Engine Control Strategy for AMT Upshifting of Commercial Vehicle

Zhen-jie LIU¹*, Chao Yi¹, Wei CAO² and Kai ZHAO¹

¹China North Vehicle Research Institute, State Key Laboratory of Vehicle Transmission, Beijing China
²NAVECO LTD Nanjing China
*Corresponding author

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Abstract. In order to improve the shift quality of automatic mechanical transmission (AMT), the upshifting process was divided into five stages and the engine target speed and control strategy of each stage were formulated based on the characteristics of clutch work. Based on SAEJ1939 protocol, Engine speed and speed limit torque control by sending engine control mode were implemented. The results of test on NJ2046 vehicle showed that the engine control strategy realized the engine control very well, and the AMT upshifting comfort was improved.

Introduction

Automatic Manual Transmission (AMT) has been widely used with the advantages of simple structure and high transmission efficiency. But AMT shift quality is not as good as other automatic transmissions because of the power interruption, out of sync between engine speed and input shaft speed when upshifting. Therefore, engine speed should be controlled by speed or torque intervention.

Engine speed or torque intervention control has three control modes such as speed control, torque control and speed & torque limit control. Engine torque mode controls the engine by calculating engine demand torque through the demand speed look-up table; this control is mainly used in passenger cars. Engine speed mode controls the engine by calculating engine demand speed, this control mode often cause the engine speed exceeding its limit because of the large inertia of commercial vehicle when AMT upshifting. Engine speed & torque limit mode controls the engine by limiting the engine speed and torque; this control is mainly used in AMT upshifting control.

In this paper, the AMT upshifting strategy was formulated on the basis of analyzing the process of upshifting. The engine speed was controlled precisely through the speed control and speed & torque limit control when AMT upshifting.

Stages of AMT Upshifting

The process of AMT upshifting was analyzed based clutch work characteristic. The first step is to make the clutch separate until slipping point in the process of AMT upshifting. And then the shift actuator move to complete selecting and engaging gear after clutch separated. At last clutch combines, AMT upshifting completed.

Take the clutch displacement as the basis of stages division, stages of AMT upshifting were showed in figure 1.
Stage 1: Clutch combines completely, so we call close stage.
Stage 2: Clutch began to move until slipping point, at this stage, clutch has been transmitting torque, so we call unload stage.
Stage 3: Clutch displacement is above slipping point. Shift actuator move, clutch has not been transmitting torque, so we call clutch open stage.
Stage 4: Shift actuator movement completed, clutch began to combine and transmit torque, so we call clutch load stage.
Stage 5: Speed difference between engine speed and prim speed gradually become smaller, when speed differences come to 100(r/min), AMT upshifting comes to fast-close stage.

Engine Control Strategy in the Process of AMT Upshifting

For AMT, upshifting comfort depends on the coordination between engine speed and prim speed, engine control based on the engine torque was eventually taken as feedback to the engine speed changes. Engine control strategy takes engine speed as control objectives; vehicle demand for engine torque will eventually feed back to the target engine speed changes.

Analysis in the Process of AMT Upshifting

Vehicle speed is considered as constant in the process of AMT upshifting, but the gear ratio changes smaller, as a result, prim speed reduced, in order to reduce shift shock, engine speed need to reduce.

The varies of engine speed, prim speed and vehicle speed was showed as figure 2.

Stage 1: Clutch is closed;
Stage 2: When there is a upshift request, clutch separate gradually until to the slipping point, clutch separate may lead to out of sync between engine speed and prim speed because of slipping;
Stage 3: Clutch separate after slipping point and separate completely, engine speed may rise rapidly because of no load. Engine speeds raise more when in Power-On-upshifting and less when in Power-Off-upshifting. Prim speed declines directly when in the process of shift actuator movement, and changes with the same as vehicle speed at last;
Stage 4: Clutch begins to move and speed difference between engine speed and prim speed becomes smaller and smaller;
Stage 5: Speed difference between engine speed and prim speed becomes very small and clutch combines completely.

**Engine Control Strategy in the Process of AMT Upshifting**

Stage 1: Clutch is closed, there is no gear request, so the engine does not control;
Stage 2: Clutch transmit torque, engine target speed should be the same as the current engine speed. In order to easy control at the next stage, engine control should be use limit speed & torque mode;
Stage 3: Clutch is opened; engine speed may increase which leading to noise whether Power-On-upshifting or Power-Off-upshifting. Engine target speed should reduce and change with the vehicle speed at the request gear ratio. Engine speed control using speed control mode is not very good, so this stage, engine speed control use limit speed & torque mode;
Stage 4: Clutch begin to combine, engine speed control use the same control mode with the previous stage;
Stage 5: Clutch combines rapidly and transmits torque increase quickly, in order to improve shifting comfort, engine speed control also use speed & torque mode.

**Test Verification**

Parameters of test vehicle are showed as table 1:

<table>
<thead>
<tr>
<th>( T_e / \text{Nm} )</th>
<th>( P_e / \text{kW} )</th>
<th>( M / \text{kg} )</th>
<th>( A / \text{m}^2 )</th>
<th>( r / \text{m} )</th>
<th>( i_i )</th>
</tr>
</thead>
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<tr>
<td>350</td>
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<td>3140</td>
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<td>4.838</td>
</tr>
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<td>( i_1 )</td>
<td>( i_2 )</td>
<td>( i_3 )</td>
<td>( i_4 )</td>
<td>( i_5 )</td>
<td>( i_6 )</td>
</tr>
<tr>
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<td>3.154</td>
<td>2.041</td>
<td>1.365</td>
<td>1</td>
<td>0.791</td>
</tr>
</tbody>
</table>

Based on test vehicle, the proposed control strategy in dsPACE rapid prototyping platform was verified.

Engine control strategy based on engine speed control and speed & limit control were tested in AMT upshifting.

**Results in AMT Upshifting Based Engine Speed Control Mode**

Results in AMT upshifting based engine speed control were showed as figure 3.
From figure 4, engine speed control mode was used at stage 2-4, speed & limit control mode was used at stage 5. In the initial of stage 3, engine speed was higher than engine target speed because of no load; there were engine speed increased in the middle of stage 3 because of engine overshoot. This phenomenon which engine speed was higher than engine target speed reduces the shifting comfort greatly.

Results in AMT upshifting based engine speed & torque limit control were showed as figure 4.

From figure 4, engine speed & torque limit control mode was used at stage 2-5. At stage 2, engine speed was little lower the engine target speed; at stage 3, engine speed declined continuously, the result was the same as stage 4; at stage 5, in order to reduce engine speed decline, engine target speed was little higher than engine speed. Shifting comfort greatly increased by using speed & torque limit control mode.

**Summary**

In order to improve the shift quality of automatic mechanical transmission (AMT), the upshifting process was divided into five stages and the engine target speed and control strategy of each stage were formulated based on the characteristics of clutch work. Based on SAEJ1939 protocol, Engine speed and speed limit torque control by sending engine control mode were implemented. Based on test vehicle, the proposed control strategy in dsPACE rapid prototyping platform was verified. Test
results showed that the engine control strategy realized the engine control very well, and the AMT upshifting comfort was improved.

References


