Bicycle transmissions

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Abstract. Nowadays the bicycle is considered both a means of transport and recreation. In order to improve bicycle performance, various drive mechanisms have been proposed. In the present paper these mechanisms are presented and analyzed. Bikes have undergone periodic transformations since the first model called the "Celerifer" made in 1790 to the present day where the drive mechanisms have been modified and made of different materials. For the movement of the bicycle, different types of actuation mechanisms have been used since the early years of the apparatus and the use of the bicycle. The most widely used and known transmission is chain transmission that is widely distributed, found to be used in almost all types of bicycles . It is also important to know that we also use gears and cardan shafts.
The classic, pedal and chain drive mechanism has the disadvantage of providing an inconstant torque moment to the engine wheel. This disadvantage is particularly noticeable when climbing the slopes or walking on rough terrain. In the paper are presented and analyzed mechanisms that can reduce this disadvantage. There are patented mechanisms, capable of providing a moment of cavity-constant torsion to the wheel. For their action, the movement of the legs is a natural one, close to that of walking, compared to the rotational movement made by the legs for the action of the classic mechanism.All of these changes in drive mechanisms lead to increased bicycle performance.

1. Introduction
Between small-distance means of transport, with man-operated vehicles, the most important place is the bicycle. The article presents the appearance and development of the bicycle, the mechanisms for its action, as well as cycling. Throughout this period the bicycle has undergone various aesthetic and technical changes.

Nowadays, the bicycle is defiled as a two-wheeled, in-line road vehicle, one behind the other, set in motion by two foot pedal-operated pedals.

2. Brief history
The history of the bike begins with the "celerifer", considered the ancestor of the bike. It was invented in 1790 by the French Count Sivra by attaching two carriages to a wooden frame. The movement was made by pushing the feet into the ground.

It is not known who first attached the bicycle pedals. Some testimonies point to the Scots of K. MacMillan (1839) or G. Dalzell (1845), but there is no clear evidence to that effect. The attachment of the pedals to the front wheel hub (1862) is attributed to the French P. Lallement, who built the bicycle called "Drezina". This is how the high-richer bike has been developed, with the front wheel with maximum diameter (limited only by the foot of the cyclist's foot), powered by pedals mounted directly on the wheel hub. In order to reduce the weight of the bicycle and to make it easier to climb, the front wheel has remained small compared to the front wheel. In this category we can mention the unequal wheels produced by James Starley, William Hillman, Adolphe Clement.

Thus, the need to achieve higher speeds led in the first phase to the direct drive of the front wheel and to the exaggerated increase in its diameter (at a complete rotation of the bicycle pedals advance with a distance roughly equal to the circumference of the large wheel).

These drums had the following disadvantages:

- difficult climb in it;
- unstable balance due to the too high center of gravity;
- difficult cornering.

A remarkable improvement of the bike was to move the front and rear wheel drive using a multiplier chain transmission. In the first models, such as the "Rudge" bicycle (launched in 1877), traditionally the front wheel remains significantly larger in diameter than the rear wheel. Some of these shortcomings have been removed on the "Hamber Saffetty" bicycle, which appeared in 1884, currently in a museum in London. The modern bicycle takes shape in 1885, when John Starley built the bicycle called "Rover Safety", which had almost equal wheels and chain transmission on the rear wheel. Even in this model the bicyclist was too far off the wheel, which was uncomfortable, but the risk of falling was minimal. In addition, friction was reduced by the use of ball bearings. However comfort is still desirable because the tires were made of solid rubber. However, John Starley has revolutionized the configuration of the bike, which is still preserved. It is officially considered that the year that the contemporary bicycle was born is 1900 and that since then both components and shape are preserved, without any major changes.

The advances made in the twentieth century in the field of bicycle conception have been reduced to a series of minimal perfections, consisting in particular in the improvement of materials and manufacturing technologies and, to a lesser extent, the product's structure.

