International Journal of Computational Science and Engineering Research
ISSN: 3107 -8605 (Online) , http://www.ijcser.com/
Regular Issue , Vol. 2, Issue. 2 (April – June), 2025 , Pages: 48 - 53
Received: 28 January 2025 ; *Accepted:* 29 April 2025 ; *Published:* 30 June 2025
https://doi.org/10.63328/IJCSER-V2RI2P10
Original Paper : Applied Research – Compare and Contrast Research Paper

Revolutionizing Automotive Performance: Exploring the Benefits and Mechanics of Dry Dual Clutch Transmission System

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Abstract: Transmission technology has advanced dramatically in the automobile industry, with dual-clutch transmissions (DCTs) emerging as a notable breakthrough in recent years. Due to its unique design and performance qualities, the "Dry Dual- Clutch Transmission" has gained significant interest among DCT versions. Dry dual-clutch transmissions are a form of automated manual gearbox that differs from wet clutch transmissions in that they employ friction clutches rather than an oil bath for cooling. This design decision has numerous noticeable advantages, including increased fuel efficiency, less power loss, and greater responsiveness. Rapid gear changes, fluid power delivery, and the flexibility to preselect ratios are all advantages of dry dual-clutch gearboxes, all of which contribute to a smoother and more enjoyable driving experience. Furthermore, these gearboxes are frequently lighter and more compact, allowing for better vehicle packaging and contributing to overall vehicle weight reduction. Finally, dry dual-clutch gearboxes are a substantial advancement in vehicle transmission technology, providing improved efficiency, performance, and driver involvement. While addressing heat management challenges requires careful engineering, adequate thermal management solutions are critical to preserving long-term durability and performance.

Keywords Dry Dual-Clutch Transmission, Friction Clutches, Fuel Efficiency, Rapid Gear Shifting, Thermal Management.

1. Introduction

In the dynamic realm of automobile engineering, the pursuit of enhanced performance, efficiency, and driving enjoyment has been a driving force. The Dry Dual Clutch Transmission (DDCT) technology is one of the most spectacular technological advances in recent years, drastically changing automotive performance. This cutting-edge transmission technology has raised the bar for automobile quality while also altering the way we enjoy driving. This study goes deeper into the fascinating topic of DDCT systems, demonstrating their intricate physics and a wide range of benefits that make them an engineering marvel. We'll embark on an expedition that begins with the invention of this groundbreaking technology and finishes with its implementation into current automobiles, demonstrating how it has fundamentally transformed the way enthusiasts drive. and regular drivers alike. The complex world of DDCT systems, It deconstructs the inner workings of this gearbox technology, exposing the dual-clutch idea and revealing the inventive technical solutions that have made it an intrinsic component of current car design. DDCT systems have made an indelible impact on the automobile industry, from enhanced fuel efficiency and lightning-fast gear changes to smooth power delivery and decreased drivetrain losses. Transmission systems shed light on how they have altered the very core of vehicle performance and added a new degree of excitement to the driving experience.

2. Literature Review

Jiayi Chen et al. [2019] Investigate ways to improve fuel efficiency by lowering the effort required by hydraulic mechanical braking systems and recovering braking energy. During the downshift process, the driving motor adapts to variations in torque and speed demands, which can improve DCT shift quality without sacrificing fuel economy or engine emissions.

Nikolay Sergienko et al. [2022] looked into the Work on the mode transition between the engine and motor has a substantial influence on the power and driveability of single-shaft parallel hybrid electric vehicles (HEVs). The motor starting engine and clutch control

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issues have a substantial influence on driving quality, especially during the mode shift from pure motor-drive to solely engine-drive operation. Solutions have the potential to increase dynamic performance in specific cases. In this work, a novel mode transition control strategy is provided to enable a rapid and smooth mode changeover procedure.

Jiejunyi Liang et al. (2018) developed and investigated a dual clutch transmission-based regenerative braking power-on shifting control system as a potential solution to the limited driving range per charge issue in electric vehicles. When a wheel and power source are adjusted, a process known as "power-on shifting" happens in which the power flow is not interrupted but instead permitted to continue within a specified range. This characteristic is more noticeable when regenerative braking is activated than while driving normally since the motor produces the bulk of the braking force during regenerative braking.

Zhiguo Zhao et al. [2020] highlighted how they developed fault-tolerant control algorithms for a 6-speed DCT automobile in the case that an actuator motor fails during the upshift operation for one of the clutches. If the actuator motor fails, the automobile is programmed to leap upshift with a single clutch and activate the no-fault clutch, giving the driver the option of driving the car in its current gear or shifting into a higher or lower gear. This ensures that even if one clutch actuator motor fails, the automobile will continue to run with better power and fuel economy. Finally, the methodologies were validated using the DCT hardware-in-the-loop test bench.

