wheelchairs which have batteries and electric motors incorporated into their frames. They are controlled by either the user *or* an attendant, most commonly via a small joystick mounted on the armrest, or **on the upper rear of the frame.**

In [ 4]a wheelchair consisting of a mobile platform with four fixed wheels, a chair and two serial manipulators was developed as shown in Fig 3. The two serial manipulators consisting of two links connected by revolute joints and could move on irregular surfaces helping the disabled person carry out tasks like opening doors.

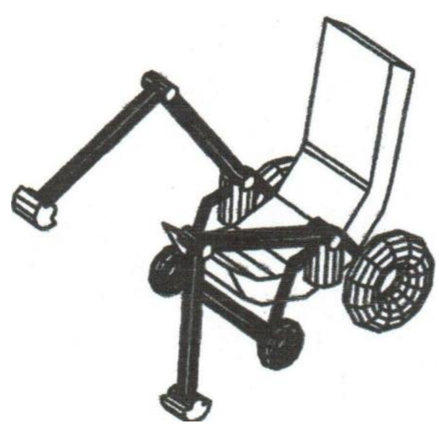

Fig 3: wheelchair with legs [6]

In [5] a wheeJchair was developed. It consisted of four wheels (two fixed wheels and two omnidirectional wheels), a 3D joystick, a chair and three motors as shown in Fig 4. The developed wheelchair could be navigated in both indoor environments and outdoor environments. The third motor could rotate the chair at the centre of the mobile platform.

Fig 4: wheelchair with omnidirectional wheels [7]

In *[6]* a wheelchair consisting of four fixed wheels, two motors, two 12V batteries, a solar module and a frame made using galvanized steel and a control module was designed as shown in Fig 5. The wheelchair was affordable and capable of moving in two opposite **directions.**

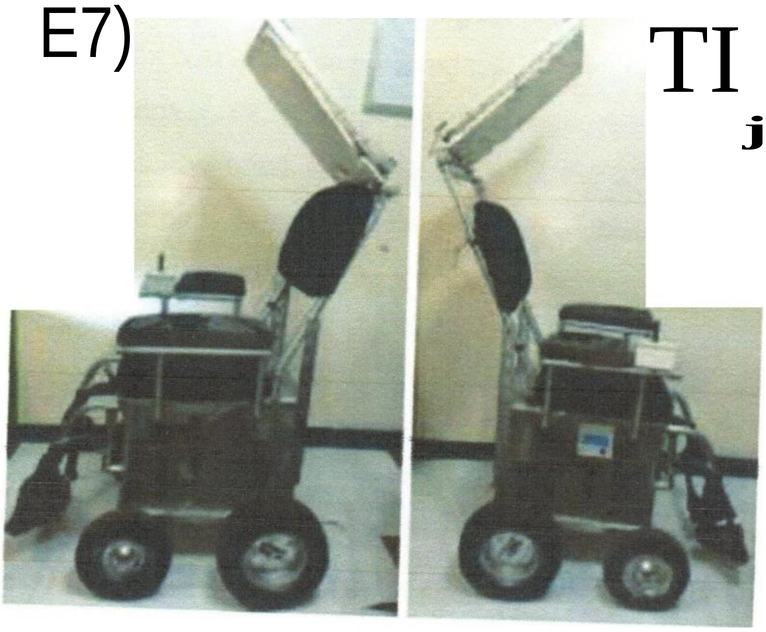


Fig *5:* Affordable wheelchair **fl]**

Ajibola et a1 in [7] developed a low-priced, electrically powered wheelchair consisting of two fixed wheels, two castor wheels, bamboo, angle bars, galvanised metal pipes and two batteries as shown in the Fig 6. Cheap materials were used to fabricate the wheelchair and this made it affordable to an average person.

Fig 6: low priced electrically powered wheelchair (8]

## 2.3 Smart wheelchairs

**Smart wheelchairs are powered wheelchairs that use a control system to replace user control** by reducing or eliminating the user's need of driving the powered wheelchair.

Noman et al. [8] designed a cost effective powered wheelchair consisting of an ATMega328 processor, L298N motor driver, DC Gear Motor, Ultrasonic Sensor, Bluetooth Module, IP **Camera and TTP224 Capacitive touch sensor as shown in Fig** 7. **The developed wheelchair** was controlled using an In-built gesture function of a smartphone and a touch sensor. The proposed wheelchair was equipped with an **IP** camera that provided visual and acoustic information to the attendee of the user.

Fig 7: cost effective powered wheelchair [9]

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In [9] an economically feasible wheelchair consisting of a voice interface, a gesture interface and a joystick was developed as shown *in* Fig 8. The developed wheelchair was electrically powered and consisted of three different controlling interfaces. It also contained attached ultrasonic sensors for obstacle detection.

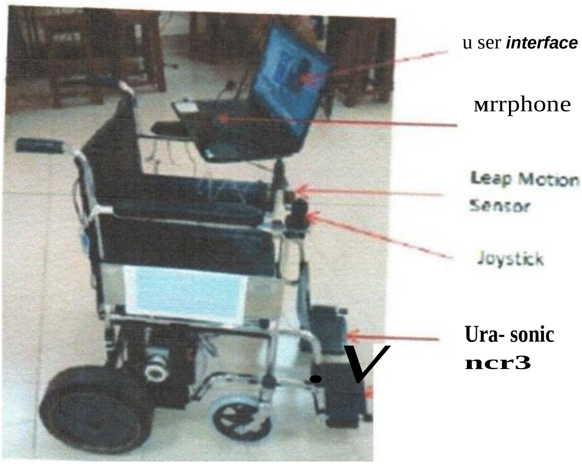


Fig 8: economically feasible whedchrur [10]

In [ 10]. an intelligent wheelchair was developed consisting of a gesture drive system, a thumb drive system, a flash light, an LCD and a heart rate detector as shown in Fig 9. The proposed wheelchair was controlled by either thumb or gesture control strategy. The user selects the control strategy from the menu. The proposed wheelchair was equipped with occupant health **monitoring system.**

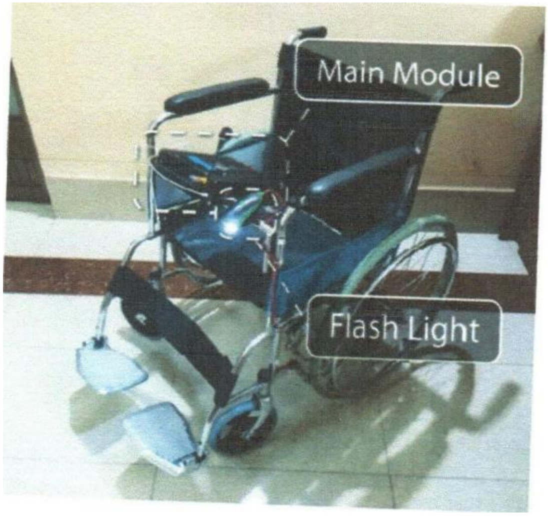


Fig 9: Intelligent wheelchair **[1**1]

## 2.4 Wheel types

Wheels are the most commonly used locomotion mechanism in mobile robots. They are classified into conventional and special wheels as described in [ 11] . Conventional wheel types include; powered fixed wheels, castor wheels and powered steering wheels. Special wheel types include; Swedish wheels and ball spherical wheels. Swedish wheels are further divided into universal wheels (Swedish at 90") and Mecanum wheels (Swedish at 45%)

### 2.4.1 Conventional wheels

Powered fixed wheels, these are driven by motors attached to the vehicle at a given position as shown in *Fig 10.* Their axis of rotation has a fixed direction with respect to the platforms coordinate frame.

