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Automated Manual Transmission Using Servo Motors for Sequential Gearbox

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ABSTRACT: This project is about the design and fabrication of an automated gear shifting and clutch operating mechanism specialized for a motor-cycle. The system is operated by two motors one for each operation namely gear-shifting and clutch engagement. The actuation of the clutch is the only operation which is fully automated whereas the gearshift is done manually by pressing switches provided. This mechanism is designed to reduce manual effort to the minimum and eliminate the use of clutch so as to have better control and efficiency for the vehicle.

KEYWORDS: Automated Manual Transmission, AMT, Servo Motors, Gear shifting, Sequential Gearbox.

I. INTRODUCTION

In a conventional motorcycle, the driver has to press the clutch lever first and then engage the required gear and release the clutch for the gear to take effect. As easy it may seem, driving in heavy city traffic, which is almost always the case, is quite strenuous. This problem aggravates if we take in to consideration a driver who is physically challenged. Having an electronic system for such functions solves plethora of problems in daily life.

The loss of strain after driving for a long time is one of the primary benefits of this mechanism as it eliminates all the actions mentioned above. Also having an automated clutch system increases the efficiency of the engine as there will be no delay in engaging the clutch, which is not possible while driving manually. Apart from this high accuracy, increase in speed of gear shifting is an advantage which cannot be disregarded. We can also use this design without making any fundamental changes to the existing motorbike.

Automated manual transmission is quite prominent in this generation of four wheeled vehicles. Overlooking this system and comparing it to the manually driven cars, we observe the efficiency improvements in them which compliments improved driving comfort in such vehicles. In most of these cars planetary gear system is used for automatic gear shifts. The most popular system used in cars is the hydraulically operated system. However having a hydraulic system in a motorcycle is not feasible. Hence this system is an attempt to incorporate the same system in motorcycles with suitable changes in it.

Primary components used are two Servo motors, a PCB (printed circuit board), connectors, and an engine to test the system. The selection of these specific parts is made based on their functional advantages over others.

The system has three aspects (disengage; gearshift; engage) which work in conjunction with each other and program has been fine tuned to this operation. This only gives a premature idea about the workings of the system. In order to understand the system we need to study nuances in modes (of operation), the programming related to it, forces while shifting gears and mountings among other things discussed below.

II. WORKING OF THE SYSTEM

The complete system works mainly on the three components, namely; actuators, microcontroller and buttons. The clutch actuator and the gear shifting actuator perform the actual mechanical functioning of the system. But an Arduino-Uno microcontroller controls these actuators with the help of the feed program, according to the received input signals. DC servo motor works as an actuator for clutch actuation as well as gear shifting. Also, two push-button switches are

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provided for upshifting and downshifting of gears which are installed on the dashboard, so the driver can use it to send the commands for actuation. Similarly, there is a four bar linkage in place to connect the DC servo motor and the gear lever to perform the gear shifting.

- **Clutch Actuation:**

Now in order to shift the gear, the switch is used which actuates the clutch first and the clutch disengages. The command is given through the microcontroller to the servo. The clutch once disengaged must be engaged slowly so that the power transfer from engine to gearbox is smooth. In manual transmission the clutch is being actuated manually. Also a delay time is to be given in the program as the clutch has to be disengaged before the gear is shifted.

- **Gear Actuation:**

When clutch is disengaged, microcontroller Arduino-Uno sends a signal to the gear shifting servo. This signal actuates the DC servo motor and it rotates. Since the motor is connected to a gear shift lever through four bar linkage, that lever rotates with the motor. This shifter exerts a force to shift the gear up or down.

When the gear is shifted the motor needs to stop as the gear lever comes back to its original position. The gear shift indicator will generate a signal once the gear is shifted and that is given to microcontroller as the input. Thus microcontroller gives an output signal which stops the motor from rotating by cutting off its supply. As motor is in rest condition the reverse motion of the gear lever is not resisted and it comes back to its original position. Once the gear is shifted the clutch is engaged back into its original position. While downshifting of the gear again first the clutch is disengaged and the gear is shifted by rotating the motor in opposite direction.

