Global Journal of Researches in Engineering: B
Automotive Engineering
Volume 14 Issue 1 Version 1.0 Year 2014
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Development of DC Motor Controlled Automated Manual Transmission (AMT)

By Mr. M. S. Kumbhar, Dr. Dhananjay Panchagade
& Mr. Kapil Baidya
D. Y. Patil College of Engineering, India

Abstract- Automated Manual Transmission (AMT) has been the best competitive solution to address the problem of increasing fuel prices and to meet the emission norms. Automotive world today mostly uses Automated Manual Transmission (AMT) based on hydraulic actuators. Hydraulic actuators are costly, complex in design, bulky and invite drastic design changes in existing gearbox. AMT system which is low cost and fuel efficient has been developed using DC motor controlled electro mechanical linear actuators. The AMT system consists of three electro-mechanical linear actuators, one for clutch and two for gear shift actuations which are controlled by Transmission control unit (TCU). The wear of synchronizers can be easily taken care by reprogramming the stroke lengths of linear actuators. This system can be retro fitted in vehicle with existing manual gearbox and involve minor design changes. The focus of paper is to introduce the system developed.

Keywords: *actuator, AMT, automated manual transmission, transmission.*

GJRE-B Classification : *FOR Code: 090203, 090299*

Strictly as per the compliance and regulations of :

Development of DC Motor Controlled Automated Manual Transmission (AMT)

Mr. M. S. Kumbhar [α], Dr. Dhananjay Panchagade [σ] & Mr. Kapil Baidya [ρ]

Abstract- Automated Manual Transmission (AMT) has been the best competitive solution to address the problem of increasing fuel prices and to meet the emission norms. Automotive world today mostly uses Automated Manual Transmission (AMT) based on hydraulic actuators. Hydraulic actuators are costly, complex in design, bulky and invite drastic design changes in existing gearbox. AMT system which is low cost and fuel efficient has been developed using DC motor controlled electro mechanical linear actuators. The AMT system consists of three electro-mechanical linear actuators, one for clutch and two for gear shift actuations which are controlled by Transmission control unit (TCU). The wear of synchronizers can be easily taken care by reprogramming the stroke lengths of linear actuators. This system can be retro fitted in vehicle with existing manual gearbox and involve minor design changes. The focus of paper is to introduce the system developed.

Keywords: actuator, AMT, automated manual transmission, transmission.

I. Introduction

Today the automobile industry is ruled by two forms of transmission, the Manual Transmission (MT) and the Automatic Transmission (AT). The MT is the most efficient transmission available as it lends itself to providing good fuel economy for the vehicles it is employed in. The MT is relatively easy to manufacture because it has very few parts. Another plus point is that the MT is reliable and easy to maintain. However, the major drawback with the MT is that it is less easy to drive than an AT especially, in congested traffic as it requires the driver to operate the clutch for each gear shift. There has been clear trend in automotive industry in recent years towards increased ride comfort and fuel efficiency keeping cost factor in mind. 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 (MT) has overall efficiency of 96 percent which is highest in all types. Belt type CVT (Continuously variable Transmission) has overall efficiency of 85 percent. Automatic Transmission has efficiency of 86 percent and Automated manual transmission (AMT) has efficiency par with manual transmission. AMT is essentially a MT with an automated control system [1]. Combining the fuel efficiency of an MT with the seamless shifting of an AT, this approach shows excellent promise as a compact and cost-effective transmission for future vehicles.

If a transmission could have the benefits of both the MT and AT and the weaknesses of either, this would introduce a new option to the existing market segment. Many researches and studies are directed towards developing AMT. To avoid torque interruption by use of Assist clutch (ACL) by replacing fifth gear synchronizer in gearbox is add-on feature in AMT system [1]. System that allows gear shift in zero seconds was developed, thus eliminating torque interruption during gear shifting [2]. Many researches on AMT Drivetrain modeling and control have also been carried out. In studies devoted to gear shift control [3], considered reduced-order driveline models, clutch and gearbox actuator dynamics have been described by simple models or have been neglected.