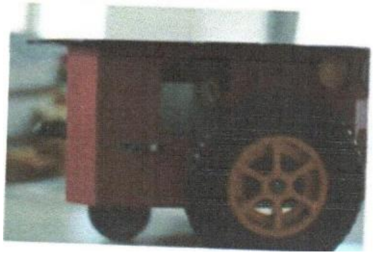

Fig 10: fixed wheel [13]

Castor wheels are not powered but they can rotate freely about the axis perpendicular to their axis of rotation as shown in Fig 11.

Fig 11: Castor wheel [BJ

Powered steering wheels are rotated by a drive motor about the axis perpendicular to their axis ofrotation as shown in Fig 12. They can be with offset or without offset.

Fig 12: Powered steering wheel with JongitudinaJ offset [ 13 J

### 2.4.2 Special wheels

These are designed for better manoeuvrability, they can have activated traction in one direction and passive motion in another.

Swedish wheels are further divided into universal wheels/ Omni directional wheels and Mecanum wheels. Universal wheels/Omni directional wheels provide constrained and

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umconstrained motion during turning, they consists of small roller mounted on their **ruference** perpendicular to the axis of **the wheel's** rotation as shown in Fig 13.

Fig 13: Universal wheel [13]

**Mecanum** wheels are similar to the universal wheels expect that the rollers are mounted at an angle of 45" to the axis of the Wheel's rotation as shown in Fig 14.

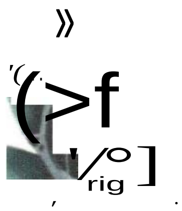

Fig 14: Mecanum wheel (13]

### 2.4.3 Advantages of using Swedish wheels

The key advantage of this design is that, although the wheel rotation is powered only along the one principal axis (through the axle), the wheel can kinematically move with very little friction along many possible trajectories, not just forward and backward.[12]

## 2.5 Drive systems

A drive system is an interconnected network of components that are used to control the speed, torque and direction of an electric motor. The types of drive systems include;

#### 2.5.1 Differential drive

This drive consists of two independently driven fixed powered wheels mounted on the left and right side of the robot platform. This is the simplest mechanical drive since it does not need rotation of a driven axis. If the wheels rotate at the same speed, the robot moves straight forward or backward. A typical example of this type of drive system is the eye personal robot.

### 2.5.2 Tricycle drive

in this drive a single wheel which is both driven (powered) and steered is used. Two freerunning ( unpowered) fixed wheels in the back are used. *in* order to have always the three point contact required and keeps the robot stable.

### 2.5.3 Omni directional drive

This drive can be achieved by using three, four or more Omni directional wheels. When three wheels are used to achieve this drive, universal wheels with a roller angle of 90" are used. When four wheels are used, Mecanum wheels with a roller angle of 45" are used.

### 2.5.4 Synchro drive

This drive may have three or more wheels that are mechanic-ally coupled together, It is an interesting drive because, although there are three driven and steered wheels, only two motors are used in total. The one translation motor sets the speed of all three wheels together, and the one steering motor spins all the wheels together about each of their individual vertical steering axes. This mechanicaJ steering synchronization can be realized in several ways, for example, using a chain, a belt or gear drive as shown in Fig 15.[12]

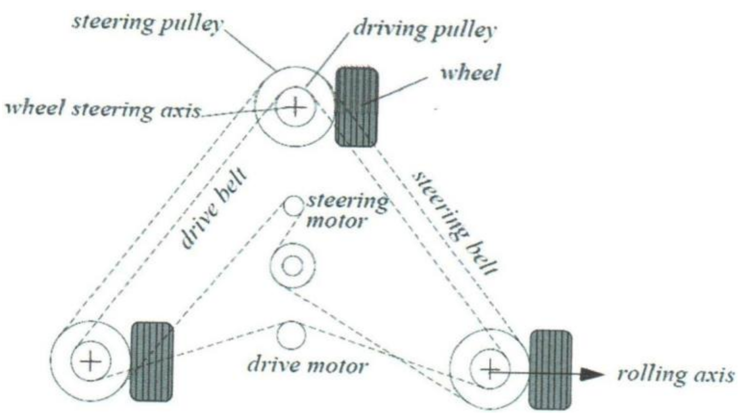


Fig 15: Synchro drive

## [12] 2.6 Scissor mechanism

A scissor lift mechanism (i.e. four bar parallel mechanism) is used in automobile and industries for elevation of work According to[13] the main use of a scissor lift elevating platform is vertical transportation of load in assembly works( e.g. aircraft part assembly, motor part assembly),maintenance of constructions( e.g. street lights ) and inner material transportation systems. Most of the scissor lifts are operated by hydraulic and pneumatic actuators that are highly efficient and easy to apply. These actuators are however expensive and cannot be relied on when it comes to safety. In [14] alternative mechanisms of operating the scissor mechanism are investigated, mechanically operated scissor lifts are considered to he more safe and these can be operated using a rack and pinion method or lead screw method.

# CONCEPTUAL DESIGN

## 3.1 System description overview

The proposed wheelchair consists of a chair, a double scissor mechanism and a mobile platfonn as shown in Fig 16.

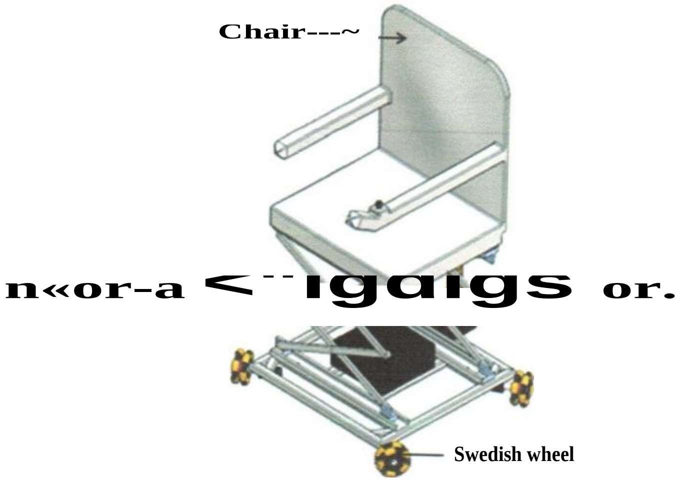


Fig 16: Extendable wheelchair

### 3.1.1 Mobile platform

The mobile platf onn is the supporting structure, to which all components are attached as shown in Fig 17. The double scissor mechanism and four Omni directional wheels are al] mounted on to this platform. It is made using four plan carbon steel hollow sections joined together to form a square of 600mm. The Omni directional wheels were angled at 60 degrees to prioritize forward motion while optimizing motion in other directions. An Omni directional drive is used to drive the wheels.

