

Research on Dual Clutch Transmission (DCT)

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ABSTRACT

The article first introduces the development history of the dual-clutch automatic transmission (DCT), then analyzes the structure and working principle of the DCT, compares and analyzes the advantages and disadvantages of the DCT and other automatic transmissions, and discusses the key technologies in the development of the DCT. difficult problem. It also looks forward to the future development prospects of DCT, the current international and domestic DCT development status, predicts the development trend of DCT gearboxes in the domestic market based on the current market conditions, and points out that DCT gearboxes are the most suitable for China's manual gearbox production. This article summarizes the structural features, working principles, control methods, etc. of the dual-clutch automatic transmission, and then gradually expands the description and conducts more detailed analysis and supplements. Therefore, it will have better development prospects.

Keywords: Dual clutch, Automatic transmission, Shifting process, Characteristic.

1. INTRODUCTION

The double clutch transmission (DCT for short) is innovatively developed based on the power transmission principle of parallel shaft manual transmission. The odd-numbered and even-numbered gears of the gearbox are innovatively arranged on the two input shafts connected with the two clutches. Gear switching is achieved by precisely controlling the separation and combination of the two clutches, thereby completing the switching of the torque transmission path. Thanks to efficient gear transmission and unique shifting principle, DCT gearbox has the advantages of high transmission efficiency, continuous shifting power, good shifting comfort, and low production cost. It is very suitable for the basic national conditions of my country, where manual transmission production facilities are the mainstay. Since the advent of DCT gearbox, through continuous improvement and upgrading and related technical progress, the product performance has been comprehensively improved. Therefore, more and more car companies have invested in the development of DCT and new products have come out one after another. The application of DCT will be more extensive, especially in the self-owned brand market, the market share will be further increased.

2. THE BRIEF INFORMATION OF DCT

2.1. The development process

In 1940, Darmstadt University professor Rudolph Franke applied for the first patent for a dual clutch gearbox. Relevant tests have been carried out based on trucks equipped with this gearbox prototype, but mass production has not been realized in the end.

Then enter a small amount of application stage. DCT originated from racing cars, and its practical application first appeared when Porsche also applied dual-clutch technology to sports cars, Porsche 962C (Porsche Doppel Kupplungen, PDK for short) in the early 1980s; Audi applied dual-clutch technology to racing cars in 1985. The Audi sport quattro S1 RC (named "Audi Sport Quattro S1 racing car with dual-clutch technology" at the time) benefited from the fast shifting of the dual-clutch, which made the Audi racing win a number of races at that time.

However, due to issues such as durability, after more than ten years of improvement, it has been widely used in ordinary production vehicles. In the late 1990s, Volkswagen and BorgWarner collaborated to develop and produce the first dual-clutch transmission suitable for mass production and mainstream models, the DualTronic(R). BorgWarner industrializes the DCT with the use of new electro-hydraulic components. In 2002,

DCT was applied to the Volkswagen Golf R32 and Audi TT V6. The Dual Tronic dual-clutch automatic transmission wet clutch and control system developed by BorgWarner for the dual-clutch automatic transmission was mass-produced in 2003. It was used in Volkswagen Audi's innovative product DSG (Direct Shift Transmission), and was first applied to the Volkswagen Golf in 2003.

Since 2003, DCT gearboxes have been extended to other models such as Golf. By the end of 2007, the number of sedans matching DCT has exceeded 1 million worldwide. Up to now, DCT gearboxes have been widely used, and the dual-clutch Dual Tronic technology enables manual transmissions to have the performance of automatic transmissions.

2.2. The Principle and relevant theories of DCT

2.2.1. The principle of DCT

The power transmission is connected to the two input shafts through two clutches to work alternately. During the shifting process, the power is continuously transmitted through the slip friction control of the clutch.

Simply put, this type of gearbox has two clutches, one for 1, 3, and 5 gears, and one for 2, 4, and 6 gears. During the entire shift period, the two sets of clutches work in turn to ensure that at least one set of gears is outputting power, so that the power does not appear to be interrupted. When the first gear is used, the second gear is ready, so the gear shift time is greatly shortened and there is no delay.

