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A Review on Design Developments in Bicycle

R G Dhamak [1], Prof. P S Nagare [2], Prof. A K Mishra [3]

PG Scholar, Department of Mechanical Engineering, Amrutvahini College of Engineering Sangamner, India [1]

Associate Professor, Department of Mechanical Engineering, Amrutvahini College of Engineering Sangamner, India [2,3]

Abstract: Bicycle is one of the most commonly used form of transportation in the world. It is two wheeled vehicle, powered by a rider and steered using a handle. It is considered as eco-friendlier and an economical mode of transport in the world. Existing form of bicycle is evolved from the developments in its past history. Research is carried on making the bicycle economical and more comfortable. In this review paper, various designs developed in the history of bicycle are described. This review paper summarizes an up-to-date progress in different methods for transmission of human power on the pedal to the rotation of the wheels and the major advantages and disadvantages of these transmission methods. It covers how the energy efficiency of the bicycle is calculated considering the case of a chain driven safety bicycle. It is intended to help readers to obtain a comprehensive review on design developments in bicycle.

Keywords: Bicycle, Economy, Eco-Friendly, Human Power.

I. INTRODUCTION

There were several unverified, claims for the invention of machines like bicycle. In 1493, the earliest comes from a sketch which being attributed to Gian Giacomo Caprotti. Primitive version of a bicycle sketch was surfaced in 1974 by Leonardo da Vinci. [1]

Fig -1: Caprotti sketch

A. Celerifere

It was built by Comte de Sicrac, in 1791. The Celerifere, purportedly was a hobby horse with two wheels instead of a rocker. A rider would power forward by running or walking with their feet. In 1817, German Baron, Karl Drais Von Sauerbronn invented a laufmachine, means a running machine, an improved two-wheel version of the celerifere,. It was variously called the running machine, velocipede, Draisienne and Dandy horse. It had a steer-able front wheel directing the front wheel a bit. [3]. In 1839, Kirkpatrick MacMillan built the first mechanically propelled 2-wheel vehicle. In Velocipedes, the system of driving levers and pedals that allows rider to propel the machine with feet off the ground was introduced by him.

Fig – 2: Wooden Draisine Drais' 1817

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Fig -3: A velocipede, 1819

B. Velocipede [5]

Velocipede, the bike literally a bone shaker, was manufactured with straight angles, steel wheels and stiff materials which made this bike to ride over the past cobblestone roads. The Velocipede was provided with direct drive with peddles by front wheel and a fixed gear, with one speed. This bike was also known as the bone shaker. French blacksmith, Ernest Michaux designed commercial version in 1863. In commercial design the front wheel hub was mounted with rotary cranks and pedals. [6]

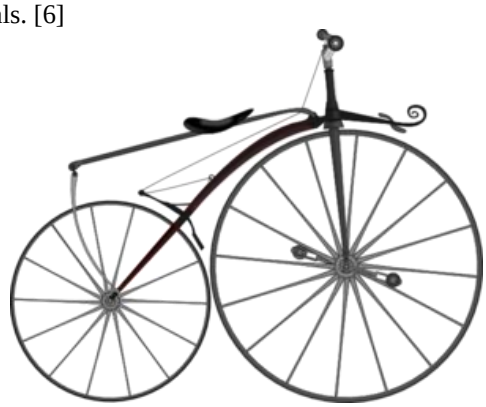

Fig -4: Bone shaker [4]

C. Ordinary or Penny Farthing [6] [7][8]

Penny Farthing was the first machine to be called a bicycle i.e. two wheels. The Penny Farthing also referred to as the ordinary bicycle was invented by a British engineer; James Starley in 1871. Penny Farthing was really efficient bicycle, consisting of a small rear wheel and large front wheel pivoting on a simple tubular frame with tires of rubber. This was the first metal machine.

Fig – 5: High Wheeler [6]

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In Penny Farthing there was no free wheel mechanism. The pedals were directly attached to the front wheel. The chance of falling was higher since, the rider sat so high above the center of gravity. Henry J. Lawson, in 1879 patents a rear wheel, chain-driven safety bicycle, the Bicyclette. In 1888, an Irish veterinarian, Dunlop, first applied the Pneumatic tire.

