

## Design and Analysis of power-train system of New Pure Electric City Bus

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**Abstract.** Realizing the traffic energy diversification and low exhaust is important to promote competitiveness of the automobile industry in our country and realize sustainable development of the society. Due to the trips of pure electric city bus are relatively short and fixed, it has great application value in urban public transport industry where environmental protection is important. Based on operation characteristics of the pure electric city bus, the overall design of power-train system was completed. The motor was selected using MATLAB. The universal transmission shaft system, main retarder, differential mechanism, wheel drive, driving axle housing and so on were designed. Three-dimensional model of the transmission system was established and the parametric model of the general subsystems was established to facilitate its application in the expansion of the other models. Finally, the finite element analysis of the transmission device of wheel has been done.

### Introduction

Auto demand is increasing rapidly, while the development of auto industry and increase of car ownership will lead to a series of energy and environmental issues directly. Currently, new energy vehicles are developing in worldwide, and there are diverse species such as pure electric vehicles, hybrid vehicles, extended range electric vehicles, fuel cell electric vehicles, and hydrogen engine cars, etc.[1]. Pure electric vehicle is pushed by battery and its technology is simple and mature. It has the following characteristics, including convenient charging, almost zero emissions, poor acceleration performance and weak endurance. Hybrid vehicle is drove by gasoline-electric power source and has good endurance and excellent vehicle dynamic. However, the structure of hybrid vehicle is complex and it cannot achieve zero emissions, and also the fuel efficiency of it is not obvious in long distance running. Fuel cell electric vehicle can realize zero emissions and has good fuel economy, running smoothly, low noise, but high fuel cell costs [2,4].

Obviously, pure electric vehicles have great application value in urban public transport industry where environmental protection is important and trips are relatively short and fixed. This paper combines the design experience and methods of traditional cars with the structure characteristics of the modern pure electric vehicle, the power-train system of pure electric city bus is designed.

### Designing the power-train system of pure electric city bus

The main task of the transmission system is to act in concert with motor to realize a variety of movements. Therefore, any form of transmission system should have such functions as decreasing speed, increasing torque, changing speed, traveling backwards, discontinuing power transmission of transmission system, and having different rotating speed for both sides of the drive wheel. According to the operating characteristics and structural characteristics of the pure electric city bus, the design parameters are determined, as shown in table 1.

The overall scheme of the transmission system of new pure electric city bus is shown in Figure 1. The transmission system is mainly composed of motor, transmission shaft assembly, main reducer, differential, wheel gearing, wherein the main reducer, differential and wheel gearing are located

inside the drive axle. The position of the drive axle is depending on the position of the wheels. In order to make the left and right axle general, the center-line of differential should coincide with the center-line of car.

Table 1 Design parameters of the pure electric city bus

Design parameters	Parameter Value
Total vehicle mass (kg)	8250
Windward area (m <sup>2</sup> )	5.88
Maximum speed(km/h)	69
Rolling radius of wheel (m)	0.36
The acceleration time from a standing start to the specified speed(s)	25
Drive ratio of the main reducer	6.33
Static load of the drive axle under full load state(N)	53684

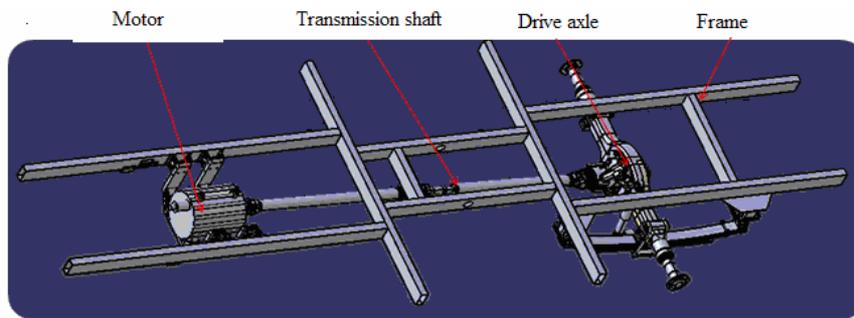


Figure 1 The overall scheme of the transmission system

**Motor Selection Based on Matlab.** The condition of pure electric city bus is complex. According to the automobile balance equation, the maximum speed, maximum grade, and acceleration time are used to calculate the maximum power of the motor, and then they are combined with the average driving conditions to calculate rated calculation load of motor. Based on the Matlab, the calculation process is finished and the motor type is determined. Part of the calculation process is shown in Figure 2.

