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Dynamics simulation of AVL CRUISE pure electric vehicle and analysis of influencing factors of urban cycle conditions

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Abstract. Nowadays, the world is in a critical period of energy utilization transformation, and the development of the automobile industry is greatly influenced by energy. New energy vehicles represented by electric vehicles are the new direction of the development of the automobile industry in the future. The AVL-Cruise software system has many features, such as simple modeling function, visual design analysis and research, which provides technical support for the simulation projects under complex working conditions of vehicles. Taking the front wheel drive pure electric vehicle as an example, this paper uses AVL_CRUISE software to establish the power system model of electric vehicle, and uses this software to calculate its dynamic performance. The simulation results show that the maximum speed is 178km/h, the 100km acceleration time is 11.59s, and the maximum climbing slope is 30%. The simulation results show that the electric vehicle meets good design requirements. The total energy consumption is 4608KJ. By changing the data such as air resistance coefficient and vehicle quality, the relationship between the dynamic performance and the influencing factors is explored. The corresponding expression is obtained by fitting the data, which provides data support and reference experience for the optimization of electric vehicles.

Keywords: AVL-Cruise, simulation, electric vehicle, fitting.

1. Introduction

In today's world, the energy crisis is serious and restricting the development of the whole automobile industry. New energy vehicles represented by pure electric vehicles will definitely be a new direction for the development of Chinese automobile industry. In the overall design and optimization process of pure electric vehicle products, reasonable adjustment of peak motor efficiency and improvement of vehicle body structure can comprehensively improve the dynamic performance of vehicles. Based on AVL CRUISE, dynamic performance and urban cycle conditions of pure electric vehicles can be simulated and calculated, providing data support and reference experience for the optimization of electric vehicles.

2. Dynamic simulation

2.1 Mathematical model of electric vehicle dynamics

The driving force of electric vehicle is obtained from the motor output torque transmitted to the driving wheel through the transmission system. The relationship between the driving force of an electric vehicle and the output torque of the motor is

$$F_t = \frac{T_e i_t \eta_t}{r}$$

F_t is driving force for electric cars. T_e is output torque of the motor. i_t is the total transmission ratio of the transmission system. η_t is drivetrain efficiency. r is the rolling radius of the tire.

To calculate the motor torque, the calculation formula is:

$$T_e = \begin{cases} T_c & n \le n_b \\ \dfrac{9550P_e}{n} & n > n_b \end{cases}$$

T_c is the low speed constant torque of the motor; P_e is the high speed constant power of the motor. n is the motor speed, n_b is the motor base speed.

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The relationship between the driving speed of electric vehicles and the motor speed is as follows:

$$\mathrm{u} = \frac{0.377\mathrm{rn}}{\mathrm{i_t}}$$

U is the driving speed of electric vehicles.

In the process of driving, electric vehicles are mainly subjected to rolling resistance, air resistance, slope resistance and acceleration resistance.

$$F_f = mgf\cos\alpha$$

$$F_w = \frac{C_D A u^2}{22.15}$$

$$F_i = mg\sin\alpha$$

$$F_j = \delta m \frac{du}{dt}$$

Then the driving equation of electric vehicle is:

$$\frac{\mathrm{T_e i_t \eta_t}}{\mathrm{r}} = \mathrm{mgf\cos\alpha} + \frac{\mathrm{C_D A u^2}}{22.15} + \mathrm{mg\sin\alpha} + \delta\mathrm{m}\frac{\mathrm{du}}{\mathrm{dt}}$$

2.2 Electric vehicle parameters

According to the statistical results, the maximum speed of common electric vehicles in the market is 120km/h and the maximum acceleration is $2.5\mathrm{m/s^2}$.Based on this, this paper selects a front-drive electric vehicle in the market. The parameters of the front-drive electric vehicle are shown in Table 1.

Table 1 Driving parameters of a front-drive electric vehicle

Project	Number value
Unloaded weight m/kg	1580
Static rolling radius r/m	0.287
Dynamic rolling radius r/m	0.301
Coefficient of tyre friction f	1
Reference wheel load P/N	3260
Wheel load correction factor I	0
Coefficient of air resistance	0.284

The parameters of the designed motor battery are defined in Table 2.

