

Clamping Force Control for Dry-Type Dual Clutch Transmission Using Kissing Point Estimation

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ABSTRACT

In this paper, a kissing point estimation is proposed for a 2-speed dry-type dual clutch transmission. The kissing point estimation is performed using the gradient change of the motor actuator torque and rotational displacement. Using the kissing point estimation, clamping force control is proposed, and its performance is investigated by the simulator of electric vehicle with 2-speed dry-type dual clutch transmission. It is found from the simulation results that the shift quality can be maintained by the clamping force control using the kissing point estimation.

CITATION: Ahn, S. and Hong, S., "Clamping Force Control for Dry-Type Dual Clutch Transmission Using Kissing Point Estimation," *SAE Int. J. Passeng. Cars - Mech. Syst.* 6(3):2013, doi:10.4271/2013-01-2585.

INTRODUCTION

In electric vehicles (EV), a reduction gear with single gear ratio has been used instead of transmission because electric motor can generate higher torque at low speed, and its speed range is wider than that of engine [1, 7]. However, recently, transmission for electric vehicle has become hot issue to improve fuel economy, i.e., electric driving distance, and reduce electric motor size. Using the transmission, electric motor can be operated more efficiently, and its size can be down-sized. It is not easy to use conventional transmission such as multi-speed automatic transmission, continuously variable transmission and multi-speed dual clutch transmission due to their cost, weight, and parasitic power losses [1,6,7].

To overcome these disadvantages, a 2-speed dry-type dual clutch transmission has been investigated for the EV transmission [1,7]. Since the clutch wear occurs in dry clutch, kissing point where the power begins to be transmitted to the output shaft through clutch plate changes. Therefore, clutch clamping force needs to be controlled by considering this change.

In dual clutch transmission, clamping force control is an essential element for shift performance such as shift time and shift quality. Because the clutch clamping force depends on the actuator travel, a relationship between the actuator travel and clamping force needs to be obtained [1,4].

Since dry clutch characteristics change depending on the clutch wear, kissing point estimation is required to sustain the proper clamping force for actuator travel change [4].

This paper presents the kissing point estimation and clamping force control for 2-speed dry-type dual clutch transmission. To estimate the kissing point, current and voltage of the motor actuator are obtained by SCU (stroke control unit), and rotational displacement is measured. Using these information, the kissing point is estimated, and is used to modify actuator stroke profile. Based on the kissing point estimation, a clamping force control is proposed.

Modeling of the Motor Actuator System

Figure 1 shows a structure of the motor actuator system of clutch 1 for 2-speed dry-type dual clutch transmission of a EV under study. The SCU commands the motor actuator to engage or disengage a clutch plate with a flywheel. As the motor actuator rotates, the screw moves linearly to make the release bearing push the diaphragm spring. The pulling cover pulls the clutch plate, and then it approaches toward the flywheel. As soon as the clutch plate and the flywheel are engaged, the driving motor power of the EV is transmitted from the flywheel to the transmission through clutch 1.

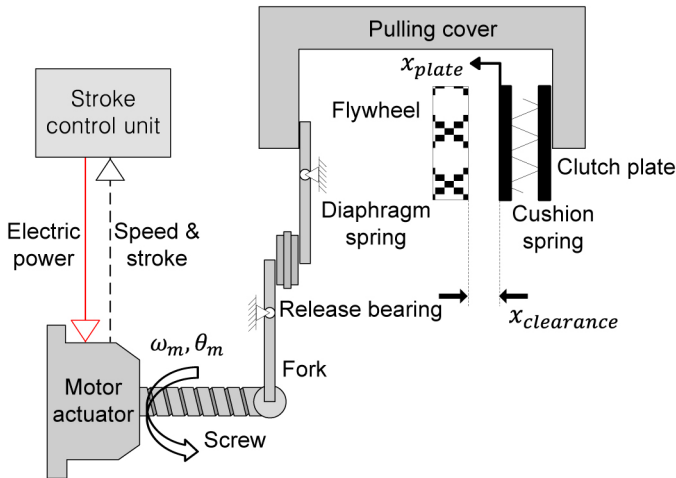


Figure 1. Structure of the motor actuator system for clutch 1

A. Motor actuator

Brushless D.C. motor (BLDC motor) is used as the actuator. The motor actuator is modeled as follows.

