

Development of Automated Manual Transmission System for New CIVIC

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ABSTRACT

An automated manual transmission for the new CIVIC was developed to realize lower fuel consumption, easy driving and sportiness. The light and compact 6-speed transmission was developed by adding a gear change and clutch actuator to a conventional manual transmission, thus making it easier to drive and providing a sporty feel. The system achieved a 3% fuel economy improvement over the base transmission through system optimization.

1. Introduction

Recently in Europe, automated manual transmission vehicles aimed at reducing driving load and enhancing fuel economy have gradually increased their market presence. An automated manual transmission called “i-SHIFT” has been developed by Honda to provide improved fuel economy, easy driving and sportiness for the new model CIVIC⁽¹⁾. The aims of development and technical features of i-SHIFT are described below.

2. Outline of i-SHIFT

The i-SHIFT is an automated transmission system that uses electronic control to perform the starting and gear shift operations of a conventional manual transmission⁽²⁾. A system diagram of the i-SHIFT is shown in Fig. 1.

3. Development Goals

The i-SHIFT is intended to enhance fuel economy and minimize the inconvenience of manual gear changes, while retaining the sporty feeling of a conventional manual transmission. Specifically, the development goals are as follows:

- (1) To enhance the fuel economy to a level at least that of a manual transmission vehicle in EU mode
- (2) To realize a simple, lightweight and compact system configuration

- (3) To realize easy driving through complete automation of starting and gear shifting
- (4) To realize a direct & sporty driving feel by manual gear shifting

4. System Configuration

4.1. Actuators

Electro-hydraulic and electric motor actuator systems are typically used for small vehicles. An electro-hydraulic system can operate under large loads, and with the gear selection actuators hydraulically operated, such a system has the advantage of only needing one electric motor. However, a complicated hydraulic circuit is required, so there are weight and cost issues that must be considered. The electric motor system requires a high operating force due to clutch wear, so a large actuator is typically needed.

Based on the existing manual transmission, this 6-speed automated manual transmission uses three independently operated actuators to electronically control the shifts, gear selection and clutch operations. The clutch actuator performs clutch control by operating the release fork under the hydraulic pressure generated from the electric motor. The motor drive section contains a speed reduction mechanism and uses a self-adjusting clutch (hereafter called SAC), enabling the actuator to be lighter, more compact and less expensive. The actuator has a simple configuration and good power transmission efficiency. Also, it can be easily installed onto the base manual transmission.

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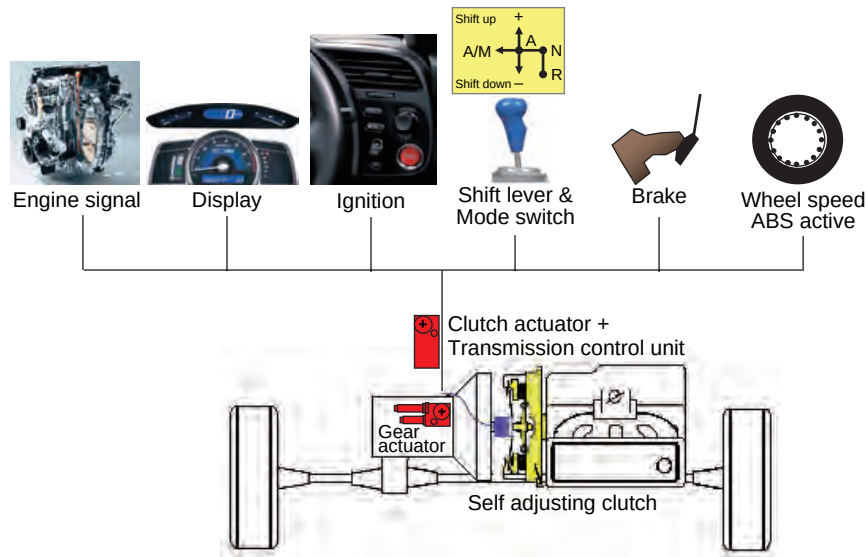


Fig. 1 Configuration of "i-SHIFT"

The gear-change actuator, which performs the shift and selection operations, performs gear changes using the drive force from an electric motor. The actuator is of an integral construction and has mounting compatibility with the chassis of conventional manual transmissions.