Due to their higher efficiency and superior shift performance than other types of gearboxes, dual-clutch transmissions (DCTs) are becoming increasingly widespread in modern mass-produced automobiles, as demonstrated by Sooyoung Kim et al. [2018]. However, because torque converters do not give the same smoothing benefits as torque converters, automobiles with DCT are more prone to driveline oscillations, which can cause poor driving, especially while shifting gears. Torque transfer via the driveline must be precisely managed by the engine and two clutches to achieve the DCT's excellent performance.

Fork-lever actuators are becoming increasingly common in dry dual clutch gearbox (DDCT)-equipped conventional and electric vehicles (EVs), according to Mingxiang Wu et al. (2019). This is due to the several benefits they have in terms of manufacturing costs and building dimensions, as well as their ability to accurately and swiftly adapt to driver requests. The displacements of the microscopic ends of diaphragm springs, as well as the rates at which these displacements vary, are recognised as critical state variables for studying the best dynamic behaviours of EVs equipped with DDCT. The two-speed EV's DDCT driveline dynamic model is designed and integrated with this sort of actuator.

The working item analysed by Xie Chao et al. [2020] is a passenger car's dry dual clutch, and CATIA software builds a three-dimensional model of it. Based on this, the ABAQUS software assesses the thermal load characteristics of the dry dual clutch when there are many starts on the ramp. The study results show that the thermal stress and temperature rise of the components caused by friction heat are within the intended range, indicating that the pressure plate and intermediate drive plate designs are appropriate.

In order to overcome the challenges associated with modelling the starting system of dual clutch gearbox (DCT) vehicles, YANG YANG et al. [2020] proposed the state-dependent autoregressive with exogenous variables (SD-ARX) model whose functional coefficients are approximated by sets of radial basis function (RBF) networks to describe the dynamic characteristics of DCT vehicles starting process in this study. An actual automotive test validates the correctness of this modelling technique. On this basis, an SD-ARX model-based nonlinear predictive controller is developed.

The major issue of the study, as mentioned by Qingkun Xing et al. [2019], is the optimum control approach for the Dual Clutch Transmission upshift process during the torque phase. The two power flow paths and the upshift mechanism are thoroughly examined. The analytical findings demonstrate that if two clutches slip together during the DCT upshift method, a torque hole or power circulation will occur. To avoid these two circumstances, the torque connection between two clutches is adjusted to allow the off-going clutch to disengage without slippage. The Matlab / Simulink platform is used to develop the DCT dynamic model.

Dong Guo et al. [2022] build the gearbox gear rattling dynamics model with the 1st gear without preselection and the preselected 4th gear, respectively; The model considers time-varying mesh stiffness, mesh damping, nonlinear oil film force, nonlinear backlash, and the drag torque created by the clutch when it is not engaged. Furthermore, the bench test confirmed the dynamic model's practicality.

Jihao Feng et al. [2022] created a powertrain mount that produces jittering and shrugging throughout the vehicle's starting and shifting activities. Previous research has overlooked the effect of mounts on automobiles. In light of the aforementioned issues, this work develops a DCT vehicle coupling dynamic model that takes into account the six degrees of freedom of the

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powertrain mount and the engine dynamic torque, as well as the nonlinear properties of a dual-mass flywheel. Other issues include the time-varying stiffness of gear systems.

[2019] Jinyue Tian et al. The dynamic characteristics of the investigated gearbox system are used as input variables, and the complete evaluation index of the weighted form of the jerk and friction work is used to generate the optimisation objective function. The optimisation problem of dynamic parameter input variables is turned into a parameter optimisation problem that a particle swarm can solve using the Fourier transform.

Michael A. Laukenmann and colleagues [2021] discussed Legislative mandates to reduce emissions are fueling an increase in hybridization of car powertrains. When compared to prior gearbox systems, Hybrid Dual-Clutch Transmissions with an electric machine have significantly reduced losses, making them an important component of this issue. On the one hand, hybridization brings about additional characteristics such as electric driving, boosting, and many more. However, the extensive interaction between the engine, electric machine, clutches, and vehicle increases complexity and need improved control algorithms.

Seibum Choi and colleagues [2018] Look at parallel hybrid vehicles; dry clutches are becoming increasingly frequent in engine clutch systems and gearbox systems of small and medium-sized cars. This tendency emphasises the need of being able to manage the torque delivered by the dry clutch in an appropriate manner. This paper describes a clutch friction model-based feedforward clutch torque management technique for a dry clutch during slip engagement. The clutch friction coefficient is frequently viewed as the only variable in the ambiguous clutch friction model.