D. Safety Bicycle

John Kemp Staley, British inventor, in 1885 was first to design the safety bicycle with two equally-sized wheels, a steerable front wheel, and a rear wheel with chain drive. The safety bike is safer than the ordinary one. It consists of the chain and sprocket system. The speed of a huge high wheeler can be attained by adjusting the gear ratios. In the history of the bicycle, the most important change was arguably the safety bicycle.

Fig – 6: Safety Bicycle [6]

The main advantages of chain drive are that it provides improved speed as well as comfort, because the drive is transferred to the non-steering rear wheel. This allows free pedaling without causing any injury to the rider. As the four major aspects namely safety, steering, comfort and speed improved, the safety bicycles became very popular among Europe and North America in 1890s. The first bicycle that was suitable for women namely, the freedom machine, was popular among women in large numbers. The start of the 20th Century was the golden age for bicycle, as cycling had become an important means of transportation in many parts of the world. Sturmey Archer invented internal hub gears in 1903. These internal hub gears were used on bikes by 1930. In 1950s the parallelogram derailleur were introduced in the market. Tullio Campagnolo in 1930s patents the quick release hub. Also Schwinn made the fat tire, spring fork, streamline Excelsior. Almost fifty years, early mountain bikes frames were the Schwinn Excelsior model.

Fig – 7: Recumbent Bicycle

Recumbent bicycles were banned from all forms of officially sanctioned racing in the year 1934, by the Union Cycliste International. Human powered speed record on level ground in a faired recumbent streamliner in 2009 of 132 km/h was set at Battle Mountain by Sam Whittingham. Parallelogram derailleur which is being operated through cables are introduced by Tullio Campagnolo, in 1950.for two decades, it stands as a true racing bikes. Shimano introduced integrated brake and gear levers in 1990. First mass-produced hydraulic break system, commonly known as power disc was introduced in 1994 by (SRAM) Sachs. In 2000, Rohloff produced the speed derailleur system and in 2002 Campagnolo introduced 10 Co- gear clusters that allow 30 speed bicycles .

II. BICYCLE DESCRIPTION

For the safe cycling, first the rider should have an understanding of the dimensions of the bicycle and its operational characteristics. These are the critical design factors while planning both on-road and off-road bicycle facilities.

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2.1. Dimensions of a Safety Bicycle [9]

While considering the safety of bicyclists, bicycle dimensions must be taken into account, along with design and planning of bicycle facilities.

Typical bicycle are with the following dimensions

1) Handlebar height varies between 0.75 to 1.10 m
2) Width of handlebar 0.61 m
3) Length of bicycle varies between 1.5 - 1.8 m
4) Width of the tires varies from 20 mm to 60 mm with an approximate contact surface of 3 mm wide.

The study conducted by Federal Highway Administration regarding dimensions and operational characteristics of bicycles and their average physical dimensions and speeds are exhibited in Table 1.

TABLE -1: Average Dimensions and Speed of Bicycle [9]

Type	Avg. Width	Avg. Length	Avg. Speed
Bicycle	.61m	1.68 m	17 Km/h

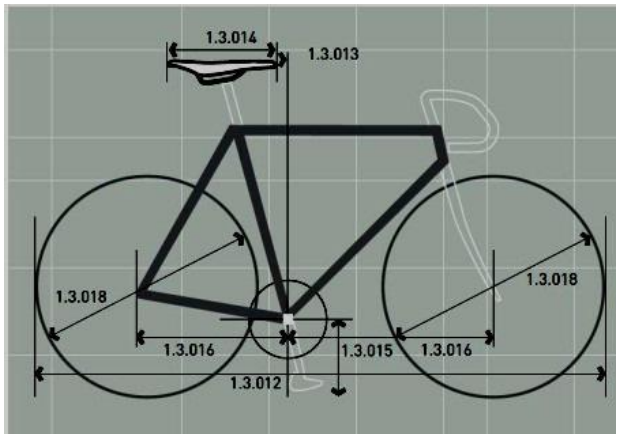

Fig – 8: Approximate dimensions of bicycle [10]

2.2. Bicycle Parts [11]

The parts of a typical bicycle are shown in figure 9.