3.Bicycle types

There is currently an extensive range of bicycles, as shown by the following classification.

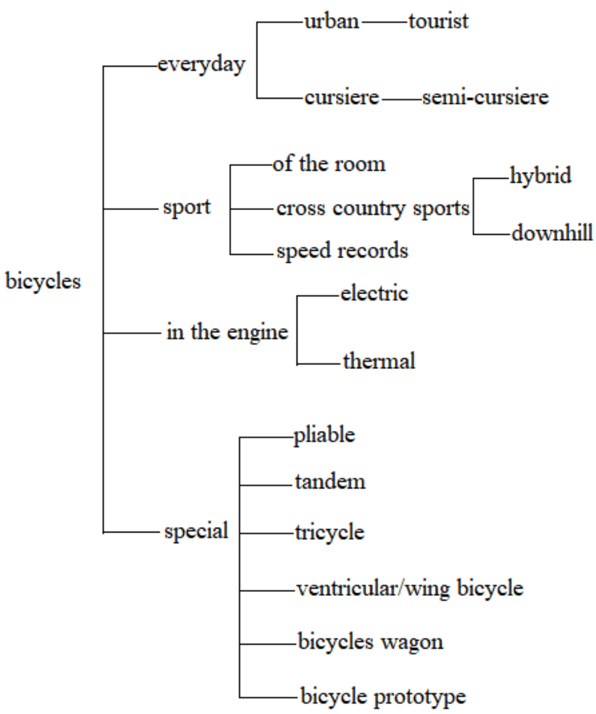

Figure 1. Types of bicycles

4.Bicycle Transmissions

Bicycle transmission can be done as follows:

- chain;
- with toothed belts;
- with cardan shaft

Chain transmission is the most common, found to be used in almost all types of bicycles. The movement is transmitted by winding and engaging the chain wheel chain mounted on two shafts.

Figure 2. Chain transmission

a-chain ,b- sheet, c- pinion, d- back wheel bicycle.

Advantages of chain transmission are:

- avoid slipping;
- transmission of large forces;
- the length of the training;
- making gearshifts to drive the chain on pinions and sheets.

Chain transmission also has drawbacks:

- produces noise;
- has a relatively high weight;
- is relatively expensive;
- requires regular chain maintenance (lubrication), etc.

Toothed belt has replaced the classic chain with some bike models and even some motorcycles (Harley Davidson) and its use is gradually increasing. Instead of the pinion and the sheet, two gears are mounted. The transmission strap is made of carbon fiber reinforced rubber. Probably for this reason in English it is called "carbon belt drive".

Compared to chain transmission, transmission through the toothed belt has the following advantages:

- low wear;
- minimal maintenance;
- silent running;
- lower weight;
- longer life.

The drawbacks of the toothed belt are the following:

- is weather-sensitive;
- has a high price (thanks to carbon fiber reinforcement);

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- has the widest width;
- there are few producers on the market.

Cardan shaft transmission is an older solution that tends to return to fashion. The movement is also transmitted to the rear wheel, but with a cardan shaft.
The advantages of this transmission are:

- looks nice;
- transmits high moments without relative slides;
- it is well protected from weathering;
- remove the chain, sheets and pinions;
- it is silent.

The disadvantages of cardan shaft transmission are:

- high cost;
- increased weight, etc.

The most common mechanism for cycling is the pedal that performs a circular motion and chain drive or toothed belt at the rear wheel hub.
Advantages of this drive mechanism are:

- is simple;
- it is reliable;
- has easy maintenance.

The main disadvantage of the above mechanism is that the moment of torsion transmitted to the rear wheel is not conspicuous.

5. Mechanisms for bicycle action
Various types of actuation mechanisms have been used to move the bicycle since the early years of the apparatus and use of the bicycle.