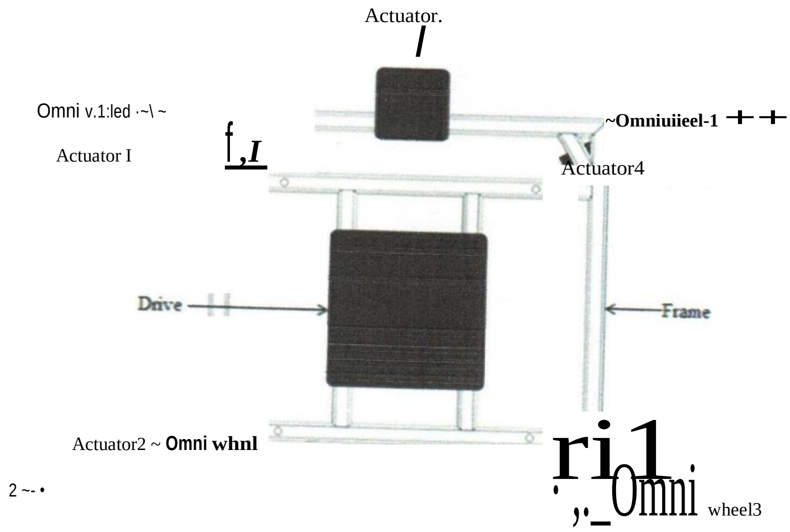


Fig 17: Mobi1e platfonn

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### 3.1.2 Scissor mechanism

The 2 DOF double scissor mechanisms consists of two mechanisms i.e. four bar mechanism and the slider mechanism as shown in Fig 18. The links of the four bar mechanism form a parallel kinematic mechanism and are connected by revolute joints. Each four links form a rhombus like structure where the length of each link is the same. *The* scissor mechanism is moved by a linear actuator in form of a lead screw that propels it upward and downward according to the needs of the wheelchair user. **The links** are made out of plain carbon steel.

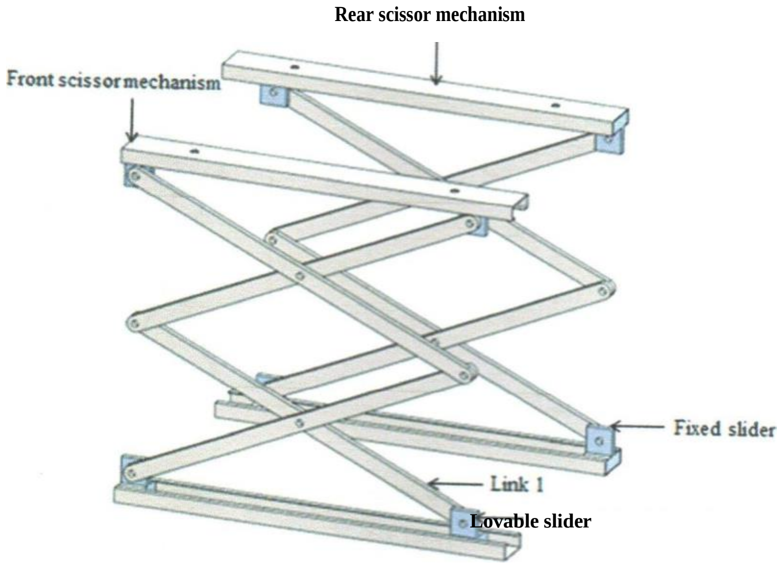


Fig 18: Double scissor mechanism

### 3.1.3 Chair

The chair *is* made out of plastic and consists of a joystick used to *control* the wheelchair as shown in Fig 19.

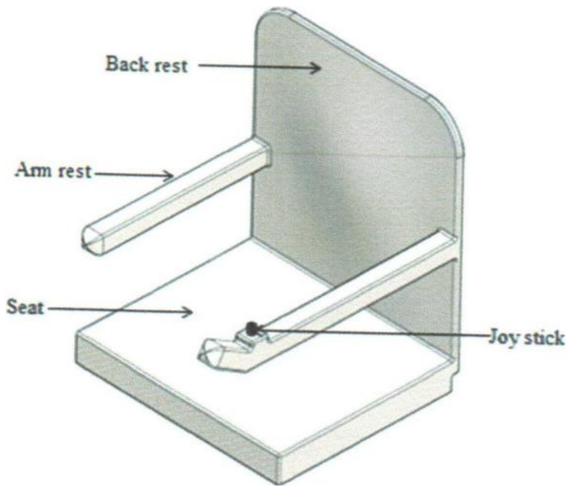


Fig 19: Chair

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## *3.2* Working principle

The wheelchair can move from one place to another with the help of the four Omni directional wheels that are driven by motors, The wheelchair is moved upward and downward with the help of a scissor mechanism driven by a linear actuator.

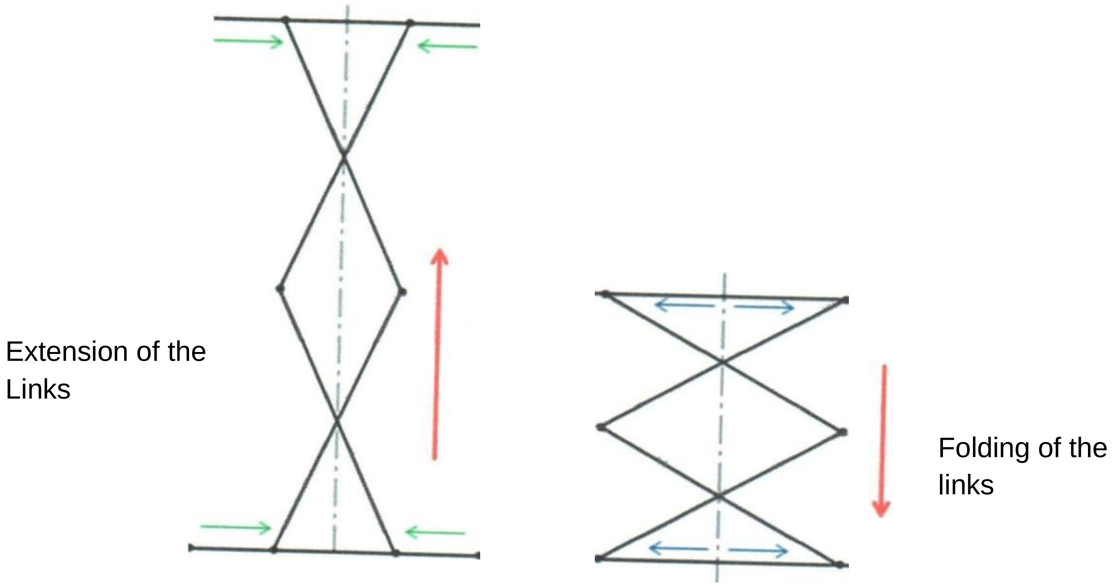


Fig 20: Extension and Folding of the scissor mechanism links

When both the lower base and upper base links of the scissor mechanism are pushed together, the scissor structure extends helping the occupant access elevated places. When the distance between the links increases, the scissor structure folds. The occupant is brought back to the normal wheelchair height. As shown in Fig 20 above.

DESIGN AND SIMULATION

# 4.1 Design of the scissor mechanism

## 4.1.1 Link length

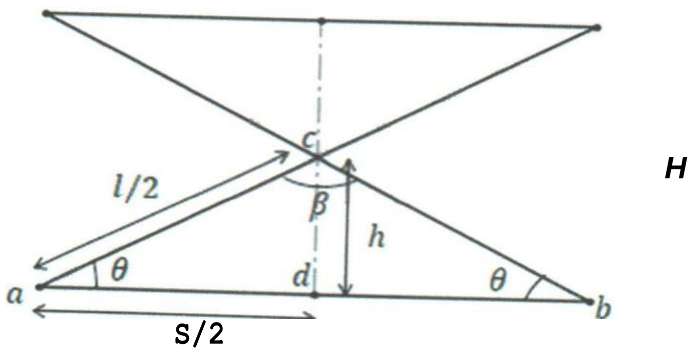


Fig 21: kinematic analysis of the scissor mechanism

From *Fig* 21 above, triangle *adc* forms a right angled triangle.

