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Construction and Performance Test of a Motor Driven Treadmill Bicycle

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ABSTRACT
This report is about converting a regular bicycle into a treadmill bicycle. The main intention is to build an eco-friendly vehicle that has a runway attached to a bicycle by replacing the pedal mechanism. The frame of this bicycle has been fully changed, and the treadmill has been installed between the two wheels and one extra rear wheel is added for stability. The electric motor drives the treadmill bicycle. Human effort would be needed to move the bicycle from one location to another. When the user walks on the treadmill, the belt travels to the back and rotates the treadmill rollers, which provides the initial torque. The initial power is provided by the batteries to the DC motor. The walking frame of the treadmill is slightly slanted backward to make comfortable for the person standing on it. This treadmill bicycle is less expensive than motor bikes, emit no pollutants and it is simple to use. Instead of having two different individual devices for transportation and exercise purpose, treadmill bicycle fulfills both these purposes with a single device at minimum cost. It saves a lot of space compared to the space occupied by a bicycle and a treadmill. The performance test of the treadmill bicycle is conducted on various road surfaces such as Asphalt Road, Concrete Road and Brick Road. The average speed is generally higher in asphalt road and lower in brick road.

Keywords: Physical Activity, Aerobic Exercise, Treadmill, Pedal Mechanism, Lead Acid Battery

1. Introduction

According to statistics, over one billion people are affected by chronic pain, which affects more people than diabetes, heart disease, and cancer combined. Around 40% of patients seeking care from general practitioners have pain as their primary symptom. The expenses of treating chronic pain are astronomical, with treatment-related costs and lost productivity totaling more than $100 billion [1]. Chronic pain can reduce quality of life by causing physical, relational, social, and psychological damages, in addition to financial pressure. Pharmacologic management is often the choice of medication for chronic pain; however, it does not address both physical and psychological effects of chronic pain. Opioids have been shown in an increasing body of research to fail to offer pain relief and can contribute to reduced functioning in many chronic pain patients. Despite this, opioids remain one of the most commonly prescribed medications, with over 235 million prescriptions written. With this knowledge, it's critical to raise awareness about the need of physical activity and to look into other, more integrated approaches to managing the complicated and devastating impacts of this increasingly severe condition. Although there are few known successful treatment options for chronic pain patients, incorporating alternative treatments into a traditional medical treatment plan can help manage chronic pain and minimize dependence on medicines. For several years, the recommended cure for chronic pain was inactivity and rest; however, recent research has shown that the opposite is successful [2].

Physical activity is defined as any bodily movement that necessitates the expenditure of energy and is produced by skeletal muscles. The words "physical activity" and "exercise" are not synonymous. Exercise is a disciplined, repetitive, and purposeful subcategory of physical activity. “A sound body has a sound mind,” which means that if a person is tired, dull, or ill, he will be unable to perform his duties effectively and quickly. Physical activities can be classified into two categories based on their overall impact on the human body [3]. One is aerobic exercise, which is described as any physical activity that involves the use of large muscle groups and causes the body to consume more oxygen than it would at rest. The goal of aerobic exercise is to develop cardiovascular endurance. Aerobic exercise includes cycling, swimming, quick walking, skipping rope, rowing, hiking, basketball, continuous training, and long slow distance training. Another option is anaerobic exercise, which includes strength and resistance training. These exercises help to strengthen muscles, develop bone strength, and improve balance and coordination. Strength exercises include push-ups, lunges, and dumbbell bicep curls. Anaerobic exercise improves short-term muscle strength and includes weight training, strengthening exercises, concentric training, strength exercises, sprinting, and high-intensity aerobic exercise. It can also be classified into three groups based on the intensity of the exercise, such as Light, Moderate, and Vigorous Exercise. The heart rate is commonly used to determine the duration of an exercise session. Heart rate is a good measure of how difficult the workout is on the cardiovascular system [4].

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Aerobic exercise is the most common and well-known exercise in modern times. It requires less effort, and the entire body may participate in the fat-burning process. Treadmill running is the most common aerobic exercise nowadays [5]. A treadmill is a machine that allows one to walk, run, or climb while remaining stationary. Treadmills were created before powered devices in order to use the strength of animals or humans to complete tasks. Treadmills are a form of grain mill in which grain is ground by an individual or animal traversing the steps of a treadwheel. Treadmills were later utilized in jails as torture devices for inmates sentenced to hard labor [6]. The terms treadmill and treadwheel were used interchangeably to describe the control and punishment system. Treadmills are a new type of workout machine that allows you to run or walk in one spot. Instead of the user running a mill, the system provides a moving platform with a large belt conveyor driven by an electric motor or a flywheel. The user must run or walk at the same speed as the belt when it reaches the back [7]. The speed at which the belt moves correspond to your walking or driving speed. As a result, running speed may be controlled and measured. The more costly, heavy-duty variants are motor-driven (typically by an electric motor), but the simpler, smaller, and much less expensive variants resist motion and only operate when walkers press their feet against the belt. Treadmills that are operated by hand are known as manual treadmills [8].

