A Literature Review on Automated Manual Transmission (AMT)

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Abstract--- Automated Manual Transmission as the name suggests is a manual transmission with clutch and gear actuation done with help of actuators, either electromechanical or hydraulic. The whole AMT system has a control strategy to decide the actuation of actuators. Over the last two decades, significant research effort has been directed towards developing vehicle transmissions that reduce the energy consumption of an automobile. This effort has been a direct consequence of the growing environmental concern imposing the directives of reduced exhaust emissions and increased vehicle efficiency on current vehicle manufacturers. Consumers also expect the same level of performance, comfort and ease of use as in standard cars, to a competitive price. To construct a competitive solution, it must both be comparable in terms of performance, comfort and price of existing vehicles on the market. Automated Manual Transmission (AMT) is the best competitive solution to address the problem of performance, comfort, cost, efficiency. The main aim of this paper is to study the various research work done on AMT system in terms of design and control strategy.

Keywords: - AMT, Automated Manual Transmission, Transmission, actuators

I. INTRODUCTION

As the power transmission unit, transmissions play an important role in vehicle performance and fuel economy. There are currently several types of transmissions and associated technologies that offer different priorities in vehicle. Manual transmission has overall efficiency of 96.2 percent which is highest in all types. Belt types CVT have overall efficiency of 84.6 percent. Automatic Transmission (AT) has efficiency of 86 percent whereas Automated Manual Transmission (AMT) has efficiency par with manual transmission [1]. It is common to use analytical models for prediction and assessment convince in automotive industry. Day to day there has been need for improvement in Design, Concept of transmissions to

1. Reduce gear torque interruption.
2. Reduce gear shift time and improve driving comfort.
3. Increase fuel efficiency.
4. Improve the gear shift quality.

II. WORKING PRINCIPLE OF AMT

AMT is a clutch-less (without clutch pedal) manual transmission system which uses electronic sensors, processors and actuators (hydraulic or electro mechanical) to do clutch actuation and gear shifts as per command of the driver. Fig. 1 shows that Amt system uses a conventional manual transmission, actuators and control unit to automate the whole process. Fig. 2 shows a control architecture system of AMT. The system consists of three sections of sensors, processors and Actuators. The processor, TCU (Transmission Control Unit) gets the input signals from various sensors like Gear position sensor , Clutch position sensor , brake position sensor , transmission output speed and also Vehicle related signals like torque requirement , engine speed and throttle position from ECU (Engine control unit). The TCU has a control strategy which on receiving the input signals, generates the output signals to clutch actuator and gear shifting actuator. [1]

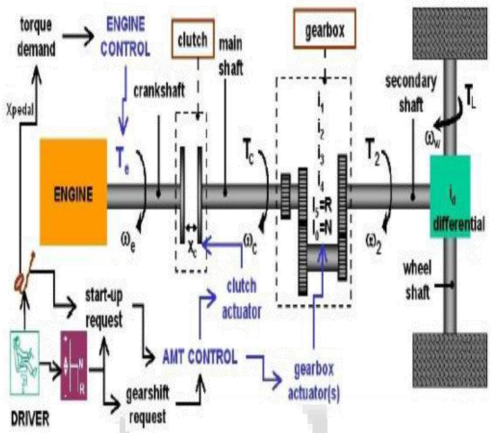

Fig. 1: AMT System

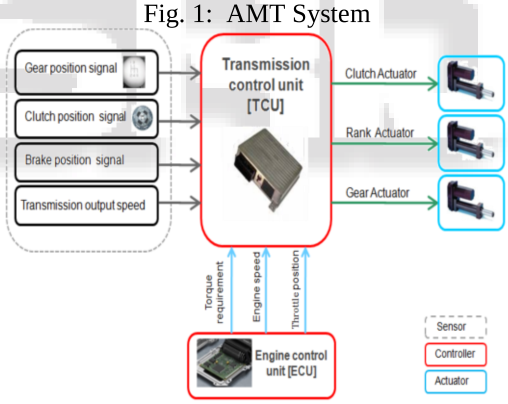

Fig.2 Control architecture of AMT

III. LITERATURE REVIEW

A. The contribution of Transmission to vehicle fuel economy by D Simmer, [2] shows the importance of transmission towards fuel efficiency. This research highlights how transmission plays an important factor for the fuel economy. Fuel economy which is the prime factor can be influenced by transmission system in four ways and not just transmission efficiency alone.

1. Parasitic losses in transmission i.e. Oil churning, seal and bearing drag.
2. Power proportional losses at gear, chain or belt mesh.
3. The weight and rotational inertia of transmission and driveline components.
4. The configuration and control of actual transmission hardware.

