High Efficient Low Cost Propelling Tricycle using Steering Column

S A Goudadi[1] S R Kulkarni[2] S S Mahajan[3]
[1,2]Department of Mechanical Engineering
[1,2]Hirasugar Institute of Technology, Nidasoshi Belagavi-591236, Karnataka, India [3]B V V S Polytechnic, Bagalkot, Karnataka, India

Abstract— Now a day wheel chair propulsion is much preferred than manual wheel turning. A normal wheel chair used for physically challenged and the tricycle users for normal people use hand drive or propulsion or foot pedal propulsion. The manual propulsion is having much scope, because the wheelchairs using by individuals is growing and requires good mobility to maintain a quality of life. Design changes have been taking place in improving manual wheel chair propulsion, viz, changes in the wheels and tires, adding gears and designing alternative propulsion systems. Still, experts and consumers are not happy with the present design changes. Studies have been going upon how to achieve the breakthrough innovations. Much fatigue could be reduced by using improved propulsion technologies.

Key words: Tricycle, Lumbar pain, hand operated, Fulcrum, Physically challenge

I. INTRODUCTION

A three wheeler are with three wheels powered by human, viz, trikes, tricars and cycle cars. The term tricycle is used somewhat interchangeably, but more often the three wheeler word suits to motorized vehicles.

Basically There are two popular types of propulsions in present scenario. One is a manual assist that uses gear rations to reduce the effort required to propel the vehicle and the other is a power assist that uses a battery powered motor to reduce the effort.

Wheel chair users naturally suffer from Pain and upper extremity injury. Manual wheel chair users suffer much shoulder injuries which is up to 81%. In addition, the prevalence of elbow, wrist and hand pain has been reported to be 18%. More energy is required to propel the chair forward. In addition, the component of force provides friction between the hand and the push rim.

Force amplification could be achieved by using a tool, mechanical device or machine system. A desired amplification in the output force is obtained by preserved input power. An ideal mechanism transmits power without adding to or subtracting from it. Ideal mechanism is frictionless and constructed from rigid bodies that do not deflect or wear and no power source is included.

II. LITERATURE SURVEY

In the 6th century BCE inscription of wheeled furniture was found on a stone slate at China. The first records show that wheeled seats being used for transporting physically challenged people in china. The Chinese used wheel barrow to move people as well as heavy objects. The same wheel chairs are used for several hundred years with no changes.

Fig. 1: Wheel Chair

Auto Rickshaws are a common for public transportation. The rickshaws are an essential for urban transport system

Fig. 2: Trihawk, a Tadpole-type trike

A model of two wheels in the front and one wheel at the back presents two advantages. It has improved aerodynamic. A teardrop shape is desirable for lowest wind resistance. It's wide and round at the front, tapering at the back.

Fig. 3: Bond Bug at Silverstone

The above model shows one wheel in front and the two wheels at the back greatly decreases lateral stability while braking.

Fig. 4: Crashed Reliant Robin

Lateral instability is the main criterion as there is a high chance of tipping over while turning before it slides. To prevent it place the centre of masses much closer to the ground, place the center of the mass closer to place with the 2 wheels. Increase the track width.

Self-propelled wheelchair was developed late 19th century. The basic design was same but few changes were made with it's materials.

A. Different Types Of Wheel Chairs:

Manual operated wheel chairs contain a seat, foot rests, hand rims and four wheels (caster wheels and two large wheels). Highly customized wheel chairs are with seat dimensions, height, seat angle, footrests, leg rests etc.

Fig. 5: Wooden wheelchair

Folding chairs or rigid chairs are the two types of wheel chairs. The rigid chairs are with welded joints and fewer moving parts. There will be considerable reduction in the energy required to push the chair also reduces the overall weight of the chair. Modern wheel chairs consisting of ultra light weight material (aluminum, titatium, with polymer shock absorbers)

Fig. 6: Wheelchair with Mecanum wheels

A simple joystick operated electric wheelchair is fitted with Mecanum wheels, it can take forward, backward side, and diagonal movement, and also turned round on the spot or turned around while moving, all operated from.

