

# Analysis of Development of Transmission in Hybrid Electric Vehicle

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## ABSTRACT

Under the background of carbon neutralization and peak carbon dioxide emissions, most of the industries are taking measures to reach goals. As the pillar industry in the national economy, the vehicle industry is experiencing the transformation. Faced with the request of reducing emissions, the industry gradually manufactures hybrid electric vehicles to meet the command of the times. The vehicle industry is a highly integrated industry. The transmission system plays a critical role in transmitting the power. Since Toyota introduced the Prius to the global market in 2000, many vehicle manufacturers have developed hybrid models. The transmission system of the hybrid electric vehicles plays a role in changing the transmission ratio, cutting off the power and realizing reverse gear[1]. The study will work to know about the condition of the transmission in hybrid electric vehicle. Then people will find the market share of the transmissions in HEV by analysing data of the sales market. In this article, the author will focus on the development of the hybrid vehicle transmission and explore the trend of the transmission system in the future.

**Keywords:** Hybrid electric vehicle, Planetary gear mechanism, Add-on Hybrid Transmission DHT, Future trend.

## 1. INTRODUCTION

With the development of the global standard for traffic industries, the vehicle industry also convert traditional oil-fueled automotive into fuel cell vehicle, blade electric vehicles and hybrid electric vehicle. Limited by the prices and low energy density, the fuel cell vehicle cannot be applied to the market in a large scale. For blade electric vehicles, most customers express worry about driving range. In a number of regions, there are not enough stations to provide the electricity for users. Under this kind of background, hybrid vehicle comes to complete the transition. It has the advantage of saving fuel consumption and increasing the driving range. Although it has a relatively high price, it needs little finance in the process of using. Nowadays, more and more advanced hybrid vehicles come to the market will do research on the condition as well as the future trend of hybrid electric vehicle will quote existing articles and market information to analyse the limitation of hybrid electric vehicles ,find approximate solutions and have a clear expectation of its future trends. Through these work, we can provide reasonable advice for manufacture companies to make correct decisions. During the process

of the manufacturing, companies can balance the cost and using experiences so that they can choose the most reasonable transmission system for their vehicles.

## 2. THE BRIEF INFORMATION OF HYBRID ELECTRIC VEHICLE

A hybrid vehicle is a vehicle driven by two or more energy sources, and there can be one or more driving systems. Common energy sources include fuel oil, batteries, fuel cells, solar cells, compressed gas and so on, while common driving systems include internal combustion engines, motors, turbines and other technologies. For example, the internal combustion engine is used to drive the generator, and the generator provides power for the motor. For example, the diesel electric train using diesel engine to drive the generator and the engine to drive the motor, and the submarine using diesel engine when surfaced and battery when underwater. Other ways of storing energy include pressurized fluid in hydraulio hybrid power[2].

## 2.1. Toyota Company as a typical example

In 1997, the Toyota company introduced Prius (first mass production hybrid electric vehicle) which was regarded as the success[3]. After that, the Toyota gradually upgrades the Prius. It is obvious that Japan occupies in the dominant situation all over the world. Recently, a number of countries propose policy to encourage the research and development on the HEV.

Also, the customers can acquire subsidy to some extent. We will discuss the significant composition of the vehicle-transmission.

## 2.2. Vehicle-transmission system

For hybrid electric vehicles, the transmission system has the responsibility of the bridge from engine and electric motor. It needs to coupling power from both sides. At present, we can divide transmission systems into two types (Add-on Hybrid Transmission and Dedicated Hybrid Transmission, DHT).

First, the two systems of Vehicle transmission will be explained in the following section

### 2.2.1. Add-on Hybrid Transmission.

This kind of transmission is based on traditional transmissions by concentrating on a electricity-driving model. Traditional transmission includes AMT, DCT, AT and CVT. In China, we can see P3+DCT. The structure of the transmission keeps unchanged while the electric motor is located in the output of the transmission.

### 2.2.2. Dedicated Hybrid Transmission.

DHT is a newly invented hybrid transmission which attracts attention from various aspects. It is created for the power and twist moment of the engines and electric motors. We can usually see single row star gear mechanism, single gear ring compound planetary gear mechanism, ordinary unipolar fixed axis gear and double row ordinary unipolar planetary gear.

