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Design and Fabrication of Efficient Wheelchair

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Abstract: This paper collects the information about efficient wheel chair which is operated by lever (A Rod). There are people in the world who anguished and have faced adversity that caused them physical disability. There are many conventional and non-conventional wheelchair are available right now though there are people who still require some cheaper and easier mode. So, our main objective is to make such easy driven, cheaper wheelchair which is cost effective and reliable. Through the introduction of lever we are capable of reducing the human effort with more torque and ultimately covers more distance for less effort as compared to conventional wheelchair. Through certain engineering techniques we did the whole work. This work is purely mechanical and in consideration to minimize the cost and human power.
Keywords: Efficient wheel chair, Wheelchair Design, Fabrication of Efficient Wheelchair, Mechanism of Lever, Mechanism of Chain and Sprocket.

I. INTRODUCTION

This work involves the design of Efficient wheelchair which is propelled by lever. In the design of Efficient wheelchair which used the conventional bicycle wheels to move it forth. The lever movement by rider is responsible for the movement of wheels which is connected via chain and sprocket mechanism. The centre objective of this work is that it include as possible less effort and provide high torque which cover longer distance so that it feels easier to people to run the wheelchair. So, the project work includes the working of wheelchair which is used for both inside and outside and easily driven.

People with spinal cord injury, multiple sclerosis, cerebral palsy, spina bifida, leg amputation, traumatic brain injury, and other disabilities can use efficient wheelchair. This wheelchair is capable of meeting the needs of people who gone through above mentioned injuries and certain types of others. Apparently, this wheelchair does not include push rim to move as we have provided lever as replacement to propel the chair so, it is much easier to operate avoiding the push rim moving requirement.

The people who are enthusiastic for outdoor activity can use the efficient wheelchair. This could also be choice for longer run of wheelchair as require less effort. The people feel much comfortable while running the wheelchair. People can use this for rough terrain and also for recreational activity consist of wheelchair. So, with this they really enjoy and feel happy. It is just a work to bring back the happiness to people.

II. METHEDOLOGY

The main function of the lever mechanism is to withstand maximum load with minimum load applied. This law infect gives the people a path to propel the wheelchair with less effort.

As we all know, the injured people require less effort to move the chair. So, this design provides them the facility to self-propel the wheelchair. All the power transferred by lever is transferred to sprocket and via chain to wheel which ultimately move the wheelchair. The chain sprocket mechanism involves one long chain and two sprockets. The maximum tension is on the chain. This mechanism provides more torque. As the chain, sprockets are part of conventional bicycle. So, people can manage to find it anywhere. These parts are easily replaceable and cost very less.

The efficient wheelchair is quite compatible with in terms of use, parts replacement, etc.

III. STAGES OF DESIGN

According to the above mentioned methodology, the design started on the solidworks Software. The design involves the wheelchair frame, mechanism of chain and sprocket and mechanism of lever. We walk behind the design of tricycle.

A. Main Frame

In the main frame the parts for support, lever mechanism and seat of the wheelchair. These should be designed so well to withstand the load of the rider.

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B. Mechanism of Chain and Sprocket

For chain sprocket mechanism we walk behind the design of normal bicycle. Here we used two sprocket connected by chain. The larger sprocket is of 44 teeth and the smaller sprocket is of 18 teeth. The larger sprocket is installed with lever and the smaller sprocket installed with the wheels. The total force by rider through lever to these sprockets is transferred to wheels to move it forward.

C. Mechanism of Lever

The lever is the part by pushing which we get the motion. This lever is composed of MS material and installed with lager sprockets on both the side of wheelchair. The lever makes the work easier to transfer the power to the wheels. The brakes are attached with the lever on the top side to control the motion of the wheelchair. The lever is of length 58.7 cm and so attached so that the rider feel comfortable while pushing it and in steady state.

IV. STAGES OF FABRICATION

A. Initial Stage

We fabricated the main part in primary stage which has to be made. The primary stage includes the working of cutting and welding process with tools takes place. The frame is the base and made of mild steel. We made frame with the consideration of its strength.