Oliver Sawodny et al. [2019] highlighted a new work that produced a near time-optimal two-staged flatness based feed-forward controller for the filling process of a hydraulic clutch system within an automated gearbox. The filling phase has a substantial impact on shift quality and is hence an important aspect of gearbox management. For the two stages of the filling phase, two simplified physical models of the hydraulic actuation system are built. A flat output can be determined for both models, and the differential parametrization may be computed symbolically. Following that, an online trajectory generator is used to construct a near-time optimum trajectory for the flat outputs.

Guoqiang Li et al. [2018] proposed increasing driving comfort, with the control goal of streamlining the upshift method. An observer architecture that takes into account the sensors that are now available in cars for feedback control is offered to track the immeasurable variables. Shift performance may be enhanced by minimising jerk during both the torque and inertia phases, according to simulation results. Furthermore, as compared to typical controllers for the upshift process, the proposed control strategy can reduce shift jerk and improve shift quality.

Because the clutch actuator motors of the six-speed dry dual clutch gearbox (DCT) will often start, halt and stall, Qiqi Huang et al. [2022] researched the working hours grow, there is a larger possibility that the clutch actuator motor may fail during the shifting process. Fault-tolerant control that is appropriate for the scenario will be required to prevent shifting failure, give poor riding comfort, and maybe jeopardise driving safety. When one of the clutch actuator motors breaks during the power-on downshift operation, the corresponding fault-tolerant control techniques are developed to manage the problem.

Jun Guo et al. [2023] evaluated the performance of the P2.5 plug-in hybrid electric cars with a wet dual-clutch gearbox; in this work, an adaptive beginning control technique is proposed, which regulates the two clutches involved in the starting process at the same time. Under diverse working situations, a fuzzy controller is designed to discern the starting intention and determine the desired torque. The beginning process is separated into five stages, with the third period using linear quadratic optimum control to produce the reference torque trajectory, while the others are determined by adaptive control by adjusting the adjustment coefficients based on the starting conditions.

Dariusz Wdrychowicz et al. [2021] emphasised the evaluation of the stepped gearbox, which consists of six to eight gears and two friction clutches, either wet multi-plate or dry single-plate. This gearbox may be thought of as two separate gearboxes. Each clutch is coupled to a separate clutch shaft; the first clutch is in one, while the second clutch is in the other. The final driving gear joins the two primary shafts. Volkswagen began commercial manufacture of this in 2003.

Datong Qin et al. [2022] described how to adapt to time-varying start intentions, reduce jerk and friction, and improve start quality using a dual-clutch gearbox start control approach based on data-driven control and pseudo-spectral optimisation. First, the optimal clutch engagement target trajectory is established accurately using the adaptive pseudo-spectral technique, with the jerk, start time, and friction work acting as optimisation indices. Then, for the objective clutch engagement trajectory, a dual deep gated recurrent unit network-based real-time planning approach is provided.

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Guanlong Sun et al. [2020] suggested a novel decentralised pump-controlled hydraulic technique to reduce the hydraulic actuator power consumption of a dual clutch gearbox. Qualitative study shows that by dividing the typical centralised valve-controlled hydraulic system (CVHS) into three subsystems: clutch control, clutch cooling, and gearbox lubrication, energy loss may be efficiently decreased. A forward design technique is used to construct this revolutionary hydraulic system. This study establishes the decentralised pump-controlled hydraulic system (DPHS) and centralised CVHS efficiency models.

Ruitian Luo et al. [2022] discussed a recent study that establishes the gear rattling dynamics model of the transmission with the 1st gear without preselection and the preselected 4th gear, respectively, to accurately explore the transmission rattling phenomenon and the influence of different factors on the dynamic characteristics of the gear rattling of the dual-clutch transmission under the condition of preselected gears; Furthermore, the bench test validated the feasibility of the dynamic model.

Antai Li et al. [2022] explored how the dynamic friction coefficient of a wet clutch, which fluctuates depending on oil and friction plate temperatures as well as friction plate wear, affects the quality of the vehicle's shifts. An adaptive control system for shifting dual clutch transmissions (DCTs) is proposed in this article. Method based on the empirically determined dynamic friction coefficient of a wet clutch with a given service mileage. Creating a linear time-varying model of the DCT powertrain and constructing the upper controller using linear time-varying model predictive control yields the optimal shift reference curves for clutch pressure and engine torque.

Vehicles may tremble and shrug as they start and shift, according to Yonggang Liu et al. [2022], which may be quite uncomfortable. This is most likely the result of a poorly constructed powertrain mount. However, previous research has disregarded the effect of mounts on autos. This work develops a DCT vehicle coupling dynamic model in light of the aforementioned issues, taking into account the nonlinear features of a dual-mass flywheel, time-varying stiffness of gear systems, six degrees of freedom of the powertrain mount and engine dynamic torque, and other considerations.

