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CONCEPT OF REDUCING BATTERY CONSUMPTION AND INCREASE THE EFFICIENCY OF E-BIKES BY USING GENERATOR

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Abstract—In this research and prototype, shows the effectiveness of reducing battery consumption and increasing the efficiency of e-bikes. The prototype uses a combination of the generator at the front wheel and the motor at the back wheel. This charges the battery while in motion because it can convert the front wheel mechanical energy into electrical energy, which can then be used to charge the battery. This is particularly useful in situations where there is no access to an electrical outlet, or when the battery needs to be charged while on the move. The results show that the system was effective in reducing battery consumption by up to 19.3%, while also improving the overall efficiency of the e-bikes.

Keywords— E-bike, prototype, body frame, Dc motor, Generator, Controller, Battery, Supercapacitor, Chain and sprocket. E-bike efficiency, Battery consumption.

I. INTRODUCTION

An electric bicycle is a type of electric vehicle based on a traditional bicycle to which an electric motor has been added to help propel it [1]. It is an ecological and urban means of transport and its source of energy is a battery. In the 20th century, electric bicycles began to play a more important role because they were an economic and simple option for urban transport problems and had environmental advantages [2], especially in highly populated countries like China [3]. To highlight this fact, it is enough to indicate that over 31 million e-bikes were sold in 2012 [4]. The main advantages of an electric bicycle are both economic and environmental. Among the economic advantages we can find the total cost per kilometer traveled by an electric bicycle (including the energy, purchasing and maintenance), is less than 0.7 cents, compared to \$0.031/km for a gasoline scooter [5], or \$0.62/km traveled by car.

The batteries of the electric bicycles can be recharged by connecting them to a plug or when pedaling in some gears. In addition, a typical electric bicycle needs 6–8 h to charge the battery [6]

and has a range of travel of 35 to 50 km at a speed of about 20 km/h (depending on rider weight) [7]. This means that, with a single battery charge, it would be enough to go to work, visit friends, and return home on a normal day, since statistics show that about half of the trips and procedures of a normal urban person are carried out within a distance of 15 km from his/her house, therefore within the reach of these bicycles [3].

From an environmental point of view, for petrol car consumption in urban areas, the emissions are HC (Hydrocarbons) 3.57 g/km, CO 3.15 g/km, CO_2 1.82 g/km, and NO_x 2.29 g/km [8]. Therefore, the electric bicycle, as an alternative means of transport to the car, shows that for every 100 km an average of 8.5 L of gasoline is saved, and this pollution would be avoided. The electric bicycle as a new form of private transport has led to a new approach to mobility, especially in cities, both for countries with large populations and for countries that are concerned about the environment. The research on the electric bicycle is relatively new, but today, nobody knows where the efforts are being focused, nor what the main points of interest of the scientific community are. The objective of this manuscript is to detect how worldwide research on the electric bicycle is being developed, and, especially around which scientific domains it is clustered. Finally, the main trends in this field can be identified.

A brief overview of the electric bicycle

Electric bicycles began almost at the same time as traditional bicycles. In the 1890s, several patents were granted for electric bicycle engines. In 1895, Ogden Bolton was granted in the United States the patent (US Patent 552,271, 1895) for a bicycle battery with six brush poles, a DC collector and a hub motor mounted on the rear wheel [9]. In 1897, Hosea W. Libbey in Boston invented an electric bicycle (US Patent 547,441, 1895) that was powered by a double electric motor. That same design was later used by the Giant Lafree e-bikes (electric-assist bicycles) brand in the 1990s [10].

In 1920, Heinzmann, a German company, started to mass-produce electric motors for bikes. Their first motor was mounted on a tandem. Later, it continued to develop engines that incorporated German mail distribution bicycles. In the 1930s, Minneapolis-based Lejay Manufacturing register patents that are the germ of the GoBike, an electric bicycle with a generator of a Ford T coupled to the rear wheel. Later, Moulton Consultants Ltd. manufactured a double-chain transmission, one from the bottom bracket and another from the electric motor. In the 1940s, electric bicycles registered an increase due to a shortage in large motorized vehicles, as a result of the war efforts of the Second World War. Several patents were granted for prototypes that were eclipsed by the development and investment in the motorcycle industry, which played a more important role during that war. In post-war Europe and Asia, due to the prohibitions on countries like Italy and Japan to build and rearm their aeronautical industry, many engineers who were dedicated to the development of engines for airplanes saw a niche and dedicated themselves to the motorcycle industry, and in the shadows of this development were electric bicycles, which went a bit ignored but benefited from the new technologies and innovations in that industry.

