TECHNICAL SCIENCES

HIGH TECHNOLOGY IN E-BIKE POWER SYSTEM USING MODELING DEVELOPMENT

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Abstract

The following work consists of the mechanical Computes Assisted Design (CAD) for an electric bicycle, which involves a detailed and structured process ranging from the creation of individual components to the integration of complete systems. A comprehensive global review of current e-bike technologies was conducted, focusing on the selection of lightweight and strong materials to optimize the energy efficiency and maneuverability of the bicycle. The chassis was designed primarily from carbon fiber. The selected electric motor has a capacity of 2000 W, providing an optimal balance between power and efficiency, enabling the bike to reach an autonomy of 90 km and a significant range. This project brings an innovative solution to the e-bike market using advanced design and careful selection of materials, resulting in a lightweight, durable and efficient vehicle. The novelty lies in the integration of advanced design technologies and high-quality materials, which not only improve the user experience, but also promote sustainability in urban transportation.

Keywords: E-bike, power system, modeling development, high technology in materials, CAD.

1.0 INTRODUCTION

In recent years the world has developed new means of transportation, the most used in these times in the electric bicycle or also called E-BIKE, it is economical and avoids contamination with gases dangerous [1,2]. In this way an electric bicycle is different to a regular bicycle, the electric bicycles are becoming more popular due to their convenient mode of transportation. Various nations of the world, including China, the United States of America, Switzerland, México, Colombia, Cuba the Netherlands, and Japan, use electric bicycles for daily transportation. The electric bicycle has been demonstrated that the greenhouse gas emissions of electric vehicles were significantly influenced by the chosen system boundary for analysis, whether it encompassed the well-to-wheel perspective or the entire vehicle lifecycle. The study showed that emissions assessed on a well-to-wheel basis were lower compared to those calculated over the vehicle's commercial [3,4]. One of the first patents for an electric system in a bicycle was filed by Ogden Bolton Jr, in 1895. Its design included an electric motor mounted on the bicycle frame. Later S. Argyris in 1948 also developed an electric bicycle. From there the famous E-BIKE for electric mobility began, for more years later this project added more things in the E-BIKES that had more impact towards the means of transporting people[5]. The use of E-BIKES benefits the development of different persons such as, police or law enforcement, tourists, delivery workers, boys, tenders, students, teachers, purchasers of different products, and people with health issues. It is a way of representing sustainable eco-friendly transport solutions for cities and towns. Advantages clearly observed are strengthened accelerations from stand still, allowing different loads, improved hill climbing, increased ride distances and higher average speeds [6, 7].

Electric mobility has long been considered a technological solution to the environmental problems caused by current transportation patterns (especially their impact on climate change), characterized by a high proportion of car trips powered by fuel injection [9, 10]. The electrification of mobility marks this change by being part of the means of transportation that does not require fossil fuels. Furthermore, electric transportation will be the future that is gradually being accepted and must be realized because it is the way out of environmental changes and has the technology to solve all transportation problems [2, 7, 10].

The design of the E-BIKE in the software CAD includes the next steps.

a) Planning and conceptualization. Before starting the design in software CAD, it is crucial to define the requirements and specifications of the e-bike, is necessary the type of e-bike (e-mountain bike, e-cargo bike, e-folding bike, and others), the specifications help to determinate the features such as frame size, motor type, battery capacity, drive system and other key components, in the last decade the research took wide application on the existing designs and perform analysis to understand functionality and aesthetic requirements **[**11**]**.

b) Creation of the frame and main components. The frame modeling starts with an initial sketch with the profile of the structural part to the frame, the sketching tools are used in software CAD, to create the basic shapes of the product, in the actual systems are necessaries tools as extrusion, revolve and others, it let apply extrusion and revolution operations to shape the frame, when the parts are modeled is possibly make a component assembly, also the design allow have the mounting points for the motors, battery, wheels and suspension and other components **[**11, 12**]**.

c) Assemblies and adjustments of components, it is possible using the software CAD assembly tool to design the frame, motor, battery, rim and other components with precision, in this point the positioning adjustments allow sure all components fit correctly and make adjustments if necessary **[**11, 13**]**.

d) Simulation and analysis. The CAD software allows the stress analysis, the perform simulations to evaluate the resistance of the frame and other components, with the tools in motion simulation that checks the range of motion of moving parts and ensures there are no interferences **[**11, 13**]**.

e) Documentation and technical drawing. The software lets you generate detailed drawings for manufacturing, including plan views, elevations, cross sections, dimensions, tolerances, configuration to assembly and materials in technical drawings. Create assembly and maintenance manuals to facilitate the construction and maintenance of the e-bike [13**]**.

f) Prototyping and testing. If it is possible, use 3D printing or manufacturing prototype, the 3D printing or rapid manufacturing techniques to prototype components and test the design, with the prototype the evaluation is possible and let make adjustments based on prototype testing and return to software CAD, to modify the design if necessary. The real field tests are necessary to evaluate the performance of the e-bike in real conditions and adjust the design according to the results obtained [12, 13].

1.1 E-BIKE power system modeling development

The power system of the E-BIKE, this term consists of several operations, both design and manufacturing, applicable as mentioned, electric bicycles are a means of transportation for people who want a better path without having to go through a series of already known problems, the E-BIKE power system consists of important parts which will be mentioned.