4.2. Clutch

In a conventional clutch, the diaphragm spring setting angle changes due to friction material wear. This causes an increase in

the release load which requires a larger actuator. In a SAC, the pivot of the diaphragm spring moves along with the wear surface, and the diaphragm spring setting angle is maintained at a nearly constant angle throughout the life of the clutch. Consequently, the release load does not increase with wear and the clutch operating force remains stable⁽³⁾. By using the SAC to stabilize the clutch operating force, it was possible to use a small electric motor. Figure 2 shows a typical SAC assembly and Fig. 3 shows operating characteristics.

5. Control

When the driver presses the accelerator or brake pedal, the i-SHIFT recognizes the driver's intent from the change in the rotational speed of the four wheels and performs the optimum starting or gear change operation. Figure 4 shows an outline of the system. The gear shift schedule is optimized according to the road gradient, loading situation and driver intent, based on the shift map which takes into account high fuel economy. In addition, a

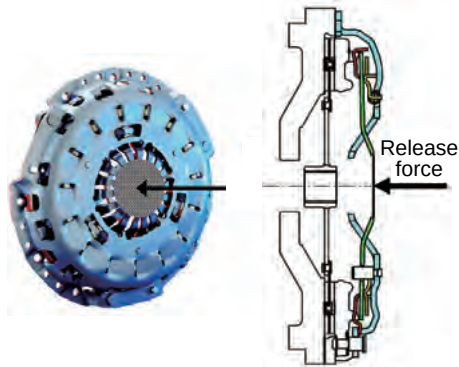


Fig. 2 Construction of Self-adjusting-clutch

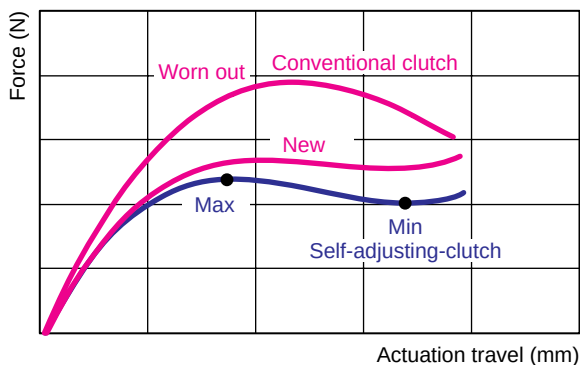


Fig. 3 Component characteristics of Self-adjusting-clutch

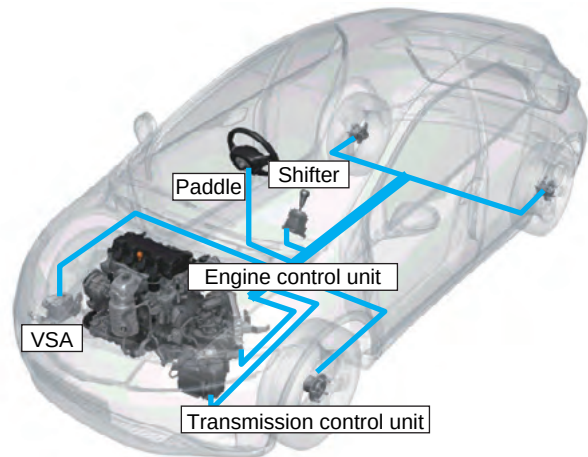


Fig. 4 System overview

control mechanism is implemented that eliminates the discomfort experienced by the driver when cornering at high speeds, abruptly decelerating, or braking (Fig. 5). For example, the driver of a vehicle traveling at high speed slows to enter a corner and then reapplies the accelerator pedal in order to make a fast exit. If normal control is used in this situation, the driver may feel discomfort due to the delay in drive force caused by excessive shifting. As another example, after overtaking another vehicle, the driver slightly releases the accelerator pedal. Under normal control logic, the transmission may up-shift excessively and would require subsequent down-shifts to maintain cruising speed. This can cause a reduction in the distance between the driver's vehicle and the overtaken vehicle. To avoid these kinds of situations and eliminate discomfort, up-shift is limited. Conversely, when braking, control is performed so as to promote an early down-shift, and thereby enhance the response during re-acceleration.