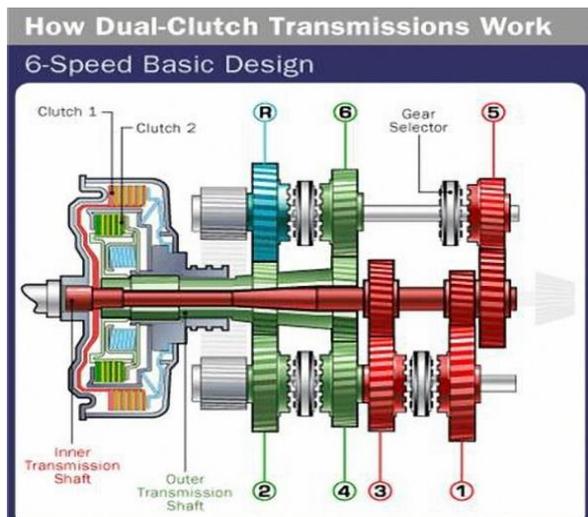


Figure 1 The steps of how Dual-Clutch Transmission work

2.2.2. The relevant theories of DCT

The dual-clutch automatic transmission mainly consists of a dual-clutch module, a shift module, a

hydraulic control module, a transmission gear mechanism and a TCU control module. The shift control module is composed of shift forks, shift fork shafts, synchronizers and coupling sleeves, which realizes the power transmission and disconnection of the adjacent gears and is driven by the hydraulic control module. The hydraulic control module is mainly composed of a hydraulic oil pump, a control valve plate and a cooling system, which mainly realizes the switching action between the driving dual clutches, the shifting action of the shift module and the cooling function of the hydraulic oil. The transmission gear mechanism is mainly composed of various levels of gear sets and gear shafts to realize the forward and backward changes of the car and the change of the transmission ratio. The TCU control module is mainly composed of a control computer, sensors, solenoid valves and wiring harnesses. It collects shift signals (such as oil temperature, vehicle speed, gear position, and throttle opening), according to the shift rule curve or program stored in the computer in advance, Control the actuator solenoid valve to drive the hydraulic control module to work and finally realize the gear shift to meet the driving conditions of the car.

3. CHARACTERISTICS

3.1. Power shift characteristics

DCT realizes the shift action through the matching switching of the two clutches. The shift is fast and smooth, and the shift time can reach 0.3s-0.4s, and the driver will not have a significant power interruption feeling. In the process of shifting, the power of the engine is almost continuously transmitted to the wheels to realize the power shift and ensure that the vehicle has good acceleration performance. As shown in the figure, it is the simulation curve of the shift characteristics of the DCT transmission. It can be seen that the acceleration of the vehicle fluctuates slightly in the process of shifting, but the time is extremely short and the shifting shock is small.

3.2. High efficiency characteristics

The transmission efficiency of the transmission has a great influence on the economy and power of the vehicle. DCT is developed on the basis of parallel shaft manual transmission and inherits the advantages of high transmission efficiency of manual transmission. Experimental research shows that the Gol R32 equipped with DSG transmission (DCT) consumes only 10.2L per 100 kilometers (according to MVEG's 99/100EG standard test), and the acceleration time of 0~100km/h is only 6.0s, and the corresponding manual transmission is installed. The fuel consumption of R32 is 11.5L per 100 kilometers, and the acceleration time is 6.4s from 0-100km/h. The highest speed of the two is also 247km/h. It can be seen that, compared with manual transmission,

dual-clutch transmission can make the vehicle have excellent fuel economy and power performance⁰.

