Design of 25.7kW Pure Electric Tractor

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Abstract

This paper designs a pure electric tractor based on the existing electric vehicle design theory and traditional tractor design theory. Through the corresponding calculation, the power battery pack with 30kW drive motor and total energy of 216.9kWh was selected. Finally, the gear ratio of each gear position and the design of the gearbox were determined, and the three-dimensional design of the whole machine was finally completed.

Keywords

Electric tractor ,motor, power battery pack,transmission system.

1. Introduction

As the main power machine for agricultural production, tractors increase their quantity year by year, but the energy consumption of traditional fuel tractors is due to the special and complicated working conditions of tractors and the low speed area of high power under most of the time period. The rate is relatively large and the emissions are relatively poor. At present, China's agricultural electric vehicles are still in the research stage. Therefore, research on the key technologies of energy-saving, environmentally-friendly and efficient pure electric tractors is to promote the research and development of agricultural electric vehicles in China, and to alleviate the energy crisis and environmental pollution. Very significant meaning [1.2]. In this paper, the drive motor, power battery, and transmission box of the electric tractor are calculated and designed, and finally the whole machine model is obtained.

2. Drive motor power design

In combination with the traditional fuel tractor, the output of the motor can be divided into two parts, P_1 - the forward of the tractor and the traction part of the work to provide power, P_2 - the power source of the PTO of the tractor's power output shaft.

The traction power of pure electric tractors should first meet the demand for rated traction [3]. The power of the traction motor should meet the requirements of the rated traction and operating speed of the pure electric tractor during the plowing operation, namely:

$$P_{TR} \geq \frac{F_{RN} V_R}{3600 \eta_R} \quad (1)$$

Where, P_{TR} - power of the traction motor, kW; V_R - is the maximum speed of the tractor during plowing operation, km / h; η_R -is the traction efficiency; F_{RN} - is the rated traction.

The impact of traditional fuel tractors. The traction efficiency of the pure electric tractor is affected by the mechanical transmission efficiency, the driving wheel sliding efficiency, the rolling efficiency, and the traction motor power loss. The specific performance is as follows:

$$\eta_R = \eta_{mm} \eta_m \eta_\delta \eta_f \quad (2)$$

Where η_{mm} - is the traction motor efficiency; η_m - is the efficiency of the mechanical transmission device; η_δ - is the slip efficiency, η_R =1-δ, δ- is the slip rate; η_f - is the rolling efficiency.

Calculate the range of the traction motor power P_{TR} according to the formula (1), and then select the motor that meets the requirements. The rated power P_{TR} must satisfy:

$$P_1 \geq P_{TR} \tag{3}$$

Deserved by experience: $\eta_R = \eta_{mm}\eta_m\eta_\delta\eta_f = 0.9*0.9*0.9 \approx 0.7$

Calculate the power of the traction motor from the traction efficiency: P_{TR}=15.5kW

The generally output PTO power is directly output by the power output device from the gearbox, and the power can be approximately considered to be constant. The total power of the motor is:

$$P_1 = P_1 + P_2 = 15.5\text{kW} + 14.9\text{kW} = 30.4\text{kW}$$

According to the above calculation results, it can be concluded that the power of the drive motor of the vehicle can reach the design requirement at around 30.4kw. After comparison, the permanent magnet synchronous 30kw motor designed by Ocean Electric was selected[4].

3. Power battery pack design

1.Meet the voltage and current requirements of the motor controller

Select bulk polymer battery, lfp09185190, basic parameters: monomer voltage 3.2V, 25Ah, 190*185*9, weight 0.55kg. The connection method (single group) is determined according to the parameters of the motor controller: 113 strings meet their voltage requirements, 10 and meet the current requirements. A total of 1130 cells are shared, and the combination of energy storage devices is 10 and 113 strings.

2. Meet the working time

According to the design requirements, the electric tractor can meet the plowing operation time of 6h on a single charge, and the required electric energy:

$$W = P_N * s \tag{4}$$

Where, P_N -motor rated power, kW, s-working time, h

Battery energy calculation method:

$$W_s = C_e U_e M N \eta_{dod} \tag{5}$$

Where, C_e -Battery capacity U_e -Battery cell rated voltage M - Number of cells in series N - Parallel battery pack η_{dod} - Battery discharge depth, η_{dod} = 0.8, W_s - Discharge power of single battery

$$W_s = C_e U_e M N \eta_{dod} = 25*32*113*10*0.8 \approx 72.3\text{kWh}$$

Therefore, the number of batteries required: $n = W/W_s = 2.4$

Electric tractors also have hydraulic suspension systems. The electronic power assist system and other auxiliary devices require electrical energy, and a certain margin is reserved.