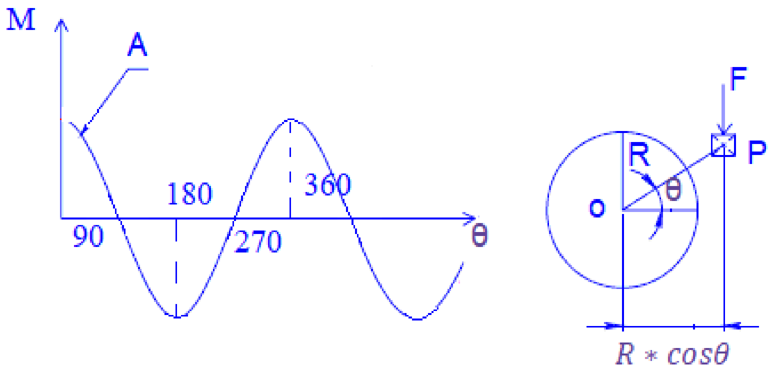
The classic mechanism for driving a bicycle has the disadvantage of not transmitting a torque constant to the wheel. The mechanism currently used for the transmission of bicycles provides a moment of inconstant torque. If the pedal force F is considered to be uniform, then the torsion moment varies cosine-like, as in the figure. 2(when the pedal is in horizontal position, the moment is maximum, and when it is in the upright position it is null).

If the pushing force F is constant, a moment is made:

$$M_t = FR\cos\theta$$

Extreme cases:

- the horizontal pedal ($\theta = 0$), the moment is maximum. ($M = F \cdot R$)
- the vertical pedal ($\theta = 90°$), the moment is null. ($M = 0$)



a) b)

Figure 3. Torque variation according to the pedal angle for the classic mechanism, [14]. a) Torque variation according to the pedal angle, b) Classic drive mechanism

In reality, the force F is not absolutely constant over the duration of a complete rotation.The surface cupped between the diagram given by the function $M(\theta)$ and the θ axis is proportional to the mechanical work performed. Some mechanisms have a larger surface (that is to say, provide more mechanical work) compared to the classic bicycle transmission mechanism. This diagram shows (θ) which is the angle of rotation of the shaft, (M) moment and (A) classic mechanism.

There are mechanisms of action at which the movement of the feet is a natural one, close to that of walking, compared to the movement of the rotation made by the legs to the action of the classic mechanism. To overcome the disadvantages described above, many types of bicycle drive mechanisms have been designed and built.

To improve bicycle performance, several drive mechanisms have been patented in our country and other patent applications are under review. Prof. Vitalie Belousov from "Gheorghe Asachi" Technical University of Iasi patented and tested a bicycle drive mechanism with pedaling pendulum. Although the movement of the legs is quite natural, similar to walking, the pedals also act on a classic bicycle mechanism.

Some of these mechanisms, which could awaken the interest of bicycle builders and inventors. Most of these mechanisms resulted from the abandonment of the crank mechanism and the rotary pedal, at which the engine moment varies during a half-turn, from a minimum in the upper pedal position, to a maximum at a horizontal position and then again to a minimum in the lower position. The force on the motor wheel ranging from sinusoidal, the bicycle acting by pulses.

These mechanisms to make the most of the pedal in the optimal position in order to obtain the maximum efficiency of the rider-bicycle assembly. Following the way the cyclist's legs acted, and the kinematic form or created different mechanisms. The mechanisms emphasized the movement of legs and kinematic solutions. Will be remembered by known mechanisms and will briefly present a rack mechanism that wants to eliminate the loss of force transmitted to the wheel.