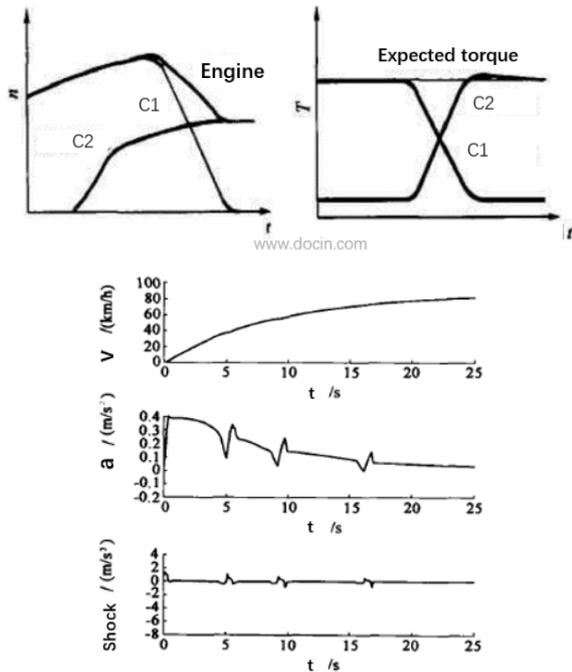


Figure 2 DCT transmission shift characteristic simulation curve

4. KEY TECHNOLOGIES AND DIFFICULTIES OF DCT PRODUCT DEVELOPMENT

4.1. Key technologies

4.1.1. Development of the dual clutch module

As an important part of the DCT gearbox, the dual clutch module largely determines the performance and durability of the DCT.

4.1.2. DCT starting control strategy

The starting process of the vehicle is realized by the slippage of the main and driven plates of the clutch until synchronization. By optimizing the dynamic model of the clutch, perfecting the control strategy of clutch engagement and improving the tracking quality of the clutch actuator, it is the main way to improve the starting performance of the vehicle.

4.1.3. Formulation of intelligent shifting rules

DCT gearboxes have the concept of pre-selection, so based on the two-parameter shifting rules, it is necessary to consider the rate of change of the accelerator pedal, vehicle weight, road gradient and other information on the shifting rules, including The optimization of the pre-selected gear rules avoids frequent accidental up-and-down movements, which can improve the vehicle NVH

performance and shift comfort, and increase the life of the shifting mechanism.

4.2. Difficulty

In DCT, two clutches have overlapping phases of torque transmission during gear shifting, so higher requirements are put forward for clutch control during gear shifting. In order to ensure the quality of shifting and the working life of the clutch, it is necessary to precisely control the switching timing of the clutch. If the control is improper, it may cause shifting shock, which will cause the transmission system to generate a large dynamic load, cause clutch self-excited vibration, transmission system shock, etc., and cause the temperature of the friction plate to rise, deformation and even ablation damage, which will directly Affect the life of the clutch⁰.

However, the specific technical difficulties of product development mainly lie in

(1) NVH optimization: Based on the basic principle that the gears transmit motion and power, and push the synchronizer to shift gears through the shift fork, while the transmission is efficient, it also brings gear whistle, shift fork noise and gear knocking Hit and other NVH issues. By improving gear manufacturing accuracy, reducing gear transmission errors, reducing backlash, optimizing shift fork control and clutch torque control, these NVH performances can be significantly improved, increasing customer satisfaction.

(2) Active thermal management technology: Whether it is a dry clutch or a wet clutch, an efficient thermal management system needs to be developed. The wet clutch can effectively improve the thermal load resistance of the clutch, which is the main development trend of DCT products in the future. However, in order to maximize transmission efficiency, thermal management of the clutch needs to be quantitatively cooled and lubricated on time and on demand.

(3) Optimization of system diagnosis strategy: The higher the complexity of the system, the higher the reliability requirements of the system for related components. The development of accurate and reasonable fault diagnosis strategies can avoid the situation that the transmission power is interrupted due to wrong diagnosis. At the same time, the development of a reasonable limp strategy can ensure that the transmission maximizes the basic functions to improve user satisfaction.

5. THE CURRENT MARKET STATUS AND FUTURE DEVELOPMENT

5.1. China market status

With the introduction of DCT gearbox by Volkswagen into China and its successful promotion,

many domestic automakers of independent brands have also invested in the development of DCT. The DCT360 mainly developed by SAIC was successfully applied to Roewe and other models in 2014 and successfully put on the market; the 7-speed DCT independently developed by FAW was also applied to Hongqi models; in 2012, Dongfeng Group and GETRAG jointly developed and produced small torque Wet DCT150; Geely showed its self-developed 7-speed DCT for the first time at the 2009 Shanghai Auto Show; the newly launched Borui GE and other models are also equipped with DCT gearboxes; BYD has successively developed traditional DCT and hybrid DCT and applied them in On many of its models; GAC, JAC, Chery, etc. have independently developed corresponding DCT products.

DCT has good production inheritance, can make full use of the original manual transmission production equipment, and is very suitable for the modification of the original manual transmission. Compared with the production equipment investment of about 1.5 billion yuan required by AT, its production investment has huge economic and social benefits. At the same time, all the technology and equipment for manual transmission, as well as engineering and technical personnel, can serve the DCT. Unlike AT, CVT and other products that require completely different production lines, the development and promotion of DCT technology in China can not only reduce production costs, but also greatly shorten production costs, so DCT is very suitable for China's current national conditions⁰.

