Development of a CVT without an electric oil pump to achive a start-stop system achived before the vehicles stops

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Summary

For a mini-vehicle CVT without an auxiliary transmission, JATCO has developed a start-stop system that does not have an electric oil pump and can be activated before the vehicle stops. The new start-stop system was achieved by discontinuing the electric oil pump and improving CVT shift control in order to satisfy the requirements for vehicle fuel economy and re-acceleration performance. This article describes the CVT technologies that contribute to ensuring re-acceleration performance.

1. Introduction

Directly engaging the torque converter lock-up (LU) clutch while a vehicle is decelerating and cutting off fuel injection to the engine are techniques adopted for continuously variable transmissions (CVTs) to improve fuel economy for reducing carbon dioxide (CO_2) emissions. After the vehicle stops, the fuel supply is suspended by the start-stop system while the vehicle is stationary.

However, the idling of the engine consumes fuel as the vehicle decelerates in the interval from lock-up clutch release to the activation of the start-stop system when the vehicle becomes stationary. In order to reduce such fuel consumption by engine idling, JATCO initiated development of a start-stop system that is activated before the vehicle stops (Fig. 1).[(1)]

The new start-stop system has been applied to the Jatco CVT-S (CVT-S) for use on mini-vehicles to improve vehicle fuel economy and to ensure the desired re-acceleration performance after the engine is restarted. This article describes the development details.

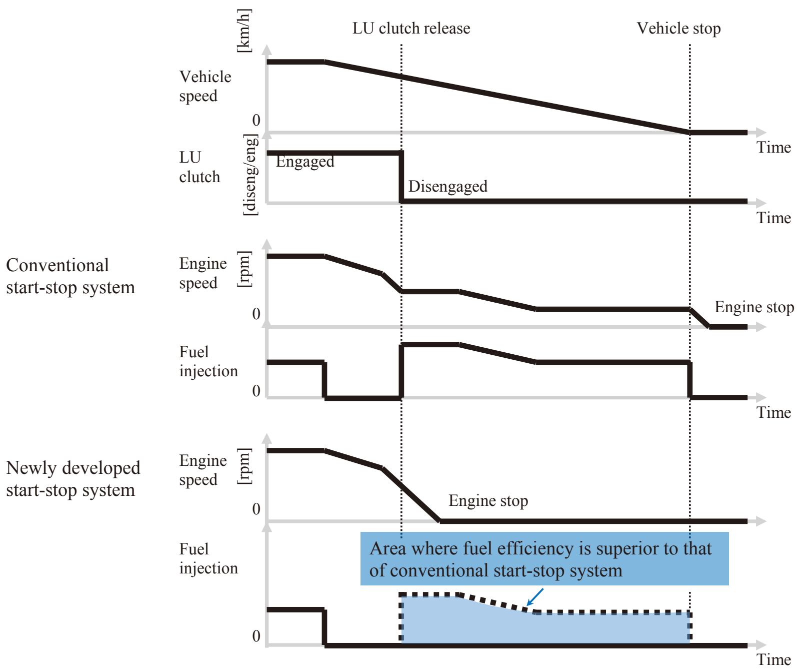

Fig. 1 Start-stop system timing chart

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Table 1 Specifications

Item			Jatco CVT7 (Current small CVT)	Jatco CVT-S (New CVT)
Torque capacity (Nm)			98	100
Control system			Electronic	←
Torque converter size (mm dia.)			185	←
Gear ratios	Ratio coverage		7.3	6.0
	Pulley ratio		2.200 - 0.550	2.411 - 0.404
	Final gear ratio		4.575	6.54 - 7.756
	Planetary gear ratios	1st	1.821	1.000
		2nd	1.000	
		Rev.	1.714	0.952
Total low ratio			18.33	15.77
Weight (wet) (kg)			65.0	60.8
Overall length (mm)			346	356
Distance between pulley shafts (mm)			147	←

