Optimization of pedaling force by using sector & pinion arrangement in bicycle

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I.ABSTRACT:

A cycle is meant for transport passenger or goods in public area. The conventional cycle has many shortcomings. Major problems associated with existing bicycle has its less efficiency and mechanical advantage. In this paper, modified drive system is presented in order to optimize its operating performance by improving mechanical advantages & lessening the pedaling force loss.

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II.INTRODUCTION:

Various locally made configurations of cycle are used across world. In an eco-sensitive zone where motor vehicles are banned, man-pulled cycles are still one of the major forms of transport .These vehicles are widely used in South Asia and Southeast Asia shown in fig-01, where bicycle driving provides relief to society keeping in mind of economic status & pollution. Generally, gear system in a chain driven bicycle is inefficient and hard to use due various losses i.e., less efficient & having poor mechanical advantages.

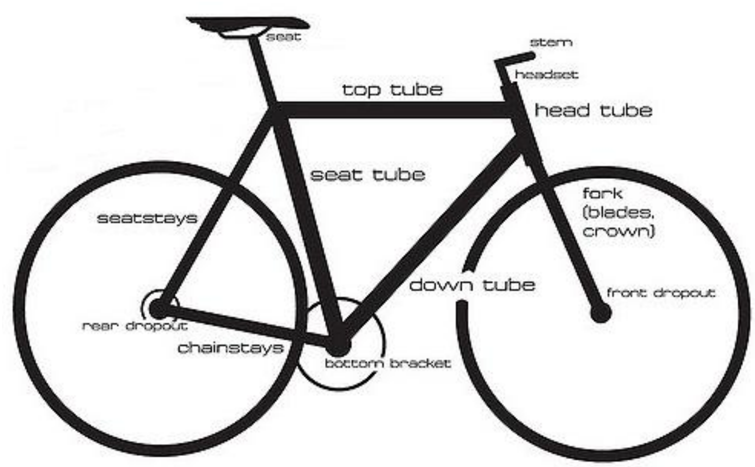
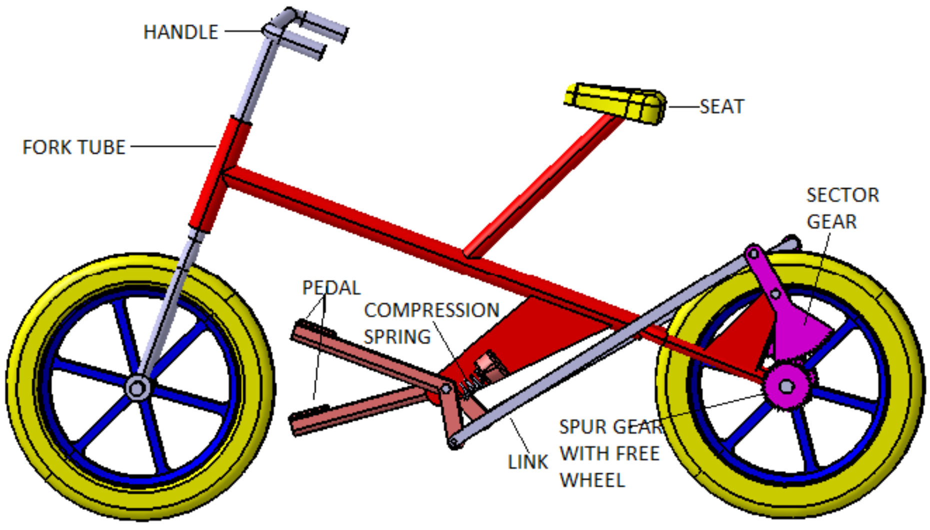


Fig-01

In conventional cycle, the crank with pedal, single chain, single sprocket with free wheel arrangement is the major driving component for transmission.