Traditionally, the AMT has good fuel economy, inferior performance as compared to the MT. The latter can be optimized by refining control strategy. By automating the MT, a cheap and economic transmission is developed. The aim of this paper is to introduce the concept of DC motor controlled AMT. This paper is split into following sections: First, the objective and feature are discussed. Secondly, the concept and working principle are explained. Then gear shifting strategy is discussed. Finally the system performance is evaluated by discussing simulation based results of DC motor controlled AMT.

II. Objective and Features

The objective of this project was to develop a system that can be retro fitted on vehicle with existing MT. The developed system should be compact, simple to manufacture, low cost and should have efficiency par with MT. The developed DC motor controlled electro-mechanical AMT has many advantages over conventional hydraulic AMT in terms of cost and complexity.

The Low cost AMT has three electro-mechanical linear actuators that are retro fitted on existing MT vehicle. Clutch actuation is done by clutch actuator by modifying existing clutch cable whereas gear select and shift actuation is done by select and shift actuators by modifying existing gear select and shift cables. The actuators are controlled by Transmission control unit

Author α: PG Student, D. Y. Patil College of engineering, Akurdi, Pune. e-mail: mak.loves@gmail.com
Author σ: Head of Department of Mechanical Engineering, D. Y. Patil College of engineering, Akurdi, Pune.
Author ρ: Assistant General Manager, Tata Motors Ltd.

(TCU). This system helps in reducing torque interruption during gear shifts. Thus a low cost, simple and efficient AMT system has been developed which can be retro fitted on existing MT vehicle.

III. Concept and Working Principle

Fig. 1 shows DC motor based AMT system concept which uses a conventional MT, actuators and TCU to automate the process of clutch actuation and gear shifting. The clutch actuator is connected to clutch lever via clutch cable. Similarly the gear shift and select lever are connected to gear shift and select actuators via shift and select cable respectively. The driver command for gear shift is received by TCU and the corresponding command for actuators are generated after processing all input signals through a gear shifting control strategy.

