OPEN ACCESS

International
Journal
Of Modern Engineering Research (IJMER)

Dual Clutch Transmission of Automobile

Mr. Amol A. Parihar[1], Mr. Amit C. Gunge[2], Mr. Udhav M. Parbhane[3]
[1,2,3] *(Lecturer Department Of Mechanical Engineering, MGM's Polytechnic Aurangabad, India.)*

ABSTRACT: *A Dual clutch transmission (DCT) is a type of automatic transmission featured with a dual-clutch module and two input shafts. A DCT is able to provide a high-quality gear shifting with a gear pre-selection procedure and overlapping of clutch engagement. The gear pre-selection procedure means that the synchronization of the oncoming gear has been completed before the actual gear shifting procedure starts. And due to the overlapping mechanism of the two clutches, torque is transferred from the engine to the driving wheels without interruption during gear shifting. Therefore, it provides a rapid gear shifting without sacrificing fuel efficiency and riding comfort. In addition, with a precisely computed and accurately controlled slippage of the dual-clutch module, the DCT is able to provide a fast and smooth gear shifting. The performance of a DCT during gear shifting relies on a well-designed clutch engagement controller. A good clutch engagement controller should be able to achieve (1) a fast clutch-to-clutch shifting and (2) a smooth gear shifting without noticeable torque disturbance. This research work proposes a newly designed clutch-to-clutch shifting controller that satisfies both objectives mentioned above. The presented control law is implemented in a linear 9 control method that explicitly separates the controlling of the two clutches. The presented control method can be applied to a wide range of applications with easy implementation and a good robustness. Computer simulations in Simulink proved that the control objectives were realized with a robust and relatively simple controller. According to the simulation results, the average magnitudes of the output torques were reduced by 32.5% with the help of the proposed clutch-to-clutch control law. Also, by observing a couple of contrast simulations, we found that the output torque difference grew larger as the clutch actuator time constant became larger. In addition, simulation results showed that smaller clutch pressure changing rate contributed to a smoother gear shifting.*

Keywords: *Automobile, Control strategy ,Dual clutch transmission, Gear, Gear shift rule, Torque,*

I. INTRODUCTION

In the automotive industry, the automatic transmission has long been regarded as a substitute for manual transmission. As a key performance indicator of automobile, the economic performance of vehicle fuels has been gradually valued, and the control strategy of automobile's automatic transmission is very important. The development trend of automatic transmission is mainly reflected in such aspects as excellent economy and comfort of driving and so on.

To select the appropriate gear through the cooperation between the intention of the driver and the controller of the vehicle, low fuel consumption can be realized in most operation cases of the engine, while the control of the transmission of the conventional automatic transmission is realized through the control of torque converter and a planetary gear set. Though after years of improvement, the efficiency of mechanical transmission is still lower than that of the manual transmission. Therefore, the primary goal of the automotive industry is to improve the mechanical efficiency, and at the same time, to ensure the comfort and high quality of automatic gearshift [1-2].

DTC (Dual Clutch Transmission) is a new type of automatic transmission device in the field of automotive automatic transmission. It realizes power transmission and interruption, and shifting without power interruption through respective connection between the two transmission shaft and two clutches. It also combines the advantages of manual transmission and traditional torque mechanic transmission so as to equip the vehicle with the same convenience and comfort with manual transmission vehicles, but better fuel economy [3-4]. Shift control is the key technology of DCT vehicles, and an important index to measure the driving comfort of vehicles, therefore, to carry out targeted shift analysis and control of the DCT seems quite necessary.