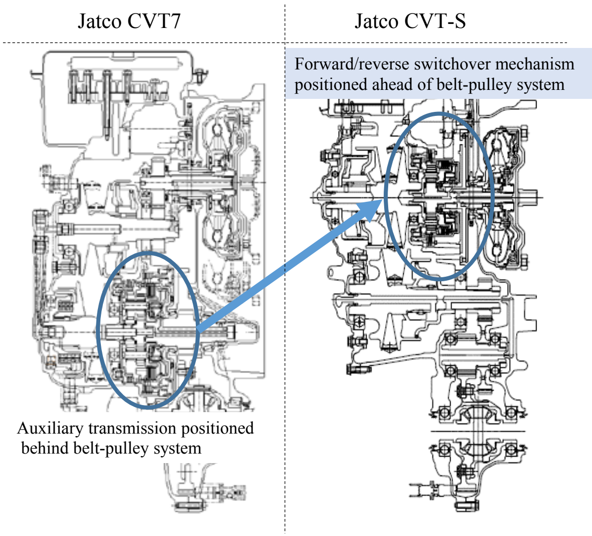

Fig. 2 Cross-sectional view of CVT7 and CVT-S

Table 2 Comparison of conditions for activating start-stop system

	Jatco CVT7 (Current small CVT)	Jatco CVT-S (New CVT)
Vehicle speed [km/h]	13 or less	13 or less
Vehicle deceleration [-]	0.3G or less	0.3G or less
Pulley ratio [-]	Over 2.1 @High gear of auxiliary transmission	Over 1.5

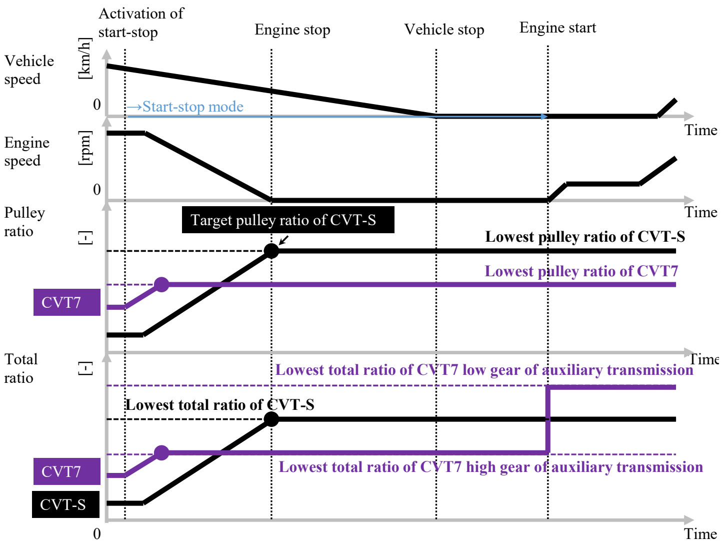

Fig. 3 Timing chart of the pulley ratio and through ratio of CVT7 and CVT-S

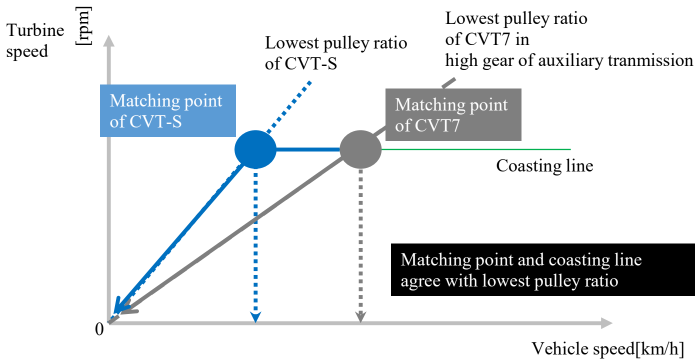

Fig. 4 Shift schedule of CVT-S and CVT7

2. Development concept and structure

The CVT-S was developed to fit the engine compartment layout of mini-vehicles as a smaller, lighter unit than the Jatco CVT7 (CVT7) and thereby improve interior roominess, comfort and safety.