Fig. 4.1 initial design

B. Peripheral Stage

After that, we attached the wheels to the frames. We did it so that the attachment we have done is perfectly balanced. We have taken care of the centre of gravity so that it coincide with the patient. The lever is attached and that chain and sprocket thing is attached,

Fig. 4.2 frame with wheels

C. Final Stage

This was the most difficult stage. We need to attach lever with larger sprocket so that the rider postion and hand are in comfortable position. At last, we assembled seat, backrest, armrest. The wheelchair is painted for good look of chair and to avoid corrosion.

Fig. 4.3 final stage

V. CALCULATION

A. Assumptions Taken While Calculation

1) Wheelchair velocity = 1.0 m/sec (we assume velocity for comparison between two for Force applied)
2) Diameter of wheel = (200 * 2) mm
   = 400 mm
3) Velocity ratio of driving & driven chain is 2,i.e; V.R =2
4) Max weight of human = (80 kg * 10 m^2 / sec)
   = 800 N
   Weight of wheelchair = (20 kg * 10 m^2 / sec)
   So, total weight = 1000 N
5) Length of lever = 0.6 mm

B. Calculation

Total weight applied by wheelchair,

W = 1000 N

Reaction force applied by ground on wheelchair,

R = W = 1000 N

SO,

Frictional resistance = μ R

$F_R = \mu R$

For tyres and dry road surface, coefficient of friction is,

μ = 0.7

Therefore,

$F_R = 0.7 * 1000$

$= 700$ N

To overcome this friction resistance we applied equal and opposite force, so that it can dismiss the frictional resistance, i.e:

$F_A = F_R = 700$N ....(i)

1) Revolution per minute (RPM) of wheelchair (N) = V * D / π D
= 1 * 60 / π * 0.4
N = 47.746 RPM
2) Angular velocity of wheel (w) = 2 π N / 60
w = 2 π * 47.746 / 60
w = 5rad / sec
3) Power transmitted (P) = force * linear velocity
= f * V
= 700 * 1
P = 0.7 KW

Minimum number of teeth on smaller sprocket for velocity ratio, V.R = 2
T1 = 27 (From MDB Table No 21.3)
V.R = $w_1 / w_2 = T_2 / T_1$
2 = T_2 / 27
T_2 = 54
Where, T_1 & T_2 are min and max no of teeth of sprocket

4) Angular velocity for larger sprocket,
V.R = w_1 / w_2
2 = 5 / w_2
w_2 = 2.5rad / sec

C. Pitch

Empirical formula for pitch,

$$c_1 \sqrt[3]{\frac{p \times k}{T_1 \times w_2 \times p_b \times x}}$$

Here,
P = pitch
X = no of chain strands
P_b = allowable bearing pressure
K = load factor = k_1 * k_2
K_1 = takes into account the nature of load and service condition
K_2 = takes into account the method of lubrication
C_1 = value of coefficient = 28
Now, P = 0.7 kw
T_2 = 54
w_2 = 2.5 rad / sec
P_b = 35 N / mm^2 (from MDB Table No. 21.4)
X = 1
K_1 = k_2 = 1 (from MDB Table No. 21.5)
Put all values in above formula, we have
P = 0.014815 m
P = 14.8157 mm

D. Centre Distance

The best result is obtained with,
C = 30 p to 50 p, with normal value of 40 p (From MDB page no.709)
Therefore,
C = 40 p
C = 30 * 14.8157
C = 592.628 mm

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E. Length Of Chain

$L = m * p$

Where, m = no of chain links

$M = 2C/P + (Z2 + Z1) / 2 + \{P * (Z1 - Z2)^2\} / (4 * \pi^2 * C)$

Putting the values in above formula, we have

$M = 120.96164$

$L = m * p$

$= 120.96164 * 14.8157$

$= 17992.13$ mm

$L = 1.79213$ m

1) Pitch circle diameter of smaller sprocket,

$d_p = p / \sin(\pi/T_1)$

$= 14.8157 / \sin(\pi/27)$

$d_p = 127.6193$ mm

2) Pitch Circle Diameter of Larger Sprocket

$D_P = p / \sin(\pi/T_2)$

$D_P = 14.8157 / \sin(\pi/54)$

$D_P = 254.8068$ mm

3) Torque applied by human hand to overcome friction = torque applied by small sprocket and chain to overcome friction (force on circumference of wheel) * (radius of wheel) = (force in tight side of chain) * (pitch radius of smaller sprocket)

