Study on the Relationship Between EV Cost and Performance

Pupeng Wan, Zhiqiang Du, Qiqian Jin, Yi You and Fuquan Zhao

Abstract This paper aims at studying the relationship between Electric Vehicle and its performance in the perspective of technology and economy. First, GT software is used to simulate vehicle performance. Second, cost is analyzed by technology condition and price, and then the relationship between performance and cost is discussed. Performance and cost are mutually affected by battery energy. In the aspect of performance, Vehicle performance increases initially and then decreases with increase of battery energy and there is a turning point. With respect to cost analysis, cost keeps increasing with cumulating of battery energy. Namely, cost is positively proportional to battery energy. There are two intersection points between performance and cost. In designing vehicles, the location of performance and cost properties should be restricted inside the region formed by those two intersection points as much as possible.

Keywords Electric vehicles · Vehicle performance · Cost analysis · Simulation · Vehicle weight

Recently, Ministry of Science and Technology published the "National Twelfth Five-Year Special Planning for Electric Vehicle Technology Development" and clearly set 'Electric Driving' as the strategy direction of vehicle power source. Considering of current technology level, the energy density of battery is not comparable to that of fossil fuel and short driving range of EVs has become the

F2012-B03-018

P. Wan (✉) · Z. Du · Q. Jin · Y. You · F. Zhao
Zhejiang Geely Automobile Research Institute Co., LTD, Hangzhou, China
e-mail: wanpp@rd.geely.com

SAE-China and FISITA (eds.), *Proceedings of the FISITA 2012 World Automotive Congress*, Lecture Notes in Electrical Engineering 191,
DOI: 10.1007/978-3-642-33777-2_52,

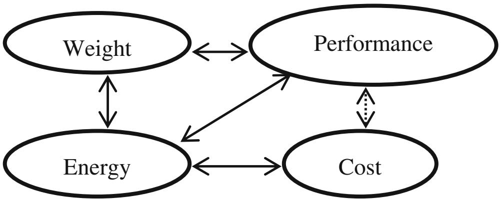

Fig. 1 The interrelation of energy, weight, performance and cost

bottleneck of EV development [1]. In order to extend the driving range, increasing of battery pack energy is regarded as a general approach under current technology level [2]. In the condition of maintaining other components unchanged, battery pack energy is proportional to vehicle weight and manufacture cost. Improving of battery pack energy will increase vehicle manufacture cost and vehicle weight and thus affect its overall performance. The interrelation of energy, weight, performance and cost are presented in Fig. 1. The relationship of above four factors is analyzed in the perspective of technology and economy in this paper.

1 Performance Analysis

Vehicle performance is simulated by software—GT in this paper and the study subject is an Electric Vehicle. The power system is consisted of battery package, e-motor and transmission system of which the parameters are listed in following Table 1. By disregarding of space arrangement limits and the limits of national standards to battery weight, the battery energy and vehicle weight are gained respectively during the simulation based on a certain pattern. The vehicle performance is then calculated with respect to different battery energy.

The influence of battery energy to vehicle performance is displayed in Fig. 2. Initially, battery discharging power is insufficient, which results in long accelerating time and low climbing speed. With increase of battery energy, e-motor driving ability is sufficiently utilized although vehicle weight is increased as well. As a consequence, accelerating time is minimized and climbing speed is maximized. After e-motor reaches its maximum driving ability, increasing of vehicle weight starts to affect vehicle performance gradually. Acceleration time is then extended and climbing speed is reduced. Overall, accelerating time and climbing speed both experience a process from increasing to decreasing. So there are some advantages for both acceleration and climbing performance due to increase of battery energy initially, however, it turns into disadvantages later because of excessive battery weight. This indicates that, for a certain vehicle model, there is an optimum battery energy choice of which the vehicle performance is optimized. Figure 3 depicts the relation between battery energy and driving range. Battery energy increases linearly with increase of battery weight, which is computed by the ratio of battery weight to battery energy. Corresponding vehicle weight also increases linearly in condition of remaining other components unchanged. Driving

Table 1 E-motor and transmission system parameters

Vehicle parameters	
Kerb mass (kg)	1250
Fully loaded mass (kg)	1514
Wheel base (m)	2.34
Front area (m^2)	1.87
Drag coefficient	0.42
Dynamic rolling radius (m)	0.275
Rolling resistance coefficient	0.13
Ratio	9.34
E-motor parameters	
Peak/rated power (kW)	70/35
Peak/rated torque (Nm)	220/60
Max. Speed (rpm)	12000

