Smart Electric Wheelchair System for Disabled People

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ABSTRACT

The proposed system of this paper is easy and effective in solving the problem of handicapped people, and is also fully automated. The wheelchair feels more flexible and intelligent than a traditional joystick-controlled chair. Such a smart wheelchair is designed for people with disabilities or having a difficulty in moving in developing countries because it was very inexpensive than the other existing ones.

This research aims to design and build a smart electric wheelchair system that is controlled automatically or through gesture interfaces based on the movement of the hand. Furthermore, it utilizes ultrasound sensors that help to detect obstacles laying ahead of the wheelchair, a microcontroller Atmega328a (Arduino) for controlling the mechanism, and a motion sensor that is fixed on the head for full movements of the system. A servomotor speed device, the Vibrotip, is used to determine and measure the motor speed. The speed of the wheelchair, power, and torque are calculated by the interpolation limits method. The speed of the motor and the torque on the motor shaft based on the different source voltage is analyzed by using a MATLAB program. The aim of this research is to facilitate the movement of people who are fully handicapped allowing them to be independent in an easy and effective manner with least efforts.

Keywords: Wheelchair, Sensors, microcontroller, joystick, DC motor.

1. Introduction

Physically handicapped people are neglected at every stage of their lives. Approximately 15% of the world's population today suffers from some form of disability [1]. Even if they are capable of doing much more, they cannot express themselves because of their disability, and the world today makes a huge difference for people with controlled mobility. 650 million people are handicapped. Progress in technology makes a significant contribution to people with disabilities [1, 2].

The solution presented in this paper enables traditional wheelchairs to move smartly as well as to detect and avoid obstacles in its path. This is done by the use of latest technology such as sensors and controllers. Focus on electric chairs that help people who find it difficult to walk by themselves [3], previous solutions do not give full mobility to people with disabilities and may reduce their guardians in many ways [3]. The physically handicapped are independent [4]. In addition, in [5], the authors made use of voice commands and GPS to locate and detect obstacles [5].

In [6], a collaborative control system is proposed to control the wheelchair. They used a joystick, the 16X2 LCD display, and the ATMega328 microcontroller to display sensor readings to make the system more user-friendly. Other proposed solution are included in [7, 8]. Both use the ATMega328 microprocessor. More approaches that are creative are proposed in [9] and [10]. [9] uses an EEG electroencephalography along with a mobile phone app while in [10] authors propose a wheelchair-based brain wave detection interface. The use of an RGB camera, infrared camera, LIDAR, and ultrasonic sensors would prevent the wheelchair obstacle [11]. Most people because of certain other limitations are unable to control the direction of the electric wheelchair on their own [12].

Disabled people are mostly neglected and everyone thinks of them as a burden to society most of the time only because they cannot move their own and can be solved using this proposed motion gesture-based wheelchair technology [13, 14].

2. Materials and Methods

The design and fabrication requirements for the proposed smart electric wheelchair comprises three major parts: input and control unit accessories, body support framework, and a power unit. The proposed smart wheelchair system is an electric wheelchair system that includes two 12V DC servomotors, 4 relays modules, two front wheels, two caster wheels, angle bars, capacitors, emergency alarm, resistors, a joystick, an Arduino Uno board , and a computer to test and control all chair motions.

Figure (1) shows the Bluetooth module HC-06 with a wheelchair control system of the Arduino board comprises two components that are the hardware component of the wheelchair and the navigation of software component for the user. The architecture of the Arduino Uno microcontroller system is to synchronize the entire configuration by driving the DC motor for the directional and linear movement of the wheelchair. In general, its physical range is typically less than 10 m. It can perform within the area range up to 100 m (330 ft.).

Fig 1 shows the Bluetooth module HC-06

An important sensor for smart wheelchair is the MPU6050 module as shown in figure (2) which is a complete 6-axis Motion Tracking Device. It combines 3-axis Gyroscope, 3-axis Accelerometer and Digital Motion Processor all in a small package. In addition, it has the additional feature of on-chip temperature sensor [15,16]. It also has an I2C interface to communicate with the microcontrollers. The MPU6050 consist of a 3-axis Gyroscope with Micro Electro Mechanical System (MEMS) technology [17]. The sensor is used to detect rotational velocity along the X, Y, Z axes.

