

Design of low-cost manual cum Electric-powered wheelchair for Disabled person's to use in indoor

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Abstract — Wheelchair usage in India is increasing day by day because of ageing population, road accidents and injuries etc. In case of nuclear families, the elder people those who are unable to do their regular activities without assistance, are left alone at their home. Manual propelling is difficult for aged people, so to avoid it they choose the motorized wheelchair. However, the cost of the motorized wheelchair is quite high and it is difficult for the middle class people to afford it. In order to avoid the above obstacles we propose a novel wheel chair named as “Design of low-cost manual cum electric-powered wheelchair for disabled person for indoor usage”. In this design, we employed Mechanical lever and gear box system. The lever is used to change mode of operation and the gear box system is used, to establish the contact between wheels of the wheel chair and two DC motors. The calculated result shows the robustness of the manual cum powered wheelchair design. Based on the result we ensure that the proposed wheelchair will improve the quality of the life of the elderly people and those with disabilities.

Keywords—Manual-Wheelchair, Mechanical lever, Electric-Power, Gear box, Joy stick, Battery.

I. INTRODUCTION

Wheelchair usage in India is increasing rapidly because of ageing of the people, road accidents, and miss-happenings at home etc. Due to surge in nuclear families globally and particularly in India, the elderly people are left alone during the day time and majority of them belong to the lower middle class. According to the Census of India in the year 2011, out of total Indian population approximately 20.3% people are disabled [1] due to various mobility impairments and the figures are higher when compared with the year 2001. The people with mobility impairments need an appropriate wheel chair, but in case of aged persons and children's with quadriplegia, spinal cord injuries (SCI) and amputation, require motorized wheelchair rather than the manual wheelchair. It is very difficult to control and maintain the joystick controlled motorized wheelchair which is available in the Indian market for people and its cost are quite high.

In our project, the development of “low-cost manual cum power wheelchair” capable of doing movement according to the user desire could lead to the improvement in the quality of life for elders and disabled persons. The wheelchair discussed in the paper has been designed in order to meet the following

requirements:-

- ✓ It can be designed for people with different mobility impairments, lifestyle disorders, life roles and backgrounds.
- ✓ It should be customized based on the user requirements, maintained and repaired easily at low costs by the user or local mechanic.
- ✓ It should be operated always in the safe mode and durable for long period and cost effective.

The remaining part of this article is organized as follows: Section II explains an overview of manual wheelchair, power wheelchair and related work. The detailed description of the proposed methodology is presented in Section III. Calculated results of the proposed work are presented in Section IV, and Section V provides the overall conclusion and future work.

II. RELATED WORK

A. Overview of the manual wheelchair

Manual wheelchair is used to provide limited mobility to a sick, injured, and disabled person from one place to another. Based on the condition of the rider, they may be able to operate the wheelchair personally by using special round handles that loop around the wheels, or someone may need to push the wheelchair for sick person by using the handles on the back. The manual wheel chair along with its parts is as shown in figure – 1.

The drawbacks of the manual propelled wheel chair compared with power wheelchair are as follows:-

- ✓ It requires physical exertion by patient or helper.
- ✓ Based on the condition of a patient, it could be difficult to operate the manual wheelchair on a flat or level surface.
- ✓ It is difficult to use manual wheelchair for hilly domain or on sloped pathway even with adequate upper body strength of a patient.

B. Overview of the power wheelchair

An electric-powered wheelchair (EPW) would utilize an electric motor for powering it rather than manual propelling.

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Based on the location of the electric-power motor the EPW are classified into three types named as, back-wheel drive wheelchairs, caster-wheel drive wheelchairs and single-wheel drive wheelchairs. The structure of EPW along with its parts is as shown in Figure – 2.



Fig – 1 Basic structure of manual wheelchair with parts

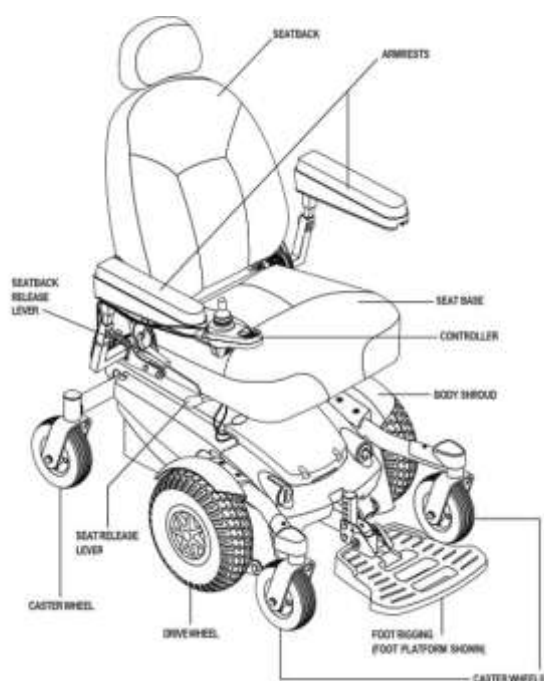


Figure – 2 Basic structure of EPW wheelchair with parts

The draw backs of the EPW compared with manual wheelchair are as follows.

