Paper ID: AM-19

Design, Simulation and Construction of an Automatic Wheelchair

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Abstract

Driving a manual wheelchair or crutches is a difficult task and past invented automatic wheelchair are not available in present market that can be bought and used for physically disable persons. The purpose of this research work is to propose of an automatic wheelchair system which facilitates the users. The proposed wheelchair has been implemented with design, simulation and construction of the whole body. Due to high sustainable stress, low cost and availability, Mild steel has been chosen over Aluminum, Cast iron, Stainless steel for frame material. The constructed wheelchair has a frame; four rear wheels with two shafts units; two front caster wheels for smooth turning and a chain driven gear train for power assist to rear wheel from motor shaft. The Sprocket gear is joined with chain which is connected with another smaller cassette that is mounted directly on motor shaft. In this wheelchair the chain is used to transmit power to drive wheel from the dc gear motor. Whenever the motor shaft rotates then the sprocket of rear spindle starts rotating and thus the wheel starts moving. Extensive testing was performed to ensure design integrity. This wheelchair has the potential to deliver increased freedom to a considerable consumer base.

Keywords: *Automatic Wheelchair, Sprocket Gear, Cost-Effective Electro-Mechanical.*

1. Introduction

An automatic wheelchair or electric-powered wheelchair is a wheelchair that is propelled by means of an electric motor rather than manual power. Automatic wheelchairs are useful for those who are not able to impel a manual wheelchair or who may need to employ a wheelchair for distances or over terrain which would be strenuous in a manual wheelchair. They may also be used not just by people with conventional mobility impairments, but also by people with cardiovascular and fatigue based conditions.

Today, worldwide there are around 600 million persons aged 60 and over; estimated one billion people live with disabilities. It is estimated that 16 million people in Bangladesh are living with disability (**Fig.1**) [1], whereas the actual scenario is much more acute. This is very frightening news, since aged people suffer from partial paralysis, trembling and usually unmovable problem.

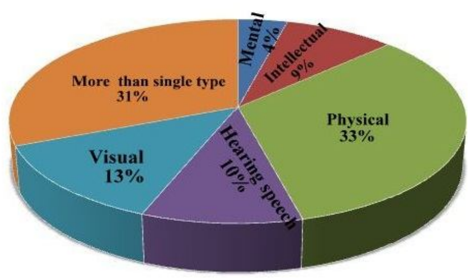

Fig. 1. Percentage of disable people in Bangladesh

Manual wheelchair and Automatic/Electric power wheelchair are available in current situation for assisting handicapped people. Manual wheelchairs can be operated by persons who have the use of their upper body or someone available to assist. But it only can move in limited surface only. In order to propel a manual wheelchair, a user not only has to move their weight, but they have to move the weight of the wheelchair as well. Some disabilities problems do not permit to move wheelchair manually. Most automatic wheelchairs are

implemented by modifying existing Powered Wheelchair systems. Examples include the Bremen Autonomous Wheelchair [2] and the Maid (Mobility Aid for Elderly and Disabled people) robotic vehicle [3]. These approaches arrange sensors and computing hardware around an existing infrastructure. They are able to take advantage of pre-built control and motor systems. One such project, the Tin Man wheelchair [4], uses servomotors to control the host chair through an unmodified joystick. Wheelchair equipment has also been designed from scratch. These devices enhance traditional designs in order to increase the possibilities of travel in challenging environments. They present complex control problems but can yield impressive results. One such project [5] proposes four hydraulic, wheeled, robotic legs. It aims to produce a device capable of ascending multiple stairs and lifting itself into vehicles. Another model [6], being developed by a commercial concern, can reputedly raise and balance itself on its rear wheels alone through the use of sophisticated gyroscopes and multiple Pentium processors.
Automatic wheelchairs, by their nature, demand specialized user interfaces. Whilst many projects do not address this issue directly, invariably using joysticks [2, 3, 5, 6], others do. One wheelchair [7] uses a visual display that shows a sequential scanning of commands (left, right, increase speed, stop, and etcetera). A highlighted command can be selected by pushing a button. Another design [9] uses natural language commands, such as "move forward" or "move left", though a headset microphone. More ambitious groups [4] have proposed commands such as "go to the kitchen" or "stop at the next door on the left". Other groups [10] have opted for voice recognition based on a user defined vocabulary and voice print techniques.
User uses the traditional wheelchairs need help from others or their own body power. Moreover physically weak users also face problems to grip joystick for moving the automated wheelchairs. In this circumstance, this project aims to design an automatic prototype wheelchair with button control which is fabricated from locally available resources and cheaper technologies that would be viable for disable person in the developing country like Bangladesh.
This project's wheelchair is distinguished from most other similar projects in its attempts to produce practical results using a minimum of equipment and computing power. These aims can be further defined through several distinct criteria;

