Modelling a Jerk-free gear shift controller using LabVIEW

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ABSTRACT

In this paper, a dynamic model of a vehicle driveline with an automatic transmission is built up and implemented in the Graphical programming language, LabVIEW. The transmission model is built in a modular way to facilitate reuse and make the model well-arranged. The model has been developed from an existing model that describes the driveline of a vehicle with manual transmission. The purpose of this project is to develop an Automatic Transmission controller model that can be used to simulate clutch engagement and Gear shifting of a driveline. This paper proposes a solution by presenting the result and methodology of implementing smooth gear shifting control and Jerk-free automatic clutch engagement and disengagement of a common four wheeled vehicle using NI lab VIEW compact RIO (NI CRIO) with enough GUI. With add-on facilities, this Automatic Transmission controller model can be used as a system design support tool, which provides highly sophisticated simulation environment in mere future.

Keywords- Automatic gearbox system, Gear shifting control and Jerk-free automatic clutch engagement.

1. INTRODUCTION

The transmission plays an important role in vehicle performance and fuel economy because it smoothly transfers the engine torque to the vehicle with the desired ratio. Currently, many types of transmission, such as (automated) manual transmission, continuously variable transmission, and dual-clutch transmission, have been applied for various purposes. However, automatic transmission is the most popular type among these choices due to its good performance and its need for less maintenance during its product life. During gear shifting, the gear ratio should be controlled from one level to another by these frictional clutch components, considering driving comfort and component life. Many researches on gearshift quality control have been published in the last decades. In general, closed-loop control is applied in the inertia phase to enhance the gearshift quality, because the oncoming clutch is expected to engage, and the speed ratio intensively changes in this phase.

1.1. Manual Transmission

Just like that of a manual transmission, the automatic transmission's primary job is to allow the engine to operate in its narrow range of speeds while providing a wide range of output speeds. Without a transmission, Vehicles would be limited to one gear ratio, and that ratio would have to be selected to allow the car to travel at the desired top speed. If you wanted a top speed of 80 mph, then the gear ratio would be similar to third gear in most manual transmission vehicle. You've probably never tried driving a manual transmission vehicle using only third gear. If you did, you'd quickly find out that you had almost no acceleration when starting out, and at high speeds, the engine would be screaming along near the red-line. A vehicle like this would wear out very quickly and would be nearly undividable. In order to protect the transmission from serious damage, driver should buy vehicles equipped with transmission coolers.

The key difference between a manual and an automatic transmission is that the manual transmission locks and unlocks different sets of gears to the output shaft to achieve the various gear ratios, while in an automatic transmission; the same set of gears produces all of the different gear ratios. The planetary gear set is the device that makes this possible in an automatic transmission. Before the gear switching is on according to output speed, the gears have to be energised from the torque force developed by the torque converter. A torque converter is a type of fluid coupling, which allows the engine to spin somewhat independently of the transmission. Just like manual transmission cars, cars with automatic transmissions need a way to let the engine turn while the wheels and gears in the transmission come to a stop. Manual transmission cars use a clutch, which completely disconnects the engine from the transmission. Transmission cars use a torque converter. As mentioned below, there are four components inside the very strong housing of the torque converter:

- Pump
- Turbine
- Stator
- Transmission fluid

The housing of the torque converter is bolted to the flywheel of the engine, so it turns at whatever speed the engine is running at. The fins that make up the pump of the torque converter are attached to the housing, so they also turn at the same speed as the engine. The cutaway below shows how everything is connected inside the torque converter.

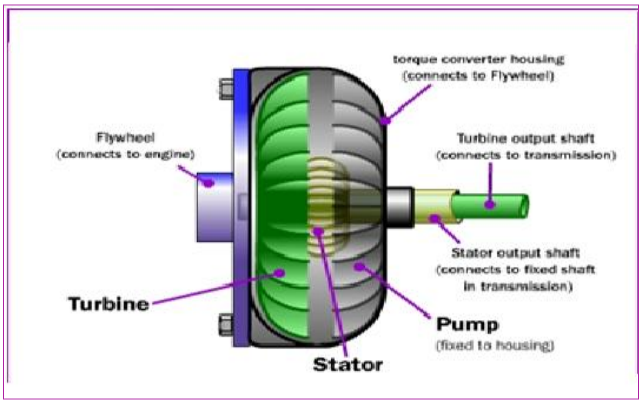

Figure 1 How the parts of the torque converter connect to the transmission and engine.

The pump inside a torque converter is a type of centrifugal pump. As it spins, fluid is flung to the outside, much as the spin cycle of washing machine flings water and clothes to the outside of the wash tub. As fluid is flung to the outside, a vacuum is created that draws more fluid in at the centre.

