## Eureka - the bicycle

This article is dedicated to one of the latest inventions in the field of bicycle construction, namely, the bicycle stepped mechanical transmission. Why do people still continue to “reinvent the bicycle” and is it worth spending your precious time to get acquainted with an innovation in such a seemingly insignificant sphere as the bicycle industry? Let us, at the beginning of the article, try to open the scale of the raised question.

It has already happened so that practically all over the world, except for the countries of the former Soviet Union, the bicycle has firmly entered the life of modern man as one of the most important items of everyday use. In developed countries, the bicycle is the most optimal combination of a general-development sports equipment and a universal tourist vehicle, in developing countries, the bicycle is mainly an efficient means of transportation. Moreover, in the last decade, there has been a tendency of geographical universalization in the use of different types of bicycles. In Western Europe, “cycle rickshaws” and entire bicycle districts with limited automobile traffic have appeared, and in Asia, bicycle tourism has started to develop intensively. The market for bicycles of various modifications is steadily growing and, paradoxically, the world's economic turmoil is only spurring its growth.

According to the most cautious estimates, more than a billion bicycles are used worldwide. Its affordability, lightness, small size, lack of fuel requirements, relative safety, and good ratio of effort to speed have made it the most common means of transportation. Approximately 70% of all bicycles serve as a means of transportation, 29% are used for recreation and only 1% for sporting events.

In some countries, the bicycle is the primary means of short-distance transportation, for example, in China, traffic controllers on the busiest urban routes in China observe an average of 10,000 cyclists per hour.

In 2005, a UK public opinion poll ranked the bicycle as the greatest technical invention since 1800.

Among industrialized countries, bicycles are the most popular among residents of Western Europe: 115 million people have bicycles there, and many amateurs use several bicycles for different purposes. Thanks to specially created conditions - bicycle lanes, parking places, along with efficient organization of traffic flows and freight transport - bicycles are used for urban mobility up to 50% of the time. Bicycles are also very popular in the United States, although there they are used more for weekend recreation and tourism.

The very realization of the urgent need to improve the main one in use at the moment, the so-called “external” stepped bicycle drivetrain, occurred in the sunny and dusty Crimea. It was the Crimean extreme field conditions, with their complex of unfavorable factors of influence on the open shifting system, forced to think about options for its improvement.

The mentioned design of the bicycle transmission has already quite a respectable technical age, because it was invented in 1950 by the famous Italian cyclist Tullio Campagnolo (en:Tullio Campagnolo). For more than half a century since its appearance, mankind has managed to explore the nearest space, create and change several generations of much more complex technical devices, and this transmission design remains just an incredible longevity.

For correctness of presentation and supposing that not every reader completely owns the subject of presentation, let's briefly describe “external” transmission.

In this transmission, the sprockets (both rear and front) are mounted in blocks. The front sprocket block is called a system, the rear sprocket block is called a cassette. Shifting is accomplished by laterally shifting the chain to the desired sprocket. The rear derailleur is equipped with a special tensioning device to ensure even tensioning of the chain at different gear ratios. The bicycle can be equipped with 3 to 11 sprockets and 1-3 front sprockets, thus providing up to 33 gears.

However, the gears often overlap (e.g. the 32/16 and 22/11 positions are equivalent); but this overlap is necessary for more comfortable and smooth shifting. The shifters are controlled by cable tension, which is adjusted by special shift knobs, usually located on the handlebars.

The main advantage of the now classic “external” stepped mechanical transmission is that it provides a wide range of gear ratio changes and is a good value for money for most cyclists.

There are considerably more disadvantages to this system. Let's start with the fact that to properly control such a bike you need to acquire certain skills, which different people develop differently.
In addition, the open arrangement of rather wide sprocket cassettes in this transmission, allows them to be exposed to the full range of unfavorable external factors, the most unpleasant of which are mechanical shocks. Active cyclists spend a lot of time servicing, adjusting, maintaining and repairing complex shifting systems. While most ordinary cyclists do not have the

simplest skills to repair and maintain bicycle mechanisms. Working the chain under constant misalignment and the influence of unfavorable external factors does not contribute to its longevity.

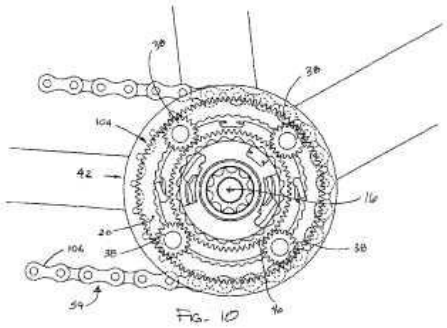
A certain spread and placed on the axle of the rear wheel planetary gearbox or variator gears. These transmissions are mainly used by cyclists in Europe and America. Compared to “external” transmissions, these transmissions are housed in a sealed enclosure and are more comfortable to operate.