The battery is the heart of the power system. It stores the electrical energy necessary to power the motor. The most common batteries in e-bikes are lithium (Li-ion) due to their high energy density, low weight and long life. The battery capacity, measured in watt-hours (Wh), determines the range of the bicycle, while the motor is the component that converts the electrical energy from the battery into mechanical energy to propel the bicycle. The motors can be located in the front, rear wheel hub or bottom bracket axle. Motor power is measured in watts (W) and may vary depending on the e-bike model. Another element is the controller, it is the brain of the power system. It regulates the amount of power the motor receives from the battery and manages the interaction between the battery, motor and sensors. The controller also allows you to adjust different assistance modes and manage additional functions such as regenerative braking. The charger allows you to recharge the battery when it runs out. Chargers are designed to provide the correct amount of voltage and current to the battery for safe and efficient charging. Today it is necessary to use a display and control panel. It provides the rider with information on battery status, speed, motor assist level and other relevant data. Control panels can be integrated into the handlebars or a separate unit. The sensors include torque (force) and speed sensors that adjust motor assistance based on the power the rider applies to the pedals and the speed of the bike. These parts are very important because it is the function of the entire E-BIKE power system, therefore the quality that the part contains must be considered and in order to better understand what is being explained, the software CAD, will be used, but I will detail more in the next part [14].

1.2 Model in software CAD

In the software CAD all the parts of the E-BIKE were designed respecting the measurements under the standard but with different modeling and function in the power system. Here the CAD was used to develop a functional product and have less mistakes, this came to the assembly part and exploded, however there was complexity in the part of the sprockets and chain mechanism, a good material was applied to each piece and different from that of the other models that already exist, these materials will be listed in an orderly manner and with their different properties, in the part of CAE the electrical analysis tool was used [10-13].

2.0 Method and materials

The achievement of an electric bicycle, the so-called E-BIKE, as a solution for sustainable mobility in cities requires a series of planned tasks and a multidisciplinary approach, such as those that have been carried out within the framework of this work where has developed an efficient and accessible electric bicycle, with the application of new design and simulation tools. The design using CAD allows the use of appropriate materials and components, as well as the use of lightweight materials, as a point of reference when proposing a solution that meets the expectations of current and future users. The different materials that have been used and the different methodologies used when carrying out this project are detailed below [15].

2.1 Materials

The development of the electric bicycle model was carried out using CAD software. The program was chosen for the possibility of generating an accurate three-dimensional model and performing finite element analysis. The latter is crucial to evaluate the structure's strength and aerodynamic capabilities.

Tools and equipment used

In this development a software CAD was used for its versatility and power in the area of mechanical design and simulation using original license version 2022. The software allowed each component of the e-bike to be modeled with the greatest precision. In this case the computer needs a wide memory in RAM, and the process recommended by the software. The hardware all-in-one computer was used. This computer was equipped with a high-performance processor I5, 16GB in RAM and an advanced graphics card. This setup was critical to being able to work with complex 3D models and perform detailed simulations without losing speed and efficiency.

The combination of CAD software with computer equipment allowed not only to develop a detailed and functional model, but also to carry out simulations that anticipate and reduce problems before physical manufacturing. As a result, the final design is ensured to be optimized for manufacturing, resulting in lower cost and production time, without compromising quality.

Materials used in design

In this project were reviewed different options of materials and products of high technology and were found to the E-BIKE the aluminum 606 being one of the most used aluminum alloys in the industry due to its combination of mechanical properties, corrosion resistance and ease of manufacturing. It contains magnesium and silicon as the main alloying elements, which gives it good mechanical properties and resistance to corrosion. It has a tensile strength of approximately 290 MPa (42,000 psi) and a yield strength of 240 MPa (35,000 psi). The density is approximately 2.7 g/cm³, making it a lightweight material. Other material found was carbon fiber. It is an advanced composite material known for its high strength and lightness. It is widely used in high-performance applications, including bicycles, due to its excellent physical and mechanical properties [15]. It is composed of extremely fine carbon filaments that are intertwined and combined with an epoxy resin matrix to form a composite material. It has a tensile strength that can exceed 6000 MPa (870,000 psi), and its modulus of elasticity (stiffness) can be greater than 230 GPa. This makes it extremely strong and rigid compared to metals. The density is approximately 1.6 g/cm³.

2.2 Methodology

The development of the electric bicycle was carried out in different phases, all of them planned in order to guarantee an effective and functional design.

The first phase of the project was an investigation into the market and technology that existed at that time for e-bikes. This included an analysis of existing technology trends, user demand, and available component capabilities. From this research, the technical specifications of the project were defined, for example, battery capacity, motor power, chassis materials and control systems. These parameters established the design and performance objectives that were to be achieved.

With the established specifications, the 3D model of the e-bike was designed using a commercial CAD software in the field of design. Aerodynamics and structural integrity of the chassis were especially considered. Once the 3D design was completed, stress simulations and aerodynamics analysis were carried out in order to detect and optimize the critical areas of the design. These simulations allowed us to calculate the resistance of the chassis to different types of loads and reduce wind resistance, an aspect of utmost relevance at the level of energy efficiency and autonomy.

The choice of materials was a very important point of the project. The design of the electric bike was made with materials such as aluminum and carbon fiber. The predominant material of the chassis structure was aluminum. It was chosen for its high strength-to-weight ratio and corrosion resistance. Carbon fiber was used for critical components to decrease the overall weight of the bike, improving maneuverability without compromising structural strength.

Finally, once the design was adjusted, a meticulous validation of both the design itself and the entire e-bike was carried out, so that all elements of the bicycle met the technical and safety requirements of the regulations. This validation included a final series of simulations and tests that ensured that the electronic bicycle was correctly sized for subsequent production and use by users.

