CHAPTER 1
INTRODUCTION

1.1 Automated Manual Transmission

Vehicle transmission systems are typically sorted into three types: manual transmission (MT), continuously variable transmission (CVT), and automated transmission (AT). Manual transmission is the most historical transmission system which has very high reliability, high transmission efficiency, and low cost. However, the operation of manual transmission is more complicated comparing to continuously variable transmission and automated transmission, that driver should control throttle pedal, clutch pedal, and shifting stick. Continuously variable transmission offers a continuum of infinite gear ratio and adjusts it automatically. In which ratio spectrum, it can increase the overall powertrain efficiency and eliminate the unknown jerks associated with manual and automated transmissions. On the other hand, it has difficulty with high torque and low speed transmission requirements [1]. Automated transmission system, likes the name it is, operates with no requirement for driver to control the shifting stick or clutch pedal, and has the ability to transmit larger torque than CVT. Torque converter on automated transmission system provides a smooth coupling between engine and gear box. However, the slippage within the torque converter, which is an inherent character, results in plastic losses, thereby decreases the efficiency of transmission. Furthermore, the shifting operation in automated transmission requires hydraulic pumps which pressurize fluid for gears to shift and torque converter to engage. The power required to pressurize the fluid introduces an additionally parasitic losses in powertrain [2][3].

Automated manual transmission system is gradually developed in recent years. It combines both the advantages of manual transmission and automated transmission. An automated manual transmission is essentially a manual transmission. Engine power is transmitted from engine shaft to gear box by a clutch coupling with the two shafts between engine and gear box, and synchronizers are utilized to shift gear ratios. However, the control of clutch and synchronizer are substituted by clutch actuator and shifting actuator in automated manual transmission. The actuators are controlled by electrical control unit (ECU). In such way, automated manual transmission works like automated transmission, that driver only needs to decide the working conditions of park, reverse, neutral, or drive. Besides, automated manual transmission is able to transmit power with higher torque, higher efficiency, and less fuel cost comparing to automated transmission since no hydraulic component like torque converter and hydraulic pumps are used. And the transmission efficiency is even higher than manual transmission. Because it always works in a condition with higher system efficiency controlled by a computer. Furthermore, the cost is lower than both CVT and AT. A comparison of auto-shifting transmission systems is shown in Table 1.1-1, and structure of automated manual transmission system is shown in Figure 1.1-1.

Transmission Method		**Automated Transmission**	**Continuously Variable Transmission**	**Automated Manual Transmission**
Performance	**Comfort**	good	very good	*middle*
	Reliability	good	bad	*good*
	Max. Torque	very high	<250 Nm	*very high*
	Transmission Efficiency	85%	90%	*>93%*
Complexity	**Mechanical Structure**	high	middle high	*middle*
	Control System	Middle high	high	*high*
Starting Years		1930’s	1970’s	*1990’s*
Design Cost		1	1	*<0.75*
Manufacturing Cost		1	1	*<0.75*

Table 1.1-1 Comparison of AT, CVT, and AMT [4]

