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Design, Analysis and Manufacture of a Solar Electric Vehicle

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ABSTRACT:

Solar energy is mainly used as an energy source for cars, replacing traditional energy source, gasoline. The structure of the solar electric vehicle, including the body structure, tires, engine systems, transmission systems and electrical circuit design was introduced briefly in the paper. Work principle and ideal performance are carefully analysed. In the laboratory, the vehicle model is designed and manufactured. Through the laboratory tests, it can be shown that the designed vehicle can travel with low speed with good endurance with no pollution to the air.

KEYWORDS:

Solar electric vehicle; Frame; Solar cells; Tire and brake system; Electrical circuit; Finite element analysis

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1. Introduction

With the development of the automotive industry in the world, one of the biggest challenges facing the automotive industry is the environmental pollution caused by energy consumption and emissions. At present, most cars use gasoline and diesel as fuel; oil for a long time will still be the choice of fuel for vehicles. Automobile exhaust gas contains 150-200 different compounds, the most harmful to people, carbon monoxide, hydrocarbons, nitrogen oxides, lead compounds and carbon particles. Harmful gas diffusion causes air pollution. The air pollution caused by cars accounts for 60% to 90% of urban air pollution. Solar cars will become the focus of the automotive industry in the future. The development of solar electric vehicles is imperative to really get rid of dependence on non-renewable energy. This paper mainly introduces the three sub-systems of solar electric vehicle which include electric driving sub-system, energy sub-system and auxiliary control system sub-system. The designed solar electric vehicle was tested in a laboratory.

2. Material and methods

2.1. Basic structure of electric vehicle

Traditional fuel vehicles use fuel as the source of power and driven by internal combustion engine, due to internal combustion engine is replaced with a mass of cell box that serves as the source of power, there happened quite a big variation on the structure of the whole electric vehicle when compared with that of the fuel vehicle [1]. The main feature of electric vehicle is flexibility. Energy is transferred by flexible electric wire in electric vehicle, not through the rigid shaft, so it offers engineers a high degree of flexibility in arrangement of electric vehicle's parts. As shown in Fig. 1, the system of electric vehicle can be subdivided into three sub-systems: electric driving sub-system, energy sub-system and auxiliary control sub-system. Electric driving sub-system consist of electric control unit, power converter, motor and mechanical transmission. Energy sub-system is made up primarily of energy source, energy management system and charge system. The function of auxiliary control sub-system is power steering, temperature control and auxiliary energy supply. According to the signal from accelerator pedal and brake pedal, electric controller generates control command to control the activation and deactivation of power facility. The function of power converter is regulating the power flow between motor and power supply [2]. The kinetic energy of regenerative breaking can be recycled by energy source when broken. Auxiliary power supply system mainly provides the power for the power steering system, air conditioning system and braking system. Except for input signal from the accelerator pedal and braking pedal, steering wheel angle is an important input signal for electric vehicle.

