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CATIA-Based Urban Mini EV Design

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Abstract: This article introduces a mini EV for urban single drive, a the car intended to work as conveyance for city workers, thereby relieving urban traffic pressure, improving traffic congestion and reducing urban pollution. The paper primarily designs a electric reversed tricycle and determines its motor and battery parameters, fixes the cockpit installation location by ergonomics, and finally completes vehicle arrangement. CATIA is mainly used for modeling and ergonomics analysis during the design process.

Keywords: CATIA, Ergonomics, Mini EV, Reversed tricycle.

1. INTRODUCTION

With the worsening of global energy shortage and environmental pollution, governments and the auto industry have clearly recognized that energy conservation is the main direction to the future development of automotive technology. Energy and environmental issues have become the biggest obstacle to the development of conventional cars, that is finding and developing new. Clean power source has become a hot research field in the today's automotive sector. EV has unparalleled advantages in terms of environmental protection and energy saving compared to conventional fuel vehicles because of its notable features of high efficiency, low noise and zero emissions [1]. Meanwhile, the development of modern high-tech, the birth of new materials and the wide used of electronics, motors and computer technology have greatly contributed to the renewal and development of electric vehicles technology [2]. Therefore, EV has potential to enter the mainstream transportation in 21st century.

In addition, due to the rapid growth in the number of private cars, city traffic has become very busy and crowded. But when people drive to work, the vehicle's interior space has not been used effectively. That is if the car has the capacity to accomodate 4-5 people, there is only one driver sitting, resulting in vehicle flow increase instead of passenger flow increase. In order to alleviate this urban traffic congestion, electric bikes have become a popular means of transport. However, the electric bike has its inherent flaws such as its poor efficiency when coping with bad weather, poor security, etc. Therefore, we hope to design a product that can both have the advantages of cars and electric bikes, that is, a tiny, inexpensive, easy maintenance, secure, and energy-efficient electric car.

2. WHOLE SCHEME DESIGN

2.1. General Design Requirements

The mini EV designed in this paper is intended to achieve the electric drive, reduce vehicle weight, reduce drag and improve transmission under certain conditions (for a given performance requirement, the apparent size, *etc*.), so that endurance mileage is maximized. Here are some basic requirements for the vehicle design in Table **1**.

Table 1. The basic requirements for EV.

Item	Parameter
Seats	1
Vehicle quality/kg	240
Maximum mileage/km	75
Maximum speed/km/h	40
Maximum gradeability	≥15%
Total length/mm	≤2200
Total width/mm	≤1200
Total height/mm	≤1500

2.2. Traveling System

2.2.1. Wheels

Cars generally have four wheels, but for mini EV, Tricycle style is considered the best choice whether it is its practical application or the ease of design and power steering. There are two main forms of tricycle arrangement, one front two rear and the other front one rear [3]. Tricycles with one front two rear have poor steering stability and can easily rollover when turning with fast speed, which greatly reduces the driving safety of mini EV. Tricycles with two front one rear are widely used in all kinds of energy-saving racing cars. This arrangement ensures that cars can obtain good handling stability and ride comfort even having small running resistance. What's more, tricycles with this arrangement don't need axle shaft, differential and some other structures, reduce the complexity of the mechanism and vehicle quality. And when the vehicle is decelerating before a curve, the load is assigned to two front wheels, so that cornering stability can easily be guaranteed. Therefore, the arrangement of two front one rear (two front steering wheels, one rear driving wheel) was selected for mini EV.

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2.2.2. Frame

As an important part of mini EV, frame must have lower quality and sufficient strength and rigidity to ensure that it is not destroyed by stress and deformation. Generally, the quality of the frame itself should be controlled by the less than 10 percent of vehicle curb mass [4]. Considering the requirements of strength and rigidity of mini EV, vehicle arrangement and ease of manufacture, Pipe-type frame which is often used in energy-saving racing cars, is selected for mini EV. Pipe-type frame contains a lot of steel welded into a skeleton, then the various components are fixed on the frame [5]. The frame materials should cost lower while meeting the requirements of strength and stiffness. Aluminum alloy that has high specific strength and specific stiffness, low density and is cheap, should be the most appropriate material [6].

2.2.3. Suspension

For city driving, independent suspension often used to obtain a lower vehicle centroid height, better ride comfort and handling stability. Single wishbone, double wishbone, single trailing arm, double trailing arm, single oblique arm, McPherson and torsion bar, etc. are the most common types. Considering the wheels of two front one rear, rear-wheel drive and Pipe-type frame, double-wishbone independent suspension is used for front suspension, whereas single trailing arm independent suspension is used for rear suspension.

2.3. Steering System

The steering wheel is arranged according to the position of hands which is designed based on ergonomics. Steering shaft axis and steering wheel center are disposed within the vehicle longitudinal vertical plane. The position and tilt angle of steering wheel should make driver manipulate with portable devices [7]. In addition, the location of steering column should not hinder the driver's need of normal leg movement. Steering rod and steering gear are disposed between the upper and lower wishbones of double wishbone suspension and the front of frame, to check whether the interference will occur between the various components.