2.1 Structure and specifications of CVT-S for mini-vehicles

The CVT-S specifications in Table 1 were determined on the basis of the development concept.[2] After analyzing the constituent elements of a CVT, a structure was selected that positions the forward/reverse switchover mechanism ahead of the belt and pulley system as traditionally done in JATCO's midsize CVTs. In contrast, the CVT7 has the auxiliary transmission located behind the belt and pulley system (Fig. 2). Moreover, the CVT-S was developed without an electric oil pump in order to reduce the cost.

2.2 Application of start-stop system activated before the vehicle stops

The aim of the new start-stop system is to improve fuel economy by stopping the engine simultaneously with the release of the LU clutch. The conditions for activating the system are shown in Table 2. In order to ensure re-acceleration performance, the pulley ratio must return to a low gear ratio before the vehicle comes to a stop. However, because the CVT-S does not have an auxiliary transmission, it is necessary to continue shifting by means of the belt and pulley system until a lower vehicle speed is reached than with the CVT7 (Figs. 3 and 4).

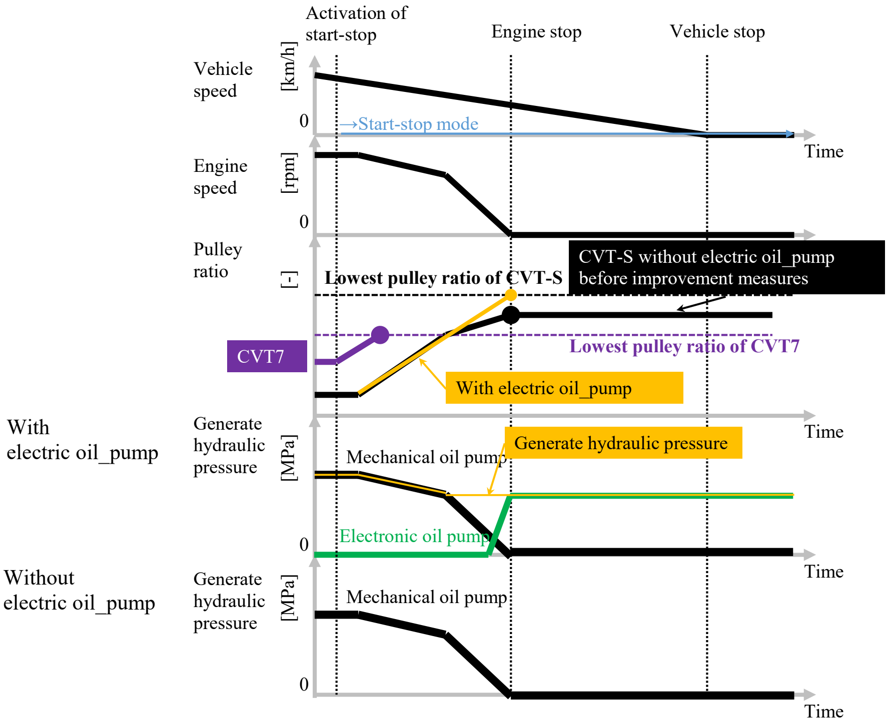

Fig. 5 Shift schedule timing chart of the belt-pulley system during vehicle deceleration

Table 3 Specifications of forward clutch

	Jatco CVT7 (Current small CVT)	Jatco CVT-S (New CVT)
Volume of hydraulic pressure chamber of forward clutch [cc]	16.5	21.4

