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Design and fabrication of convertible wheelchair

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ABSTRACT

It is inevitable for any country to have people with disabilities or have trouble with standing up, especially arthritis patients. The most commonly used devices for disabled people are wheelchairs. What's more, the life quality of disabled people and patients has caught attention by society. A modernized convertible wheelchair has become a popular engineering challenge for decades.

We aimed to design a new mechanical system in the wheelchair to help people stand up as well as they can rest and sleep, this mechanism should be safer, simpler in structure, less power consuming and more economic. The structure is designed for the wheelchair to fit the natural human standing, sitting and sleeping posture.

The standing and sleeping convertible wheelchair we will design may help people with disability to surge self-esteem; reach objects placed high, deliver a speech on the podium. By the way, it's boring for a person to sit for a long time.

Keywords:

1. INTRODUCTION

With the development of Indian society, many people and organizations pay more attention to life quality of people with disabilities. Wheelchairs play an irreplaceable role in aiding people for few decades. Therefore, the upgrade and refreshment of wheelchair function and mechanical structure will be a priority for community and welfare institution. If the patient wants to reach a higher position or move from chair to bed, even deliver a speech at a podium, he or she will be willing to form a standing up the process. At this time, standing wheelchair will help him or her to accomplish this goal. We searched for most common types of standing and sleeping convertible wheelchair on the Internet. We found all wheelchair is either operated with costly electric component or there is no combine mechanism of standing as well as sleeping. The wheelchair, which we designed that use less electrical energy to help people standing and sleeping, nevertheless it is convenient as an electric wheelchair.

2. MAIN DESIGN

As shown in figure-1 main design consist of structure and mechanism, body structure consists base frame and chair part where the human body can sit.

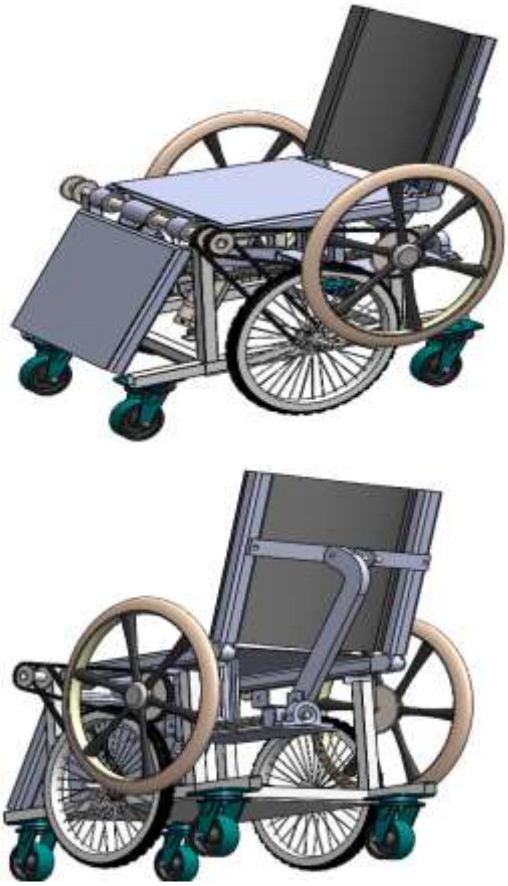

Figure 1 Main Design

2.1 Base Frame/Structure

This frame is the main frame which is hold all other parts together like a chair, all mechanisms, wheels. We use square section for the base frame and hold all section by TIG welding. However, also there is pipe section which is used to hold the chair. Dimension we used is similar to a standard wheelchair.

Table 2 Specification Base frame

1	Square section dimensions	30×30×1.02 mm
2	Material	Stainless steel 202
3	Length	476.42mm
4	Width	460mm
5	Maximum Height (at the front)	376.27mm
6	Minimum Height (at back)	322.65mm

2.2 Chair parts

The chair is a comfort for the patient, so it should be in optimum dimensions where patient feel relax when he/she sit on it. As shown in figure 1, the chair is supported by mechanisms and base frame, we use standard wheelchair dimensions to make this chair. For the material of chair, we take an aluminum square section to lighter the wait of the wheelchair. Aluminum section welded by argon welding.