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Pemax1=1/eta_T*((ma*g*fr)/3600*Va
max+(CD*A)/76140*Vamax^3)
i=0.15
ua=20
% eta_T-ηT
eta_T=0.90
ma=8250
g=9.8
fr=0.015
CD=0.65
A=5.88

Pemax2=1/eta_T*((ma*g*fr)/3600*ua+(
CD*A)/76140*ua^3+ma*g*i*ua/3600)
ut=50
t=25
dert=1.08
% eta_T-ηT
eta_T=0.90
ma=8250
g=9.8
fr=0.015
CD=0.65
A=5.88
.....]

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Figure 2 The calculation process of motor

After calculation, the parameters of motor are shown in Table 2.

Table 2 the parameters of motor

Motor parameters	Peak power (kw)	Maximum rotating speed (r/min)	Maximum torque (N·m)
Parameter Value	60	3500	1000

**Designing the Universal Transmission Shaft.** The power between two shafts is transferred through universal joint when the vehicle is moving. The pure electric city bus adopts the structure of preposition engine and rear wheel drive. Due to the distance between drive axle and transmission of pure electric city bus is large, so two shafts and bail-type cross universal joint are adopted. The structure of universal transmission shaft as shown in fig.3. The component of it from left to right is

cross coupling, shaft tube, intermediate support, cross coupling, spline shaft, shaft tube and cross coupling.

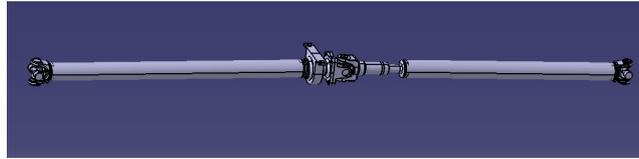


Figure 3 The structure of universal transmission shaft

The main failure mode of cross universal joint is the wear of journal of cross shaft and needle bearing. So the journal of cross shaft, diameter of oil passage hole, length of cross shaft, cross-sectional dimension and the type of needle bearing must be designed. In order to avoid the motion Interference which caused by the changing of relative position between the connecting members, the spline must be designed on the transmission shaft which can slide along the axial. Generally, the shaft tube is made by welded steel pipe. It has many excellent features, such as thin-walled (1.5mm-3mm) ,high torsional strength, big bend strength, suitable for high speed rotation, uniform wall thickness, etc..

**Designing the Drive Axle.** Drive axle is composed of main reducer, differential, gearing for driving wheel and axle[5]. The structure type of drive axle is closely interrelated with suspension form of driving wheel. The non-disconnected type drive axle is adopted in this paper, see Fig.4.

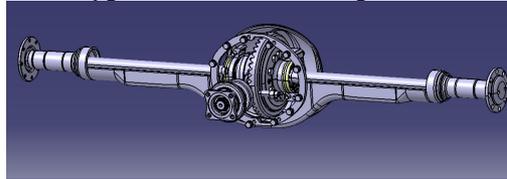


Figure 4 The structure of drive axle

The design of main reducer: Because single-stage main reducer has simple structure, small size, light weight, and low manufacturing costs, so it has wide application in medium and small car whose main reduction ratio is less than or equal to 7.6. The single-stage main reducer made by "Gleason" hypoid gears is adopted in this paper[6]. After calculation, the main parameters of active hypoid gear and driven hypoid gear as shown in table 3. The type of four bearings supporting gears is selected as following:A-31308; B-31309; C-32917X2; D-32917X2.

Table 3 The main parameters of active hypoid gear and driven hypoid gear

Number of teethz	Diameter of pitch circle of big end (mm)	End surface modulus	Tooth width (mm)	Offset (mm)	Helix angle (°)	Normal pressure angle (°)
z1 = 9	D1 = 54	6	b1 = 58	E=35	§1=33	α=20
z2 = 57	D2 = 342		b2 = 53		§2=47	

The design of differential: Differential can make the left and right driving wheels rotating with different angular velocity. In this paper, the symmetrical bevel gear differential is used. It has many features, such as simple structure, smooth operation and easy manufacturing. After calculation, the main parameters of symmetrical bevel gear differential is listed in table 4.

The design of half axle : Half axle can realize the power transmission between differential and driving wheels. The inner end of it connect with gear through spline, and another end connect with the hub through bolt. The support form of half axle can be divided into three types, including Semi-floating, 3/4 floating and full floating. The full floating type is adopted in this scheme. After calculation, the main parameters of half axle is achieved as table 5.