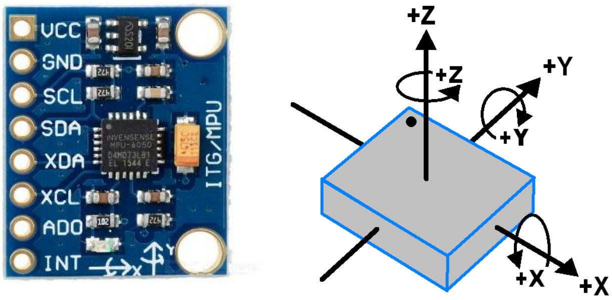

Fig 2 shows the MPU6050 motion sensor [17]

One of the intelligent attributes of the wheelchair developed in this study is the integration of a joystick-based input control system and head-mounted motion sensor based on the MPU6050 sensor to improve smart navigation specifically the obstacle detection and avoidance system. Upon completion of the input instruction, the controller synthesizes the command and affects the required action by steering the wheelchair to the specified position [17,18].

Motor Drivers DC Servomotors are chosen because they have suitable speed in addition to its strength to withstand sudden shocks**.** Light-dependent resistors (LDR) are light sensitive devices most often used to indicate the presence or absence of light or to measure the light intensity.

Manual wheelchair**:** An appropriate wheelchair is utilized to allow the motors to be installed on it. An LDR sensor is used to avoid an obstacle in dark places with economical lamps.

Figure (3) demonstrate the Ultrasonic Proximity sensor sake of providing maximum security to the user, the HC-SR04T, having both high precision and waterproofing, has been installed in the chair.

$$\mathbf{D} = \frac{\mathbf{T \times V}}{\mathbf{2}} \quad (\mathbf{cm}) \qquad (\mathbf{1})$$

where D= distance (cm) , V= speed of sound (cm/µs) and T= time (µs)

Fig 3 shows the Ultrasonic Proximity sensor

An analytical study of the power, speed, and torque of a DC servomotor for wheelchairs is presented in the next section.

a. Analytical study of Electric Wheelchair movement

Since most of the charger's voltage sources lose their value when moving the electric wheelchair, and because of these losses, the motor speed will decrease, so the curve of the relationship between the power resulting from the voltage and the motor speed was used.

To model this curve in the form of an equation, numerical methods are used, such as the Complementary boundary method, to get the highest level of accuracy. The general form of a polynomial that lies at all points of the given data set is**:**

$P_n(x) = a_0 + a_1 x + a_2 x^2 + \cdots + an$

In this work, only second-order integer values were obtained and many methods aim at this, thus, the direct method was used. This method is needed in all design stages to get the general equation of the system:

i. The relationship between speed and power of the servo motor curve

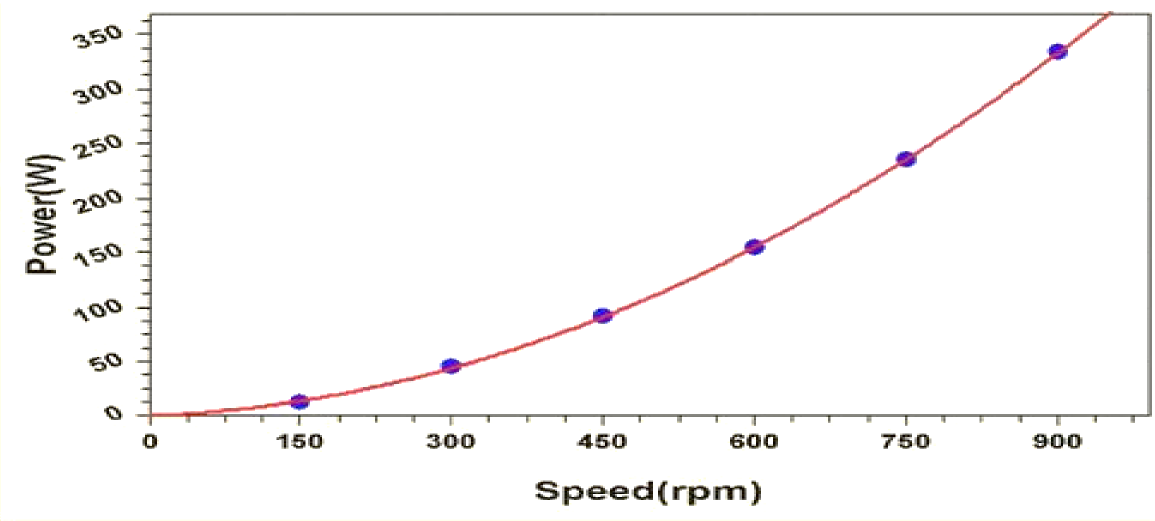

Fig 4 shows the relationship between power and speed of the servo motor

Three readings are used from the curve diagram of the relationship between motor speed and power output from the source as shown in Figure (4) according to the following table. Table 1 shows the readings between speed and power.