$F_A * R_w = f_c * R_{SS}$

$700 * 0.2 = fc * (127.6193/2)$

$F_c = 2194.024984$ N

Where,

F_c = tension on tight side chain

F_A = force applied by hand on wheel

R_{SS} = smaller sprocket radius

R_{BS} = biger sprocket radius

R_w = radius of wheel

L_L = length of lever

4) The same chain force transmitted from smaller tolarger sprocket through tight side chain

So, torque applied by larger sprocket through chain = Torque applied by lever

$F_C * R_{BS} = F_L * L_L$

$2194.024984 * (254.8068 / 2 * 10^3) = FL * 0.6$

$F_L = 465.877$ N ....(ii)

a) From equation (i) & (ii), we can see that for moving with same velocity (v = 1 m/sec) or overcoming the resistance (FR = 700 N), there is less force is required (FL = 465.877 N) in comparison to force applied on circumference of wheel (FA = 700 N)

b) V.R = 2, it means if wheel rotate with w1 = 5 rad/sec and we need to rotate our hand with w2 = 2.5 rad/sec. while if we take conventional wheelchair we need to rotate our hand at 5rad/sec with same speed of the wheel.

F. Design Of Roller Chain

1) Roller diameter, $d = 5/8 \times$ pitch

$d = 5/8 \times 14.8157$

$d = 9.2598$mm

2) Pin diameter, $d_p = 5/16 \times$ pitch

$d_p = 5/16 \times 14.8157$

$d_p = 4.629$mm

3) Chain width i.e; the distance between the roller link plates

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bi = 5/8 × pitch

b_i = 9.2598mm

4) Thickness of link plate

t_p = 1/8 × pitch

t_p = 1.85196mm

5) Width between outer plate

b_o = bi + 2tp

b_o = 9.2598 + (2×1.85196)

b_o = 12.9637mm

6) Maximum height ofpin link plates or coupling link plates, i.e; the the outer plate

h_o = 0.82 × pitch

h_o = 0.82 × 14.8157

h_o = 12.148mm

7) Maximum height of roller link plates ,i.e; the inner plates

h_i = 0.95 × 14.815

h_i = 14.0749mm

8) Length of roller

l = 0.90 × bi – 0.15

l = 0.90 × 9.2598 -0.15

l = 8.18382mm

Since lever length varies with diameter of the wheel. Therefore, we calculate lever length to match with the diameter of wheel.

Torque on wheel centre

$f_A \times R_w = f_c \times R_{ss}$ (f_A is fixed)

$$f_c \propto \frac{R_w}{R_{ss}}$$

Now see how smaller sprocket diameter depends upon wheel diameter

$(R_{SS})_p = (D_{SS}/2)_p$ ……………….(ii)

Where,

$(R_{SS})_p$ = smaller sprocket pitch radius

$(D_{SS})_p$ = smaller sprocket pitch diameter

Teeth (T) is already fixed

$$D_p \propto p \qquad \text{……………….(iii)}$$

We know,

$$c_1 \sqrt[3]{\frac{p \times k}{T_1 \times w_2 \times p_b \times x}}$$

Here,

$$p \propto \sqrt{\frac{1}{w_2}} \propto \sqrt{D_w} \qquad \text{…….(iv)}$$

From equation (iii) & (iv)

$$D_p \propto \sqrt{D_w} \qquad \text{……(v)}$$

From equation (i), (ii), (v)

$$f_c \propto \frac{R_w}{\sqrt{R_w}} \propto \sqrt{R_w}$$

Torque on larger sprocket centre

$f_C \times R_{BS} = F_L \times L_L$

we want to produce the same force as calculated in previous design of chain sprocket

so,

$$L_L \propto (f_C \times R_{BS}$$

$f_C \propto \sqrt{R_w}$

$and\ R_{BS} \propto \sqrt{R_w}$

Hence,

$L_L \propto \sqrt{R_w} \times \sqrt{R_w}$

$L_L = C \times R_w$

If we put $L_L = 0.6$m and R_w – 0.2 m

We get, c = 3

So,

$L_L = 3R_w$ (relation between lever length and wheel radius)

