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Design and Development of Treadmill Bicycle

Kismat Patel[1], Rajat Prajapati[2], Nirav Trivedi[3], Prof. Ravi K. Patel[4]

[1,2,3]Students, Department of Mechanical Engineering, U.V. Patel College of Engineering, Ganpat University, Gujarat, India.
[4]Associate Professor, Department of Mechanical Engineering, U.V. Patel College of Engineering, Ganpat University, Gujarat, India.

Abstract: *This project brings the treadmill and bicycle together. Treadmill fitted on bicycle frame develops an innovation named 'Treadmill bicycle'. A 3D modeling is prepared with help of SOLIDWORKS Software. The materials used for the project are easily available in market and less costly. As the rider gives throttle, the motor starts rotating and it propels treadmill cycle forward as well as runs treadmill. People likes to do exercise with treadmill, Similar kind of exercise experience is obtained by the rider with help of this device, it combines exercising and joy of riding. It runs on a non-conventional energy source, so yaa! This is eco-friendly also.*

Keywords: Treadmill, Physical fitness, Exercise device, Eco-friendly, Zero emission.

INTRODUCTION

Treadmill is a popular type of home exercise equipment, which provides a simple, aerobic workout. Those who want to begin new exercise routine prefer to choose treadmills because most individuals tolerate walking regardless of back conditions and fitness problems. As strength and endurance are developed, the treadmill can be used for jogging and/or for interval training. For walking or running while being at the same place treadmill is generally used.[1]

Before the development of powered machines treadmills were introduced, to do work by using the power of human or machines, mostly animal or person operated treading steps of tread wheel to grind grain. For people sentenced to hard labor in prisons treadmills were used as punishment devices. For the power and punishment mechanisms the terms treadmill and tread wheel were used interchangeably.[1]

Nowadays treadmills are used for walking, jogging or running. This is a simple workout and is good for beginners.

Treadmill bicycle is the unique way of exercising while travelling. As this device works on battery so one can use it as an e-bike also. This gives great riding experience.

PROBLEM FORMULATION

In day-to-day life, the people mostly use cars, bikes, etc. to travel which results in increase in pollution and as we know pollution is a big problem nowadays. Also, the parking space available nowadays is limited to everyone. People are using health exercise instruments to keep them fit and healthy. The treadmill is one of the most popular instruments which is widely used for exercise at home. The treadmills are heavy in weight and stationery so people get bored while running on it, and slowly they reduce frequency of using it for exercise.

To overcome these problems, the idea of developing a mode of transportation born, which not only serve purpose of transportation but also serves helps in maintain health, solve parking space issues. The design and development of the Treadmill bicycle solve these issues. It helps in keeping the body fit while moving on to offices.

DESIGN OF COMPONENTS

The design of treadmill bicycle is such a typical task. The design is based on parameters like ergonomics, speed of treadmill bicycle, weight of rider, etc. The components are used in this treadmill bicycle are divided into two parts.

1) Structural parts.
2) Transmission parts.

✧ Structural parts:

These are the parts which sustains the different loads acting on treadmill bicycle and also supports the whole structure. These are integral for the whole structure, and are mentioned below:

i. Main frame
ii. Rollers
iii. Treadmill belt
iv. Steering assembly
v. Wheels

✧ Transmission parts

These are the parts which are responsible for transmission of motion or power.

i. Chain and sprockets
ii. Battery
iii. Motor

1. Roller

Roller is a part that is designed like cylinder or pipe or tube and used for pressing, smoothing, spreading, shaping operations. One can say that they are revolving cylinders.

Here, the material selected for rollers is C45 steel round bar (standard=ASTM A29 1045)

Material Properties

Moderate carbon steel
Good machinability and good tensile properties.

Calculation for roller

For diameter

Load analysis of the selected material:

Maximum applied load(P_r) = 1471.5 N
Maximum allowable load(P_r) = 1471.5 N(considering maximum weight of rider)
Length of roller(L_r) = 500 mm
Uniformly distributed load = 2.943 N/mm
(Consider simply supported beam)

$\tau_p = 0.3 \times s_y t$
$= 0.3 \times 600$
$= 180\ {}^{N}/_{mm^2}$
$\tau_{max} = 0.30\ s_y t$
$\tau_{max} = 0.18\ s_u t$

Where τ_P = Permissible shear stress
$s_y t$ = Yield tensile strength

$\tau_p = 0.18 \times s_u t$
$= 0.18 \times 700$
$= 126\ {}^{N}/_{mm^2}$

Considering smaller value of $\tau_P = 126\ {}^{N}/_{mm^2}$
Assuming K_b =1.5 and K_t =1

K_b = Bending Stress Factor
K_b = Life Load Factor

Power =P(KW) $= \frac{2\pi NT}{60 \times 10^6}$
T= M_t =10,802.37 N.mm
$M_{b(max)} = (2.943 \times 500) \times 250$
=367,875 N.mm

As per ASME code, $\tau_{max} = \frac{16}{\pi d^3}\sqrt{(K_b M_b)^2 + (K_t M_t)^2}$

Diameter of roller = $d_r \approx 32$ mm

For speed of roller

The length of the belt is = 2000 mm
(As the belt is surrounded the rollers in both upper and lower sides).