**Where;**

***l* is the link length,S is the input and *h* is the output.**

Applying trigonometric functions,

Calculating for the tangent of *0*

$$\tan\theta = \left(\frac{h}{\frac{S}{2}}\right)$$

$$\theta = \tan^{-1}\left(\frac{2h}{S}\right)$$

Calculating for the sine of*0*

$$\sin\theta = \left(\frac{h}{\frac{l}{2}}\right)$$

$$l = \left(\frac{2h}{\sin\theta}\right)$$

Calculating for ~

$$\beta = (180 - 2\theta)$$

## 4.1.2 Link breadth and thickness

The Fig 22 below shows a free body diagram of distributed load "- acting on the chair that is 2 reduced to a point load.

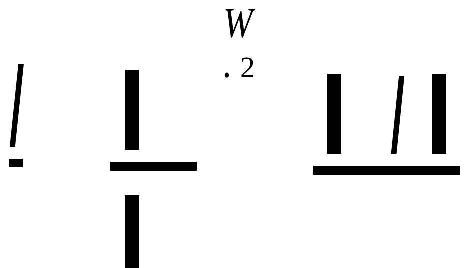


Fig 22: Distnbuted load

Force analysis is then carried out with the use of the point load as shown in the Fig 23 below.

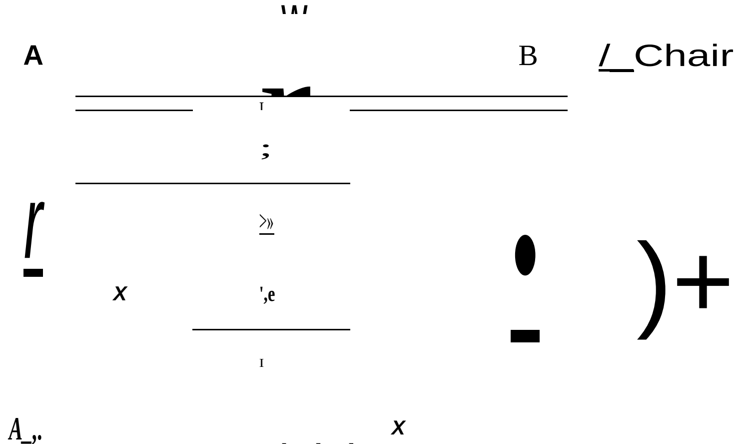


Fig 23: Free body diagram

Resolving forces in the vertical direction and taking upward forces as positive

$$\sum Fy = Ay - B, - \frac{W_C}{2} = 0$$

Taking moments about A, with clockwise moments being positive

$$-\frac{W_C}{2a} + 2xB, = 0$$

Solving the equation above,

$$\frac{W_W}{4}$$

The Fig 24 below shows the force *By* acting on one of the Jinks

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t

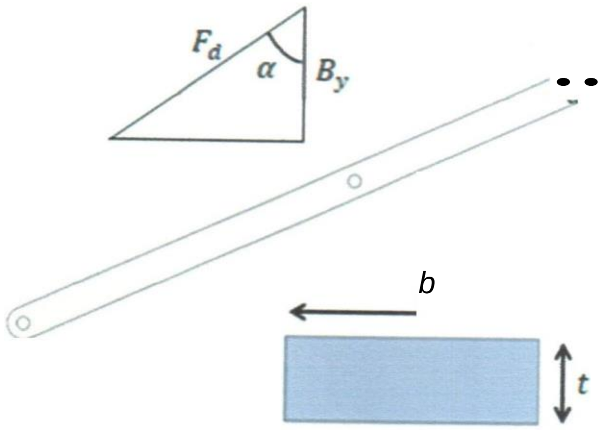


Fig 24: force acting on the link

Form the right angled triangle

$$\cos\alpha = \frac{B_y}{F_d}$$

$$F_d = \frac{B_y}{\cos\alpha}$$

Working stress o is given by

F

Uw= A

Assuming that breadth, b is 3 times of the thickness t, then b

t

3

O

A=

Selected material is mild steel, with yield strength of <lp = 350 N /mm² [15]

Assuming the factor of safety, f, = S

0,

f,=

O

## 4.2 Singularity analysis of the scissor mechanism

Singularity is mathematica11y defined as the point at which a given mathematical object is not defined or a point where the mathematical object ceases to be well behaved in a particular way.[16]

For the above scissor mechanism, the angle of theoretical singularity posture,~ is180° in the lowered position and 0° in the raised position.[17]

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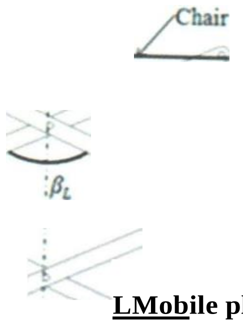
The Fig 25 below shows the raised and lowered positions of the scissor mechanism




**Lowered position**

**Raised position**

**1.2.3and 4 are links**

Fig 25: **singularity analysis**

*B*= (180° - *20)*

If~ ≤ **180°** ***and*** **> 0°, No singularity will occur.**

## 4.3 Design of screw

The screw is made out of square threads because they have a high efficiency and can easily **self-lock.**

The lead screw is subjected to three types of stresses namely;

1. Compressive *stresses*
2. Torsional stresses
3. **Bending moment**

The Fig 26 below shows the compressive force acting on the lead screw.

W,

rr--~!--,,,.__ Chair

---,'1'.--~- Mobile platform

H's

Fig 26: compressive stresses

Ww

''<<')

Where;

*O is the compressive stress*

*de is the core diameter of the screw*

W's *is the amount of weight acting on the lead screw*

Selected material is plain carbon steel, with yield strength of $<T_y = 400\ N/mm^2$ [15]

The lead screw is also subjected to torsional and bending moment. The Fig 27 and Fig 28 below show the bending moment and torque diagrams.

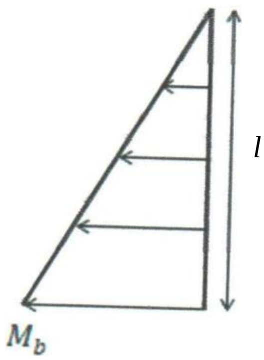



Fig 27: Bending moment diagram

The bending stress, *ah* is given by

0, *32M,*

*nd* 3 *c*

$M_t$

Fig 28: Torque diagram

The torsional shear stress, r is given by

$$\tau = \frac{16M_t}{\pi d_c^3}$$

Where

$$M_t = \frac{W d_m}{2} \tan(\emptyset + \alpha)$$

A square threaded screw with 24mm nominal diameter and 5mm pitch is selected from the **Error! Reference source not found.** below[18]

| Nominal diameter, d (mm) | Pitch, p (mm) |
|---|---|
| 24,28 | 5 |
| **32,36** | 6 |
| 40,44 | 7 |
| 48,52 | 8 |
| **60** | 9 |
| 70,80 | 10 |
| 90,100 | 12 |

Table 1: Proportion of ISO trapezoidal threads

*But* $d_c = d - p$ *and*

$d_m = d - 0.5p$ *where* $d_m$ *is the mean diameter of the screw.*

Assuming the screw has single-start threads then $l = p$

*from* $\tan\alpha = \frac{l}{\pi d_m}$, $\tan = p = 0.18$ *or* $\emptyset = 10.20°$

*If* $\emptyset > \alpha$*, then the screw is self locking*

The principal stress is given by

•

max = $\left(\frac{ab}{5}\right)^2$ +co?

lc = $\frac{S_y}{max}$ = $\frac{0.5 * !Ty}{tnax}$

If the factor of safety *is* greater than 5 then the design is safe.