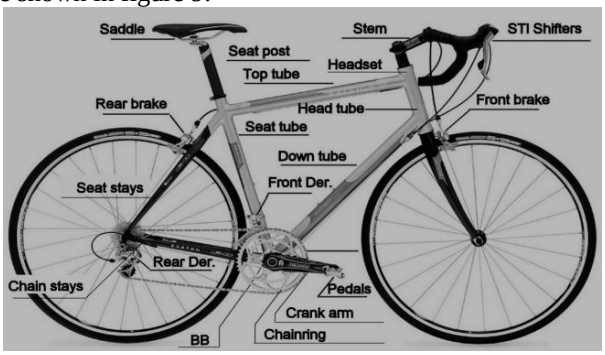

Fig – 9: Bicycles in 19th century

Bicycles are made of different parts. The main part is the frame. The core is made of metal tubes which are welded together. Tubes are named, as in figure 9.

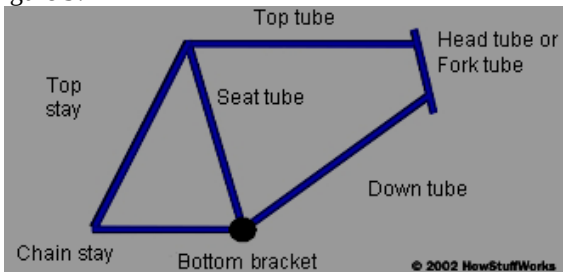

Fig – 10: Bicycle Frame [11]

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1) The movable part of the frame is the front fork which holds the front wheel.
2) The wheels are provided with the spokes, a hub along with the metal rim on which the rubber tires is provided.
3) The rider sits on the seat supported by seat post.
4) The handlebars
5) The handlebars are connected to the frame through the handlebars stem.
6) The pedals, the crank, the brake, the brake cable, the brake calipers, and the brake pads.
7) The gears and the chain drives

The ball bearings are used to reduce friction in the bicycles;
1) In wheels :- front and rear hubs
2) In the bottom bracket
3) In the fork tube
4) In the pedals
5) In the freewheel

2.3.1. Fork Tube Attachment [11]

The fork tube bearings are exhibited in figure 10.

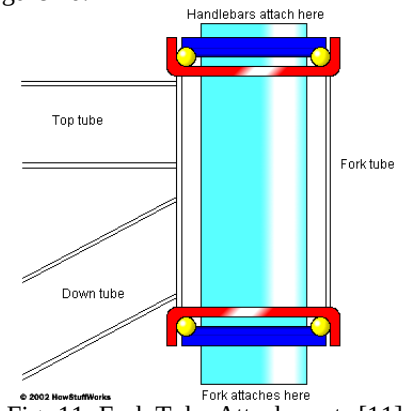

Fig -11: Fork Tube Attachments [11]

The ball bearings freely rotate in a cup. The cones are screwed on to the tube attached to the fork. The cones are tightly adjusted so that there is no play in the fork. The pedals and wheel hubs performs exactly the same way. Lubrications should be provided to the bearings for smooth working.

2.3.2 Bicycle Gears [11]

The main advantages of using gears in bicycles are that it can reduce the wheel size in diameter. Gears and gear ratios help to cover longer distance in each pedaling.

2.3.2.1 Bicycle Gear Ratios [11]

The provision of multiple gears on a bicycle is to change the distance that the bicycle moves forward with each pedal stroke. The chain wheels are known to be the gears at the front. Usually bicycles have two to three chain wheels as shown in figure 11.

Fig -12: Chain Wheels [11]

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The Freewheel has usually five to nine gears on it, depending on the bicycles. A freewheel spins freely in one direction and locks in the other, which allows the rider to either pedal or not pedal.

2.3.3 Derailleurs [11]

The gear shifting in bicycles are done with the aid of front and rear Derailleurs. The rear Derailleurs consists of two freely spinning cogs. The arm and lower cog is to tension the chain. A spring is in connection with the cog and the arm so that, the cog pulls backward all the time. When gears are changed, the changes in the angle of the arm take up.

Fig -13: Rear Derailleurs [11]

The top cog is placed close to freewheel. The adjustment of the gears on the handlebar with the provision of lever, the cog moves to a different position on freewheels, dragging the chain with it.

2.3.4 Freewheel Mechanism [11]

The simple freewheel mechanism that makes it all work common to a number of mechanical applications but particularly in transport. The design used on the majority of bicycles is a simple ratchet system that allows the bicycle wheels to keep moving forward when the pedals are kept stationary. This is a technological development first commercialized by Ernst Sachs in 1898 that forever changed the bicycle and brought about countless thrills from coasting downhill at tear inducing speeds.