In this way, it has been possible to create an electric bicycle that not only meets the needs of current urban users, but also promotes sustainable mobility and the reduction of the carbon footprint of the entire e-bike.

3.0 Results and discussion

The work presents the results of the modeling of the electric bicycle with high technology (Figure 1) and the characteristics that it must present. Likewise, in this work the shape, the mass of the E-BIKE and the energy system that must accompany it were developed.

The modeling of the electric bicycle was a widely detailed procedure, from a process of creating the drawing in a CAD software, two additional characteristics of the e-bike have been expected to be taken into account: structural resistance and aerodynamics. The electric bicycle frame is made up of a high-strength carbon fiber frame. It has been made of this material not only because it is among the strongest unthinkably light frames, but also because its function is to provide a robust platform for all the components. remaining part of the design [14].

The design has an adjustable seat, a support frame for the battery and motor, and a rear space for the high-capacity battery. A protection system has been chosen for the engine and internal components, keeping the main part of the system safe from breakdowns regardless of what is used.

The main parts of the model are detailed below:

1. Battery
2. Electric motor
3. Body or structure
4. Rim
5. Tires (Figure 2)
6. Control of the velocity
7. Adjustable seat features
8. Battery charger independent

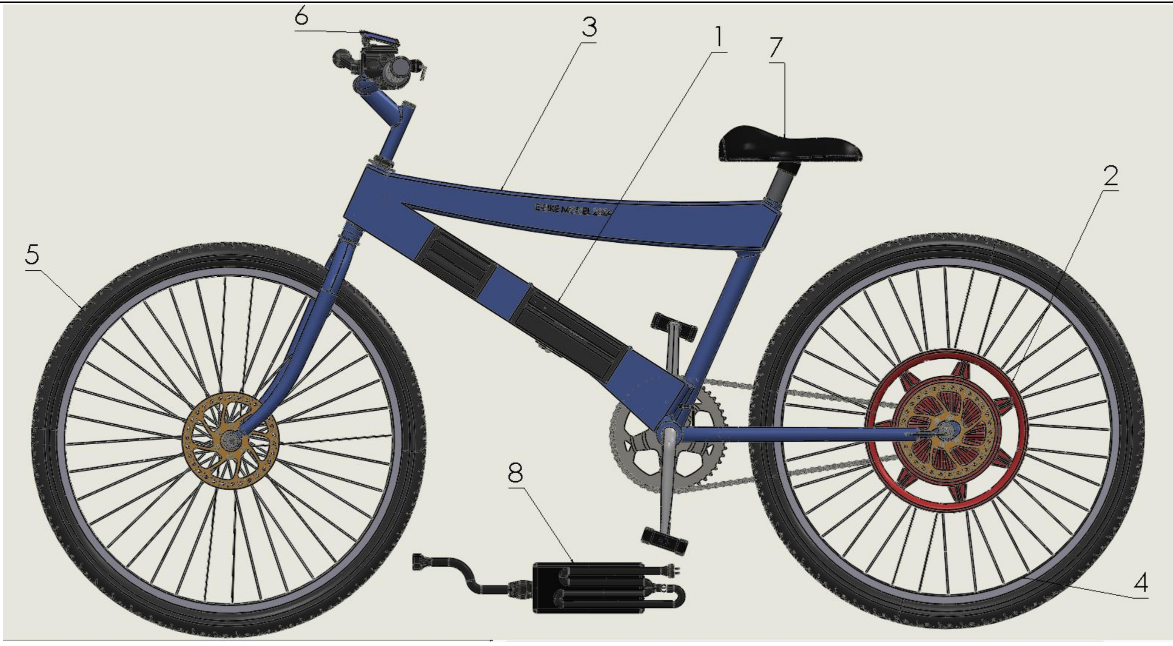

Figure 1. Diagram of the E-BIKE in the software CAD.