However, it was not until the first oil crisis in 1973, that the use of electric bicycles began to be promoted, although they did not have much popularity. It was in the United States where electric bicycles played a preponderant role in urban transport as a clean option for the oil problem. This first mass-marketed model was a bit rough and heavy compared to the current models, as it had a solid steel frame and was cumbersome to transport. However, it proved to be very versatile and economical compared to the large and powerful engines of the cars of the seventies. This bicycle, like its predecessors, did not harm the environment nor depend on the fluctuations of the oil market. In 1982, the inventor Egon Gelhard developed a subtype of an electric bicycle that worked with the electric cycle pedal principle, where the driver is aided by the electric traction of the engine when pedaling.

Electric bicycles began to gain more notoriety in the nineties. In 1992, Sinclair Research Ltd. sold the Zike, a bicycle that included nickel-cadmium batteries. It was a portable bicycle that weighed 11 kg with a small electric motor driving the rear wheel and with batteries built into its frame. Only 2000 units were sold. In 1993 the Japanese company Yamaha helped spread the model of “bicycle” or “pedelec” (pedal electric cycle) in Japan, with the name “Power assist”, which was highly successful.

At the end of the 1990s, various models of torque sensors (US Patent 4,966,380, 1990) [11] and power control [12] were developed, as well as new types of more durable batteries [13]. Furthermore, at the end of the 1990s, the big bicycle brands dominated the market, but at the beginning of the year 2000, the sales of electric bicycles diminished radically, only to resurface in the year 2005 with the boom of the lithium battery. This boom at the beginning of the 21st century began thanks to the reduction in the weight of the bicycle: Panasonic built the lightest electric bicycle on the market (19.9 Kg). Soon after, Honda released its Step Compo model, the first electric folding bicycle to weigh 18.7 Kg. Later Panasonic adopted the Lithium-ion battery to revolutionize the market again. So, in 2012, 854,000 e-bikes were sold in the EU27, which means 1.7 e-bike sales per 1000 inhabitants, and the total number of bicycles sold means 4.2% [4]. In France, 134,000 e-bikes were sold in 2016, compared to 37,000 in 2011. In Italy, more than 124,000 e-bikes were sold in 2016 and nearly 24,000 were produced in the same year, growing by 40.5% compared to the previous year [14].
It is estimated that around 21 million electric bicycles were circulating in China in 2009, which is more than the total number of cars in China (9.4 million autos) [15]. In fact, Xinri is the largest worldwide manufacturer of electric bicycles [16]. Their customers are, for example, the Chinese police, and the postal service. However, the rapid expansion in the use of e-bikes in this country has led to a consequent increase in the number of injuries [4]. From a global point of view, in 2015, just over 40 million e-bikes were sold worldwide, of which more than 90% were in China, 5% in Europe, and only 0.7% in the USA. From the point

of view of the main performance regulations of the global e-bike markets by Motor power limit (W) and Top speed (km/h), in the USA it is 750 W and 32 km/h, in the EU it is 250 to 100 W and 25 km/h, and in China, it is 25 km/h with no limit on Motor power but the bike must weigh <45 kg [17,18].

The greatest advantages provided by this means of transport are:

- In the morning while leaving home, my time is appreciated at every minute and speed makes this model of electric transport attractive for many urbanites, as the time of preparation of the vehicle is considerably reduced.
- It also eliminates the need to look for parking, which not only means an inestimable time saving but above all significant money savings in the urban economy.
- It is possible to convert a routine displacement carried out under pressure into an opportunity to do exercise since we work on the cardiovascular system during the ride. In addition to avoiding traffic jams, we are taking care of bodies, so the known excuse of not having time to exercise can be resolved most practically and comfortably. In short, it is compatible to take care of yourself while going to work.

Given the advantages of electric bicycles both from an environmental and energy savings point of view, especially in urban transport, in this work, we set out the objective to study the research trends in scientific publications related to electric bicycles.

