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Based on AVL CRUISE pure electric vehicle simulation and FTP75 circle power consumption factor analysis

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Abstract. In today's world, we are at a crucial juncture in the transformation of energy utilization, with the automotive industry significantly impacted by energy considerations. Electric vehicles, as representatives of new energy vehicles, are shaping the future direction of the automotive sector. The AVL-Cruise software system is equipped with a range of features, including a user-friendly modeling function and visual design analysis capabilities, offering invaluable technical support for simulating vehicle performance under complex operating conditions. For instance, in the context of a front-wheel-drive electric vehicle, this study leverages the AVL-CRUISE software to create a power system model and evaluate its dynamic performance. The simulation outcomes reveal impressive metrics, with a maximum speed of 178 km/h, a 100km acceleration time of 12 seconds, and a maximum climbing slope capability of 55%. These results affirm that the electric vehicle aligns with favorable design specifications, showcasing a total energy consumption of 8000KJ. Further explorations involve manipulating variables like air resistance coefficient and vehicle mass to dissect the relationship between dynamic performance and influencing factors. Through data analysis and model fitting, the study acquires a comprehensive understanding, offering valuable insights and reference points for optimizing electric vehicles.

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

1. Introduction

In the contemporary era, the energy crisis represents a significant obstacle to the advancement of the automotive industry as a whole[1]. As the vanguard of new energy vehicle innovation, pure electric vehicles will spearhead the development trajectory of China's automotive industry. During the overall design and optimisation of pure electric vehicle products, strategic adjustments to the peak efficiency of the motor and improvements to the body structure can be employed in conjunction with one another to enhance the dynamic performance of the electric vehicles[2]. The utilisation of tools such as AVL CRUISE enables the effective modelling of the dynamic performance and operating conditions of the pure electric vehicles, particularly in urban cycles. Such simulations not only furnish crucial data but also offer invaluable empirical insights for the continuous optimisation of electric vehicles[3]. To illustrate, in the context of a front-drive electric vehicle, this study employed the AVL CRUISE to construct a powertrain model and assess its dynamic performance. The simulation results satisfy the performance and subsequent simulation requirements, with a maximum speed of around 180 km/h, a 100 km acceleration time of 12 seconds, and a maximum hill climbing capacity of 55%. Subsequent research involved a series of variables, including vehicle mass, with the objective of elucidating the relationship between dynamic performance and the various influencing factors. The study employed the data analysis and model fitting techniques to gain a comprehensive understanding of the subject matter and to provide valuable insights and reference points for the optimisation of electric vehicles.

2. Dynamic simulation

2.1. Vehicle Motion Equation

The motor generates the torque and transferred it to the driving wheel by passing through the transmission system. Let F_t being the driving force and T_t being the torque which is acting on the driving wheel. The equation between F_t and T_t is

$$F_t = \frac{T_t}{r}$$

where r is the radius of the driving wheel. Considering the aggregate transmission ratio i of transmission system and the mechanical efficiency η_T of the transmission system, the equation is

$$T_t = T_{tq} i \eta_T$$

where T_{tq} is the output torque of motor. Therefore, the driving force presented by the output torque of motor is

$$F_t = \frac{T_{tq} i \eta_T}{r}$$

The resistance must be considered. When vehicles are on the inclined ground, the rolling resistance between ground and wheels is

$$F_f = mgf cos\theta$$

where f is the rolling resistance coefficient and θ is the angle between inclined ground and horizontal plane.

The air resistance for no wind condition can be calculated by

$$F_w = \frac{C_D A u_a^2}{21.15}$$

where C_D is the coefficient of air resistance, A is the windward area. u_a is the speed of vehicles, which is calculated by

$$u_a = 0.377 \frac{rn}{i}$$

where n is rpm of motor.