III. SELECTION OF ACTUATOR

Servo motor is the main component of this system as it acts as an actuator. DC servo motor is selected, because of its precision in controlling, capability of programming and compactness it adds to the system. As battery is available in the motorcycle, it can be used as a power source for the servo motor. Hence, system does not require any additional power source.

Force required for shifting gears and actuating clutch is very minimal, in case of manual transmission. This is because of the concept of leverage. Depending upon the length of the lever, force required to actuate changes, according to the concept of leverage. But the torque remains the same at every joint of the mechanism. Hence, we focused on the torque for various calculations. We used force meter to measure the force required to shift gears and actuate clutch for a given length of a lever. Using force and length, we calculated the required torque.

- **Gear shifting calculation:**

$$\begin{aligned}\text{Force required} &= 4 \text{ kg} \\ &= 4 * 9.81 \\ &= 39.24 \text{ N.} \\ \text{Length of the lever} &= 9 \text{ cm} = 0.09 \text{ m} \\ \text{Torque required} &= 39.24 * 0.09 \\ &= 3.53 \text{ N.m}\end{aligned}$$

- **Clutch actuating calculation:**

$$\begin{aligned}\text{Force required} &= 3.5 \text{ kg} \\ &= 3.5 * 9.81 \\ &= 34.34 \text{ N.} \\ \text{Length of the lever} &= 11 \text{ cm} = 0.11 \text{ m} \\ \text{Torque required} &= 34.34 * 0.11 \\ &= 3.78 \text{ N.m}\end{aligned}$$

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Since, we need torque of minimum 3.53 N.m. to shift gears and 3.78 N.m. to actuate clutch, we selected 2 servo motors of 4 N.m. torque.

IV. CIRCUIT DIAGRAM

The fig 1 (a) shows the simple circuit diagram of the electronic part of the system. The circuit uses primarily two motors, two switches, a PCB and power supply. The fig 1 (b) shows the prototype of the circuit which we used. Actual circuit is more complicated than the prototype. Actual circuit consists of a display to indicate the driver about the engaged gear. Also, battery available in the motorcycle is used as the power supply for the whole system. Because of this connections will also be more complicated. In order to simplify the circuit, those have been omitted.

As seen in the fig 1 (a), the two switches are the buttons that would be pressed by the driver as and when he feels the need to change the gear. One of the two is used for upshifting while the other for downshifting. They are connected to their respective servo motors through input and output pins on the PCB.

The connections to the servos and the program related to it, is to be done vigilantly, as both servo motors serve different purposes, any divergence from this might have unwanted ramifications. The resistors are used to limit the current flow through the switch which prevents it from getting damaged. Both the servos are connected in a similar way. The display connections mentioned above are all made using the remaining pins on the PCB. For the initial system prototype, a bread board was used. However taking into account its mounting feasibility on the bike, a PCB was designed to suit the purpose.

The power supply though initially used was an external one; the supply required on the bike is to be taken from the battery already available on board. The switches mentioned above too are open to damage from the supply. They need to have a resistor suitable with respect to the supply provided. Initially we used Arduino board for testing and tuning of the system, hence the supply had to be regulated according to the PCB limitations. However a self-designed PCB would not have such constraints and the system would be used in a wide range of supply.