The leading manufacturers of planetary shifters are Shimano, SRAM and Rohloff.

The main disadvantage of planetary mechanisms is that at relatively high cost they require careful handling, do not allow prolonged exposure to high loads and temperature rise inside the sealed gearbox housing. Due to the relatively high weight of the hub and its location on the place of not sprung axis of the rear wheel, when the wheel jumping off obstacles or running over them, the gears of the gearbox are exposed to dynamic shock loads, leading to the destruction of bearings and gear teeth.  Therefore, cyclists use them for leisurely rides on not very rough terrain. Self-maintenance is available only for the simplest three-stage planetary gearboxes. Because of these disadvantages, such a complex and expensive transmission design could not get widespread use.

Variator transmissions, to an even greater extent, have all the disadvantages of planetary transmissions and, in addition, add their own - a relatively short service life and efficiency losses due to friction of friction surfaces.

We are also aware of several patented variants of planetary gearbox placement in the pedal-crank area of a bicycle. It is difficult to judge about disadvantages or advantages of these designs, because they have not yet been produced in metal, but their design complexity is noticeable from the description.  Here, for example, is a patent of the American company SRAM CORP.  EP1980484 (A1) 2008-10-15,




only in the description of the design contains more than a hundred and thirty kinematic elements, when organizing production this number may triple, which does not contribute to competitiveness in terms of price and durability.

Simplicity of management and operational durability, the lack of need for regular maintenance of conventional road bicycles leads to the fact that even in countries with a developed bicycle culture, the overwhelming number of cycling enthusiasts ride them. It is safe to say that for developed western countries, the price of a bicycle is not such a determining factor as it is in our country. A quality-made ordinary road bike with a single-stage transmission can serve its owner for years without requiring any maintenance and adjustments.

Despite the really huge market for bicycles of various designs and purposes, it is very narrow in terms of the drivetrains used on them, and most of the bicycles produced have a simple single-stage transmission. Therefore, there is a need for a bicycle with a durable and reliable multi-stage transmission, relatively easy to maintain and repair, and housed in a closed housing.
At this point it should be emphasized that Honda's motorcycle division was the first to design a bicycle to this specification.


In their HONDA RN01 mountain bike, shown in the photo, they also placed the torque-conversion mechanism in a protected housing, which in turn is mounted in a space frame at the bike's center of gravity. There's no point in analyzing this excellent design in detail, just its excellent geometry and the fact that the engineers didn't try to change the drivetrain itself by inserting a traditional cassette mechanism into the housing.

In our design, the gearbox housing integrated into the base of the frame increases its rigidity, and on the axle of the rear wheel it becomes possible to

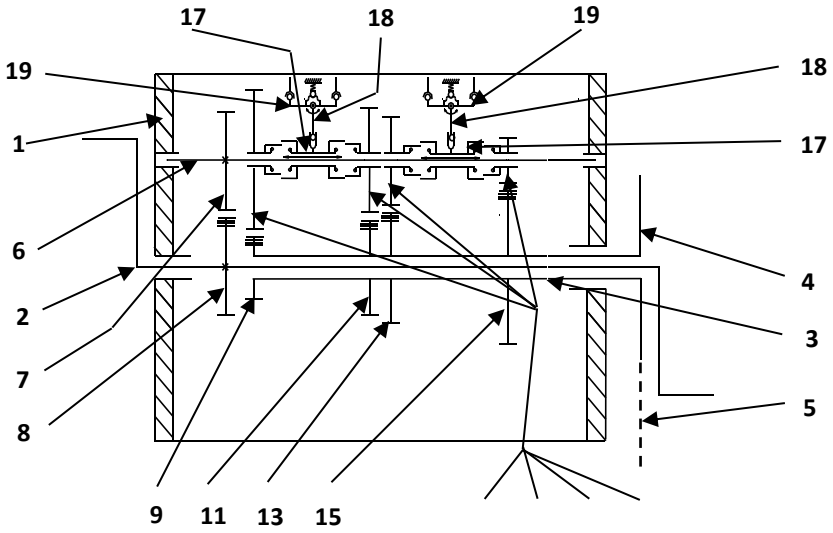
use a conventional “torpedo” type brake hub. Comfortable one-step gear shifting is realized on a bicycle handlebar.