II. COMPONENT DETAILS

The electric bicycle is an electrical-assisted device that is designed to deliver electromagnetic momentums to a present bicycle, therefore relieving the user of producing the energy essential to run the bicycle. It contains a strong motor and enough battery power that just needs charging to help in hill climbing, generate greater motoring speeds and provide completely free electric transportation. Electric vehicles price more and perform poorer than their gasoline counterparts. The aim is mainly because gasoline cars have been promoted from a century of intensive development; electric cars have been virtually overlooked for several years. Even today, gasoline cars profit from billions of dollars of research every year while electric vehicles receive a small fraction of that quantity of money. The primary principle for the Universities" support of electric-powered over petrol-powered has been towards improving air quality, though air quality alone is not a satisfactory justification to mandate electric bicycles. The single biggest advantage of an electric bicycle is that it is cost-operable as it mainly only entails building costs as the running cost would only require the charging of the battery. An Electric bicycle would, however, offer other solid benefits that are overlooked by the marketplace. These include the intense reduction in oil consumption that its widespread use would bring about. Much less oil would be needed because only a tiny proportion of electricity is generated from oil. The further major non-market benefit would be lower greenhouse gas emissions.

A. Body frame

Fig. 1 An old bicycle.

For the body frame, an old bicycle is used. The body frame is designed to withstand the extra weight and force of the e-bike motor and battery. This is important for the longevity of the bike and the safety of the rider. E-bikes are heavier than regular bikes, so a sturdy body frame can provide more stability and comfort when riding. The frame also plays a role in absorbing shocks and vibrations from the road, making the ride smoother.

Integration of Components: The body frame is designed to integrate with the e-bike motor and battery, which are typically larger and heavier than those on a regular bike.
This integration helps to distribute the weight of the bike and provide a balanced ride. E-bikes are becoming more popular, and many riders want a bike that looks sleek and modern. The body frame can be designed to look stylish and complement the overall look of the bike.

B. Dc Motor

A DC motor is one of a class of rotary electrical machines that converts direct current electrical power into mechanical power. The most mutual types rely on the forces created by magnetic fields. Nearly all types of DC motors have a specific internal mechanism, either electromechanical or electronic, to periodically change the direction of current flow in a portion of the motor. DC motors were the first type commonly used since they could be powered from present direct-current lighting power distribution systems. A DC motor's speed can be controlled over an extensive range, using either a variable supply voltage or by changing the strength of the current in its field windings. Tiny DC motors are used in tools, toys, and appliances. The universal motor can operate on direct current but is a lightweight motor used for convenient power tools and appliances. Bigger DC motors are used in the propulsion of electric vehicles, elevators and hoists, or in drives for steel rolling mills. The arrival of power electronics has made the replacement of DC motors with AC motors possible in many applications.

Fig. 2 Dc motor [18]

DC motor specification;-

- Output Power: 250 Watt.
- Rated Voltage: 24V
- Rated Speed: 360 RPM
- Full load Current: ≤13.4A
- No load Current: ≤2.2A
- Torque Constant: 0.8 N.m (8.15 kg-cm).

C. Generator

A generator is used to charge the battery while in motion because it can convert the front wheel mechanical energy into electrical energy, which can then be used to charge the battery. This is particularly useful in situations where there is no access to an electrical outlet, or when the battery needs to be charged while on the move.
Generators work by using a vertical washing machine motor(VWMM) mounted on the front wheel of the bicycle connected parallel to a supercapacitor, which stores the power. And later used to charge the battery. Electrical current that can be harnessed to charge the battery.

Fig. 3 Generator Rotor (VWMM)   Fig. 4 Generator Stator(VWMM)

Note:- Due to not availability of VWMM in the local market and issues of covid-19 the research has to continue without the VWMM. As an alternate auto rickshaw starter is been used as a generator

Fig. 6 Generator used in prototyping [20]

Generator specification:-

- Item Weight: 800 Grams
- Item Dimensions: 10 x 8 x 6 Centimeters
- Amperage: 16 A
- Voltage: 28 V
- Wattage: 50 KGW
- Horsepower: 50 W

D. Controller

The speed controller of an electric bike is an electronic circuit that not only controls the speed of an electric motor but also serves as a dynamic brake. This controller unit uses power from the battery box and drives it to the motor. Different forms of controllers are used for brushed and brushless motors. For adaptive e-bikes, a conversion kit is used and the controller is the core component of that kit. The electric bike speed controller sends signals to the bike's motor at many voltages. These signals detect the direction of a rotor relative to the starter coil. The suitable function of speed control depends on the employment of various mechanisms. In a purpose-built electric bike, Hall effect sensors help detect the location of the rotor. If your speed
the controller does not include such sensors and the speed controller on an adaptive bike may not have the electromotive force of the un-driven coil calculated to get the rotor orientation. The mechanism of an electric speed controller differs depending on whether you own an adaptive or purpose-built electric bike. An adaptive cycle includes an electric drive system installed on a normal bicycle. A purpose-built bike, more expensive than an adaptive bike, provides easier acceleration and extra features.

