

Development of iQ with CVT for USA

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ABSTRACT

TOYOTA has developed the iQ with a 1.3L engine for the Scion brand in USA. Due to the importance of fun-to-drive factor for the Scion brand image, a responsive driving performance is required even with compact packaging and a small engine. In addition, because of the recent attention to global-warming and energy issues on a global scale, development of vehicles with high fuel economy is one of the most important issues for a car manufacturer. Therefore, it is necessary for a vehicle to have both high driving performance and fuel economy. TOYOTA has adopted the CVT-i as the transmission for this purpose.

The following were achieved by adopting the CVT-i as the transmission for the iQ(1.3L).

1. Responsive driving performance with shift changes without a time lag.
2. Compact transmission for efficient vehicle packaging
3. Class-leading fuel economy performance.

Moreover, it was developed with adjustments for the US market by improving the shift schedule for a linear acceleration feel. This paper describes the main structural elements of the transmission and the control system technology for fuel economy and driving performance.

2. INTRODUCTION

In a market where both responsive driving performance and fuel economy are important, a CVT is the most suitable transmission for these demands. CVT can accelerate a vehicle

quicker at kick down compared to an AT while controlling the engine revolution for the best fuel economy.

TOYOTA expanded its CVT application for the iQ by introducing the CVT-i for the US market.

This paper describes the main structural elements, hardware, control strategies suitable for the US market, and the technology for reducing CO₂ emissions.

3. DEVELOPMENT OBJECTS

CVT-i for USA has been developed with three objectives in mind.

1. Responsive driving performance with shift changes without a time lag.
2. Compact transmission that reduces vehicle overhang.
3. Class-leading fuel economy performance.

4. DRIVABILITY ACCOMMODATION

CVT-i can accelerate a vehicle quicker at kick down compared to an AT because it changes the shift continuously without a loss of driving force from using a clutch.(Fig.1)

In Japan, the congested urban areas and suburbs have large frequency of a start-stop and low to middle speed driving conditions. Hence a smooth take off performance is important to the Japanese market.

However, in USA, a responsive take off performance and acceleration is of more importance than Japan due to the

traffic environment, such as a 4-way stop and highway merging.

Therefore, TOYOTA has improved the shift schedule to meet the drive feeling that is preferred in USA.

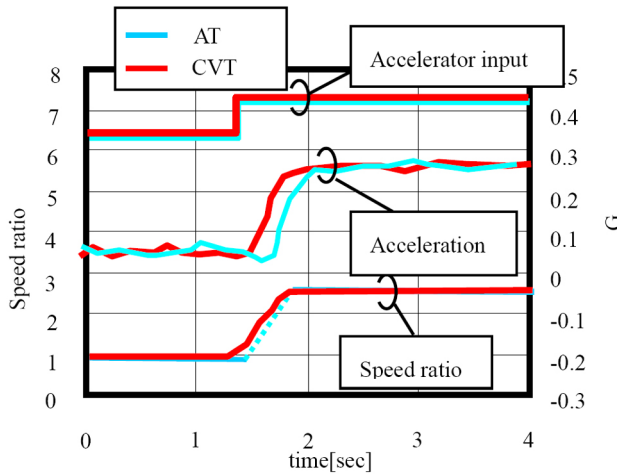


Fig.1. Image of acceleration of AT and CVT

(1). Basic Shift Schedule Setting

In USA market, a drive feel that's similar to an AT is preferred because the majority of customers are AT users. With considerations to this matter, TOYOTA mainly aimed at the following items, in order to improve the control strategies for every driving condition:

A. Linear Acceleration Feeling

In phase B of Fig.2, the speed ratio is held like an AT which optimizes the engine revolution slope during a long duration of acceleration. This, in turn, results in better acceleration feel compared to the Japanese/European calibration.

In phase C of Fig.2, the control behaves as a stepped AT which controls the stagnation feeling when the engine revolution has reached a high level for long duration.

Typically, when a quick up-shift is done, it can cause a shock due to the inertia change. However, the CVT-i has achieved a quick up-shift without a shift shock by controlling the engine throttle during a shift as shown in Fig. 3.

B. Re-Acceleration Response After Deceleration

When the accelerator pedal is released slowly, the engine revolution is dropped like an AT for fuel economy as shown in Phase D of Fig. 2. However, when the accelerator pedal is released quickly the control holds a low gear ratio to prevent the engine revolution from quickly dropping and enables engine braking. This gives better engine braking performance

and a quicker response during re-acceleration as shown in Phase E of Fig. 2.

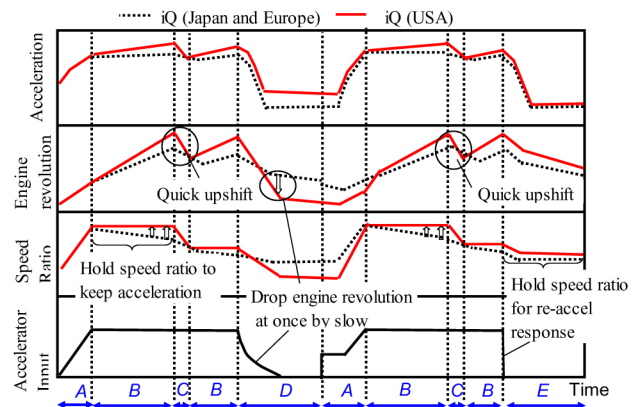


Fig.2. Image of shift schedule during a sequence of acceleration, deceleration, and re-acceleration

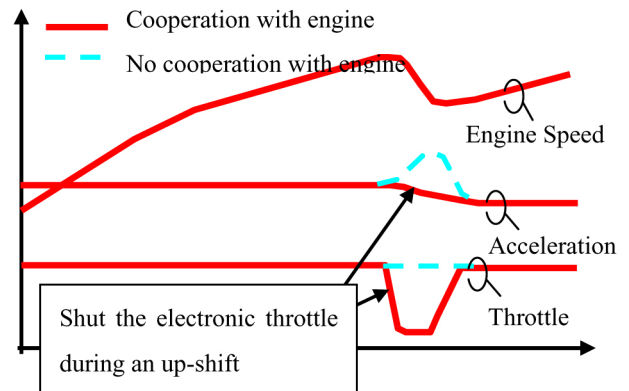


Fig.3. Smooth up-shift by throttle control during an up-shift

(2). Uphill/Downhill Shift Control

For Uphill/Downhill shift control, up-shifts are limited on uphill for a smooth driving, and downshifts are automatically executed on downhill to achieve optimum engine braking force and decrease the braking operation by the driver.

In addition, a smooth driving has been achieved by adjusting the driving force and engine braking force for any vehicle speed by controlling the shift changes continuously thus making the best use of the features of CVT-i. (Fig.4, Fig.5, Fig.6)

With an AT, the driving force changes due to a stepped gear ratio but with the CVT-i an ideal engine revolution is maintained (Fig. 7)