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Design and Fabrication of Detachable Wheelchair Automator

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Abstract -
Mobility solutions are essential for improving accessibility for individuals with physical disabilities. Manual wheelchairs, while practical, often require considerable effort from users. To address this, this paper presents the development of a detachable wheelchair automator that converts a regular manual wheelchair into a semi-powered one. The system features a unique latch-based locking mechanism that enables quick attachment and detachment of the motorized module. A 24V, 250W PMDC motor is used for power transmission via a chain-sprocket system, though the battery used was a basic one and not optimized for long-range or hybrid functionality. Mechanical parts were designed in Siemens NX software, and structural analysis was conducted in ANSYS to ensure durability and strength under load. The prototype was fabricated and tested for functional validation. The focus is on ease of operation, low cost, and simple mechanical integration.

Keywords:
Wheelchair automator, detachable drive module, latch locking mechanism, NX CAD, ANSYS, PMDC motor, mobility aid.

1. INTRODUCTION

Manual wheelchairs are widely used by individuals with mobility impairments, but they pose challenges such as physical fatigue and limitations on longer journeys or uneven terrain. Fully motorized wheelchairs are effective but are often bulky and expensive. To bridge this gap, we designed a detachable motorized module that can be connected to a manual wheelchair using a latch-based locking mechanism. The aim was to develop a low-cost solution that improves ease of use without altering the existing wheelchair's structure.

This project focuses on mechanical simplicity, practical utility, and structural safety. CAD modeling was done in NX software, and ANSYS was used to simulate stress and deformation conditions on critical parts.

2. LITERATURE REVIEW

Several studies and developments have focused on enhancing mobility for wheelchair users by introducing powered assist modules. Prior works have explored electric wheelchair designs using hub motors, joystick control, and battery-powered systems. However, many of these systems are costly, non-detachable, or require complete wheelchair replacement. Researchers have emphasized the need for modular, retrofittable solutions to reduce cost and increase accessibility.

Latch mechanisms have been effectively used in other assistive devices for secure yet quick attachment and detachment. Studies in mechanical joint safety suggest mild steel as a reliable, affordable material for low-stress applications. Chain drive systems and PMDC motors are also commonly used due to their efficiency and ease of control.

Building upon these insights, this project focuses on a detachable automator module with a latch-lock mechanism, ensuring both usability and affordability for everyday wheelchair users.

Objectives:

To design a detachable module for a manual wheelchair using a latch-lock mechanism.

- To ensure simple attachment and detachment without tools.
- To validate the mechanical structure using simulations in ANSYS.
- To fabricate and test the prototype under real load conditions.

Design Methodology:

- CAD Design (NX Software)
- The design was developed in Siemens NX CAD with a focus on:
- Compact and lightweight chassis
- Integration of a 24V PMDC motor
- Sprocket and chain power transmission
- Proper alignment for latch locking mechanism

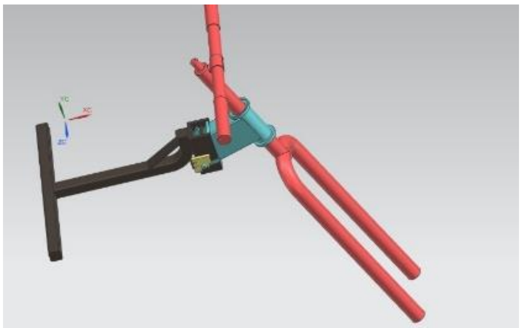


Fig. Cad Design

3. DESIGN AND SIMULATION

3.1. Design Latch-Based Locking Mechanism

A mechanical latch was designed to attach the automator module to the wheelchair frame securely. It uses a simple mechanical hook and spring-lock system, allowing users to:

- Quickly attach/detach the module
- Operate the mechanism without tools
- Maintain connection under vibration or surface impact

> This is the most unique feature of the project and contributes to ease of use and safety.