The slope resistance F_i can be calculated by

$$F_i = mg sin\theta$$

The acceleration resistance is

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

where δ is automotive rotating mass conversion factor

Therefore, from the driving equation of electric vehicle

$$F_t = F_f + F_w + F_i + F_j$$

$$\frac{T_{tq} i \eta_T}{r} = mgf cos\theta + \frac{C_D A u_a^2}{21.15} + F_i + mgsin\theta + m\frac{du_a}{dt}$$

2.2. Select Pure Vehicle Parameters

The parameters of the pure electric vehicle that is selected in this article and the model of pure electric vehicle that is built by Avl Cruise are given below

Table 1. Driving Parameters and Motor Battery

Driving Parameters	
Projects	Value
Unload Mass m	1885 kg
Friction Coefficient of Tire μ	0.98
Air Resistance Coefficient C	0.219
Static Rolling Radius r	285 mm
Dynamic Rolling Radius r	310 mm
Reference Wheel Load P	3.3 kN
Wheel Load Correction Factor	0
Motor Battery	
Maximum Energy Storage E	10 Ah
Initial Charge	95 %
Nominal Voltage U	300 V
Maximum Voltage U_M	400 V
Minimum Voltage U_m	220 V
Running Temperature T	22 ℃
Internal Charging Resistance R_c	785 $m\Omega$
Internal Discharge Resistance R_d	620 $m\Omega$
Performance	
Maximum Acceleration	2.8 m/s^2
Maximum Speed	180 km/h

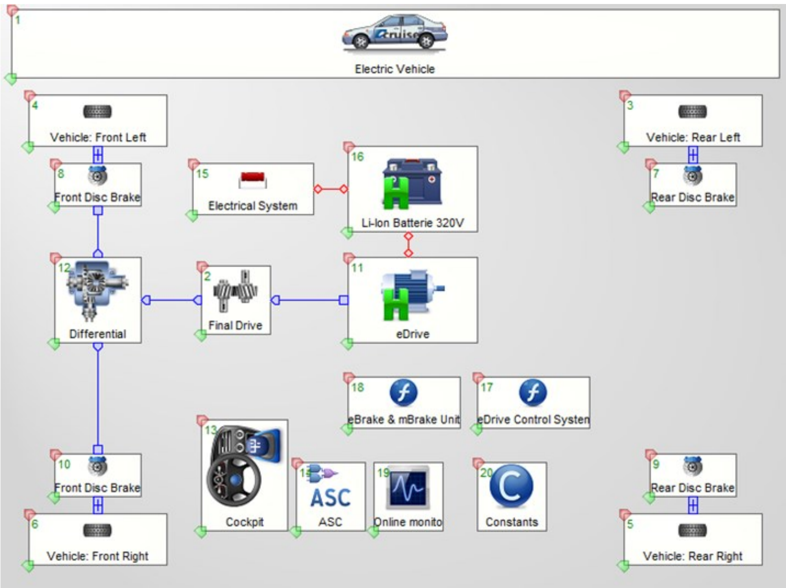

Figure 1. Urban Cycle Simulation of Distance, Velocity and Acceleration pf VehiclesFigure The Pure Electric Vehicle Model

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2.3. Simulation results and analysis

To meet the requirements for analyzing real-time simulation of pure electric vehicle performance, it is necessary to select appropriate simulation task environment and vehicle conditions[4]. This process involves implementing simulation with optical step value and acceleration accuracy. The simulation task includes real-time simulation of maximum speed performance in constant drive simulation tasks; real-time simulation of maximum acceleration accuracy performance in full-load acceleration simulation tasks; and simulation of climbing performance in climbing tasks and performance tasks[5].