5.1. Starting Control

Regarding the starting control mechanism, when the shift lever is in the neutral position, the change mechanism and the clutch are in neutral. When the shift lever is put in the auto-mode position,

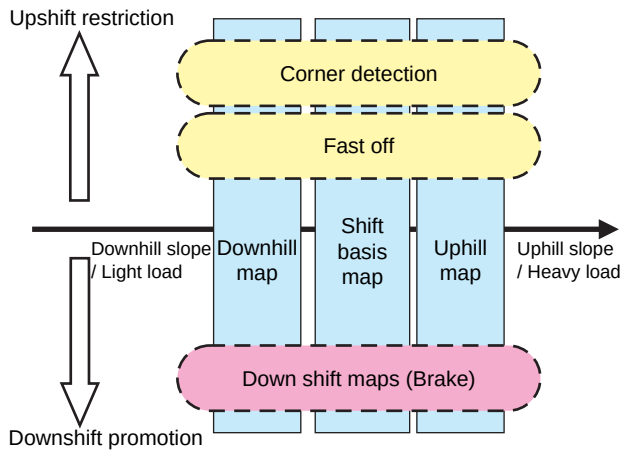


Fig. 5 Shift restriction

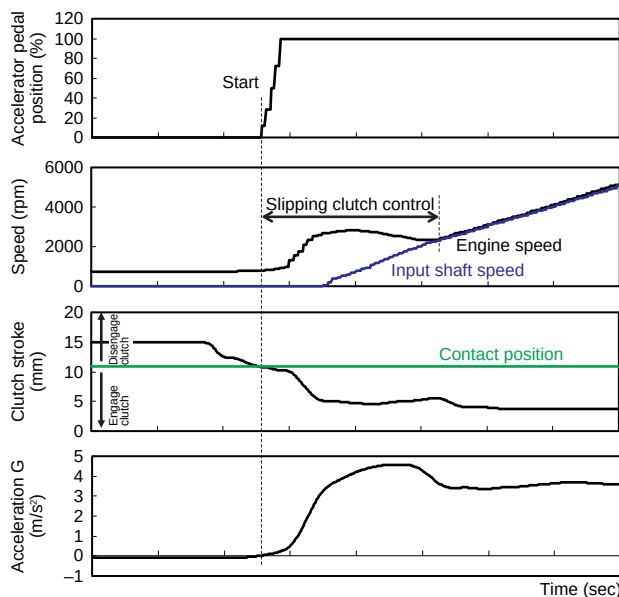


Fig. 6 Example of starting control

the gear enters the start stage, and the clutch stroke moves to its standby position to prepare for starting. When the driver depresses the accelerator pedal, the clutch strokes to the contact position, after which the vehicle starts smoothly under clutch position control. As a result, complicated manipulations when starting the vehicle have been eliminated, and clutch wear has been reduced and evened out. An example of this is shown in Fig. 6.

5.2. Gear Shifting Control

For engine control during shifting, the transmission controller commands the necessary torque to the Electronic Throttle Control System (ETCS). Torque reduction, gear change, speed synchronization and torque recovery are implemented cooperatively with the ETCS. By disengaging the clutch when the engine torque becomes zero, the clutch disengagement shock is reduced. Directly

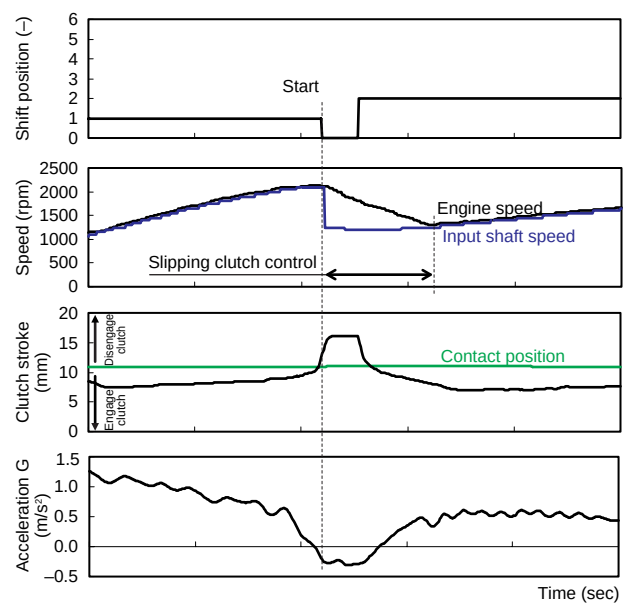


Fig. 7 Example of gear shifting control (upshift)