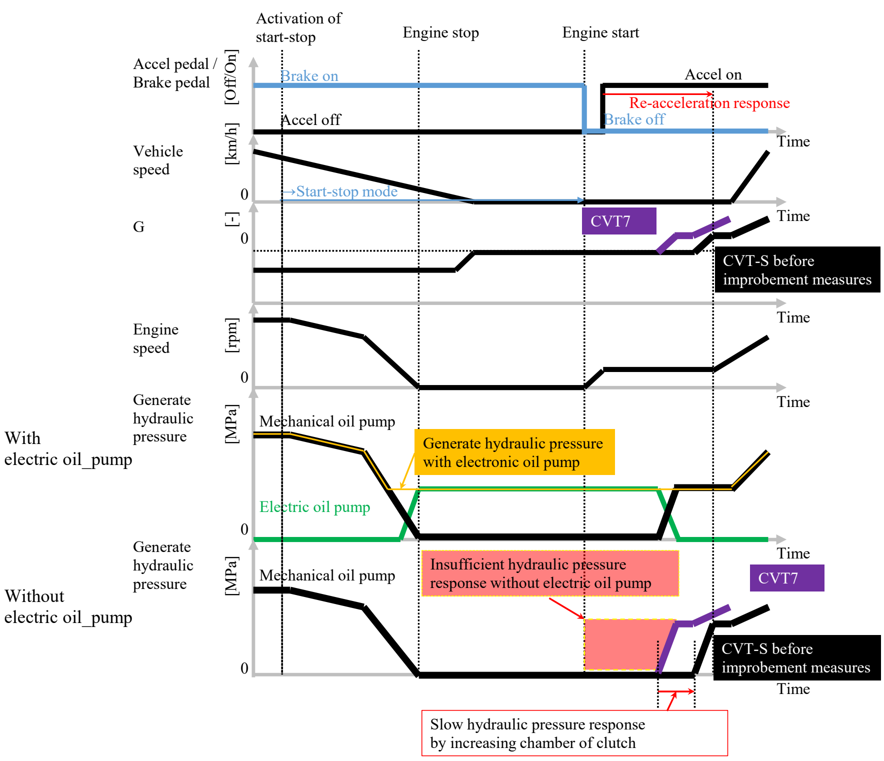

Fig. 6 Timing chart of hydraulic pressure response

3. Concerns about re-acceleration performance

One concern about re-acceleration performance was that the pulley ratio would not return to a low gear ratio before the vehicle came to a stop. Another concern was a possible response lag in generating hydraulic pressure after engine restart.

3.1 Concern about shift controllability of belt-pulley system during deceleration

The pulley ratio must return to a low gear ratio before the vehicle stops moving. However, because the CVT-S does not have an electric oil pump, if the engine was stopped while the vehicle was still in motion, the mechanical oil pump could not discharge any pressure. This would mean that no pulley pressure could be generated, making it difficult to return the pulley ratio to a low gear ratio (Fig. 5).

3.2 Hydraulic pressure response after engine restart

Because the CVT-S does not have an electric oil pump, CVT fluid flows out of the pulley pressure chamber while the engine is stopped and it leaks internally from the hydraulic pressure circuit. In addition, the forward clutch pressure chamber of the CVT-S has a larger volume than that of the CVT7 (Table 3). Consequently, after engine restart, it takes longer for the mechanical oil pump to supply a sufficient quantity of fluid to fill the pulley pressure chamber (Fig. 6).

4. CVT technologies contributing to re-acceleration performance

The adoption of the technologies described below has contributed to ensuring the desired re-acceleration performance.

4.1 Shifting to a low gear ratio before the engine stops

In order to ensure the desired re-acceleration performance, the pulley ratio must shift to a low gear ratio before the vehicle comes to a stop. In general, the ways of shifting to a low gear ratio include raising the hydraulic pressure of the secondary pulley or lowering the hydraulic pressure of the primary pulley. The hydraulic pressure of the primary pulley could not be reduced below the limit

