Drivability improvements for a single-motor parallel hybrid electric vehicle using robust controls

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Key objective

In a single-motor parallel hybrid electric vehicle, the engine should be started with the motor via the clutch when needed. Consequently, the clutch torque causes significant disturbance to the driveline, especially at the end of the clutch engagement process in which the clutch lockup causes a step torque disturbance. These disturbances can result in drivability problems including driveline oscillations and jerks which can cause discomfort for the passengers. The objective of this paper is to improve vehicle drivability during mode transitions for a single-motor parallel hybrid electric vehicle. The structure of the single-motor parallel hybrid electric vehicle is shown in Fig. 1.

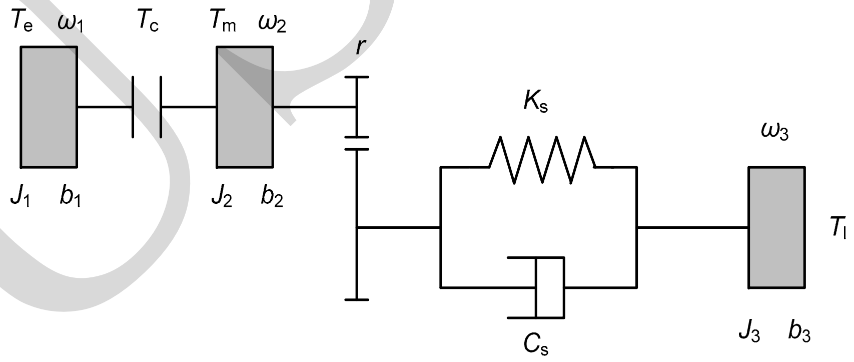

Fig. 1

Key methodology

Two controllers are proposed. The first controller is the engine-side controller for engine cranking/starting and speed synchronization. The second controller is the motor-side controller for achieving a smooth mode transition with reduced driveline oscillations and jerks under the clutch torque induced disturbance and system uncertainties. The controllers are all composed of a feed-forward control and a robust feedback control.

Key conclusions

The proposed controller is able to achieve a smooth mode transition with reduced driveline oscillations and jerks under the clutch torque induced disturbance and system uncertainties, as shown in Fig. 2 and Fig. 3.

Notes: The condition for the simulation is a mode transition from electric drive mode to engine drive mode, which includes engine cranking/starting, speed synchronization and clutch lockup.

