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Automated Manual Transmission for Two Wheeler

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ABSTRACT

The driving comfort of an automobile depends upon the smoothness of gear shift. The Smooth gearshift depends upon an index of clutching impact and the quickness of gearshift. At the same time vehicle economy depends upon an optimal gear shift. This is a main reason for an automated manual transmission (AMT) to become a popular transmission in commercial vehicles. An AMT provides a driving comfort as well as a good economy at less price tag. An AMT with hydraulic drive unit is a conventionally proven option in heavy vehicles. But sluggish response and leakage issues make it less appropriate for small vehicles like two and three wheelers. A retrofittable mechatronic unit can be a good option to automate two wheeler transmissions. The conventional automatic transmissions are costly and less economical for usage as well as the maintenance. A DC motor based electromechanical device is proposed in this paper for a two wheeler transmission. The mechanism shows quick gear shift and promising reliability. The proposed AMT mechanism is an imitation of human leg movement and the movement is controlled by a DC. An embedded controller operates DC motor as per driver's intensions. It shows quick gear shift and jerk less operation. Few issues like wear and tear of AMT mechanism and the emissions study are also required to be studied in the regard. The use of a neural network and fuzzy logic, and LQR based algorithm enhancement techniques will be considered for the future scope of AMT tuning.

Keywords— **Automated manual Transmissions, Optimal gearshift, Mechatronics, Embedded systems, DC motors**

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I. INTRODUCTION

There are mainly three types of automotive transmissions. The manual, semiautomatic and automatic transmissions are those types. The automated manual transmission (AMT) is a semiautomatic transmission. In AMT, the manual transmission is automated and tuned by using a mechatronic unit. The cost of AMT is less than automatic transmissions. An AMT has more mechanical efficiency than automatic transmission and more comfort than manual transmission.

The research on AMT (Automated Manual Transmission) is mainly concentrated on the pattern recognition, learning algorithms and control strategy. The AMTs are mainly made for passenger cars. But the AMT is far more important for commercial vehicles in which the clutching is very laborious and bad gear shifting habits reduce fuel efficiency. According to the authors [2], with present mechanism, it is necessary to modify gear box case. This is costly as well as time consuming. The novel gear selector is proposed by Tongji university team which is directly retrofitted on a manual transmission of a sedan. The concept is to separate gear shifting actuators from gearbox through cables which bear pulling and pushing force. So the gearbox case modification is avoided. The optimal control algorithm is based on LQR (Linear Quadratic Regulator). The mathematical model has a focus on dynamic performance, stability and endurance since it is an automotive part [2]. The gear shift is accurate if the axle shaft torque is known. For a good AMT it is important that the nonlinear dynamic error due to elasticity of axle and propeller shafts, clutch springs shall be minimal. In commercial vehicles like mini trucks etc. load variation depends upon actual vehicle load, road conditions etc. So the research suggests use of an observer for all the gear positions. The dynamic error is input to state stable. And the observer gains are calculated by convex optimizations which are helpful with large variations of commercial vehicles [4].

The dynamic programming is used for getting optimized gear shift sequence [3]. An AMT-clutch less is advantageous for electric vehicles with axle DC motor. Because DC motors have precise speed control and fewer vibrations; so the sleeves are used for gear engagement instead of synchronizer which has simplified the AMT structure and the cost. The speed synchronization takes half of the total gear shifting time in clutchless AMT. So to use a control strategy based on H∞-linear quadratic regulator is effective [5]. In many AMTs, the torque gap filters are used to reduce the driving torque interruptions, hence the jerks. But M/s Hitachi has proposed a new model to do the same. The model is named as assist clutch (ACL). An assist clutch replaces the fifth gear synchronizer on traditional AMTs. The clutch is a low cost and compact solution. The gear shift is based on vehicle speed (v), acceleration (a) and throttle angle (ϴ) for an AMT. But this three parameter model needs huge amount of data, actual testing and computations. So the use of iterative learning control based on pattern recognition can be employed in approaching optimal shift [7].

The researchers are working on various solutions to make AMT efficient. The main focus of these projects is to get smooth gearshift. An electro-mechanical mechanism with an extended state observer (ESO) and Active disturbance control (ADC) has shown good potential in the regard. An ESO with inverse system method (ISM) estimates and compensates uncertainties, parameter variations and external disturbances while an ADC improves tracking accuracy of synchronization process. The simulation and experimental set of this scheme has effective control for optimal gear shift [10].