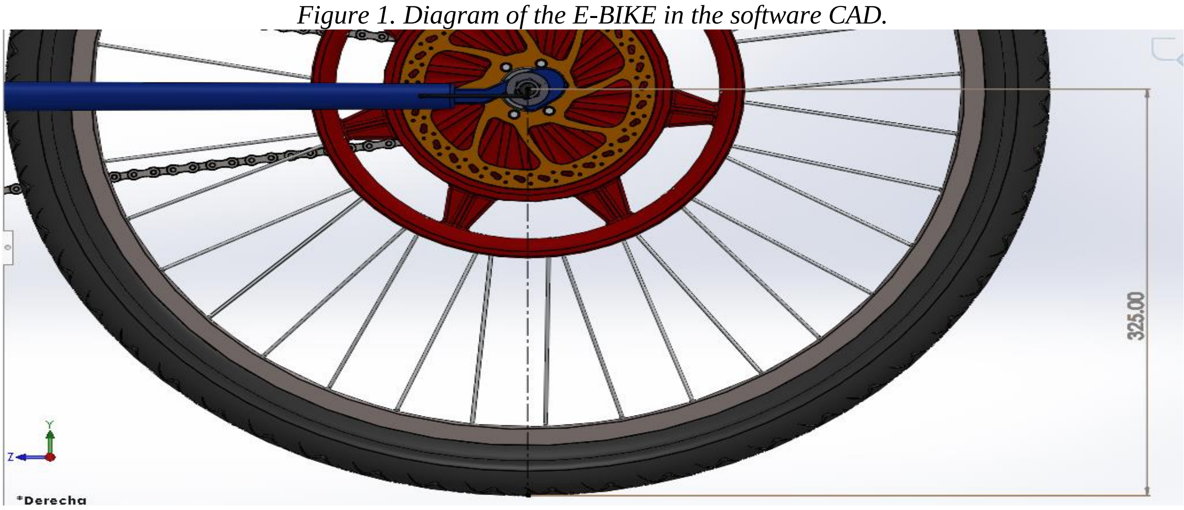

Figure 2. Assembly of the parts of E-BIKE in the software CAD

The final results of the design of the E-BIKE are those that have the most impact both on electric mobility and on the CAD software. Each component of this vehicle has its own characteristics and properties of materials, mainly the body or structure of the E-BIKE. It was modified to alloy aluminum, it is a light and resistant material because the objective is for it to be lighter than the other materials seen in these vehicles. The electric bicycle lithium-ion battery can work at a temperature between -20 and 60C, and the discharge efficiency can reach 95%. Make full use of the battery, and the riding distance is longer. When the battery is not used, the self-discharge rate does not exceed 3%. It can save battery power.

The project was amazing and use many time and other resources, was modified again and again, the design of every with detail, the analysis of the elements, the shapes of design, the selection of configuration, found different batteries, motors, wheels, materials and functional configuration was a work widely analyzed (Figure 3).

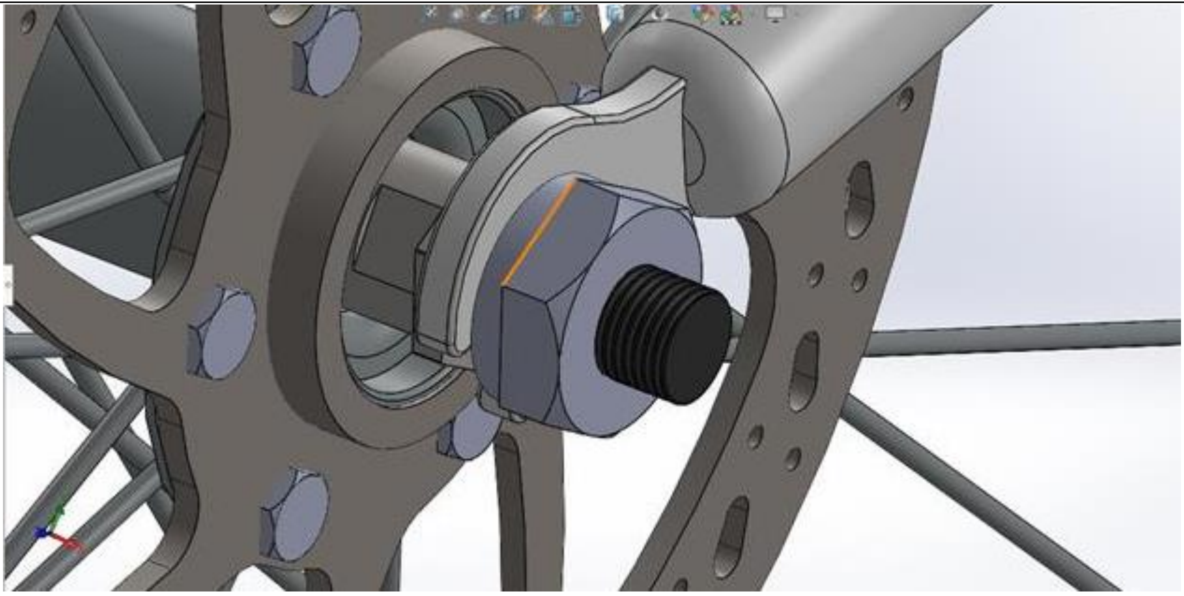

Figure 3. Detail of the parts to E-BIKE in the software CAD

Figure 4 was shown the stress analysis with the software having a value that allows verifying the mechanical resistance is over the values of stress obtained under load and it. In the figures 5 y 6 are shown the steps used in the development of the models.

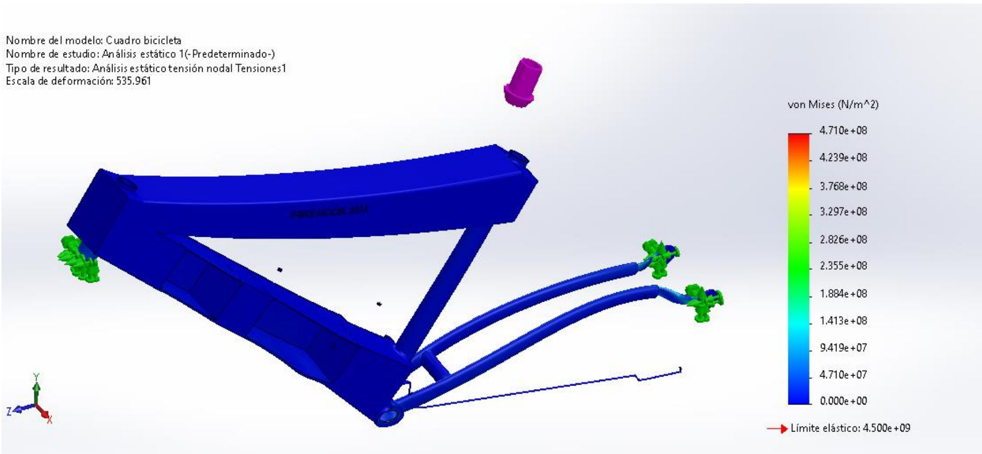

Figure 4. Stress analysis with the software CAD.