4. Transmission system design

Electric tractors are versatile and have different requirements for driving speed and driving torque. Different operations require different speeds, and the working speed is lower when ditching, plowing, and fertilizing operations, and faster working speeds are required for transportation operations. The driving speed of a pure electric tractor during plowing operation is generally 4-6 km/h, and the maximum speed at the time of transition is set to 40 km/h[5].

$$i_j \approx 0.377 * nr / u_j \tag{6}$$

Where i_j -the total transmission of the tractor under j gear; n-rated speed; n=3000 rpm/min, r-tire radius; r=0.589m; u_j -the theoretical speed at j; u_I =6km/h u_{II} = 40km/h

From the above data, it can be seen that the total gear ratio of the first and second gear is 110.3 and 44.41 respectively.

The transmission system consists of gearbox, central drive and final drive, and each system participates in the transmission ratio. The relationship of the transmission ratio is as follows:

$$i_j = i_{bj} i_m i_z \tag{7}$$

Where, i_{bj} -the gear ratio of the jth gear; i_z -central transmission ratio; i_m -the final transmission ratio

In the design system, the final transmission mechanism is simplified, the final transmission ratio is 3, and the central transmission is 4.

$$i_{bj} = i / i_m i_z \tag{8}$$

Where i_{b1} - gear ratio of the first gear; i_{b2} - gear ratio of the second gear

It can be seen that the gear ratio of the gearbox of the first gear is 9.25, and the gear ratio of the gearbox of the second gear is 3.6. The three-dimensional design result of the transmission case is shown in the figure1.