According to the characteristics of DCT synchronizer which can be pre-engaged in the shift, under the premise of ensuring the accurate realization of the synchronizer's function, Yang Weibin [5] put forward the control law of DCT synchronizer, achieving accurate control of synchronizer, but he did not take into account the control of clutch; Ma Jin [6] took the up shift of Block 1 to Block2 as an example to describe the DCT shift process, and put forward the control method to improve shift quality according to the clutch engaging speed and engaging time, which has obtained certain results, but has not involve the driver intention, nor economic and dynamic effects were representative; Zhao Zhiguo [7] conducted shift researches targeted at a five speed dry dual clutch transmission to discusses the torque coordinated control between the engine and DCT. Considering the characteristics of the physical structures, they established 5 degrees of freedom shifting dynamics equation, and the results showed that the proposed torque coordinated control strategy based on models reflected the driver intention of shifting, which improved the shift quality of DCT, but the control structure was relatively complex.

Aiming at a five rates wet DTC, this paper conducts dynamics analysis of the DCT shifting process and makes model and analysis of key parts; on this basis, it develops a shift schedule based on driver intention, and makes detailed analysis for gear shifting process to develop a shift control strategy; finally, based on the MATLAB/Simulink simulation platform, it builds DCT shift model and conducts simulation test to verify the validity of the shift control strategies.

II. STRUCTURE AND PRINCIPLE OF DCT

Structure diagram of is as shown in Fig.1. The structure has 5 forward gear blocks and 1 reverse gear block, and two clutches respectively control the odd and even gear block. Similar with the traditional manual gear box structure, it includes helical cylindrical gear set and the synchronizer gear set, wherein Block 1 adopts the connection between one-way clutch and the input shaft as the constant mesh gear pair. Two clutches couples with input shaft through the transmission gear pair. Therefore, the two clutches can be engaged with the motor, by controlling the switch between the two clutches (isolating the off going clutch, and at the same time engaging the ongoing clutch), to complete the shift.[3]

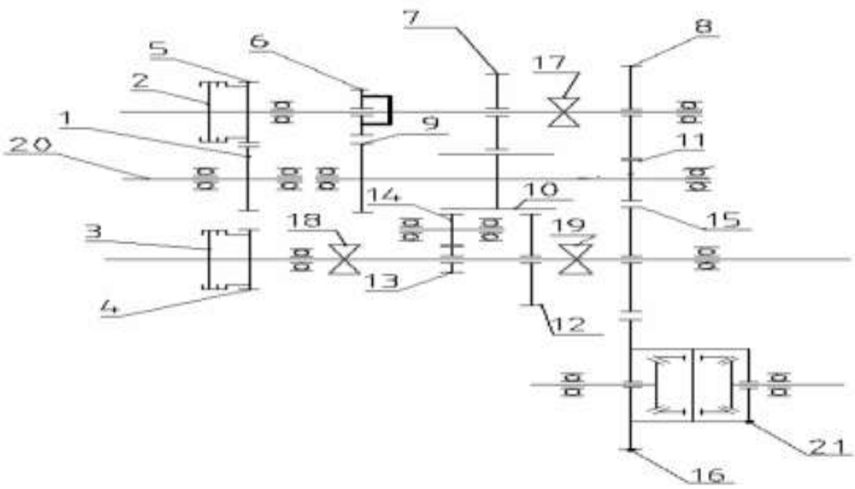

Fig. 1. Structure Diagram of Double Clutch Automatic Transmission

1-the main gear of the input shaft (connects to the output shaft of the engine); 2- the odd clutch; 3- the even clutch; 4- the shaft of the even clutch; 5- the shaft of the odd clutch; 6-8- the number of diver gears of the reverse gear, block 2 and block 3; 11 -the driver gear of block 5; 12- the main gear of block 2; 13- the main gear of the reverse gear; 14, the falling wheel of the reverse gear; 15, the main gear of block 4; 16, the driver gear of the main decelerator; 17- the synchronizer of block 3 and block 5; 18- the synchronizer of the reverse gear; 19- the synchronizers of block 2 and block 4; 20- the input shaft; 21,-the main decelerator.