Table 1 Speed and Power Readings

$V(rpm)$	$P(\mathrm{W})$
332	50
590	150
680	200

By applying this

Eq. $\mathrm{V} = \mathrm{a}_0 + \mathrm{a}_1\mathrm{P} + \mathrm{a}_2\mathrm{P}^2$ (2)

where V is motor speed, P is the source power and when we apply these values into equation (2) we get:

$\mathrm{a}_0 + \mathrm{a}_1 * 50 + \mathrm{a}_2 * 50^2 = 323$

$\mathrm{a}_0 + \mathrm{a}_1 * 150 + \mathrm{a}_2 * 150^2 = 590$

$\mathrm{a}_0 + \mathrm{a}_1 * 200 + \mathrm{a}_2 * 200^2 = 680$

Put them in the matrix.

$$\begin{bmatrix} 50 & 50 & 50 \\ 150 & 150 & 150^2 \\ 200 & 200 & 200^2 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \end{bmatrix} = \begin{bmatrix} 323 \\ 590 \\ 680 \end{bmatrix}$$

Using the Gaussian method of elimination, we can find the values of coefficients (a0, a1, a2) as follows. $a_0 = 146, a_1 = 3.8299, a_2 = -0.0058$ Then the general equation of the curve between the power and speed becomes:

$v = 146 + 3.8299P - 0.0058P^2$

(3)

ii. the relationship between speed and Torque of the servo motor curve

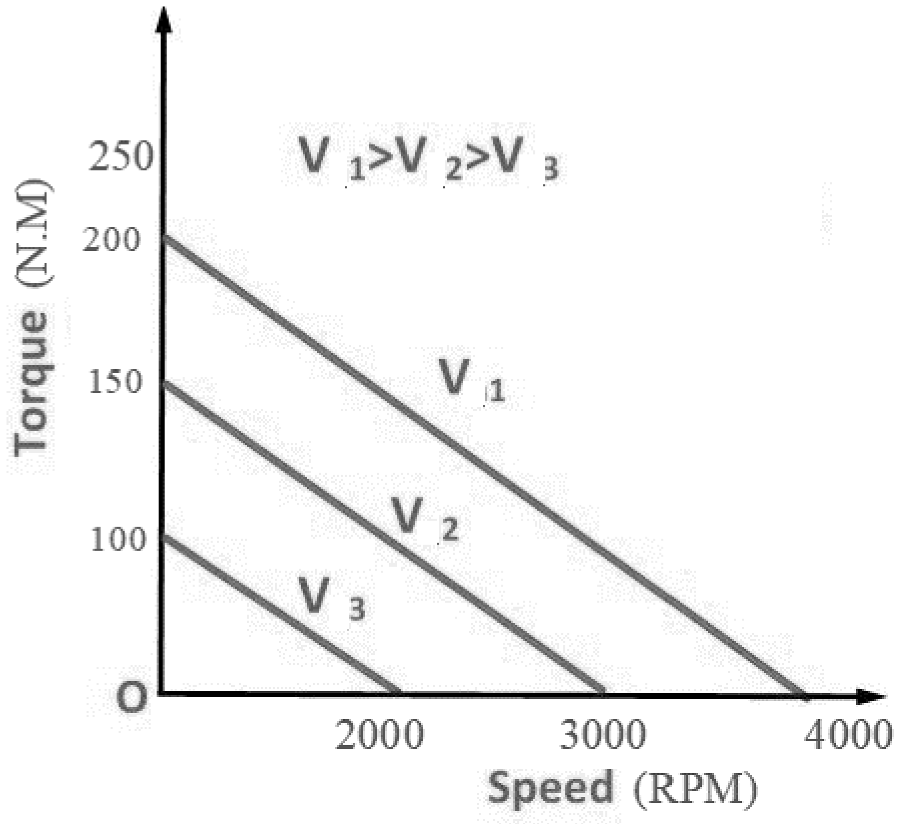

Fig 5 the relationship between torque and speed of the motor

- Calculation of the torque acting on the servo motor shaft.