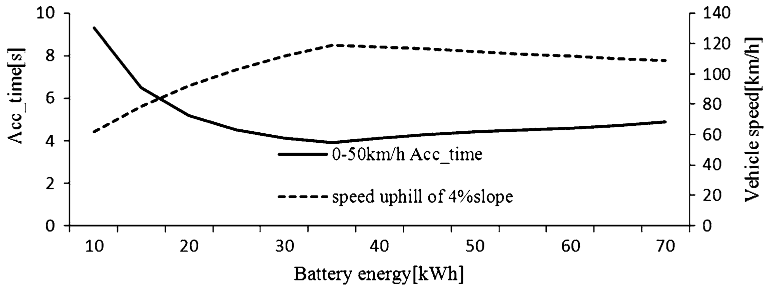

Fig. 2 The influence of battery energy to vehicle performance

range is extended because of increase of battery energy, however, due to increased weight, the changing rate of driving range (i.e. the slope of driving range curve) declines gradually. According to this trend, it could be estimated that driving range would increase to a particular value and then hold steady or decline. It can also be discovered from the figure that vehicle energy consumption rate (i.e. energy consumed per unit distance) increases gradually. After increasing of battery energy, the influence of battery weight to driving range becomes more apparent. There even exists a circumstance where battery weight is larger than that of other vehicle components. The driving range determined by battery energy should base on market demands when designing vehicles. It is not always good to have too large driving range. According to above analysis, the relationship between battery energy and vehicle performance could be abstracted as the one shown in Fig. 4. Vehicle performance trends to be better at the first place and turns to be worse later on which can be described as a parabola.

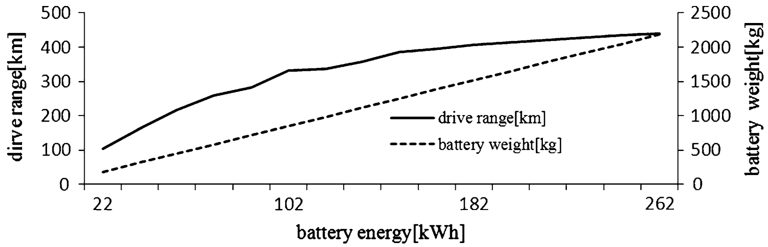

Fig. 3 The relation between battery energy and driving range

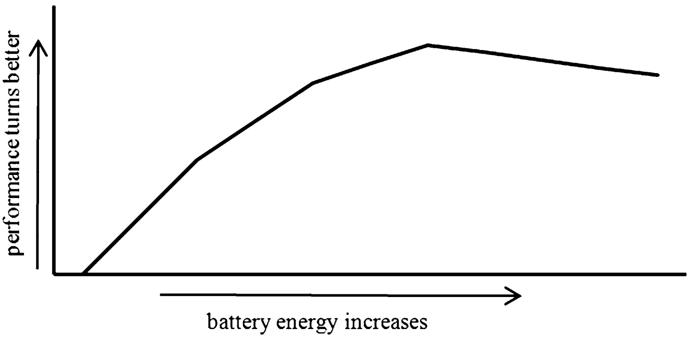

Fig. 4 The relationship between battery energy and vehicle performance

2 Cost Analysis

The analysis subject is lithium ion battery of which the actual performance target and market average price are listed in Table 2. According to current technology and market price [3], the cost of taking 1 kWh energy out of the battery (i.e. battery use cost) can be estimated. Assumptions have been made as follows: (1) Charger efficiency is 0.95 (2) Electrical cost from national grid is 0.58 Yuan/kwh (ignore on-peak or off-peak electricity) (3) Charging and discharging efficiency is 0.9. It can be deduced from Table 2 that lithium ion battery use cost is 0.75 Yuan when 1 kWh of electricity is taken from the battery (charged by national grid). In accordance with the simulation results in Fig. 3 vehicle energy consumption rate can be obtained. By combining battery use cost and energy consumption rate, the actual cost of vehicle running for a certain distance can be determined as shown in Fig. 5. The overall trend is that more distances vehicle travelled will result in more use cost. This can be explained by combination of Fig. 2 that increase of use cost is a result of gradual increased energy consumption rate. When driving range increases, demanded battery energy will increase accordingly. The increase of battery cost can be calculated based on battery market price. In the condition of maintaining other components unchanged, increase of battery cost can reflect the increase of vehicle cost

Table 2 The actual battery performance

Battery type	Lithium ion battery
Specific energy (Wh/kg)	120
Market average price (Yuan/kWh)	4000
Battery use cost (Yuan/kWh)	0.75

(i.e. vehicle acquisition cost). As can be seen from the figure, energy consumption rate will increase 0.37 kWh/100 km when driving range increases for every 10 km due to increased battery weight. By consideration of battery price, the use cost will be added for 0.26/100 km which is relatively low. The acquisition cost, however, will increase 10,000 Yuan which is considerable. Above all, the relationship between the battery energy and cost can be abstracted as shown in Fig. 6. The cost will increase linearly when battery energy increases.