Table 2 Basic parameters of motor battery

Project	Number value
Maximum energy storage E/Ah	10
Initial charge	95%
Nominal voltageU/V	320
Max voltage Uh/V	420
Minimum voltage Ul/V	220
Running temperatureT/℃	25
Internal charging resistance Rc/Ω	0.8
Internal discharge resistance Rd/Ohm	0.6

The electric vehicle simulation model established in AVL CRUISE is shown in Figure 1.

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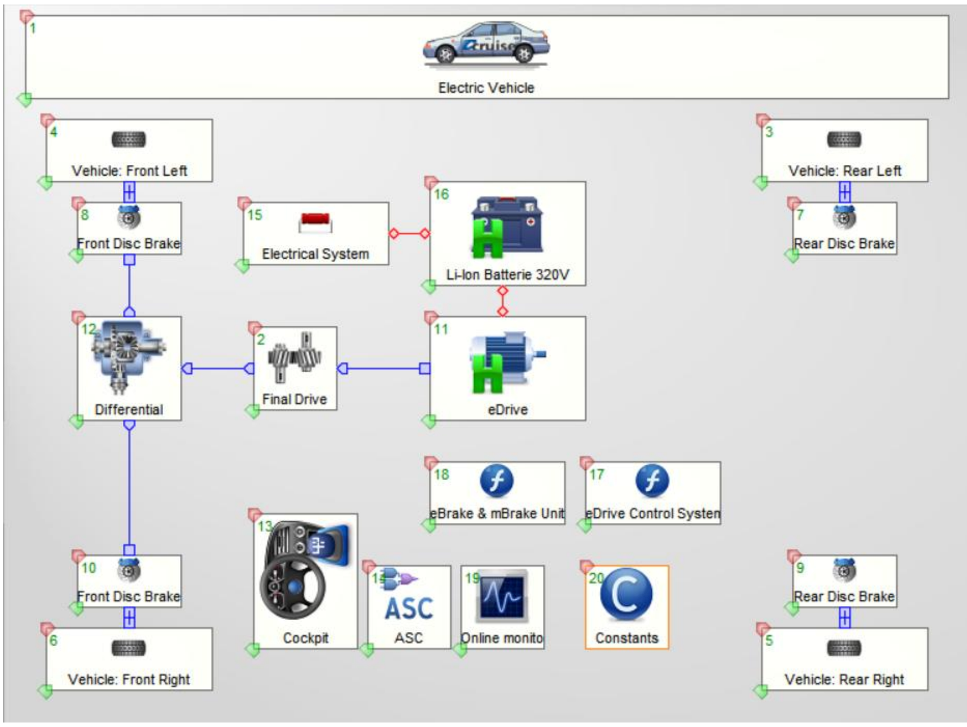

Fig 1 Electric vehicle simulation model

2.3 Simulation results and analysis

According to the requirements of real-time simulation analysis on the performance of pure intelligent electric hybrid vehicle, the corresponding type of simulation task environment and vehicle working condition are selected, and the most appropriate step value and acceleration accuracy of the actual simulation task are set to calculate the performance simulation. Setting simulation tasks can include: real-time simulation of maximum speed performance in the simulation task Constant Drive; Or in the simulation task Full Load Acceleration real-time simulation EV maximum acceleration precision performance; Simulation of Climbing Performance in mission climbing and mission performance.