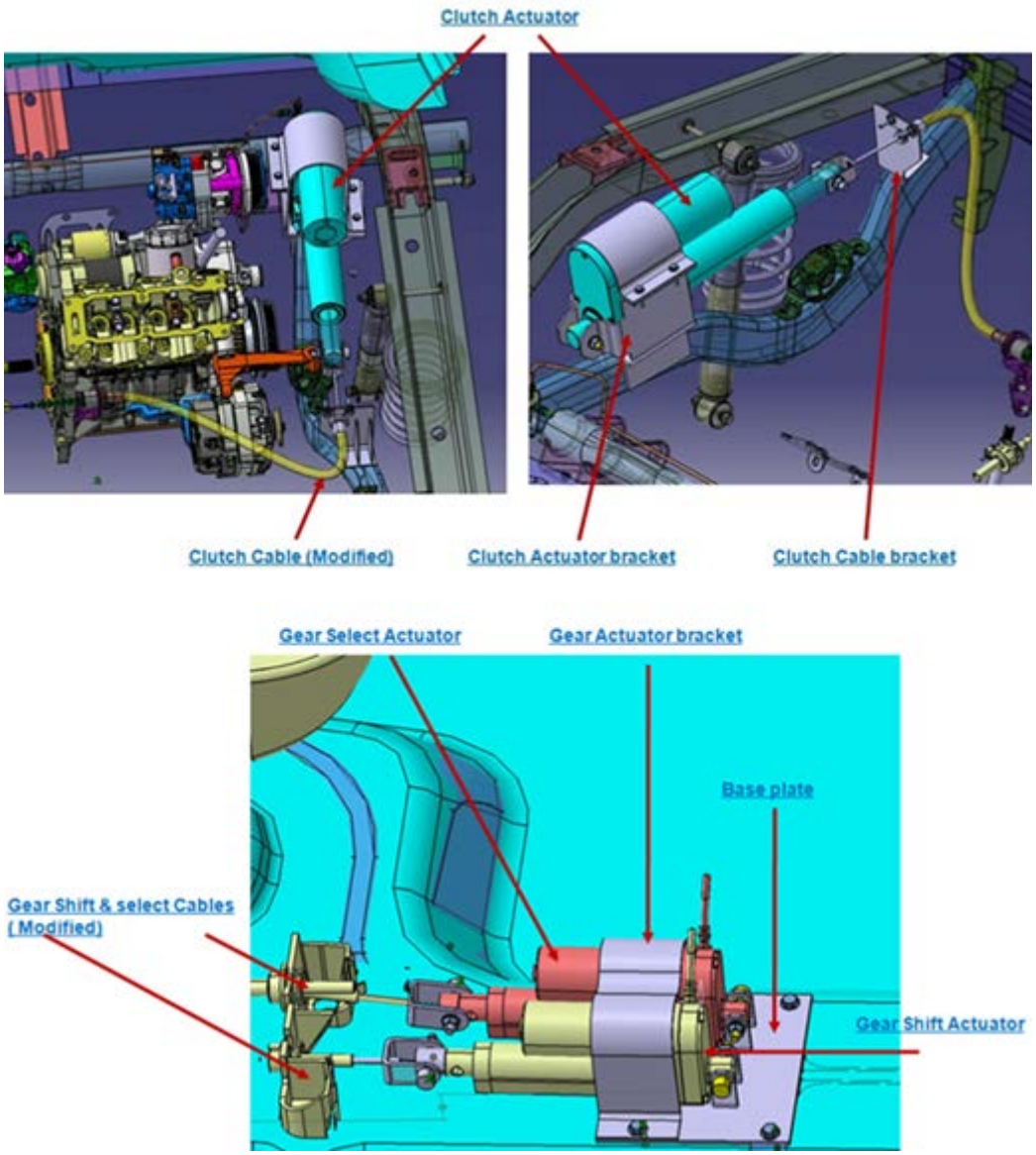

Figure 1 : DC motor controlled AMT system concept

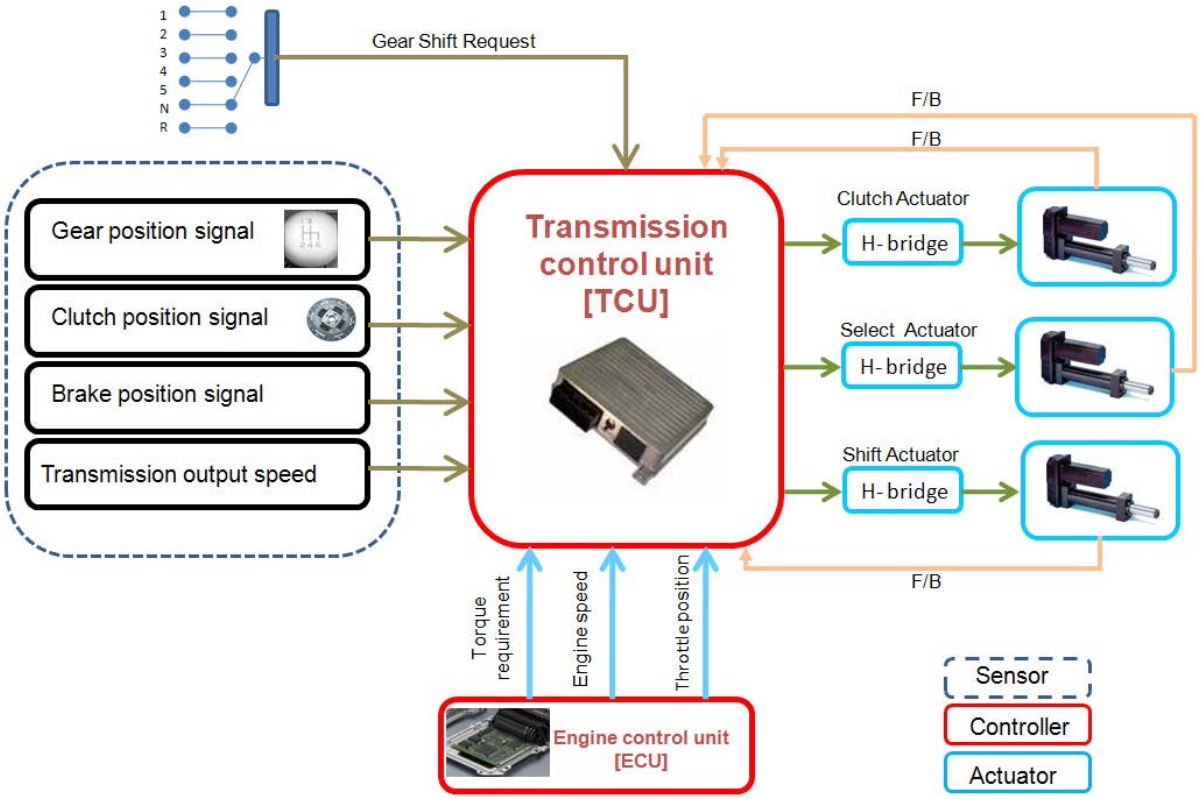

Figure 2 : DC motor controlled AMT system configuration

Fig. 2 shows the system configuration of developed DC motor controlled AMT. It consists 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) along with driver shift commands. The TCU has a gear shifting control strategy which on receiving the input signals, generates the output command signals to clutch actuator and gear shifting actuators.

The linear actuators used in our system are DC motor based. For downsizing, weight and cost reduction DC motor based linear actuators are used. DC motor requires H-Bridge circuitry. The H-Bridge circuitry receives the command signal from TCU and controls the linear actuators. The software for microcontroller is developed in such way that it gives PWM signals to the driver IC. The analog feedback signals from actuators are given to the microcontroller in H-Bridge circuitry to analyze and control linear movement of actuator. ADC (Analog to Digital converter) of microcontroller reads this analog value.

Actuators are selected based on force and linear speed required for gear shift operation. The forces were experimentally measured on clutch lever, gear shift lever and gear select lever and linear speed was finalized from benchmarked standards. Accordingly the linear actuators were selected to suit the purpose.

IV. Gear Shifting Stratergy

Fig. 3 shows the core of control strategy for gear shifting process. First, control is transferred from the driver to the TCU, entering the torque control phase. The engine is controlled to a torque level corresponding to zero transferred torque in the transmission when the clutch is disengaged by clutch actuator. The gear shift actuator actuates followed by actuation of select gear actuator for rank selection and neutral gear is engaged. Then the speed synchronization phase is entered. Here the engine speed is controlled to track the transmission speed as per new gear desired, and the new gear is engaged after select and shift actuator actuations. Finally, the torque level is transferred back to the level that the driver demands when clutch is engaged with help of clutch actuator. It is important to minimize the total time needed for a gear shift to reduce the torque interruption. The shifting strategy is written such that gear shifting takes place in most efficient zone of engine operating condition.