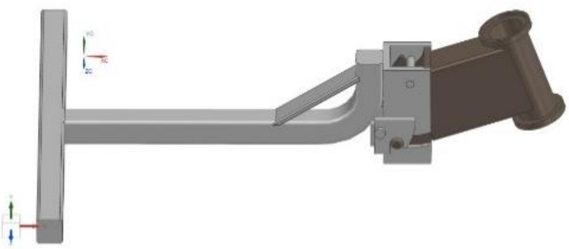


Fig. Design Latch-Based Locking Mechanism

3.2. Structural Analysis (ANSYS):

Finite Element Analysis (FEA) was performed using ANSYS software on the main frame and latch mechanism.

- Materials: Mild steel for frame, EN8 for shaft
- Loading condition: 130 kg (user + module weight)
- Boundary conditions: Fixed supports at attachment points

Results:

- Max stress on latch joint is 31 Mpa
- Factor of safety > 2
- Deformation is under limit
- Latch tested under impact loading and showed no failure

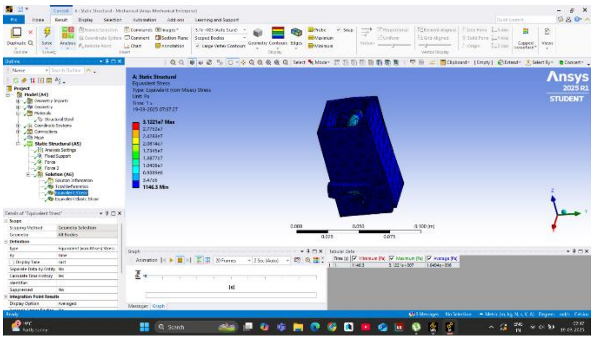


Fig. Stress Simulation and analysis

3.3. Primary Load Calculations:

This part deals with the basic calculations associated with the primary operations and components that would be detail in the model thus making it one of the important steps that decides the maximum of the project. It includes topics related to motor and battery performance, loads and moments acting on frame, The factor of safety and external factors that influence Operation.

Mass Range Calculations

Person Weight	=	100kg
Battery Pack	=	6kg
Motor & Controller	=	4kg
wheelchair weight	=	10kg
Total	=	120kg

So, Battery & Motor are required to propel the Bicycle with the weight of 120kg.

Motor calculation:

1. Diameter=10inches=0.254m
2. Voltage=24v
3. Power=250w
4. Radius of wheel=0.127m

Assumed values:

1. Acceleration=0.5m/s2
2. Desired top speed=2.5m/s
3. Total mass of vehicle(M)=130kg

Step 1: To find Gross Vehicle Weight

GVW=M*9.81 =130*9.81

GVW=1275.3N

Step 2: To find total tractive effort requirement for the vehicle

TTE=RR+GR+AF

Where,

1. TTE=Total Tractive Effort(N)
2. RR=Rolling Resistance(N)
3. GR=Force required to climb a grade(N)
4. AF= Acceleration Force (N)

1. Rolling Resistance (RR)

RR=GVW*CRR

Where,

GVW=Gross Vehicle Weight

CRR=Co-efficient of Rolling Resistance For good concrete, for road it is 0.01

RR=1275.3*0.01=12.75N

2. Grade Resistance (GR):

GR= GVW*Sin(ϴ)

= 130*9.81*Sin(5 desgree)

=66.74

3. Acceleration Force (AF)

FA=M*a

Where, a= Acceleration=0.5m/s2

FA=130*0.5

FA=65N.

➢ Total Tractive Effort (TTE)

=RR+GR

=12.75+67.74+65

=145.5N.

Step 3: To find the wheel torque Wheel Torque (TW)

Torque= Total Tractive Effort*Radius of wheel

=145.5*0.127

= 18.47 N/m

Reduction in chain drive

Front axle sprocket: 18 teeth's

Teeth's Motor sprocket: 9 teeth’s

So, Torque required Motor shaft = 18.47/2

Motor torque required =9.23 N/m

Step 4: Power Required

P=(2*3.14*N*T)/60

=(2*3.14*150*9.23)/60

=145 Watt

Thus, we select 24V 250W PMDC motor

Step 5: To calculate speed

N=300 RPM at motor shaft , But due to gear ratio 2:1 it is 150 RPM at wheel shaft

