

Development of the Multi Locking Hydraulic Variable Valve Timing Control System(VTC) for Hybrid Engines

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ABSTRACT

The development of environmental improvement technologies in the automobile industry is underway. These technologies are also developed for internal combustion engines, which remain the mainstream power source for most vehicles. Nissan Motor Company has developed a multi-locking hydraulic VTC (Valve Timing Control) system and adopted it on the newly developed QR25DER engine of the Pathfinder and Infiniti JX hybrid vehicles.

The implementation of the developed system allows for an optimized variable valve timing at both, cold engine start, and idle stop re-start from EV mode.

This paper describes an outline, the principle, and effects of the multi locking hydraulic VTC system.

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INTRODUCTION

Rising concern worldwide about environmental issues in recent years has increased the importance of developing technologies for mitigating the environmental impact of automotive engines, typically by reducing fuel consumption and exhaust emissions, and among them the importance of hybrid technology has increasingly grown. Nissan Motor Company has developed a multi-locking hydraulic VTC (Variable valve timing control) system and adopted it on a newly developed QR25DER engine in Pathfinder and Infiniti JX Hybrid (HEV).

In 2012, a valve timing control system using optimum angular position locking mechanism was developed in order to reduce both fuel consumption and exhaust emissions which was implemented to the 13MY ALTIMA's engine.

By implementing a multi-locking mechanism, the newly developed valve timing control system is able to achieve optimum valve timings both, at engine start when the vehicle is cruising in EV mode (engine re-start from idle stop) and at low temperature engine start.

In this paper, the implementation of the above-mentioned multi-locking intermediate VTC system as well as a description of the undertaken challenges involved in its development process are explained.

1. HEV ENGINE-START VALVE TIMING

There are basically two kinds of engine-start in an HEV engine. The first one being cold engine start, and the second one an engine re-start from idle stop. Each one of them differs as follows:

a. Cold Engine Start

Since the catalytic converter is not fully functional when the engine is started at low temperatures, it is crucial to reduce the engine output emissions (EOE) in such conditions. Therefore, simultaneously opening the intake and exhaust valves (valve overlapping) is effective in such scenarios.

On the other hand, an excessive overlap at low load driving conditions will lead to an unstable combustion process. Hence, the right amount of overlap is selected considering the effects in combustion stability and output emission reduction. For the

developed system, the valve overlap when the intake VTC is locked to the intermediate position was set to 12 deg (crank angle).

By increasing valve overlap at cold start, the engine output hydrocarbon concentration is reduced as shown in Figure 1.

b. Engine Re-Start from Idle Stop

The HEV system to which the developed multi-locking mechanism VTC system was implemented, has a one-motor two-clutch configuration. When the driving conditions of the vehicle fall into the idle stop range, the vehicle idle stops, but as the vehicle starts to accelerate again, the engine is started while doing so in EV mode. In such scenarios, vibration induced by the engine start is perceptively transmitted to the vehicle. In order to reduce this vibration, a de-compression valve timing achieved by delaying the IVC timing of the engine is implemented. The reduction of the vehicle floor vibration when applying such a de-compression valve timing is shown in Figure 2. In the other hand, by delaying the IVC at the de-compression phase, the engine output torque is reduced. The countermeasure to this issue is described later in this paper.

