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Development and trend analysis of the Cybertruck

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Abstract. Considering that the popularity of electric vehicle trucks (EVs) is growing, this paper takes Tesla's Cybertruck as an example and discusses its power system, autonomous driving system, design concepts and materials. The purpose of this research is to explore the trends of future automobile development that are more environmentally friendly, more capable of living, more intelligent, and more multi-functional. Through the analysis, it can be found that the future automobile technology will develop in the direction of electrification, intelligence, multi-function and multi-modal. First of all, vehicles are more inclined to use battery engines with stronger endurance and faster charging speed to further reduce energy consumption and improve efficiency. Secondly, to improve fully autonomous driving technology, future vehicles tend to combine artificial intelligence (AI) with driving control systems. Moreover, according to the different needs of different models, the most suitable design scheme is combined with aerodynamics, and the materials with stronger strength, lighter weight and easier recycling are selected for the manufacture of the body.

Keywords: Tesla Cybertruck, Engine Performance, Intelligent control system, Vehicle body structure design

1. Introduction

Trucks are symbolic of those hard-working blue-collar workers including occupations from construction to ranching and farming. Yet, in recent years, pickup trucks have evolved into one of the most popular mobility options among Americans. For example, according to Kelly Blue Book's (2022) year-end report, the top three most sold vehicles in the United States were the Ford F-Series at 653,957, the Chevrolet Silverado at 513,354, and the Dodge Ram pickup at 468,344 [1].

However, in recent years, the problem of carbon emissions around the world has become more serious. Global CO_2 emissions from transport are 9000 billion tons, 18% of which are man-made emissions, and these are expected to grow by 60% until 2050 [2]. Hence, there is a growing need for electrification of transport.

Therefore, the market share of electrified passenger cars is growing and becoming bigger every year, already having reached a global stock of 1.2 million battery-electric cars by the end of 2017 [3]. The car manufacturers and main suppliers have recognized the market shift toward full-electric vehicles and are planning or in the process of introducing full-electric vehicles into their range of models. Most car manufacturers plan to have multiple electrified powertrains in their range of models by 2020 and the market is increasingly growing without depending on subsidies. The same holds true

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for battery electric buses and coaches. In 2017, the largest European battery electric bus fleet of 43 buses (VDL) was put in use in Eindhoven, The Netherlands [4], and sales of BEV buses in China are estimated at over 100000 sales in 2017 [5].

Because the development of battery technology is making battery electric heavy-duty trucks technically and commercially viable, several manufacturers have introduced full electric trucks recently [6], including Cummins AEOS, Thor ET-One, Tesla Semi, Volvo FL electric, Mercedes Benz eActross, Freightliner eCascadia, DAF CF electric VDL e-power, MAN eTruck, E-Force One E18, BYD T9 [7].

Furthermore, consumer truck culture is shifting to value EV pickups as an exclusive form of recreational mobility. With this effect, EV trucks are placed into a marketed audience that is similar to someone who would purchase a sports car. For example, through rigorous research and development, Tesla's team crafted Cybertruck which defied the norms and exemplified the future of electric mobility.

In this paper, the engine performance of the three versions of the Cybertruck was outlined and compared to the engine performance of several conventional gasoline pickup trucks to analyze where the strengths and weaknesses lie between pure electric pickup trucks and gasoline-powered pickup trucks. In addition, this paper also discusses the intelligent control system of all-electric trucks and the multi-functional characteristics of Cybertrucks, analyzes the future possibility of combining artificial intelligence and autonomous driving, and the innovation of the body design and manufacturing materials of Cybertrucks. This study can provide suggestions to solve the problems of insufficient range and inadequate charging equipment, and explore the great potential of electric pickup trucks in the future global market.

2. Developments of Engine Performance for Cybertruck

2.1. Electric Motor of Cybertruck

For most conventional trucks, the most common engines are gasoline engines and diesel engines. Diesel engines are more fuel-efficient with low RPMs and high torque, and because of the lower RPMs and less ignition system, the failure rate and durability are much better. They are suitable for large and heavy trucks that frequently pull heavy cargo and climb hills. Gasoline engines have better power comfort and faster acceleration and are suitable for light pickup trucks that do not haul heavy loads often in plains areas. However, both gasoline and diesel engines cause large amounts of carbon emissions, which have a detrimental effect on the environment. Figure 1 shows gasoline and diesel engines for conventional internal combustion engine trucks.