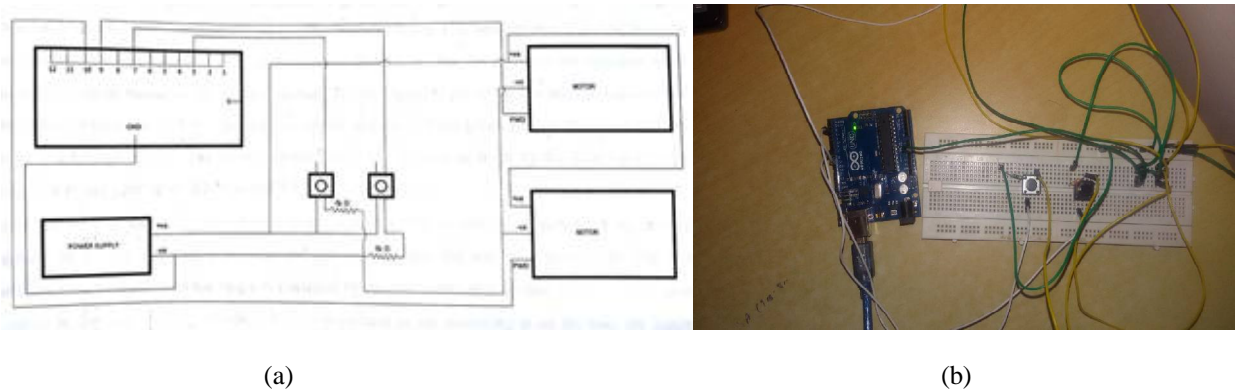


Fig. 1 Circuit Diagram

V. FOUR BAR MECHANISM

A four bar mechanism is used to transmit motion from one rotary link to another link which can either rotate or slide depending upon the type of joints used in the mechanism. There are 3 different types of four bar mechanism, namely: Planar quadrilateral linkage, Slider-crank linkage, Double Slider linkage. For our purpose, we implemented planar quadrilateral linkage. There are four links and four revolute joints in the planar quadrilateral linkage. One link in this type of linkage is always fixed and it is called as ground link. Other two links which rotate are called crank and rocker arm. The remaining link which joins crank and rocker arm is called as coupler.

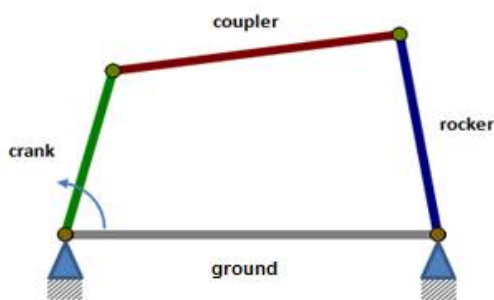
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Planar quadrilateral linkage is used to transmit the motion of DC servo motor to gearshift lever so that gear is shifted. In this linkage, crank (small link) acts as input link which is attached to the DC servo motor, while rocker arm (big link) is the gear shift lever used to rotate the shaft which is coupled to rocker arm.



VI. CONDITIONS FOR PROGRAMMING

1. Delay In Gear Actuation

If both motors are actuated simultaneously, gear will start shifting while clutch is disengaging. This is not a desirable condition, since engine torque is still being transmitted through gearbox which will wear out or break the synchro-rings. Hence, a delay is provided in the program so that gear is actuated after clutch is disengaged.

2. Holding Position Till Synchro-rings And Gear Teeth Align

Sometimes servo has to wait for few milliseconds till teeth of synchro-rings and gears are aligned and ready to engage. Torque is necessary to hold that position during this time to avoid delays.

3. Different Clutch Engagement Speeds:

For 1st gear, clutch needs to be engaged at much slower rate than other gears. With the help of program, we can provide desired speed to servo motor.

4. Limiting Gear Shifting:

If driver tries to downshift from 1st gear, then program should avoid this task. Similar is the case of upshifting from 5th gear. Hence, gear counter loop is used in the program to prevent actuating these types of situations.

5. Achieving Neutral Between First And Second Gear:

Less torque is required to attain neutral between first and second gear. Also, the angle required to shift into neutral is different than other gears. Hence, angle and speed, corresponding to the required torque, is added in the program to achieve neutral state.

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VII. RESULTS

The system being tested on TVS Star city we have noticed the observations:

Table 1: Gear shift time for each gear

Gear Engaged	Gear Shift time (secs)
1 st	0.85
2 nd	0.75
3 rd	0.65
4 th	0.7

As seen in table no.1, the time mentioned consists of the total time required to completely engage the gear (clutch disengage + gear shift + clutch engage). The graph in fig. 2 elaborates given values in the table by bifurcating the time and comparing them.