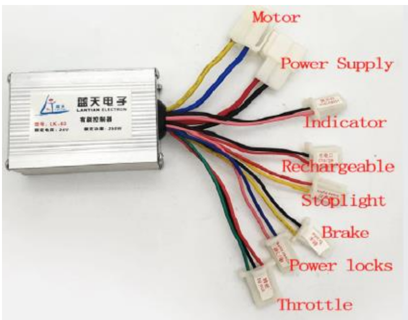

Fig. 7 Speed Controller [21]

Speed controller specification;-

- Rated voltage: 24 v DC
- Current limit: 33A
- Rated power: 250 W
- Matching motor: dc brushed motor
- Under Voltage Protection: 20V

Wire Connection;-

- Red & Black (large cable): Battery connections
- Yellow & Blue: Motor connections
- Yellow & black: brake
- Red & Yellow: Brake light
- Red&Black(a small cable): indicator light
- Red, Black & Blue: Speed Regulator Throttle

E. Battery

Four lead acid rechargeable batteries of 12v and 9 amp are used which are connected in parallel positions. It basically stores the electrical energy generated and utilized it to run the motor. A battery has a positive terminal called the cathode and a negative terminal called an anode. The terminal marked positive is at higher electric potential energy and the terminal marked negative is the source of electrons when connected to an external
circuit that will flow and deliver energy to the external device Rechargeable batteries are recharged multiple times.

Fig.8 Battery placement.

F. Supercapacitor

Fig. 9 Supercapacitor [19]

Supercapacitors can store and release energy much faster than batteries, which makes them ideal for use in EVs. They can quickly charge and discharge, providing the necessary power for acceleration and braking. It can work in parallel with batteries to provide additional power when needed, reducing the load on the battery and increasing its efficiency. This can help extend the range of the EV and prolong the life of the battery. It can also be used to capture and store energy during regenerative braking, which occurs when the vehicle slows down or stops. This energy can then be used to power the vehicle during acceleration, reducing the demand on the battery and improving overall efficiency. They are considered to be more environmentally friendly than batteries because they do not contain toxic chemicals or heavy metals. They also have a longer lifespan than batteries, reducing the need for frequent replacement and disposal.

Supercapacitor specification;-
1. Voltage input: 12V
2. Maximum power output during shutdown: 150W
3. Dimensions: 146 x 41.6 x 101.6 mm.

G. Chain and Sprocket

A standard teeth ratio pedal sprocket to back wheel sprocket is 53/39. And the same size of the sprocket connected to the motor sprocket is 53/13. Two 53-tooth sprockets are welded together at the pedal shaft. One of the sprockets is connected to the back wheel sprocket, another one is connected to the motor and generator sprocket through the chain.

Fig. 10 Pedal sprocket

H. Display, lighting and music system

The display is used to monitor power, current and voltage. Lighting and music system is used for the aesthetic look of the E-bike.

Fig. 11 Display and Music system.

III. METHODOLOGY

The working of this prototype explain by using the components mapping sprocket chain connection as follows