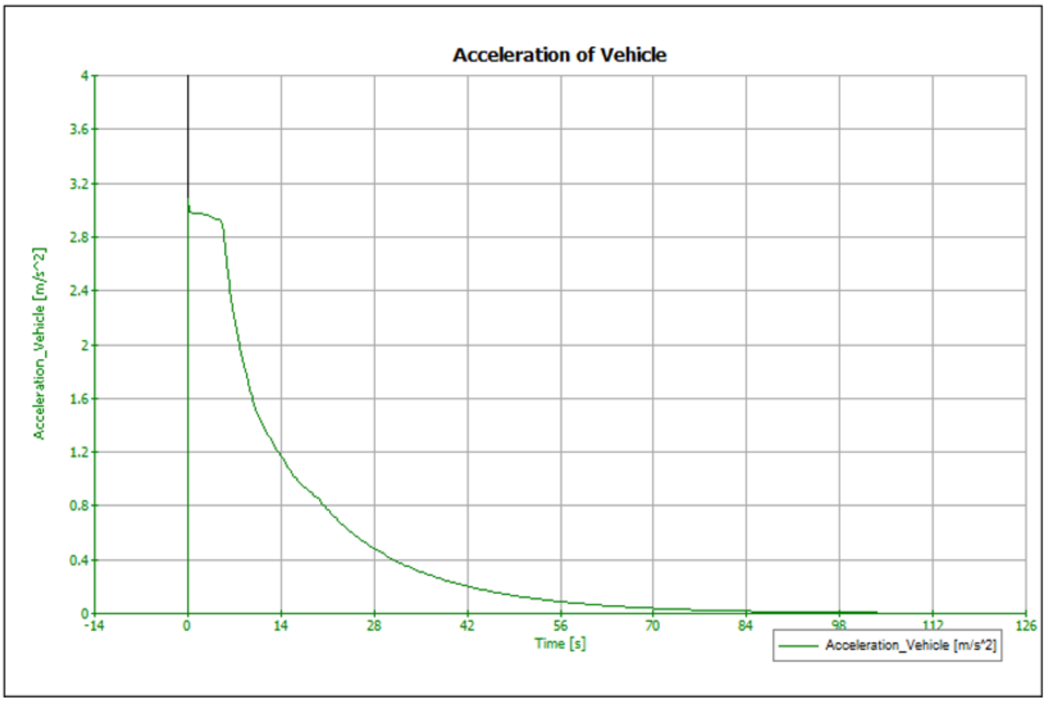

Figure 2. Simulation of acceleration performance

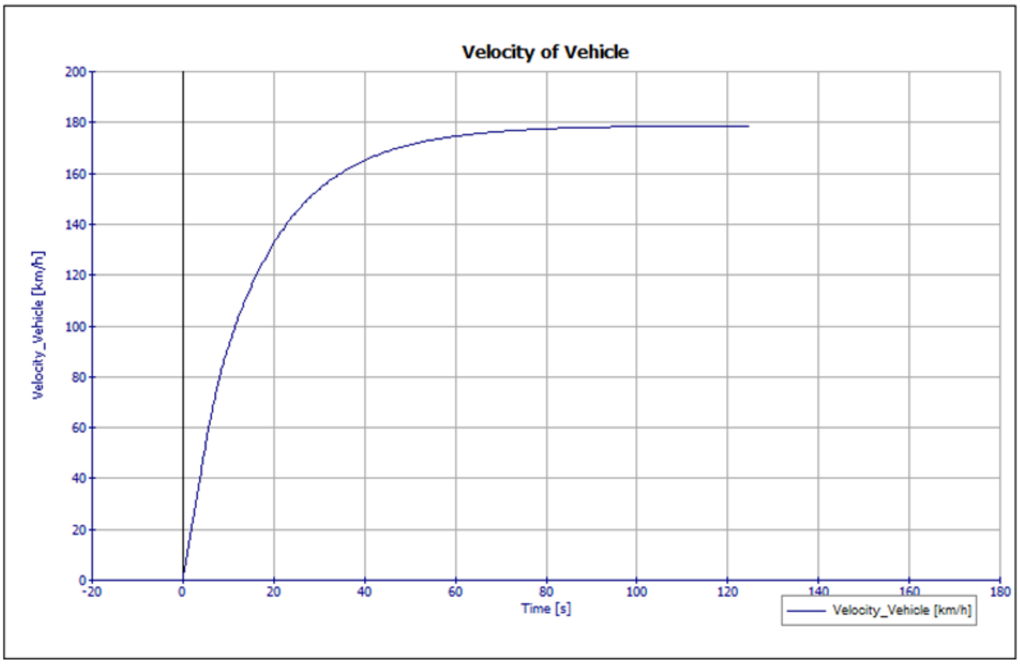

Figure 3. Maximum Speed Acceleration

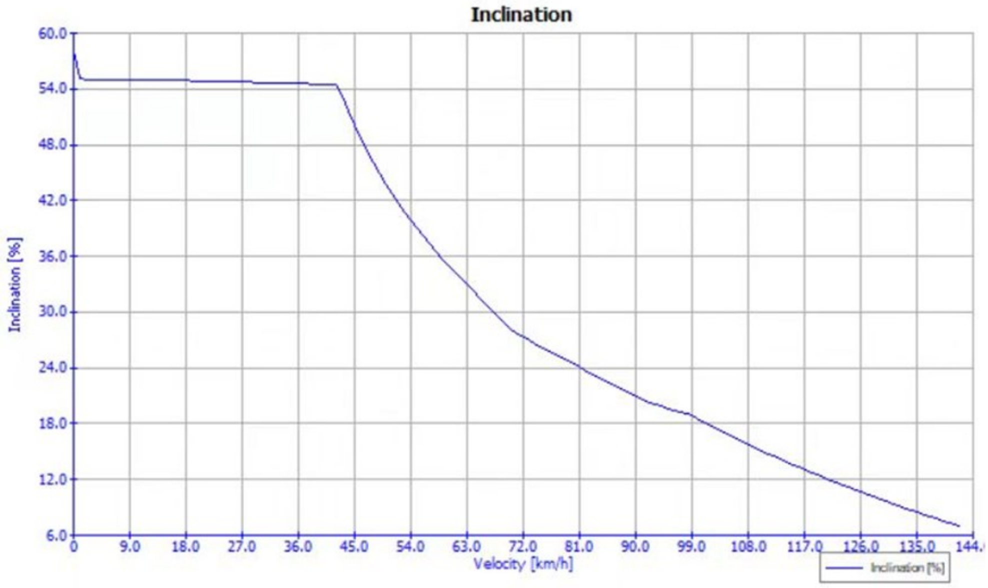

Figure 4. Simulation of acceleration performance

According to Figures 1 and 2, the maximum acceleration of the simulated electric vehicle is about 3 m/s^2, and the 100 km acceleration time is about 12 s. The acceleration time of the vehicle from standstill to 50 km/h is about 5 s, and the static acceleration response time at 50 to 80 km is about 3.5 s. According to Figure 2, the maximum speed of the vehicle is approximately 