What matters most is that the DHT can create the possibility of environmental protection travel. On the drive of the electricity, the internal combustion engines can accurately run in the range of power. The energy consumption can be reduced consequently. Last but not the least, the electricity drive can maintain running at extra power so that the power as well as the driving pleasure can be acquired.

It is obvious that planetary gear mechanism is applied in a large scale. It is important to have a good command of the structure of the system. The detailed analysis will be shown in the following sections.



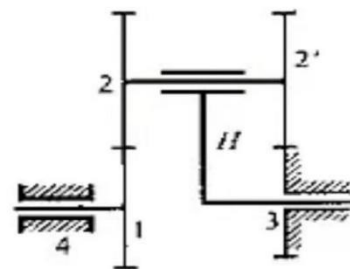
**Figure 1** The planet gear

The planetary gear mechanism has the ability of dividing the power. It is widely applied in the vehicles and aerospace mechanism.

### Composition and Movement

The transmission system is composed of several rows planetary gear mechanism. There are a sun wheel, several planetary gears and gear ring. It is apparent that planetary gears usually contact sun wheel and gear ring. Helical gear is used to reduce the vibration. Due to the existence of planet carrier, three axis can be in existence to permit the input or output of power. As a consequence, the relationship of the contact can make up several combination.

## 3. THE FUNCTION OF THE PLANETARY GEAR MECHANISM



**Figure 2** The sketch map of the transmission mechanism

The planetary gear mechanism systems can use several evenly-distribution planetary gear mechanism to transmit the move and power. These planetary wheels produce centrifugal inertia force which can be offset by radial component force from tooth profile reaction force. As a consequence, the main axis shoulder little force. In addition, the size of the whole gear keeps smaller than the common gears.

### The compound of the movement

Two kinds of input motion can be composed to an output movement. The freedom of differential gear train

is 2. Only two random component parts are given can another component part can be defined. The simplest kinematic gear train is given below.

#### Future Trend

According to the development of global hybrid electric vehicle market, the demand for hybrid electric vehicle transmission keeps huge. By contrast, the DHT

has an advantage of high efficiency and compact. In the meantime, the DHT has a trend of acquiring benefits. Also, the oil consumption is an aspect where DHT overpasses Add-on Hybrid Transmission. (as the chart below) When the mass of the vehicle keeps similar, the oil consumption of DHT can be significantly reduced. This is also the reason why DHT is more likely to be welcomed by customers

The type of transmission	Vehicle mass/kg	Oil consumption under WLTC electric balance
Add-on	1700	6.2
DHT	1635	3.61

**Figure 3** Contrast of oil consumption

## 4. ANALYSIS OF MARKET SHARE

From the chart, we can tell that DHT will acquire more appreciation. The account for DHT will increase further.

With more policies applied to encourage developing HEV, the author are convinced that the market of the HEV transmission will be broaden under the background of carbon neutralization and peak carbon dioxide emissions.

Electric car market share increases to 5.14 percent and 5.19 percent, respectively. However, based on the results of the consumer cost sensitivity study, we can conclude that research should be concentrated on lowering battery costs rather than increasing driving range or decreasing charging time. Only 1.23-1.99 percent of the market potential for BEVs is increased by the installation of charging infrastructure. Because PHEVs are designed to be charged at home, their commercial potential is relatively unaffected. Even so, PHEVs will have a larger market share than BEVs (7 percent versus 5 percent). Due to technological and economic advancements, electric car technologies will have a greater market potential: battery costs will decrease, driving range will improve, charging time will be reduced, and driving range will increase. Furthermore, charging infrastructure, like as charging stations, will be improved.

For example, in California, we used data from two independent polls to identify households that acquired an in 2012.

The total target market consists of new car owners in California who filed for the California Vehicle Rebate Project (CVRP) for plug-in owners between February and August 2012 and have owned their vehicle for more than 6 months. This group contains the majority of PEV customers during this time period, including most Nissan LEAF, Chevrolet Volt, and Plug-in Prius owners. Only

PEV owners who were eligible for the CVRP are included in the sample. The California Center for Sustainable Energy (CCSE) conducted the poll in collaboration with the California Air Resources Board (ARB). There were 3,881 started surveys and 3,201 usable surveys, resulting in a response rate of around 30.6 percent. After receiving state incentives, PEV owners expressed their experiences and strong feelings of gratitude. Only ten percent of the people in the sample bought the car for less than nine months. Nissan LEAF owners spent the most time with their vehicles, an average of more than 10 months. Between January 2010 and June 2013, the survey covered approximately 13.6 percent of the CVRP population and about 10% of the PEVs sold in California, and provides a good representation of the three main vehicle models in use: the Nissan LEAF, Chevrolet Volt, and Plug-in Prius, as well as all five major metropolitan areas.