A. Components mapping

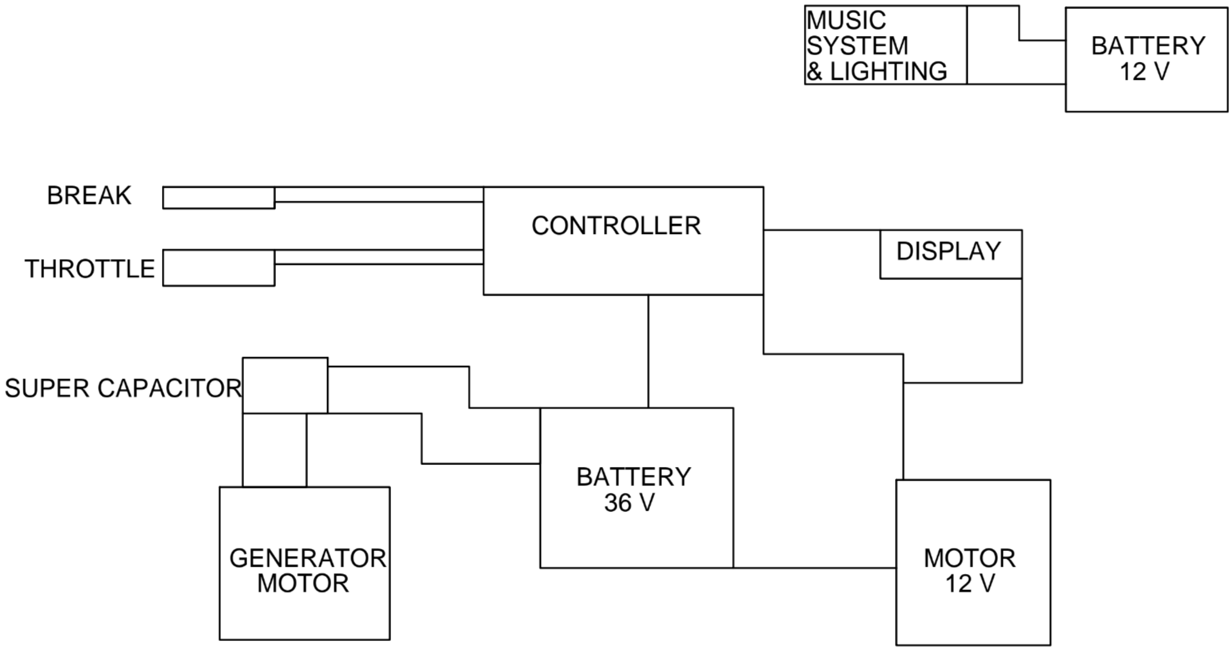

Fig. 12 Components mapping

B. Connection of chain with sprockets

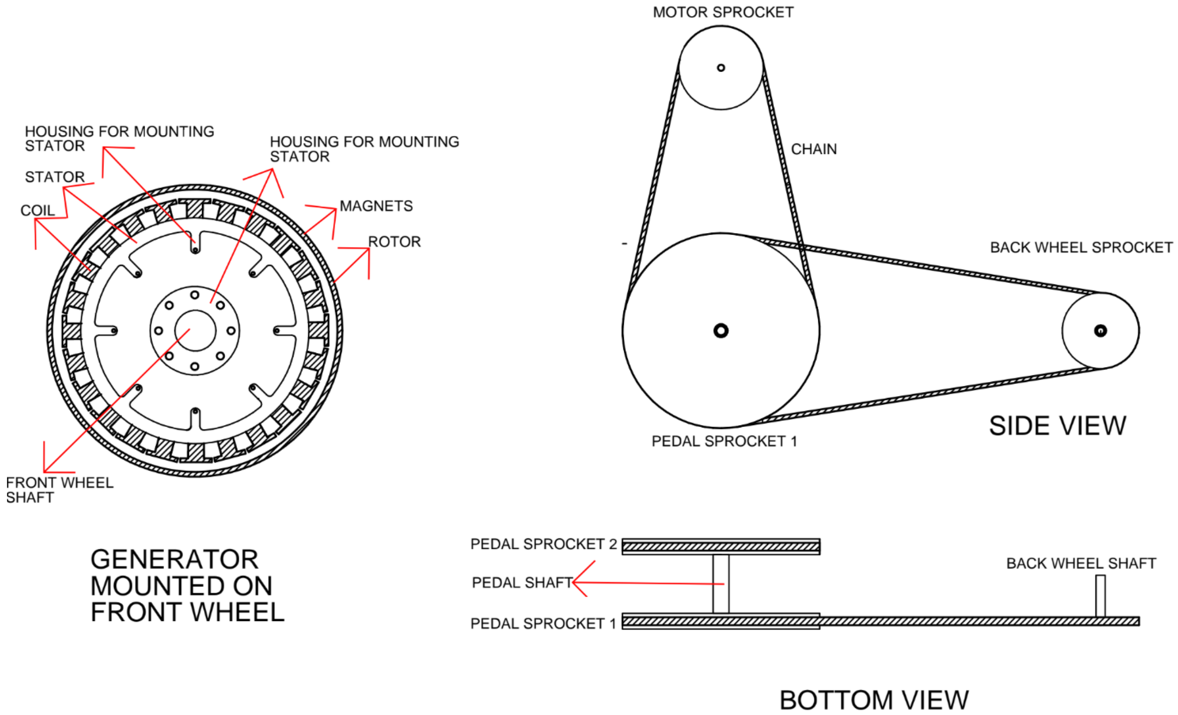

Fig.13 Connection of chain with sprockets with VWMM Generator

Note:- Due to not availability of VWMM in the local market and issues of covid-19 the research has to continue without the VWMM. As an alternate auto rickshaw starter is been used as a generator