180 km/h. In terms of Figure 3, the max climb slop is around 57%. The slop remains at approximately 55% in the range of 1 km/h and 43 km/h, followed by a continuous decrease to 7% which the velocity raises to 144 km/h.Therefore, the acceleration performance and maximum speed as well as climb performance of the model meet the design requirements.

3. FTP75 cycle performance simulation and optimization

3.1. FTP75 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:

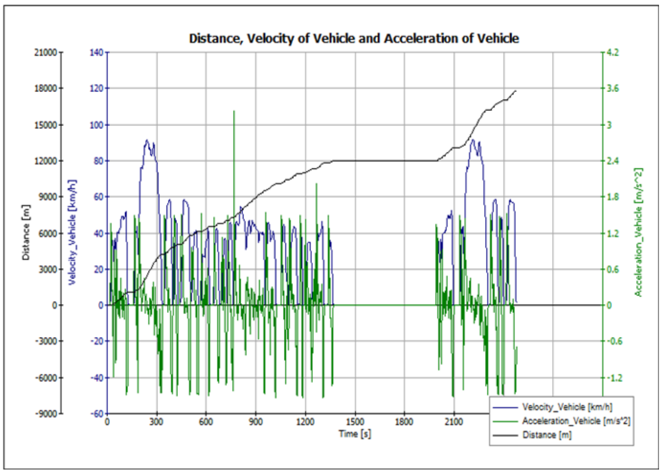

Figure 5. FTP75 Cycle Simulation of Distance, Velocity and Acceleration VehiclesFigure The Pure Electric Vehicle Model