III.PROPOSSED MODEL OF NEW BICYCLE:

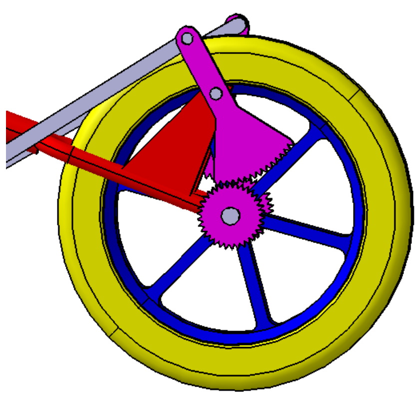
In this design the major components are two sets of L-shaped pedal lever, compression spring, link rod, spur gear sector & spur gear free wheel unit and a single set of all components mounted on either side of cycle as shown in fig-02.



(Fig-02)

A.SPUR GEAR FREE WHEEL UNIT:

Spur gear free wheel unit is meshing with the external gear of sector. They are machined in horizontal milling machine. Chamfering of edges is done in lathe

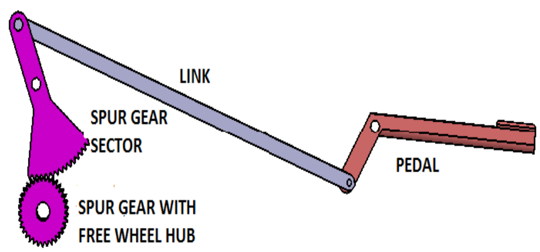


(Fig-03)

The pitch & module of both sector & spur gear free wheel are same for propare meshing without any back lash as shown in fig-03.

B.POWER TRANSMISSION SYSTEM:

In this design on either side of cycle, L-shaped pedal & spur gear sector is pivoted to the separate brackets welded to down tube of cycle. Gear portion of sector is meshed with spur gear of freewheel unit which is mounted on rear-axel & rigidly connected to wheel hub as shown in fig-04 & 05.



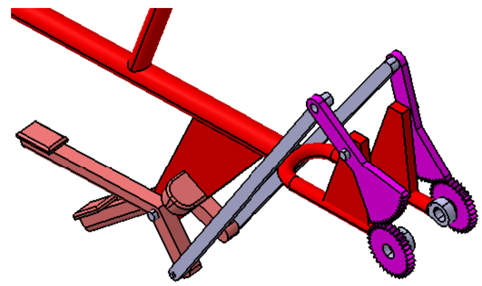


Fig-04 **fig-05**

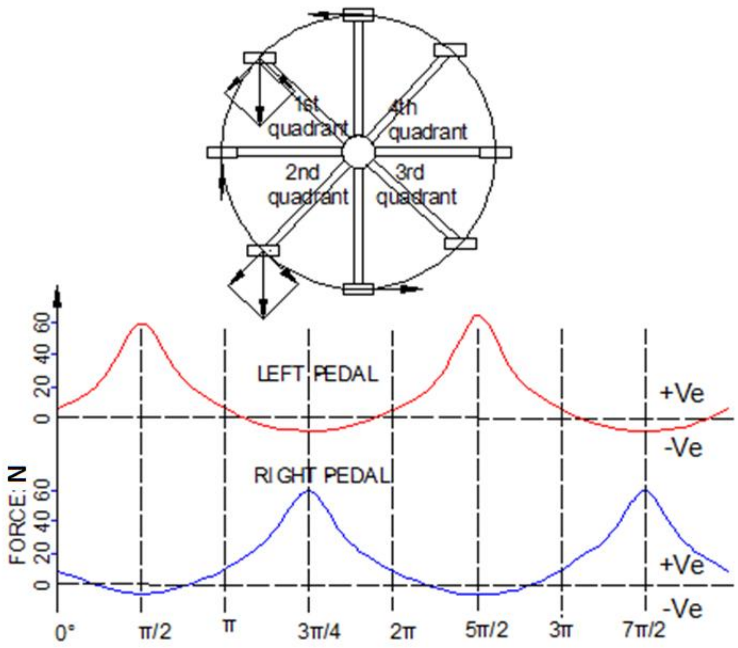
IV.WORKING PRINCIPLE:

In this design, foot pressure of passenger transmitted to rear wheel through either side of power transmission system i.e., from L-pedal to link, link to sector & sector to spur gear free wheel unit & ultimately to rear wheel. The rear wheel continuously rotate by alternating the load on pedal on either side .In this operation, compression spring mounted on down tube bracket goes on compress while loading the pedal down to it extreme bottom reach & at the idle period that compression of spring brings back the pedal to its extreme top position for next operation.