Three different voltages are used as follows: V1=36 volt, V2=28 volt, V3 = 21 volts, to study the relationship between torque and speed of motor for each curve.

In the first case that the voltage is 36 volts, in this case, three reading are taken from figure 3 as shown in table 2.

Table 2 Speed and Torque readings at 36 volt

T(N.m)	V(rpm)
160	200
170	600

180	1000

$T = a_0 + a_1 v + a_2 v^2$

(4)

From equation 4

$a_0 + a_1 * 200 + a_2 * 200^2 = 160$

$a_0 + a_1 * 600 + a_2 * 600^2 = 170$

$a_0 + a_1 * 1000 + a_2 * 1000^2 = 180$

Then using the Gaussian method of elimination, we can find the values of coefficients (a0, a1, a2) as follows.

$a1 = 1.84996e + 02; a2 = -0.0249844; a3 = -1.20329e - 08$ the general curve equation the torque and motor speed

$T =$

$1.84996e + 02 - 0.0249844v - 1.20329e -$

08 (4)

In the second case, the voltage is 28 volt, similarly from figure 3 that three reading values was used as shown in table 3**.**

Table 3 Speed and Torque readings at 28 volt

$T(N.m)$	$V(rpm)$
127	200
137	600
147	1000

$a_0 + a_1 * 200 + a_2 * 200^2 = 127$

$a_0 + a_1 * 600 + a_2 * 600^2 = 137$

$a_0 + a_1 * 1000 + a_2 * 1000^2 = 147$

The coefficients are $a1 = 1.22e + 02; a2 = 0.02498; a3 = 1.20329e - 08$ the equation of torque with speed at 28volt is:

$T = 1.22e + 02 + 0.02498v + 1.20329e - 08v^2$

(5)

In the last case, the voltage is 21 volt and the readings were as follows**.**

Table 4 Speed and Torque readings at 21 volt

$T(N.m)$	$V(rpm)$
99	*200*
100	600
101	1000

From the general equation, we get

$a_0 + a_1 * 200 + a_2 * 200^2 = 99$

$a_0 + a_1 * 600 + a_2 * 600^2 = 100$

$a_0 + a_1 * 1000 + a_2 * 1000^2 = 101$

$The\ coeffiecients\ are\ a1 = 1.01496e + 02; a2 = -0.00248; a3 = -1.2577e - 08$

, the torque equation with speed at 21 volt is:

$T = 1.01496e + 02 - 0.00248v + -1.2577e - 08v^2$

(6)

3. Results and Discussion

a. System Evaluation

Figure (6) shows the installation of the mounting tape, the joystick, motion sensor, ultrasonic sensors, Bluetooth connection and light sensor to the Arduino board. Moreover, the relays are connected to the Arduino to take the start and stop commands, and they are connected to the two motors and the source of the electrical voltage to give the movement of the smart chair.