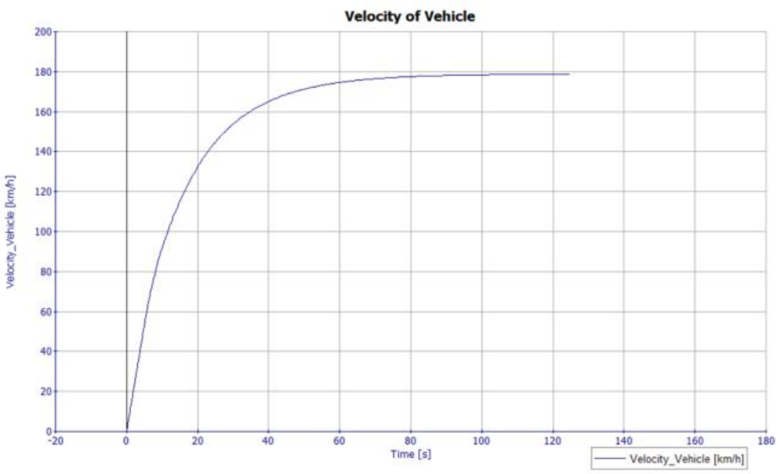

Fig 2 Simulation of maximum speed

Under the condition that the total transmission ratio is 7.9, the maximum speed of the simulated pure electric vehicle is about 178km/h, which meets the requirements that the maximum speed of the design of electric vehicle dynamic technology is greater than 120km/h, and achieves the expected effect of electric vehicle.

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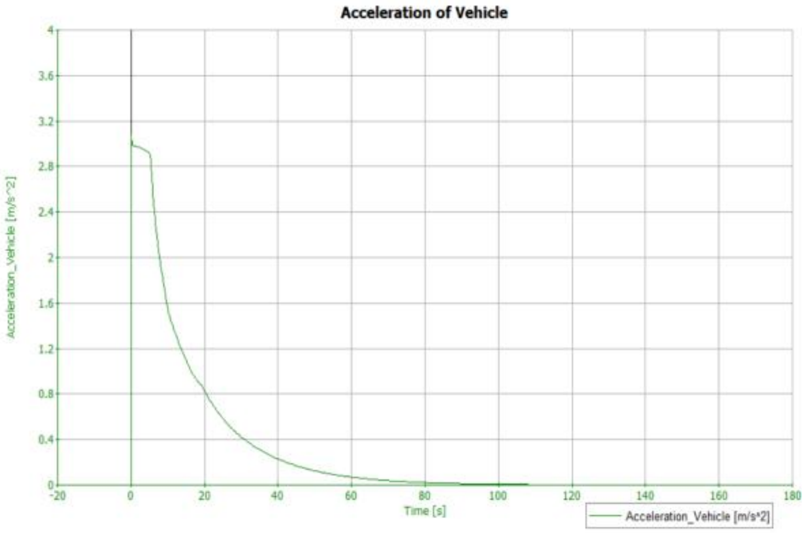

Fig 3 Acceleration performance simulation

Acceleration time performance. According to the simulation analysis results of acceleration time of electric vehicles, the average acceleration and rest time of electric hybrid vehicles is about 11.59s for 100 kilometers, and the rest and rest time of electric hybrid vehicles is generally about 4.70s between 0 and -50km /h, which is less than 6s. At 50-80km/h, the response time of static acceleration is about 3.43s, which has a relatively good steady-state acceleration starting ability, which meets the stable acceleration performance requirements of pure electric hybrid vehicles.

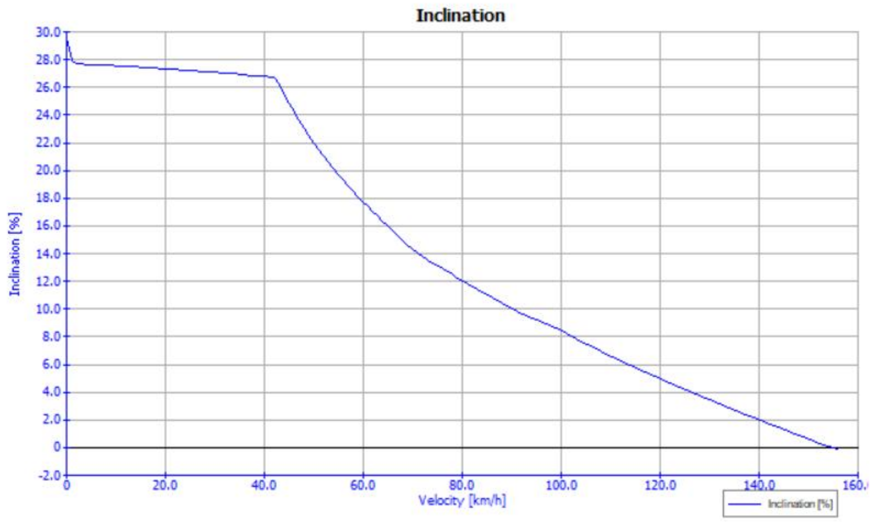

Fig 4 Simulation of climbing performance

The maximum climbing slope is 30%. When the electric vehicle runs stably at 1-40km/h, the maximum climbing slope it can climb is 26%, which is greater than 25%, meeting the climbing performance requirements of electric vehicles and achieving the expected effect of electric vehicles.