III. PHYSICAL AND DYNAMICS MODEL OF DCT

For the convenience of establishing DCT models, the dynamic transfer system is simplified as follows: the gear is simplified as the only quality without elastic concentrated moment ; the shaft is simplified without quality and only the torsional stiffness of elastic rod, the quality equivalent of each shaft section is put to the two ends of the gear; friction equivalent at the bearings is simplified as viscous damping at the gear which is proportionate to transmission speed; the structural damping of the gear mesh stiffness, gear and shaft are not considered. Take Block 1 as an example, a simplified physical model and power flow line DCT is shown in Fig. 2. [6]

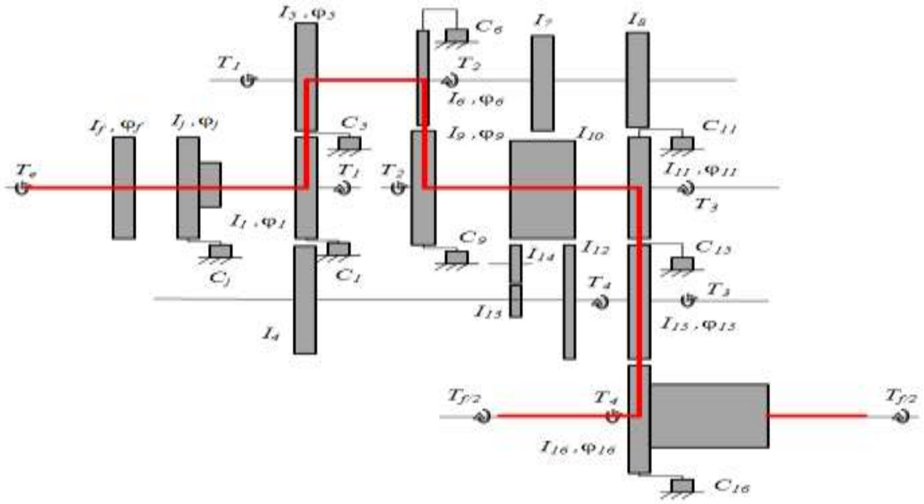

Fig. 2. Dynamics Model of Double Clutch Automatic Transmission

IV. BASIC DESIGN OF DUAL CLUTCH TRNSMISSION

A dual-clutch transmission offers the function of two manual gearboxes in one. To understand what this means, it's helpful to review how a conventional manual gearbox works. When a driver wants to change from one gear to another in a standard stick-shift car, he first presses down the clutch pedal. This operates a single clutch, which disconnects the engine from the gearbox and interrupts power flow to the transmission. Then the driver uses the stick shift to select a new gear, a process that involves moving a toothed collar from one gear wheel to another gear wheel of a different size. Devices called synchronizers match the gears before they are engaged to prevent grinding. Once the new gear is engaged, the driver releases the clutch pedal, which re-connects the engine to the gearbox and transmits power to the wheels. [7]

So, in a conventional manual transmission, there is not a continuous flow of power from the engine to the wheels. Instead, power delivery changes from on to off to on during gearshift, causing a phenomenon known as "shift shock" or "torque interrupt." For an unskilled driver, this can result in passengers being thrown forward and back again as gears are changed.

A dual-clutch gearbox, by contrast, uses two clutches, but has no clutch pedal. Sophisticated electronics and hydraulics control the clutches, just as they do in a standard automatic transmission. In a DCT, however, the clutches operate independently. One clutch controls the odd gears (first, third, fifth and reverse), while the other controls the even gears (second, fourth and sixth). Using this arrangement, gears can be changed without interrupting the power flow from the engine to the transmission. Sequentially, it works like this:[8,9]

- A car travelling in second gear is controlled by the inner clutch .Power is sent to second gear along the outer transmission shaft
- As the car increases speed, the computer detects the next gearshift point and the third gear is pre-selected.
- When the driver changes gears, the inner clutch disengages and the outer clutch is activated.
- The power is transferred along the inner transmission shafts to the pre-selected gear.