### 4.3.1 Buckling considerations

For a circular cross-section of diameter *de*

M--. J rrdc4 oment o mertia = f
64

Cross-sectional area $A$ = -- $\frac{na}{4}$

Radius of gyration $k$ = (1)

The slenderness ratio of the screw is given bys = $\frac{l}{k}$

Since one end of the screw is fixed in the nut and the other end is free, the end fixity coefficient is 0.25, the borderline between long and short column is given by,

$$\frac{S_{yt}}{2} = \frac{nn^2 E}{\left(\frac{l}{k}\right)^2}$$

Where(~) *is the critical slenderness ratio*

If the *slenderness ratio* < *the critical slenderness ratio* then the screw should be treated as a short column and Johnson's equation is applied.

nos*e*.- *a*[-±*a* (&)]

The factor of safety for the bulking considerations is given by

$$f = \frac{P,}{7_s}$$

If the factor of safety is greater than 3 the screw is safe against buckling.

## 4.4 Design of nut

Material selected is bronze $S,$ = 190N /mm² [19]

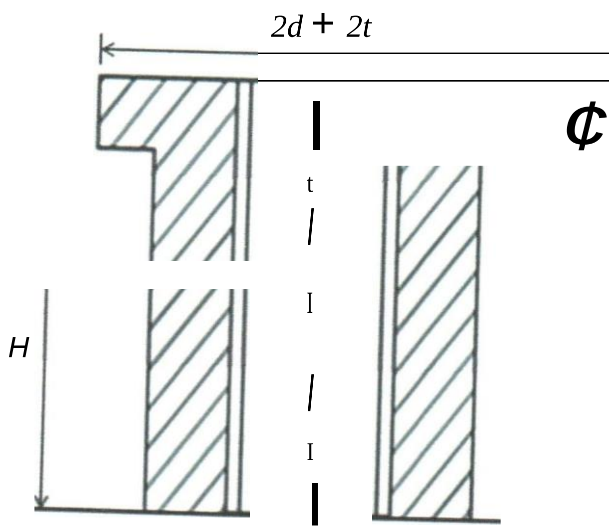



Fig 29: Nut

The permissible bearing pressure between the steel screw and the bronze nut islO $N/mm^2$ as shown in the Fig 29 above. The number of threads required to support the load is $z$.

$$z = \frac{4W}{\pi S_b (d^2 - d_c^2)}$$

The axial length of the nut $H$ is given by;

$$H = zp$$

The transverse shear stress at the root of the threads in the nut is given by

$$\tau = \frac{W}{\pi d t z}$$

The factor of safety $f_s$ is given by

$$f_s = \frac{S_{su}}{\tau} = \frac{0.5 S_u}{\tau}$$

If the factor of safety is greater than 3 then the nut is safe

## 4.5 Dynamic analysis by ADAMS

The goal of the extendable wheelchair simulation and analysis based on ADAMS is to analyse the chair displacement, velocity, acceJeration, and force. The following steps were followed during the dynamics analysis of the wheelchair as shown in the Fig 30 below.

Importation of the mode]

Applying appropriate material

Defining the joints

Defining the motion

Running the simulation

Fig 30: Steps followed during dynamics analysis

### 4.5.1 Importing the model

The 3D model saved in PARASOLID format is imported into the ADAMS environment as shown in the Fig 31 below.

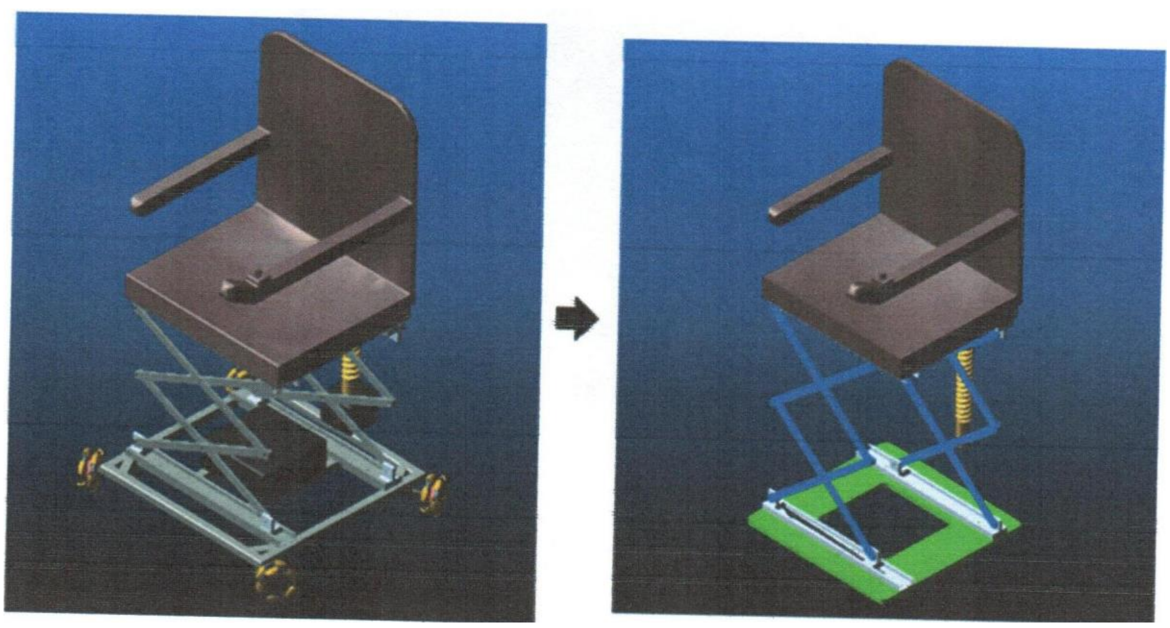


Fig 31: Imported model

### 4.5.2 Application of appropriate material

The material from which the extendable wheelchair components are made is selected providing the mass and inertia properties as shown in the Table 2 below

| Material | Young's modulus | Poison's ratio | Density |
|---|---|---|---|
| Steel | 200 Gpa | 0.29 | 7850kg/m' |

Table 2: Material properties

### 4.5.3 Defining the joints

Fixed, translational, revolute and inline joints were applied to the different components of the extendable wheelchair as shown in the Fig 32 below.

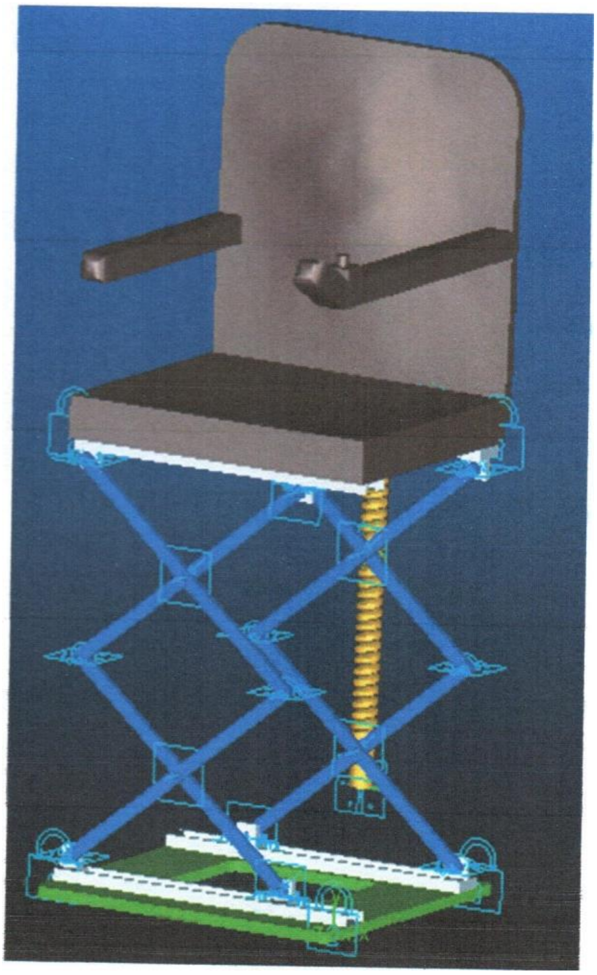


Fig 32: Defining the joints

### 4.5.4 Defining the motion

Translational motion was applied between the lead screw and the nut and the simulation run for lO seconds. As shown in the Fig 33 below.