3. Result and Discussion

Nikolay Sergienko et al. (2022) and Jiayi Chen et al. (2019) worked on increasing fuel efficiency by optimising hydraulic mechanical braking systems and improving DCT shift quality.The adaption of the downshift process and unique mode transition control algorithms help to increase fuel efficiency and dynamic performance.

Jiejunyi Liang et al. (2018) investigated regenerative braking power-on shifting management for electric cars in order to overcome the issue of restricted driving range per charge. Mingxiang Wu et al. (2019) stressed the usage of fork-lever actuators in conventional and electric car dual-clutch gears.

Zhiguo Zhao et al. (2020) created fault-tolerant control algorithms for DCTs, ensuring that operation continues even if the clutch actuator motor fails. Qiqi Huang et al. (2022) focused on fault-tolerant control for clutch actuator motor failures during shifting, stressing driver safety and comfort.

YANG YANG et al. (2020) suggested an SD-ARX model for DCT vehicle starting operations, demonstrating an automotive-validated modelling method. Qingkun Xing et al. (2019) employed MATLAB/Simulink for dynamic modelling to optimise the upshift process during the torque phase. Guoqiang Li et al. (2018) proposed an observer architecture for simplifying upshift approaches and improving shift performance by minimising jerks.

Dong Guo et al. (2022) created a gearbox gear rattling dynamics model and tested its feasibility via bench testing. Jihao Feng et al. (2022) investigated powertrain mount dynamics by taking into account the six degrees of freedom and nonlinear features of a dual-mass flywheel.

Michael A. Laukenmann et al. (2021) discussed the increase in hybridization of powertrains to reduce emissions, highlighting the complexity of control algorithms in Hybrid Dual-Clutch Transmissions. Seibum Choi et al. (2018) proposed a clutch friction model-based feedforward clutch torque management technique for dry clutches in parallel hybrid vehicles

Oliver Sawodny et al. (2019) demonstrated a near-time-optimal two-staged flatness-based feed-forward controller for hydraulic clutch systems, highlighting the influence of the filling phase on shift quality. Datong Qin et al. (2022) presented a data-driven control and pseudo-spectral optimization strategy for dual-clutch gearbox start control, with an emphasis on adjusting to time-varying start intentions.

Guanlong Sun et al. (2020) proposed a decentralised pump-controlled hydraulic approach for lowering power consumption, with an emphasis on energy-efficient subsystems. Ruitian Luo et al. (2022) investigated the mechanics of gear rattling and verified a dynamic model using bench testing.

Antai Li et al. (2022) examined the dynamic friction coefficient of wet clutches and presented an adaptive control method based on the experimentally established

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friction coefficient, therefore assisting in the optimization of shift reference curves.

Jun Guo et al. (2023) presented an adaptive starting control strategy for P2.5 plug-in hybrid electric vehicles, concentrating on various operating conditions and employing fuzzy and linear quadratic optimal control.

The literature as a whole demonstrates a multidisciplinary approach to solving DCT difficulties such as fuel economy, dynamic performance, fault tolerance, modelling, control techniques, gearbox dynamics, hybridization, and adaptive control. Continued R&D in these areas helps to enhance DCT technology, assuring optimal performance, dependability, and energy economy in both conventional and electric cars.

4. Conclusion

In Several studies, like those by Jiayi Chen et al. [2019] and Michael A. Laukenmann et al. [2021], emphasise the significance of increasing fuel economy and lowering emissions in the context of hybridization and DCTs. Integration of electric machines and the development of control algorithms have been regarded as critical components in accomplishing these objectives.

Nikolay Sergienko et al. [2022] and Guoqiang Li et al. [2018] underline the importance of sophisticated control tactics in maximising DCT performance. To improve driving comfort, shift quality, and overall system robustness, strategies such as mode transition control, fault-tolerant control, and observer structures are used.

The creation of dynamic models for different components, including as clutches, gearboxes, and powertrains, is extensively discussed in the literature. As established by research such as Dong Guo et al. [2022] and Ruitian Luo et al. [2022], dynamic models are critical for understanding and optimising the behaviour of DCTs under various operating situations.

Mingxiang Wu et al. [2019] and Xie Chao et al. [2020] investigate the design and components of DCTs, with a particular emphasis on fork-lever actuators and thermal load characteristics. These studies attempt to improve the transmission system's durability, efficiency, and overall performance. [2022].

Yonggang Liu et al. [2022] and Jihao Feng et al. [2022] investigate vehicle vibrations during start and shift operations. To decrease pain and improve overall driving experience, the studies stress the relevance of powertrain mounts, dual-mass flywheels, and time-varying stiffness in gear systems.

Several research, like those by Jun Guo et al. [2023] and Datong Qin et al. [2022], focus on the difficulties associated with starting and shifting procedures. To accomplish smooth and efficient transitions during vehicle start-up and gear shifts, adaptive control methods, fuzzy controllers, and real-time planning approaches are offered.

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