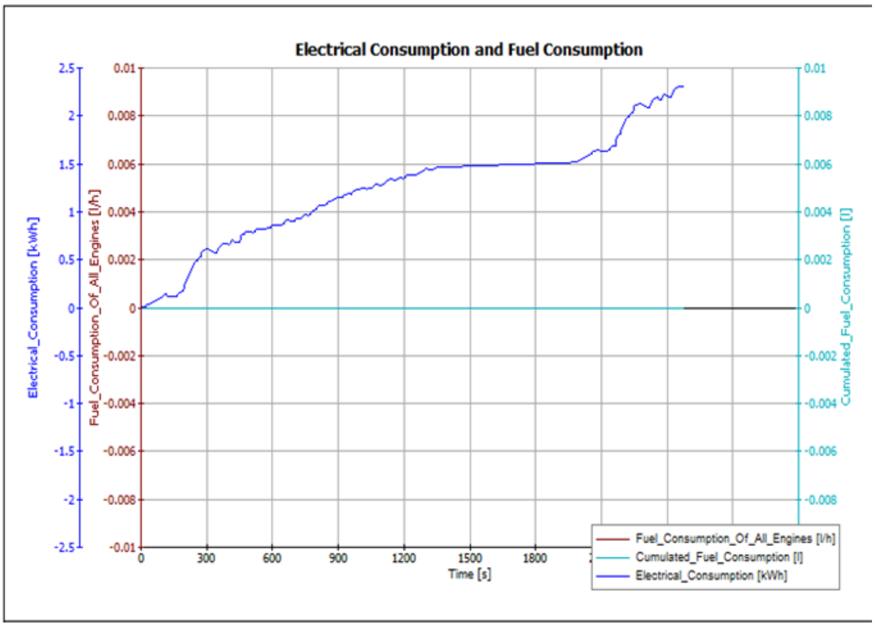

Figure 6. FTP75 Cycle Simulation of Electrical Consumption and Fuel Consumption

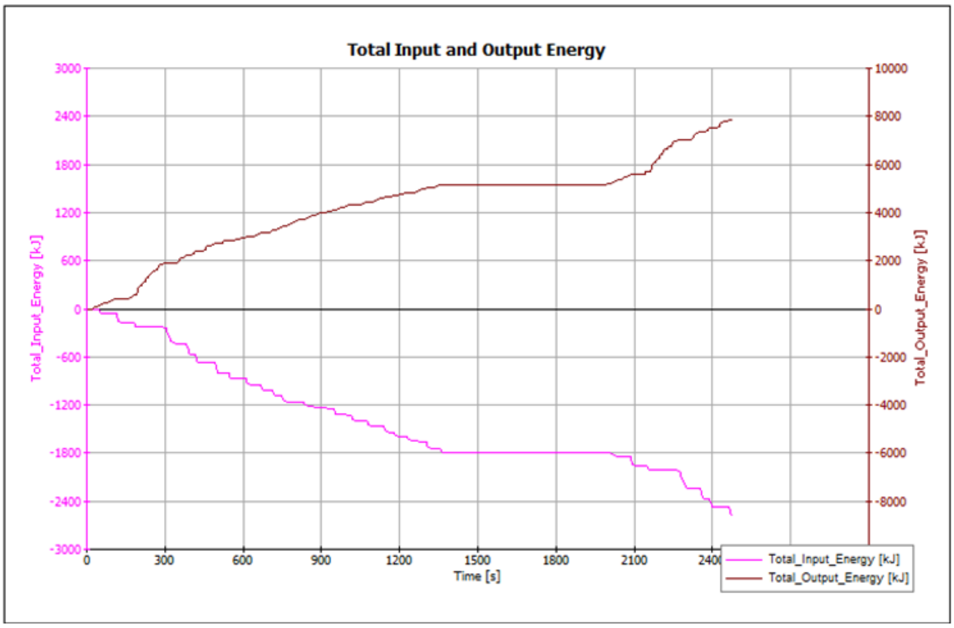

Figure 7. FTP75 Cycle Simulation for Electric Machine eDrive of Total Input and Output Energy