So, for one full rotation of the belt a man has to run 2 m.

If a man running at a speed 5 km/h then in one hour the belt rotates = 2500 times

So, the speed of the belt rotation is 2500 r.p.h.= 42 rpm.
Here, the diameter of roller is = 48 mm.
So, For each rotation of the belt one roller completes

$$= \frac{2000}{\pi \times d_r}$$

$$\approx 13 \text{ time}$$

For each revolution of belt roller rotates 13 times.

Speed of the roller = 13 × 42 r.p.m
= 546 r.p.m

Fig -1: Rollers[2]

2. Wheel

Wheel is a component of circular shape which rotates on axle. Force is applied on the axle and this causes the wheel to rotate. Wheel is a discovery of utmost importance, which makes movements of machine very easy. Here, both the wheels are of different sizes. Front wheel is larger than rear wheel because, to match with the ergonomic design. The rear wheel is smaller because, to keep CG (centre of gravity) nearer to ground and for best arrangement of space for battery. On the wheel, tubed tires are used, because they are less expensive and consumes less time for fitting compared to tubeless tires.

Diameter of rear wheel = 20 inches
Diameter of front wheel = 24 inches

Calculation for speed of rear wheel
Rear wheel size of bicycle = 20 inches = 508 mm

Required speed of bicycle = 40 km/hr (Maximum)

Linear velocity is converted into angular velocity.

Linear velocity= $V_r = r \times \omega$

$$N = \frac{60\omega}{2\pi}$$

Speed of rear wheel = $N \approx 420$ r. p. m

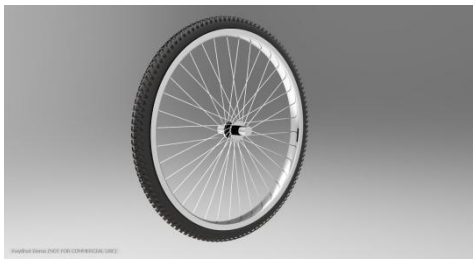


Fig -2: Wheel[3]

3. Main frame

Main frame is the core structure on which rollers are mounted and are covered by belt. This is the main component on which most of loads are applied. i. e. weight of rider and roller, etc.

Here, frame is made of mild steel material of grade IS 2062 because this material has high tensile strength as well as high ductility, etc.

Load calculation on main frame

Load applied on the frame (P_f) =1962 N (considering weight of roller, rider and treadmill belt).

Length of frame (L_f) =1000 mm

Width of frame (w_f) =500 mm

Uniformly distributed load =1.962 $\frac{N}{mm}$

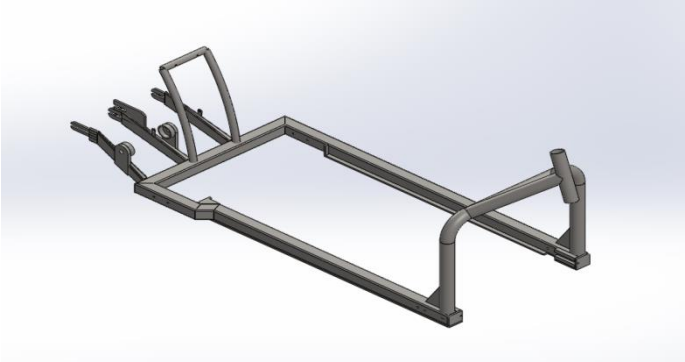


Fig -3: Main frame

4. Battery

Battery is a device consisting of single or multiple electrochemical cells. This is used for supplying electric power.it has two terminals: 1. Anode, which is negative terminal and 2. Cathode, which is positive terminal. The electrons travel to cathode from anode.

There are two most common types of batteries: lithium ion battery and lead acid battery. The lithium ion battery is made from lithium and lead acid consists lead. Both are suitable for storage solutions. The comparison between them is as under :

	Lithium ion Lithium ion battery	Lead acid Lead acid battery
Cost	✘	✔
Efficiency	✔	✘
Lifespan	✔	✘
Capacity	✔	✘

Generally, lithium ion batteries are preferred over lead acid batteries because they are more reliable and more efficient.[4]

Here 36 V 10 Ah rated lithium ion battery is used.

5. Motor

Motor is an electrical device which converts electrical energy into mechanical energy. In this work, the brushless hub motor is used because they are simple, lightweight, more rugged and requires low maintenance as compared to ordinary motors. The specifications of motor are : 250 watt, 36 volt, 300 rpm.