Table 3 Specification of Chair parts

1	Aluminum square section dimensions	40×40×1 mm
2	Material	aluminum 7604
3	Width of Chair	460mm
4	Length of sit rest	460mm
5	Length of back rest	480mm
6	Length of foot rest	340mm

2.3 Leadscrew Mechanism for sleeping position

This mechanism is used convert the chair from sitting to sleeping posture and vice versa. Also, this will help to get standing posture. So, we can say this mechanism use in for the position. Leadscrew is attached under rest seat with help of a frame. To support the leadscrew two pedestal is used. At the one end of leadscrew belt and pulleys are provided to rotate the leadscrew by electric DC motor. Links are a connection between foot rest, back seat and leadscrew mechanism. Links are attached to the two nuts of leadscrew mechanism by pin joints.

Figure 2 Sitting posture

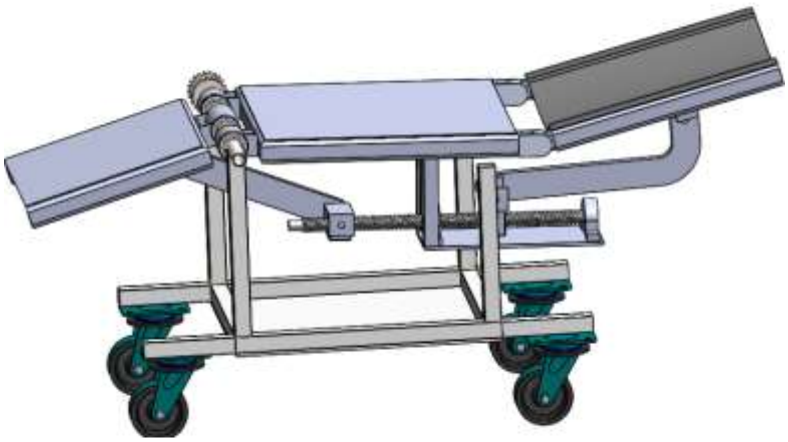

Figure 3 Sleeping posture

Here leadscrew act as a column as it is supported by bearing at two ends. Hence it acts under compressive load as well, so we calculate buckling load for finding the diameter of the shaft.

Table 4 Specification of Leadscrew

No.		**Value**
1	thread length	500mm
2	working load	70kg
3	yield stress	21.24 kg/mm^2
4	lift rate	635mm/min
5	screw angular speed	100 rpm
6	Screw core diameter	19mm

Calculation

Buckling load,

$$= \frac{Working\ stress\ (Ws) \times Srew\ cross\ section\ area}{1 + a\left(\frac{L}{k}\right)^2}$$

$$= \frac{21.41 \times 176.625}{1 + 0.000133\left(\frac{1000}{7.5}\right)^2}$$

= 358.099 kg

So, by the human body, the normal load acting on lead screw while coming into sitting to the sleeping position is about 100kg and as we calculate from buckling load equation the critical load of leadscrew is 358.099kg, which is under safe condition.

a = 1/7500 for mild steel
L = 2*thread length of screw for one end fix other end free
k = radius of gyration = d/4
d = core diameter of shaft
A = cross section area = $\frac{\pi}{4}d^2$

Working stress of mild steel = 214 MPa
= 21.41 kg/mm^2

Pitch = $\frac{lift\ rate}{screw\ angular\ speed}$
= 635/100
= 6.35 mm

Height of teeth (h1) = 0.5×Pitch

Outer diameter = (2×h1) + core diameter
= 21.35mm

Safe working load = 1.5×working load
= 105 kg

As per lift rate and angular speed we get 20 seconds of time to lift up or down the patient which is optimum time. No jerk will feel by the patient due to smooth operation. And 20 seconds time is good enough that patient does not feel the irritation of taking a long time.

DC Motor calculations

The load acting on timing pulley which is connected to the motor is about 70kg and Diameter of timing pulley is 2.5cm.

Torque required to drive the timing pulley under loaded condition will be,

Torque = load x radius of pulley

= 70 kg x 1.25cm

= 87.5 kg cm

= 8.75 NM (1NM = 10 kg cm)

From above calculation we required 87.5kg cm of torque to drive the timing pulley.