The following presents urban cycle simulation data based on AVL Cruise, with Figures 5, 6, and 7 illustrating the Distance, Velocity, and Acceleration of Vehicles, Electrical Consumption and Fuel Consumption, and Electric Machine eDrive of Total Input and Output respectively (the parameters of the vehicle model remain unchanged, as previously described). According to Figure 6, the Electrical Consumption at the end of the urban cycle is approximately 0.009 kWh. As shown in Figure 7, the final energy consumption of the electric vehicle is almost 8000 kJ. To address the energy consumption issues prevalent in most vehicles on the market, the factors affecting vehicle energy consumption under urban cycle conditions will be discussed below.

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

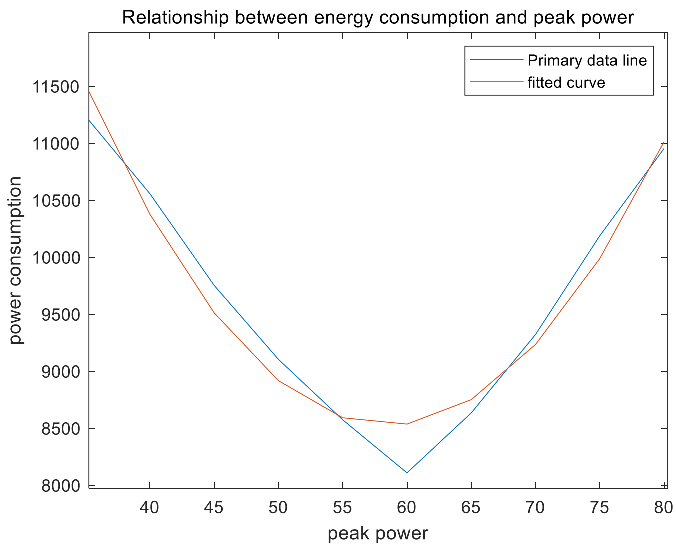

Figure 8. Relationship between energy consumption and peak power

From the figure 8, the energy consumption is obtained by change the peak power value of the motor when simulation in the city cycle condition. According to fitting results, the relationship between the motor power and energy consumption is,

$$E = 5P^2 - 631P + 27004$$

where it is in the city cycle condition and there is no limitation of velocity. What's more, in order to reduce the energy waste, the power of the motor should be remained at around 60 kw.

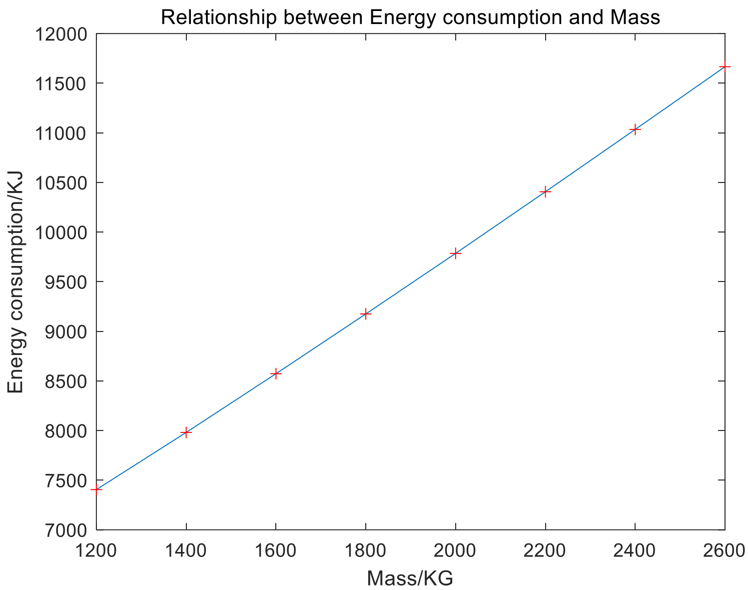

Figure 9. Relationship between energy consumption and Mass

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According to figure 9, mass and energy consumption has an approximate linear relevance. Spss is used to conduct correlation analysis based on Pearson coefficient method, and the correlation coefficient obtained is 0.929, indicating a significant correlation. Therefore, the equation of mass and energy consumption is,