Dia of wheel=10inch=0.25m

Speed (m/s)=Circumfarance*RPM

=(N*3.14*D)/60

=(150*3.14*0.254)/60

=2.00m/s

Therefore, 150 RPM with the diameter of 0.6 m corresponding to approximately 2.00 m/s.= 7.2 km/h

Step 6: Battery Calculations

A) Motor Current (I)

P=IV

I=Power/Voltage

=145/24 =6.04A

B) Battery energy (E)

E= Voltage*Capacity of battery in Ah

=24*10 = 240 W

C) Battery runtime(t)

t= Capacity(Ah)/current(I)

=10/6.04 =1.65 hr

(approximate 100 min.)

D) Range (R)

R= Speed of vehicle * battery runtime

= 7.2*1.65= 11.88 Km

4. EXPERIMENTAL WORK

4.1. Raw Materials for Mechanical Fabrication

- Scrap Cycle Fork
- Pneumatic Wheels
- Rectangular Mild Steel (MS) Bars
- L-Shaped MS Angle Bar
- U-Bolt (Mild Steel)
- Spray Paint (Black)
- Chain and Sprocket

4.2. Electrical Components Selection

- PMDC Gear Motor (24V, 350W)
- Motor Controller for PMDC Motor
- Throttle / Accelerator Handle
- Braking System (Drum Brake with Cable)
- Battery System (2×12V Lead-Acid Batteries)

Electrical Components

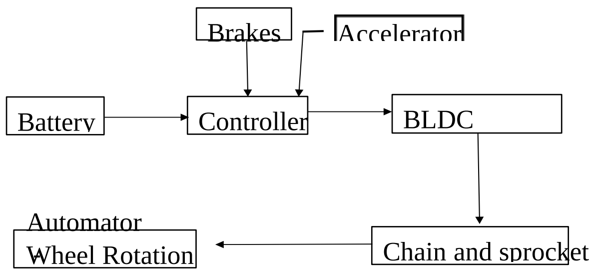
4.3. Fabrication Process

- Purchase of Scrap Cycle
- Fork Cutting and Length Adjustment
- Bracket Fabrication for Frame Attachment
- Frame Welding and Assembly

- Painting and Finishing
- Electrical Mounting and Wiring
- Final Testing and Adjustment

4.4. Working Process

- Attach automator using latch lock mechanism
- Switch ON main power
- Accelerate using throttle
- Power transmitted from motor to wheel via chain drive
- Front wheel rotates to pull the wheelchair
- Apply brake → motor cut-off activated
- Detach automator using latch lock system



4. RESULTS

Functional Testing

- Automator module attaches/detaches in under 1 minute.
- Maximum speed achieved: 10–12 km/h on flat surfaces.
- Efficient braking system with instant motor power cut-off on brake application.

Fig. Final Model

Mechanical Stress Validation

- Maximum stress on latch joint: 31 MPa, well within safe limits for mild steel (yield strength ~250 MPa).
- Latch-lock mechanism and joints remained intact after multiple attachment/detachment cycles.

Power and Efficiency

- 24V, 350W PMDC motor provides sufficient torque for flat and mild inclines (~5–7 degrees).
- Battery range: 8–10 km per full charge.
- Charging time: approximately 4 hours.

Modularity and User Experience

- Designed for easy retrofit on existing manual wheelchairs without structural modification.
- Module weight: approximately 15 kg, maintaining portability and ease of use.
- Noise and vibration levels are minimal due to pneumatic wheel use.

Cost and Application

- Total fabrication cost: approx. ₹9,500, much lower than commercial alternatives.

6. CONCLUSIONS

The detachable wheelchair automator was successfully designed and fabricated to enhance the mobility of manual wheelchair users. The use of a latch lock mechanism enabled easy attachment and detachment, making the system modular and user-friendly. Performance tests confirmed reliable operation, with safe stress levels (31 MPa) and adequate power output from a 250W motor. The project demonstrates a cost-effective, retrofittable solution for urban mobility with basic power assistance, offering a practical alternative to expensive powered wheelchairs.

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