Fig -4: Hub motor[5]

6. *Chain*

This is a series of connected metal links that are joined together. Chains are used to transfer from one sprocket to another. A chain drive is intermediate between belt drive and gear drive. Chain drive has some characteristics of belt drive and some of gear drive. Chain drive can be used for long and short centre distances. It can operate without full lubrication film between joints unlike gear drive. The efficiency of chain drive is more than belt drive. It is compact compared to belt drives.[6]

Here, two chains of different lengths are used and they are made of stainless steel(303SS). This material has good corrosion resistance and wear resistance.

Selection of standard size of chain for motor to treadmill roller and free wheel

Chain	No. 35 (1/4th)
Chain Pitch	9.525 mm
Bush link inside Width	4.78 mm
Bush Outside Diameter	5.08 mm
Teeth width	4.3 mm
Material	SS(T-303SS)
Length of Chain	1223 mm

Fig -5: Chain

Selection of standard size of chain for free wheel to bicycle

Chain	No. 35 (1/4th)
Chain Pitch	9.525 mm
Bush link inside Width	4.78 mm
Bush Outside Diameter	5.08 mm
Teeth width	4.3 mm
Material	SS(T-303SS)
Length of Chain	600 mm

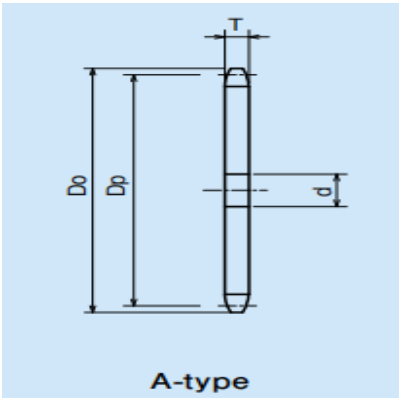
Fig -6: Chain

7. Sprocket

Sprocket is a component used to engage links of chain. One can call it a toothed wheel, with the help of chain and sprockets power transmission system can be formed. Here, there are total five sprockets of different teeth and diameter are used to obtain required speed ratio. The sprockets are made of same material as chain(Stainless steel - 303SS).

Selection of standard size of sprocket according to required speed ratio :-

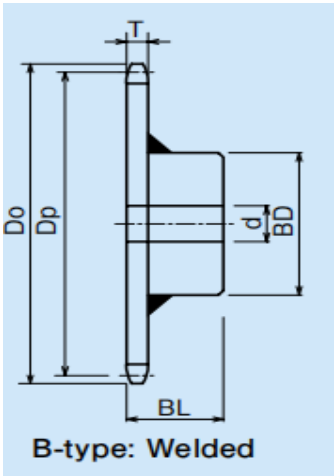
1. Motor Sprocket :-



Type of Sprocket	35 A (Steel plate Sprocket)
No of Teeth	50
Outside Diameter (D_0)	157 mm
Pitch Diameter (D_p)	151.70 mm
Shaft Bore Diameter (d)	14-15 mm
Weight (kg)	0.60
Teeth Width (T)	4.3 mm
Material	SS(T-303SS)

Fig -7: Motor sprocket

2. Free Wheel Sprocket :-



Type of Sprocket	35 B (Steel plate with hub)
No of Teeth	38
Outside Diameter (D_0)	121 mm
Pitch Diameter (D_p)	115.34 mm
Shaft Bore Diameter (d)	12-13 mm
Weight (kg)	0.37
Teeth Width (T)	4.3 mm
Material	SS(T-303SS)

Fig -8: Free wheel sprocket

3. Treadmill Roller Sprocket :-

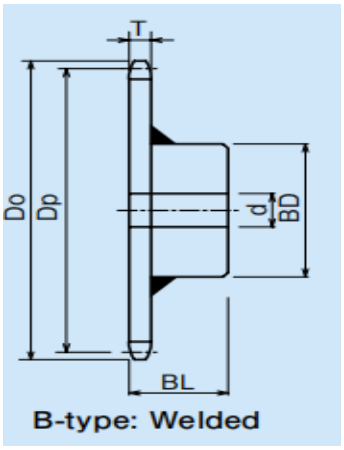


Fig -9: Treadmill roller sprocket

Type of Sprocket	35 B (Steel plate with hub)
No of Teeth	28
Outside Diameter (D_0)	90 mm
Pitch Diameter (D_p)	85.07 mm
Shaft Bore Diameter (d)	11-12 mm
Weight (kg)	0.18
Teeth Width (T)	4.3 mm
Material	SS(T-303SS)