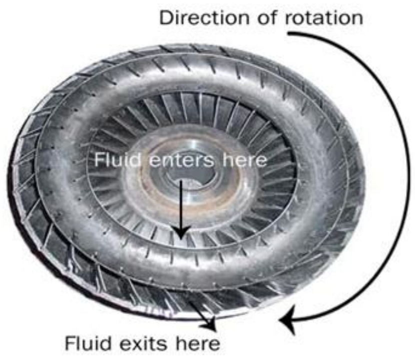

Figure 2 The pump section of the torque converter is attached to the housing.

The fluid then enters the blades of the turbine, which is connected to the transmission. The turbine causes the transmission to spin, which basically moves your car. You can see in the graphic below that the blades of the turbine are curved. This means that the fluid, which enters the turbine from the outside, has to change direction before it exits the centre of the turbine. It is this directional change that causes the turbine to spin.

In order to change the direction of a moving object, you must apply force to that object -- it doesn't matter if the object is a car or a drop of fluid. And whatever applies the force that causes the object to turn must also feel that force, but in the opposite direction. So as the turbine causes the fluid to change direction, the fluid causes the turbine to spin. The fluid exits the turbine at the centre, moving in a different direction than when it entered. If you look at the arrows in the figure above, you can see that the fluid exits the turbine moving opposite the direction that the pump are turning. If the fluid were allowed to hit the pump, it would slow the engine down, wasting power. This is why a torque converter has a stator.

2. OBJECTIVE

An Automatic transmission is a type of motor that can automatically change gear ratios as the vehicle moves, freeing the driver from having to shift gears manually.

- To control the clutch slip and gear shifting
- To engage the lock ON and OFF during every gear shifting.
- To sense the brake pedal operation and actuate the Auto Retarder valve solenoid.
- To sense the pressure and temperature of the transmission and drives the appropriate warning indication.

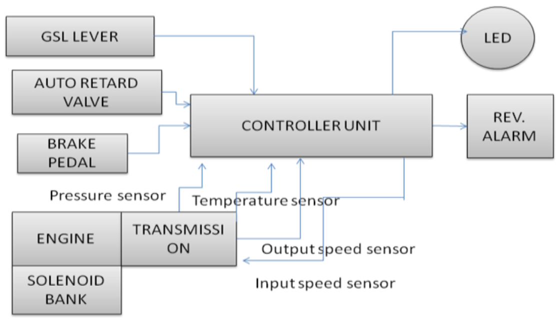

Figure 3 Block diagram of proposed automatic transmission controller.

3. METHODOLOGY

The method chosen to design the controller here is open loop method. An open-loop controller, also called a non-feedback controller, is a type of controller that computes its input into a system using only the current state and its model of the system. A characteristic of the open-loop controller is that it does not use feedback to determine if its output has achieved the desired goal of the input. This means that the system does not observe the output of the processes that it is controlling. Consequently, a true open-loop system can not engage in machine learning and also cannot correct any errors that it could make. It also may not compensate for disturbances in the system. An open-loop controller is often used in simple processes because of its simplicity and low cost, especially in systems where feedback is not critical. Open-loop control is useful for well-defined systems where the relationship between input and the resultant state can be modelled by a mathematical formula.

4. SYSTEM MODEL

The automatic transmission considered here is a four-speed automatic transmission, which consists of a torque converter, a planetary gear system with the final speed reducer, frictional components, and a electro hydraulic control system. The power for the automatic transmission is from a gasoline engine. The torque converter transfers the power from engine to transmission, and its variable torque amplification improves acceleration and performance. Clutches are the frictional components in any automatic transmission, and the various speed ratios are realized by clutch engagement and disengagement to regulate the operating range of the engine. The electro hydraulic control system is an important part in an automatic transmission, providing fluid pressure to the clutches by pushing the fluid oil into the clutch cylinder. The general block diagram of an automotive transmission controller is as given below.

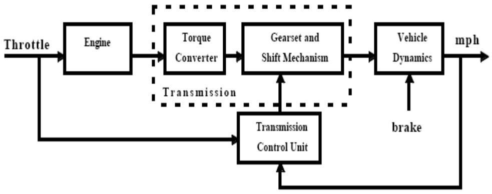

Figure 4 Generic block diagram for a drive train system

The throttle opening is one of the inputs to the engine. The engine is connected to the impeller of the torque converter which couples it to the transmission.

The input-output characteristics of the torque converter can be expressed as functions of the engine speed and the turbine speed.