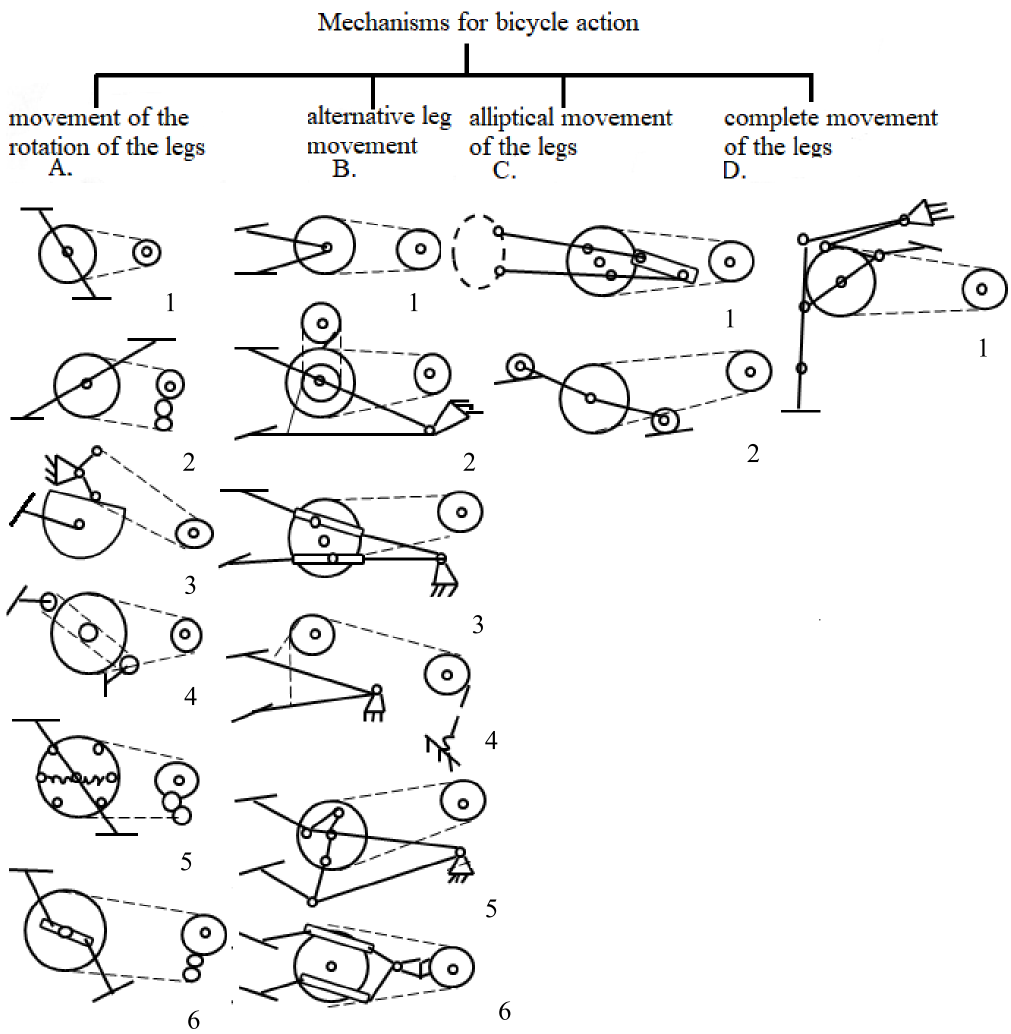


Figure 4. Bicycle drive mechanisms, [16].

The mechanisms shown in the figure 3 are the following;
A.1. Mechanism with rotating cranks, offset by 180 and pedals, having the advantage of constructive-functional simplicity;
A.2. Mechanism with rotary cranks, 180 ° and pedals, with elliptical motor chain wheel;
A.3.Mechanism with independent rotating pedals and cams, for the movement of the rotation movement of the legs in an alternative movement of a chain;
A.4. Mechanism with rotating cranks and pedals decoupled in front;
A.5. Mechanism with crank and variable transmission ratio depending on the load;
A.6. Mechanism with oscillating toothed plate and variable cycle ratio;
B.1. Mechanism with oscillating cranks and pedals, acting alternately by means of ratchets or couplings;
B.2. Mechanism with swinging cranks and pedals, with rattles attached to a chain wrapped around two chain wheels;
B.3. Lever-oscillation-sliding-double-inverse mechanism;

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B.4.Lever-oscillating mechanism with cable and ratchet drum.
B.5. Double articulated quadrangular mechanism with pedals located at the ends of the two swingers;
B6. Lever-oscillating mechanism and double-reversed-profile;
C.1. Lever-oscillating mechanism with crank and roller with fixed cam;
C.2. Mechanism with crank and pedals fixed on free-rotatable rings;
D.1. Mechanism with normal rotation.

