Challenges and Opportunities in Automotive Transmission Control

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Automotive Transmission Technologies

- Step gear automatic transmission
- Manual transmission
- Starting clutch/friction launch transmission
- Automated manual transmission
- Continuously variable transmission
- Electrical variable transmission
Step Gear Automatic Transmission

- Increasing number of speeds
- Migrate to clutch to clutch shift
Starting Clutch/Friction Launch Transmission

- For better fuel economy and possible lower cost, a starting clutch is used to replace the torque converter
- Clutch slip control is critical to achieve desirable drivability

\[ T = f(\mu, P) \]  \hspace{1cm} T: Torque \hspace{1cm} \mu: Friction coefficient

\[ V_{slip} = f(P) \]  \hspace{1cm} V_{slip}: Slip speed \hspace{1cm} P: Pressure
Continuously Variable Transmission

- Better fuel economy and drivability
- Unique actuation challenges
  - Belt drive CVT
  - Chain drive CVT
  - Toroidal drive CVT
- Control objective: enable fast and smooth ratio change while maintain required torque capacity
Electrical Variable Transmission

- New transmission for hybrid electrical vehicles
- Better fuel economy and emission
- Potential control challenges

- Coordination between engine, motor and generator
- Power recirculation issues
- Smooth shift

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Clutch Fill Control

- The fill process
- Over fill and under fill
- Potential remedies
Effect of Clutch Over Fill on Upshift

Power-On Upshift

- Engine Speed
- Output Torque
- Offgoing Pressure
- Oncoming Pressure command & actual

Time (s)

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Clutch Slip Control

Objective: To reduce fuel consumption and provide driveline damping by clutch slip control

Clutch slip control is essential for many different transmission technologies:

• Starting clutch/Friction launch
• Dual clutch transmission
• Electrical converter clutch control (ECCC)
Effect of Clutch Slip Control

- **Upshift with No Control Damping**
  - Engine Speed
  - Output Torque
  - Oncoming Pressure
  - Offgoing Pressure

- **Upshift with Control Damping**
  - Engine Speed
  - Output Torque
  - Oncoming Pressure
  - Offgoing Pressure
Transmission Control Calibration

- Challenge: number of calibration variables goes up quickly with more gear ratios and new powertrain features

- Approaches: systematic approach for calibration
  - Automated tuning
  - Model based control
  - Adaptive learning

- Issues: complexity vs robustness
  - Non-model based control: compatible with traditional calibration process, but may not reduce the complexity drastically.
  - Model based control: greatly reduce or potentially eliminate the calibration complexity, but system robustness highly depends on the fidelity of the model
Shift Schedule

- Objective: Optimize the fuel economy while maintaining drivability

- Traditional way of scheduling shifts
  - Throttle angle
  - Vehicle speed

- New trend in shift scheduling
  - Shift business avoidance
  - Dynamic programming, fuzzy logic, learning control
Hardware Development

- Sensing level
  - Torque sensor
  - Pressure sensor

- Actuation level
  - Fast hydraulic control valve
  - Alternative clutch actuation device

- System level
  - Mechatronic transmission (gear-box integrated electronics)
Alternative Clutch Actuation Device

Objective: To replace the electro-hydraulic clutch actuation system

Benefits: Reduced fuel consumption and enhanced clutch controllability and bandwidth

• Electrical motor driven clutch actuation
  – Require some type of gearing
  – Limited power density

• Smart material based clutch actuation
  – Electrorheological (ER) and magnetorheological (MR) material based clutch
  – Torque capacity and durability
Summary

Key drivers for automotive transmission development:

- Fuel economy and emission
- Market trend
- Cost

Research and development in both software and hardware are needed to further advance the automotive transmission technology.