For a given throttle in a given gear, there is a unique vehicle speed at which an up shift takes place.

4.1 Gear up shifting and down shifting

The vehicle output speed and its corresponding gear up shifts is considered and the model is designed. Similarly, to slow down the vehicle speed and finally to stop the vehicle, gear down shifting logic is implemented.

Apart from considering vehicle in normal mode and its corresponding shift points, a vehicle especially cannot restrict it from hilly terrain. Thereby the gear shift points in hill mode is also effectively programmed.

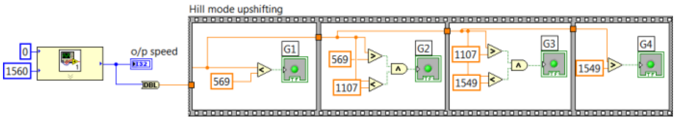

Figure 5 Lab VIEW programming for hill mode up shifting.

4.2 Energising gears

The gear solenoids are energised as per the GSL positions. If the GSL is in 1, then SF & S1 are energised. S2, S3 & S4 are all in de-energised conditions.

If GSL is in 2, then SF is continued to be in ON; S1 is made OFF and S2 is made ON continuously.

If GSL is in 3, then SF is continuous to be in ON continuously; S1 & S4 are in OFF condition.

If GSL is in 4, then AUTO mode is enabled. SF continuous to be ON. Any one of the gear solenoid S1, S2, S3 or S4 is made ON with respect to the output speed and the position of Normal/Hill mode selection.

If GSL is in reverse, SR and S4 are made ON simultaneously. All other solenoids are i.e., S1, S2 or S3 should be in OFF condition.

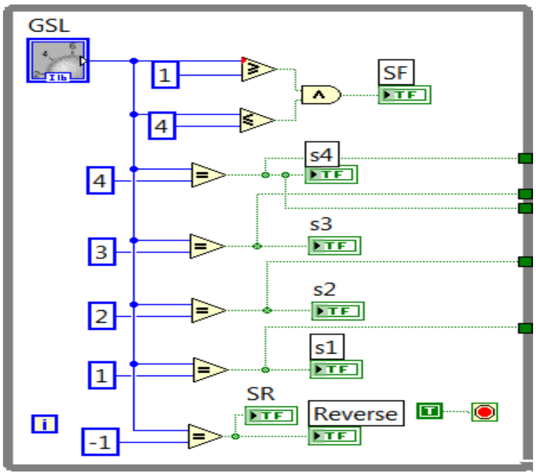

Figure 6 Programming for energising of gears.

4.3 Lock up solenoids

Lockup solenoids are electronic components found in some automatic transmissions. These solenoids are designed to lock a torque converter in place under certain circumstances, such as highway speeds. This is done for a variety of reasons, including to keep the transmission from overheating and to improve gas mileage. When a lockup solenoid fails, the torque converter may fail to lock into place at highway speeds, or can stay locked up even after the vehicle slows down. This can result in poor gas mileage, the stalling of an engine, and other problems.

The main component is a torque converter, which functions as a fluid coupling between the engine and transmission. Similar to the operation of a mechanical clutch, a torque converter is able to lock up and transfer power to the transmission, or spin freely when the vehicle is not in motion. To ensure the shifts of gear and thereby to sustain in that particular gear in driving mode corresponding to the vehicle output speed, solenoids of the individual gears has to be locked up. To assure that these solenoids are locked up during every gear shift, Lock up solenoid engagement logics are framed. It includes following conditions:

- SLU should not be engaged when GSL is in Neutral or Reverse.
- SLU remains engaged whenever SRET is energised, except during Gear shifts.
- LU should be disengaged in any gear if the output speed is less than 250 rpm.
- If GSL is in 1/2/3/4 (Forward) and the ratio between the engine speed & Turbine speed exceeds 0.76, then LU should be engaged. Should be disengaged when ratio is less than 0.76.

The above logics are programmed effectively in Lab VIEW.

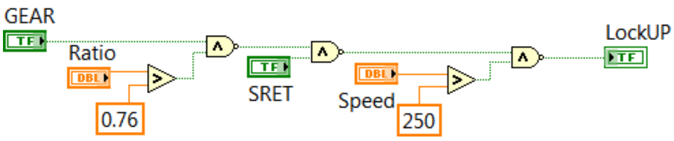

Figure 7 Lock up solenoid programming satisfying conditions.

4.4 Retarder solenoid

A retarder is a device used to augment or replace some of the functions of primary friction- based braking systems. Retarders serve to slow vehicles, or maintain a steady speed on declines, and help prevent the vehicle from 'running away' by accelerating down the decline. They are not usually capable of bringing vehicles to a standstill, as their effectiveness diminishes as vehicle speed lowers. They are usually used as an additional 'assistance' to slow vehicles, with the final braking done by a conventional friction braking system. As the friction brake will be used less, particularly at higher speeds, their service life is increased.