G. Calculation For Real Data

1) Diameter of wheel = (215 × 2)mm
2) (Pitch diameter)$_{\text{larger sprocket}}$ = 23.217cm
3) (Pitch diameter)$_{\text{smaller sprocket}}$ = 11.628cm
4) Lever length, L_L = 3Rw

$L_L = 3 \times 0.215$

$L_L = 0.645$m

Frictional resistance (fR) = 700N

Torque applied by human hand on circumference of wheel = Torque applied by smaller sprocket chain

Fa × Rw = fc × RSS

$700 \times 0.215 = f_C \times 0.05814$

$F_C = 2588.579$N

Now torque applied by larger chain sprocket = Torque applied by lever

$f_C \times R_{BS} = F_L \times 0.645$

$F_l = 465.54$N

From this calculation we came to know that by changing the diameter of wheel. There is no disturbance in force on lever. Same amount of force is reduced in fractional data value as in case of theoretical design.

H. Design Of Lever/Selection Of Material For Lever

Lever of chain sprocket is similar tofixed support cantilever type which has length equivalent to length of lever and equal amount of force is applied on the end of cantilever beam.

For safety consideration, FOS = 2

New applied force F’ = F × FOS

F’ = 465 × 2

F’ = 930N ≈ 1000N

Now, moment at point B,

MB = 1000 × 0.645 = 645N-m

Let us assume diameter of lever = 3.5cm

Stress induced at point B,

$$\sigma = \frac{M}{I} y$$

OR, $\sigma = \frac{M}{Z}$

Where,

$\sigma = bending\ stress$

M = bending moment

I = moment of inertia of cross section

Y = distance between natural and upper surface

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Z = section modulus
We know that,

$$Z = \frac{\pi d^3}{32}$$

$$Z = \frac{\pi \times 0.35^3}{32}$$

SO,

$$\sigma_B = \frac{645 \times 32}{\pi \times 0.35^3}$$

$$\sigma_B = 153.234 MPa$$

Now we calculate shear stress which is equal at every section
So,
Shear stress at point B

$$\tau_B = \frac{645}{\frac{\pi}{4} \times 0.035^2}$$

$\tau_B = 0.67039 MPa$

At the point B, there is bending tensile stress and shesr stress act simultaneously.
Magnitude od principal stress σ_1 *and* σ_2

$$\sigma_1 / \sigma_2 = \left(\frac{\sigma_x + \sigma_y}{2}\right) \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}{}^2}$$

Where,
σ_x = stress in direction of axis of beam
σ_y = stress perpendicular to axis of beam
τ_{xy} = shear stress

$$\sigma_{max} = \left(\frac{\sigma_x}{2}\right) \pm \sqrt{\left(\frac{\sigma_x}{2}\right)^2 + \tau_{xy}{}^2} \qquad (\sigma_x = \sigma_B)$$

$$\sigma_{max} = \left(\frac{153.234}{2}\right) \pm \sqrt{\left(\frac{153.234}{2}\right)^2 + 0.67039^2}$$

σ_{max} = 153.2369MPa ....(i)

I. Maximum Shear Stress

$$\tau_{max} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}{}^2}$$

$$\tau_{max} = \sqrt{\left(\frac{153.234}{2}\right)^2 + 0.67039^2}$$

τ_{max} = 76.619MPa ....(ii)

J. According To Theories Of Failure

1) Maximum principal stress theory (Rankine's)

$\sigma_{max} \leq \sigma_y$ σ_y = yield tensile strength

From equation (i)

σ_y = 153.23MPa ……………..(iii)

2) Maximum shear stress theory (guest &Tresca)

$$\tau_{max} = \frac{\sigma_y}{2}$$

$$\sigma_y = 2 \times \tau_{max}$$

$$\sigma_y = 153.23MPa$$

From equation (iii) & (iv) we found that material of lever has yield strength equal to 153.23 or greater than this value.

So, with suitable FOS we choose steel, structural ASTM A36 steel which has yield strength of 250MPa.

VI. FEATURES OF PROPOSED MODEL

A. To make the wheelchair cheaper, reliable, easy driven.

B. Its commercial use will give more comfort to the user of wheelchair.

C. To achieve high torque with less human effort to cover more distance.

D. It provides the literature review on efficient wheelchair.

E. Give shape to the idea by using engineering techniques.

VII. CONCLUSION

In conclusion we can say that our endeavour to design and fabricate Efficient wheelchair got success. We designed a cheaper, easy driven wheelchair. It is capable to run on normal as well as rough terrain. This wheelchair cover more distance in less effort. Our work results in increase of velocity as compared to conventional wheelchair.