The project aim is to create an environmentally friendly bicycle. It is focused on cutting-edge vehicles in the future. Its sole purpose was to build "A New Way of Moving." It's a fun and eco-friendly mode of transportation. The project's moto was that everyone should be able to jog without having their shoes dirty. This bike can be driven by anyone of any age. It also had the same appearance for both men and women. People can ride this bike in any outfit, whether traditional or western. The concept behind this bike was to create a treadmill that could be used outside of the gym. Walking needs no more effort than a stroll through the park. All other advances in transportation result in higher car prices, but it was inspired to bring back the most common mode of transportation, the bicycle, on the roads in a newer and more economical way than other vehicles.

2. Construction and Methodology

2.1 Construction Procedure:

For constructing the Treadmill bicycle, the walkway was built first. The frame was rectangle in shape with dimension of 90cm × 60cm. It was made from rectangular hollow mild steel bar. The old rollers were purchased from local market to reduce the cost. Moreover, the width of the treadmill was kept 60 cm because of this. 14 rollers and a rubber belt were mounted on the frame to complete the construction of runway. After constructing the runway, a conventional hollow handle bar, fork and front wheel were assembled together with the frame. The DC motor was attached to the rear left side of the frame so that, the rubber belt might not slip over the rollers. For a DC motor calculation, rpm = 200 (assumed), Volt = 48V and Current, I = 5A.

Let, the correction factor is = 0.80

We know [4],

$$P = I \times V$$
$$P = 5 \times 48$$
$$P = 240 \text{ watt}$$
$$P = \frac{240}{0.80} \quad \text{[Dividing by the correction factor]}$$
$$P = 300 \text{ watt}$$
$$\text{HP of the Motor} = \frac{300}{745.7} \text{ hp} \quad \text{[1 hp = 745.7 watt]}$$
$$= 0.40 \text{ hp}$$

Considering the friction on the road surface it is better to choose 0.50 hp.

Again, we know [5],

$$T = \frac{5252 \times HP}{rpm}$$
$$= \frac{5252 \times 0.50}{200}$$
$$= \frac{2626}{200 \times 0.80} \quad \text{[Dividing by the correction factor]}$$
$$= 16.41 \text{ lb.ft}$$
$$= 22.32 \text{ N.m} \quad \text{[As, 1 lb. ft = 1.36 N-m]}$$

The calculated power was 0.50 hp without considering the load on the vehicle and road surface condition. So, 1 hp DC motor was used for providing the sufficient amount of power with various load and road condition.

The batteries were mounted on the rear portion of the vehicle. There were two matching spur gears. The teeth of the gears were slightly different in order to increase the initial torque. It depends on gear ratio. The number of teeth of the driver pinion was 34 and the number of teeth of the driven gear was 38.

Gear Ratio

$$= \frac{\text{Driven (A)}}{\text{Driving (B)}} = \frac{\text{No. of teeth of gear}}{\text{No. of teeth of pinion}} = \frac{34}{38}$$

=17:19

For the average speed of the chain and length of the chain,

Here,

n = 24.8 RPM

D_o = 72 mm

We know,

$$v = \frac{\pi Do \times n}{60}$$
$$v = \frac{3.1416 \times 72 \times 24.8}{60}$$
$$v = 93.44 \text{ mm/sec}$$
$$v = 0.0933 \text{ m/s}$$

Length of the chain:

Let us assume,

Central distance between the sprocket and driving gear, x = 762 mm

We know, the length of the chain must be equal to product of the number of chain links and pitch of the chain [41]. Therefore,

$$l = k \times p$$

Number of chain links [41],

$$k = \frac{t1 + t2}{2} + \frac{2x}{p} + \frac{t2 - t1}{2\Pi} \times \frac{2p}{x}$$

$$k = \frac{12+18}{2} + \frac{2\times762}{12.5} + \frac{18-12}{2\times3.1416} \times \frac{2\times12.5}{762}$$

$$k = 136.95$$

Length of the chain [41],

$$l = k \times p$$

$$l = 1643.42\ mm$$

$$l = 1.64\ m$$

On the bottom right side of the frame, the driver pinion was mounted along with the roller. Another meshing driven gear was mounted on the shaft with the driver pinion. Two bearings were used at the end of the first shaft. Two shafts were used along with a chain sprocket mechanism. Chain sprocket mechanism transmitted the power from the first shaft to the second shaft. The sprockets were different in size in order to increase the number of rotations. The two rear wheels were attached at the two ends of the rear shaft. Finally, a metal safety cover was used to cover the construction at the back portion of the Treadmill bicycle in order to avoid any unexpected accident for the user.