3 Technological and Economic Analysis

The article above discusses the relationship between vehicle performance and battery energy and also the relationship between cost and battery energy respectively. As shown in Fig. 1 battery energy is treated as a bond for yielding the relationship between vehicle performance and cost. Consequently, the relationship between performance and battery can be described as depicted in Fig. 7. Main part of the cost is acquisition cost. This can be verified from Fig. 5 that the use cost is insignificant compared with acquisition cost and it can be neglected. Specific relationship between vehicle performance and cost depends on vehicle technology level and battery technology level as well as its prices. For certain vehicle technology level, battery unit price has to be decreased so as to reduce vehicle cost. For certain vehicle cost, increase of battery energy density can result in reduction of vehicle weight and make contribution to improvement of vehicle performance [4]. There are two intersection points in the curve of performance and cost. In front of the first intersection, vehicle cost is quite low but vehicle performance is undesired which cannot even satisfy the national standards. This should be abandoned. Only by increasing of battery energy in this phase, vehicle performance could be improved. After passing the second intersection point, vehicle performance is inversely proportional to cost. Increase of cost will lead to decrease of performance, which is also unacceptable. By reduction of battery energy could pull the second intersection point back a little. Therefore, designed vehicle should be placed in the region constructed by those two intersection points. Specific vehicle performance should be determined by the market.

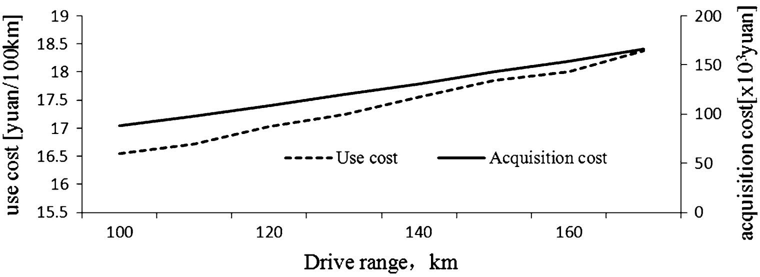

Fig. 5 The relationship between drive range and cost

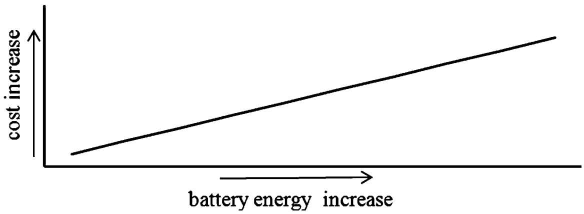

Fig. 6 The relationship between the battery energy and cost

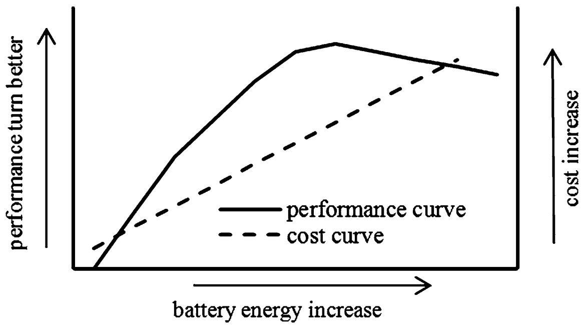

Fig. 7 The relationship between performance and battery

4 Conclusion

This paper analyzes the relationship between performance and cost of electric vehicles in the aspect of technology and economy. Performance and cost affects each other through battery energy. By consideration of vehicle performance, it increases first and then decreases with increase of battery energy and there is a turning point. As a consequence, it is not always good to have much battery energy. By taking account of cost, vehicle cost keeps increasing with increase of battery energy and the correlation is positive linear. There are two intersection points between vehicle performance and cost. Beyond the region constructed by these two points, the design is not acceptable. Therefore design of vehicles should maintain inside this region. Specific vehicle performance and cost should be determined by the market.

References

1. Zhen-po W, Feng- chun SUN (2004) Analysis of energy consumption distribution and factors of influence in electric vehicles. Trans Beijing Inst Technol 24(4)
2. Rand DAJ, Woods R, Dell RM (1988) Batteries for electirc vehicles. Society of Automotive Engineer, Warren dale
3. Ehsani M, Gao Y, Emadi A (2010) Modern electric, hybrid electric and fuel cell vehicles-fundamentals, theory, and design second edition. China Machine Press, Beijin
4. Chan CC, Chau CC (2001) Modern electric vehicle. Technologies Oxford University Press, Oxford