Many Automakers are working on use of dry clutches [17]. The dry clutches are environment friendly and a control scheme based on decoupled and cascaded feedback loops based on engine RPM, clutch speed, throughout bearing position and estimation of transmitted torque [11].

The recent developments of AMT are aimed for optimal fuel economy. So one proposed method is to regulate fuel injection during gearshift using an auxiliary control device. It is done by developing a hydraulic accelerator unit with a fuel injection control [12]. In the heavy vehicles with pneumatic control, it is necessary to control clutching process at gearshift start point. The authors have compared two strategies based on engine rpm control and clutch engagement speed [13]. The use of multimode controllable shifter (MCS) has also been tested for AMT. It is capable of providing uninterrupted shift transmission (UST). The system prototype has shown a promising one way clutching technique with minimum slip [14].

A knowledge based gear position decision algorithm follows experienced driver’s skill to decide the gear shift points. This technique removes a typical AMT problem of frequent and unnecessary gear shifts. It has three layered intelligent control structure. The basic idea proposed is to use all available information about road pattern and engine parameters to choose an optimal gear. The idea of combining neural networks and fuzzy logic is a base for experienced driver mapping. It needs huge number of data samples and a modern data pattern recognition technique. The earlier systems were very basic in the nature. An adaptive algorithm is a way to add human skill to automotive gear shifting [7].

Another area of AMT enhancement is to use robust integrated motor transmission power train system over CAN. It uses Taylor series expansion for linearization of parameters control driveline oscillations. A robust peak to peak control is applied to improve transient response of system against oscillations and the control law is based on multivariable PI control [16].

But in two wheelers, an AMT is not applied commercially. The continuously variable transmission (CVT) based transmissions are costly and not fuel efficient. There have complex mechanisms which are difficult for maintenance and service. The automatic transmissions and moped is not very effective on slopes. The torque could not be maintained on steep roads. An AMT mechanism and algorithm is proposed in the paper, not only have smooth gear shift but also it is cost effective. The proposed mechanism shows smooth and optimal gear shift depending on engine RPM. The main objective of this dissertation is to show quickness of gear shift with respect to in inputs and hence the jerk free gearshift which is

II. BASIC LAYOUT

An AMT test rig consists of Honda Street- 100cc engine with gearbox, 12V battery, AMT mechanism, electronic control system with AVR microcontroller. The basic schematic is shown in Fig 1. Fig1 and table1 show tests rig of proposed AMT set up for two wheelers. Most of the two wheelers have 5-speed or 4-speed gear boxes. In this dissertation 4-speed gear box with auto clutch is used.

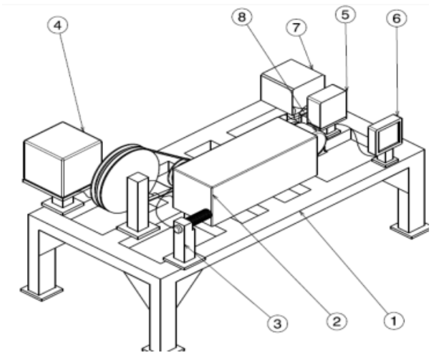

Fig1. Test Rig Layout (AMT unit is not shown in the view)

TABLE I
PARTS INDEX

8	DC motor
7	Battery 12V
6	Display
5	Panel
4	Fuel tank
3	Accelerator
2	Gearbox + Engine
1	Table
Part Number	Part Name

So two DC motors can be used to control clutch as well as gear shift. Here auto-clutch system is used for dissertation so that only one DC motor is necessary which controls the gear shift.

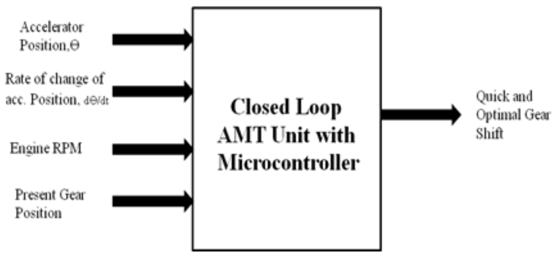

Fig.2 Inputs and outputs

Fig.2 shows an AMT inputs and output. The proposed system is a closed loop electro-mechanical unit which is controlled by an embedded system. The system is programmed by using standard gear shift data. The Gear shift is based on user's intensions. When a user is in rush he accelerates at higher rate *($d\Theta/dt$)* at the same time at less speed the rate of acceleration is less. Also at slow speed the torque requirement is more hence the system is needed to switch to lower gear ratios. Embedded systems are robust and cost effective.