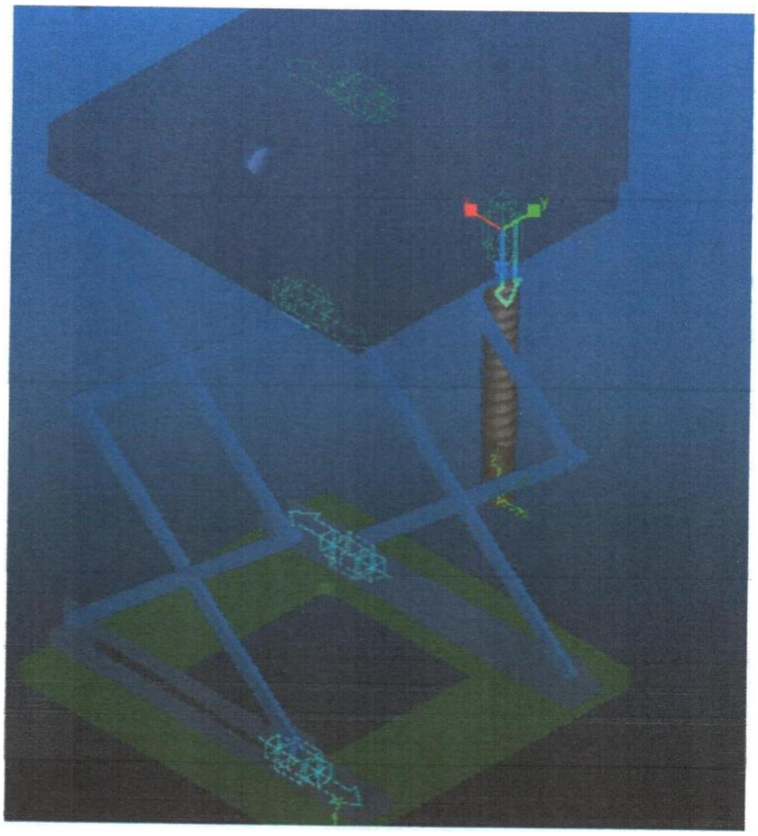


Fig 33: **Motion**

## 4.6 Finite Element Analysis (FEA) by solid works

The following steps were followed during the finite element analysis study in solid works. The steps are illustrated in the *Fig* 34 below.

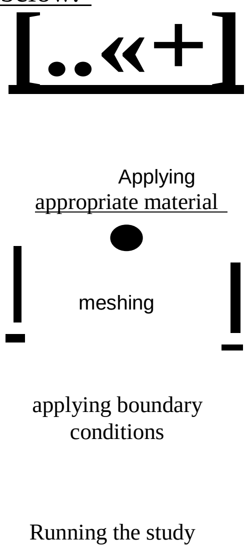



Fig 34: Steps followed during finite element analysis

### 4.6.1 Starting a new study

Before the study was started, some parts of the wheelchair are neglected namely; the chair and the mobile platform. The double scissor mechanism was then connected using connecting rods.

### 4.6.2 Applying appropriate material

The material from which the scissor links are made was selected, with properties as shown in the **table 2 below.**

| Material | Yield strength | Mass Density | Tensile strength |
|---|---|---|---|
| **Plain** carbon steel | **2.206 x 10°(N/m?)** | 7800(kg/m) | **4.0 x 10°(N/m?)** |

Table 3: Material properties

### 4.6.3 Meshing in solid works

During the meshing process a fine mesh density was selected and. the created mesh was as shown in the figure below.

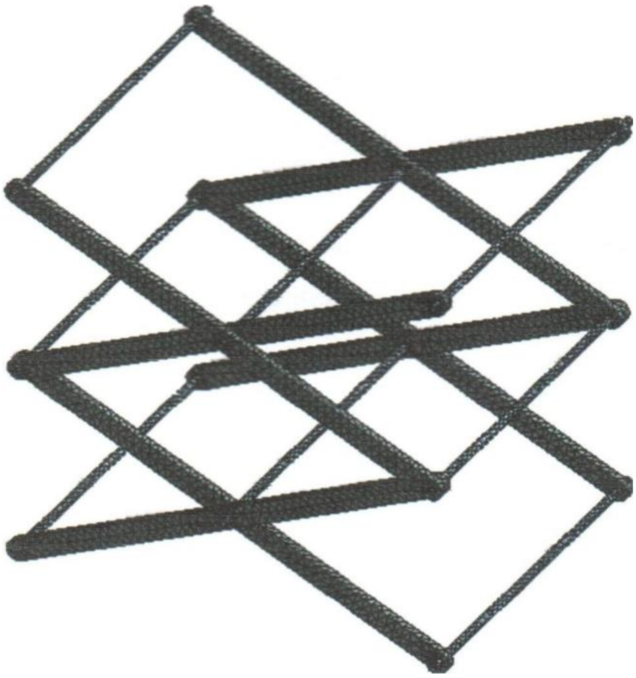


Fig 35: Meshing

### 4.6.4Boundary conditions in solid works

Boundary conditions were then applied using the fixture advisor and the generated boundary conditions were as shown in the figure below.

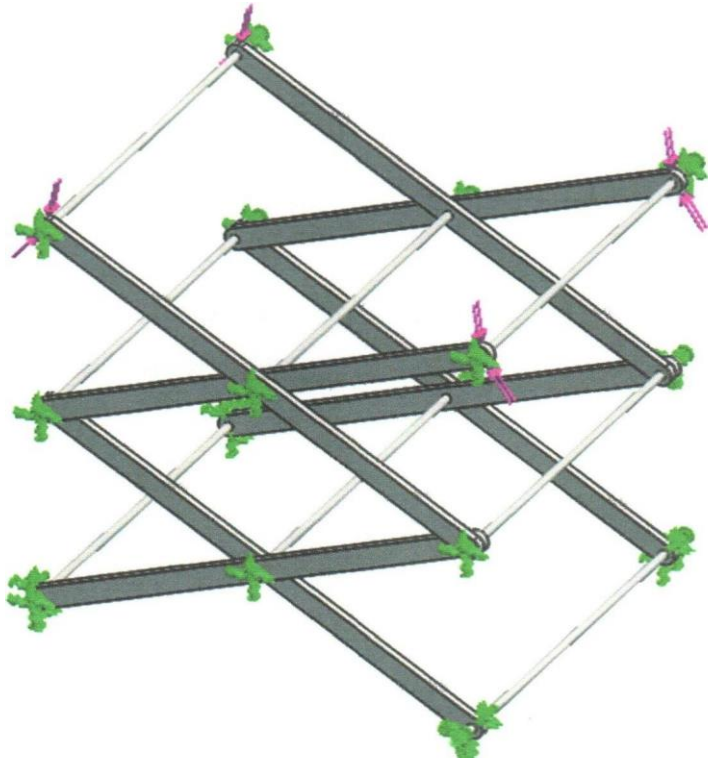


Fig 36: Boundary conditions

### 4.6.5 Running the study

**The study was the run and results of both static stress and static displacement** generated. The results are discussed in detail as shown in chapter 5.