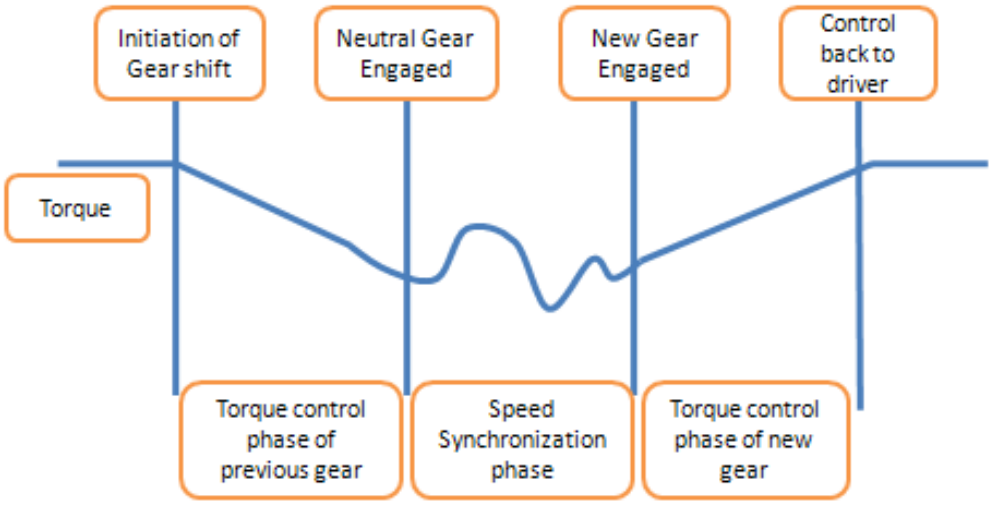

Figure 3 : Phases in Gear Shifting

V. System Performance

In this section we will summarize our assessment of how well the DC motor controlled AMT achieves the seamless shifting of an AT and the fuel economy of an MT. Fig. 4 shows the torque interruption in AMT and AT. It can be seen that the total shifting time of AMT is less than MT. So traction loss is less in case of AMT and hence greater efficiency.

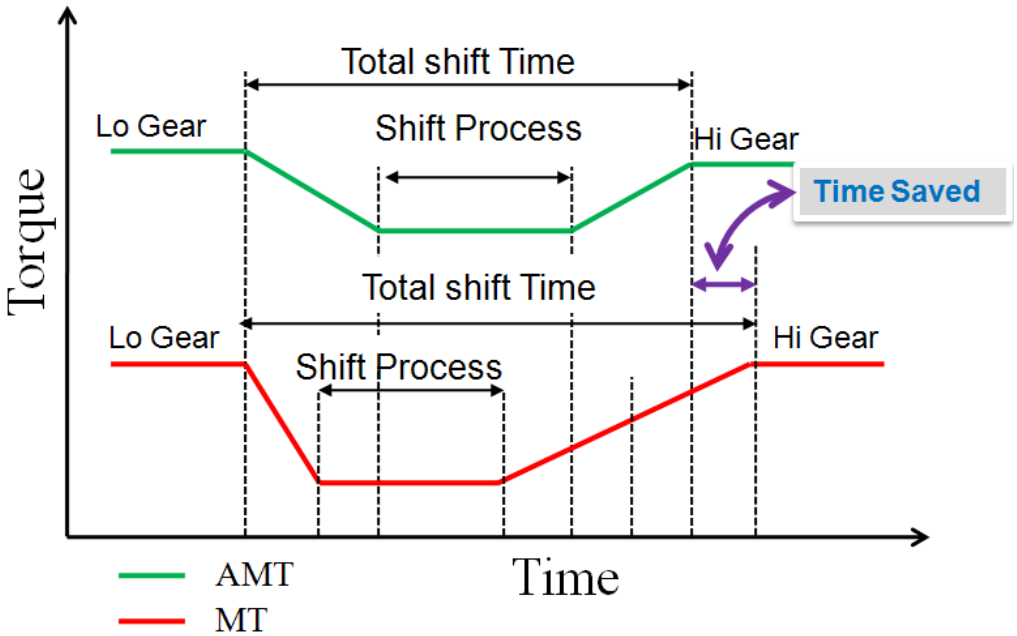

Figure 4 : Torque interruption in AMT and AT

Fig. 5 compares the DC motor controlled AMT with a conventional AT across six different performance measures which are made from the practical data collected on field. It can be seen that the up and down-shifting performance of the DC motor controlled AMT is almost the same as the AT. As there is no slippage from the torque converter that is required by an AT, the fuel efficiency and acceleration response of the DC motor controlled AMT are significantly better. On the other hand, the torque converter on the AT gives somewhat smoother starts and more power when accelerating as compared to the DC motor controlled AMT unit but we believe based on this overall assessment that the DC motor controlled AMT has excellent potential as a compact and fuel-efficient next-generation transmission that is also affordable. This DC motor controlled unit can be a good alternative for conventional AT unit. Cost is a major factor which can lead to a breakthrough in the

Asian Market with this DC motor controlled AMT serving as the future technology for car manufactures. With minimum modification made to the existing MT unit it is a highly feasible option in the market in terms of its reliability and easy service.