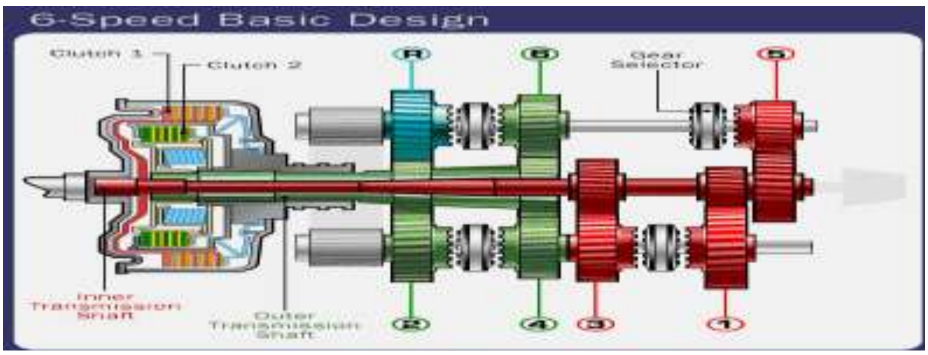

Fig.3. Basic design of DCT

Drivers can also choose a fully automatic mode that relinquishes all gear-changing duties to the computer. In this mode, the driving experience is very similar to that delivered by a conventional automatic. Because a DCT transmission can "phase out" one gear and "phase in" a second gear, shift shock is reduced. More importantly, the gear change takes place under load so that a permanent flow of power is maintained. An ingenious two-shaft construction separating the odd and even gears makes all of this possible. [8]

V. DUAL CLUTCH TRANSMISSION SHAFT

A two-part transmission shaft is at the heart of a DCT. Unlike a conventional manual gearbox, this houses all of its gears on a single input shaft, the DCT splits up odd and even gears on two input shafts. The outer shaft is hollowed out, making room for an inner shaft, which is nested inside. The outer hollow shaft feeds second and fourth gears, while the inner shaft feeds first, third and fifth.

The diagram below shows this arrangement for a typical five-speed DCT. Notice that one clutch controls second and fourth gears, while another; independent clutch controls first, third and fifth gears. That's the trick that allows lightning-fast gear changes and keeps power delivery constant. A standard manual transmission can't do this because it must use one clutch for all odd and even gears.[2]

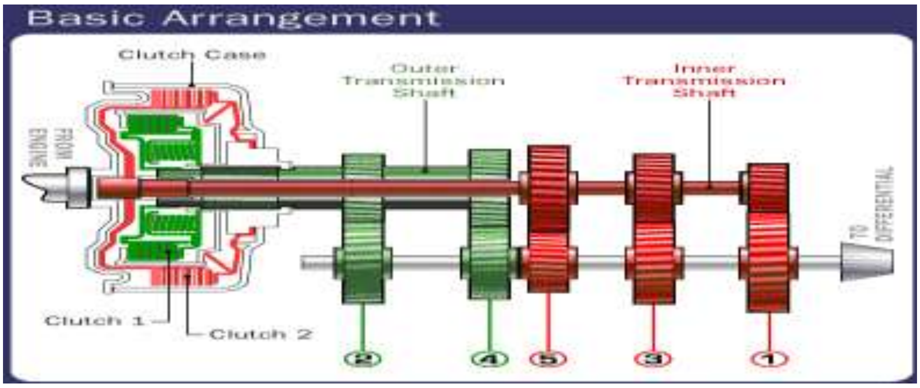

Fig.4. Basic arrangement of DCT shaft

VI. MULTIPLE CLUTCH

Since a dual-clutch transmission is similar to an automatic, one might think that it requires a torque converter, which is how an automatic transfers engine torque from the engine to the transmission. DCTs, however, don't require torque converters. Instead, DCTs currently on the market use wet multi-plate clutches. A "wet" clutch is one that bathes the clutch components in lubricating fluid to reduce friction and limit the production of heat. Several manufacturers are developing DCTs that use dry clutches, like those usually associated with manual transmissions, but all production vehicles equipped with DCTs today use the wet version. Many motorcycles have. single multi-plate clutches Like torque converters, wet multi-plate clutches use hydraulic pressure to drive the gears