$$E = 3M + 3725$$

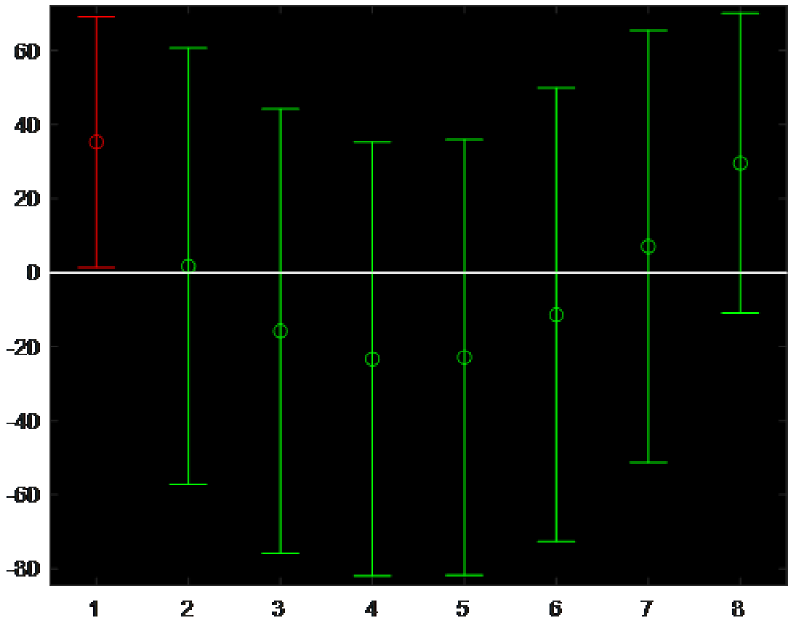

Figure 10. residual plot

In terms of the figure 6, the residual analysis is showed. All the data points are in the confidence interval. As a results, the energy consumption could be decreased each 300 kJ when the mass is reduced every 100 kg. Thus, the energy use could be reduced by reducing the mass of the vehicle. For example, optimize vehicle chassis design and structure, thereby reducing chassis mass or optimize the structure of the battery and reduce the mass of the battery.

4. Conclusion

In conclusion, this paper presents the development of a simulation model of a pure electric vehicle and its subsequent evaluation of powertrain performance utilising AVL Cruise. The initial evaluation of the model concerned the dynamic performance of the electric vehicle. The simulation results demonstrated that the electric vehicle met the design requirements in terms of top speed, 100 km acceleration time and hill climbing ability, which were 180 km/s, 12 seconds and 55%, respectively. The model also analyses the factors affecting the performance of the pure electric vehicle in the urban cycle. The simulation results demonstrate that the power consumption at the conclusion of the urban cycle is approximately 0.009 kWh, with the final energy consumption of the pure electric vehicle approaching 8000 kJ. Following the adjustment of the parameters and optimisation of the simulation, the results demonstrate a squared-fit relationship between the peak engine power value and the energy consumption. Furthermore, the energy consumption is observed to decrease when the peak engine power value is increased. As the peak engine power increases, so too does the energy consumption. However, when the peak engine power is increased further, the energy consumption is lowest when the engine power is maintained at approximately 60 kW. Thereafter, the energy consumption begins to increase. Concurrently, a linear relationship exists between vehicle mass and energy consumption, whereby energy consumption decreases as vehicle mass decreases. The model offers invaluable data and insights that can be leveraged to optimise electric vehicles, thereby expanding the scope and focus of electric vehicle development.

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