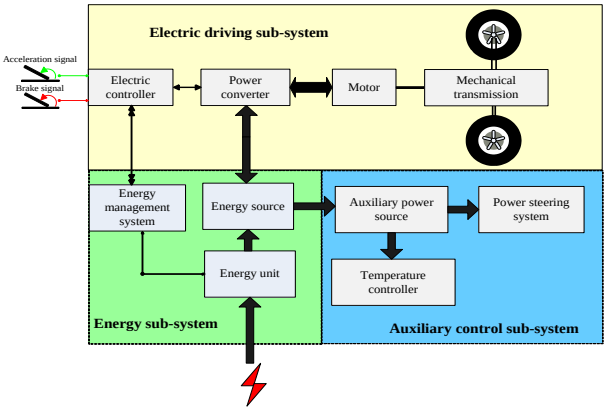

Fig. 1: Basic structure of solar electric vehicle

2.2. Electric driving system

There are several driver types - Engine front wheel drive (FF), Engine front rear wheel drive (FR), Rear engine rear wheel drive (RR), Mid-engine, rear wheel drive (MR) and Full drive (AWD) [3]. Considering the energy saving and cost, a rear wheel drive is selected to reduce the consumption of service quality and the mechanical energy loss of the transmission. Electric driving system is the key part of the electric vehicle. It can transform the chemical energy of storage battery into the kinetic energy of electric vehicle efficiently, or feed-back the surplus energy to the storage battery. Sensors, junction circuit and actuator are three functional units of electric controller, the performance parameter, such as current, voltage, temperature, speed and torque, can be changed into electric signal by sensors, then input it to microprocessor for process and control, the output amplified by amplifying circuit can drive semiconductor component of power converter. The driving motor should have high power density, so that can reduce the mass of the vehicle and extend range per charge [4]. According to the technical requirements of electric vehicles to the motor, brushless direct current motor can meet the basic needs of the operation of electric vehicle, So, brushless direct current motor, as shown in Fig. 2, becomes the first choice for entry-level electric vehicle. Brushless direct current motor's speed range is not wide and the maximum speed is only about 6000rpm, it is hard meet the demand of operating condition, under these circumstances, you have no choice but to configure reducer or gearbox, this technological structure has a negative impact on entire vehicle design in terms of spatial arrangement and weight control.

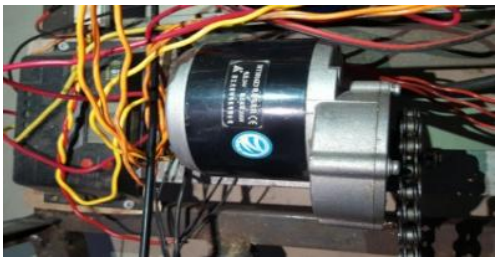

Fig. 2: Brushless direct current driving motor

Compared with belt drive, chain drive without elastic sliding and skidding, can maintain accurate than the average transmission; the tension of the needs of small, low pressure acting on the shaft, the bearing can reduce the friction loss; the structure is compact, in oil, high temperature and other harsh environment of the work. The chain drive has more accuracy than the average transmission but usually only used for transmission between parallel shafts [5]. Because the chain is rigid, so the polygon affect, the motion characteristics of the instantaneous transmission ratio changes and causes additional dynamic load and vibration. Taking into account of the cost of production, installation accuracy and the distribution of the centre of the vehicle, the final choice is to use dedicated 410 chains as shown in Fig. 3.

Fig. 3: 410 chain transmission mechanism

2.3. Design of vehicle frame

In order to reduce the weight and ensure the stiffness and strength of the vehicle frame, the structure should be simplified as much as possible. According to the layout of the wheel, the vehicle frame has main choices as Stainless steel ladder frame, Aluminium alloy ladder frame, Trapezoidal steel tube frame, Aluminium frame bearing frame, Aluminium bearing frame and Advanced material frame. The trapezoidal steel frame is adopted due to good strength and easy for processing/welding or riveting. Considering the production cost, 30×30mm square tube frame of 2mm thickness, as shown in Fig. 4, is selected for the current solar electric vehicle. Vehicle frame design takes in to account of the placement of solar panels, wind resistance, beautiful appearance and assembly of various systems. In order to make full use of the material properties, the vehicle frame is fully loaded in a bending condition using finite element method [6]. The size optimization of the frame was carried out using RADIOSS software to select the appropriate tube wall thickness for the required stiffness and strength. The displacement and stress fringe plots for the optimised frame are shown in Fig. 5(a) and (b) respectively.