a) Cost Effectiveness: This wheelchair will benefit the most individuals if the cost is not prohibitive. This factor is currently controlled by using locally available material and technology.
b) It must use practical components: Components should consider total system weight and dimensions. They should seek to maximize on-board battery life through power efficiency and minimize maintenance concerns through simplicity and durability.
c) It guarantees easy and comfortable driving.
d) It facilitates learning to handle the chair and obtaining maximum efficiency.
e) It should make the electronic system open to future additions.
f) It provides the ultimate easy movement & effortless independent operation without assistance by handicapped.

2. Material

Initially four materials were selected for frame. It was Aluminium 1060 alloy, Gray Cast Iron, Stainless Steel, Mild Steel and numerical analysis was done on it by Solidworks 2015. This simulation was done with 980N (User's Weight). Stress analysis on Alluminium, Cast Iron, Stainless, Mild steel is showed in **Fig. 2, Fig. 3, Fig. 4**, **Fig. 5** respectively. Stress, Strain, Displacement Result is showed in **Table.1**.

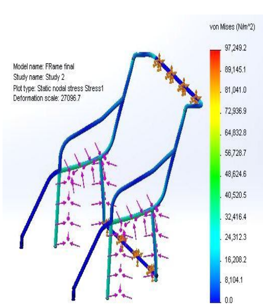
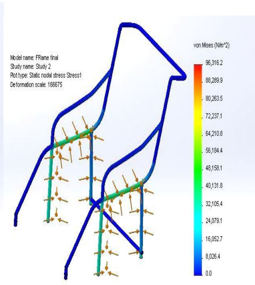
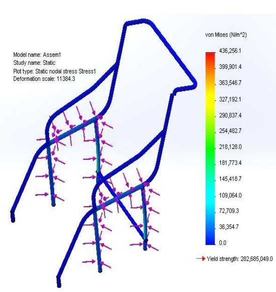
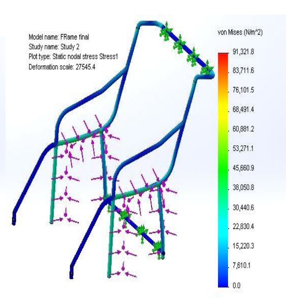

Fig. 2. Alluminum **Fig. 3.** Cast iron **Fig. 4.** Stainless steel **Fig. 5.** Mild steel

From Simulation result it is showed that Mild steel can sustain higher stress and it's Strain & displacement is very low than other material. Due to good simulation result, low market cost and availability Mild steel has been selected for frame material. The property of this material is given in **Table. 2.**

Table. 1. Stress, strain, displacement result by simulation

Material	Max. Stress (N/m^2)	Max. Strain	Max. Displacement (mm)
Alluminium	91321.8	1.136×10^{-6}	5.033×10^{-3}
Cast Iron	97249.2	1.167×10^{-6}	5.09×10^{-3}
Stainless Steel	96316.2	3.874×10^{-7}	6.987×10^{-4}
Mild Steel	436256.1	9.403×10^{-7}	1.101×10^{-2}

Table. 2. Property of mild steel

Property	Value	Unit
Elastic modulus	2.0499×10^{11}	N/m^2
Poisson's ratio	0.29	N/A
Shear modulus	7.9987×10^{10}	N/m^2
Mass density	7858	kg/m^3
Tensile strength	425000003.2	N/m^2
Yield strength	282685049	N/m^2
Thermal expansion Coefficient	1.2×10^{-5}	/K
Thermal conductivity	52	W/(m.k)
Specific heat	486	J/(kg.K)

3. Mechanical Design

The design of the wheelchair and stress & displacement analysis is done by using Solidworks 2015 software and the outlook view is generated with Keyshot4 software. Mild steel is used as material for simulation purposes. The design of the wheelchair is done by considering the maximum weight of the person is 100kg. So, the structure of the wheelchair has to be capable of carrying 980N load. Von Mises stress analysis and URES displacements indicate the validation of structure strength, using Mild steel under 980N load. Designed structure of the wheelchair is given in **Fig. 6**.