4. Bicycle Wheel Sprocket :-

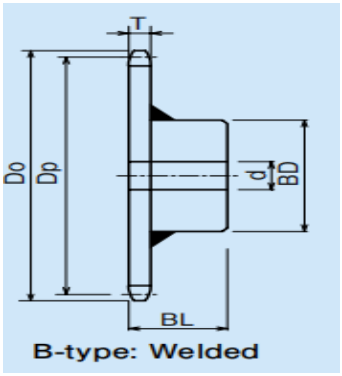


Fig -10: Bicycle wheel sprocket

Type of Sprocket	35 B (Steel plate with hub)
No of Teeth	36
Outside Diameter (D_0)	115 mm
Pitch Diameter (D_p)	109.29 mm
Shaft Bore Diameter (d)	12-13 mm
Weight (kg)	0.32
Teeth Width (T)	4.3 mm
Material	SS(T-303SS)

Calculation for speed reduction

- 1st Gear reduction ratio (Motor to Free Wheel) :-

$$i_1 = \frac{N_2}{N_1} = 1.33$$

Component	Speed (r.p.m)	No. of teeth
Motor	300	50
Free Wheel	400	38

$$\frac{N_1}{N_2} = \frac{T_2}{T_1}$$
$$\frac{300}{400} = \frac{T_2}{50}$$
$$T_2 = 38$$

- 2nd Gear reduction ratio (Free Wheel sprocket to treadmill roller sprocket) :-

$$i_2 = \frac{N_3}{N_2} = 1.365$$

Component	Speed (r.p.m)	No. of teeth
Free Wheel	400	38
Treadmill roller	546	28

$$\frac{N_3}{N_2} = \frac{T_2}{T_3}$$
$$\frac{546}{400} = \frac{38}{T_3}$$
$$T_3 = 28$$

- 3rd Gear reduction ratio (Free Wheel sprocket to bicycle sprocket) :-

$$i_3 = \frac{N_4}{N_2} = 1.05$$

Component	Speed (r.p.m)	No. of teeth
Free Wheel	400	38
Bicycle	420	36

$$\frac{N_2}{N_4} = \frac{T_4}{T_2}$$
$$\frac{400}{420} = \frac{T_4}{38}$$
$$T_4 = 36$$

- **Final Output Ratios :-**

Primary gear reduction ratio	Secondary gear reduction ratio	Final gear reduction ratio
1.33	1.365	1.05

- **Final Output Speed :-**

Primary gear reduction ratio	Secondary gear reduction ratio	Final gear reduction ratio
300	546	420

8. Steering

Steering is used to guide the direction of any vehicle. A system formed by various components like fork, handle bar, stem, etc.(specially for bicycle).The fork has a shock absorber which absorbs the jerks caused by movement of bicycle on road. Handle bar is used to guide the vehicle and also to mount break levers and hand grips. Stem is a component which connects the handle bar and fork.

Fig -11: Fork[7]

Fig -12: Stem and handle bar[8]

9. Treadmill belt

Treadmill belt is one type of belt made of rubber material, which is covered on rollers in treadmills. Runner runs or walks on this and this is rotated by any external resource. Here, single ply treadmill belt is used. It is one solid piece of rubber. The dimensions of treadmill belt are as under:

Width of belt = 500 mm
Length of belt = 2300 mm
Thickness of belt = 2 mm

Fig -13: Treadmill belt[9]

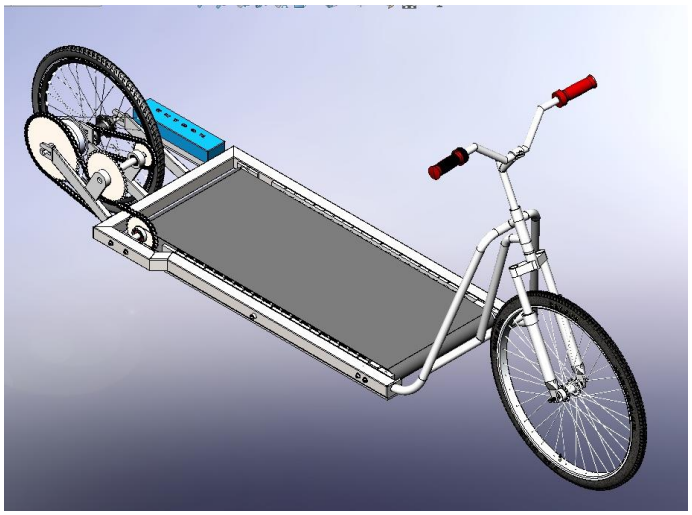


Fig -14: 3D model of treadmill bicycle

CONCLUSION

This innovation can be perfectly used for both travelling and exercising purposes. As it runs on electric energy so there is no emission, we can say it emission free device. And is also fuel saving as well. It is pleasant to those people who loves to exercise. In future, an alternator can also be added for generation of electricity to charge a battery itself while walking on the treadmill and the stored energy can be utilized in requirement of excess power.

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