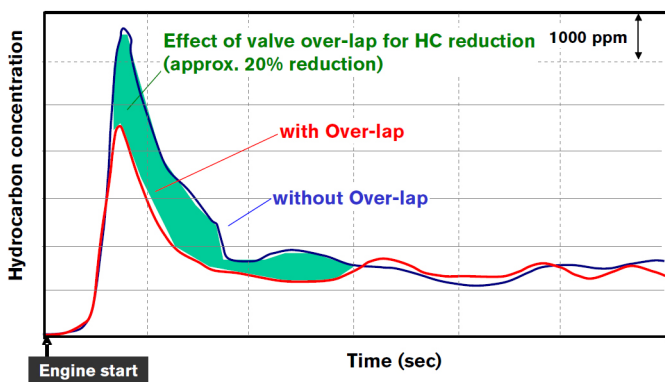


Figure 1. Actual effect of valve over-lap for hydrocarbon reduction

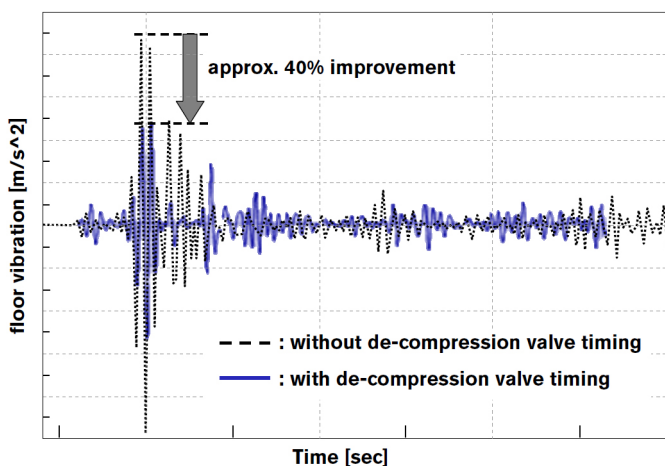


Figure 2. Actual floor vibration reduction effect after applying a de-compression valve timing

The above-mentioned valve timings are shown in Table 1.

In order to deal with these two options, a multi-locking VTC system was developed that was capable of fixing both engine-start valve timings.

Table 1. Valve timing of cold start and re-start from idle stop

	Valve timing for cold start	Valve timing for Re-start from idle stop
Valve Timing		
IVC [deg@ABDC]	43	91(de-compression)
VTC phasing		
VTC phasing angle[degCA]	48 (Intermediate locking)	0 (Maximum retard locking)

2. SYSTEM STRUCTURE

The present VTC system is fitted to the front end of the camshaft. The system transmits the rotational force of the crankshaft to the camshaft by means of a timing chain and, at the same time, continuously adjusts the rotational phase.

Figure 3 shows the structure of the optimum angular position locking VTC system that was used in the development process. This system consists of an optimum angular position locking VTC unit, an oil control valve (OCV) that controls the phase of the optimum angular position locking VTC unit, an oil switching valve (OSV) that locks and unlocks the lock keys of the optimum angular position locking VTC unit and will be described later, and an oil pump that provides the hydraulic pressure for driving the VTC system. The developed VTC system has an OCV and OSV, and is controlled by the engine control unit (ECU), depending on the driving conditions.

1. Basic Structure of the Multi-Locking VTC System

A comparison between the described multi-locking VTC system and the already existing intermediate locking VTC is shown in Figure 4, and a detailed structural description of the developed component is shown in Figure 5. The feature of the developed VTC consists of having two locking positions, one located at the maximum retard position, and other one located at an intermediate position. Structurally, the multi-locking function is achieved by inserting the lock-key (b) into the rotor groove at the maximum retard position. The intermediate position lock-key is controlled by the OSV, while the maximum retard position lock-key is controlled by the OCV.

The difference between the developed multi-locking intermediate VTC and the existing intermediate locking VTC is that the developed VTC has a groove at the maximum retard position and a greater shifting dynamic range, resulting in a simple design.