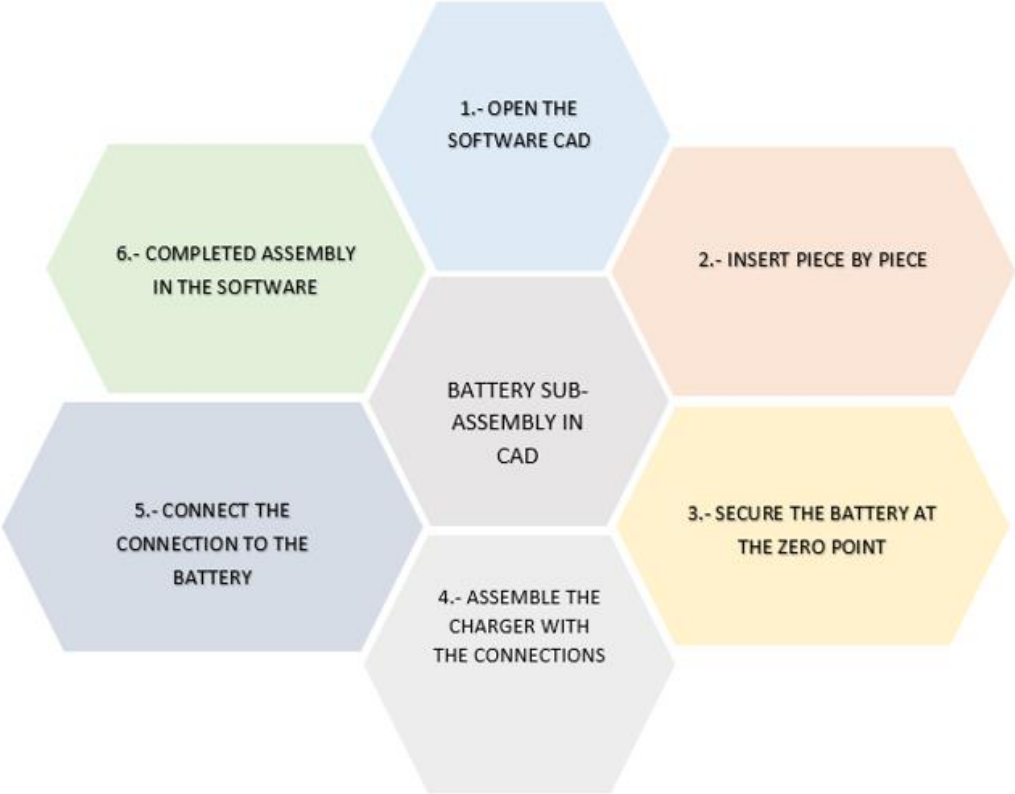

Figure 5. Steps in the modeling of parts with the software CAD.

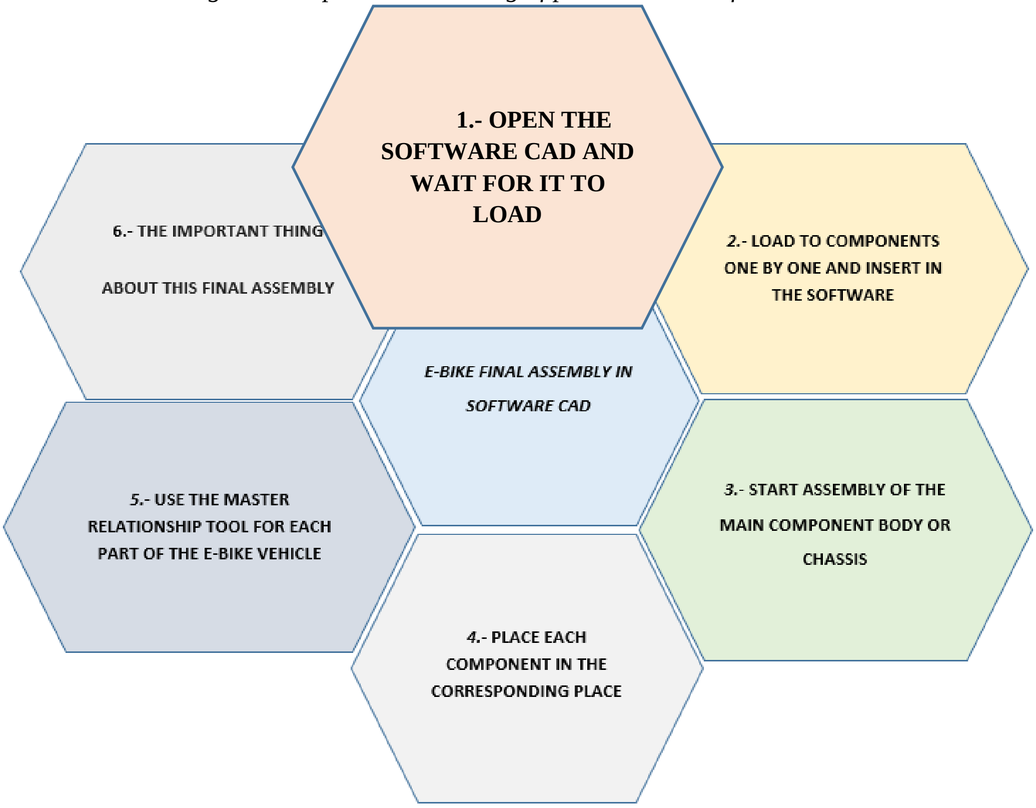

Figure 6. Steps in the modeled of assembly with the software CAD.