Fig. 7: Antique wheelchair

In the year 2000 Rozendaal LA, Veeger DE evaluated the correlation between mechanical effect and musculoskeletal effort cost in wheelchair propulsion. They have evaluated For nine wheelchair users driving at 20 W, 1.39 m/s. [1]. J.C. Martin in 2001 investigated on effects of cycle crank length on maximum cycling power, minimal or maximal pedaling rate, and minimal or maximal pedal speed, and to know the required length of crank to length of leg ratio for maximal power production [2]. In the year 2002 Paola , Alberto E. Minetti, Pietro E. di Prampero focused upon the mechanical efficiency with his newly manufactured proto type of pedal. The experimental values are compared with standard pedal–crank system (SP) [3].

In the year 2005 a scheme called ADIP was developed as per government of India Ministry of Social Justice and Empowerment, the main aim of the Scheme ergonomically designed ISI equipments at an affordable cost [4].

Later in 2012 Abdulkadir Baba Hassan, designed the special wheelchair occupants of healthy Upper torso with lower lumbar to foot restraint. The main aim was to provide mobility and comfort they desire [5].

In the year 2014 Shuh Jing Ying modified old tricycle models with an electric motor and battery. The speed is controlled by attaching an additional sprocket which was also helpful during forward and backward movement [6].

III. CONSTRUCTION AND WORKING PRINCIPLE

This is a single seater three wheeled vehicle with front wheels being steered by the steering column. The steering column has the outer tube which is hinged at the base and the other side extension of the steering column is pulling and pushing the cranking mechanism of the rear wheel. The internal rod of the steering column is hinged to the link mechanism to the front wheel to steer the wheel as the steering handle is being rotated which is held at the top side of the steering column. The steering column is holding the steering rod within the bearings. The cranking mechanism is on one of the rear wheel axle. The rear wheels are held on two different axles. The bearing housing of the rear axles are welded to the frame. The entire frame is made of mild steel square tube of approximately 20mmx20mm.

The steering column when pulled or pushed, the steering column pivoted at the base from a distance. This is termed as a lever that pivots on a fulcrum attached to the fixed frame. The lever operates by applying force at the steering handle, at distance from the fulcrum or pivot.

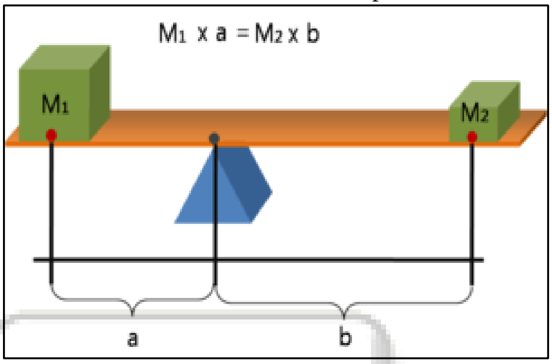

Fig. 8: Fulcrum

The mechanical advantage:

MA= Fb / Fa +a / b

This is the law of the lever which was proven by Archimedes using geometric reasoning. It shows that if the distance a from the fulcrum to where the input force is applied (point A) is greater than the distance b from fulcrum to where the output force is applied (point B), then the lever amplifies the input force.