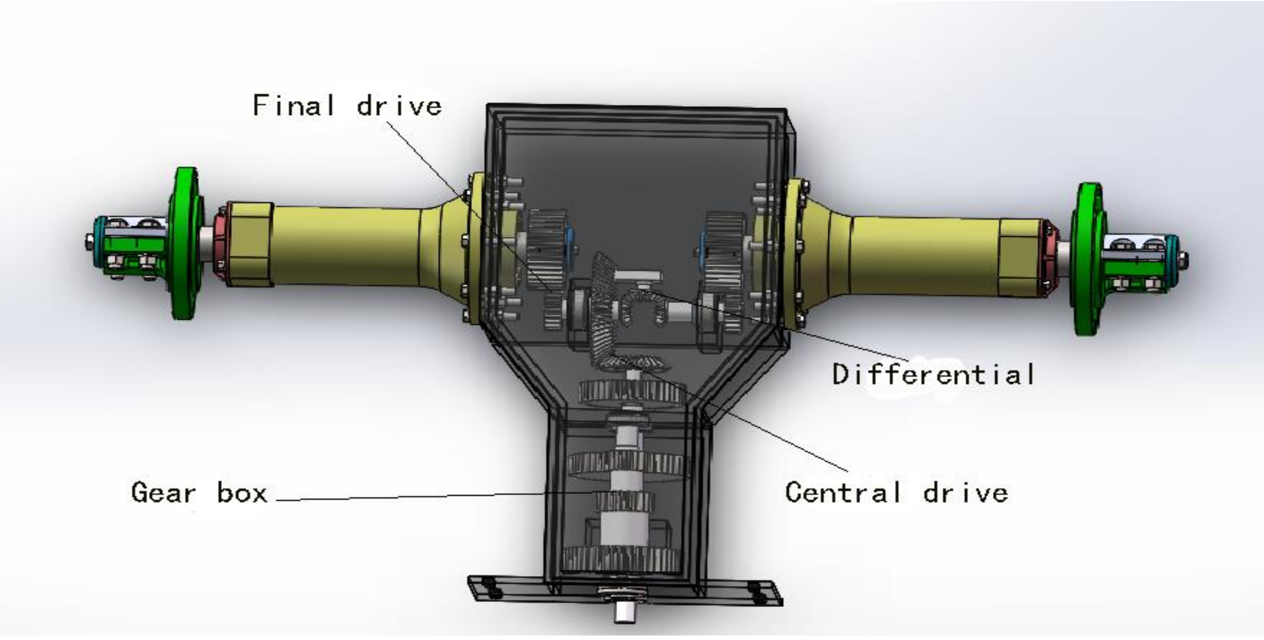

Fig.1 3D illustration of electric tractor transmission system

5. Conclusion

Based on the above calculated data, modeling is performed according to the existing conventional tractor model. The pure electric tractor drive system designed in this paper consists of power battery pack, controller, electric motor, high and low multi-output gearbox, PTO, drive axle and drive wheel. This type of pure electric tractor drive system has a small improvement on the traditional tractor drive system, which is convenient for retrofitting and transforming the traditional tractor, which is conducive to the rapid advancement of the marketization process of the pure electric tractor. On the other hand, the drive system can fully reflect the basic structure and performance of the pure electric tractor drive system, and can be used as a carrier for performance analysis of pure electric tractors. Therefore, this paper selects it as the final overall transmission scheme of the pure electric tractor drive system. The specific design results are shown in Figure 2 and Figure 3.

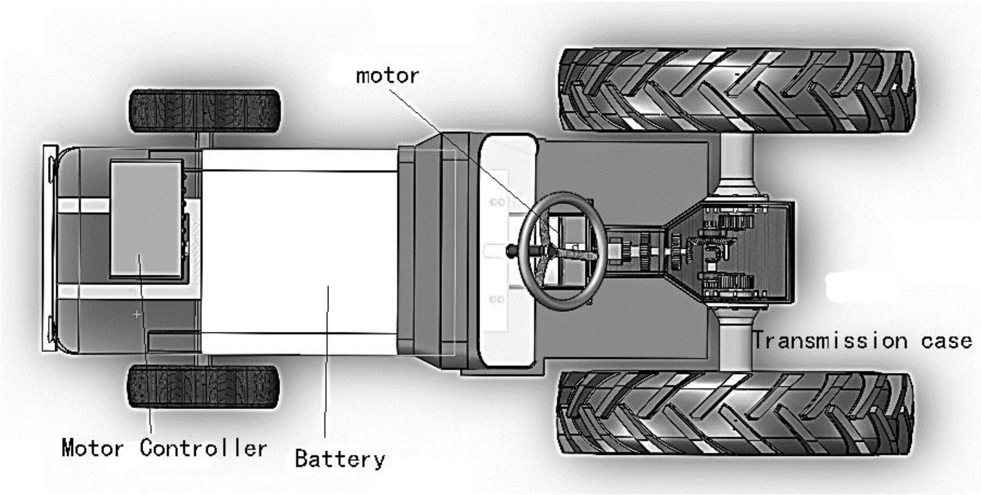

Fig.2 Machine layout

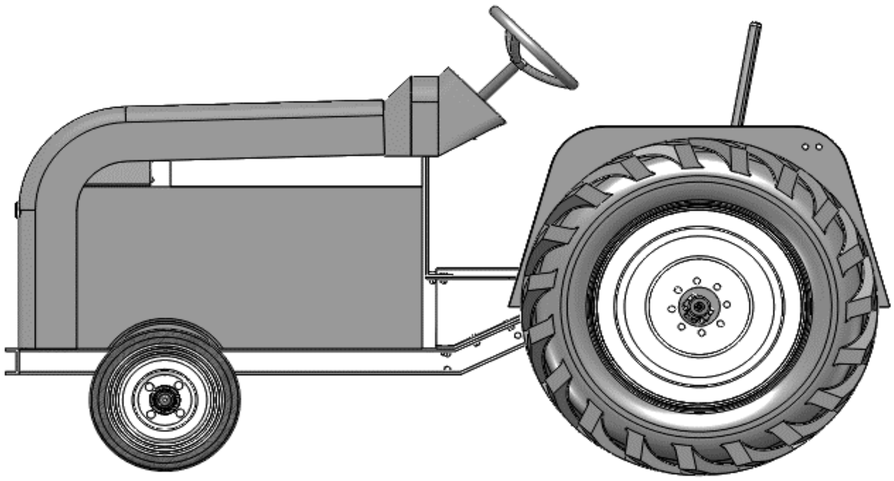

Fig.3 Front view

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