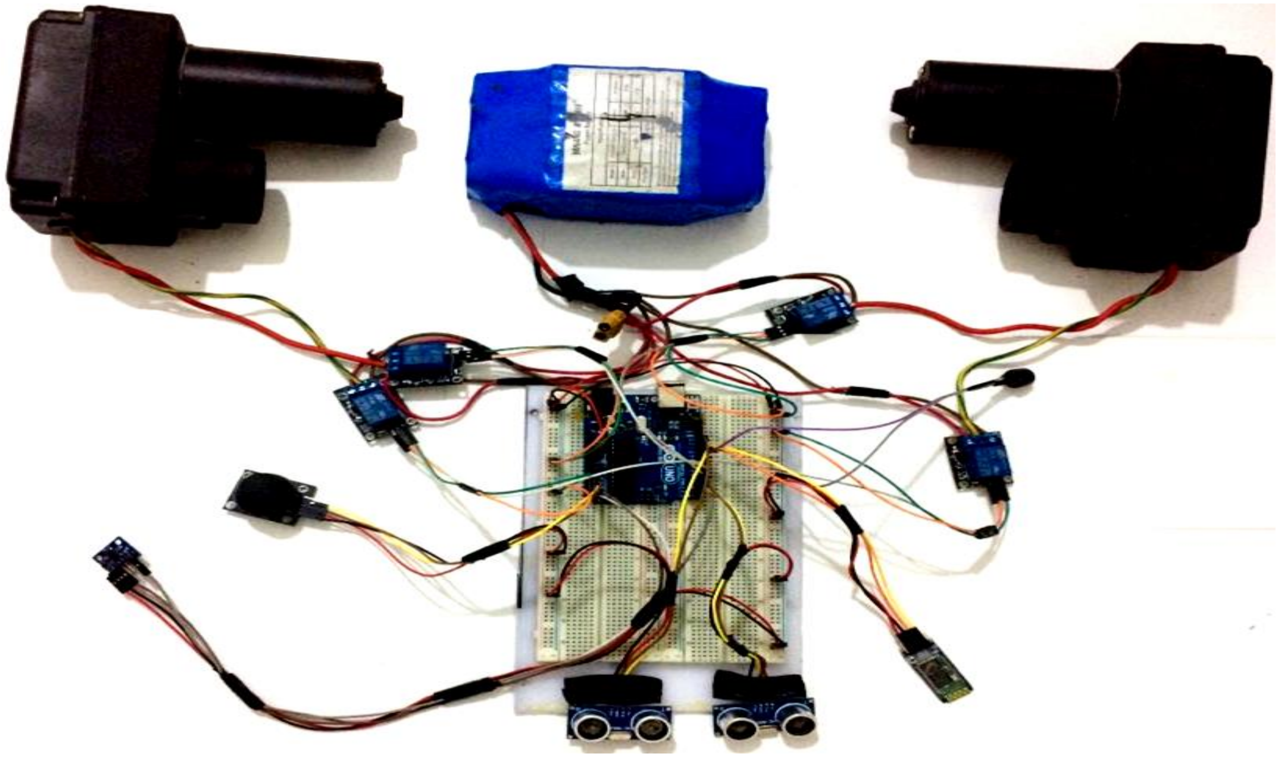

Fig 6 shows the system test before installation in the wheelchair

Figure (7) shows the final connection of the system and the verification of the operation of the entire system, and the installation of these parts and sensors in the specified place on the smart motion chair.

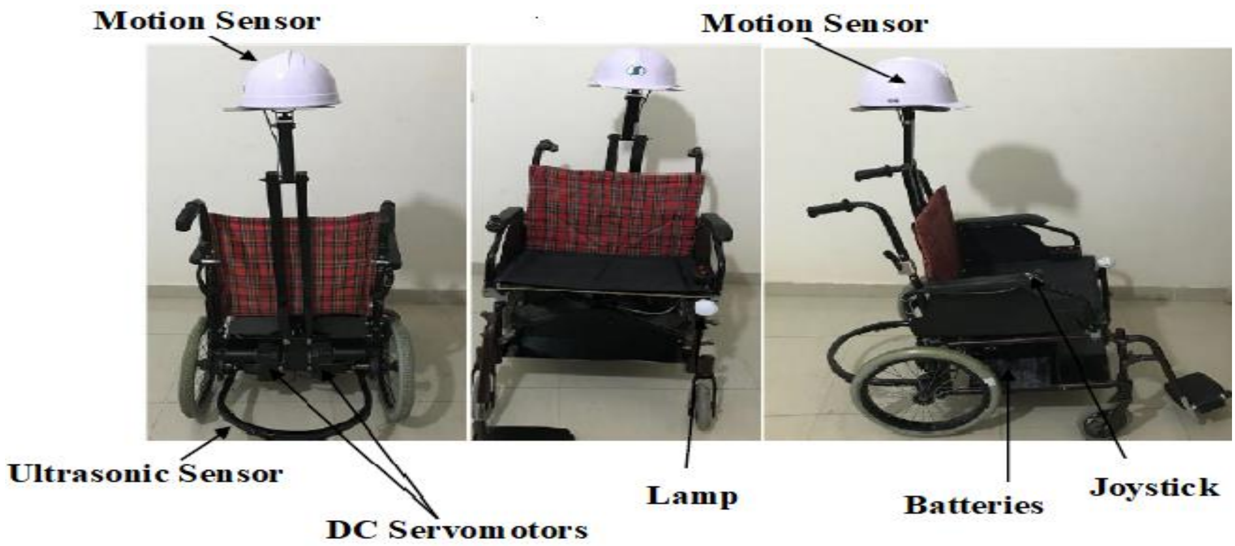

Fig 7 shows the final connection of the system

3.2 Speed and Torque test of DC motor at different voltages

A servomotor speed device, the Vibrotip is used to determine and measure the motor speed. The wheelchair's speed, power, and torque are calculated by the interpolation limits method. The speed of the motor and the torque on the motor shaft based on different source voltages are analyzed by using a MATLAB program.