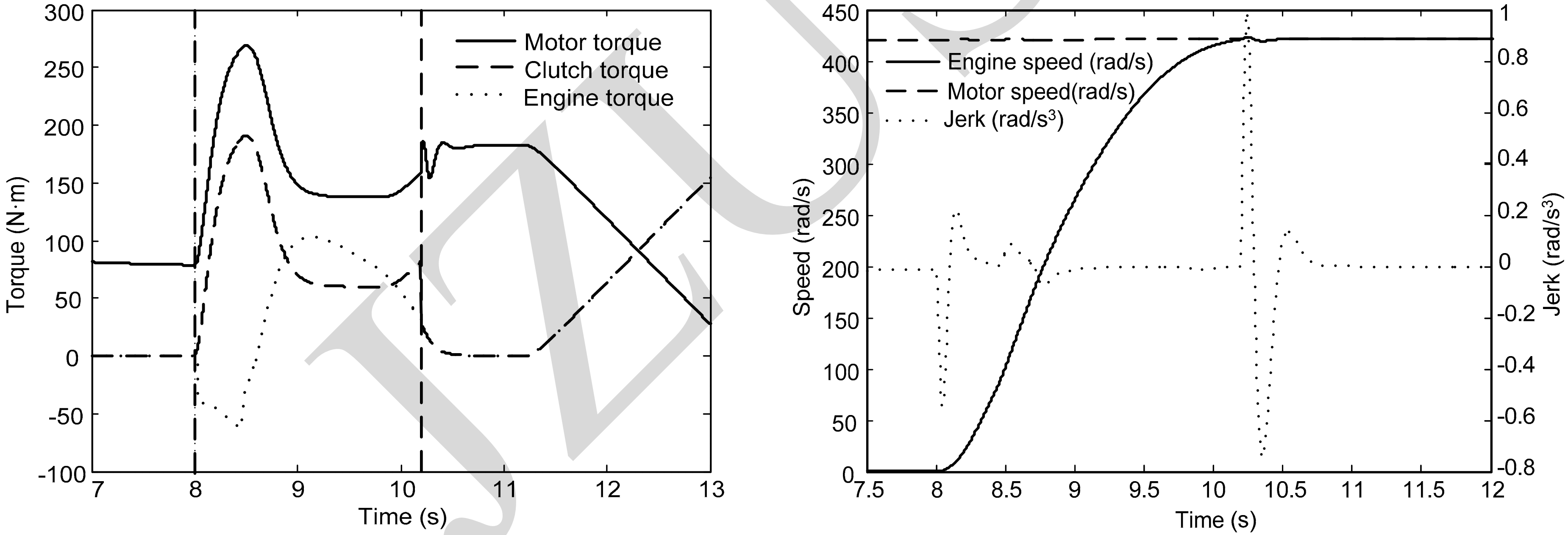

Fig. 2 Nominal simulation results with proposed engine side control and proposed motor side control

Key conclusions

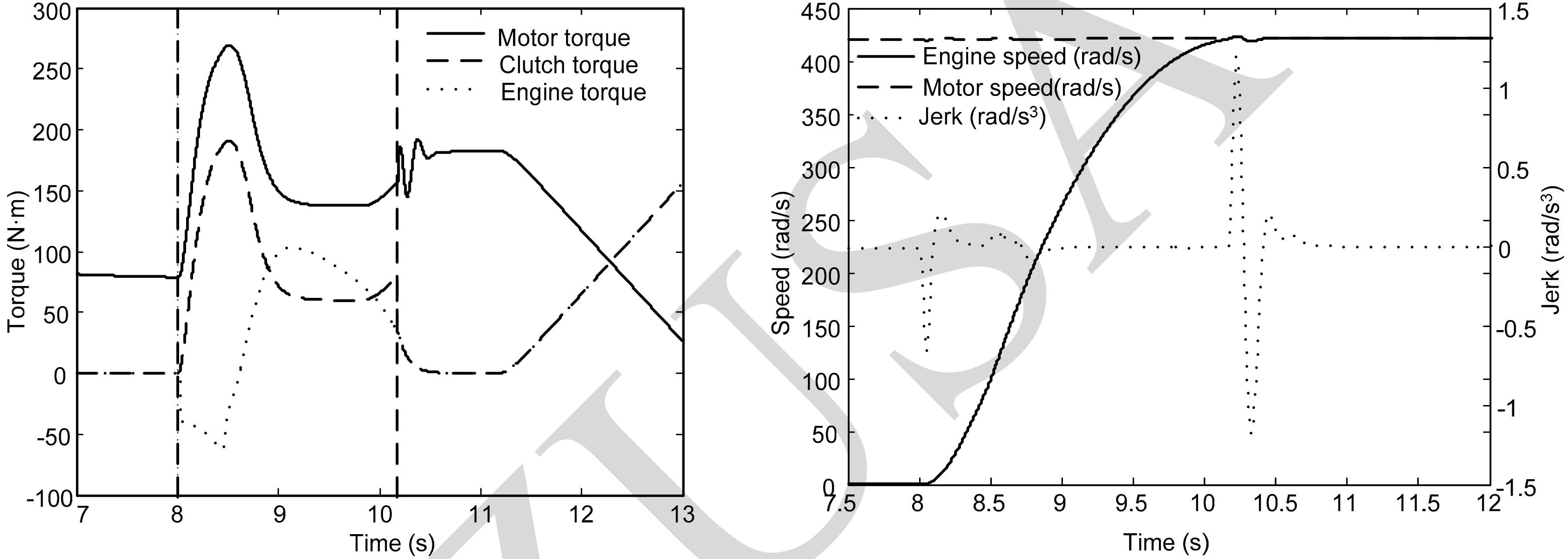

Fig. 3 Simulation results with system uncertainties and time delays using proposed engine side control and proposed motor side control

As shown in Fig. 3, when system uncertainties and time delays are taken into account, the driveline jerk is slightly increased but is still within an acceptable range. The control system is robust to parameter uncertainties and time delays.