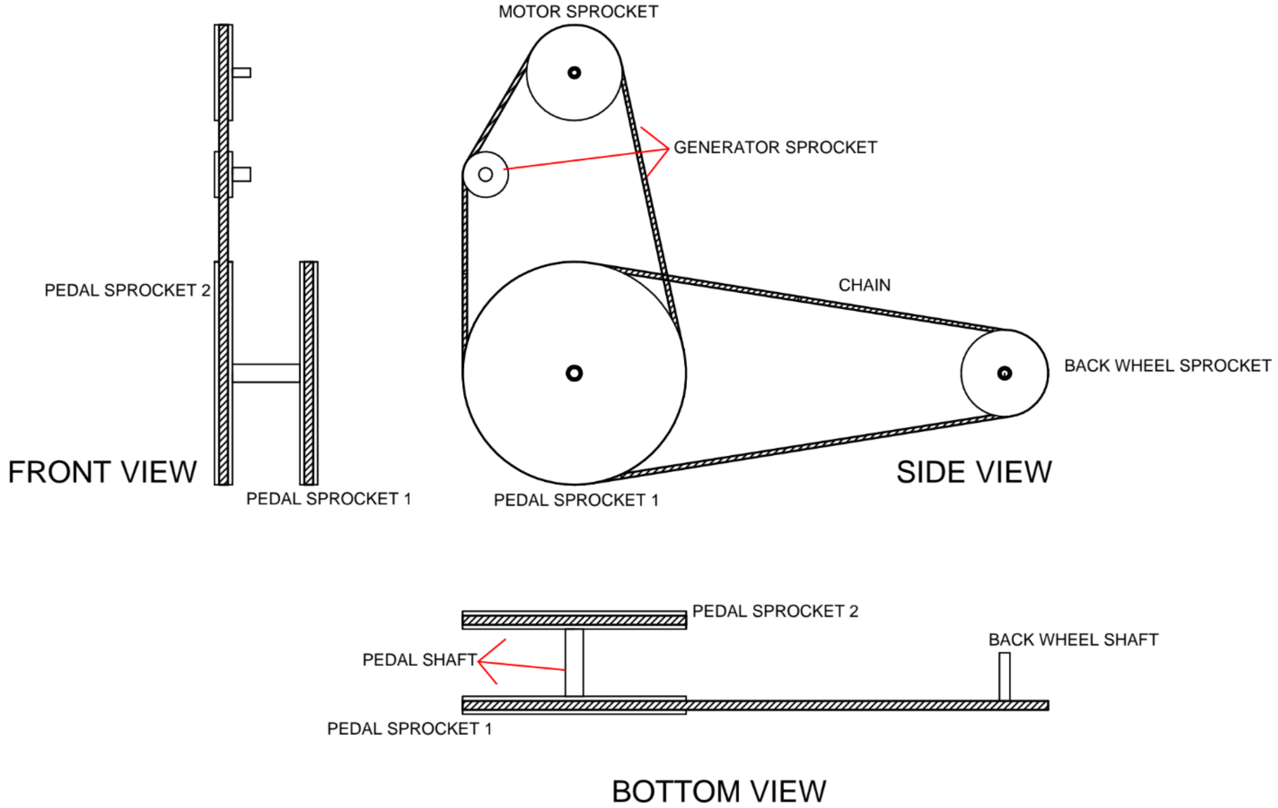

Fig.14 Connection of chain with sprockets with prototype generator

C. Prototype

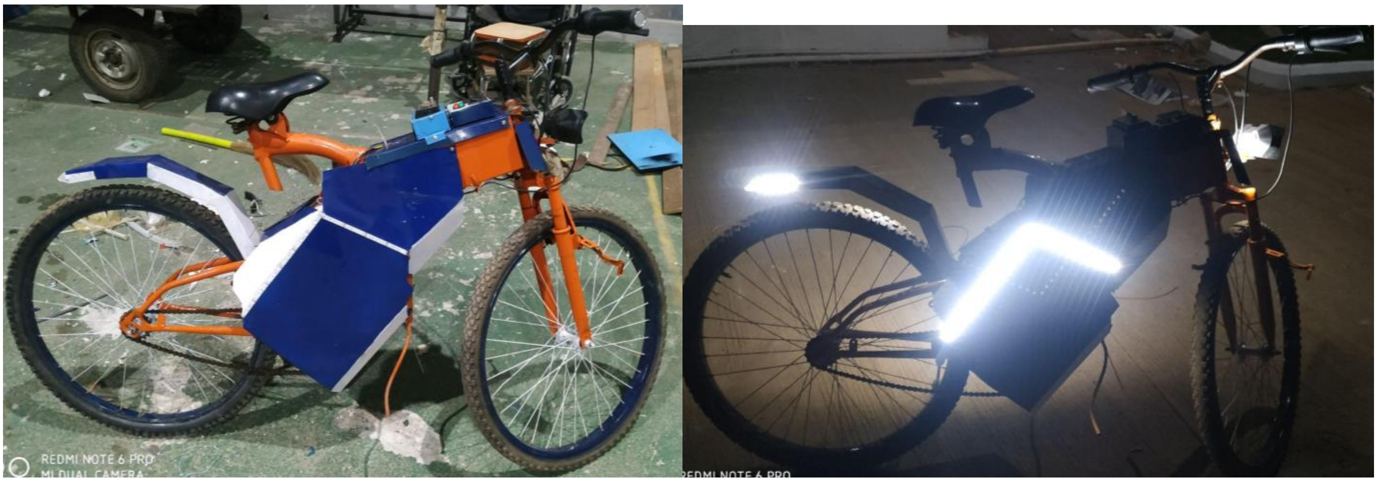

Fig.15 Prototype

IV. CALCULATION

Step 1:-Battery energy consumption without the generator

Battery output:-
Energy Stored (Wh) = Voltage (V) * Capacity (Ah) * Number of Batteries
= 12 V * 9 Ah * 3
= 324 Wh

Energy consumed by the motor:

Energy Consumed (Wh) = Power (W) * Time (h)
= 250 W * 1 h
= 250 Wh

Percentage of battery energy consumption = Energy Consumed / Battery output * 100
= 250 Wh/324 Wh * 100%
= 77.16%

Step 2:-Battery energy consumption with the generator

Battery output:-
Energy Stored (Wh) = Voltage (V) * Capacity (Ah) * (Number of Batteries + 1)
Note: + 1 is for the generator
= 12 V * 9 Ah * 4
= 432 Wh

Energy consumed by the motor:

Energy Consumed (Wh) = Power (W) * Time (h)
= 250 W * 1 h
= 250 Wh
Percentage of battery energy consumption = Energy Consumed / Battery output * 100%
= 250 Wh/n432 Wh * 100%
= 57.87%

Step 3:-Differences Battery energy consumption without the generator and with the generator

= Percentage of battery energy consumption without a generator - Percentage of battery energy consumption without a generator

= 77.16% - 57.87%
= 19.29 %

Therefore by using a generator with a battery the energy consumption of the motor will be reduced to 19.29%.

Note:- This Theoretical calculation and partial calculation were not conducted due Covid -19 the prototype being in the lab.

V. Conclusion

This research and prototype are to reduce battery consumption and increase the efficiency of E-bikes. e-bikes can help riders achieve longer distances and reduce their reliance on battery charging. Additionally, e-bikes can also help reduce carbon emissions and promote sustainable transportation options.

Furthermore, with the increasing popularity of e-bikes, there is a growing market for advanced battery technologies, which will likely lead to further improvements in battery life and efficiency. As more people adopt e-bikes as a viable transportation option, we can expect to see a positive impact on the environment and a reduction in reliance on traditional vehicles.

Overall, the benefits of e-bikes in terms of reduced battery consumption and increased efficiency make them a promising solution for sustainable transportation. As technology continues to advance and battery technology improves, we can expect e-bikes to become even more efficient and effective in promoting sustainable transportation options.

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