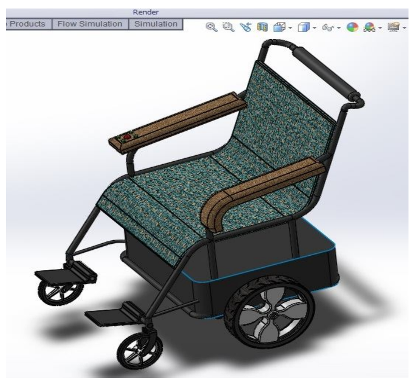

Fig. 6. Complete view of designed wheelchair

3.1 Von Mises stress analysis

Von Mises stress analysis is used to find the yielding criteria of isotropic or ductile materials under complex load. According to Von Mises yield criterion, it is independent of first stress invariant. But the ductile materials will exceed yield point when the second deviatory stress invariant will reach a critical value. The stress analysis of wheelchair frame, seat and rear shaft are given in the **Fig.7**, **Fig.8** and **Fig.9** respectively.

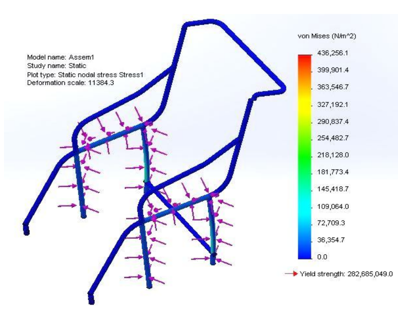

Fig. 7. Stress analysis on frame

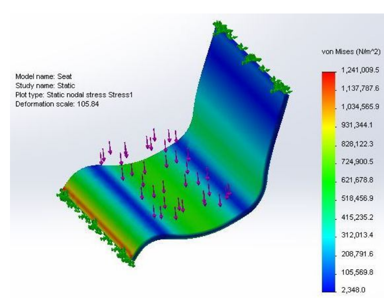

Fig. 8. Stress analysis on seat

From the stress analysis of the wheelchair frame, seat and shaft, it is found that the structures will sustain under the applied load.

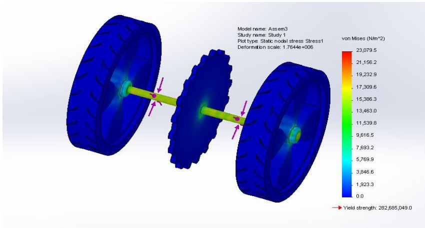

Fig. 9. Von Mises stress analysis on shaft

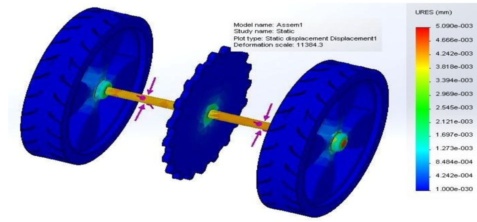

Fig. 10. URES displacement on shaft

3.2 Resultant displacement

The resultant URES displacement of Solidwork shows the average displacement of the wheelchair structure. It is found from the analysis that the highest deformation of the wheelchair frame is 0.001101mm under the applied load. The URES displacement of the wheel shaft, frame and seat are shown in **Fig.10**, **Fig.11**, and **Fig.12** respectively.

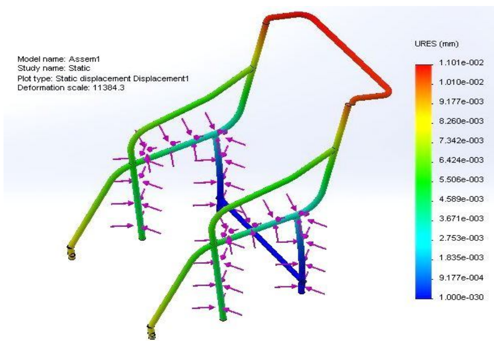

Fig. 11. URES displacement on wheelchair frame

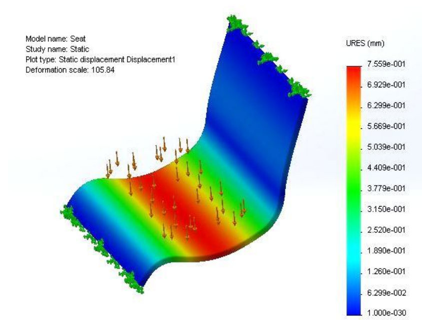

Fig. 12. URES displacement on wheelchair seat

4. Construction

The prototype wheelchair has been made with locally available material, such as; wood for seat, back rest and wheel, mild steel for frame, commercially available shaft & sprocket gear was used.