# RESULTS AND DISCUSSION

## 5.1 Scissor mechanism design calculations

### 5.1.1 Link length

Considering the wheelchair to be in the lowered position,h = 125mm $S$ = 500mm and $0$ = 26.565°. The link lengthl = 559.02mm

With the above link length the double scissor mechanism is able to achieve a maximum height of 1000mm and a minimum height of 500mm, this enable the wheelchair user to access elevated places easily.

### 5.1.2 Link breadth and thickness

Considering 100kg as the maximum weight the wheelchair can accommodate and neglecting the weight on the lead screw W=981N $B,$ = 245.25N $a$ = 63.435° $F,,$ = 548.4N $b$= *5mm t*= *1.7mm*

Since a maximum weight of 100kg is used during the sizing of the link breadth, the double scissor mechanism wi11 be able to accommodate disabled personnel with weights lower than 100kg without any failure to its links.

### *5.2* Singularity analysis

With $PL$ = 126.87° at the raised position 126.87° < 180°

**Since the angle is less than 180 degrees there will be on singularity at the maximum raised** position and hence the double scissor mechanism will operate normally without any singularity.

## 5.3 Screw design calculations

Assuming the factor of safety,f, = 5 and $0,$ = 400 $N$ /mm$^2$ then $d,$ =4mm

Selecting a square threaded screw with 24mm nominal diameter and 5mm pitch $d,$ = 19mm $d,,$= 21.5mm $l$= $p$= 5mm $a$ = 4.234° $M,$ = 2714.36 *Nmm* $t$ = 2.0155$N$/mm?$a,$ = 3.46 $N$ /mm$^2$ Assuming the bending stress is equal to the compressive stresses $T_{max}$ = 2.6562 $N$ /mm$^2$and the calculated factor of safety for the screw $f,$ = 75

Since > *a the screw is self locking*

Since the calculated factor of safety is greater than *S* the design is safe.

### 5.3.1 Buckling calculations

Taking into consideration the buckling of the screw $I$= 6397.12mm$^4$A = 283.53mm$^2$k = 22.563mm assuming $l$ = 550mm $s$ = 24.377 $s,$ = 50.53 since the $s$ < $S_{er}$ the screw is

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treated as a short column Applying Johnson's equation *Per*= 100217N *f*, = 102 since the factor of safety is greater than *5* the screw is safe against buckling.

## 5.4 Nut design calculations

For the nut calculation, $z = 0.58$ $H = 2.9$mm $\tau_n$ =**SN** /mm$^2$ $fs =$ **19** since the factor of safety is greater than 3 the nut is safe

## *5.5* Simulation graphs from ADAMS

**The displacement, velocity and acceleration graphs were generated after the simulation** as shown in Fig 3 7, Fig 38 and Fig *39* respectively.

### 5.5.1 Displacement graph

**The chair moves in the positive y direction from an initial displacement of 525mm and** is able to achieve a maximum displacement of 820mm. This is illustrated in the figure below.

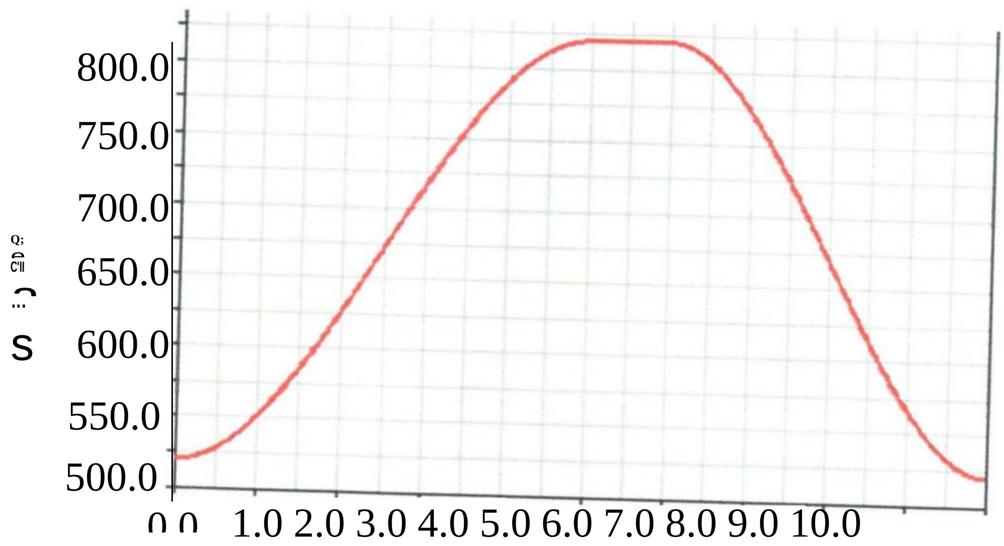


Fig 37: Displacement of the chair

### 5.5.2 Velocity graph

The chair attains a maximum velocity of 97.5 mm/sec during the upward movement and a maximum velocity of 112.5 mm/sec during the **downward** movement. This is illustrated in the figure below.

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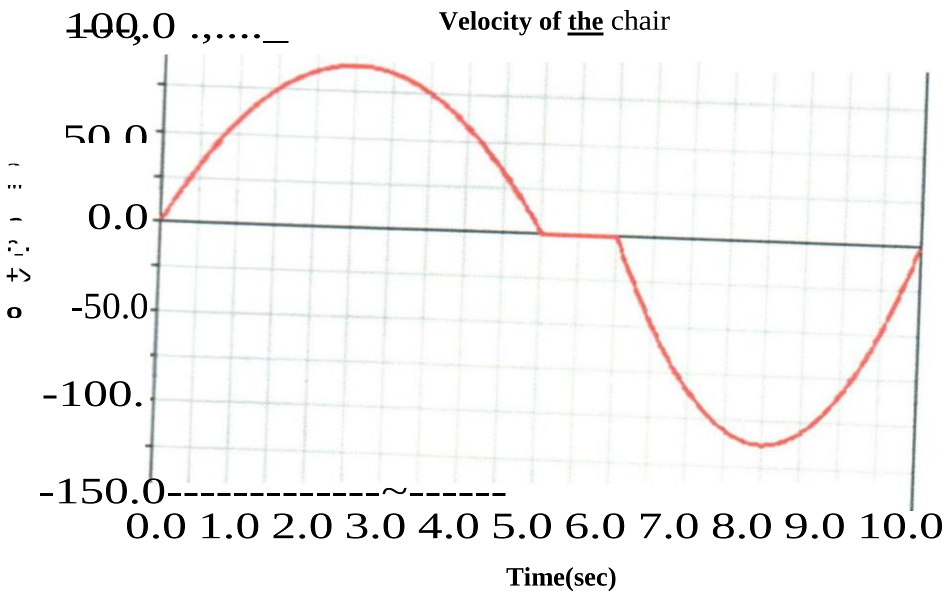


Fig 38: Velocity of the chair

### 5.5.3 Acceleration graph

The figure below illustrated the behavior of the acceleration of the wheelchair according to the simulation. Since the acceleration doesn't tend to infinity the simulation is valid.