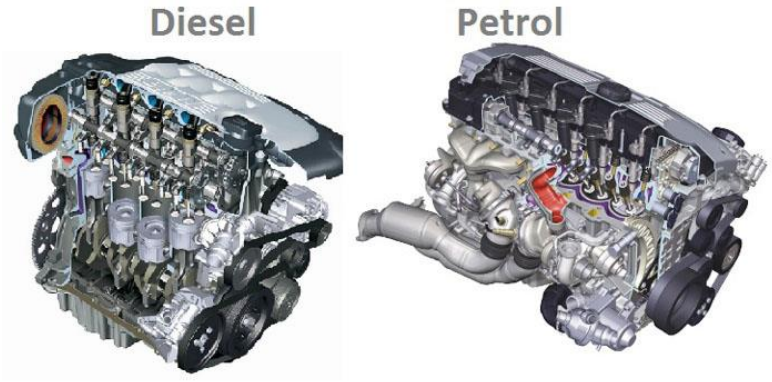

Figure 1. Diesel engine and petrol engine[8]

As an all-electric vehicle, the Cybertruck is a champion of eco-friendly transportation. With zero tailpipe emissions, it helps reduce air pollution and dependence on fossil fuels. As the world

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transitions to cleaner energy sources, the Cybertruck plays a significant role in reducing carbon emissions with its all-electric powertrains and efficient energy consumption.

On the price front, Tesla has continued to lower the price of its cars at a time when inflation has made everything more expensive. Tesla's obsession with lowering the cost of its cars continues with the Cybertruck motor.

The dual-motor AWD version uses an induction motor on the front axle with a maximum output of 303 hp (226 kW) and a permanent magnet motor on the rear axle with a maximum output of 297 hp (221 kW) for a total power output of 600 hp (450 kW). The three-motor AWD version, known as the "Cyberbeast", features a reconfiguration of motor placements with a permanent magnet motor positioned at the front axle, an induction motor at the rear axle, and an additional induction motor added to the rear axle. The two induction motors on the rear axle do not require a clutch to disengage them. They offer a maximum combined output of 845 hp (630 kW) in Beast Mode, split as 276 hp (206 kW) for the front motor and 284 hp (212 kW) for each rear motor.

The motors applied to the Cybertruck are made in-house by Tesla. In the case of the three-motor version of the Cyberbeast, only one of the truck's three motors is a permanent magnet, unlike the Rivian R1T, which uses four. Permanent magnet motors are more expensive to produce and require rare earth materials, however induction motors do not.

Tesla quadrupled the low voltage side of this car, which means anything that was running at 12 volts is now running at 48 volts, which reduces the current demand by a quarter, meaning the car only needs a quarter of the copper. The automotive industry has been trying to move to 48-volt architecture for decades, but suppliers and car companies have failed to make such a switch due to incredible dysfunction, Cybertruck has managed to break through this technological barrier. The main beneficiary of the 48-volt system is steer-by-wire, which for the first time ever appears in a production car. There is no physical connection between the steering wheel and the front wheels on the Cybertruck. The steering wheel on the Cybertruck is connected only to a bunch of sensors and a force feedback unit. The front wheels are turned by a pair of redundant electric motors mounted on the steering rack, and the rear wheels are turned by a third motor. Simply turning the car on allows the driver to control the steering of the wheels.

The benefit of this is also obvious, at high speeds the steering becomes very slow and normal. At low speeds, even though the Cybertruck has a very large body, its turning radius is about as large as a Model S.

2.2. Power Performance of Cybertruck

Table 1. Comparison of the performance of Cybertruck and mainstream American gasoline pickup trucks.

Vehicle Model	Cybertruck	Ford F-150	Chevrolet Silverado 1500	Ram 1500	GMC Sierra 1500	Toyota Tundra
Towing capacity/t	3.1/ 4.5/ 6.3	6.4	6	5.8	6	5.4
100-km acceleration/s	6.5/ 4.5/ 2.9	5.4	5.4	4.5	5.4	5.7
Top speed/km/h	177/ 180/ 210	193	183	190	160	170
Horsepower/hp	?/600/845	400	420	395	420	437
Range/km	402/ 547/ 515	1185	1032	1030	888	978

*Sources: Marklines, Wikipedia, company official website, Sina Auto, Tencent, TopElectricSUV, eefocus, Huafu Securities Research Institute.