4.1 Rear shaft

Basically shaft carries the total load of a vehicle body. Major change is done in this structural construction. Instead of using common shaft, two modified axle usually called shaft is used in the automatic wheelchair's wheels which are not connected. Available wheel chair in present market has got 15.25 cm long and 12 mm diameter's axle in each rear wheel. But this construction has got 30 cm long and 2.5 cm diameter's axle. For easy unique controlling mechanism, two separate shaft has used. This shaft contains two wheels, bearing, bush, sprocket gear. The shaft with its component is showed in **Fig. 13**.

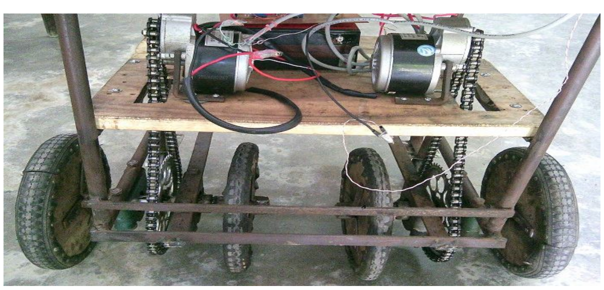

Fig. 13. Rear shaft mechanism

Fig. 14. Gear and chain drive mechanism

4.2 Gear and chain drive

Based on a top speed of five kilometer per hour and wheelchair wheels with a 25 cm radius, the output speed of the drive system had to at least equal 105 rpm. Chain drive has one main advantage over a traditional gear train.

Only two gear wheels and a chain are needed to transmit rotary motion over a distance. With a traditional gear train, many gears must be arranged meshing with each other in order to transmit motion. The Gear and chain drive mechanism is showed in **Fig. 14**.

4.3 Mechanism of automatic wheelchair

Major change is done in the structure and mechanism for this project. Two modified Shaft is used with sprocket. This Sprocket is joined with chain which is connected with another smaller cassette that is mounted directly on motor shaft. Whenever the motor shaft rotates then the sprocket of rear spindle starts rotating and thus the wheel starts moving. In this wheelchair the chain is used to transmit power to drive wheel from the dc gear motor. A wooden tray is attached underneath the seat to mount the dc gear motor and battery. Two dry cell batteries are used for power. The control circuitry is placed underneath the seat which is covered in a box. After completing the connection of the electro-mechanical equipment, the structure of wheel chair which is implemented is given in **Fig. 15**.

Fig. 15. Constructed automatic wheelchair

5. Result and Discussion

The expectation of this project was that a prototype would be produced that would conceptually prove that an effective automatic wheelchair could be designed that exceeded the performance of wheelchairs. These expectations were far exceeded as the finalized prototype performed exceedingly well in all aspects of the design specifications. Careful design and selection of mechanism and mechanical components combined to create a prototype that could meet the majority of wheelchair testing. Testing was conducted on the finalized prototype to ensure the design integrity. Integrity was determined by how well the wheelchair met the design specifications. Testing was performed with 100 kg a human occupant. Weights were added to the occupant to reach the required 980N weight to simulate a worst-case test scenario in all test scenarios. Stability testing was performed to ensure that the wheelchair could be proficiently operated in approved environments.

Dynamic stability testing was performed to ensure that the wheelchair could travel safely on flat ground. Wheelchair users could effectively move the wheelchair when required power applied to the motor.

The distance between the rear wheels was increased since the both motor-side wheel is located 15 cm further away from the wheelchair frame. The overall width of the wheelchair is 91 cm. This modification is slightly wide than existing wheelchair but it didn't so problem.

The automatic wheelchair prototype successfully allows a user to move without propelling the wheel by their arm. The power-assist motor completely replaces the function of the affected arm. In comparison with the existing dual-rim and lever-arm wheelchairs, the prototype clearly excels in maneuverability and no more arm strength required and the cost analysis also represents that it is going to be the cheapest wheelchair model (showed in **Table. 3**).