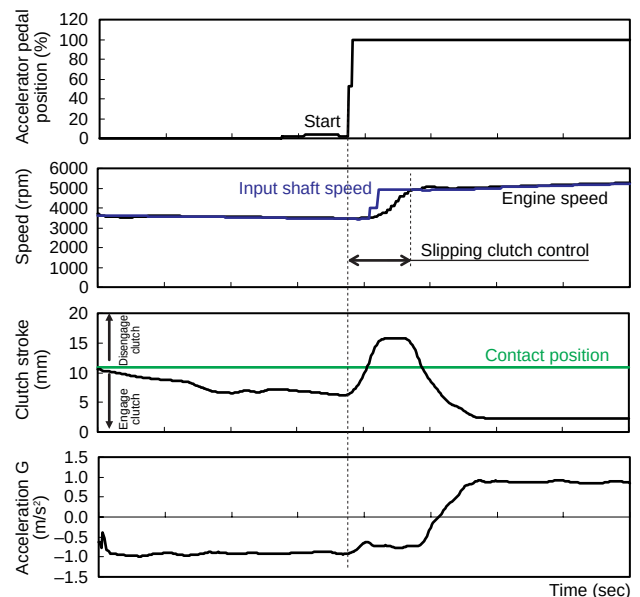


Fig. 8 Example of gear shifting control (downshift)

after clutch disengagement, the gear select, shift operation and speed synchronization take place. Subsequently, the clutch gradually moves in concert with the increasing engine torque - from zero to demand torque - and the gear shift operation is complete. During shifting, the optimum clutch position for good feeling is obtained from the accelerator pedal position, the rotational speed of the engine, and the rotational speed of the transmission. Examples are shown in Figs. 7 and 8.

5.3. Realization of High Fuel Economy

Up-shifting at a lower speed than the base vehicle with manual transmission greatly enhances fuel economy. However, if the engine is run at an excessively low speed, the drive force is insufficient. As a result, the accelerator needs to be pressed further, and the fuel economy deteriorates. Additionally, if the shift is performed in a shorter amount of time, less acceleration is lost, enhancing the fuel economy. However, the associated shift shock is larger. For this reason, the optimum shift schedule and shift time that can simultaneously realize fuel economy and product marketability are set. By optimizing the shift schedule and the shift time, it is possible to improve the fuel economy compared to that of the base transmission by 3%. As a result, top class fuel economy is achieved when compared to vehicles with equal displacement engines (Fig. 9).

5.4. Realizing Easy Driving and Sporty Driving Feel

In auto mode the following characteristics were evaluated: the responsiveness and smoothness at starting, the change in torque corresponding to accelerator pedal movement, and the responsiveness and smoothness of shifting. In manual mode, it was

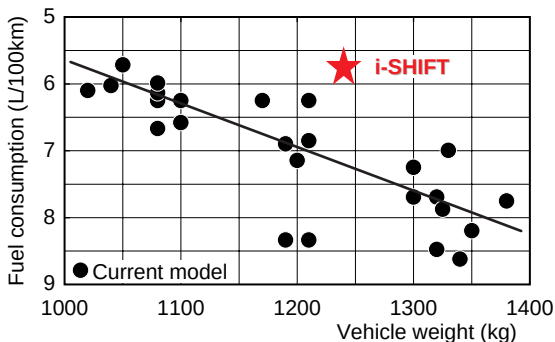


Fig. 9 Relationship between vehicle weight and fuel economy

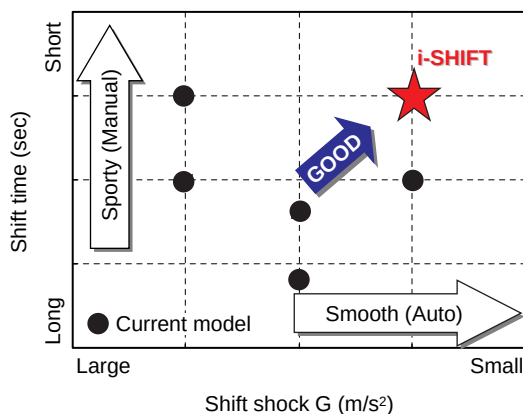


Fig. 10 Easy-to-drive and sporty feeling

confirmed that the direct cruising sensation and sporty driving feel were the same as those in a vehicle with manual transmission. As a result, it was possible to realize easy driving that responds to the driver's intention as well as a sporty driving feel (Fig. 10).

6. Conclusion

The i-SHIFT system was developed, with the following results:

- (1) The fuel economy was 3% better than that of the base manual transmission.
- (2) The use of an electric motor actuator made it possible to create a simple, lightweight and compact system.
- (3) In auto mode, easy driving including smooth starting and gear shifting was realized and the intention of the driver was incorporated into the control logic.
- (4) In manual mode, direct and sporty cruising was realized.

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