Paper ID: AM-124

Design and construction of a two-wheel independent drive smart electric wheelchair for mobility impaired people

Md. Fahim Bhuiyan[1], Mohammad Rejwan Uddin[2], Zaima Tasneem[3] and Khosru M Salim[4]

Department of Electrical and Electronic Engineering
Independent University, Bangladesh, Dhaka, Bangladesh
E-mail: fahim887@gmail.com
rejwanuddin@yahoo.com
zaimatasneem@gmail.com
khosrumdsalim@yahoo.com

Abstract

Conventional wheelchairs are widely used by mobility impaired people in Bangladesh. Human labor required by these manual wheelchairs can result in muscle and joint pain and degradation, torn rotor cuffs, repetitive stress injury and carpal tunnel syndrome; which causes secondary injury or further disability. External supports like people's help or electrical energy to move the wheelchair can minimize these problems. A supporting hand is not available every time. Therefore, both children and adults benefit substantially from access to a means of independent mobility. An electric wheelchair can reduce such problems as the user will be independent and faster. However, it is expensive and not affordable by most of the people of our country. Therefore it is a challenge to develop a smart electric wheelchair using local technology to minimize cost, with good control and performance.

In this paper, design and construction of a two-wheel independent drive smart electric wheelchair for the mobility impaired people is described. Mechanical 3D modelling was completed by using Google Sketch Up software. Arduino Uno and PIC microcontroller were used for electrical drives and controls. Electrical simulation was carried out by using PROTEUS Design Suit. After completing full project, the performance of this smart electric wheelchair is also discussed.

Keywords: Electric wheelchair; Smart electric wheelchair; two-wheel drive; Independent motor drive; Relay motor control

1. Introduction

According to World Health Organization (WHO) about 10% of the total population is disabled in Bangladesh [1]. After losing mobility, a disabled person has to rely on others for his basic needs. After losing one leg accidentally, sometimes people can get back to normal life using some assistive devices such as walking ortho aids, crutches, walkers, hand stick etc. though these staffs have their own limitations. After losing both legs or if both legs get paralyzed, it becomes very tough for a person to move from one place to another. In these cases, in a poor country like Bangladesh, people prefer using manual wheelchair instead of going for modern treatment, such as, using artificial legs or using electric wheelchair. Conventional manual hand driven wheelchairs are cheaper than electric wheelchairs, easy to maintain and lightweight. But there are a lot of difficulties and hassles involved with the mobility of the physically challenged people in the society while using assistive devices and manual wheel chairs or even three-wheelers for their daily movements. For these reasons, electric wheelchairs or power wheelchairs are introduced to reduce problems and give comfort to the user. Despite of having few demerits, the main problem of an electric wheelchair is its high price and high maintenances. In these circumstances, it is rarely affordable to use an electric wheelchair by the poor people of Bangladesh. All these limitations can be overcome by designing a low maintenance, low cost electric wheelchair which will be easily affordable for middle income family or even lower income families. The lower structure of the electric wheelchair will be constructed by using MS steel frame and an ordinary chair will be mounted on the structure. Wheels and others materials will be collected from local market. Two wheel independent drive system will be designed by using two DC gear motors. Speed will be controlled by using a DC to DC converter and motor driving system will be operated by an Arduino Uno. Fig.2 shows the block diagram of basic electrical control system.

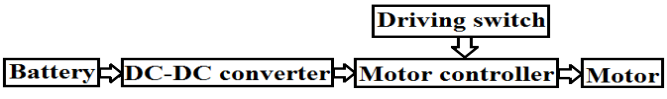


Fig.1. Block diagram of the electric wheelchair

2. Design of the proposed electric wheelchair

While designing this electric wheelchair it was considered to minimize the cost by using local technologies. The control system of the wheelchair is designed very simply so that elderly person or children can use this easily. There is no steering for turning left or right. Only four push buttons are used to move forward, backward, left or right. A push button module is attached with the handle of the chair so that the user can easily move this chair to his desired direction. Before starting hardware construction, first a 3D model of the electric wheelchair structure was designed using 'Google sketch up' software.