2.4. Cockpit

The cockpit is disposed in the back of the battery, in the rearward part of the EV, that is making steering system arrangement easy to handle. It can also increase the load applied on the rear axle, as well as the adhesion between the rear wheel and the ground.

2.5. Battery

Taking into account the use of rear-wheel drive, in order to increase the adhesion between the rear wheel and the ground and to shorten the distance between the battery and the motor, the battery is arranged in the back of the seat, before the top of the rear wheel.

2.6. Cargo Box

Cargo box is arranged above the rear wheel, making the car more compact layout.

3. DRIVE SYSTEM PARAMETER CALCULATION

3.1. Motor Parameter Calculation

The rated power and rated torque are the main parameters for motor. The rated power is determined by the maximum speed of EV to ensure the efficiency of the motor. Meanwhile, the power consumption of the vehicle increases with the speed of the vehicle, and the velocity of the vehicle in normal driving is generally lower than the maximum speed, so the rated power of the motor should be higher than or equal to all the running resistance power when the vehicle is running with the maximum speed [8].

The rated power of motor can be given by:

$$P_e \geq \frac{1}{\eta}\left(\frac{mgf}{3600}u_{\max} + \frac{C_D A}{76140}u_{\max}^3\right) \tag{1}$$

Where m is the vehicle quality, A is the frontal area, η is the transmission efficiency, f is the rolling resistance coefficient, C_D is the air resistance coefficient, $u_{\max}$ is the maximum speed.

Rated torque can be calculated by the rated power and motor speed:

$$T_e = \frac{9550 \cdot P_e}{n} \tag{2}$$

When the vehicle is in the climbing conditions, the instantaneous power needs that overload power is higher than rated power, that can be given by:

$$P_{\max} \geq \frac{1}{\eta}\left(\frac{mgf\cos\alpha}{3600}u_a + \frac{mgi}{3600}u_a + \frac{C_D A}{76140}u_a^3\right) \tag{3}$$

Where r is the tyre rolling radius, i is the max slope, α is the max slope angle, u_a is the climbing speed.

Also in the climbing conditions, the maximum toque of mini EV can be calculated by:

$$T_{\max} \geq \frac{r}{\eta i_0}\left(mgf\cos\alpha + mg\sin\alpha + \frac{C_D A}{21.15}u_a^2\right) \tag{4}$$

3.2. Battery Pack Parameter Calculation

3.2.1. Battery Effective Capacity

According to the design index of 75 km vehicle mileage, battery effective capacity can be given by:

$$M_e = \frac{N}{V} \cdot \frac{\mathrm{S}}{u} \tag{5}$$

Where N is the motor rated power, V is the motor rated voltage, S is the vehicle mileage, u is the vehicle speed.

3.2.2. Battery Rated Capacity

At present, new power battery calibrate its rated capacity by 5 h discharge rate, and the above calculations show that the battery is actually working on 2 h discharge rate, However, Lead-acid battery discharge characteristics test data shows that: the effective capacity of the battery with 2 h discharge rate is only 70% of the rated capacity of the battery with 5 h discharge rate.

The battery rated capacity can be written by:

$$M = M_e / 0.7 \quad (6)$$

3.3. Dynamic Parameter Calculation

Depending on design specification, refer to the relevant information to draw basic parameters of mini EV in Table **2**.

Table 2. Basic parameters.

Item	Parameter
Vehicle quality/kg	240
Maximum speed/km· h-1	40
Maximum gradeability/%	20
Rolling resistance coefficient	0.01
Air resistance coefficient	0.3
Frontal area/m2	2.1
Transmission efficiency	0.98
Tire rolling radius/m	0.226
Vehicle mileage/km	75

According to the basic parameters above, drive system parameters are calculated by the basic dynamic equation of drive system. The results are shown in Table **3**.

Table 3. Drive system parameters.

Item	Parameter
Motor rated power/kw	0.807
Battery pack rated output voltage/V	48
Battery pack rated capacity/Ah	55.71

Taking care of both calculation results and actual situation, select 48 V/1 kw motor and select and four 12V/15Ah maintenance-free lead-acid motive battery are selected in series as the power source.

4. COCKPIT DESIGN

In this part, ergonomics will be used for aided design. First, establish a human model in Human Builder module in CATIA [9], then select the 95th percentile of the human dimensions of Chinese adults and adjust the joint angle of human model as shown in Table **4**.

There is an important point "H-point" that needs to be determined when arranging the position of human model's in body. H-point is the pivot point measured for the actual vehicle that connected human torso and thigh, H-point is the reference point which can more accurately determine the location of the driver or the passenger in the seat [10].

Table 4. Joint angle of human model.

Human Joint	Angle/(°)
neck joint	165
Shoulder joint	25
Elbow joint	110
Hip joint	105
Knee joint	115
Foot joint	100

Firstly, draw a two-dimensional human model as described above, and determine the H-point according to the requirements of the cockpit arrangement. Then paint a slash that is 8 degrees to the vertical direction from H-point, and get point F at 765 mm upward along the slash from H-point. Point F is equivalent to the highest point of the head of the 50th percentile driver. Next, take point at 100~135 mm vertically upward from point F, that point is the highest point of the roof trim lines. The roof above the roof trim lines includes steel sheet, skin and isolation layer, whose total thickness is about 15~25 mm. Furthermore, the highest point on the cross-section of the car roof needs to add 20~40 mm from that point because the cap is generally upwardly convex contour surface and is symmetrical to the longitudinal plane of the car. As shown in Fig. (**1**).