So, we select standard motor of having 100 kg cm (10NM) of torque which is satisfying our requirement.

POWER Requirement for 100 kg cm (10 NM) of torque will be,

$$P = \frac{2 \times \pi \times N \times T}{60}$$

$$= \frac{2 \times 3.14 \times 100 \times 10}{60}$$

$$= 104.66 \text{ WATT}$$

So, for 10 NM of torque, we required about 104 watts of power.

Current(I) required =4 amp

Input voltage =24-volt DC.

2.4 Linear Actuator for standing position

The linear actuator is the major component for stand up the patient. In standing up the patient requires more power than any other operation, this will lift the patient, as well as all other part, attach with chair-like wheel rim, leadscrew, motor. as per dimension of the body, we need linear actuator of 350mm stoke length. Actuator attaches with the base frame and sitting area at around 45^0 in a retarded position. When actuator extended its full stroke, sitting will incline at 66.3^0 and actuator is at 72.2^0.

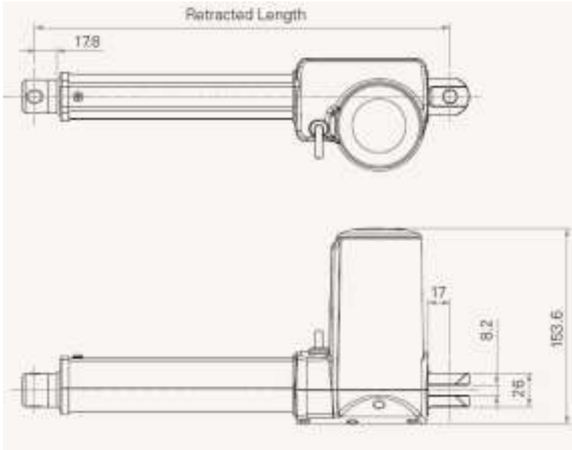

Figure 4 Dimensions of the linear actuator

Table 5 Specification of the Linear actuator

1	Stroke length	13.78 inch (350mm)
2	Weight lifting capacity	4000-6000 N (including FOS=4)
3	Power supply	24 V DC
4	Speed	5.5 mm/sec
5	Diameter of rod	26 mm

Figure 5 Standing position

Exerting Speed of the stroke is 5.5 mm/sec that means to stand up the chair with patient needs around 60seconds. As illustrated in figure 5, we can say that it perfectly fits in that wheelchair and also load carry capacity fulfill the requirement that we need to lift the weight of more than 80kg and additional weight of wheelchair component and mechanism.

2.5 Driving mechanism by a chain sprocket

In the driving mechanism, we use chain sprocket to drive the wheelchair manually that helps to reduce power consumption in DC battery. But the major challenge is to make a mechanism that can manually drive the wheelchair in all three position. So as we design, there are two wheels on one side shown in figure 6. Upper wheel is driving wheel (also called as wheel rim) and smaller or lower wheel is driven wheel. To drive the wheelchair in all position, driving wheel attaches to the chair, and driven wheel attaches to the base frame where the whole wheelchair supported on. Now there is one point where driving and driven wheel connected with chain and sprocket as shown in figure 6. The connection point is the pipe section welded on the base frame. On that pipe, there is sprocket connected rigidly with each other, and both are connected by both wheel's sprockets chain. The sprocket of driving wheel has higher teeth than another sprocket for the higher torque. There is the same mechanism will attach to another side of the wheelchair.