- ✓ The cost of the EPW is five times higher than the manual wheelchair, thus making it unaffordable to many.
- ✓ The structure of the EPW is not unique; it is difficult to customize according to the rider needs.
- ✓ Some EPW structures do not have freewheel mode. In case of any failure in the motor, it is quite difficult for the rider to propel the EPW.

C. Overview of the related work

Benjamin Romero et al [2] designed a low-cost electric powered wheelchair based on the vision based control system, it does not have the free wheel mode, which will reduce the strain of the person when the wheelchair was operated in manual mode. Yu Munakata et al [3] designed an active-caster drive system to motorize a manual wheelchair. The design of this wheelchair was complex, high cost and its control was difficult for the rider. R. Rahulanker and V. Ramanarayanan [4] designed “Battery assisted wheelcChair” the dimensions of the wheel chair was not according to the World Health Organization (WHO) standards and hence not popular for usage[5].

Marcelo A. Jose et al [6], developed a hardware and software design for the electric wheel chairs. However, it was not suitable for the elders who are illiterate and from the rural areas. Joelle Pineau et al [7] explained about the difficulties and unsafe conditions occurring during the usage of powered wheelchair. Alfredo Chavez et al [8] explained about the different power wheelchair control modes for those with severe motor impairments. Wei – Chen Lee, Jyun – An Yao [9], developed an under actuated wheel module for electric wheelchair which increased the cost of the wheel chair.

III. PROPOSED METHODOLOGY

In this paper, we introduced a hybrid prototype model design which combines the advantages of manual wheelchair and EPW. To design this model we used “PTC Creo parametric 3.0” student version software. The design of manual wheelchair was done according to the WHO guidelines [5]. We added gear box and mechanical lever to the manual wheelchair to avail features of EPW. The overall design of the prototype model is as shown in Figure – 3.

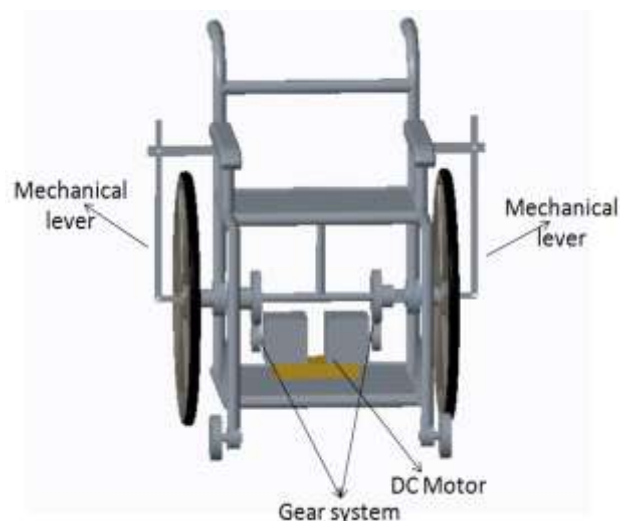


Figure – 3 Front view of the hybrid prototype model

The gear box is used to establish a contact between rear wheel and motor. The mechanical lever is used to change mode of operation. If the lever is pushed away from the rider, the rear wheel gears are engaged with motor gear causing the movement of wheelchair by utilizing the electric power generated from the battery. If the lever is pulled towards the rider, the rear wheel gears are disengaged from the motor gear which creates the free wheel movement so that the rider can easily move by putting less effort manually. When compared with normal EPW, the diameter of the rear wheels was increased three times to enable the manual propelling, but when it was used in the power mode the motor required more torque for movement, thereby more power which reduced the battery life. In order to avoid, the above problem we introduced gear system between the Rear wheel and motor. The nature of the gear system inside the gear box is as shown in figure – 4.