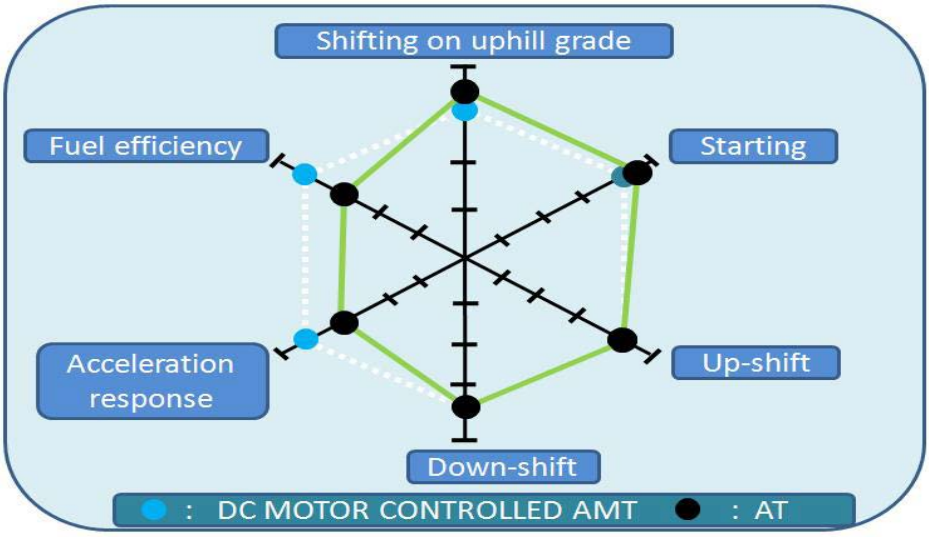

Figure 5 : Performance of Dc motor controlled AMT

A simulation was designed in the ADVISOR (2001) [4], a simulating software tool used in Matlab in order to check Engine performance between MT and our AMT system. Receiving the vehicle speed-time history as input, the simulation works backwards and calculates motion parameters as outputs. The vehicle subsystems in the simulation include engine, clutch, gearbox, differential, wheels, and axles of a default small passenger vehicle with 1400 kg vehicle mass and SI engine. Simulation was carried out on BS-IV Indian drive cycle (Urban part) with conventional vehicle model and our AMT vehicle model with similar configurations in terms of engine and gear box parameters. Fig. 6 shows the Engine efficiency graph for MT and our AMT for urban part of BS-IV Indian drive cycle. It can be clearly seen that Engine efficiency is high in most part of drive cycle for our AMT as compared to MT for same vehicle thus confirming that in DC motor based AMT optimized gear shifting takes place in most efficient engine efficiency operating zone.