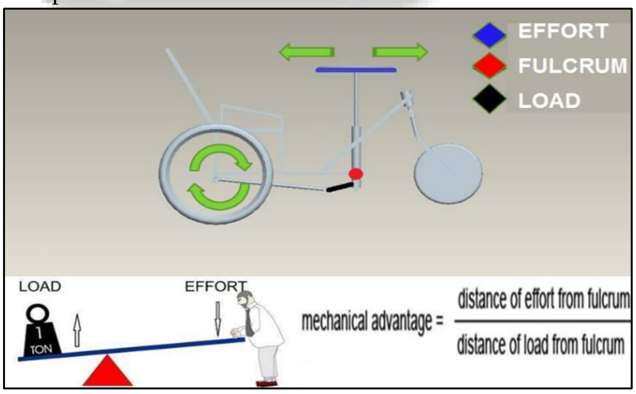

Fig. 9: Working mechanism with fulcrum example

Using the above principle, we are using the steering column as lever to get the mechanical advantage by using the pivot and use the smaller distance from the fulcrum to connect the crank link of the wheel to propel the wheel to effect the drive.

The seat is divided into three parts, the back rest being pivoted to the base and the foot support also one part being pivoted to the base. The back rest and foot supports both are joined by link mechanism and locked as per the posture required to create the resting support for the user. Again it can be retained as the seat when required.

IV. MANUFACTURING OF PARTS INVOLVED

A. Seat:

This is made out of mild steel cold rolled closed annealed square tube of size 20mm x 20mm cut for the lengths of 520mm---2nos, 460mm—4nos410mm---2nos, all are cut and straightened by hammering and then corner ground for removing sharp corners and right angle is made and then welded to each other to make two number of rectangular frame of size 520mm x 460mm and another frame of size 410mm x 460mm. Both are then ground for the corners and edges for sharp corners and then hinge bushes are welded as hinges to make the seat rest and the back rest to support the tilting of the seat for adjustment for the back rest as required by the user.


Fig. 10: Seat

B. Rear Support:

This is made out of CRCA (cold rolled and closed annealed) steel square tube of size 20mm x 20mm cut for the length of 300mm---2nos, 150mm---1nos and then flattened by hammering and then corner grinding is done and then all three are joined, the base as 150mm and the vertical legs as 300mm at both the end of 150mm. This is then welded fo the front support to make the main frame of the vehicle.

C. Front Support:

This is made out of CRCA (cold rolled and closed annealed) steel square tube of size 20mm x 20mm cut for the length of 400mm---2nos, 120mm---2nos, 130mm---2nos, 210mm----1nos and then flattened by hammering and then corner grinding is done and then all are joined, the base as 210mm and the vertical legs as 130mm at both the end of 210mm, again 120mm lengths are joined at both the ends of 210mm and then vertical legs of 400mm are joined at both the ends as per the sketch. This is then welded to the rear support of the vehicle.


Fig. 11:

D. Rear Axle:

This is made out of C30 steel cut from the round material of 20mm for length 355mm---2nos and then turned on lathe machine to make the diameter as 15mm for the length of 320mm and step turned and threaded to suit the M10 standard nut. It is faced from the opposite side to make the entire length as 350mm. Such two number of axles are made for this project.

Fig. 12: Axle

E. Cranking Offset Flat:

This is made out of mild steel flat of size 25mm x 5mm thick being cut for the length of 70mm and flattened by hammering and then marked for the distance of 60mm from one end and then drilling for the hole diameter of 15mm is done and then welded to the one rear axle. On the hole made, a round pin of diameter 15mm of length 25mm is welded to create the offset cranking pin.

F. Steering Arm:

This is made out of mild steel flat of size 20mm x 4mm thick being cut for the length of 500mm---2nos and then flattened by hammering and then marked for the drill of hole size 8mm at both the ends and then marked for the bending at 40mm distance at both the ends as per the sketch. Such two number of arms are made for this project.

G. Steering Actuator:

This is made out of mild steel flat being cut from the material of 25mm x 5mm thick cut for the length of 150mm---2nos, 200mm---1nos, and then flatted by hammering and then joined together keeping 200mm as base and 150mm as verticals at both the ends. 15mm round bar of length 35mm are taken and welded at both the ends as per the sketch. This is welded to the steering rod at the base.