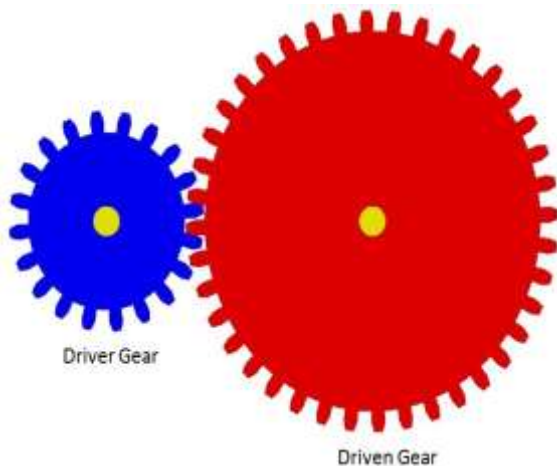


Figure – 4 the nature of the Gear system inside the Gear box

Gear is a device having teeth on its periphery and used for transmission of mechanical power from one shaft to another. It is known as positive drive and it has to be used when the center to center distance between the shafts is small. The combination of two or more gears results in gear train. The type of gear train depends upon requirement of velocity ratio between the shafts and the relative position of the axes of the shafts.

The relation between speed of the driver and driven gear as well as between the numbers of teeth on them is given by the velocity ratio. It is defined as the ratio of speed of the driver gear to the speed of the driven gear. Mathematically it is shown as in equation (1)

$$N_1/N_2 = T_2/T_1 \text{----- (1)}$$

N_1 = Speed of the Driver gear (rpm)
 N_2 = Speed of the Driven gear (rpm)
 T_1 = Teeth of the Driver gear
 T_2 = Teeth of the Driven gear

Here, we tested the different possible conditions to design the wheelchair in mechanical perspective. We calculated the speed of the wheel required to achieve the required linear speed of the wheelchair for different rear wheel dimensions by using the relation between the linear speed and the angular speed. The mathematical formula [10] is as shown in equation (2).

$$u = \pi dn/60 \text{ m/s -----(2)}$$

u = Linear speed of the wheelchair (m/sec)
 π = Constant
 d = diameter of the rear wheel of the wheel chair (meter)
 n = Speed of the rear wheel of the wheelchair (rpm)

The required power to move the wheelchair for different weight and size of rear wheel was calculated by using the relation between the power, weight and speed of the wheel chair. The mathematical relation [10] between above three parameters is shown in equation (3).

$$\text{Power} = \text{weight} \times \text{speed} \text{----- (3)}$$

The diameter of the Driver gear and Driven gear [6] are chosen to satisfy the following condition.

The distance between the motor shaft and rear wheel shaft = Sum of the Diameter of the Driver gear and Driven gear

The number of teeth for gears is chosen based on the relationship between the speed of the gear, number of gear teeth and diameter of the gear. The mathematical relation [6] between above three parameters is shown in equation (4).

$$N_1/N_2 = \tau_2/\tau_1 = d_2/d_1 \text{-----(4)}$$

N_1 = Speed of the Driver Wheel (rpm)
 N_2 = Speed of the Driven Wheel (rpm)
 τ_1 = Torque produced by the Driver wheel (N – m)
 τ_2 = Torque produced by the Driven wheel (N – m)
 d_1 = Diameter of the Driver wheel (meter)
 d_2 = Diameter of the Driven wheel (meter)

The different views of components employed to design the proposed wheel chair with its dimensions [11] is as shown in figure – 5 and Figure – 6 respectively.