Vehicle Model	Days own the car					
	N	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Nissan Leaf	2205	616	135	3	610	622
Toyota Plug-In Prius	851	362	52	2	359	366
Chevrolet Volt	661	329	54	2	325	333
Tesla Roadster	48	778	203	29	719	837
Ford Focus Electric	36	300	24	4	292	308
Mitsubishi i-MiEV	35	428	62	10	407	450
Other PEVs	45	323	45	7	310	336

**Figure 4** Days PEV Vehicle Owned by Vehicle Model

PEV owners clearly have a higher income than the general population. This allows them to purchase new cars that are more expensive than comparable IC vehicles. How similar are PEV owners to other car buyers, such as hybrid vehicle purchasers? According to surveys conducted by Caltrans in 2012 and the National Highway Traffic Safety Administration in 2009, two-thirds of households polled had not purchased a new car

in the previous five years. Based on the household present fleet, we know that 7% of households purchased two or more new automobiles in the last five years.

Only 29% of the 3,800 PEV owners who bought their car after February 2012 leased it, while 71% bought it. The Volt has the biggest leasing share of 38 percent, followed by the Leaf at 31 percent and the Plug-in Prius at 18 percent. We are convinced that higher number of buyers show trust in the new technology. Prius owners anticipate to keep their car for longer than LEAF or Volt owners, so the discrepancies between the models may reflect market preferences. In the meantime, it may also reflect the preferences of car dealers and car manufactures. We also discovered that the decision to lease or buy is independent to household income, with 28% of households earning more than \$200,000 a year leasing their vehicle. In Los Angeles, we identified a correlation between location and lease prices, which could be explained by the huge number of auto industry personnel that lease PEVs and live nearby [5]. The customers of cars are looked on as a small group in the population with unique socio-demographic characteristics. They belong to a group which has common characteristics but higher salary, several fuel cars, education, and live in a single family. In spite of these common characteristics, these buyers are not a part of regular conventional car buyers and some have not purchased a new car for plenty of years before buying a new plug-in. All in all, new car buyers don't live in MUDs, PEV owners seem to be less likely to live in MUDs or to be single-vehicle households[5].

Hutchinson et al.[6] found that the increased cost of a HEV or PHEV concentrates mainly on the style of driving. According to Hutchinson et al. [6], HEVs and PHEVs have a payback period of 6.7 and 10.1 years for city driving, respectively, but do not reach cost parity for highway driving. The higher advanced efficiency and more reasonable economy of HEVs and PHEVs in urban driving explains a shorter pay-back time which was calculated in Hutchinson et al. This paper estimated this to be greater than the vehicle lifetime in California[6]. Hutchinson et al. expressed conclusions in this article such that HEV and PHEV TCO is closer to cost parity with traditional internal combustion vehicles in the UK than that in the USA[6].

Charging infrastructure is a main barrier to the adoption. Although most PHEV owners have access to charging equipment at home, public charging infrastructure is significant for practical use just as gas stations[7]. Although in Texas the number of charging stations is lagging behind at 885, the number of charging stations in California has increased to 3820 [8]. Japan has determined to invest heavily in charging infrastructure which is aimed at stimulating uptake[9]. In the UK, charging infrastructure has been installed strategically in plenty of regions[10]. It can be forecast that more and

more consumers will choose HEVs with the construction of charging stations. If the number of charging infrastructure is equivalent to that of gas stations, the market of HEVs will expand to a large extent.

## 5. CONCLUSION

The author expressed the structure of the planetary gear mechanism. Then, the author did research on the data on HEV. Due to the transmission system is a significant composition of the HEV, it can be forecast that the market share for transmission system in HEV is huge. With the improvement of the technology, more advanced equipment will be invented to satisfy the command of the environment. As the most eco-friendly approach, the HEV provides ways to reduce wastes of energy. Finally, the author had a good expectancy of transmission in the near future. This article is weak in collecting data about the sales data of the hybrid electric vehicle. The expectancy of the market is limited. As the author, the author will concentrate more efforts to estimate the future trend of the vehicle industry and further find the reasonable methods to analyse the demand of the transmission.

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