H. Steering Support:

This is made out of mild steel tube of size 40mm with inner diameter as 33mm cut for the length of 480mm and then faced at both the ends to make the parallelity and then this is welded to the bearing housings at both the ends to form the steering support.

I. Steering Column Rod:

This is made out of C30 steel round bar of diameter 25mm cut for the length of 875mm and then turned on lathe machine to make the diameter as 20mm for the entire length of 870mm to suit the ball bearings of inner diameter 20mm.

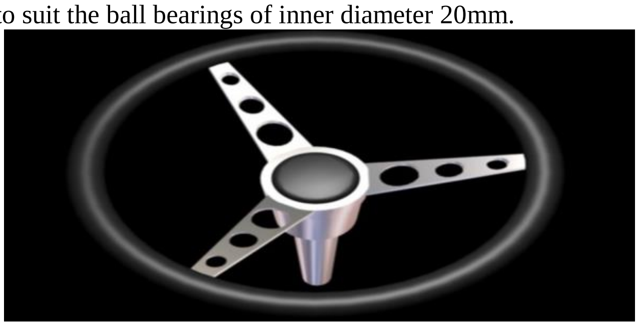

Fig. 13: Steering column

J. Guide Bush:

This is made out of mild steel round bar of diameter 25mm cut for the length of 15mm and then turned on lathe machine to make the diameter as 20mm and inner diameter drilled for the diameter of 10mm and faced from the other side to make the thickness as 10mm. Such two number of bushes are made for this project.

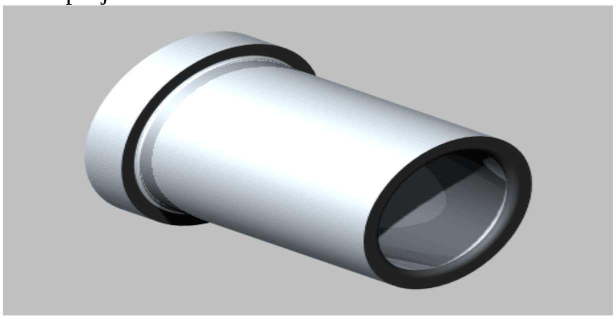

Fig. 14: Guide bush

K. Ball Bearing Housing for 15mm Inner Diameter Ball Bearing:

This is made out of mild steel round bar of diameter 50mm cut for the length 20mm------9nos and then turned on lathe machine to make the diameter as 45mm and then drilled for the diameter 18mm and counter bored for the diameter of 35mm for the depth of 10mm to suit the ball bearing outside diameter and then faced from the other side to make the total length as 15mm. Such nine ball bearing housings are made for this project.

L. Ball Bearing Housing for 20mm Inner Diameter Ball Bearing:

This is made out of mild steel round bar of diameter 55mm cut for the length of 20mm----4nos and then turned on lathe machine to make the diameter as 50mm and drilled for the size of 22mm and then counter bored for the diameter of 42mm for the depth of 10mm to suit the ball bearing outside diameter of 42mm. This is then faced from the opposite side to make the total length of 15mm. Such four number of ball bearing housings are made for this project.

M. Ball Bearing Housing for 10mm Inner Diameter Ball Bearing:

This is made out of mild steel round bar of diameter 40mm cut for the length of 20mm--2nos and then turned on lathe machine to make the diameter as 35mm and drilled for the size of 12mm and then counter bored for the diameter of 27mm for the depth of 8mm to suit the ball bearing outside diameter of 27mm. This is then faced from the opposite side to make the total length of 12mm. Such two number of ball bearing housings are made for this project.

Fig. 15: Radial ball bearing

N. *Caliper Mechanism Braking:*

This is a rim brake in which friction pads are compressed against the wheel rims, hand operated brake lever, force is applied to brake levers mounted on the steering wheel, and transmitted via bowden cables, which apply pressure to the braking surface, causing friction which slows the bicycle down.