$$di/dt = V/L - Ri/L - K_{EMF}\omega_m/L \quad (1)$$

$$T_m = K_{motor}i \quad (2)$$

$$J_m\dot{\omega}_m + T_{friction} + T_{load} = K_{motor}i \quad (3)$$

where V is the armature voltage, R is the armature resistance, i is the armature current, K_{EMF} is the back-emf constant, ω_m is the motor speed, and L is the armature inductance. T_m is the motor torque, K_{motor} is the motor torque constant. $T_{friction}$ is the friction torque, T_{load} is the load torque, and J_m is the angular inertia of the motor.

B. Screw, fork, and release bearing

As the motor actuator rotates, the screw moves in linear motion through the lead angle. End point of the screw pushes or pulls the fork. The fork operates as a lever.

C. Diaphragm spring

The release bearing pushes the diaphragm spring. As the diaphragm spring is pushed by the release bearing, it pushes the pulling cover. Figure 2 shows the characteristic curve of the diaphragm spring. The diaphragm spring is installed with initial compression.

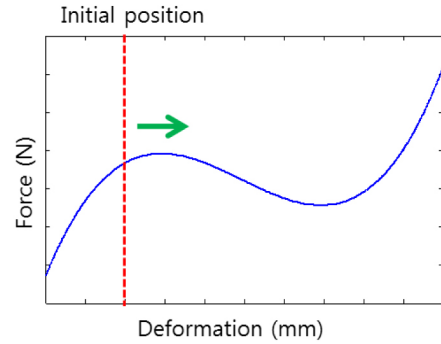


Figure 2. Characteristic map of the diaphragm spring

D. Cushion spring

The cushion spring is installed between the clutch plates. As the plate moves, the cushion spring is compressed after the clearance is eliminated. Figure 3 shows the characteristic curve of the cushion spring. At the lock up point, the cushion spring force shows the maximum force.

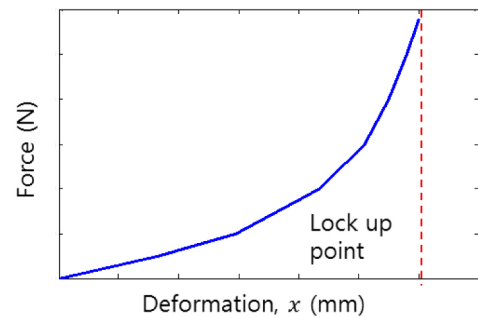


Figure 3. Characteristic map of the cushion spring

E. Simulator of the motor actuator system

A simulator of the motor actuator system is shown in Figure 4. Using the dynamic equation and characteristic map of the motor actuator system, T_{load} which is generated at the flywheel is obtained and is feed-backed to the actuator motor. As T_{load} increases, the motor actuator torque needs to be increased to supply proper input torque.

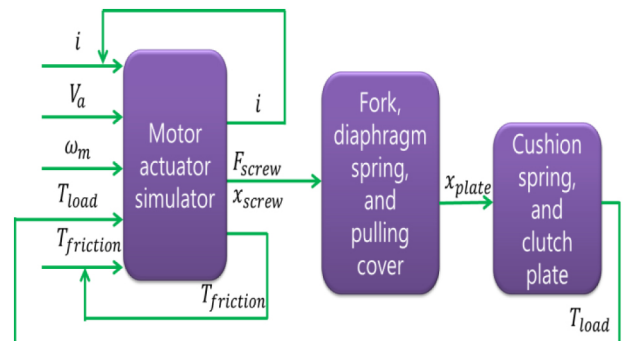


Figure 4. The motor actuator system simulator