It can also be clearly seen from the above simulation analysis results that, according to the vehicle parameters tested at present, the maximum static speed range of electric pure vehicle is 178 km/h, the average acceleration time of 100 km is about 11.59s, and the maximum climbing slope to maintain a stable speed can reach about 26%, which can meet the requirements of the dynamic performance design index of pure electric vehicle. Achieve the desired effect.

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3. Urban cycle performance simulation and optimization

3.1 Urban cycle simulation

The parameters of the selected electric vehicle are still consistent with those above. The simulation model of electric vehicle built is shown in Figure 1:

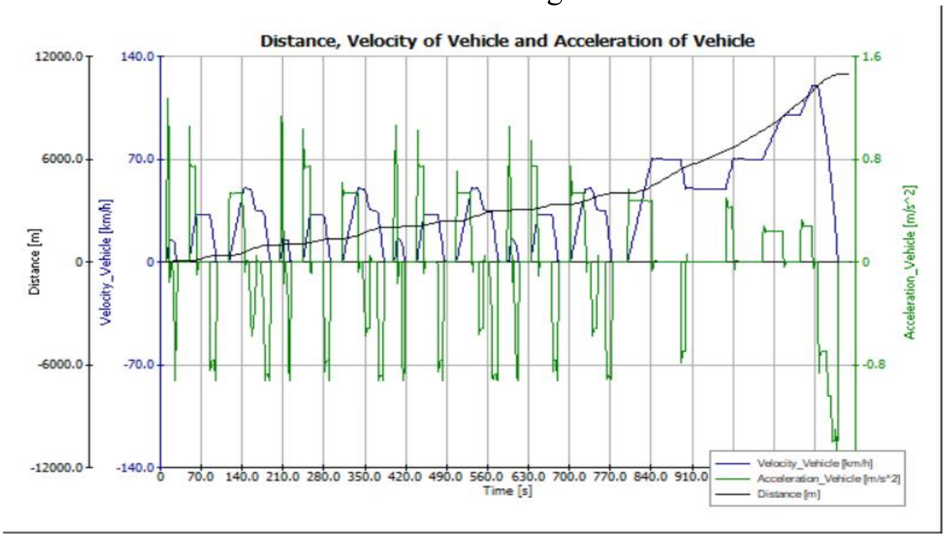

Fig 5 Urban cycle simulation

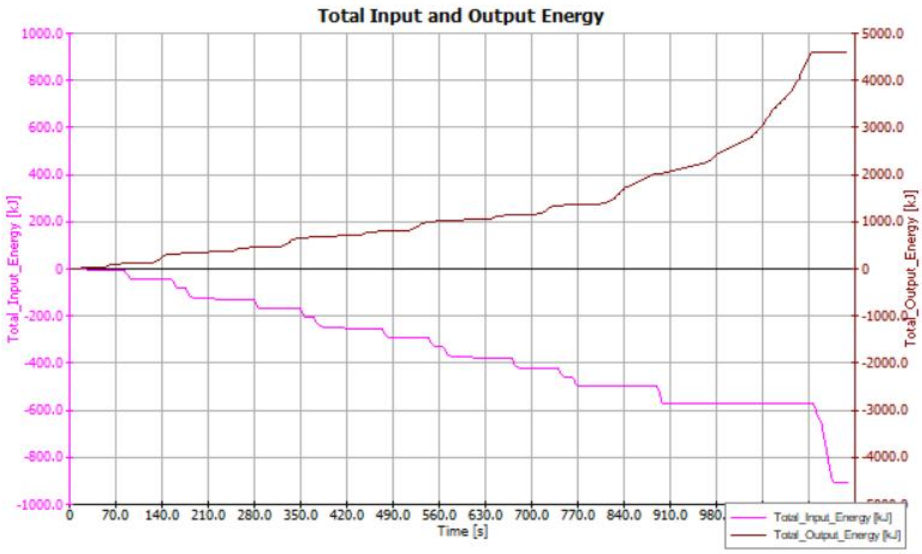

Fig 6 Energy consumption in urban cycle condition

According to the simulation image, the electric vehicle can well complete the urban cycle condition and the energy consumption is 4608KJ. Considering the energy-saving requirements of electric vehicles, this paper further explores the influencing factors of the energy consumption of electric vehicles in the urban cycle condition.

3.2 Analysis on the influencing factors of energy consumption of pure electric vehicle in city cycle condition