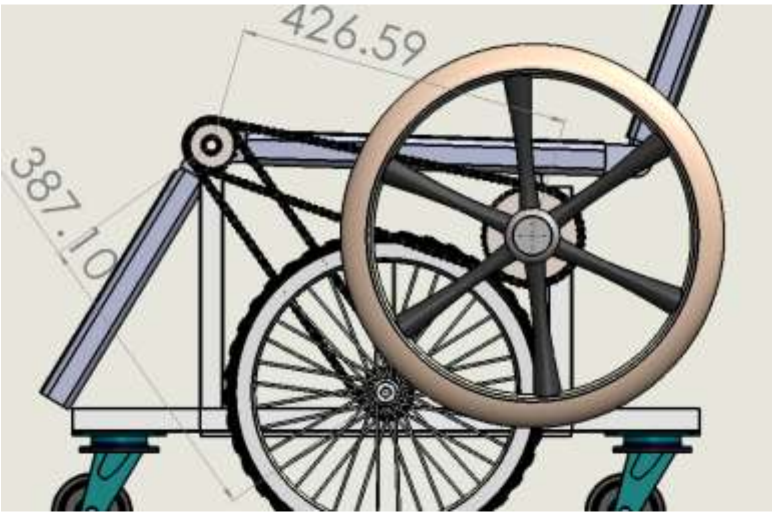

Figure 6 Driving mechanism by a chain sprocket

Calculation of Chain links requires

Let $T1$ = Number of teeth on the smaller sprocket,
$T2$ = Number of teeth on the larger sprocket,
p = Pitch of the chain, and
x = Centre distance.

The length of the chain (L) must be equal to the product of the number of chain links (K) and the pitch of the chain (p). Mathematically,

$$L = K \times p$$

The number of chain links obtained from the following expression, *i.e.*

$$K = \frac{T_1 + T_2}{2} + \frac{2x}{p} + \left[\frac{T_2 - T_1}{2\pi}\right]^2 \frac{p}{x}$$

No. of links of upper chain find by,

Let, $T1 = 21$
$T2 = 42$
$p = 12.7$
$x = 426.59$

$$K = \frac{21 + 42}{2} + \frac{2 \times 426.59}{12.7} + \left[\frac{42 - 21}{2\pi}\right]^2 \frac{12.7}{426.59}$$

$$K = 82$$

So, 82 Number of links of upper chain required.

No. of links of lower chain find by,

Let, $T1 = 21$
$T2 = 22$
$p = 12.7$mm
$x = 387.10$mm

$$K = \frac{21 + 22}{2} + \frac{2 \times 387.10}{12.7} + \left[\frac{22 - 21}{2\pi}\right]^2 \frac{12.7}{426.59}$$

$$K = 100$$

So, 100 Number of links of upper chain required.

Table 6 specification of chain and sprocket mechanism (driving mechanism)

1	Driving wheel Diameter(wheel rim)	20 Inch
2	Driven wheel Diameter	16 Inch
3	Teeth of driving wheel Sprocket	41
4	Teeth of driven wheel Sprocket	22
5	Teeth of center Sprockets	21
6	Center distance of upper to middle sprockets	426.59mm
7	Center distance of lower to middle sprockets	387.10mm
8	Pitch of link	12.7mm(0.5Inch)
9	No. of upper chain links (driving wheel to center sprocket)	100
10	No. of lower chain links (driven wheel to center sprocket)	82

3. CONCLUSION

The project was aimed at designing and fabrication of convertible wheelchair that can overcome the shortcomings of a conventional wheelchair, with focus on cost-effectiveness and utility.

The existing system has the limitation of flexibility in positions, the patient cannot move in a conventional wheelchair. This product is help for spinal cord injury patient, paralyzed patient and handicap people to get in a different position other than sitting, standing position is very help full to do work which they can't do in sitting position and without any dependency to others, they can rest easily by just one press of a button. This is a combination of three positions. The idea of Combination of this three (standing, sleeping, and sitting) position doesn't exist in past apart from very costly and fully electronic wheelchair, the price of this types of the wheelchair is around 6000 to 7000 $. But this wheelchair is manufactured in low-cost, around 25000 to 30000 INR. Such equipment can induce self-reliability and satisfaction in the users.

We achieved our goals by the use of engineering tools such as CADD/Analysis softwares and knowledge of subjects such as Design of Machine Elements, Strength of Materials and Engineering Mechanics. We made the practical model as shown in figure 7 which consist all three position.

We gained a lot of practical knowledge regarding, planning, purchasing, assembling and machining while doing this project work. We feel that the project work is a good solution to bridge the gates between the institution and the industries. We are proud that we have completed the work with the limited time successfully.

Figure 7 Convertible wheelchair Working model

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