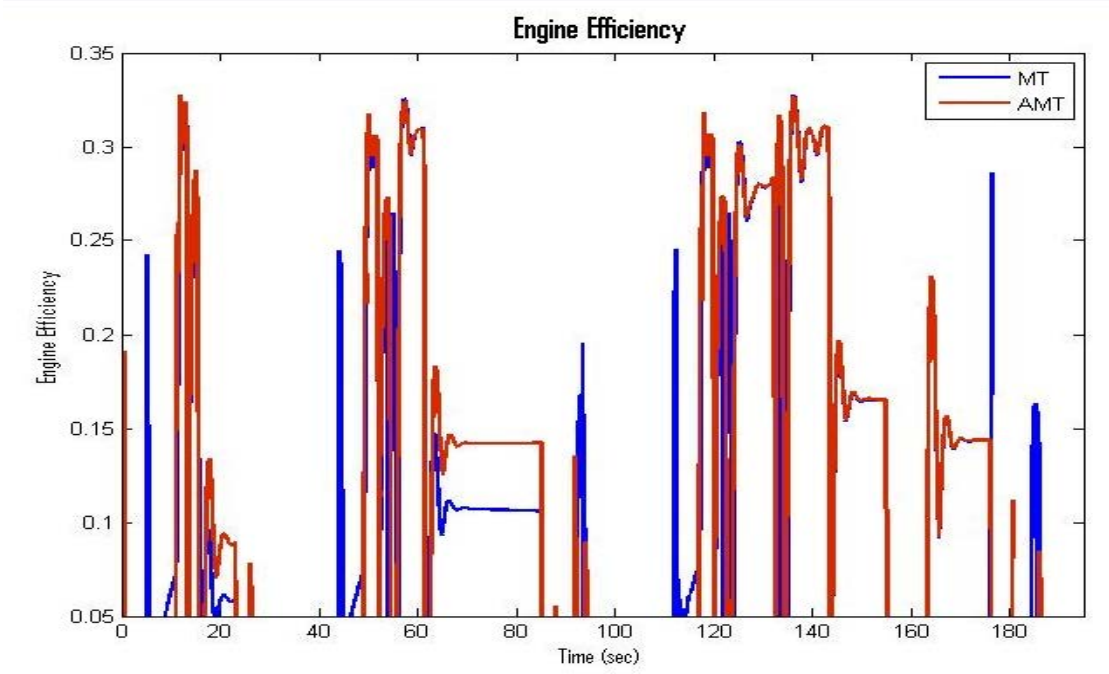

Figure 6 : Engine efficiency profile based on simulation

VI. Conclusion

A low cost DC motor controlled AMT concept was developed and performance was evaluated by simulation results. The simulation clearly indicates that DC motor controlled AMT is efficient as compared to MT. Low cost coupled with high efficiency makes the DC motor controlled AMT an extremely appropriate alternative for the conventional AMT. This type of alternative is a much desired and awaited demand of Asian and European Markets. Simplicity in packaging and uncomplicated serviceable design makes this concept a technology for future. This has the potential to become the next big tech revolution in the automobile world.

The Conversion of an Existing MT to DC motor controlled AMT has the Following Benefits

- Automated gear shift in optimum engine efficiency zone with improved shift quality.
- Improved fuel economy compared with torque converter AT.
- Improved acceleration performance and less traction losses.
- Easy to manufacture and is retro fit to install.

Since this concept of AMT system separates the actuator from the gearbox, the actuators can be designed independently and applied to different types of manual transmission with the same capacity. However, non-ideal mechanical connection between the actuator and gearbox brings some technical difficulties, such as cable wear, elasticity and mechanical clearance that need to be overcome.

In conclusion, the low cost DC motor controlled AMT is technically feasible, but there is still a great deal of research to be performed before commercialization.

VII. Acknowledgements

This project would not have been possible without the support and guidance of Mr. S. Govindarajan, General Manager, Tata motors ltd and Mr. P. Sarkar, Assistant General Manager, Tata motors ltd. We would like to give special thanks to Mr. Ashish Ranjan, Manager, Tata motors ltd and Mr. Sandeep Mante, Manager, Tata motors ltd. for their co-operation and support.

References Références Referencias

1. E. Galvagno, M. Velardocchia and A. Vigliani, Analysis and simulation of a torque assist automated manual transmission, *Mechanical Systems and Signal Processing 25*, 2011, 1877-1886.
2. R. P. G. Heath and A. J. Child, Zeroshift Automated Manual Transmission (AMT), *SAE Paper No. 2007-26-061.*
3. Magnus Pettersson and Lars Nielse, Gear Shifting by Engine Control, *IEEE transactions on control systems technology*, *Vol. 8, no. 3*, 2000, 495-507.
4. ADVISOR (2001), Advanced VehIcle Simulator, version 3.1, NREL, Colorado.