The essence of the invention is explained by the following kinematic diagram. The bicycle stepped mechanical transmission is integrated into the lower part of the bicycle frame. For this purpose, it has a housing 1 integrated into the lower part of the frame, the housing accommodates a primary shaft 2, which is at the same time the shaft of the pedal crank mechanism of the bicycle, and an output shaft 3, made with the possibility of connecting it to a device for transmitting torque to the drive shaft of the bicycle through a drive sprocket 4 of the bicycle chain mechanism 5 placed thereon. The output shaft 3 is made tubular, and the primary shaft 2 is installed coaxially therewith in its cavity. On the one hand, the primary shaft 2 of the transmission is supported on the housing 1 through a bearing, and on the other hand, through a bearing on the inner diameter of the output tubular shaft 3. In the housing 1 is also fixed intermediate shaft 6, which on both sides through bearings rests on the housing 1 and is mounted parallel to the primary shaft i output shaft. On the shafts 2, 3, 6 installed four blocks of pairs of pairs of toothed gears (7 - 16) external meshing, which form a gearbox. Blocks of gears have gear ratios of the required value, of which gears 7, 8 of one block are rigidly fixed, respectively, on the primary and intermediate shafts and permanently fastened together. Four gears 9, 11, 13, 15 from each of the pairs of gears of other blocks are rigidly fixed on the output shaft 3, they are made with increasing diameters opposite to the diameters of the gears of the intermediate shaft 6. Gears 10, 12, 14, 16, are mounted on the intermediate shaft 6 and freely rotate on it. Meshing with the corresponding gears 9, 11, 13, 15 of the output shaft 3, they form four pinion gears of external meshing with specified ratios. Transmission contains a device for shifting gears, installed in the body 1 and is made in the form of controlled slotted slider couplings 17, with made in them in the annular grooves in which they are inserted vilchasti driver 18, having a given angle of rotation around its axis, at the other end of which are attached to the kingpins 19, which are driven into rotation by flexible cables from the gear selection conductor placed on the steering wheel and conventionally not shown. Couplings splines rigidly connected to the intermediate shaft 6 in the direction of rotation, but are able to move on them along the axis of rotation to enter into mesh with one of the four gears 10, 12, 14, 16, which have counter slotted grooves, made with the possibility of rigid fixation of gears 10, 12, 14, 16 on the intermediate shaft.

The bicycle stepped mechanical transmission operates as follows. The cyclist, rotating the crank pedal mechanism with shaft 3, drives the intermediate shaft 6 of the transmission through gears 7, 8. From the intermediate shaft of the transmission, the torque can be transmitted to the output tubular shaft 3 of the transmission by one of four possible pinion gears (10-9, 12-11, 14-13, 16-15) with different ratios. By moving the gear selection conductor into the appropriate position, via the flexible cables and the driver 18, the cyclist engages one of the two sliding clutches 17 with one of the four gears 10, 12, 14, 16, which were previously freely rotating on the intermediate shaft 6. Thus, from the intermediate shaft, through the splines, the torque is transmitted to the sliding clutch 17, then through the splined connection between the sliding clutch and the corresponding pinion to one of the pinions of the intermediate shaft, then through the pinion gear the torque is transmitted to the output

tubular shaft 3, from it to the drive sprocket 4, which through the bicycle chain 5 drives the drive wheel of the bicycle.

In order to prevent spontaneous disengagement of gears, the drivers 18 of the gearshift device are equipped with a three-way spring lock which, with a spring-determined force, fixes the slider clutch in one of three positions: two extreme positions - when engaging gears and the middle one - neutral.




**In this way, we get a bicycle that is:**

- comfortable to ride thanks to the ability, without any special skills, to change gears instantly and to brake by applying backward force to the pedals as in a normal road bike;
- a sealed housing and lubrication system protects the drivetrain from external damaging factors.
-technologically simple, allowing for quick mass production at an affordable price.
- reliable and durable as a conventional road bike, but with the traction and speed capabilities provided by multistage transmissions.
- with a torque conversion ratio of up to 700%.

This is the first bicycle drivetrain that can be applied to a cargo tricycle like a cycle rickshaw. The copyright for this transmission is already protected by the state patent of Ukraine and international patent under the PCT system.

Based on the above, we can assume that the bicycle possessing the transmission with the stated performance properties, will be in demand among cycling enthusiasts of various directions and will take a worthy place in the world market of bicycle products.

## For video demonstrations of the prototype, visit:

- Demo Video 1
- Bicycle Revolution
- Transmission Revolution