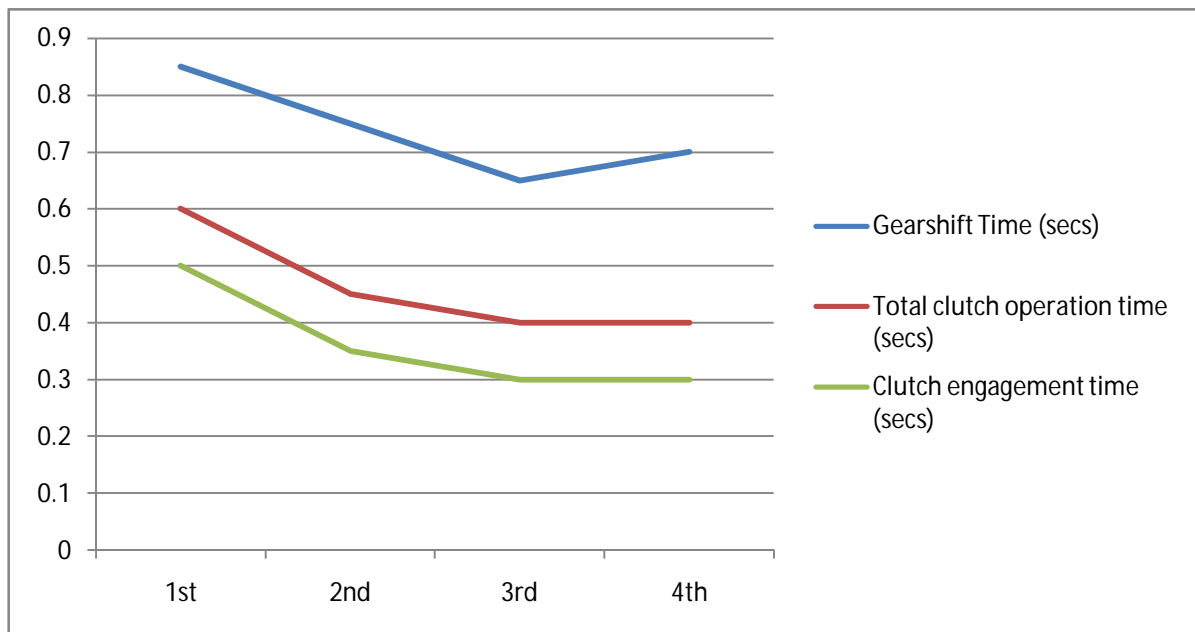


Fig. 2 Gear & Clutch Comparison

As observed in fig.2, the clutch engagement time for the first gear is highest while for the rest of the gears it is subsequently reduced. This is because, while the gears are engaged, the drive to them given by the engine-through clutch- needs to be actuated relatively slowly so as not to stall the engine. The time for clutch engagement for first gear is achieved by trial and error. This value or time is not same for any two vehicles and thus needs to be changed for a specific vehicle.

Ideally the value for gear engagement should decrease after the first gear and remain stable at a certain value. However the vehicle being old and system still to be optimized, there are some aberrations in the reading but within the acceptable limits.

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VIII.CONCLUSION

AMT concept though prevalent and efficient in cars as we have them today, it has failed to acclimate itself in the two wheeler segment. This project has shown satisfactory results even with such simplicity of it. The system tests conducted on the bike converting the presently used manual transmission to an automated transmission provides following benefits:

- Increased conform
- Shifting without delay lessening efficiency loses
- Low cost to manufacture and can be retrofitted with ease

Needless to say this system is by no means perfect and still at an infant stage. It can be even more fine-tuned to suit the vehicle. In this project we have only influenced only the manual part played in shifting mechanism-like clutch and gear. Though we have made substantial headways in making sure the system doesn't fail based the contingencies mentioned above, the program or the algorithm used in the system we have worked has limited feedback.

We have checked this system and it works as expected under suitable conditions but not all. Thus it is imperative to note the things needed to have it a full-proof system. These are nothing but a range of sensors like throttle sensor, vehicle speed sensor, Engine RPM sensor which are more prominent among them.

This system though is simple is found to be easy to manufacture and technically feasible. We can change the motor as per the requirement of the vehicle that needs to be fitted. Thus this is a scalable design and can be easily fitted to any bike having different specifications with minimal changes.

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