V.FORCE & TORQUE FOR CONVENTIONAL CYCLE:

The total moment created on conventional cycle pedal is the sum of all vector forces, produced by the foot pressure & that is converted into tangential, (M-tan) and radial, (M-rad) forces, and acting tangentially to crank rotation & is parallel to the crank rotation accordingly. Only force ultimately moment M-tan contributes to the crank rotation shown in fig-06 & graph -01.

$$M_{Total} = M_{tangential} + M_{radial}$$



(fig-06 & Graph-01)

Preferred pedaling technique contribute pushing action from top dead center at 0° to bottom dead center ie.,180° while downstroke of crank & pulling action while upstroke from 180° to 360° of crank rotation.

Mathematically,

Torque, $T = L_C x\ F\ x\ tan\ \theta$.

Generally the torque will zero at 0º & increases gradually to maximum at 90° (down stroke) and then decreases to zero at 180º at bottom and it is repeat for other side while cycling.Wher e 0° is highest position & 180º is lowest position of the crank rotation.

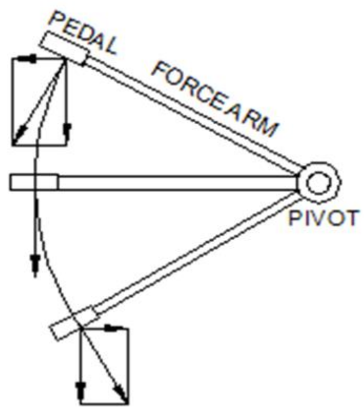
Net torque,

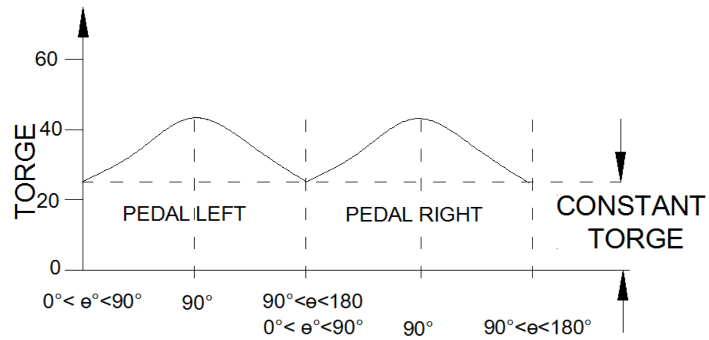
$T_{net} = T_{left} + T_{right}$(applied to the left and right shows)

For example, different peak values are asymmetry due to emphasizing an unequal pushing action during the down stroke or due to a problem with pulling during the upstroke.

VI.CONSTANT TORQUE FOR NEW DESIGN:

In this project, assuming that the human can put maximum foot pressure from 60º to 120º because in this mean period magnitude of horizontal force of tangential force is negligible & magnitude of vertical force is maximum. The moment-arm of the crank did not vary, then it would be possible to have a constant-torque through each down stroke between 60º to 120º. Above advantage i.e., maximum utilization vertical force of this a system is illustrated by fig-07 & graph-02





(Fig-07) **(Graph-02)**

VII.DESIGN ASSUMPTIONS:

1) The maximum power is obtained at an optimum pedalling cycles.
2) A rate of 50 cycles per minutes is recommended for 'healthy males' for routine bicycling. Racers are too goes up to 100 cycles per minutes for short period.
3) Extention of pedaling arm from pivot point is of same length as extention of sector gear from fulcrum.

VIII.MECHANICAL ADVANTAGES:

It is the ratio of the force that performs the useful work on a machine to the force which is applied to it. In case of cycle, amplification of force i.e., pedal force, is done to increase wheel rotation in turn to get maximum efficiency & mechanical advantages .There are two major possible ways to measure mechanical advantage while cycling listed below.
1) More distance travelled by the cycle while keeping constant magnitude of pedal force throughout the distance travelled.
2) Same distance travelled by the cycle, applying less force on pedal.