By changing the peak power of the motor for simulation, the energy consumed by the vehicle in the city cycle condition can be obtained. Using Matlab to draw, it can be obtained:

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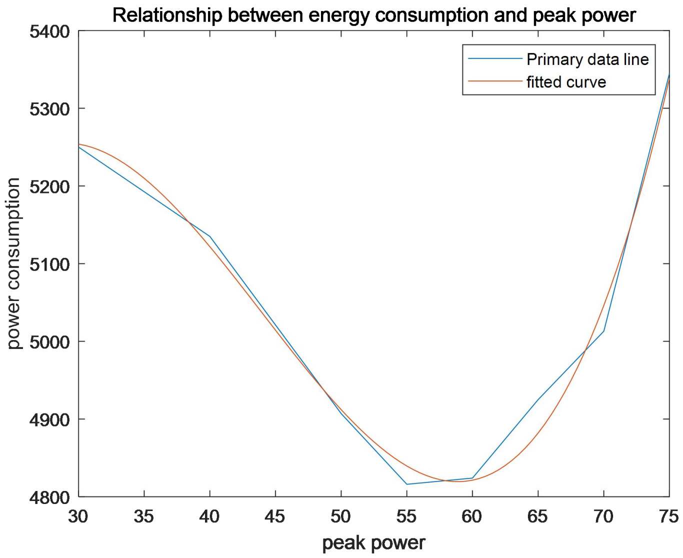

Fig 7 Relationship between energy consumption and peak power

The fitting results show that, without considering the maximum speed limit, the relationship between motor power and energy consumption in urban cycle conditions can be considered as follows

$$E=0.1P^3-4.3P^2+16.8P+3218.3$$

Therefore, in order to fully reduce the energy consumption in urban cycle conditions, the motor should be controlled at 59KW as far as possible if the conditions permit.

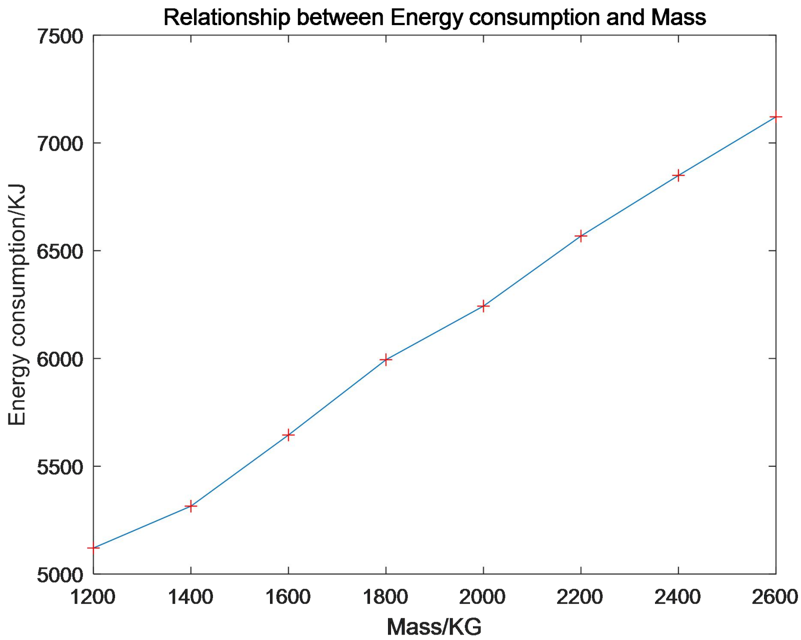

Fig 8 Relationship between energy consumption and Mass

It can be seen from the image that there is a linear relationship between vehicle energy consumption and vehicle mass. Spss is used to conduct correlation analysis based on Pearson coefficient method, and the correlation coefficient obtained is 0.936, indicating a significant correlation. Using a linear regression model, the expression between can be written as:

$$E=3.349M+15$$

The corresponding residual analysis diagram is shown in the figure below.

