Iterative Learning Control for wet-plate clutches

Gregory Pinte ¹,², Wim Symens ¹, Jan Swevers ²
¹Flanders’ Mechatronics Technology Center
²Department of Mechanical Engineering, Division PMA, Katholieke Universiteit Leuven
Celestijnenlaan 300 B/D, 3001 Heverlee, Belgium
Email: gregory.pinte@fmtc.be

1 Introduction
A wet-plate clutch (Fig. 1) is a mechanical device that transmits torque from its input axis to its output axis by means of friction. The input axis of the clutch is connected to a drum, which is a hollow cylinder with grooves on the inside. A first set of friction plates (clutch plates) with external toothing that can slide in those grooves are pressed against a second set of friction plates (clutch discs) with internal toothing that can slide over a grooved bus connected to the output axis. When the two sets of friction plates are pressed against each other by a piston, torque is transmitted. Initially, when the clutch is not engaged, the piston should be positioned as far as possible from the friction plates to avoid losses due to viscous friction of the oil between the plates. When the vehicle control unit gives the command to close the clutch, the distance between the piston and the plates should be decreased as fast as possible to zero, without the piston and the plates making brutal contact. Nowadays, this is achieved using feedforward control of the electro-hydraulic valve. However, long calibration procedures are necessary to find the optimal feedforward signal for a smooth clutch engagement. Furthermore, since the controlled system is time-varying (wear of the friction plates, variable temperature,...), regular recalibrations of the control signal are inevitable. To avoid these cumbersome calibrations, an ILC control system [1] is developed, which learns the appropriate control signal based on the quality of the previous engagements.

2 ILC controller
To bring the piston close to the friction plates, a position reference trajectory is defined that has to be learned by the ILC controller. Afterwards, the final engagement of the clutch is realized using an additional feedforward action. Good tracking of the reference leads to a small feedforward action and consequently to a smooth and fast clutch engagement. The ILC scheme, used for the reference tracking, is added to a closed position loop. The performance of this closed loop with a linear feedback controller is low because of the time delay and the nonlinearity of the controlled system. However, this performance can be significantly increased by the ILC controller, which updates the control signal at each engagement based on the control signal and the reference error at the previous engagement. To take into account varying parameters in the system, the reference trajectory of the ILC system is adapted online. Since it is too expensive to equip all clutches with a sensor to detect the piston’s displacement, in a second part of the project, a pressure sensor is used as the input in a similar control configuration.

3 Experimental results
The controllers are validated on a non-rotating wet-plate clutch. Fig. 2 shows the results for the ILC of the piston position with an adaptive reference. When the number of controlled engagements increases, the tracking response improves due to the ILC action and the engagement quality becomes better. After 5 engagements, the end point of the reference trajectory is adapted, which leads to a decrease of the feedforward action and a further improvement of the clutch engagement quality. Future work consists of an extension to a rotating set-up, where additional challenges are expected e.g. due to the centrifugal disturbing forces.

Figure 1: Design of a wet-plate clutch

Figure 2: Effect of ILC on the piston position.

References