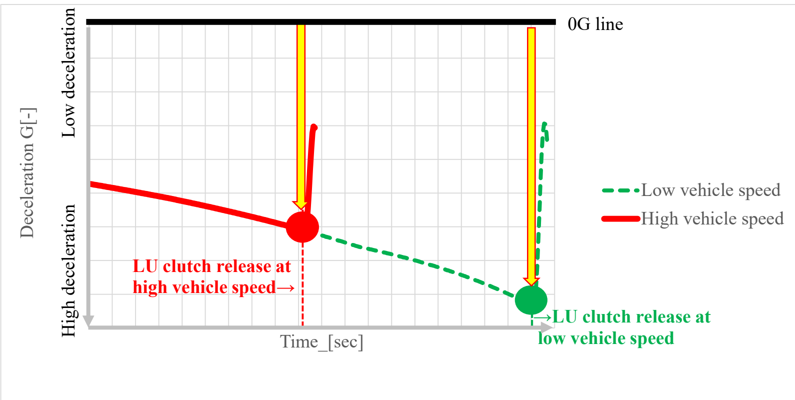

Fig. 7 Simulation results for deceleration feeling by changing vehicle speed for LU clutch release

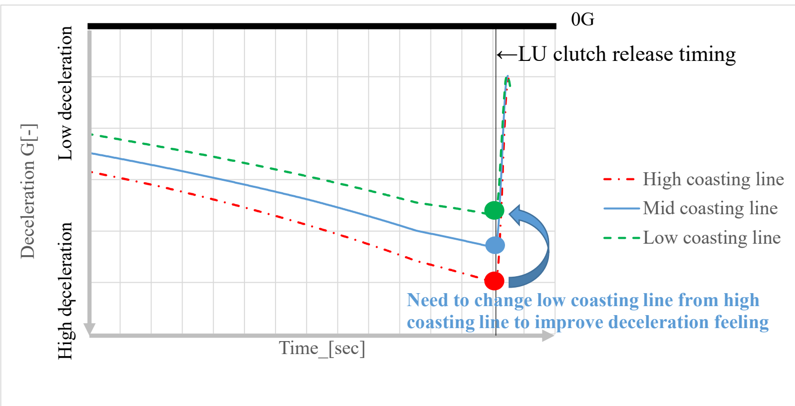

Fig. 8 Simulation results for deceleration feeling by changing coasting line

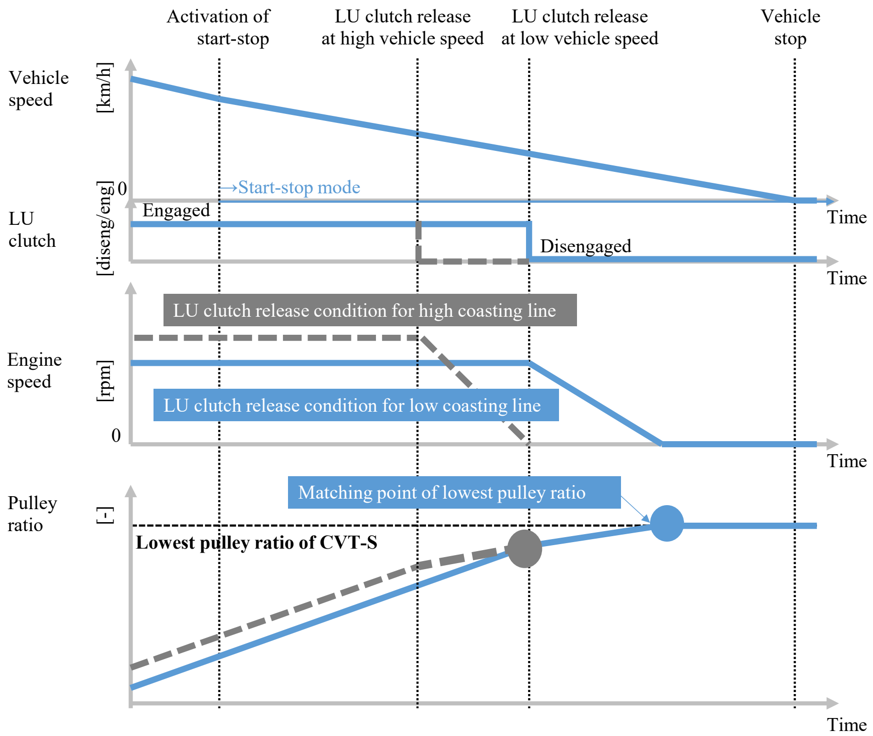

Fig. 9 Timing chart for changing LU clutch release condition to satisfy both deceleration feeling and shift control