2.2 Operating Procedure:

The treadmill bicycle's methodology is primarily based on the notion of converting a human's linear motion on the treadmill into rotary motion of the wheels using a gear system and a DC motor. At first, the person has to walk on the treadmill walkway which was mainly controlled by a DC motor. The DC motor will rotate the roller as such the conveyor belt was also moved. The motor speed was controlled by an accelerator which was attached to the handle bar. The gear arrangement is rotated and the shaft would also rotate according to the desired direction. The sprocket mounted on the shaft, was rotated to the same direction as the shaft. There was a chain which transmitted the power to the rear wheel shaft with the help of another sprocket. The rear wheel moved to the same direction as the person was moving. The person can walk or run by increasing or decreasing the speed of the motor. If anyone wishes to use this construction only as treadmill then he or she just need to disconnect the chain from both the sprockets. This would stop the power transmission to the rear wheels from the motor. So, the treadmill would just move but the bicycle remain to its original position. While constructing the treadmill, the design was compromised for some components. Considering the material's availability and cost, the two conventional bicycle wheels were used in rear portion. As a result, the Treadmill bicycle was slightly higher than expectation. The length and width of the runway was larger than usual because a conventional treadmill platform was used to save the cost. Fig. 1, shows the block diagram of the operating procedure of Treadmill bicycle.

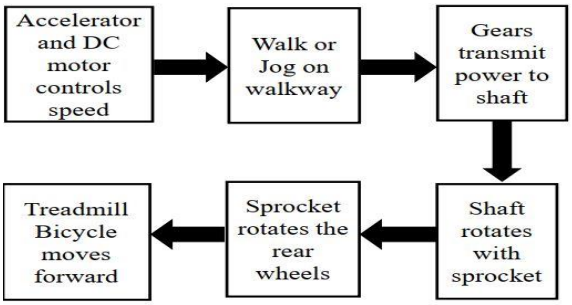

Fig. 1: Block Diagram of the operating procedure of Treadmill bicycle

2.3 Final Product:

All the procedures were completed carefully. Proposed Treadmill bicycle was constructed according to the design as much as possible. Some components were purchased from local markets. Some old components were used to reduce the cost. After construction and several modifications, the final product is shown in Fig. 2.

Fig. 2: Final Product of Treadmill bicycle

3. Experimental Procedure

Performance of the constructed Treadmill Bicycle was conducted on various road conditions. Average speed of the treadmill bicycle on various road conditions were calculated by measuring the length of the road using measuring tape. Then the time was measured by a stop watch to travel the measured distance on a particular road surface. This procedure was done several times on a specific road for more accurate result. Among all the collected data, the average value was calculated. A road mapping software was used to measure the average speed on those road surface. Finally, the deviation between experimental results and the road mapping software were calculated. Speed measurement was done on asphalt road, concrete road and bricks road.

4. Results and Discussion

4.1 Experimental Results and Discussions:

(a) Data on Asphalt Road:

Table 1: Observation-01 for Average Speed Measurement on Asphalt Road.

Exp. No.	Distance Travelled (m)	Time Required (s)	Velocity (m/s)	Avg. Speed (m/s)
01	122	40.23	3.03	3.09
02	122	38.44	3.17	
03	122	39.52	3.09	
04	122	40.12	3.04	
05	122	39.23	3.11	

From a road mapping software, the Average Speed on Asphalt Road was calculated as = 11.1 km/h. From table the average speed was 3.09 m/s or 11.34 km/h.

Fig.3: Average Speed on Asphalt Road from a Road Mapping Software

Percentage of deviation = $\frac{11.34-11.10}{11.34} \times 100\%$
= 2.22%

(b) Data on Concrete Road:

Table 2: Observation-01 for Average Speed Measurement on Concrete Road.

Exp. No.	Distance Travelled (m)	Time Required (s)	Velocity (m/s)	Avg. Speed (m/s)
01	122	46.56	2.62	2.75
02	122	42.03	2.90	
03	122	44.08	2.77	
04	122	44.23	2.76	
05	122	45.42	2.68	

From a road mapping software, the Average Speed on Concrete Road was also calculated as = 10.40 km/h. From table the average speed was 2.75 m/s or 10.40 km/h.