The mechanical advantage of a pair of meshing gears for which the input gear has N_A teeth and the output gear has N_B teeth is given by

$$MA = \frac{\omega_A}{\omega_B} = \frac{r_B}{r_A} = \frac{N_B}{N_A}$$

IX.SPEED RATIO:

The requirement for power input to an ideal mechanism to equal power output provides a simple way to compute mechanical advantage from the input-output speed ratio of the system.

The power input to a gear train with a torque T_A applied to the drive pulley which rotates at an angular velocity of ω_A is $P = T_A\omega_A$

$$P = T_A\omega_A = T_B\omega_B$$

Because the power flow is constant, the torque T_B and angular velocity ω_B of the output gear must satisfy the relation

$$MA = T_B/T_A = \omega_A/\omega_B$$

X.GEAR TRAIN:

The speed ratio for a pair of meshing gears can be computed from ratio of the radii of the pitch circles and the ratio of the number of teeth on each gear, its gear ratio.

The velocity v of the point of contact on the pitch circles is the same on both gears, and is given by

$$V = r_A\omega_A = r_B\omega_B$$

XI.CHAIN DRIVE:

In chain drive mechanism, velocity v of the chain is the same when in contact with the two sprockets: $V = r_A\omega_A = r_B\omega_B$

Where the input sprocket or pulley A meshes with the chain along the pitch radius r_A and the output sprocket or pulley B meshes with this chain along the pitchradius r_B,

Therfore

$$\frac{\omega_A}{\omega_B} = \frac{r_B}{r_A} = \frac{N_B}{N_A}$$

al advantage of a pair of a chain drive with an input sprocket with N_A teeth and the output sprocket has N_B teeth is given by

$MA = \frac{T_B}{T_A} = \frac{N_B}{N_A}$, A chain or belt drive can lose as much as 5% of the power through the system in friction heat, deformation and wear, in which case the efficiency of the drive is 95%.

XII.CALCULATION OF MINIMUM & MAXIMUM TORQUE ON SPUR GEAR FREE HEEL UNIT:

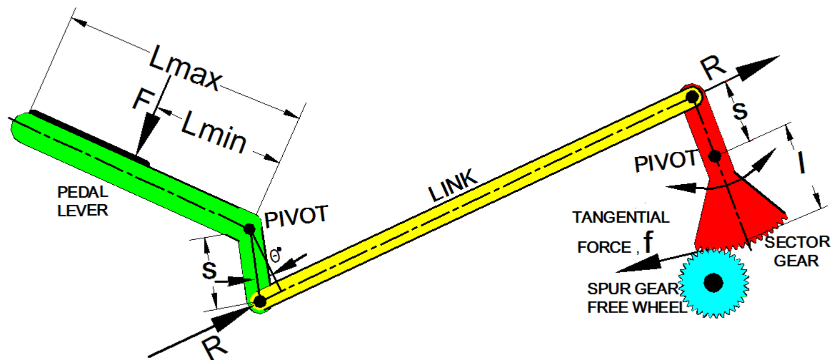


Fig-08. Free body diagram of pedal lever

f – Tangential force obtained at gear teeth

F– Applied force on pedal (body weight) Taken as 650 N

Considering reduction in total force due to shifting of body weight between the pedals & due to body poster.

$F_{mean} = 0.9\ x\ 650 = 585N$

l – Pitch radious of sector gear = 0.15 m

S= length of lever of gear sector = 0.15 m

L– Length between pedal and pivoted end

L_{min} - Minimum length of the pedal lever = 0.20 m

L_{max}- Maximum length of the pedal lever = 0.50 m

L_B =Total length of bicycle $= 1.68m$

D_w=Wheel diameter = 0.60 m

D_g =Rear free wheel pitch diameter $= 0.06m$

Calculation of force acting in the gear:

$F_{mean}x\ L_{min} = RxSxCos30^{\circ}$ ……………..(1) $585x0.2 = Rx0.15x0.866$

R = 900 N

With the tangential force ‘f ’ a minimum torque of 150Nm is to be obtained at the gear wheel