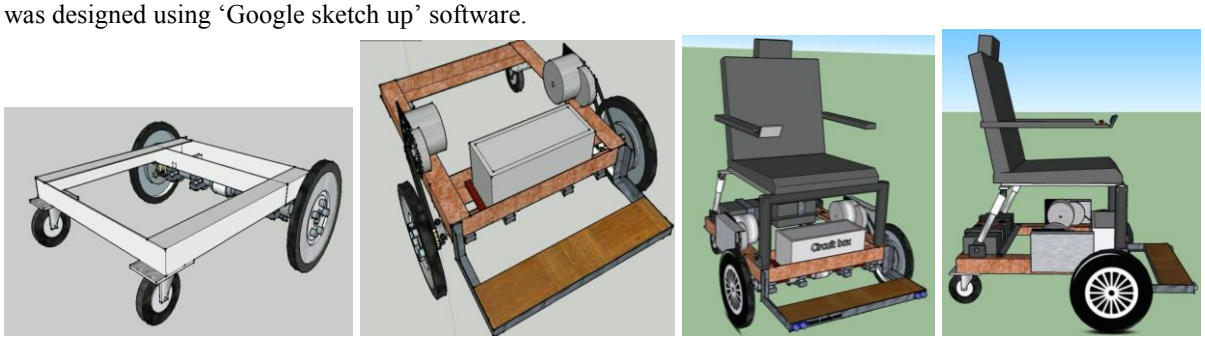


Fig.2. 3D model of the electric wheelchair

3. Drive system

In manual wheelchair disabled person has to drive his wheelchair using his hands by pushing on round bars that surround the wheels. An extra person may need to push the wheelchair if the patient doesn't have control over his hands. But if someone can control just one or two fingers, he can use this electric wheelchair. So the main focus was to build an easy control system which will make the movement or drive system easier for a disabled person. For this purpose ***Push button*** is used. Two motors are used in this electric wheelchair because the advantage of using two motor is that the drive wheels will be independent, so the wheelchair can be driven in ***Differential Drive*** system without using any steering. Difference in velocity between two motors can drive the vehicle in any required direction. If both the wheels move with same angular velocity then the vehicle moves forward/backward in a straight line. If both wheels turned with equal speed in opposite directions, the vehicle will rotate about the central point of the axis which is a big advantage. If the angular velocities are different in terms of values, i.e. if the wheels are driven at different speeds in the same direction or opposite direction, then the wheelchair makes a curve motion. If one of the wheels rotate and the other stays still then the vehicle almost makes a 90 degree turn. Thus the chair can also be turned 180 degree at the small place [2].

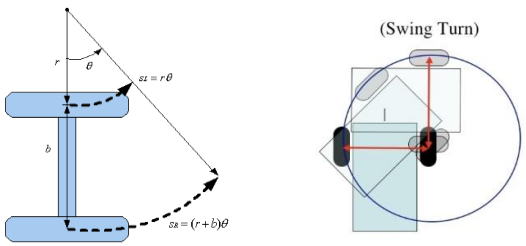


Fig.3. Differential drive

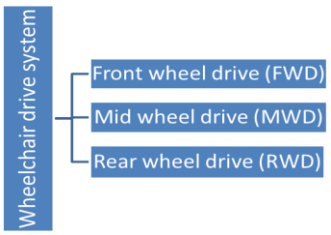


Fig.4. Drive wheel classification

Drive wheel location:

Traditionally power wheelchairs have been classified as Rear wheel drive (RWD), Mid wheel drive (MWD), and Front wheel drive (FWD) [3]. The location of the drive wheels (the wheels powered by the motor) in the rear, middle or front of the chair also has a definite effect on the chair's performance in different environments. The position of the drive wheels significantly affect the space needed for the chair to turn around and the way the chair maneuvers in tight spaces.