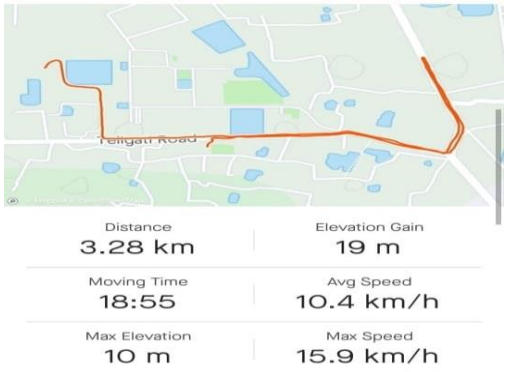

Fig. 4: Average Speed on Concrete Road from a Road Mapping Software

Percentage of Avg. Speed deviation

$= \frac{10.40-10.13}{10.13} \times 100\% = 2.67\%$

(c) Data on Brick Road:

Table 3: Observation-01 for Average Speed Measurement on Brick Road

Exp. No.	Distance Travelled (m)	Time Required (s)	Velocity (m/s)	Avg. Speed (m/s)
01	88	48.31	1.82	1.84
02	88	49.23	1.78	
03	88	48.46	1.81	
04	88	46.18	1.90	
05	88	47.02	1.87	

From a road mapping software, the Average Speed on Brick Road is = 9.60 km/h. From table the average speed was 1.84 m/s or 8.84 km/h.

Fig. 5: Average Speed on Brick Road from a Road Mapping Software

Percentage of Avg. Speed deviation = $\frac{9.60-8.84}{8.84} \times 100\%$

= 8.61%

Therefore, From the results of performance test it is shown that the average speed varies with the road surface.

Analyzing the data from the Table 1, 2 & 3, it was observed that the average speed of the treadmill bicycle varies with the road surface. The maximum average speed is found on the asphalt road and it was 3.15 m/s or 11.34 km/h. On the other hand, the minimum average speed was found on the brick road and it was 1.80 m/s or 8.84 km/h. The average speed on the concrete road was 2.77 m/s or 10.13 km/h. The minimum average speed deviation is 2.22% and it was on the asphalt road. The maximum average speed deviation was 8.61% and it was on the brick road. The average speed deviation on concrete road was 2.67%. The average speed fluctuated due to various road surface. There are some factors such as measuring the length of the experimented road, starting the stop watch in time, regulating proper speed for every observation were the reasons for deviation between experimental results and road mapping software. The deviation in brick road was slightly higher than other two roads because it was too difficult to maintain uniform speed through the whole path as the road surface was too frictional comparing with other two roads.

The treadmill bicycle is designed to perform not just as a transport but also as an exercising device. Since it is a multi-functionable device, it reduces the cost for the treadmill and a vehicle. It can fulfill the desire to travel shorter distance with burning calories at the same time by walking or running on the roller frame. Operating this type of vehicle is easy and anyone at different ages can ride this treadmill bicycle. While travelling with this bicycle the user needs to stand up onto the rolling platform, hence the user does not feel any back pain, elbow pain etc. which some people face during riding a conventional bicycle and an addition of extra rear wheel gives more stability of the vehicle. There is caliper braking system in the vehicle and it makes it easier to control the speed of the vehicle. Steering system in this vehicle is easier than others. As there is no need of fuel, the environment will not get harmed in anyway. The DC motor and the DC motor controller helps the rider to control the speed according to their capabilities. Using of mild steel frame and rollers make the structure strong enough to carry load of the vehicle as well.

As there is no fuel used, there will be no emission of CO, CO_2, N_2, and other toxic gases that can damage the ecosystem of our livings. Since it can be used both in motion or in stationary, the user may wish to use this device in their corridors or on various road surface. A curved fork is used for suspension system to ride more smoothly if the surface is rough. The battery that has used for the power supply needs to be charged after 2 or 3 days depending on the usage of the vehicle. The vehicle is basically a three-wheeler transport. But conventionally it is recognized as “Treadmill Bicycle” worldwide. Some companies named it so. This conventional name helps the companies to advertise this vehicle to the public more easily.

5. Conclusion

The treadmill bicycle is designed and constructed for more environmentally friendly and less power consuming. The overall work could be concluded as follows:

i. The design is relatively simple and user friendly.
ii. Easy to operate and easy to assemble and disassemble.
iii. Reduce human effort, saves plenty of time and energy consumption.
iv. Can operate in all area and any kind of road surfaces.
v. Fulfill not just travelling purpose, but also provide fit benefits.

No emission of toxic gases and occupy very small space.

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