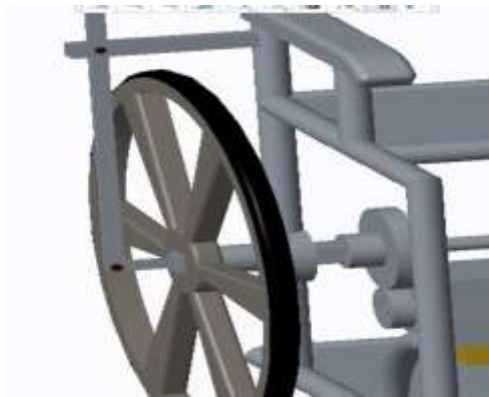


Figure – A

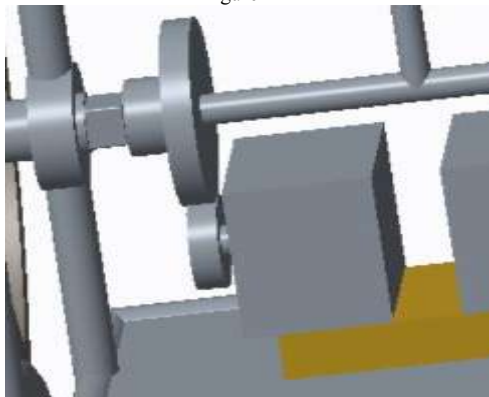


Figure – B

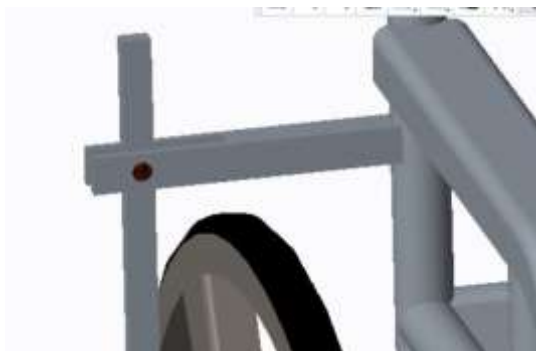


Figure – C



Figure – D

Figure – 5 Figure – A Front view of the rear wheel with gear Figure – B Back view of the gear system with motor Figure – C Front view of the lever Figure – D Side view of the wheel.

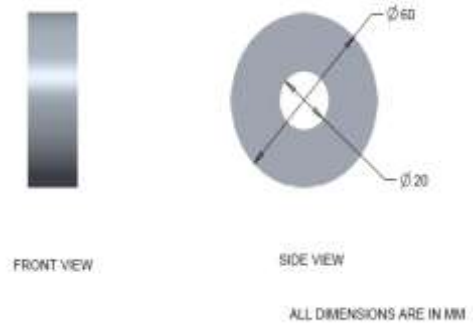


Figure – 6a

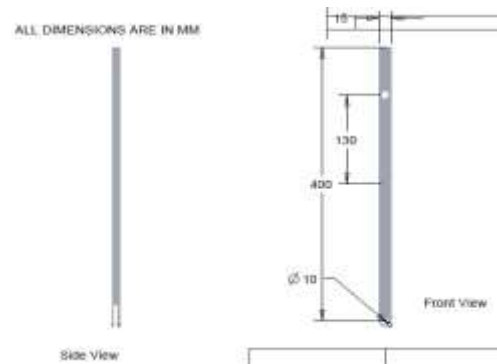


Figure – 6b

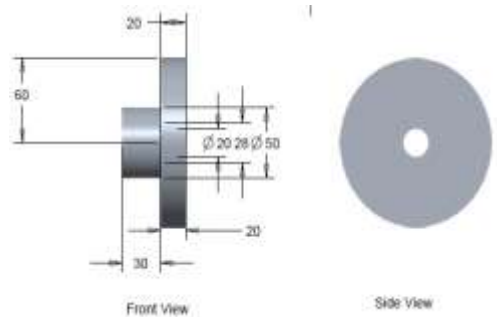


Figure – 6c

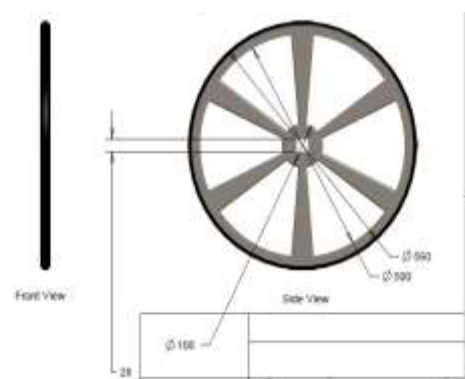


Figure – 6d

Figure – 6 Figure – 6a Dimensions of Driver wheel Figure – 6b Dimensions of lever Figure – 6c Dimensions of Driven Wheel Figure – 6d dimensions of rear wheel of the wheelchair

IV. RESULTS

For the proposed wheelchair design, we calculated the power required to move the wheelchair with different loads at different speeds for various diameter of the rear wheel, and the variation in the speed of the rear wheel with respect to the diameter of the rear wheel and linear speed of the wheelchair.

The table – 1 explains the mechanical power required for a particular load at given speed.

Table – 1 Required power for different loads

Linear speed of the wheelchair (kmph)	Total mass of the wheelchair including rider (kg)	Required power (watt)
1	150	396.9
	120	317.52
	90	238.14
	60	158.76
2	150	808.5
	120	646.8
	90	485.1
	60	323.4
3	150	1220
	120	976
	90	732
	60	488

The table – 2 provides the speed of the rear wheel for various diameter of rear wheel for different linear speed of the wheel chair.