Mid-wheel drives are the most maneuverable because they have the smallest 360 degree turning circumference and the tightest turning radius (20 to 26 inches), making those excellent indoor chairs.
Front-wheel drives have a turning radius of 25 to 28 inches and a larger 360-degree circumference than mid-wheel drives. However, they actually navigate around tight corners better than the other two drive systems because the position of the pivot point gives them a very short front end. But turning around in a small space is tricky because of the long back end.
Rear-wheel drives have the largest 360-degree circumference and turning radius (30 to 33 inches) of the three drive systems, making them more difficult to maneuver in tight spaces.

Analysing all these drive systems it is clear that Front-wheel drive provides high manoeuvrability, have less turning radius as compared to rear-wheel drives and are optimal for handling obstacles and inclines. So ***Front-wheel*** drive system is chosen for this project. Front-wheel drive is also more balancing then Mid-wheel drive. Another advantage of ***Front-wheel*** drive is optimal for traversing obstacles such as curbs, grass, gravel, uneven terrain and snow. This is because the 14-inch drive wheels are the best wheels to encounter obstacles and they pull the rest of the wheelchair over them. But for using it at home, wheelchairs don't have to be traversing that much obstacles. So in this project 10-inch drive wheel is used to reduce size and cost.

4. Apparatus

While choosing the main apparatus, it is considered to use local and low cost products. The components that were selected are:

A. Motor

For this project permanent magnet brushed DC motor is used instead of brushless DC motor (BLDC) as DC motor is cheaper and available. Alternate power supply can drive the motor clockwise or anti clockwise. Two ***My1016z2*** motor (24v, 250w) is used to drive the wheelchair. Each motor has a capacity of carrying maximum 80 kg and maximum speed is 20km/h. A gear box is attached with a gear ratio of 1:9.78. Without gear box the motor has 3850 RPM with no load and 3000 RPM in rated load and torque is 0.80 N.M [4].

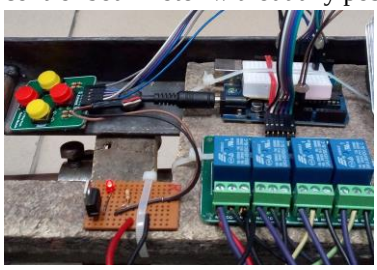
B. Wheels

Table 1. Wheel specifications

	Drive wheel	Caster wheel
Diameter	10 inch	4 inch
Weight capacity	600 Kg	200 Kg
Material	Solid rubber	Plastic
Bearing diameter	1 inch	

C. Control circuit

Generally motors are rotated clockwise or anti clockwise using H-bridge method. It takes 4 switches for one H-bridge. IGBTs/transistors or different types of switches are used to make H-bridge. But in this project relay is used to reduce cost. In this control circuit one motor is controlled using just 2 relays so it takes 4 relays to control both motor without any possibilities of short circuit.



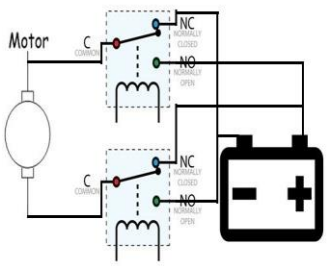


Fig.5. Relay connection with battery **Fig.6.** DC-DC Synchronous buck converter

After receiving signals from the driving buttons, a microcontroller (Arduino Uno) will send trip signal to the relay module. The relay module will get power from a DC-DC synchronous buck converter which will take

power from battery. The DC-DC converter is used for soft start and to adjust speed. User can adjust motors speed using a potentiometer [5] [6].

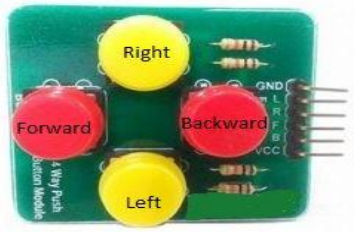


Fig.7. 4 buttons for driving the wheelchair

D. Battery

To power up the circuits and motors, a 12V 30ah electric bike maintenance free battery is used as it is available in market. [7].