Table. 3 Cost analysis

Parts name	Quantity	Price in	Price	Parts name	Quantity	Price in	Price

		BDT	in $			BDT	in $
Steel pipe	10	1500	19	Bearing	2	300	3.8
Plain rod	5	250	3.17	Caster wheel	2	300	3.8
Wood	2	400	5.08	Screw and pin	-	200	2.53
Wooden wheel	4	350	4.43	Sprocket gear	2	300	3.8
Tire	2	200	2.53	Chain drive	2	200	2.53
Shaft	2	400	5.08	Mechanic's fee	-	1500	19
					Grand total	5900	74.75

6. Conclusion

A power-assist automatic wheelchair prototype that effectively meets the various transportation needs of individuals with hemiplegia or physical disabilities has been designed, manufactured, and tested. Intricate design detail and execution resulted in a visually simplistic design that promotes low cost and low maintenance. The modular aspect of the components allows the system to be retrofit to most manual wheelchairs with only minimal modifications. The main goal of replacing power lost by a user affected arm while maintaining maneuverability and transportability was successfully achieved. The overall dimensions of the constructed wheelchair and therefore maintains its ability to be transported in the trunk or backseat of a full sized car. The minimization of expense is pretty affordable for most of the people of Bangladesh and it can be even cheaper when taken for mass production.
This project can also be counted as a brilliant initiative for the betterment of physically handicapped and disabled people's lifestyle.

7. Acknowledgement

The authors are grateful to the Department of Mechanical Engineering, KUET, and the Khulna University of Engineering & Technology for providing the fund for the research work.

References

[1] P. Norek, M. Ahmed, et al, "Livelihood Challenges for Extremely Poor Disabled People in the Southwest Costal Region of Bangladesh", *Shiree working paper* 12, January 2013.
[2]T. Röfer, & A. Lankenau, "Ensuring Safe Obstacle Avoidance in a Shared-Control System'', *Proceedings of the IEEE/RSJ/GI International Conference on Emerging Technologies and Factory Automation 1999*, Vol. 2, 1405-1414, October 1999
[3]E. Prassler, J. Scholz, M. Strobel, & P. Fiorini, "An Intelligent (Semi-) Autonomous Passenger Transportation System'', *Proceedings of the IEEE/IEEJ/JSAI International Conference on Intelligent Transportation Systems Proceedings 1999*, 374-379, October 1999.
[4]D. Miller, & M. Slack, "Increasing Access with a low-cost Robotic Wheelchair'', *Proceedings of the IEEE/RSJ/GI International Conference on Intelligent Robots and Systems '94*, Vol. 3, 1663-1667, September 1994.
[5]M. Lawn, & T. Takeda, "Design of a robotic-hybrid wheelchair for operation in barrier present environments'', *Proceedings of the 20th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, Vol. 20, No 5,
[6]J. Hockenberry, (cited 20-May-2001) "A revolutionary new wheelchair'', NBC http://www.msnbc.com/news/285231.asp, June 2000.
[7]S. Fioretti, T. Leo, & S. Longhi, "A Navigation System for Increasing the Autonomy and the Security of Powered Wheelchairs'', *IEEE Transactions on Rehabilitation Engineering*, Vol. 8, No. 4, 490-498, Dec 2000.
[8]P. Trahanias, M. Lourakis, S. Argyros, & S. Orphanoudakis, "Navigational support for robotic wheelchair platforms: an approach that combines vision and range sensors", *International Conference on Robotics and Automation 1997*, Vol. 2, 1265-1270, April 1997.
[9]G. Pires, R. Araujo, U. Nunes, & A. Almeida, "RobChair-a powered wheelchair using a behaviour-based navigation", *International Workshop on Advanced Motion Control 1998*, 536-541, June 1998.
[10]N. Katevas, N. Sgouros, S. Tzafestas, G. Papakonstantinou, P. Beattie, J. Bishop, P. Tsanakas, & D.Koutsouris, "The Autonomous Mobile Robot SENARIO: A Sensor-Aided Intelligent Navigation System for Powered Wheelchairs'', *IEEE Robotics & Automation Magazine*, Vol. 4, Issue 4, 60-70, December-1997.