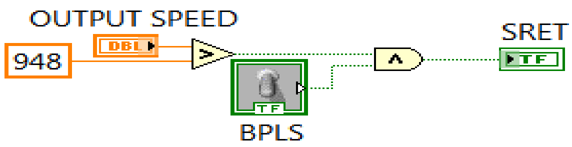

Figure 8 Brake Pedal Lockup Solenoid.

4.5 Safety interlocks

An interlock is a device used to prevent undesired states in a state machine, which in a general sense can include any electrical, electronic, or mechanical device or system. In most applications an interlock is used to help prevent a machine from harming its operator or damaging itself by stopping the machine when tripped. Household microwave ovens are equipped with interlock switches which disable the magnetron if the door is opened. Similarly household washing machines will interrupt the spin cycle when the lid is open. Interlocks also serve as important safety devices in industrial settings, where they protect employees from devices such as robots, presses, and hammers. While interlocks can be something as sophisticated as curtains of infrared beams and photo detectors, they are often just switches. At anytime only one solenoid should remain engaged electrically

- SF or S1.
- S1 or S2 or S3 or S4.

4.6 Forward- Reverse Lock

If Ne > 700 rpm or V0 > 0, S4 should not engage even if GSL is put in reverse position. If Ne > 700 rpm or V0 > 0 & S4 is in engaged condition, SF should not energise even if GSL is put in 1, 2, 3 or 4 (Forward) positions.Direction change only when vehicle is standstill; Ne < 700 rpm & V0=0 rpm.Direction change is inhibited if parking brake is ON.

In case of failure of speed sensor, the gear engaged before occurrence of fault will remain engaged. No up shift / down shift will be activated.

4.7 Alarm Annunciator

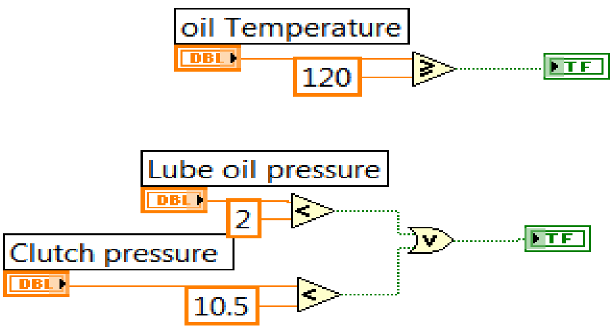

Figure 9 Alarm Annunciator.

An intimation, threat, or sign of impending danger. In other words a cautionary signal that may result in injury or death if not carefully observed or followed. In this project, to facilitate the driver with critical warning parameters such as oil temperature, oil pressure and clutch pressure that affects the transmission of the vehicle also may lead to death of the driver if ignored is concentrated and following logics are implemented. If the transmission oil temperature is > 120 deg C, a warning is displayed on the driver's LCD. If the transmission lube oil pressure is < 2 bar or clutch pressure is < 10.5 bar, warning is displayed on LCD.

5. RESULT

In summary, a gearshift controller has been developed, which is designed to regulate the turbine speed, and suppress the output shaft oscillation by single-clutch pressure control. Based on open loop technique, a transmission controller is proposed. The designed controller overcomes the influences of different friction characteristics and parameter uncertainties to the gearshift control. The simulation of 1, 2, 3 &4 up shift and down shift both in Normal mode and Hill mode indicates that the employed controller design technique is efficiently robust to friction property and uncertainties of the general transmission control system. It also shows that, for the proposed gearshift controller, additional engine torque control could be involved to improve the gearshift quality.

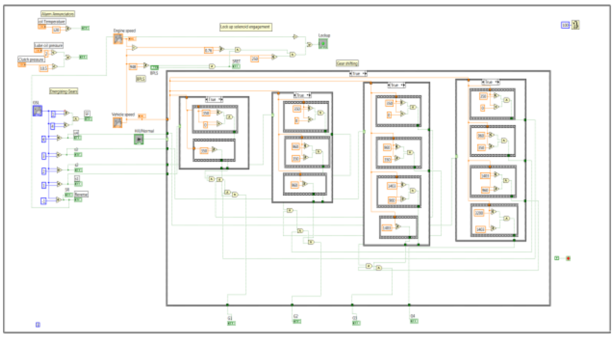

Figure 10 The simulation block diagram of an automatic transmission controller in Lab VIEW.

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