The autonomy of the E-BIKE is obtained of the next equation:

$$Autonomy\ (km) = Battery\ (Ah) \times Efficiency\ of\ system \times \frac{3600}{Power\ Consumption}$$

$$Autonomy = 60\ Ah \times 0.85 \times \frac{3600}{2000W} = 91.8\ Km$$

The parts modeled on electric elements are shown in the figures 7 and 8.

Characteristics of the elements of E-BIKE

Table1.

Characteristics of elemental parts of the power system

Component	Detail
Battery	72 volt lithium ion 60Ah
Motor	2000W
Wheel	Ultra-light
Structure	Aluminum / Carbon fiber
Time of recharge	4 hours
Autonomy with the maximum capacity	90 Km

This is the subassembly of the electric battery and the independent charger with its connections connected to the battery, this system must be assembled separately so that it can be seen how it is connected and at the end the final rendering is applied so that it is displayed with more quality in the CAD software.

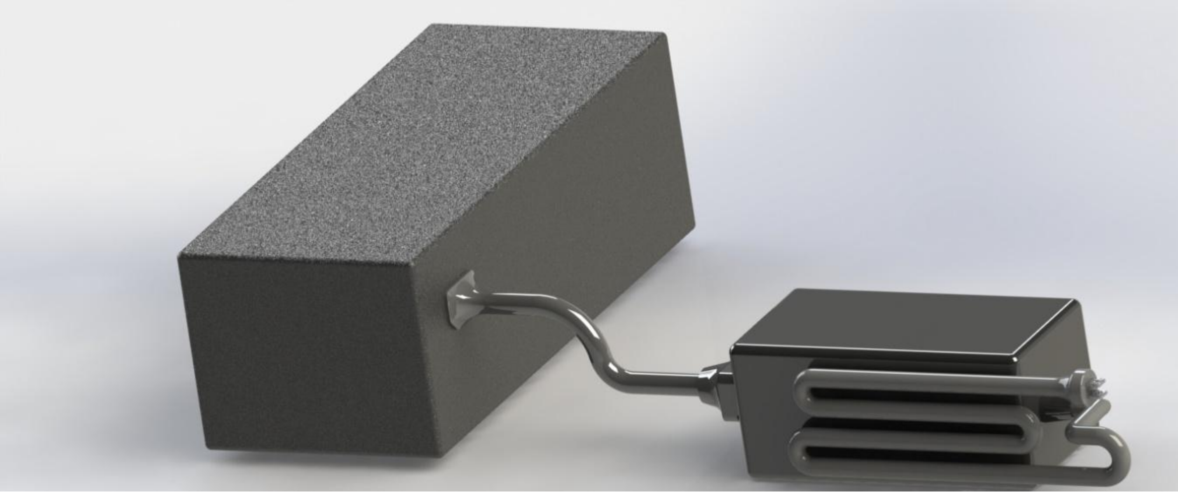

Figure 7. Battery and charger connection in CAD software.

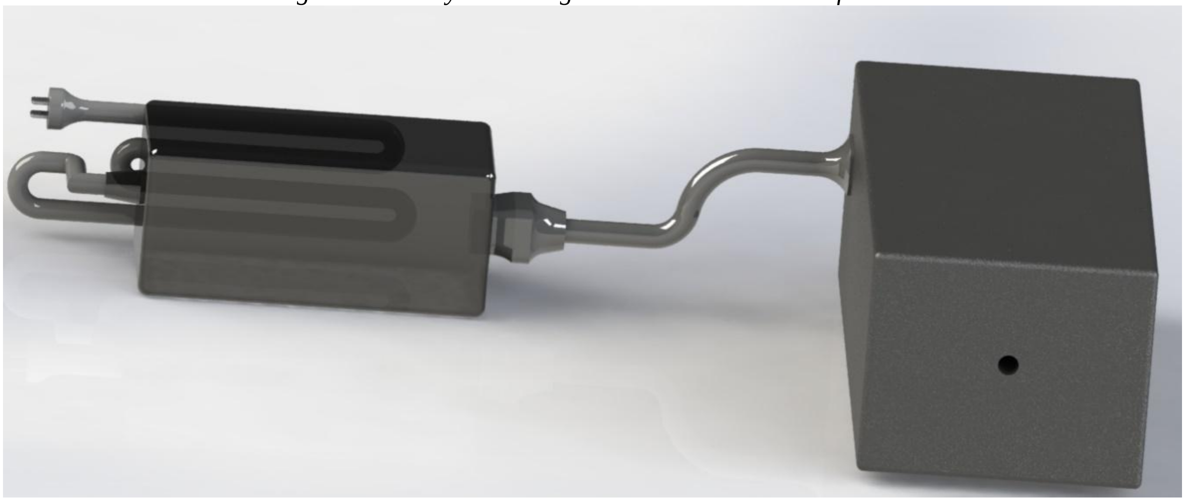

Figure 8. Battery and charger connection in CAD software.

The development of the E-BIKE model in the CAD software was detailed in every component, the colors and texturization were evaluated with different options, the need of components were integrated as the design was developed, each step was analyzed and implemented (Figure 9).

Figure 9. Assembly of the E-BIKE

In this part of the assembly, the handlebar is the one that has the speed controller integrated and also includes the display so that the numbers can be clearly seen. and at the end a rendering was applied so that the assembly could be seen realistically as is shown in figure 10.