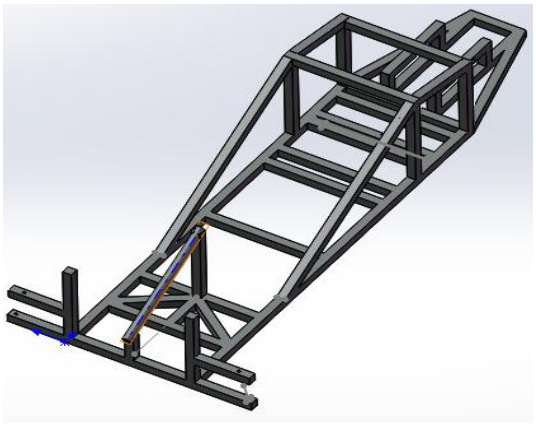

Fig. 4: Basic structure of frame

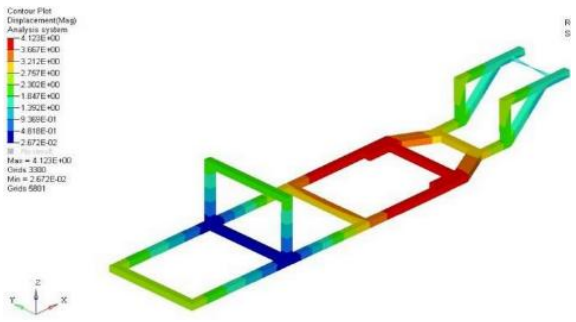

Fig. 5(a): Displacement fringe plot

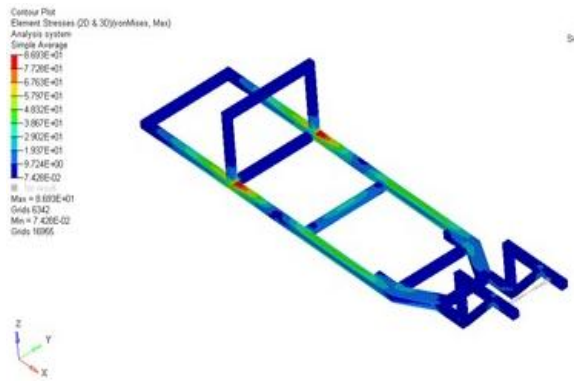

Fig. 5(b): Stress fringe plot

2.4. Design of electrical circuit

The electrical circuit diagram is used to indicate the specific arrangement of the electric circuit and the electric appliance of the automobile. The electrical circuit diagram gives the arrangement of each connector terminals, providing convenience for automobile electrical equipment and line fault search [7-9]. Electrical wiring diagram is only concerned with the location of the components and the direction of the line, as follows: (1). Headlights, arranged on both sides of the car; (2). Speed pedal, located in the driver's right foot heel; (3). Solar panels, arranged in the first car and parking spaces; (4). Reverse switch, similar to the car's gear, arranged in the steering wheel to facilitate operation; (5). The headlight switch is arranged in the seat next to the seat; (6). Solar controller, located under the hood; (7). Battery, located under the rear hood; (8). Motor controller, located under the rear hood; (9). Motor according to the rear wheel drive mechanism; (10). Instrument panel, the speed display module, alcohol alarm module, reversing radar module, instrument panel are arranged in the back of the steering wheel for easier observation by the driver; (11). Holzer sensor is arranged on the rear wheel side, by measuring the rear wheel speed to get real-time speed; (12). Ultrasonic module is arranged at the tail end of the car to measure the distance between the car tail and the obstacle. The electric circuit of the designed solar electric vehicle is shown in Fig. 6.

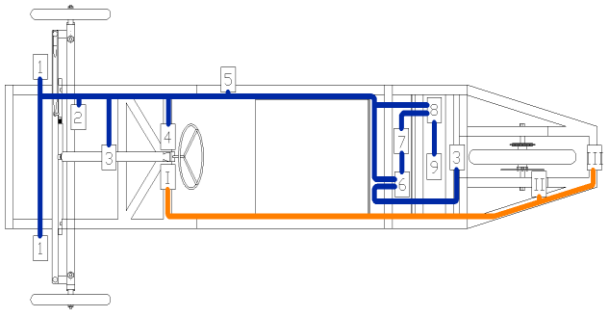

Fig. 6: Electrical circuit, (1). Headlight, (2). Speed pedal, (3). Solar panel, (4). Reverse switch, (5). Headlight switch, (6). Solar controller, (7). Battery, (8). Motor controller, (9). Motor, (10). Dashboard, (11). Holzer sensor, (12). Ultrasonic sensors