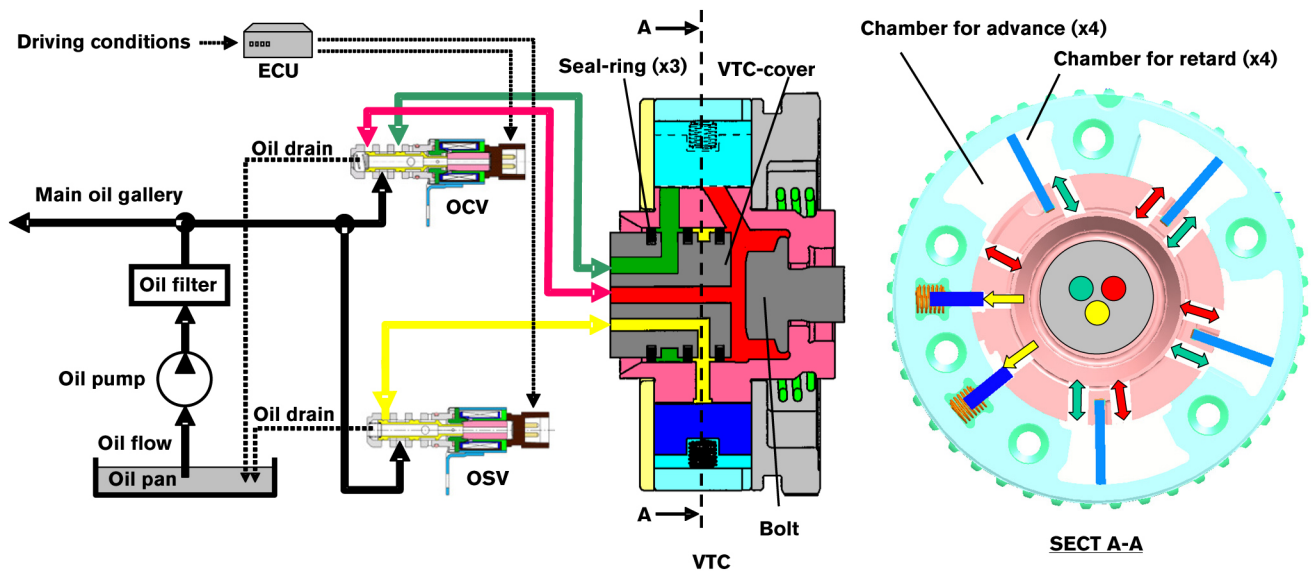


Figure 3. VTC system structure

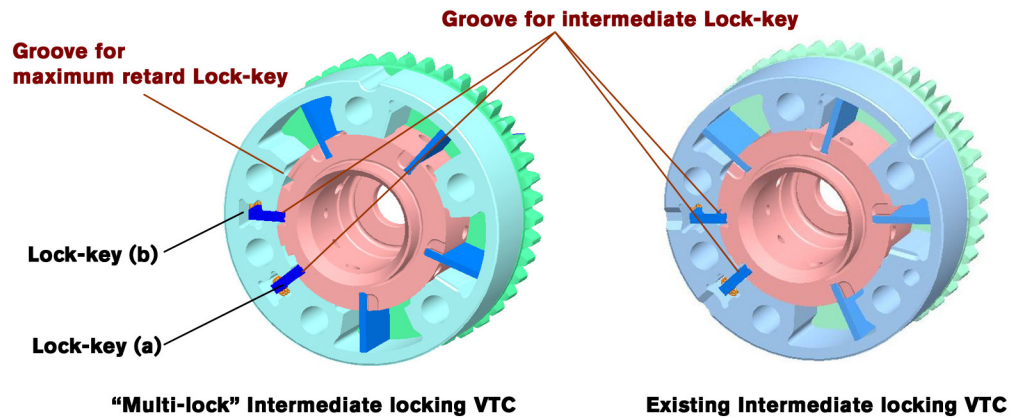


Figure 4. VTC component parts compare with Multi locking mechanism and Single locking mechanism

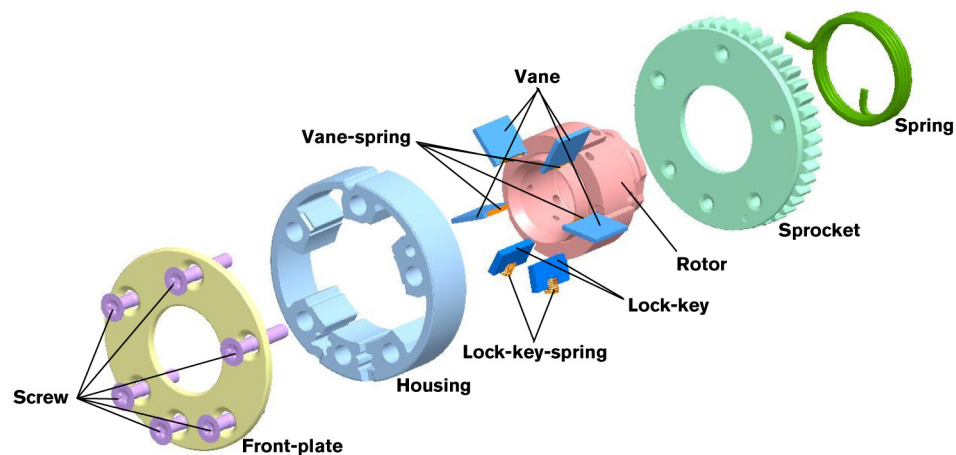


Figure 5. VTC component parts