The Cybertruck is available in three versions. The first one features a single motor rear-wheel drive or RWD, that goes from 0 to 96 km/h in less than 6.5 seconds and has an autonomy of more than 250

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miles. The second features a dual motor all-wheel drive or AWD, going from 0 to 96 km/h in less than 4.5 seconds with an autonomy of more than 300 miles. The third is provided with a tri-motor AWD, covering the distance in less than 2.9 seconds and having an autonomy of more than 500 miles [9].

The electric truck's driving range varies with the number of motors, but Tesla estimates AWD versions can travel 340 miles per charge, and the Cyberbeast will go 320 miles. Those claims rise to over 440 and 470 miles, respectively, with an optional range extender battery pack that fits inside the truck's cargo bed. When the RWD Cybertruck arrives, it'll have an estimated 250 miles of range.

Based on the comparison and analysis of the data in Table 1, the range of all-electric pickup trucks is relatively short compared to traditional gasoline pickup trucks, indicating that the range of electric pickup trucks is still limited by technology, especially when the trucks are carrying cargo. Electric trucks require frequent charging due to their limited range. However, in certain areas or under special circumstances, the energy supply may be unstable, making timely charging impossible. This would prevent electric trucks from functioning properly in emergencies, thus posing a potential threat to road traffic and cargo transportation safety.

2.3. Solar Canopy Charge Features of Cybertruck

The range of electric vehicles can be improved through the following three points

(1) Optimizing battery technology: Developing higher energy density, lighter and more durable lithium-ion batteries or hydrogen fuel cells;

(2) Improving overall energy efficiency: Optimizing drive systems and transmission devices to reduce mechanical losses;

(3) Developing charging infrastructure: Building more convenient and fast charging stations to meet the growing demand. Promoting wireless charging technology for wireless replenishment during stops.

The Cybertruck utilizes a Solar Tonneau Cover for sustainable charging. To promote sustainable energy usage, Tesla has assembled solar panels on its latest pick-up model Cybertruck, and claims that the photovoltaics (PV) can add 15 miles of driving range each day [10]. This feature harnesses solar energy to charge the vehicle's battery, extending its driving range while reducing dependency on conventional charging methods. Solar batteries have the advantages of being clean, noiseless, and zero-emission. With an emphasis on environmental protection and sustainable development, solar cells have great potential in the automotive industry.

However, there are many challenges and uncertainties in the application of solar cells. The first is technological limitations. Although solar cells have made significant improvements in efficiency and stability with technological advances and cost reductions, the current solar conversion efficiency is still low compared to traditional power systems and is highly influenced by weather conditions. The second point is the problem of infrastructure construction. To realize large-scale applications, it is necessary to establish a perfect charging network and supporting facilities. Finally, the balance between market demand and price. Although consumers are paying more attention to environmentally friendly mobility, the high price may limit its popularity.

3. Intelligent Systems

In traditional cars, the control system usually consists of multiple modules. The most important of these is the engine control module (ECM), which monitors and controls engine fuel supply, pause timing parameters, etc. In addition, there is a control module (TCM) for automatic or manual operation and adjustment. There is also an anti-lock braking system (ABS) to avoid tire locking and provide better forklift performance, as well as an electronic stability program (ESP) to help the vehicle maintain good forklift stability.

3.1. Autopilot

Each Cybertruck is equipped with basic autonomous driving functions. The vehicle can automatically accelerate, turn and stop on the same track. Tesla is also equipped with blind spot monitoring,

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emergency braking, and anti-collision warning, and can automatically drive in and out of motorways, including slip lanes and overtaking slow-moving vehicles.

The vehicle lens Cybertruck has 8 lenses that record and store the 4-sided environment of the vehicle. It is almost the best lens equipment on the market because there is currently no lens setting on the market that can record the vehicle body in all directions. Cybertruck also comes with pet mode, camping mode, and sentry mode. After parking the vehicle, you can activate sentry mode to detect any possible activities. If suspicious people or actions are found, the vehicle footage will automatically record and the mobile program will also send out a notification.