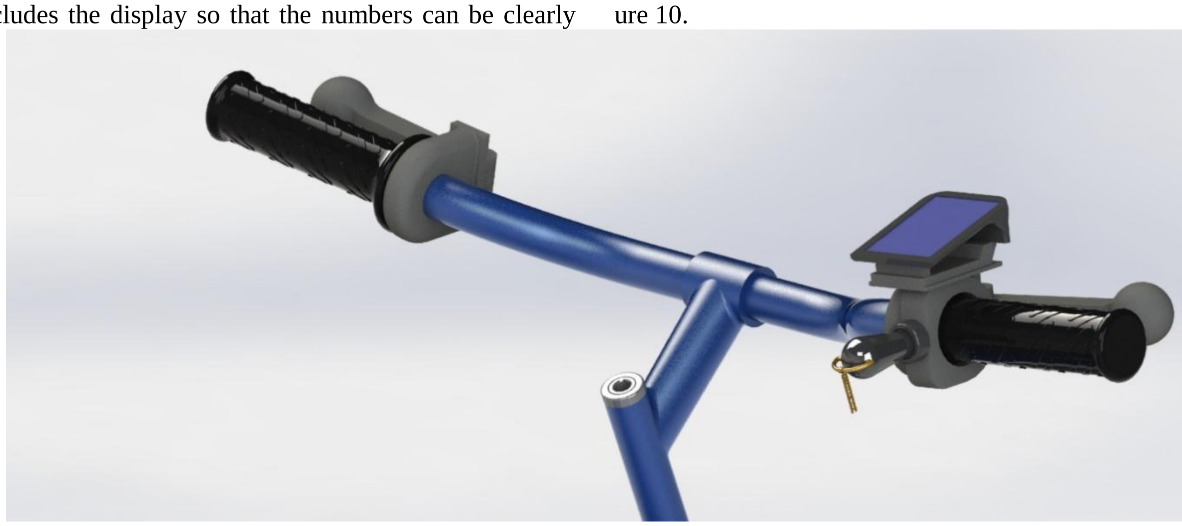

Figure 10. Handlebar and their realistically

In this figure 11, the view of the handlebar is from the front and shows the components that were added, such as the speed controller, and in that same piece is the display, which is the mirror so that the mileage numbers and the time between can be displayed. Other details, the rendering that was applied was realistic, and royal blue automotive paint was applied to make it look more original than the other e-bikes.

Figure 11. Handlebar and their realistically

In this view you can see the brake disc with the front tire. Here in figure 12 the disc was assembled but with specific shapes of geometry and position and the paint that was applied was yellow so that it looked more original and with the most realistic rendering.

Figure 12. Brake Disk.

The design of the mechanism of the motor and the rear tire of the e-bike, this idea was analyzed and implemented in the CAD software and several steps were carried out so that this system was united and both components moved on the same circumference and the rendered so that the difference in changes could be noticed (Figure 13).

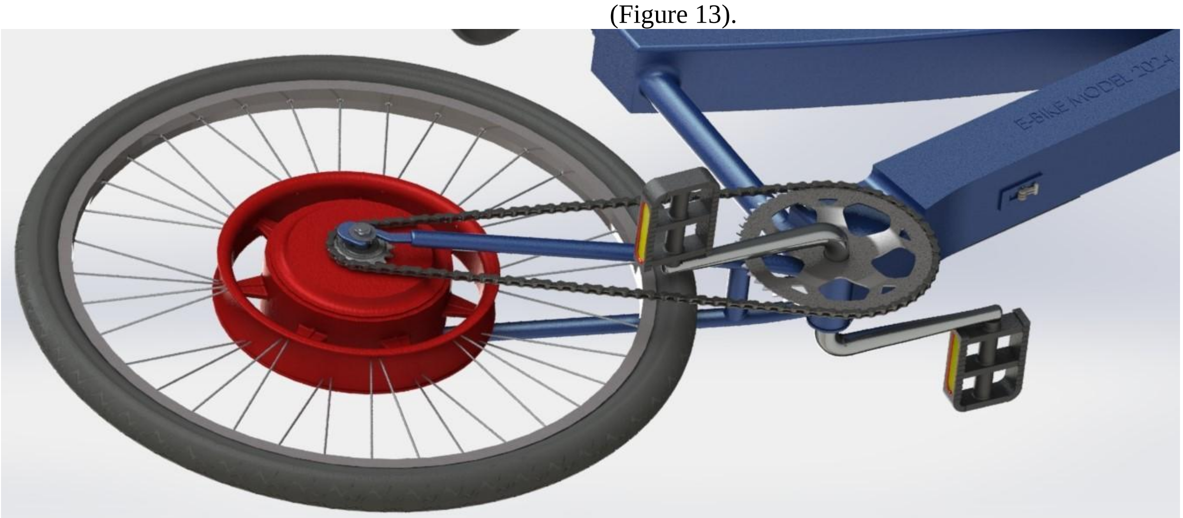

Figure 13. The engine and rear tire system were assembled.

The same mechanism is only in the 3D isometric view in the final rendering. In this part you can see the rear brake disc that is coupled with the engine and for greater support, special screws were designed for both components (Figure 14).