Fig – 14: Freewheel Mechanism [11]

Freewheel mechanism is roughly the same with a number of spring-loaded pawls engaging with an outer ring gear in only one direction, allowing the axle and hub body to rotate freely forward within the rear cog while coasting. Press down on the pedals and the pawls firmly engage in the ring gear, allowing the drive train to power the wheel forward. The click during coasting is the pawl slipping past each tooth in the ring gear.

III. TRANSMISSION MECHANISMS USED IN BICYCLES

3.1. Chain Transmission Mechanism [12], [13].

Chain drive is used to transmit mechanical power from one place to another. It often conveys power to the wheels of bicycles.

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The drive chain or transmission chain also known as roller chain is passed over a sprocket gear, with the teeth of the gear meshing with the holes of the chain links. The gear turning results pulls the chain putting mechanical force in to the system.

TABLE -2: Advantages and Disadvantages of Chain Transmission Mechanism

Advantages	Disadvantages
Transmission system is compact	Frequent maintenance is required
Can easily adapt the multi gear system	Chance to disengage from the sprocket gear is higher
Chain gear mechanism is cheap	Slack and backlash is more

3.2. Gear Transmission Mechanism [14]

Fig -15: Gear Transmission Mechanism [14]

The power from the pedal gear is transmitted to the wheel using intermediate gear mechanisms .The gear mechanism chosen for transmission is simple spur gear.

Table-3: Advantages And Disadvantages Of Gear Transmission Mechanism

Advantages	Disadvantages
Easy maintenance and lubrication	Size of the intermittent gear is large. So the system is not compact
Less noise on riding	Slack and backlash is more

3.3. Hydraulic Transmission Mechanism

In hydraulic bicycles, power to the pedals is transmitted by means of a liquid through the tubes from a hydraulic pump and to hydraulic motor and vice versa. Hydraulic bicycles are chainless.

Table-4: Advantages And Disadvantages Of Hydraulic Transmission Mechanism

Advantages	Disadvantages
Continuously variable gearing	Heavier
No slack or backlash occurs	The overall losses is higher compared to open chain system
Mechanism is clean and operates silently	Fluid leak

3.4 String Type Transmission Mechanism [15]

In string type transmission mechanism the forward momentum is obtained when triangular swinging mechanism pulls on the rope and rotates a drum on the wheel. The freewheel mechanisms is provided on either side of the rear wheel which is connected by polyethylene rope to the swinging arm. When one unit on the right is driving the bicycle forward, the other is being returned to its starting position and vice-versa.

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Fig -16: String Type Transmission Mechanism [15]

TABLE- 5: Advantages and Disadvantages of String Type Transmission Mechanism

Advantages	Disadvantages
Efficient compared to chain and gear drives.	Outer casing and swinging arm should need more attention.

3.5 Shaft Type Transmission Mechanism [16]

A chainless transmission mechanism for bicycle, comprising a front casing, a driving shaft rotatable mounted inside front casing and connected to a pedal of the bicycle, a first bevel gear fixedly mounted on said driving shaft, a rear casing, a rear-wheel hub mounted in said rear casing, a transmission shaft rotatable supported between said front casing and rear casing, a second bevel gear fixedly mounted on one end of the transmission shaft and meshed with the first bevel gear, a third bevel gear fixedly mounted on an opposite end of said transmission shaft and suspending in rear casing, and a fourth bevel gear sleeved onto a rear-wheel axle in rear-wheel hub and locked there to.

Rear-wheel axle comprises a first locating groove extending around the periphery thereof and a second locating groove axially extending across said first locating groove; said fourth bevel gear comprises an inside locating groove and a plurality of screw holes equi angularly spaced from one another and radially extending through inside and outside walls thereof; a locating rod is inserted into the inside locating groove of said fourth bevel gear and the second locating groove of said rear-wheel axle to prohibit rotation of said fourth bevel gear relative to rear-wheel axle; a plurality of screw rods are respectively threaded into the screw holes of fourth bevel gear and engaged into the first locating groove of said rear-wheel axle to prohibit axial displacement of fourth bevel gear relative to rear-wheel axle.

IV. CONCLUSION

Lots of research is being done to reduce the efforts required to drive the bicycle. The history of bicycle and its development is discussed in this paper. Different methods of transmission of human power on the pedal to the rotation of the wheels are discussed and the major advantages and disadvantages of these transmission methods are listed out. Generally, new mechanisms should be developed such that the design should be eco- friendly and more energy efficient.

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