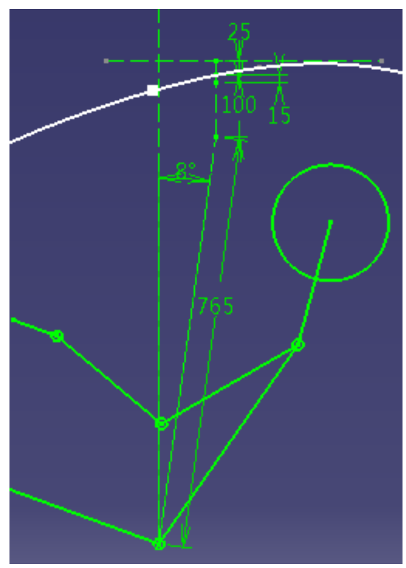

Fig. (1). The highest point of the roof contour.

The distance from H-point to the highest point of the roof is calculated as:

$$h = 765 \times \cos 8^{\circ} + 100 + 15 + 25 = 898mm \quad (7)$$

Corresponding 2D drawings, a 3D model is drawn according to the related parameters determined by ergonomics as shown in Figs. (**2**, **3**).

5. VEHICLE PARAMETERS

The other relevant parameters of mini EV are calculated in the tables below according to design specification (Tables **5-7**).

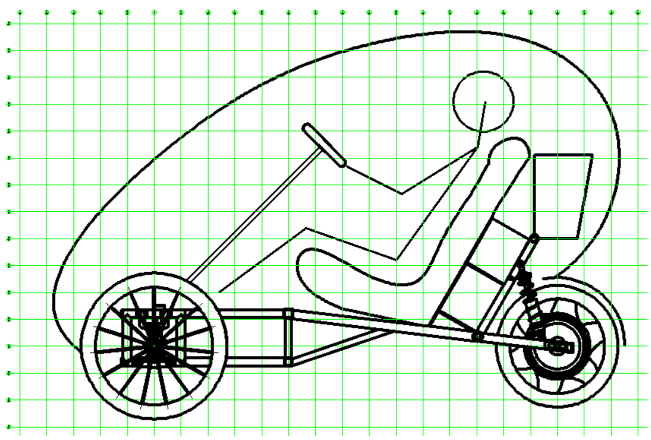

Fig. (2). 2D Drawings.

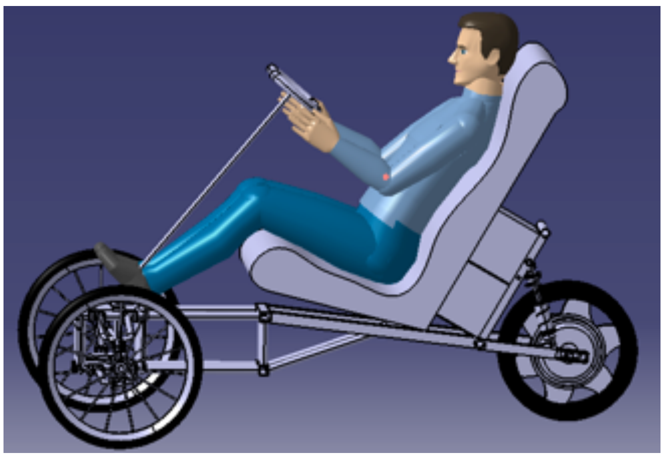

Fig. (3). 3D Model.

Table 5. Vehicle quality parameters.

Item	Parameter
Curb mass/kg	140
Total mass/kg	240
Front axle load of car with full load/N	768
Rear axle load of car with full load/N	1632
Front axle load of car with no load/N	814
Rear axle load of car with no load/N	1386

Table 6. Vehicle dimensions parameters.

Item	Parameter
Overall length×Overall width × Overall height /(mm×mm×mm)	2048×1000×1442
Wheelbase/mm	1500
Front wheel tread/mm	900
Front overhang/mm	297
Rear overhang/mm	251

Table 7. Trafficability parameters.

Item	Parameter
Minimum ground clearance/m	0.18
Approach angle/(°)	48.6
Departure angle/(°)	65.3
Minimum turning radius/m	3.195

CONCLUSION

1. This urban mini EV is only 240 kg in weight and has a small size. It is convenient to drive on the city roads, alleys, streets, communities, squares, parks, etc. It is also easy to park, easing the traffic pressure.
2. The mini EV is energy efficient, environmental friendly and low noise. And compared to the normal two wheels electric bicycles , mini EV is safer and stronger to adapt to harsh weather. It also meets people's normal demand of the car's dynamic performance by using high-performance hub motor and lead-acid battery.
3. The mini EV is cheap. It is expected that the market price will be less than 10,000 RMB. Also, it is expected to get good economic and social benefits after the car is put on the market.

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CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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