The complete approach would minimize fuel usage with acceptable emissions for wide range of operating conditions encountered by the vehicle.

B. Zeroshift Automated Manual Transmission (AMT) by R. P. G. Heath and A. J. Child, [3] shows that Zeroshift technology allows a manual transmission to change gear in zero seconds. This technology is patented new design for a transmission. The Zeroshift Automated Manual Transmission (AMT) is easy to manufacture and allows a cost effective alternative to the traditional torque converter based automatic transmission. Zeroshift offers potential fuel economy improvements from driveline efficiency and the best possible vehicle acceleration. Compared to an existing AMT, Zeroshift offers an uninterrupted torque path from the engine to vehicle which allows for a seamless gearshift. This paper provides an introduction to the technology together with test data from a demonstrator vehicle. Fig 3 shows the Zeroshift concept.

Fig. 3 Zero shift technology

C. Electric Hydraulic Accelerator Control Device in AMT by Yinong Zhaoaa and Jiabao Chena, [4] shows that in order to regulate the fuel injection quantity for the non electronic-controlled engine during the process of automatic shift, independent accelerator auxiliary control device needs to be designed .The accelerator control device should not only meet servo requirements in normal driving but also regulate the fuel injection quantity automatically in the process of automatic shift. This paper mainly describes the design of electric hydraulic accelerator control device and the experiments show that the device can meet servo requirements and regulate the fuel injection quantity automatically. The paper puts forward a new accelerator auxiliary control device for automatic shift control system with non electronic controlled engine. The new device can regulate injection quantity automatically during the process of automatic shift, not reducing the quality of controlling the engine. And it can solve the problems such as safety, reliability, the complex nature of control method and so on for common linear accelerator scheme driven by motor.

D. Modeling of an Automated Manual Transmission system by Gianluca Lucente, Marcello Montanari and Carlo Rossi, [5] shows that vehicles with Automated Manual Transmissions (AMT) for gear shift control offer many advantages in terms of reduction of fuel consumption and improvement of driving comfort and shifting quality. Complexity, nonlinearity and high-order dynamics of the automated driveline, combined with strict requirements for high performance gear shifts, demand the development of driveline models, which include a detailed description of the actuators. These models can be useful for different purposes:

1. During system development, to evaluate the achievable performance and its dependency on system properties
2. As simulation tools for gear shift control algorithm design.

In this paper, physically-based detailed nonlinear models of the electro-hydraulic actuated gearbox and of the dry clutch electro-hydraulic actuator of an automated manual transmission are developed as shown in Fig. 4. In order to analyze their behavior and their impact on the drive train during gear shifts, actuator models are integrated with a simplified transmission shafts dynamics.

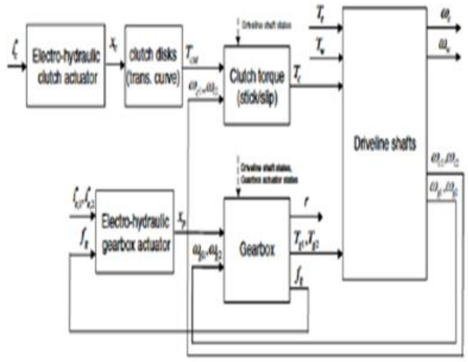

Fig. 4: Driveline layout with model

E. Development of an Automated Manual Transmission system based on Robust Design by Yoshinori Taguchi, Yoshitaka Soga, Akira Mineno and Hideki Kuzuya, [6] showed use of three actuators for automation of gear shifting and clutch actuation process. Convention transmission system with actuator was used for AMT. Two more actuators were used for shift and select actuation. A system control device was developed to improve control, stability and robustness of system. The result showed a way forward for cost effective solution for AMT. The automated clutch is constituted by a standard dry clutch controlled by an electro-hydraulic servo. The clutch actuator is constituted by disks between the flywheel and the clutch plate, whose surfaces are covered with high-friction materials. The electro hydraulic clutch actuator, which is driven by a three-way spool servo valve applies pressure to control the displacement of the clutch piston, which pushes on the release bearing. The transmitted torque can be thought as stick slip friction, while the maximum transmissible torque (related to static friction) is modulated by the normal force applied to clutch disks. In a clutch actuator model focusing on the hydraulic part and involving the release bearing position as output variable has been developed. The model is refined considering the relation between the force applied to the release bearing and the transmitted clutch torque. When no external force is applied, flywheel and clutch disks are pressed together by Belville and pre-load springs and hence engine torque can be transmitted. In order to release the clutch, the hydraulic piston pushes the release bearing The Belville spring, acting as a lever, reduces the normal force applied to the clutch plates, thus separating friction disks. The Belville spring acts both as a spring and a lever with variable coupling ratio. Hence the steady state piston force is related to the force applied to the clutch plate by a nonlinear relation dependent on the clutch piston displacement.