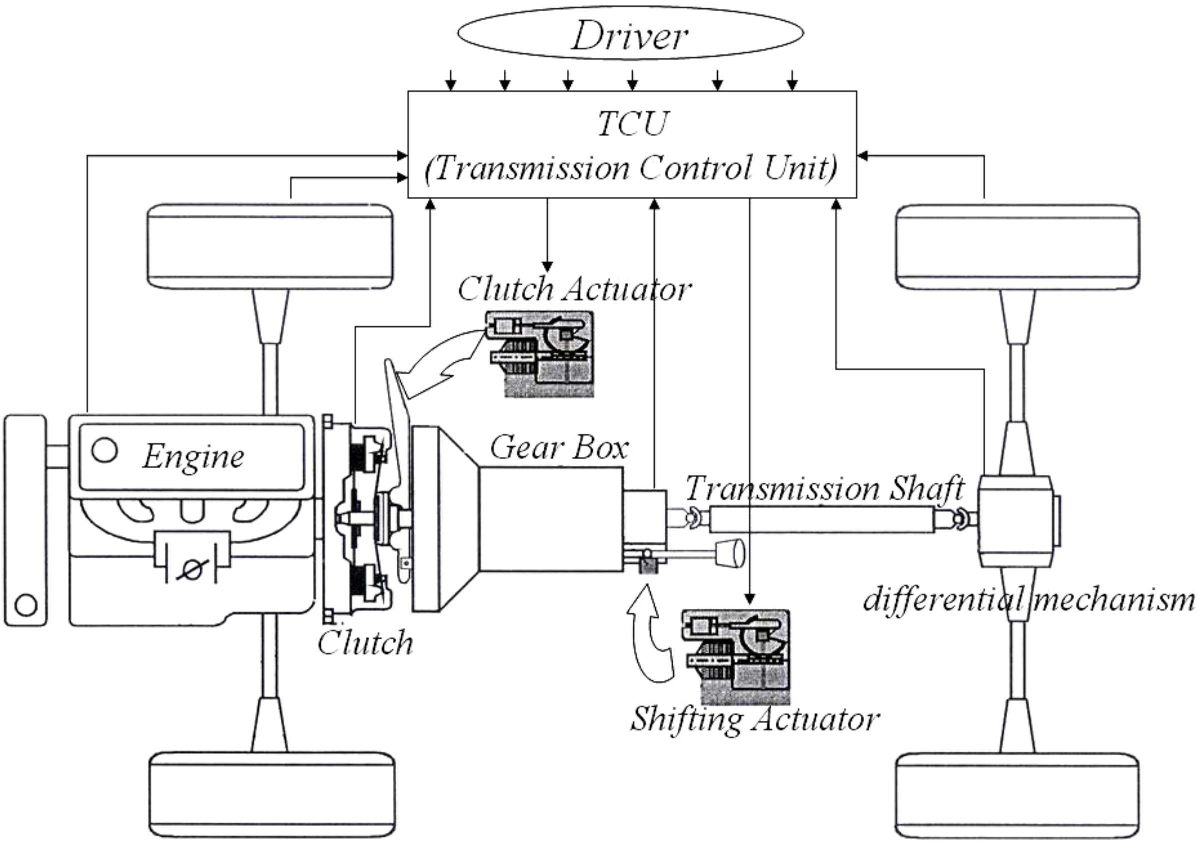

Figure 1.1-1 Structure of Automated Manual Transmission System

In these years, automatic transmission prevails in Japan, North America, and many Asia countries, manual transmission cars are main stream in Europe. However, according to Montreal Protocol 1987, Rio de Janeiro Protocol 1992, and Kyoto Protocol on Global Warming 1998, 38 developed countries are to reduce greenhouse gas by approximately 95 percent of 1990 levels by 2008~2012, and the United States is to lower its discharge of carbon dioxide (CO_2) to 93 percent of 1990 emission [5]. An astringent CO_2 regulation is required on vehicle gradually in many countries. For example: Europe, as shown in Figure 1.1-2. Automated manual transmission which has higher transmission efficiency and lower gas emission has more superiority to grow up to meet this tendency in recent years than many others [7]. Many main factories like TOYOTA, DaimlerChrysler, BMW, ZF, GETRAG, SEIKI, LUK, VALEO, etc. have invested in such project. A forecast from Industrial Technology Research Institute (ITRI) is shown in Table 1.1-2. Where DCT is double clutch transmission system, an evolution of automated manual transmission system.

Transmission System in European Markets		
Types	2000	2010
AT	11.9%	25%
CVT	0.5%	5%
MT	87%	45%
AMT	*0.5%*	*12%*
DCT	0%	13%

Table 1.1-2 Forecast of Transmission Systems in Europe

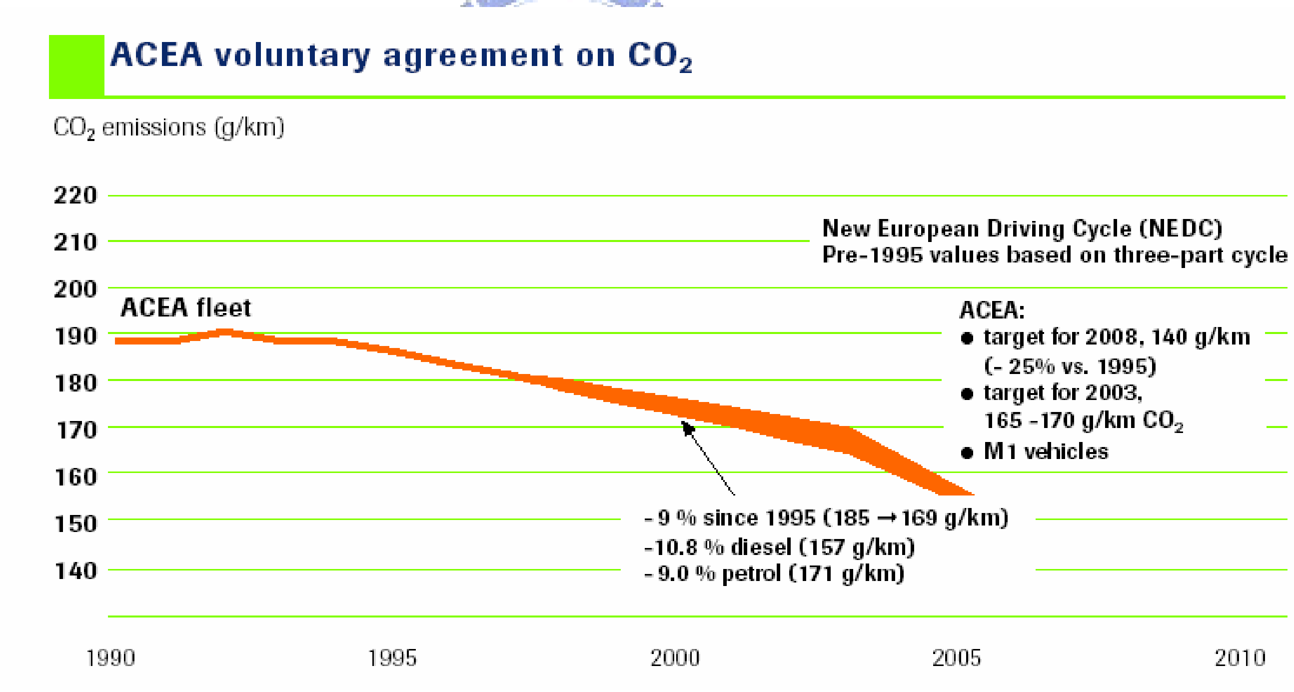

Figure 1.1-2 European Automotive Manufacturers Association (ACEA) voluntary agreement on vehicle CO2 emission [6]