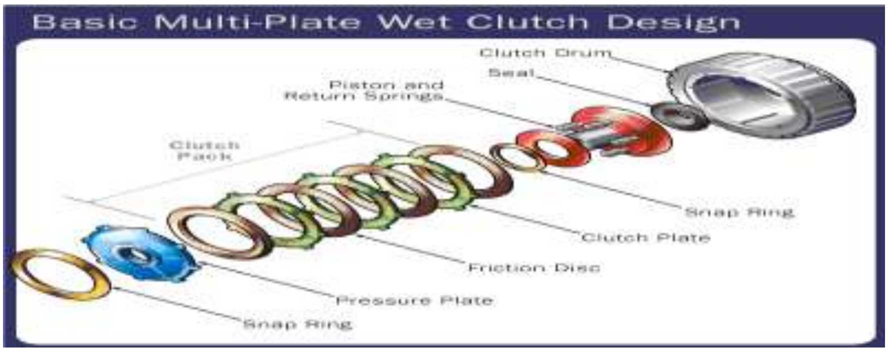

Fig.5. Basic Multi-plate wet clucth design

The fluid does its work inside the clutch piston, seen in the diagram above. When the clutch is engaged, hydraulic pressure inside the piston forces a set of coil springs part, which pushes a series of stacked clutch plates and friction discs against a fixed pressure plate. The friction discs have internal teeth that are sized and shaped to mesh with splines on the clutch drum. In turn, the drum is connected to the gearset that will receive the transfer force. Audi's dual-clutch transmission has both a small coil spring and a large diaphragm spring in its wet multi-plate clutches. [2,3]

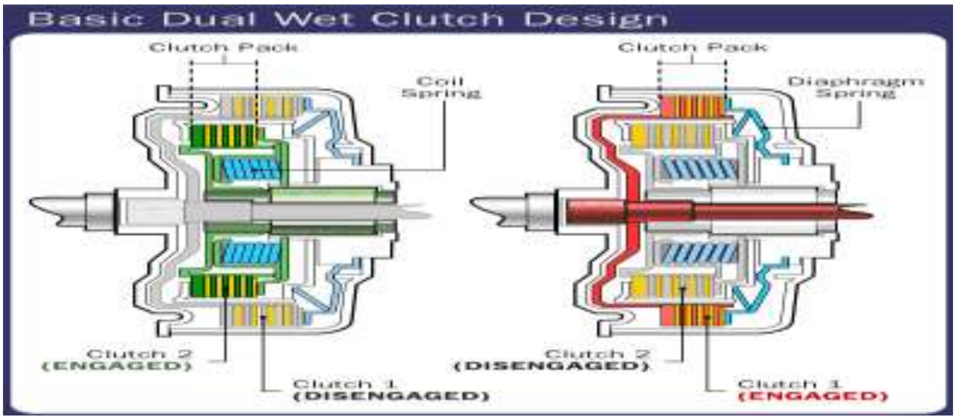

Fig.6. Basic Dual wet clucth design

To disengage the clutch, fluid pressure inside the piston is reduced. This allows the piston springs to relax, which eases pressure on the clutch pack and pressure plate.[3]

VI. CONTROLLING OF DCT

A method of controlling the clutches of a dual clutch transmission during a two-gear positive downshift, wherein the first clutch drives an initial gear and the final gear and the second clutch drives an intermediate gear. The torque transfer across each clutch is controlled so that the torque output of the transmission will be linearly changed over from the first clutch to the second clutch to cause the engine to track a target engine speed profile. The method changes over the gears driven by the first clutch from the initial gear to the final gear as the engine continues to tracks the target speed. The torque transfer across each clutch is controlled so that the torque output will be linearly changed back from the second clutch to the first clutch in an inversely proportional rate to continue to cause the engine to track the target engine speed profile.[7]