F. Analysis and simulation of a torque assist Automated Manual Transmission by E. Galvagno, M. Velardocchia and

A. Vigliani, [7] presents the kinematic and dynamic analysis of a power-shift Automated Manual Transmission (AMT) characterized by a wet clutch, called assist clutch (ACL), replacing the fifth gear synchronizer. This torque assist mechanism becomes a torque transfer path during gearshifts, in order to overcome a typical dynamic problem of the AMT that is the driving force interruption. The mean power contributions during gearshifts are computed for different engine and ACL interventions, thus allowing drawing considerations useful for developing the control algorithms. The simulation results prove the advantages in terms of gearshift quality and ride comfort of the analyzed transmission. From the analysis of the AMT ACL transmission it is possible to state that the assist clutch proves useful during up shifts, downshifts (Kick Down) and motoring mode.

G. A Study of Shift Control Algorithm without clutch operation for Automated Manual Transmission in the Parallel Hybrid Electric Vehicle by Liao Chenglin, Zhang Junzhi, Zhu Haitao, [8] shows a new shift control algorithm without clutch operation for reducing the shift shock and improving accelerating ability of a parallel hybrid vehicle with an AMT. The engagement of clutch, which is the key point of shift control in general AMT, is sophisticated and very difficult. But in the parallel hybrid vehicle, shift control without clutch operation is possible because both the engine and motor can control the speed of input shaft o gearbox. Consequently, it not only improves the shift quality of vehicle, but also prolongs the life time of clutch. Simulation results indicate that the shift amenity and accelerating ability are improved by using the shift control algorithm without clutch operation. In this paper, the gear shifting control is discussed just only in the driving mode of hybrid. There are three phases during a gear shift process. The first phase is torque control phase of old gear. In order to minimize the wear of the gearbox, the noise, and the shift shock, the most critical part of the shift sequence is the torque control phase of old gear. The second phase is speed synchronization phase. After neutral gear is engaged, speed synchronization phase is entered. It is important to minimize the total time needed for speed synchronization phase, since the vehicle is free-rolling with zero transmitted. Therefore, it is important to control the speed difference between the input shaft and the output shaft and the drive torque level near to zero as soon as possible at the moment of synchronizer's two sides meshing with each other. The last phase is torque control phase of new gear. Once the new gear is engaged, torque control phase of new gear is entered. In this phase, the hybrid torque level is transferred from torque-free state back to the level that the driver demands.

H. An Automatic gear shifting strategy for Manual Transmissions by B Mashadi, A Kazemkhani and R Baghaei Lakeh, [9] shows that based on two different criteria, namely the engine working conditions and the driver's intention, the governing parameters in decision making for gear shifting of an automated manual transmission are discussed. The gear shifting strategy was designed by taking into consideration the effects of these parameters, with the application of a fuzzy control method as shown in Fig. 5. The controller structure is formed in two layers. In the first layer, two fuzzy inference modules are used to determine the necessary outputs. In the second layer a fuzzy inference module makes the decision of shifting by up shift, downshift, or maintain commands. The behavior of the fuzzy controller is examined by making use of ADVISOR software. It is shown that at different driving conditions the controllers make correct decisions for gear shifting accounting for the dynamic requirements of the vehicle. It is also shown that the controller based on both the engine state and the driver's intention imitates unnecessary shifting that are present when the intention is overlooked. A microchip is designed in which a required speed in the form of a step function is demanded for the vehicle on level or sloping roads. Both strategies for the vehicle to reach the maximum speed starting from rest allow the gear shift to be made consecutively. Considerable differences are observed between the two strategies in the deceleration phase. The engine-state strategy is less sensitive to downshift, taking even unnecessary upshift decisions. The state intention strategy, however, interprets the driver's intention correctly for decreasing speed and utilizes engine brake torque to reduce the vehicle speed in a shorter time.