3.2. Full Self-Driving

While regulations and safety considerations still require the driver to be attentive, fully autonomous driving technology will become a mainstream trend in future developments, including AI-based navigation that can plan routes intelligently. It will go beyond standard GPS directions. It takes into account real-time traffic conditions, weather forecasts, and even driver preferences to optimize routes and ensure you reach your destination efficiently. This can not only improve driving safety but also reduce the occurrence of traffic accidents. It can also improve road utilization and reduce urban congestion.

4. Design and Material Innovations of Cybertruck

The design of the Pickup Trucks, besides the additions of slight curves or add-ons aided by advancements in other fields, has not had a significant design refresh for a long time.

Figure 2. Tesla Cybertruck [9]

Tesla recently entered the pickup market with an extraordinarily designed product named Cybertruck. Figure 2 shows the shape of the Cybertruck. The design of Cybertruck has an exoskeleton (body and frame are one piece) instead of the traditional body-on-frame (the body is assembled on a frame). This new frame structure provides a significant advantage for space, especially for the battery packs. The simple plate-like design provides cost savings. The main advantages of this frame design are to minimize manufacturing and assembly operations and eliminate painting, where these cost reductions become important. This can make the process more sustainable in terms of the cost and the environment [11].

The Cybertruck body is made of cold-rolled stainless steel which is 30 times harder. It helps resist dents, damage, and long-term corrosion while keeping drivers and passengers safe. This is the same material SpaceX uses to build its rockets. Another feature is that the windows are made of Tesla Armor Glass, a super-strong glass and polymer layered composite that absorbs and redirects impact forces for improved performance and resistance [12].

The design of future cars may tend to create different design solutions based on different models. For example, for sedans or sports cars, streamlined designs with smaller resistance will be further adopted based on aerodynamics to reduce wind resistance and improve efficiency; SUV categories tend to have more Spacious and comfortable interior space; luxury brands focus on combining luxury and technology.

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In terms of materials, future cars will use new materials that are lighter, stronger, and more environmentally friendly. For example, carbon fiber composite materials have excellent mechanical properties and lightweight characteristics and have great potential in reducing fuel consumption and improving safety. There are also new environmentally friendly materials such as degradable plastics.

5. Conclusion

Taking Tesla's Cybertruck as an example, this paper delves into the development trend of electric trucks. Firstly, this paper introduces the engine performance of three versions of Cybertruck and compares them with traditional gasoline pickup trucks to analyze the advantages and disadvantages between all-electric pickup trucks and gasoline-powered pickup trucks. From there, it concludes that electric trucks prefer battery engines with greater range and faster charging speeds to reduce energy consumption and increase efficiency. Next, this paper discusses the intelligent control system of all-electric trucks and the versatile features of the Cybertruck, analyzing the future possibilities of artificial intelligence and autonomous driving. Future vehicles tend to combine artificial intelligence with driver control systems to improve fully autonomous driving technology. Finally, it describes the Cybertruck's integrated body design concept and the innovations and benefits of cold-rolled stainless steel manufacturing materials. It is suggested that future vehicles should choose materials with stronger strength, lighter weight, and easier recycling to manufacture their bodies by incorporating aerodynamics according to the needs of different vehicle models. Overall, this paper provides recommendations to address the lack of range, improve automated driving systems, and improve body design to reduce air resistance, and explore the great potential of electric pickup trucks in the future global market.

However, the research in this paper also has some shortcomings. Firstly, although the engine performance and intelligent control system of the Cybertruck were compared, performance tests and empirical data under real driving conditions were more limited and lacked comprehensive validation. Secondly, the study mentions the future direction of automotive development, but does not explore in detail how to overcome the balance between market demand and price to lead to a wider application of electric trucks in the market.

Future research directions could focus on the following areas. First of all, validate Cybertrucks' performance under different driving conditions through more comprehensive field tests and data collection to more accurately assess its competitiveness in the market. Secondly, to propose practical solutions to electric truck range and charging infrastructure issues, such as exploring the feasibility of using hydrogen fuel cells to promote the practicality and convenience of electric trucks in actual transportation. Finally, in-depth research on the balance between market demand and price will be conducted to explore more competitive business models to promote the wider promotion and application of electric trucks in the market. These directions will help make the research more practical and instructive, and promote the sustainable development of the electric truck field.

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