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DESIGN OF AN EFFICIENT GEAR DRIVEN BICYCLE

K. Rajasuthan*, G. Balaji, M. Palpandi

* Department of Mechanical Engineering, PSNA College of Engineering and Technology, Dindigul, India

Department of Mechanical Engineering, PSNA College of Engineering and Technology, Dindigul, India

Department of Mechanical Engineering, PSNA College of Engineering and Technology, Dindigul, India

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ABSTRACT

In our project bicycle is driven with a series of spur gears which will increase the speed of bicycle and also the bicycles becomes more efficient than a conventional sprocket driven bicycle. Spur gears are used in series to transmit power from the pedal to the rear wheel of the bicycle. This bicycle enables us to put less effort for pedaling. For a very low input effort, we can get maximum output. Distance covered by this gear driven bicycle for few minutes of pedaling will also be 3-4 times more than that of the ordinary sprocket driven bicycle.

INTRODUCTION

GENERAL

The gear driven bicycle is an improved version of ordinary sprocket driven bicycle. The initial cost of this bicycle is high when compared with that of chain driven bicycle. But the main advantage of this bicycle is its efficiency. This cycle is exclusively intended for achieving high output with only less efforts. A cyclist's legs produce power optimally within a narrow pedaling speed range, or cadence. Gearing can be optimized to use this narrow range as efficiently as possible. As in other types of transmissions, the gear ratio is closely related to the mechanical advantage of the drivetrain of the bicycle. On single-speed bicycles and multi-speed bicycles using derailleur gears, the gear ratio depends on the ratio of the number of teeth on the chaining to the number of teeth on the rear sprocket (cog). For bicycles equipped with hub gears, the gear ratio also depends on the internal planetary gears within the hub. For a shaft-driven bicycle the gear ratio depends on the bevel gears used at each end of the shaft.For a bicycle to travel at the same speed, using a lower gear (larger mechanical advantage) requires the rider to pedal at a faster cadence, but with less force. Conversely, a higher gear (smaller mechanical advantage) provides a higher speed for a given cadence, but requires the rider to exert greater force. Different cyclists may have different preferences for cadence and pedaling force. Prolonged exertion of too much force in too high a gear at too low a cadence can increase the chance of knee damage; cadence above 100 rpm becomes less effective after short bursts, as during a sprint. But we are not going to use the regular gear cycle concept. Instead of the chain and the sprocket vthe bicycle is fitted with a series of spur gears with specific gear ratio and number of teeth. The number of teeth for the spur gear placed in the pedal sprocket has higher number of teeth. Then for the rest of spur gears the number of teeth gradually decreases. When coming to the rear wheel the gear fitted in the rear wheel has the lowest number of teeth. When these series of spur gears are meshed the power we give as input through the pedal is completely transmitted as output with no loss in power.

GEAR SYSTEM

A gear system is a system in which a set or a series of gears are meshed to transmit torque and power between the input and the output shaft. There are number of examples for the usage of gear systems such as all two wheelers all lathe and lathe related machines.

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ADVANTAGES OF TEETH-

- They prevent slippage between the gears - therefore axles connected by gears are always synchronized exactly with one another.
- They make it possible to determine exact gear ratios - you just count the number of teeth in the two gears and divide. So if one gear has 60 teeth and another has 20, the gear ratio when these two gears are connected together is 3:1.
- They make it so that slight imperfections in the actual diameter and circumference of two gears don't matter. The gear ratio is controlled by the number of teeth even if the diameters are a bit off.

LITERATURE REVIEW

Gear driven bicycle consists of a cycle, a set of six spur gears with different diameters and number of teeths, a TVS XL super chain cover and a bearing. In place of the sprocket the gear with the largest number of teeth is welded. Then further following that gear five consequent gears are meshed together. To make the cycle with those six cast iron gears weightless we used gas cutting process. This gas cutting process reduces the cycle's weight. Bearing is fitted in the centre of the gear with the largest number of teeth. This bearing makes pedalling easier. To cover the exposed spur gears a chain cover of TVS XL Super is bolted with the frame of the bicycle. . Instead of the chain and the sprocket vthe bicycle is fitted with a series of spur gears with specific gear ratio and number of teeth. The number of teeth for the spur gear placed in the pedal sprocket has higher number of teeth. Then for the rest of spur gears the number of teeth gradually decreases. When coming to the rear wheel the gear fitted in the rear wheel has the lowest number of teeth. When these series of spur gears are meshed the power we give as input through the pedal is completely transmitted as output with no loss in power.