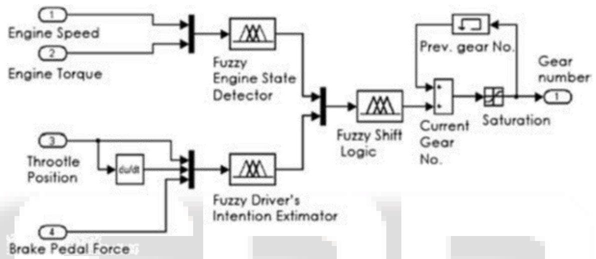

Fig. 5: Fuzzy logic for gear shifting

I. Gear Shifting by Engine Control by Magnus Pettersson and Lars Nielsen, [10] shows that by using engine control during the gear shift, a manual transmission can be automated without using the clutch during the shift event. It is then important to minimize the total time needed for a gear shift, but when doing so driveline resonances may be excited. This in turn may lead to problems with disengaging the old gear and synchronizing speeds for engaging the new gear. Internal driveline torque control is a novel idea for handling resonances and increasing shift quality. By estimating the transmitted torque and controlling it to zero by engine control, the gear can systematically be disengaged with minimized driver disturbances and faster speed synchronization. Field trials show fast shifts to neutral gear, despite disturbances and driveline oscillations at the start of the gear shift. The control scheme is simple and robust against variations among different gears. Furthermore, damping of driveline resonances can be obtained with an observer in combination with a proportional integral derivative feedback structure, despite the higher order driveline system. This approach is motivated by the following two main advantages. When the drive-shaft torsion is zero, neutral gear can be engaged fast, with only small oscillations in the transmission speed and no oscillations in the wheel speed. By controlling the drive-shaft torsion, it is sufficient to use an observer in combination with a PID controller structure, with simple tuning rules, for obtaining active damping of driveline resonances. The result is active damping of driveline resonances which gives a way of optimizing the time needed for the torque control phase. Since there will be no oscillations in the transmission speed, the new gear can be engaged with a minimum of time spent in the speed synchronization phase, and thus leading to a minimized time for a gear shift. Major user advantages are less wear, better comfort and that more drivers can handle difficult driving situations.

J. *Concept evaluation of a novel gear selector for automated manual transmissions by Zaimin Zhong, GuolingKong n, ZhuopingYu, XinboChen, XuepingChen, XiangyanXin,* [11] proposes a novel gear selector for AMT, the concept of which enables the automation of shift action remotely realized by DC motors through shifting cable that originally used on manual transmission vehicle. Evidently, the advantage of this concept is that the automation of manual transmission could be easily realized by replacing the shift lever with two motors while the original shifting cable and gearbox could be reserved. Then the cost and development period can be shorten remarkably. The concept of the novel gear selector is introduced, then the detailed mathematical model of shifting process is studied and system design and scheme selection of this concept are performed. Optimal control algorithm based on LQR for actuator position feedback control is introduced. The concept and control algorithm are verified on a sample car, and considering the influence of the long path of transmission mechanism, the validation of the stability of this concept is performed through calibration test on mountain pass and the obtained results show the concept of the novel gear selector for AMT is feasible technically with strong robust on the shifting stability.

IV. CONCLUSION

The various research works shows that the AMT system can be with hydraulic actuators or electro-mechanical based actuators. Actuators are basically used for clutch and gear shift actuations. However in some systems the actuators are also used to manage accelerator input to control fuel injections. A optimum control strategy is the key to successful working of Amt system and this has been successfully demonstrated in various research works. All research work has concluded that with respect to manual transmission, the AMT allows to improve driving comfort, increase in fuel efficiency and gear shift quality. For market sectors such as large-series and ecological cars, AMT has the advantage of lower weight and higher efficiency with respect to other typologies of automatic transmissions. Moreover, since AMT is directly derived from manual transmission with the integration of actuators into existing devices, development and production costs are generally lower than other automatic transmissions. After studying various actuators, electromechanical actuator are seems to be best solution. As electromechanical actuators are compact, light in weight, and can be controlled easily with the help of actuator. Thereby solving the packaging issues like space availability, weight added to the vehicle load carrying members.

V. FUTURE SCOPE

One of the limitations of the AMT could be driving comfort reduction, caused by lack of traction during gear shift actuation. However, this drawback is not due to intrinsic limitations of the AMT, but it can be solved by proper gear shift management. An overall strategy aiming to the improvement of the gear shift quality should take into account the reduction of shifting time, the minimization of mean vehicle deceleration due to traction loss and the minimization of vehicle and driveline oscillations due to variation of transmitted torque. Existing manual transmission is to be converted into automated manual transmission. In this case the gear shifting is done by gear stick and wire cables arrangement, where the stick acts an interface between the driver and actuating medium, and cables act as actuating medium. Here, the gear stick is to be replaced by some other interface for the driver to interact with the actuator, this interface could be push buttons either on dash board or on steering wheel, or it could be a joy stick. And the wire cable has to be replaced with actuators. Future work should basically focus on low cost system with optimized control strategy.

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