1.2 Objectives

Automated manual transmission has high transmission efficiency, high torque capacity, low gas emission, and low cost; however, the main shortcoming is the amenity which is inferior to both automated transmission and continuously variable transmission. Continuously variable transmission is essentially a system transmits power continuously with no interrupt or shifting process, it has the best amenity than any others. Automated transmission transmits power through a torque converter. The torque converter is acted to interrupt the power transmission while shifting. But due to the property of hydraulic pressure applied, the power transmitted is not fully interrupted while shitting, thus shifting with low shocks. Automated manual transmission, like manual transmission, shifting process is introduced by clutch disengagement/engagement and synchronizer movement. Clutch disengagement is to provide an occasion of power interruption for synchronizer to shift to next effective gear ratio. And clutch engages after the shifting process is completed. In general, the processes of clutch disengagement and engagement cause the power transmitted to car a termination and a restoration. This interruption sometimes produces uncomfortable driving condition if the control of clutch is not skilled. Such condition can be seen obviously when a freshman drives a manual transmission vehicle.

Since the clutch control is handled by a clutch actuator mastered by computer algorithm in automated manual transmission, the amenity can be modified better than manual transmission. Clutch control dominates the amenity of a car while shifting, which is the crucial point of automated manual transmission. There are many strategies to increase the smoothness of automated manual transmission while shifting, like double clutches [8] used on mechanical structures and torque tracking method [9] for control algorithm. However, all these strategies, which improve the performance of automated manual transmission, should base on a clutch actuator and a controller which work well as our expectation. Moreover, the vehicle dynamic characters influenced by shifting process should be understood clearly.

In this study, dynamic analysis of a clutch actuator prototype designed by Industrial Technology Research Institute is the main objective. According to this model, an expanded model of automated manual transmission system, including engine, clutch, gear box, and car loading, is built up to simulate complete vehicle dynamic characters while shifting. Besides dynamic modeling, control functions based on system dynamic characters is proposed.

Another objective in this study is optimization. Both mechanical parts on clutch actuator and control parameters for clutch control function are do be modified. In this part, using optimization methods and models created before, a new evolution of clutch control system which displays speedier and more stable is obtained. These solutions of optimizations give the prototype guidelines of modification.

With the objectives in this study, dynamic models of both the clutch actuator and the whole transmission system should be created in modules. In such way, the models not only give simulation results of the current job, but also provide a basic frame for simulation of many other transmission systems. The model should be able to be modified easily to simulate future developments like double clutches system, torque tracking controller, hybrid vehicle transmission, and some other advance transmission systems.

1.3 Thesis Outlines

There are two main components in this study according to the automated manual transmission system: mechanical component and control component. Besides model creation, computer simulation, and analysis of these two components, optimizations are introduced after discussions of both components are satisfied to provide improvements of the prototype. Both these studies are described from CHAPTER 2 to CHAPTER 5.

CHAPTER 2 and CHAPTER 3 are parts of mechanical component. CHAPTER 2 proposes the dynamic analyses and dynamic model creations of the clutch actuator and the powertrain. With free body analyses and experiment data, the dynamic characters are obtained into system equations. Finally, using Matlab Simulink, the dynamic models according to the system equations are created into modulus.

The dynamic models created in CHAPTER 2 are simulated in CHAPTER 3. The results according to the simulations are analyzed with tendency forecasting to check the exactitude. Finally in this chapter, some parts of the clutch actuator are modified by optimization method. In this section, the parts which are easy to be modified practically and capable of increasing performance are chosen to be design variables. Target and constraints of the optimization are defined according to the design requirements.

CHAPTER 4 and CHAPTER 5 are parts of control component. CHAPTER 4 is the development of control function. According to CHAPTER 2 and CHAPTER 3, which introduce the dynamic characters of the clutch actuator, the control function is created and the parameters are defined according to some control turning methods.

CHAPTER 5 optimizes the parameters of the control function created in CHAPTER 4. In this chapter, the parameters are optimized according to the dynamic models created before. Since the parameters have had been defined in CHAPTER 4 with some control turning methods, this chapter uses these parameters as an initial condition and expects a better performance after optimization. Optimization in this chapter deals with a complete automated manual transmission system model, which combines the dynamic models and the control models created before. With the integrated system model, the control functions and dynamic characters of the transmission system are merged with optimized combination. Finally in CHAPTER 5, the simulation results of the complete merged models are presented.

As a final point, CHAPTER 6 outlines the conclusions and direction of the future works.