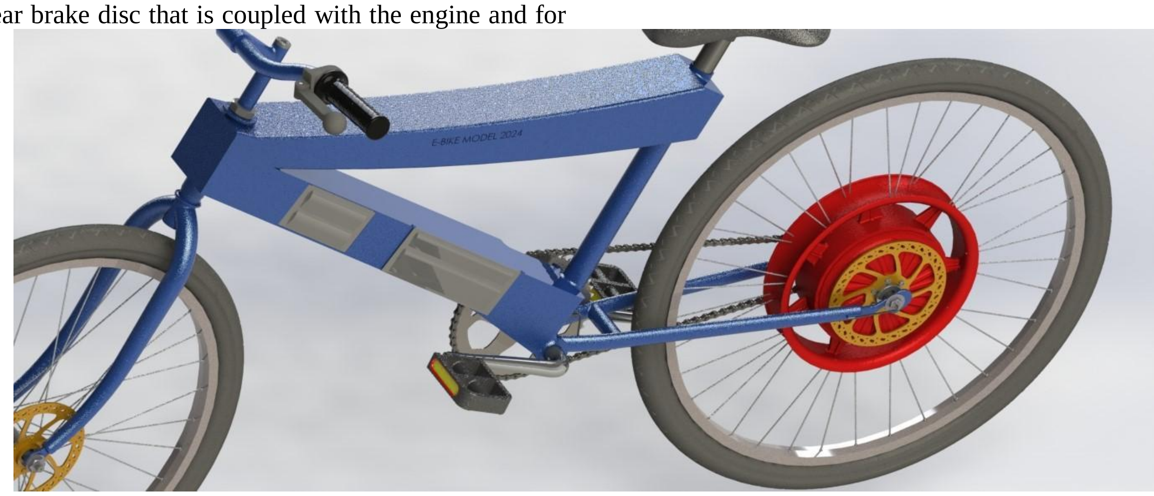

Figure 14. The engine system was assembled

In this view (Figure 15) you can see the transparent appearance of the e-bike casing where the following components were placed; electric battery and the charger with the connections for the battery and these were inserted into the housing or trunk of the e-bike.

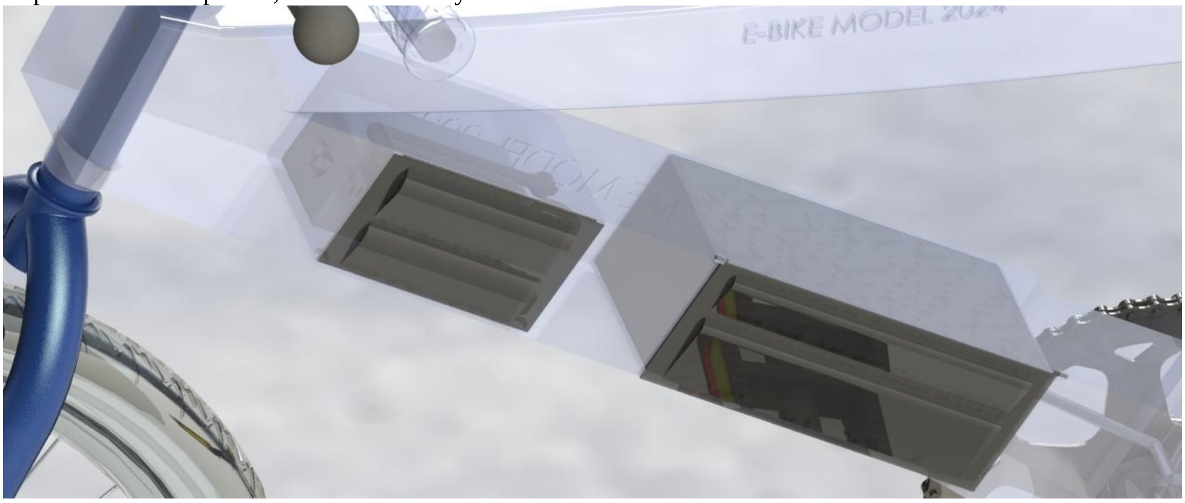

Figure 15. Trunk or casing of the e-bike where the battery and charger with their connections are stored.

In the view of figure 16, the transparent appearance was implemented in the CAD software, this in order for all the components of the e-bike to be displayed since after having assembled the design, the rendering must be done in two parts, the first is with appearance with materials and the second is with transparency.

Figure 16. View the transparent appearance of the e-bike.

Table 2.

Advantages of electro mobility.

Advantages of the e-bike in the world of electric mobility	
1	**Energy Efficiency and Low Consumption**
2	**Environmental Benefits**
3	**Mobility and Accessibility**
4	**Health Benefits**
5	**Low Operational and Maintenance Costs**
6	**Noise Reduction**
7	**Ease of Parking and Storage**
8	**Technological Innovations and Personalization**
9	**Promotion of Sustainable Mobility**
10	**Government Incentives and Support**

Conclusions

In this final E-BIKE, quite a few operations were carried out in the CAD software, first were investigated advanced components of an electric bicycle, how it works and how they were assembled both in design and in the real process. This took time to analyze and implement in the CAD software, which is to carry out this type of complex projects. The objective of the new E-BIKE design is for people in general to see the new improved E-BIKE modeling with high technology.

In addition to the development of sustainable mobility solutions, this project highlights the need for innovation in product manufacturing. Given the recent global interest in the environment and the all-too-common problem of road congestion, e-bikes have become an affordable and efficient alternative to the car for millions of people. Some of the improvements, such as increasing battery life, reducing costs, and creating more advanced features, will only solidify the position of these solutions in modern urban transportation.

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Declaration of Competing Interest

The author declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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