5. Hardware construction

First of all two 5 inch diameter flanges are welded with the drive wheel shafts and attached with the drive wheels using 5 nut-bolts. Each drive shaft is 12 inch long having 1 inch diameter. The lower frame structure is made in a local welding work shop using 2 inch "L" shape angle. The frame weighed 9.4 Kg. A footrest is also attached in the front side. After making the lower structure, both drive wheel shaft are attached with the lower frame using 4set housing, 4 Bush, 4 bearing set and 2 fixed ball bearings.

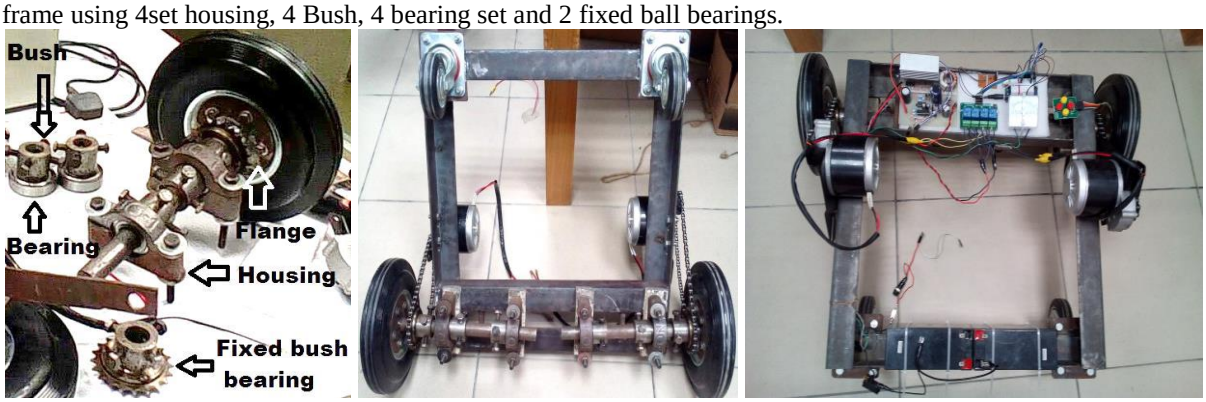


Fig.8. Different ingredients and the lower structure of the wheelchair

Both motors are mounted on the upper side of the steel frame. Fixed ball bearing and gear cycle chain is used to couple the drive wheel shafts and motor. Casters are attached with the steel frame using 4 nut-bolts each on the back side. The battery is also attached on the back side of the steel frame to keep balance as the drive wheels will bear the weight of the user. Finally a chair is mounted on the steel frame and attached which is ergonomically good. The push button module is fitted in the right handle of the chair.

Fig.9. Final prototype of the electric wheelchair

Dimension of the wheelchair:

Height: Total height: 2' 11"
Ground to seat height: 1' 10"
Width: Front width: 2' 3"
Back width: 1' 8.5"
Footrest width: 1' 8"
Seat width: 1' 5"
Length: Lower frame length: 1' 11"
Footrest length: 10", Total length: 2' 9"
Total weight of the wheelchair is 30 Kg
Carrying capacity is up to 200 Kg

Performance analysis:

The advantage of this electric wheelchair is, it takes a soft start every time, which means it starts drawing power from minimum to maximum slowly in a certain time. Maximum power consumption of this wheelchair is 39.36W (4.8V, 8.2A) which occurs at the beginning to give starting torque. But average power consumption is 26W (6.5V, 4A).