US 3891235 A discloses a bicycle drive mechanism consisting of two pinions provided with a ratchet, mounted on the rear wheel axle for one-way rotation, the drive being made by chains running over two pairs (left, right), upper and lower. Chains are driven by the two pedals through a rectilinear motion, which is broken by means of a cable as it passes over some pulleys, the movement of the pedals being achieved by means of slides that can pend through some arched guide channels, varying the direction of motion of the pedals to the vertical.

The bicycle drive mechanism of US patent 651244 A consists of two rods attached to the top of the seam tube, and at the bottom in some guide bushings fixed by the chain drive shaft hub. Rods at the bottom are fitted with rackets that engage with gears. At the outer part of the bush there are other dependent guides, in which two rods, provided at the top with some arches, are moved, and at the bottom with pedals and rackets that engage with some gears with ratchet, which in turn train some pinions fixed to the drive shaft and transmitting the rear wheel movement through a chain and another toothed wheel, also fixed by the spindle.

It is also known document US 6412802 B1 discloses a bicycle rectilinear propulsion mechanism consisting of a pedal-driven rack guide assembly which engages with some gears of gears fixed to the drive gear of a gear wheel rotation to the rear sprocket. A clutch clutch is mounted on the drive shaft to allow one-way rotation, and the racking of the racks is accomplished by means of a cable passing over some pulleys.

In order to drive the bicycle with a quasi-constant torque, it is also known the mechanism of the patent RO 118408 B, in which the pedals act on racks that engage with a cylindrical toothed wheel, the wheels being fixed to a shaft supported by the frame by means of some bearings and transmitting the alternating rotation motion of unisens couplings which work in opposite directions and are fixed to the shaft and which transmit the motion to two conical toothed wheels on the shaft, both wheels engaging with a conical pinion, from which the movement is transmitted to the rear wheel hub, through a cardan shaft and conical gears

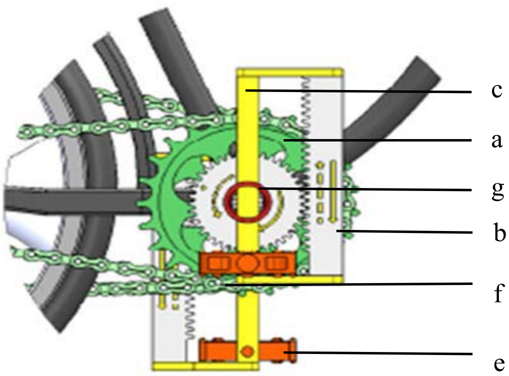

Figure 5. Quasi-dynamic drive mechanism, [14].

a-motor chain wheel, b- rack, c- guide rod, d- tooth wheel, e- pedal, f- chain, g- guide.

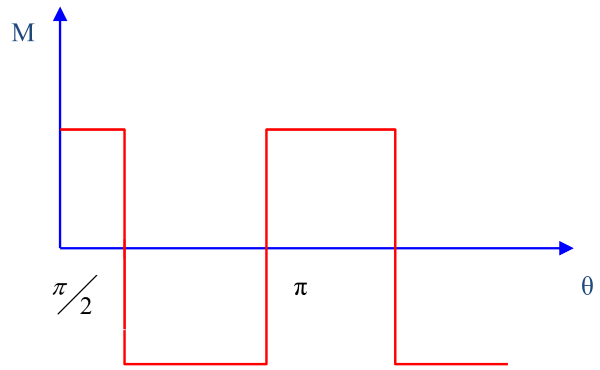

Figure 6. Torque-angle torque diagram, [14].