2.5. Design of battery management system

A solar cell is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon. Considering the performance, economy, vehicular surface area, weight, volume and other factors, SFM-50 solar panel is selected for this design. It can supply maximum voltage 18V and 21.6V in open circuit. The new energy vehicles are mainly divided into three types: pure electric vehicles, fuel cell vehicles and hybrid vehicles. At present, the pure electric vehicles accounted for the largest market share, accounting for about 92%. Pure electric vehicles use lithium batteries as a source of power. It is necessary to monitor the state of charge in real-time, for the driver to provide the remaining power, continued driving mileage and other information, as well as to prevent battery over pressure, flow, over charge, over discharge [10-12]. Through in-depth study of the current electric vehicle power lithium battery state of charge and discharge estimation techniques, open circuit voltage-ampere hour integral sampling card Kalman filtering (OCV-Ah-SPKF) algorithm is selected. Fig. 7 shows the adopted battery management system for the solar electric vehicle.

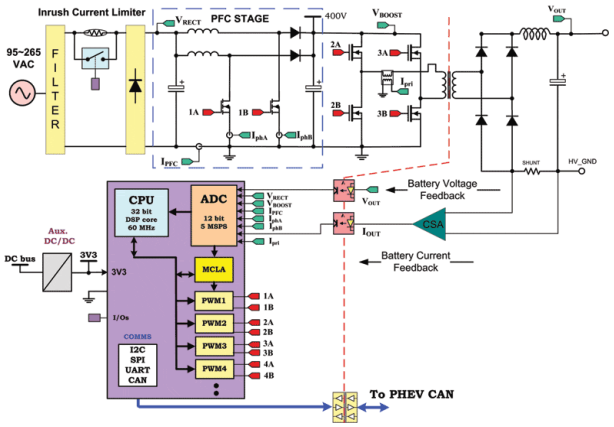

Fig. 7: Battery management system of electric vehicle

2.6. Design of tire and brake system design

Taking into account of the vehicle occupant being only one person, the bicycle wheels were chosen to optimize the solar electric energy saving vehicle servicing quality. The convenient installation of the brake disc of bicycle in the designed solar electric vehicle is shown in Fig. 8. The front and rear wheel diameter is about 300mm and 400mm respectively. In order to improve the stability, the chassis height is set to 100mm. The maximum speed of the vehicle is set to not more than 20km/h. The mass was estimated about 60kg, slow mass was estimated about 140kg.

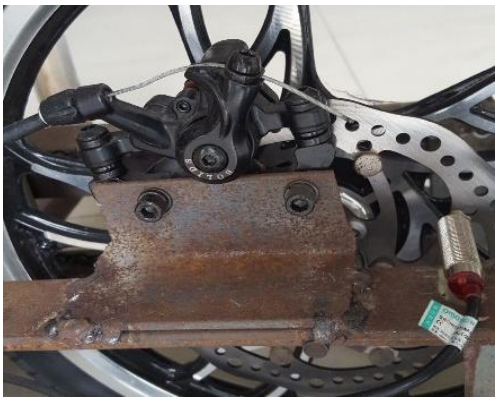

Fig. 8: Design of tire and brake system design

3. Results and discussion

The design and optimization of the body shape of the solar electric vehicle are analysed and discussed. The manufactured solar electric vehicle is shown in Fig. 9. Laboratory scale tests were conducted using this vehicle for a range of steering manoeuvres and speeds by a single driver. The noise and vibration level of the motor in operation is much less than that of the traditional internal combustion engine. In the case of idle speed and low speed, the comfort of electric vehicles is much higher than that of traditional vehicles. The power consumption of the electric vehicle is 15-20kw/h. The motor can output the maximum torque in the full speed range, so the start is very rapid acceleration. The zero pollution can be achieved in the process of operation and no harmful gas is discharged to the environment. The compaction of electrical components and battery fuel cells within structural body has paved way for the rider comfort and reduced body force is achieved.

Fig. 9: Solar electric vehicle

4. Conclusion

In this work, a solar electric vehicle is designed and manufactured considering structural design, finite element analysis of frame, electrical design, battery management system etc. The utility model has the advantages of good versatility and practicability. A laboratory scale test of the manufactured environmental friendly solar electric vehicle has demonstrated good steering control and smooth ride.

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