VII. DUAL CLUCTH TRANSMISSION: - PAST, PRESENT AND FUTURE

The man who invented the dual-clutch gearbox was a pioneer in automotive engineering. Adolphe Kégresse is best known for developing the half-track, a type of vehicle equipped with endless rubber treads allowing it to drive off-road over various forms of terrain. In 1939, Kégresse conceived the idea for a dual-clutch gearbox, which he hoped to use on the legendary Citroën "Traction" vehicle. Unfortunately, adverse business circumstances prevented further development. Both Audi and Porsche picked up on the dual-clutch concept, although its use was limited at first to racecars. The 956 and 962C racecars included [8]

The Porsche Dual Klutch, or PDK. In 1986, a Porsche 962 won the Monza 1000 Kilometer World Sports Prototype Championship race -- the first win for a car equipped with the PDK semi-automatic paddle-shifted transmission. Audi also made history in 1985 when a Sport quattro S1 rally car equipped with dual-clutch transmission won the Pikes Peak hill climb, a race up the 4,300-meter-high mountain.

Fig.7. Porsche 962

Commercialization of the dual-clutch transmission, however, has not been feasible until recently. Volkswagen has been a pioneer in dual-clutch transmissions, licensing BorgWarner's DualTronic technology. European automobiles equipped with DCTs include the Volkswagen Beetle, Golf, Touran, and Jetta as well as the Audi TT and A3; the Skoda Octavia; and the Seat Altea, Toledo and Leon.

Fig.8 Volkswagon Jetta 2.0

Ford is the second major manufacturer to commit to dual-clutch transmissions, made by Ford of Europe and its 50/50 joint venture transmission manufacturer, GETRAG-Ford. It demonstrated the Power `shift System, a six-speed dual-clutch transmission, at the 2005 Frankfurt International Motor Show. However, production vehicles using a first generation Power shift are approximately two years away. [8]

VIII. ADVANTAGES

In principle, the DCT behaves just like a standard manual transmission:

- It's got input and auxiliary shafts to house gears, synchronizers and a clutch. It doesn't have a clutch pedal, because computers, solenoids and hydraulics do the actual shifting. Even without a clutch pedal, the driver can still "tell" the computer when to take action through paddles, buttons or a gearshift.
- Driver experience is just one of the many advantages of a DCT. With up shifts taking a mere 8 milliseconds, many feel that the DCT offers the most dynamic acceleration of any vehicle on the market.
- It certainly offers smooth acceleration by eliminating the shift shock that accompanies gearshifts in manual transmissions and even some automatics. Best of all, it affords drivers the luxury of choosing whether they prefer to control the shifting or let the computer do all of the work.
- Perhaps the most compelling advantage of a DCT is improved fuel economy. Because power flow from the engine to the transmission is not interrupted, fuel efficiency increases dramatically. Some experts say that a six-speed DCT can deliver up to a 10 percent increase in relative fuel efficiency when compared to a conventional five-speed automatic.[7,9]

IX. APPLICATION

- **Trucks and buses**

Semi-automatic transmissions have also made its way into the truck and bus market in the early 2000s. Volvo offers its I-shift on its heavier trucks and buses, while ZF markets its ASTronic system for buses and coaches. These gearboxes have a place in public transport as they have been shown to significantly reduce fuel consumption.

In the UK though, semi-automatic transmission has been very popular on buses for some time, from the 1950s right through to the 1980s, an example being the well known London Routemaster, although the latter could also be driven as a fully automatic in the 3 highest gears. Leyland manufactured many buses with semi-automatic transmission, including its Leopard and Tiger coaches. Fully automatic transmission became popular with increasing numbers of continental buses being bought in the UK, and more and more British manufacturers began offering automatic options, mostly using imported gearboxes, and semi-automatic transmission lost favour. These days, very few buses with semi-automatic transmission remain in service, although many are still on the roads with private owners. Modern types of semi-automatic transmission though are becoming more common, mostly replacing manual gearboxes in coaches and small buses.[5]