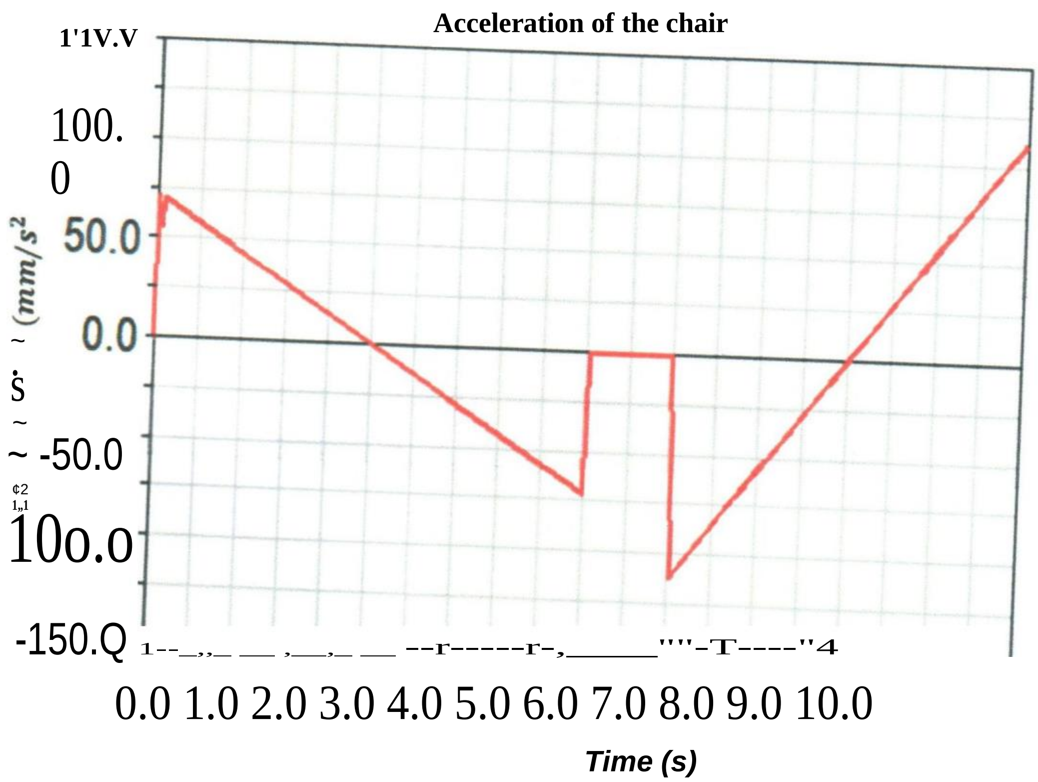


Fig 39: AcceJeration of the chair

## 5.6 Results from finite element analysis in solid works

The results generated from the solid works finite element analysis simulation are shown in Fig 40 and Fig *41* below.

### 5.6.1 Static stress results

Form the results below maximum stresses of $1.855 \times 10^6 (N/mm^2)$ are experienced with in the revolute joints connecting the links.

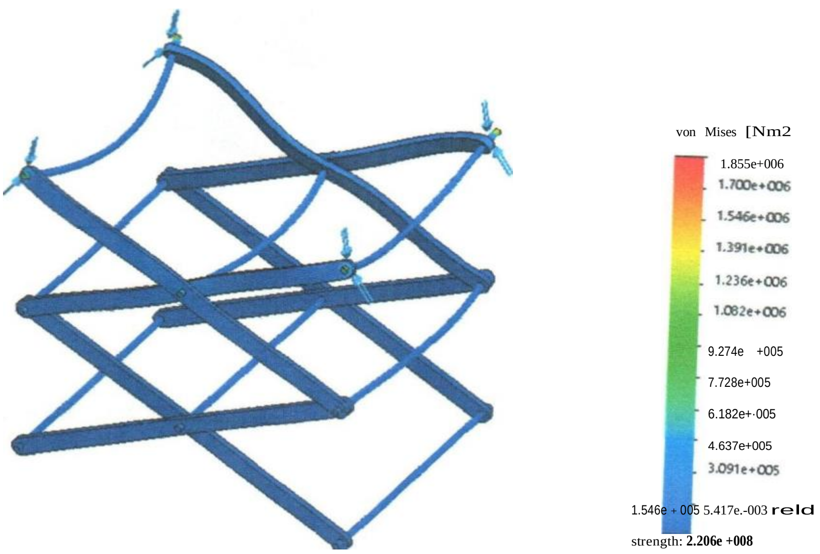


Fig **40: Static** stress

From the above results the factor of safety is given by;

$$f_s = \frac{yield\ strength}{working\ stress} = \frac{2.206 \times 10^8}{1.855 \times 10^6} = 119$$

Since the factor of safety is greater than *5* the structure is safe

### 5.6..2 Static displacement resuJts

The maximum deformation of $1.449 \times 10^3$ mm 1s experienced m the middle of the connecting rods. This is shown in the figure below.

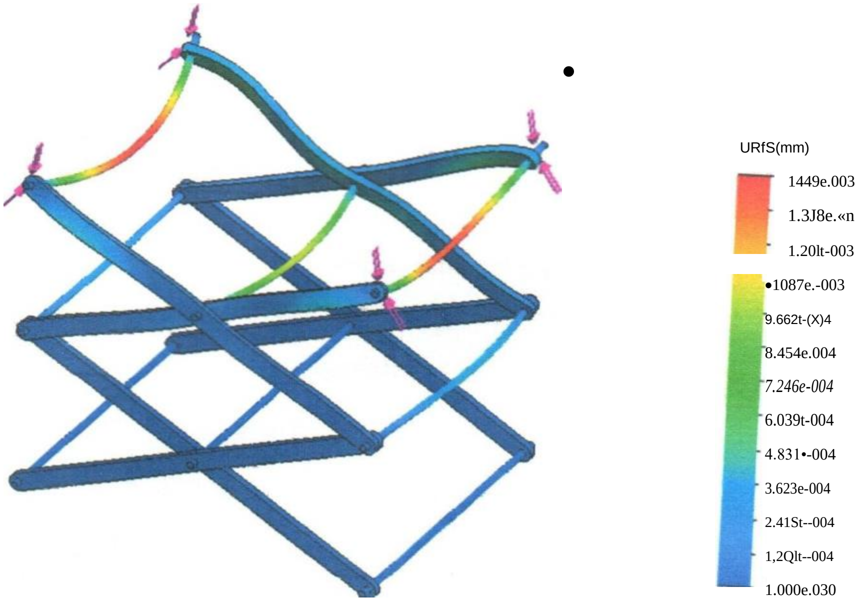


Fig 4 L Static displacement

## 5. 7 Mobile platform

The omnidirectional wheels are angled at 60 degrees to prioritize forward motion while still optimizing motion *in* other directions

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# CONCLUSION AND FUTURE WORKS

## 6.1 Conclusion

Wheelchair users/occupants are denied the freedom to access elevated places by the available wheelchairs. Most wheelchairs users have no other choice but to access these places with a lot of discomfort. An extendable wheelchair solves this problem and gives the wheelchair user freedom the access to these places. There is still more research needed to enable wheelchair users access these elevated places in a more comfortable way.

## 6.2 Future works

The future works for the above designed and simulated wheelchair include;

- Electrical design
- Controller design
- Implementation of the project

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