Fig. 16: Caliper brake

O. *Abbreviations And Acronyms*

d0 = Dia of Crank pin in mm, l0 = Length of Crank pin in mm, b = Allowable or design bending stress on the crank pin, Maximum bending moment Mbc, Fs = Factor of safety,

V. DESIGN CALCULATIONS

A. *Design of Crank Pin:*

Let

d_0 = Dia of Crank pin in mm.

l_0 = Length of Crank pin in mm.

$_b$ = Allowable or design bending stress on the crank pin.

Take σ_b = 75N/mm^2, If it's not given

Treating the cranking pin as a simple beam with concentrated load at the centre,

Maximum bending moment Mbc = F_{comb}x a/4

Where

F_{comb} = Weight of tricycle + Weight of rider

= (35x9.81) + (65x9.81)

= 981N

Mbc=981x30/4=7357.5 N mm

Dia of crank pin based on Max Bending moment

$d_0 = \sqrt[3]{((32*Mbc)/(\pi*\sigma b))}$

$= \sqrt[3]{((32*7357.5)/(\pi*75))}$ = 9.99 mm

Hence 9.99mm<10mm. Crank pin design is safe.

B. *Design of Bolt and Nut:*

Preload in the bolt = P_i = 300N

External load on the bolt = 0.98KN

Yield strength of bolt material (C30Steel) = σ_{yt}

= 400N/mm^2

Factor of safety = F_s= 2.5

Effective stiffness of parts = Kc = 2.5K_b

∴Change in pressure = $_\Delta$P= P [Kb/(Kb+Kc)]

=0.98x10^3 [1/(1+2.5)]

$_\Delta$P = 280 N

Hence resultant load acting on the bolt is

P_b=P_i+$_\Delta$P =300+280, P_b=580 N

The tensile stress area A at the bolt is given by

Pb/A= σyt/Fs$\frac{\sigma yt}{Fs}$

580/A=400/2.5

A = 3.625 mm^2

From table no 18.16 DDHB Bolt with thread M8 suitable for this application.

C. *Bearing Specification:*

Bearing Type: Single deep groove radial ball bearing

Inner Diameter: 10 mm, 15 mm & 20 mm

Outer Diameter: up to 50mm

Closures: Open, Contact seals

Ring Material: 440C stainless steel

Seal Material: Nitrile

Retainer: Crowned steel

Precision Class: ABEC1

Radial Internal Clearance: C2

Heat stabilization: S1

D. *Specification of Steering Column*

Grade 43A

20MM DIAMETER MILD STEEL ROUND BAR (2.47 KG/M)

Material Used = 0.87m*2.47= 2.1489kg

E. *Specification of Connecting Rod:*

Grade 43A

25 x 25 x 5MM MILD STEEL TEE SECTION (1.21Kg/m)

Material Used = 0.65m*1.21= 0.7865kg

F. *Calculation of Effort:*

Mechanical Advantage =Load/ Effort [For Class I Lever]

Also

$$M.A = \frac{\text{Distance of the effort from fulcrum}}{\text{Distance of the load from fulcrum}}$$

= 0.72m/0.15m= 4.8

Weight of the tricycle = 35kg = 343.35 N (Fixed)

Trail I:

1) Weight of the human = 55kg =539.55 N

$$\text{Effort} = \frac{\text{Load}}{\text{M.A}}$$

$$= \frac{(343.35+539.55)}{4.8}$$

=183.94 N

Trail II:

2) Weight of the human = 65kg = 637.65 N

$$\text{Effort} = \frac{\text{Load}}{\text{M.A}}$$

$$= \frac{(343.35+637.65)}{4.8}$$

=204.37 N

Trail III:

3) Weight of the human = 75kg = 735.75 N

$$\text{Effort} = \frac{\text{Load}}{\text{M.A}}$$

$$= \frac{(343.35+735.75)}{4.8}$$

=224.83 N

Therefore,

Average human effort required to Propel the tricycle

$$\text{is} = \frac{(183.94+204.37+224.83)}{3} = 204.38 \text{ N}$$

VI. RESULTS AND DISCUSSION

S.n	Load (N)	Mechanical Advantage	Effort (N)	Average Effort (N)
Trail 1	882.9	4.8	183.94	-
Trail 2	981.0	4.8	204.37	204.38
Trail 3	1079.1	4.8	224.83	-

Table 1:

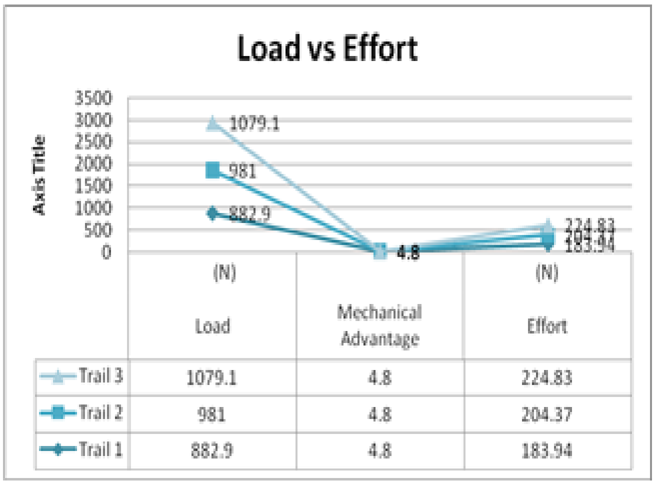

Fig. 17: Graph 6.1: Load vs. Effort

From the above graph it could be easily predicted that for the same mechanical advantage, when the loads on the tricycle increase, the efforts needed to put also increase.

Fig. 18: Fabricated Model

Highlights

Parameters	Size
Overall height	1.2m
Overall length	1.9m
Overall width	0.65m
Height of seat from footrest	0.45m
Steering column (Round section) length	0.87m
Connecting rod (Tee section) length	0.65m
Crank offset	80mm

Table 2:

VII. Applications

1) It can be used within the campus to drive not only for physically disabled but also to any normal person on the smooth road.
2) It is useful for the small city drive especially for a physically disabled person
3) It can be used for material transportation
4) It is also suitable for Para-athletes better than exciting system

VIII. Conclusions

For One Push and Pull (Oscillation) of Steering Column, the tricycle moves nearly20 metre on a smooth road. As weight of the rider increases, the human effort required to propel the tricycle also increases. Since this tricycle contains highly advanced methods and no such product is available in market, this would surely create demand in market although the initial cost is little high, through mass production we can bring sustainable benefit by lowering the cost of production.

References

[1] Force direction in manual wheel chair propulsion: balance between effect and cost, Rozendaal LA1, Veeger DE, Clin Biomech (Bristol, Avon). 2000;15 Suppl 1:S39-41
[2] Determints of maximal cycling power: crank length, pedling rate and pedal speed by J.C. Martin,Eur J Appl Physiol(2001 84:413-418
[3] Mechanical efficiency of cycling with a new developed pedal–crank by Paola Zamparo, Alberto E. Minetti, Pietro E. di Prampero- October 2002, Volume 35, Issue 10, Pages 1387–1398
[4] Scheme of assistance to disabled persons for purchase/fitting of aids/appliances (ADIP SCHEME) 2005, Govt. of India Ministry of Social Justice and Empowerment.
[5] Mitchell Batavia 2009- The Wheelchair Evaluation-A clinician's guide by Mitchell Batavia, USPTO Patent Appl. Document# 20120065825, March 2012.Power Assist Hand Tricycle With Battery For Disabled Persons by Shuh Jing Ying, International Journal of Advanced Technology in Engineering and Science, Volume No.02, Issue No. 06, June 2014 ISSN (online): 2348 – 7550