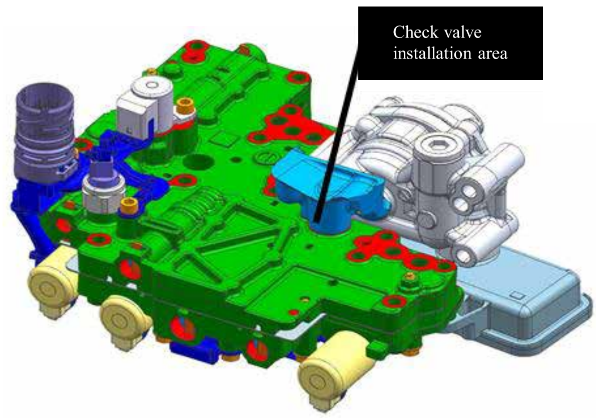

Fig. 10 Hydraulic system layout

needed to secure the torque transmission capacity desired for the belt. Consequently, in order to ensure the hydraulic pressure of the secondary pulley, the vehicle speed for releasing the LU clutch was reduced to a lower level and the timing for stopping the engine was delayed. However, lowering the vehicle speed for releasing the LU clutch would produce a stronger feeling of deceleration that might give the driver a sense that the vehicle was slowing down unintentionally (Fig. 7). Accordingly, the coasting line was lowered to improve the feeling of deceleration (Fig. 8). As the result, the vehicle speed condition for LU clutch release and the coasting line were both set so as to achieve an acceptable deceleration rate combined with shift control (Fig. 9).

4.2 Improvement of hydraulic pressure response by reducing internal fluid leakage

In order to ensure the desired vehicle acceleration performance following engine restart, the hydraulic pressure of the pulleys and clutches must be raised immediately so that driving force from the engine can be transmitted. However, the mechanical oil pump stops operating simultaneously with the stopping of the engine. Consequently, the CVT fluid filled in the hydraulic pressure circuit would flow backward and leak internally from the circuit, causing a response lag in the generation of hydraulic pressure. To avoid that condition, a check valve has been provided between the mechanical oil pump and the control valve to prevent backward flow (Fig. 10).[3] In addition, a low-leakage type of sealing ring has been adopted for the pulleys.

As a result, hydraulic pressure response has been ensured for the CVT-S that is equal to or better than that of the CVT7 even though the former unit has a larger clutch hydraulic pressure chamber than the latter unit.

5. Conclusion

A start-stop system that is activated before the vehicle stops has been developed without an electric oil pump and applied to a mini-vehicle CVT that does not have an auxiliary transmission. This was accomplished by improving the CVT shift control and hydraulic pressure response so as to satisfy customer demands for vehicle fuel economy and re-acceleration performance.

6. References

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(2) Mikiko Kunihisa and Syuuji Kurokawa, "Development of a new-generation CVT for mini-vehicles," Proceedings of JSAE 2019 Annual Spring Conference, Reference No. 20195285 (in Japanese).
(3) Makoto Oguri and Shigeru Tomoda, "Fuel consumption improvement technology of a new generation CVT for mini-vehicles," 2019 JSAE Symposium, Reference No. 09-19, pp. 45-49, 2019 (in Japanese).

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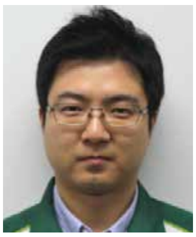
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