This low cost efficient wheelchair is meant so that everyone can take benefit of it and we fulfilled our aim.

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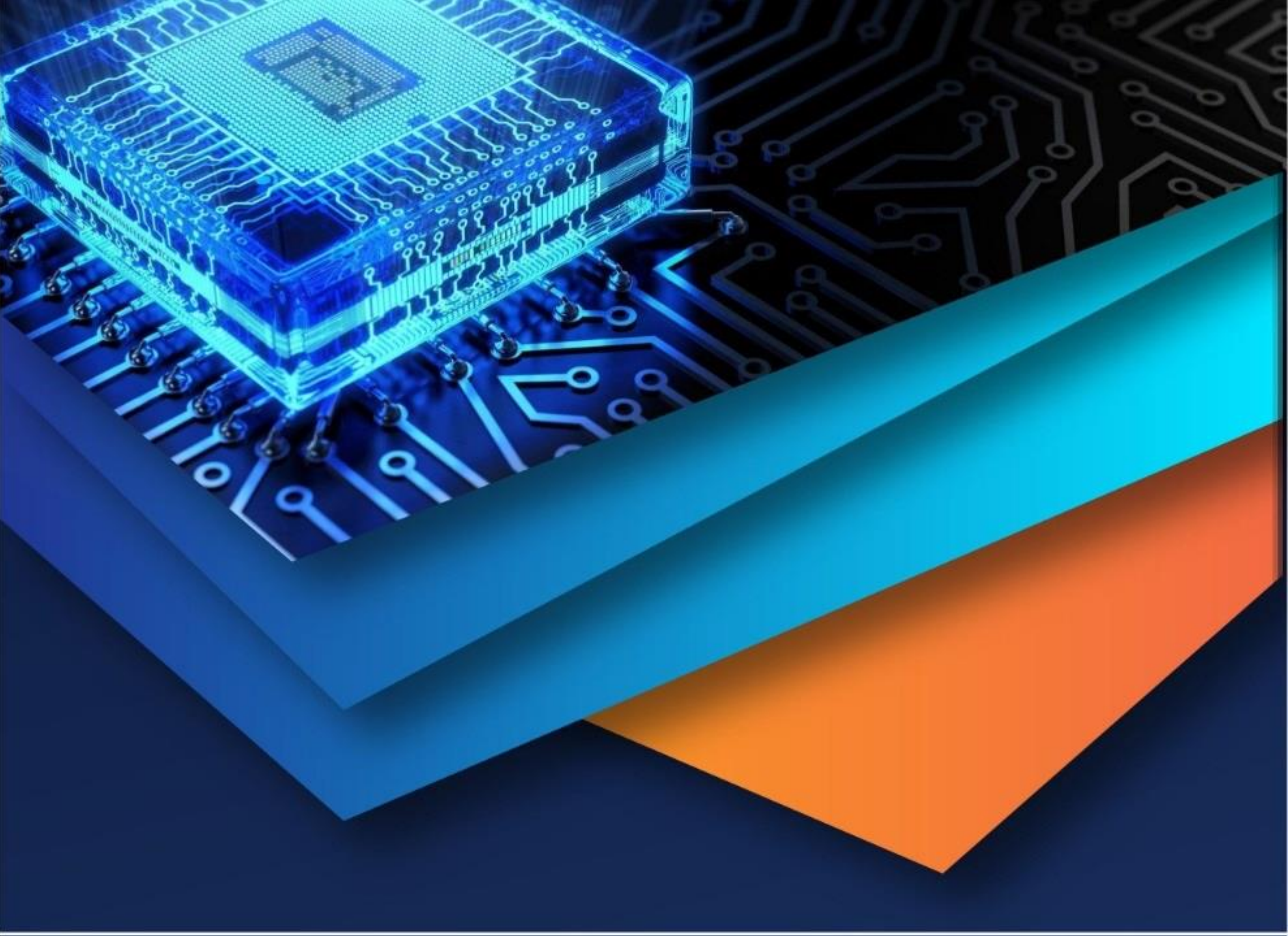

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