DESIGN OF EQUIPMENT

GEARS:

Selection of gears:

Gears are selected based on the following factors. They are as follows:

1. Application
2. Environment
3. Life
4. Noise
5. Efficiency
6. Cost
7. Space required

COMMON TYPES OF GEARS:

Types of Spur Gears:

* External Spur Gear
* Internal Spur Gear
* Rack and Pinion Gears

External Spur Gears:
External Spur Gears are the most popular and common type of spur gear. They has their teeth cut on the outside surface of mating cylindrical wheels. While the larger wheel is referred to as the gear and the smaller wheel is known as the pinion. Single reduction stage is the most basic type of arrangement of single pair of spur gears. Here the output rotation is in opposite direction to that of the input. In other arrangements of multiple stages higher net reduction can be achieved where the driven gear is connected rigidly to a third gear. This third gear in turn drives a mating fourth gear. This serves as the ideal output for the second stage. In this way, many output speeds on different shafts are produced starting from a just single input rotation.

Internal Spur Gear:
This is actually a type of Spur Gear. Internal Spur Gear is not much different from a regular spur gear. These gear by appearance shows pitch surface that is cylindrical. Here the tooth is parallel to the axis. In case of Internal Spur Gear, the gears are positioned to make internal contact. It is also referred to popularly as Ring gears. The output rotation produced by the Ring gears is direction wise same as that of input rotation.As is clear from the figure the gear tooth are cut from inside. A typical Internal Spur Gear or Ring Gear consists of typically three or four larger spur gears referred to as planets. That surrounds a smaller central pinion referred to as sun. Normally, the ring gear remains stationary. This is quite like our own Planetary system, where the planets orbit round the sun in the same rotational direction. It is quite obvious that this class of gear is known as a planetary system. It is through a planet carrier that transmits the orbiting motion of the planets to the output shaft.

In a different planetary arrangement, the ring may be left to move freely. This is done by restricting the planets from orbiting round the sun. This action results in the ring gear rotating in an opposite direction to that of the sun. Thus a differential gear drive is effected as a result of rotation of both the ring gear and the planet carrier. The output speed of the shafts are interdependent.

Rack and Pinion gear:

Rack and pinion gears are also one of the most useful gears used in all manufacturing machines. It can be used for various purposes. They are below:

Rack and pinion Gear are another variety of Spur gears. Actually a Rack is defined as a straight bar that has teeth which are cut straight and across. Basically, The Rack is considered as a spur gear that is unrolled and laid flat. Pinion is the normal gear. A rack and pinion is really a very special example of spur gearing. The rack-and-pinion has been found to be specially useful in conversion of rotary motion into linear and vice versa. Rotating a pinion produces a linear motion of the rack. Alternately moving a rack causes rotation in the pinion.

FACTORS DETERMINING THE CHOICE OF MATERIALS:
The various factors which determine the choice of material are discussed below.
Properties:
The material selected must possess the necessary properties for the proposed applications. The various requirements to be satisfied can be weight, surface finish, rigidity, strength, ability to withstand environmental attack from service life, reliability etc.