5.2. Development prospects

Global Market Insights forecasts show that from 2021 to 2027, the compound annual growth rate of DCT will be 4.9%. Global Market Insights believes that the DCT market is mainly in China, and DCT for commercial vehicles is the future growth point. However, if DCT is to be applied on a large scale in the commercial vehicle market, technical challenges still need to be overcome, such as increasing torque capacity and transmission efficiency, and reducing product costs⁰.

With the development of gear transmission technology and automation technology, DTC's market share in China will become larger and larger. DCT transmissions can also easily realize manual and automatic integration functions, and the driver can realize manual forced shifting through touch buttons. But the author does not think it will completely replace the traditional manual transmission. Although manual transmission cars require high driving skills, they are full of sportiness and fun to drive.

In the process of independently developing DCT, domestic enterprises should not only focus on the development of products matching pure fuel vehicles, but also do a good job in modular development and platform-

based planning of DCT products. Through product modular development, it can meet the application requirements of different models including traditional, hybrid and pure electric vehicles, and minimize R&D investment, material cost and development cycle. At the same time, it is necessary to make research and development breakthroughs in the technology of DCT core components, such as dual clutches and control modules, to break the monopoly.

6. CONCLUSION

Since the dual-clutch automatic transmission is developed on the basis of the manual transmission, the existing production capacity and equipment can also be directly used to develop the dual-clutch automatic transmission, which improves car comfort and fuel economy while maintaining power. The key technologies of dual-clutch automatic transmissions are still in the research and development stage in various countries. Therefore, domestic dual-clutch automatic transmissions are most likely to become a technology in the field of automatic transmission research and development to catch up with the British and surpass the United States, so as to get rid of the blockade of foreign technology. In short, dual-clutch automatic transmission is the development direction of my country's future transmission system. It can not only reduce the manufacturing cost of automobiles and improve the cost-effectiveness of automobiles, but also meet the requirements of the new era of energy saving and emission reduction. Although it seems that dual-clutch gearboxes are a little away from us due to technical and cost issues, as a new and better solution in the field of gearbox design, dual-clutch systems have become a trend. For a long period of time in the future, new transmission methods and control technologies will continue to appear, and its performance will continue to improve. This article has certain limitations, for example, it does not analyze why DCT will enter the Chinese market.

REFERENCES

- [1] Ma Zhenxin. Introduction to dual-clutch transmission [J]. *Agricultural Machinery Use and Maintenance*, 2012(01):28-30. DOI:10.14031/j.cnki.njwx.2012.01.004.
- [2] Yao Shuang. Discussion on the structure principle and control method of dual-clutch automatic transmission [J]. *Automobile Practical Technology*, 2019(21):214-216+219. DOI:10.16638/j.cnki.1671-7988.2019.21.076.
- [3] Zhu Minhui. The era of commercial vehicle transmission automation has come, and DCT usher in new opportunities? [J]. *Automobiles and Accessories*, 2021(19): 44-46.

- [4] Wang Feng, Zhou Yunlong. The structure principle and domestic development prospect of dual-clutch transmission [J]. *Modern Industrial Economy and Information Technology*, 2020,10(08):18-19. DOI:10.16525/j.cnki.14-1362 /n.2020.08.08.
- [5] Jing Chongbo, Yuan Shihua, Guo Xiaolin. Dual-clutch automatic transmission and its application prospect analysis[J]. *Mechanical Transmission*, 2005(03):56-58+3. DOI:10.16578/j.issn.1004.2539.2005.03. 019.
- [6] Meng Zhaohui, Su Tiexiong. Application prospect analysis of dual-clutch automatic transmission [J]. *Mechanical Engineering and Automation*, 2010 (04): 212-213+216.
- [7] Wang Jiangbo. The development and prospect of dual-clutch automatic transmission[J]. *Shanghai Automotive*, 2008(01): 36-39.
- [8] Li Yuting, Zhao Zhiguo, Zhang Tong. Simulation research on the optimal control method of dual clutch pressure of DCT transmission[J]. *China Mechanical Engineering*, 2010, 21(12): 1496-1501.