Document RO 118408 B discloses a bicycle drive mechanism formed by some pedals acting on racks that engage with a cylindrical toothed wheel in diametrically opposed points. The wheels are fixed to a frame-supported shaft by means of a bearing, and they transmit the alternating rotation motion to unisensed couplings, working in opposite directions, fixed to the shaft, and transmitting motion to some conical gears that are free on the shaft. Both wheels engage with a conical pinion, from which the movement is transmitted to the rear wheel hub by known means.

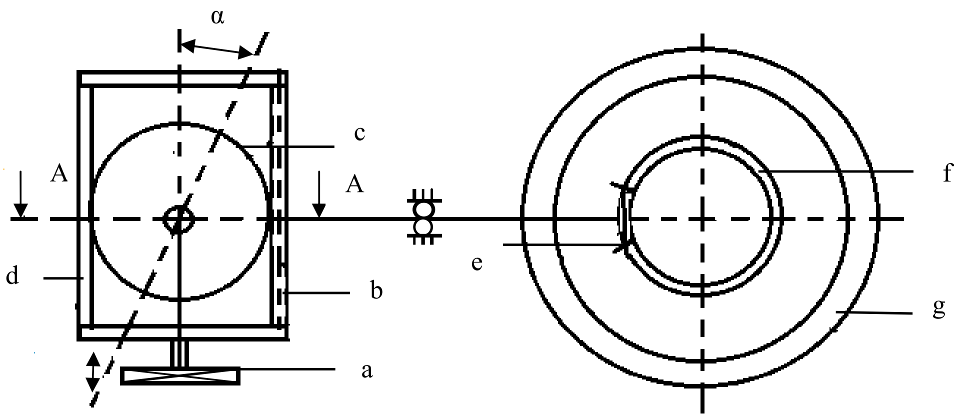

Figure 7. Cardan shaft drive mechanism, [12].

a-pedal, b- rack, c- toothed sheet, d- cardan shaft, e- pinion conical, f- rod, , g- back wheel bicycle

6.Conclusions:
In conclusion, in almost 200 years of existence, the bike has evolved and has diversified a lot. Today it is a cheap, reliable, easy to maintain and non-polluting means of transport. Equally, the bicycle is also used in sports.

We meet both the advantages and disadvantages of these patents mentioned above. As a first disadvantage to the patent mechanism is that only the foot that performs the downward stroke acts on the drive wheel, the upward pedal does not convey this movement due to the fact that they are connected by a flexible cable and pulleys which transmit only the forcing force and not compression.

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Because only the force acting on a pedal on the drive wheel the torque is lower compared to the solutions presented in the Romanian patents. This disadvantage is eliminated in the case of the patented mechanisms in Romania because the pedal acts on two racks that are not connected by a flexible cable (cable), both the downward and the upward movement transmit motion to the drive wheel. As a result, the couple is larger than patents in the United States.

The advantages of the Romanian patents are quite convincing. We encounter quasi-instant torque, there is no need for a certain positioning when starting the bike. Also, in bicycle competitions, we encounter walking in stairs, this being done only by transferring weights from one foot to another (alternation drive) compared to the classic mechanism where the pedals have to execute a complete circle or the pendulum drive mechanism to which I must move on a circle arc. This saves the rider's effort in the maximum demand stages.

At the mechanisms of the Romanian patents, the pedals can be operated vertically or at another angle that can be changed during driving. In the cardan shaft mechanism, the chain will be removed as a less reliable assembly and the incidents caused by the chain output from gearing with toothed or pinion gears will be prevented. The chain has a limited life span and should be replaced with this time.

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