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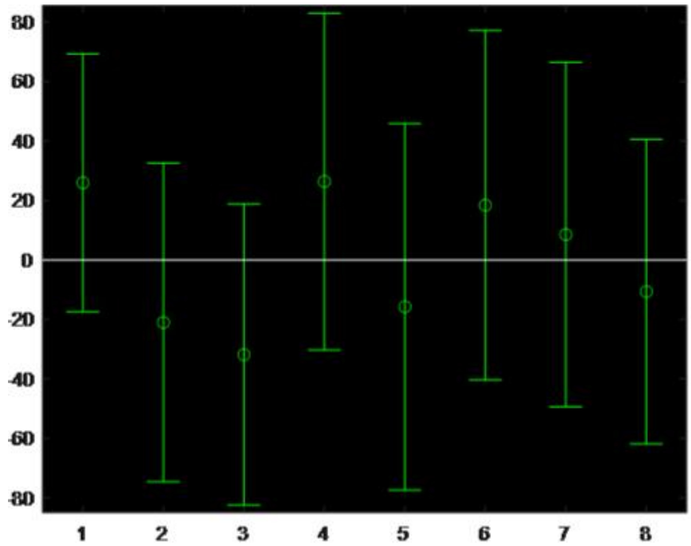

Fig 9 residual plot

All data points are within the confidence interval. It can be seen that vehicle mass has a great influence on energy consumption in urban cycle conditions, and every 100kg mass reduction can reduce 334.9KJ energy consumption. Therefore, energy consumption in urban cycle conditions can be reduced by changing the material of electric vehicles to reduce the mass of electric vehicles, so as to optimize vehicle design.

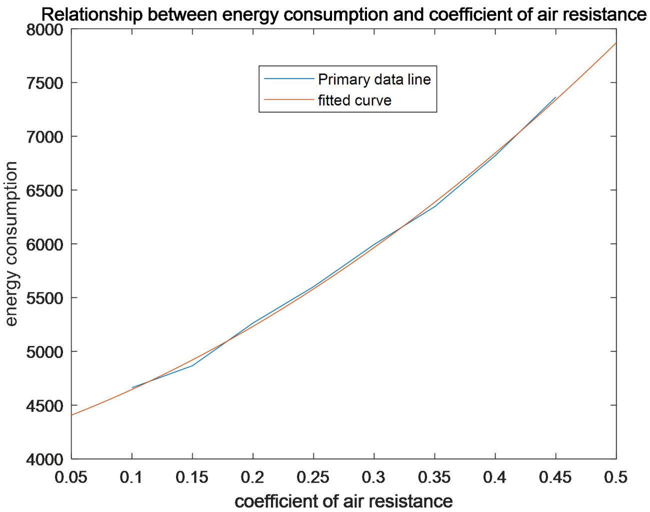

Fig 10 Relationship between energy consumption and coefficient of resistance

According to data fitting, it can be determined that the relationship between energy consumption and air drag coefficient of the electric vehicle in urban cycle conditions is as follows.

$$E = 7302.4c^2 + 3681.1c + 4204.7$$

Under current conditions, to further reduce the energy consumption of electric vehicles in urban cycle conditions, the body shape of electric vehicles can be improved and the air resistance can be reduced to reduce the consumption.

4. Conclusion

To sum up, the simulation model of an electric vehicle was built based on AVL_CRUISE software, the dynamic performance of the electric vehicle was calculated, and the influencing factors of urban cycle conditions of electric vehicles were analyzed and the function was built by changing parameters, which provided corresponding measures and data support for the subsequent

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optimization of the electric vehicle. Thus increase the development space and direction of electric vehicles.

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