- **Motorcycles**

In addition to the Hondamatic system noted above, Yamaha Motor Company introduced a semi-automatic transmission on its 2007 model year FJR1300 sport-touring motorcycle in 2006. Notably, this system can be shifted either with the lever in the traditional position near the left foot, or with a switch accessible to the left hand where the clutch lever would go on traditional motorcycles.[10]

Fig.9. Suzuki

X. CONCLUSION

New environmental and fuel efficiency legislation coupled with advances in electronics and manufacturing techniques have triggered new automated transmission technologies. The most likely winner that will replace traditional automatics and boost market penetration of automated transmissions will be the dual clutch transmission (DCT). Based on the structure and principle of DCT, the automobile gear shifting process is analyzed in view of dynamics and engine and clutch models are also established, which lay foundation for the subsequent formulation of control strategy of DCT shift process. Through the fuzzy control theory, respectively from the power and economy point of view, the shift schedule based on driver intention has been formulated, which establishes the foundation for the subsequent shift simulation model. The control strategy of the engine and clutch and the comprehensive shift control logic strategy are made in the ECT shifting process. Based on he MATLAB/Simulink software simulation platform, simulation model of vehicle shifting has been built, and the simulation results validates affectivity of the shift model, and it also indicates the good control effect of the formulated shift control strategy.

REFERENCES

[1]. M. Goetz, M.C. Levesley and D.A. Crolla, "Integrated Power trains Control of Gearshifts on Twin Clutch Transmissions Proceeding of Transmission and Driveling Systems Symposium[C]",2004, SAE, **(2004)**, pp.01-1637.

[2]. Y. Liu, D.Qinand H. Jiang, "A Systematic Model for Dynamics and Control of Dual Clutch Transmissions[J]",Journal of Mechanical Design, Transaction of ASME, vol. 131, no. 6,**(2009)**, p. 1012.

[3]. M. Wu, J.ZhangandT. Lu, "Research On optimal control for dry dual-clutch engagement during launch[C]", Proceedings of the Institution of Mechanical Engineers ,vol. 224, no. 6, **(2010)**,pp.749-763.

[4]. K.V.Berkel, T. Hofmanand A.Serrarens,"Fast and smooth clutch engagement control for dual-clutch transmissions[J]", Control Engineering Practice, vol. 22, **(2014)**,pp.57-68.

[5]. Y.A.Noweibin, C.Quanshiand W.Guangqiang,"The Synchroner Control Strategy for Dual Clutch Automate Transmission Basedon City Drive Cycle[J]",Journal of Mechanical Engineering vol. 44, no. 12, **(2008)**,pp. 243-248.

[6]. M.Jin, S.Weiand U. Guoqiang, "Research of Proving wet double clutch transmission shifting quality[J]", Modern. Manufacturing, Engineering, vol. 1, **(2013)**,pp. 46-50.

[7]. Z.Zhiguo, W.QiandC.Haijun,"Fuzzy Time Decision and Model-based Torque Coordinating Control of Shifting Process for Dry Dual Clutch Transmission [J]",Journal of Mechanical Engineering, vol. 49, no. 12, **(2013)**,pp. 92-108.

[8]. Y. Liu, D. QinandH. Jiang,"A systematic model for dynamics and control of dual clutch transmissions[J]",J. Mech. Des. Trans. ASME, vol. 131, no. 6, **(2009)**,pp. 610-612.

[9]. E. Galvagno, M. Velardocchiaand A. Vigliani,"Dynamic and kinematic model of a dual clutch transmission[J]", Mechanical Machine Theory, vol. 46, **(2011)**,pp. 794–805.

[10]. P.D. Walker, N.ZhangandR.Tamba,"Control of Gear Shifts in Dual Clutch Transmission Power trains[J]", Mechanical Systems Signal Process., vol. 25, **(2011)**,pp. 1923–1936.