3.2.1 Effect of input power on the speed of the servo

Figure (8) shows that when the source voltage decreases, the rotational speed of the motor is decreased as well. The speed reaches 80 rpm at 36 volts, and when the voltage drops to 1v the speed decreases to 19.98 rpm. The amount of slope of the curve expresses a function Positive exponential.

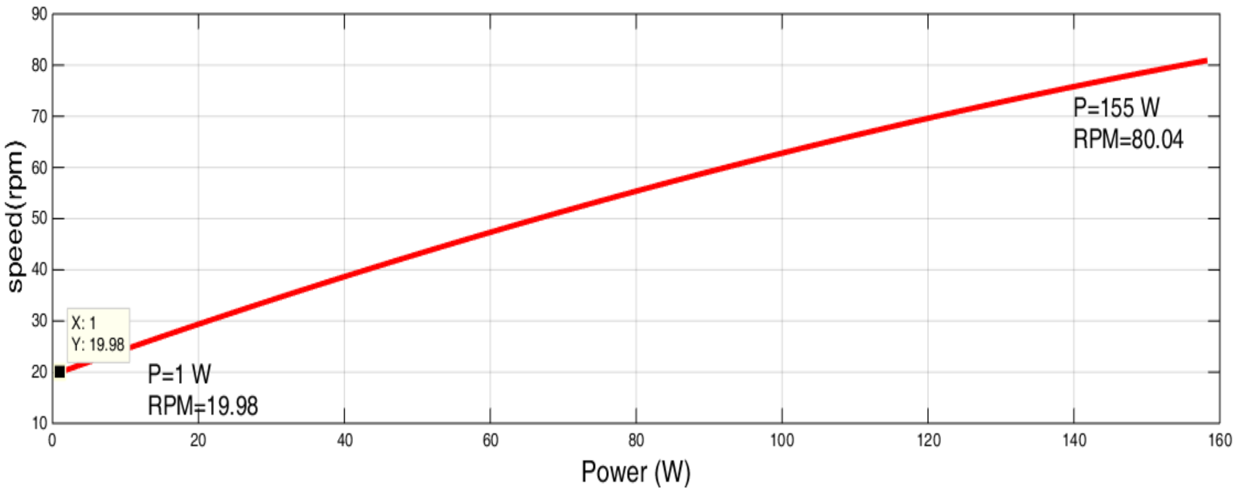

Fig 8 shows the speed decreased from 80 rpm at 36 volts to 19.98 at 1 volt

Assuming a change in velocity with a change in a person's weight within the general equation:

3.2.2 The relationship between the speed of the servo motor and the torque of the transmission shaft at (36V).

The speed of the servo motor is constant at the start of operation and decreases with the decrease in the power of the source. It is clear from Figure (9) that the torsional torque on the shaft changes slightly compared to the speed of the motor, as the lower the speed, the greater the torsion torque (80.84 rpm) was (184.5 Nm) and at speed (19.89 rpm), the torque was (183 Nm).

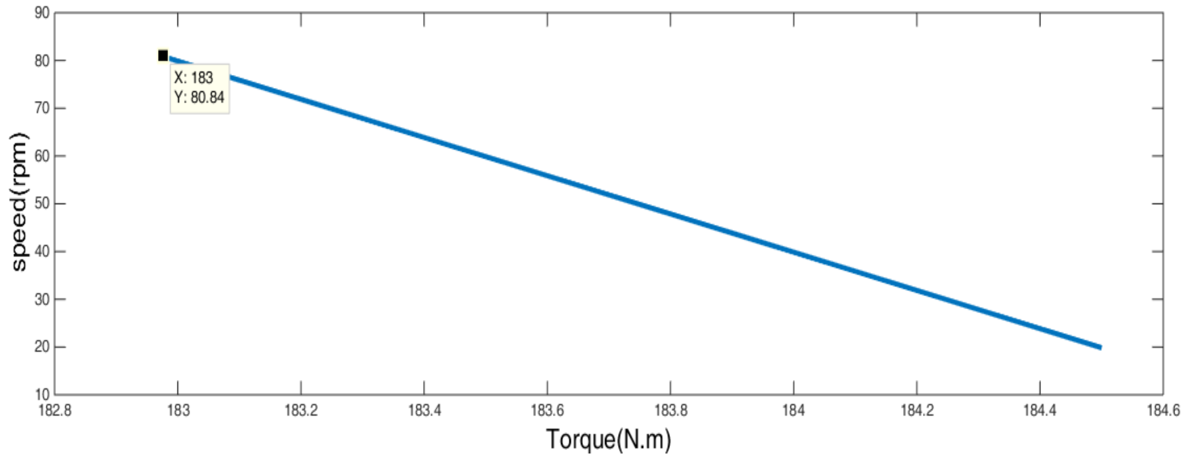

Fig 9 the relationship between the speed and the torque at (36Volt).