$T_{sector} = fxl$ & $T_{link} = RxS$

As , $R\ X\ S = f\ x\ l$

$$f = \frac{RXS}{l} = \frac{900\ x\ 0.15}{0.15} = 900\ N$$

Mimum torque on free wheel unit,$T_{fw} = 900x\ 0.03 = 27\ Nm$

It is known that, $f\ x\ r_g = f_w\ x\ r_w$

Force on wheel at ground, $f_w = \frac{f\ x\ r_g}{r_w} = \frac{900\ x\ 0.03}{0.3} = 90\ \ N$

Minimum torque at wheel at ground, $T_{min} = 90\ x\ 0.3 = 27Nm$

$$F\ x\ L_{max} = R\ x\ S\ x\ Cos\ 30^\circ$$

$$585\ x\ 0.50 = R\ x\ 0.15\ x\ Cos\ 30^\circ$$

$R = 2251\ N$

$$f = \frac{RXS}{l} = \frac{2251x\ 0.15}{0.15} = 2251\ N$$

Maximum torque on free wheel unit, $T_{fw}\ = 2251x\ 0.03 = 67.5\ Nm$

It is known that, $f\ x\ r_g = f_w\ x\ r_w$

Force on wheel at ground, $f_w = \frac{f\ x\ r_g}{r_w} = \frac{2251\ x\ 0.03}{0.3} = 225\ \ N$

Minimum torque at wheel base, $T_{max} = 225\ x\ 0.3 = 67.5\ Nm$

XIII. Wheel Rotations obtained during one complete cycle of pedaling on both system:

1) CHAIN DRIVE CONVENTIONAL CYCLE:

Perimeter of the front pedal sprocket

$= \ 2\ x\ л\ x\ r_1 = 2\ x\ л\ x\ 0.09 = \ 0.565\ m$

Perimeter of the rear free wheel sprocket

$= 2\ x\ л\ x\ r_2\ = \ 2\ x\ л\ x\ 0.03 = 0.188\ m$

No of wheel rotations: $\frac{0.565}{0.188} = 3\ nos$

2) NEW DESIGNED MODEL BICYCLE:

In one stroke of pedal, the sector rotates about 60º

Circumference of sector gear which is in contact with spur gear pinion while pedaling = $l\ x\ \theta\ x \frac{\pi}{180^\circ}$

Arc length covered for 60º rotation of sector $= 0.15\ x\ 60\ x \frac{\pi}{180^\circ} = 0.15$

Ci rcumference covered for alternate pedaling

$= 2\ x\ 0.15 = 0.3\ m$

Pitch circle of free wheel unit $= 2\ x\ \pi\ x\ 0.03 = 0.18$

No of wheel rotations: $\frac{0.3}{0.18} = 1.5\ nos$

Table-01

Sr no	New designed cycle	Conventional cycle
01	One by one pedaling is possible	possible
02	Both left & right side pedal can be operated at a time to impart more power	Not possible
03	Single side pedaling is possible	Not possible
04	It has large pedal length to adjust different power demand	Not possible
05	Mechanical advantage is good	Not good
	For compelte cycle of both,wheel rotation is 1.5	For complete cycle of both side,wheel rotation is 3.0
06	Easy maintenance and lubrication	Demand more maintenance
07	Less noise on riding	Noisy
08	It is comfortable to operate	Comparatively less
09	Backlash present in gear drive	A chain can lose as much as 5% of the power through the system in friction heat, deformation and wear

XIV. SUMMARY AND CONCLUSION:

The main aim of the newly designed bicycle is to obtain a variable output torque at the rear wheel by applying the foot pressure at different place on pedal. With this designed model a torque range of 27Nm to 67.5 Nm can be attained. The rider can easily adapt to different road surface condition & uphill gradient. The rider can comfortably ride the same by pushing both the pedal at a time to overcome the uphill climb.

The pedaling amplitude can be opted by the rider. Instead of applying continuous full stroke pedaling of the normal safety bicycle. The number of wheel rotations is 1.5 as per the designed model. The wheel rotation can be increased by using larger gear sector.

XV.REFERENCES:

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