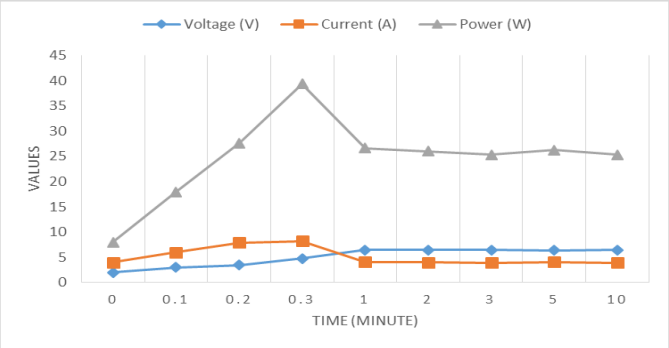


Fig.10. Operating voltage, current and power curve

6. Cost analysis

Conventional manual wheelchair's price varies from 8,000 taka to 12,000 taka whereas this electric wheelchair prototype takes around 20,000 taka to build. But generally it takes 80,000 to 200,000 taka or even more to buy an electric wheelchair which is available in market [8].

Table 4. Apparatus amount and cost

Apparatus	**Quantity**	**Price(taka)**
DC-DC synchronous buck converter	1	1000
Motor	2	6500
4 relay module, Push button	3	500
10 inch drive wheel	2	1450
4 inch Caster wheel	2	350
12 inch Wheel shaft	2	100
Flange/shaft disk	2	320
2.5 inch nut-bolt	12	50
Battery (12V, 30Amh)	1	3000
Bush (ball bearing)	2	140
Bush (bearing)	6	390
Bush nut	12	48
Bearing	6	510
Housing set	2	270
Housing nut-bolt	8	96
Housing washer	24	72
2 inch 4 mm steel angle	8'6"	564
Welding cost		1300
Gear cycle chain	1	300
Chair	1	1300
Total		**18260**

7. Conclusion

The main objective of this project was to construct a prototype of a two wheel independent drive smart electric wheelchair for home use purpose, for the people who are mobility impaired and who are incapable of using ordinary manual wheelchair for variety of reasons. After completing design, simulation, hardware construction and implementation, it seems this prototype fulfils all the criteria. This electric wheelchair is very maneuverable through doorways and other narrow or crowded areas because of independent wheel drive. Comparing with other electric wheelchairs, this wheelchair is affordable for people of our country offering same or even more flexibility. The main and unique advantage of this wheelchair is that it can take turns in a very small place for which it is highly suitable for home use. In ordinary manual wheelchairs, casters located in the front side of the chair and drive wheels fitted in the back side. But in this electric wheelchair, casters are fitted in the back of the

wheelchair and drive wheels are fitted in the front side of the wheelchair so that it can overcome small obstacles easily. For other variety of reasons, this electric wheelchair is very much suitable for the people our country.

8. References

[1] https://www.unicef.org/protection/World_report_on_disability_eng.pdf

[2] http://planning.cs.uiuc.edu/node659.html

[3] http://www.sunrisemedical.com/community/blogs/guest-blogger/june-2015/differences-between-power-wheelchair-base-configur

[4] http://www.kitsguru.com/24V-350W-MY1016Z2-Motor-for-Electric-Bike-electric-tricycle-and-Other-Applications

[5] Zaima Tasneem, Saila Ishrat Annie, Mohammad Rejwan Uddin and Khosru M Salim "A 1kW Synchronous Buck Converter for Solar Powered Conduction Cooking System in off-grid areas of Bangladesh "2016 IEEE International Conference on Power and Renewable Energy

[6] Mohammad Rejwan Uddin, Zaima Tasneem, Saila Ishrat Annie and Khosru M Salim "A High Capacity Synchronous Buck Converter for Highly Efficient and Lightweight Charger of Electric Easy Bikes" ECCE-CUET 2017

[7] Mohammad Iqbal, Rakibulhasan and Tanvir Ehsan “study on merits and demerits of two transport systems: battery operated easy bike with motor operated rickshaw at sylhet city in bangladesh” International Conference On Mechanical Engineering And Renewable Energy 2015 (ICMERE2015) 26-29 November, 2015.

[8] Md.Zulkefa Rian1 ,Dr. A. N. M. Mizanur Rahman 2,* “Study on Power Consumption and Social Aspects of Battery Operated Auto-rickshaw” International Conference on Mechanical, Industrial and Energy Engineering 2014.