3.2.3The relationship between the speed of the servo motor and the torque of the transmission shaft at (28Volt).

When the source voltage drops from (36 Volt) to (28 Volt), the torque of the transmission shaft decreases, where the torque at the maximum speed (80.04 rpm) was (120N.m) and the torque increases (121.5 N.m) with the decrease in speed (19.81 rpm) as illustrated figure (10).

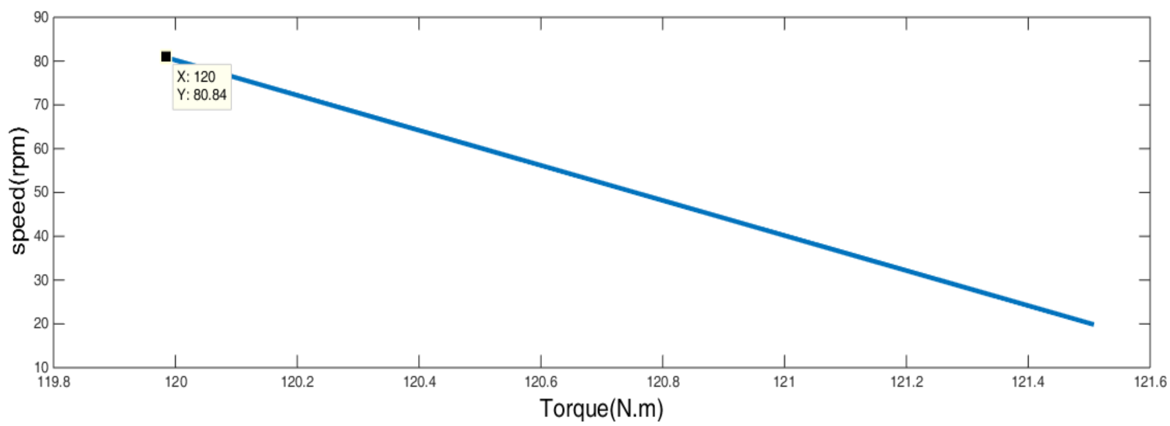

Fig 10 the relationship between the speed and the torque at (28Volt)

3.2.4 The relationship between servomotor speed and driveshaft torque at (21Volt).

Figure (11) shows that the torque difference in torsion is limited to (101.3 – 101.4N.m) with the maximum and minimum speed difference.

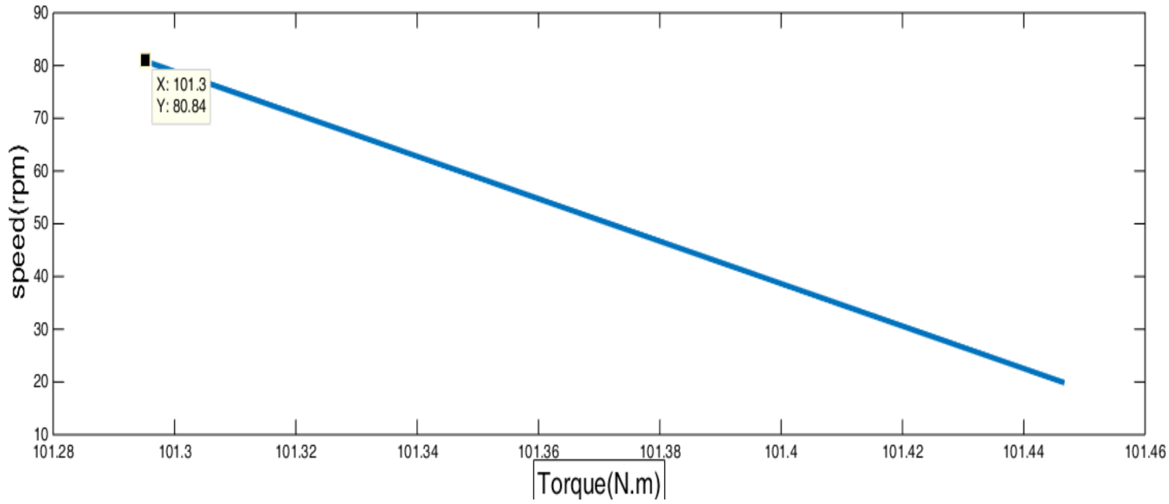

Fig 11 the relationship between servomotor speed and driveshaft torque at (21Volt).