The following two types of principle properties of materials decisively affect their selection:
The various mechanial properties concerned are sterngth in tensile,compressive shear, bending,torsion and buckling load, elastic limit, endurance limit, modulus of elasticity,hardness,wear resistance. The various manufacturing properties concerned are

1. Cast ability

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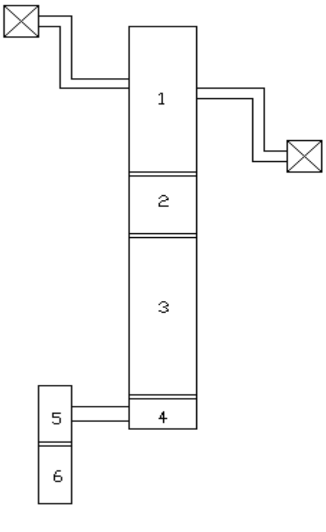
2. Weld ability
3. Surface properties

Quality of the material:
Selection of materials mainly depends on its quality. Material chosen for the manufacturing of these spur gears must be high grade cast iron and should withstand heavy load with less noise while running.

Availability of the material:
Basically materials selected for gears are based upon its availability. On such condition we are selecting cast iron as our gear material because its available in enormous amount compared to all other materials.

Cost:
When manufacturing and fabrication of any component is considered cost is the major criteria we should keep an eye on. Good quality material as well as cheap is selected for fabrication of gear.
GEAR DRIVEN BICYCLE:

2D VIEW OF THE SAME SETUP:



TOP VIEW

CONSTRUCTION
The construction of this gear driven bicycle consists of a cycle, a set of six spur gears with different diameters and number of teeths, a TVS XL super chain cover and a bearing. In place of the sprocket the gear with the largest number of teeth is welded. Then further following that gear five consequent gears are meshed together. To make the cycle with those six cast iron gears weightless we used gas cutting process. This gas cutting process reduces the cycle's weight. Bearing is fitted in the centre of the gear with the largest number of teeth. This bearing makes

pedaling easier. To cover the exposed spur gears a chain cover of TVS XL Super is bolted with the frame of the bicycle.

WORKING

The working principle of this gear driven bicycle is that when the bicycle is pedalled spur gear attached with the pedal rotates and this in turn rotates further the following series of spur gears. There are six spur gears used here for meshing. Number of gears used mainly depends upon the direction of rotation of the gears. Six spur gears are used here in order to make the rotation of the spur gear attached with the rear wheel in counter clockwise direction, so that the vehicle can move forward.

DESIGN CALCULATION

To get the power output from the driving first gear to all the entire meshing gears upto last, for each pair power output is calculated seperately, and then compared with the adjacent meshing gears.

This can be achieved as follows:

1---2 2---3 3---4 4---5 5---6

Z_1 be the number of teeth in gear 1
Z_2 be the number of teeth in gear 2
Z_3 be the number of teeth in gear 3
Z_4 be the number of teeth in gear 4
Z_5 be the number of teeth in gear 5
Z_6 be the number of teeth in gear 6
N_1 be the speed of gear 1
N_2 be the speed of gear 2
N_3 be the speed of gear 3
N_4 be the speed of gear 4
N_5 be the speed of gear 5
N_6 be the speed of gear 6

GEAR PAIR 1---2

(1). Calculation of gear ratio (i):

$$i=\frac{N1}{N2}=\frac{Z2}{Z1}=\frac{30}{115}$$

i= 0.26

$$0.26=\frac{100}{N2}$$

N2= 384.61rpm

(2). Selection of materials:

Let us take the material of all the spurgears as same.
Let the material selected be **Cast iron Grade 30.**

(3). Gear life:

We assume gear life as **20000 hrs.**
N=20000*60=**$12*10^5$ minutes**
N=$12*10^5*100$=**$12*10^7$ cycles**

(4). Calculation of initial design torque [M_t]

$[M_t]= M_t * K*K_d$

$K*k_{d}$=1.3(initially assumed)
M_t = mean torque
K = load concentration factor
K_d = dynamic load factor

$$P = \frac{2\pi n_1 M_t}{60} \text{ in which,}$$

P = Power in watts.
n_1 = Speed in rpm of pinion
M_t = Nominal twisting moment in N-m

$$M_t=\frac{60*2.5*1000}{2*\pi*100}=238.73 \text{ N-m}$$

$[M_t]$=238.73*1.3=**310.35 N-m.**

(5).Calculation of E_{eq},$[\sigma_b]$ and $[\sigma_c]$:

(a) Determine young's modulas

For Cast Iron Grade 30; **E_{eq}=1.7*10^5 N/mm^2**

(b) Determine the bending stress $[\sigma_b]$:

$$[\sigma_b] = \frac{1.4\, k_{bl}\, \sigma_{-1}}{n\, k_\sigma}$$

For HB > 350 and N ≤ 25* 10^7 cycles

$$K_{bl} = \sqrt[9]{\frac{10^7}{N}} = \sqrt[9]{\frac{10^7}{12 \times 10^7}} = 0.76$$

σ_{-1}= 0.45 σ_u = 0.45 *290

σ_{-1} =130.5 N/mm^2

For Cast iron grade 30; **n=2; K_σ=1.2**

$$= \frac{1.4 \times 0.76}{2 \times 1.2} \times 130.5 = 57.8\ \text{N/mm}^2$$

(C) Determine compressive stress $[\sigma_c]$:

$[\sigma_c]$=C_B*HB*K_{cl}

For cast iron grade 30

C_B= 2.3 HB= 260

$$K_{cl} = \sqrt[6]{\frac{10^7}{N}} = \sqrt[6]{\frac{10^7}{12 \times 10^7}}$$

K_{cl} = 0.6615

$[\sigma_c]$= 2.3*260*0.6615

$[\sigma_c]$=395 N/mm^2

(6) Calculation of centre distance (a):

$$a \geq (i \pm 1) \sqrt[3]{\left\{\frac{0.74}{[\sigma_c]}\right\}^2 \frac{E\,[M_t]}{i\,\psi}}$$

i = 0.26

$[\sigma_c]$=395 N/mm^2

E_{eq}=1.7* 10^5 N/mm^2

$[M_t]$ =310.34* 10^3 Nmm

$\varphi = 0.3$

On substituting these values in above equvation we get **a=178.9 mm**

(7) Calculation of module (m) :

$$m = 2a / (z_1 + z_2)$$

a=178.9 mm; Z_1=115; Z_2 = 30

On substituting these values **m= 2.27 mm**

For standard module; **m= 4 mm**

(8) Revision of center distance (a) :

$$a = \frac{m(z_1 + z_2)}{2}$$

m= 4 mm; Z_1=115; Z_2 = 30; **a= 290 mm**

(9) Calculation of b_1, d_1, v_1, and φ_p :

Face width :

$$b = \psi a$$

b_1 = 0.3* 290 = 87 mm

pitch circle diameter: d_1 = m* Z_1 = 4* 115 = 460 mm

pitch line velocity: $v_1 = \frac{\pi d1 N1}{60}$ **= 2.4 m/s**

$$\psi_p = \frac{b}{d_1}$$

V_1 = 0.18

Standardising φ_p = 0.2

(10) Selection of quality of gear :

For v= 2.4 m/s and HB >350

IS quality 8 gears are selected.

(11) Revision of design torque [M_t] :

(a) Revise K:

For**φ_p = 0.2; K= 1**

(b) Revise K_d :

For **v= 2.4 m/s; K_d= 1**

(c) Revise [M_t] = M_t* K* K_d =238.73* 1* 1

[M_t]= 238.73 Nm

(12) Check for Bending stress σ_b :

$$\sigma_b = \frac{(i \pm 1)\,[M_t]}{a\,m\,b\,y}$$

i= 0.26; a= 290 mm; m=4 mm; b= 87 mm

y= 0.1432

[M_t]= 238.73* 10^3 N mm

On substituting these values in the above equation we get

σ_b = 20.81 N/ mm^2

σ_b< [σ_b] Design is safe

(11) Check for induced contact stress σ_c :

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$$\sigma_c = 0.74\,\frac{i+1}{a}\sqrt{\frac{i+1}{ib}\,E\,[M_t]}$$

i=0.26

E_{eq} =1.7* 105 N/mm^2

[M_t] =310.34*10^3Nmm

b= 87mm

a=290mm

On substituting these values in the above equation we get

σ_c = 174.29 N/mm^2

σ_c< [σ_c] Design is safe

FOR GEAR PAIR 2----3

(1) Calcilation of gear ratio:

$i = \frac{Z3}{Z2} = \frac{N2}{N3} = \frac{135}{30}$

i=4.5=$\frac{384.6}{N3}$

N_3=85.46 rpm

(2) calclation of initial design torque[M_t]:

[Mt]= Mt* K*Kd

$$P = \frac{2\pi n_1 M_t}{60} \text{ in which,}$$

P = Power in watts.

n_1 = Speed in rpm of pinion

M_t = Nominal twisting moment in N – m

$M_t=\frac{60*2.5*1000}{2\pi*384.6}$

M_t=62.07 N-m

[M_t]=62.07*1.3

[M_t]=80.69 N-m

(3) Calculation of Eeq ,[σ_b] and [σ_c]:

$[\sigma b]_{1---2}$ = $[\sigma_b]_{2----3}$ =$[\sigma_b]_{3-----4}$ = $[\sigma_b]_{4----5}$ = $[\sigma_b]_{5----6}$

$[\sigma_c]_{1---2}$ = $[\sigma_c]_{2----3}$= $[\sigma_c]_{3-----4}$ = $[\sigma_c]_{4----5}$ = $[\sigma_c]_{5----6}$

(4) calculation of centre distance (a) :

$$a \geq (i \pm 1)\sqrt[3]{\left\{\frac{0.74}{[\sigma_c]}\right\}^2 \frac{E\,[M_t]}{i\,\psi}}$$

For

i=4.5

[σ_c]=395.57 N/mm^2

E_{eq}=1.7*10^5 N/mm^2

[M_t]=80.64 *10^3 N-mm

φ= 0.3

On substituting these values in above equvation we get

a=180.49 mm

(5) calculation of module (m):

m=2a/(z_{2}+z_3)

a=180.49 mm

Z_2=30

Z_3=135

On substituting these values we get

m=2.18mm

For standard module

m= 4 mm

(6) Revision of centre distance (a) :

a= m/(Z_2+Z_3)

m= 4 mm

Z_2=30

Z_3=135

On substituting these values we get

a=330mm

(7) Calculation of b_2 , d_2, v_2, and φ_p :

Face width:

$$b = \psi\, a$$

b= 0.3*330=**99mm**
pitch circle diameter :
d_2 = m* Z_2
d_2= 4*30 = **120mm**
v_2 = (π d_2 N_2)/60
v_2 = 2.14 m/sec
φ_p=0.825
Standardising φ_p =1
(8) Revision of design torque [Mt] :
(a) Revise K:
For φ_p=1
K=1.1
(b) Revise Kd :
For v= 2.4 m/s
K_d= 1
(c) Revise [Mt] = Mt* K* Kd
= 62.07* 1.1* 1
[Mt] =68.27Nm
(9) Check for Bending stress σ_b :

$$\sigma_b = \frac{(i \pm 1)\,[M_t]}{a\, m\, b\, y}$$

i= 0.45
a= 330 mm
m=4 mm
b= 99 mm
y= 0.1450
[Mt]= 68.27*10^3 N mm
On substituting these values in the above equation we get
σ_b= 29.80 N/ mm^2
$\sigma b < [\sigma b]$ Design is safe
(10) Check for induced contact stress σc:

$$\sigma_c = 0.74\,\frac{i+1}{a}\sqrt{\frac{i+1}{ib}\,E\,[M_t]}$$

i=0.45
E_{eq} = 1.7* 10^5 N/mm
[M_t] = 310.34* 103 Nmm^2
b= 99mm
a=330mm
On substituting these values in the above equation we get
σ_c = 173.33N/mm^2
$\sigma_c < [\sigma_c]$ Design is safe

CONCLUSION
This report deals with **"DESIGN OF AN EFFICIENT GEAR DRIVEN BICYCLE".** Thus the efficiency of this gear driven bicycle is 10% greater than that of the conventional chain driven bicycle. It also reduces the human effort and can be driven without feeling dried for a prolonged period of time.

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