TABLE II
VEHICLE SPEED AND GEAR POSITIONS

Vehicle Speed (kmph)	***Gear Ratio***
0-10	***1***
10-20	***2***
20-40	***3***
40-60	***4***

The table2 shows the fuzzy data used for gear positioning. The same data is applicable for upshift and downshift. The system inputs are scaled to match the vehicle speeds. This means accelerator position (Θ) and $d\Theta/dt$ are scaled to match vehicle speeds.

III. MECHATRONICS AND CONTROL STARTEGY

The dissertation has built a controller-observer- sensor system which consists of sensors for all inputs and output states to develop a closed loop feedback system. This system gets consistently updated during every gear shift.

A. Mechatronic System

In mechatronic work, the angular displacement of the accelerator, vehicle speed, engine rpm, present gear position and breaking actions are measured by using sensors as given in table2.

TABLE III
ELECTRONIC COMPONENTS

1. Microcontroller	- 32K Bytes Flash program memory - 1024 Bytes EEPROM - 2K Byte Internal SRAM
2.Voltage Regulator	MC 78XX
3. Dual Full Bridge Driver	L298
4. LCD Module	Dot Matrix, 5 x 7 dots plus cursor
5. Motor	NRS-585, 4kg-cm torque

Table 2 also shows some of the basic parts of electronic circuitry. The conventional modules are used for dissertation for cost reduction.

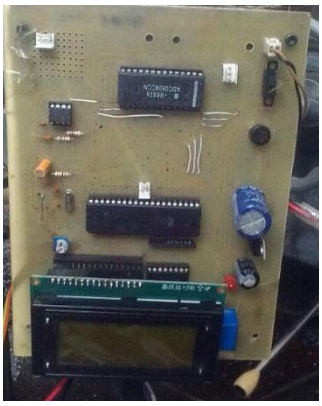

Fig.3 Electronic Panel

The figure3 show a microcontroller card, programmed in C to execute the gearshift as per table1. The LCD module shows the present gear condition and rate of acceleration.

B. AMT Mechanism

The AMT mechanism is designed to imitate human leg movement. The leverage is provided in the mechanism for proper torque transfer by motor. It is one of the main aspects of the whole dissertation.

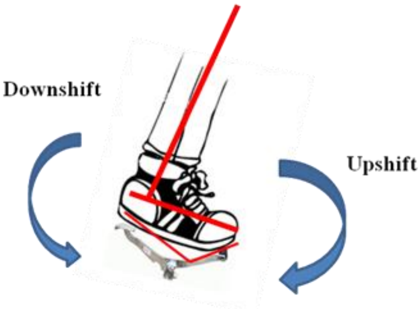

Fig.4 Imitation of leg movement during gear shift

Fig.4 shows the leg movement during gear shift. The mechanism is based on same platform.

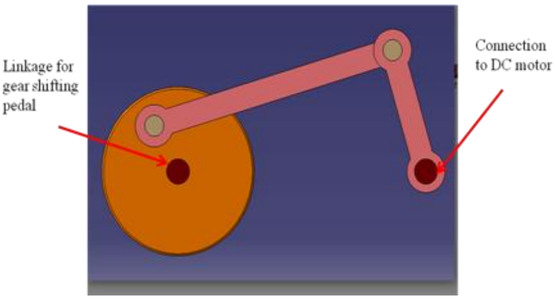

Fig.5 Type1 AMT mechanism

Figure 5 and 6 are the two types of AMT mechanisms tested for the application.

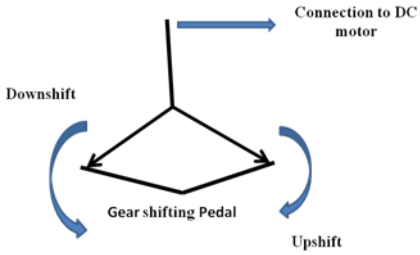

Fig.6 Type2 AMT mechanism

The type1 has shown promising results and good transient response and compactness. Hence the remaining experimentation is done with Type1.