It is noticed that the speed of the servo motor and the torque of the drive shaft for the following voltages (36, 28, 21Volt). When the voltage and velocity curves are combined, it becomes clear that at the maximum source voltage (36 Volt) it gives the largest values of torsion torque with the difference in speed, and the torsion torque decreases with the decrease in the source voltage.

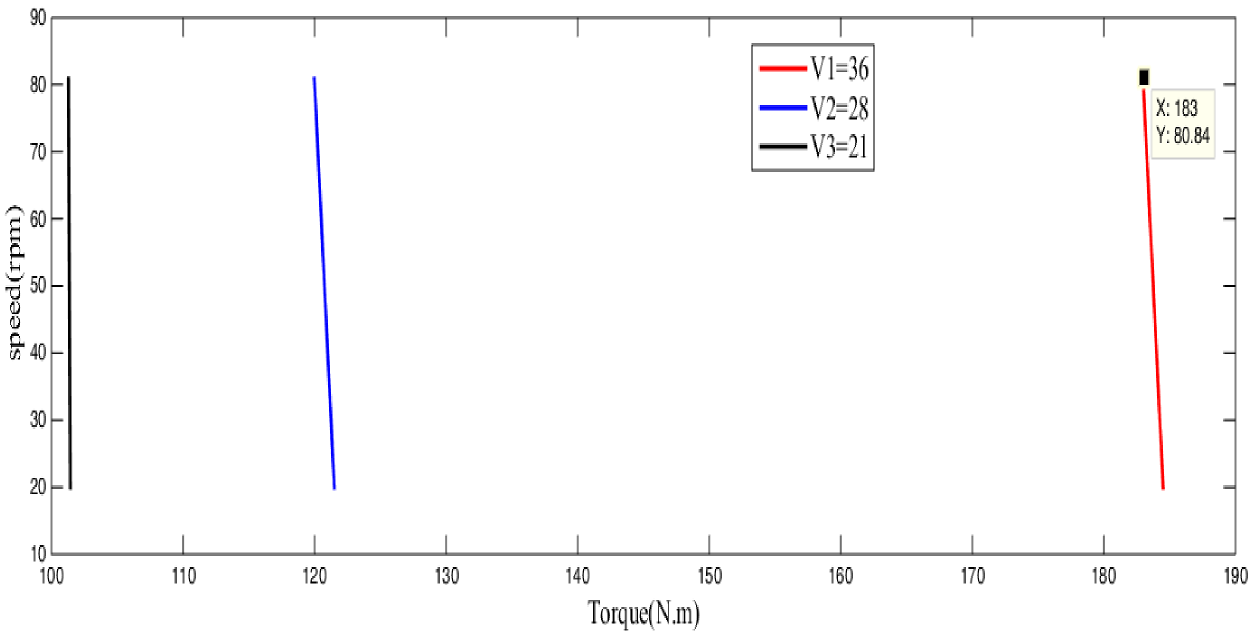

Fig 11 the relationship between servomotor speed and driveshaft torque at the three voltages (36, 28, 21Volt)

4. Conclusions

The smart electric wheelchair is targeted as it incorporated designing an embedded system that is real-time and due to the sensors, that need to be used in it. Most modern-day technologies use sensors such as accelerometers, gyroscopes, to take interactive input and in this paper; an automaton interactive system is designed that is close to humans. Moreover, a range of sensors and actuators are used to form a fully operational, fast, and real-time efficient system. These components are the accelerometer, the Gyroscope, the Joystick, and Ultrasonic Sensor. These conditions made smart electric wheelchairs suitable for its designed purpose which is to assist people with disabilities.

Completion of this study needed complete determination as many things could go wrong. The mechanical design is very important for the completion of this work, creating a mechanical structure proved to be a difficult task. However, some difficulties stimulated, many remodeling was needed, and the chair had some limitations that we learned while building it such as a problem faced during mechanical design and during designing of high-power motor driver as well. At last, the smart electric wheelchair is created very close to the adapted design philosophy.

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