Table – 2 Rear wheel speed variations

Linear speed of the wheelchair (kmph)	Diameter of the Rear wheel (mm)	Speed of the rear wheel (rpm)
1	609	8.59
	660	4.14
	711	1.85
2	609	17.5
	660	8.44
	711	3.78
3	609	26.41
	660	12.74
	711	5.71

The table – 3 shows the required torque to move the wheel chair for a particular diameter of the rear wheel with linear speed of 1kmph for different required total mass including the rider

Table – 3 Showing the required torque for 1 kmph linear speed

Diameter of the Rear wheel (mm)	Speed of the rear wheel (rpm)	Total mass of the wheelchair including rider (kg)	Required Power (watt)	Required torque (N - m)
609	8.59	150	396.9	441.44
		120	317.52	352.97
		90	238.14	264.73
		60	158.76	176.48
660	4.14	150	396.9	915.57
		120	317.52	732.38
		90	238.14	549.29
		60	158.76	366.19
711	1.85	150	396.9	2048.71
		120	317.52	1638.96
		90	238.14	1229.22
		60	158.76	819.48

The table – 4 shows the required torque to move the wheel chair for a particular diameter of the rear wheel with linear speed of 2kmph for different required total mass including the rider

Table – 4 Showing the required torque for 2 kmph linear speed

Diameter of the Rear wheel (mm)	Speed of the rear wheel (rpm)	Total mass of the wheelchair including rider (kg)	Required Power (watt)	Required torque (N-m)
609	17.5	150	808.5	441.40
		120	646.8	353.12
		90	485.1	264.84
		60	323.4	176.56
660	8.44	150	808.5	915.22
		120	646.8	732.18
		90	485.1	549.13
		60	323.4	366.09
711	3.78	150	808.5	2043.52
		120	646.8	1634.81
		90	485.1	1226.11
		60	323.4	817.40

The table – 5 shows the required torque to move the wheel chair for a particular diameter of the rear wheel with linear speed of 3kmph for different required total mass including the rider

Table – 5 Showing the required torque for 3 kmph linear speed

Diameter of the Rear wheel (mm)	Speed of the rear wheel (rpm)	Total mass of the wheelchair including rider (kg)	Required Power (watt)	Required torque
609	26.41	150	1220	441.12
		120	976	352.90
		90	732	264.67
		60	488	176.45
660	12.74	150	1220	914.45
		120	976	731.56
		90	732	548.67
		60	488	365.78
711	5.71	150	1220	2040.30
		120	976	1632.24
		90	732	1224.18
		60	488	816.12

The table – 6 shows the possible radius for driver and driven gear for different velocity ratio at particular center to center distance between the rear wheel axis and motor axis.

Table – 6 Showing the possible radius for driver and driven gear

Center to Center distance between the Rear wheel axis and motor axis (mm)	Velocity ratio	Radius of the Driver wheel (mm)	Radius of the Driven wheel (mm)
200	7	25	175
	6	28	168
	5	33	165
	4	40	160
	3	50	150
150	6	21	128
	5	25	125
	4	30	120
	3	37	111
100	6	14	84
	5	16	80
	4	20	80
	3	25	75

V. CONCLUSIONS AND FUTURE WORK

1) Conclusion

From Table – 1, we see that for fixed weight of the wheelchair, the power required to drive the wheelchair increased with increase in the linear speed of the wheelchair. For fixed linear velocity of the wheelchair, the power required to drive the wheelchair decreased with decrease in the weight of the wheelchair.

Form Table – 2, we see that for fixed rear wheel diameter of the wheelchair, the speed of the rear wheel is increased with

increase the linear velocity of the wheelchair. For fixed linear velocity of the wheelchair, the speed of the rear wheel decreases with increase in the diameter of the rear wheel of the wheelchair.

Form Table – 3, we observed that with increase in diameter linear speed is decreasing and the required torque is increasing for all the considered cases of total mass including the rider of the wheel chair. It is also observed that for a particular diameter of the rear wheel as the total mass increases the required torque also increases. Similar observations are found from the table – 4 and table – 5 as observed in table – 3.

Form Table – 6, it is observed that for a given center to center distance between wheelchair axis and motor axis we can vary the radius of driver and driven gear as per our requirement of velocity ratio. It is also observed that as the velocity ratio increases for a particular center to center distance then the radius of the driver decreases and ultimately it will be resulting in less number of teeth on driver gear.

From above tables we can conclude that, we can operate the wheelchair with less speed which enhances the life of the battery and provides safe ride for the rider. However, if we operate with less linear speed then the torque requirement are quite high. It is difficult to accommodate the high power electric motor in a confined space. It is recommended that, it is better to operate wheel chair with moderate speed, so that the required torque from the electric power motor can be achieved within the confined space.

Based on the rider weight we can choose moderate electric power motor which will reduce the cost of the wheelchair. Limitation of the proposed design was that it cannot be implemented in outdoor conditions.

2) Future work

In this paper, we presented the design and calculated results by employing different linear and angular speeds and rider weights. Implementation of this design using different materials available in the market with emphasis on local dialects would make it more customer friendly and easy to use.

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