The design of drive axle housing: The main effect of drive axle housing is to support the weight of vehicle and force as well as torque exerted by the wheels. At the same time, It is the assembly base of main reducer, differential and half axle too. Generally, the drive axle housing can be divided into separable type, integral type and modular type. Due to the integral type is beneficial to the assembly,

dis-assembly, adjustment, repair, maintenance of main reducer and differential. Therefore, the integral type of drive axle housing is used.

Table 4 the main parameters of symmetrical bevel gear differential

Number of planetary gears	4
Spherical radius of planetary gears (mm)	60
Section cone distance of planetary gears (mm)	59
Teeth number of planetary gears	12
Teeth number of Side gear	18
Module of large end	5.5
Pressure angle (°)	22
Diameter of planetary gear shaft (mm)	14
Supporting length (mm)	15.4

Table 5 the main parameters of half axle

Length of half axle (mm)	900
Modules of Involute splines	1.5
Teeth number of Involute splines	41
Effective length of Involute splines (mm)	60
Diameter of shaft (mm)	45

**Parametric modeling of generic subsystem**

In order to make the generic subsystem such as leaf spring and half axle can be applied in other types of vehicles, the parametric modeling of generic subsystem is done. The parametric modeling of leaf spring is shown in figure 5 and figure 6. Variable parameter is chord length, arc height, length of straight spring. As shown in figure 5, the shape of skeleton can be controlled by the parameters easily, and thereby the 3D model of the whole leaf spring is controlled.

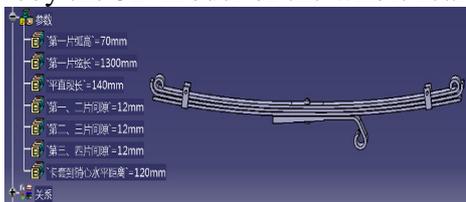


Figure 5 Parametric modeling of leaf spring

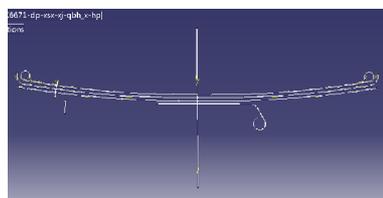


Figure 6 Parametric modeling of leaf spring skeleton

The parametric modeling of half axle is mainly focus on involute tooth profile. The parametric objects of it are modules, teeth number, pressure angle, overall length and diameter, see figure 7.

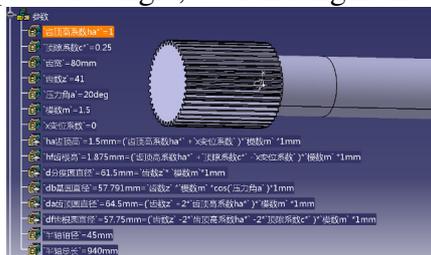


Figure 7 Parametric modeling of half axle

**Finite element static analysis of half axle**

Half axle can realize the power transmission between differential and driving wheels. If the half axle fractures, the moving car may be out of control and lead to accidents. Therefore, it is necessary to do the finite element static analysis, so as to the possibility of failure for half axle is decreased.

Pre-treatment is carried out in software HYPERMESH , while solving and post-processing is done in software ABAQUS[7]. The whole analysis process includes engineering analysis, simplified model, geometric modeling, meshing, defining materials, defining loads and constraints, submitting analysis and post-processing. Through finite element static analysis, the stress cloud of half axle is achieved in figure 8. According to the stress cloud, the maximum stress values is 603.8MPa. However, the calculated shear stress of half axle through theory calculation is 561.6768 MPa. Comparing these two results, difference is only about one-tenth. This difference may be caused by the following reasons:

- ✧ there are deviations when the shear modulus is chosen for theory calculation.
- ✧ The definition of contact is inappropriate in the stage of pre-treatment.

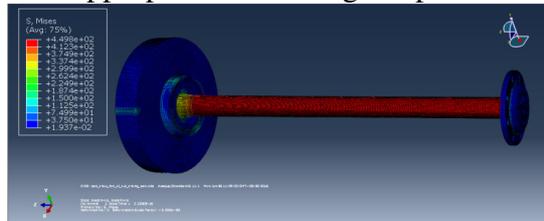


Figure 8 Stress cloud of half axle

## Summary

The development of pure electric city bus is important for energy conservation, environmental protection, and achieving sustainable development of the society. Therefore, the pure electric city bus have great development value. Effective use of three-dimensional software for design of the transmission system of pure electric city bus can decrease product design cycle, save design costs, increase economic efficiency. Simultaneously, the 3D model established lay a foundation for the dynamic analysis and optimization analysis in later stage.

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