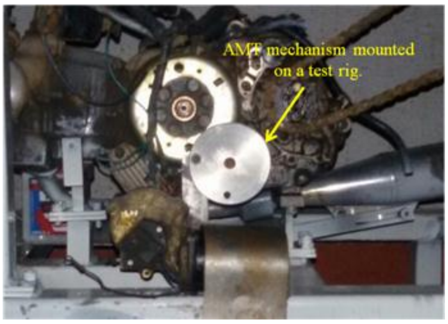

Fig.7 AMT mounting

Fig 7 shows actual mounting of AMT on the set up and consists of only three parts. The linkage is easy to manufacture.

C. Control strategy and coding

The closed loop control is important to be robust and quick. The main objective is that the controller is precise and the observer works on a minimum gain. So that whole electronic circuit works at lower voltage level.

Figure 6 shows that the rate of change of angular movement of accelerator and the change in engine rpm act as disturbances for the proposed system. The observer gain is kept as minimum as possible so that system can work on low voltage.

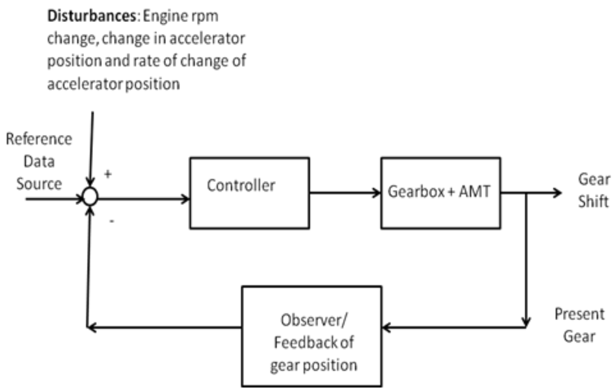

Fig.6 Closed Loop Gear Shifting

The present gear position is sent back to controller based on this data, the controller decides motor movement required for the gear shift. The reference data source is as shown in table1. The coding is done in AVR Studio Cross C compiler.

Figure 7 shows the part of C coding for the AMT system. This code is written for table 2 data. The angle ϴ of accelerator movement is used as an input for gear shift. The remaining part of coding consists of scaling and different on-road conditions like sudden applications of breaks, inclined roads and frequent gear shifting in traffic.

To define neutral condition, differentiate between braking and travelling on inclined roads at high torque are the main parts of code and algorithm.

```
File   Edit   Format   View   Help
#include "conversion.h"

char DECNUMBER[7];

char HexToDec(unsigned int val)
{
        char i=0,a;
        while(val>9)
        {
                a=val%10;
                val=val/10;

                DECNUMBER[i]=a|0x30;
                i++;
        }
        DECNUMBER[i]=val|0x30;
        i++;
        return i;
}

unsigned int DecToHex(unsigned int val)
{
        char i=1,a;
        unsigned int res=0,res1=0;
        if(val<16)
        {
                return val;
        }

        while(val>15)
        {
                a=val%16;
                val=val/16;

                res=res|a;
                res=res<<4;
                i++;
        }
        res=res|val;

        if(i>0)
        {
```

Fig.7 Part of C-Code

IV. EXPERIMENTAL RESULTS

The experimentation has been done by comparing gear upshift and downshift of a proposed AMT with a manual gear shift.

TABLE2
RESULTS

Input Parameters	***AMT***
dϴ/dt = 45/3 =15deg/sec	***2.5 sec***
Gear Upshift (N-1-2-3-4)	
dϴ/dt =45/3 = 15deg/sec	***2sec.***
Gear Downshift (4-3-2-1-N)	

The basic experimentation shows quick and smooth gearshift. The experimentation for intermediate gear shift, for example Neutral to 2, 4 to 1 etc. are still under process. The structure shows good stability and reliability. The dynamic stress analysis of structures is under process.

V. CONCLUSION

The dissertation shows promising results for developing an AMT algorithm and mechanism for commercial use. In heavy traffic countries AMT for two wheelers will provide good comfort. The optimal gear shift is useful to reduce fuel consumption and hence the emissions. The set up has to be tuned with real time data. The mechanism size is also large. The cost is another promising factor when we compare this AMT with CVT based transmissions. The future scope of this dissertation is to reduce torque gap during gear shift and hence to develop a commercially viable AMT for two wheelers where clutching process will also be automated with a separate motor.

The unit can be retrofitted on any two wheelers.

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