More Efficient Combustion Engines

Variable valve control for a camless engine with fast hydraulic actuators

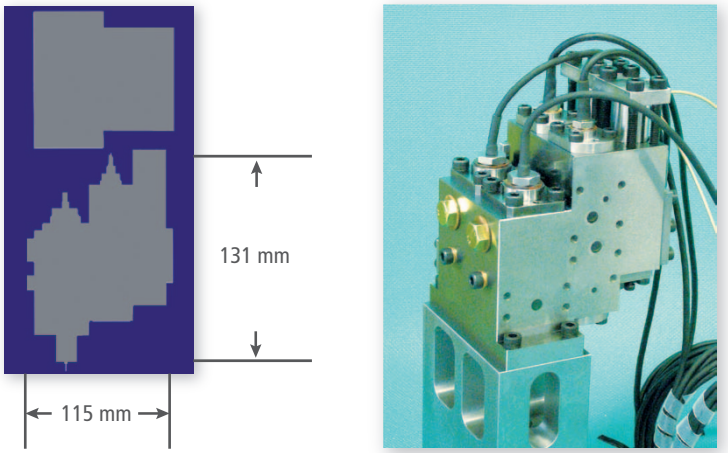


Figure 1: Dimensions (left) and structure (right) of the EVC actuator.

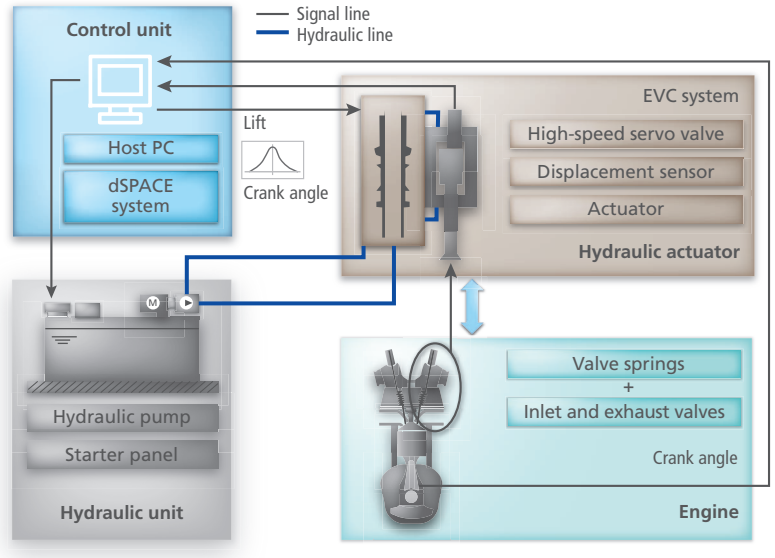
> "Our goal was to develop a dynamic hydraulic actuator. We achieved it quickly with the dSPACE system."
>
> *Ryuji Uehara, Mitsubishi Heavy Industries*

Features and Advantages of the EVC System

The EVC system is characterized by the ability to follow lift patterns accurately and at high speed. This ability is facilitated by dedicated high-speed servo valves and a real-time compensatory control logic.

The servo valve has been developed by Mitsubishi Heavy Industries to operate at a maximum actuator speed of 6 m/s, permitting a valve open-close cycle of approx. 2 ms. The valve improves the ability to follow the lift pattern at high speed, and is small enough to be fitted to small engines.

Figure 2: Schematic of the system configuration of the complete EVC demonstrator, including the control unit.



Prototype Control in the Laboratory

The control equipment consists of actuator position control, a digital signal processor to monitor safety – represented by the DS1006-based dSPACE real-time system – and a host PC to set the lift pattern and monitor the system in real time.

The control software for the system was developed in cooperation with Ono Sokki Co., Ltd. Running on the dSPACE real-time system, the software provides actuator feedback piston control and reproduces wave forms with high accuracy, and is also able to handle transient mode operation, e.g., variations in engine speed and torque.

The control also monitors mechanical functions, detecting extreme deviations, proximity warnings and abnormalities in actuator position and engine piston trajectory, and incorporates a range of safety features to prevent valve/piston collisions, etc.

Firing Tests on a Multicylinder Engine

For firing test purposes, the EVC system actuators were fitted to the cylinder head of a 4-valve, 4-cylinder diesel engine.

First, tests were run to compare the cylinder pressure in normal cam-driven operation and in a reproduction of the same lift pattern with the EVC system (figure 3). Results for the two cases are closely matched, verifying that the accuracy obtained with the EVC is comparable to that with nor-

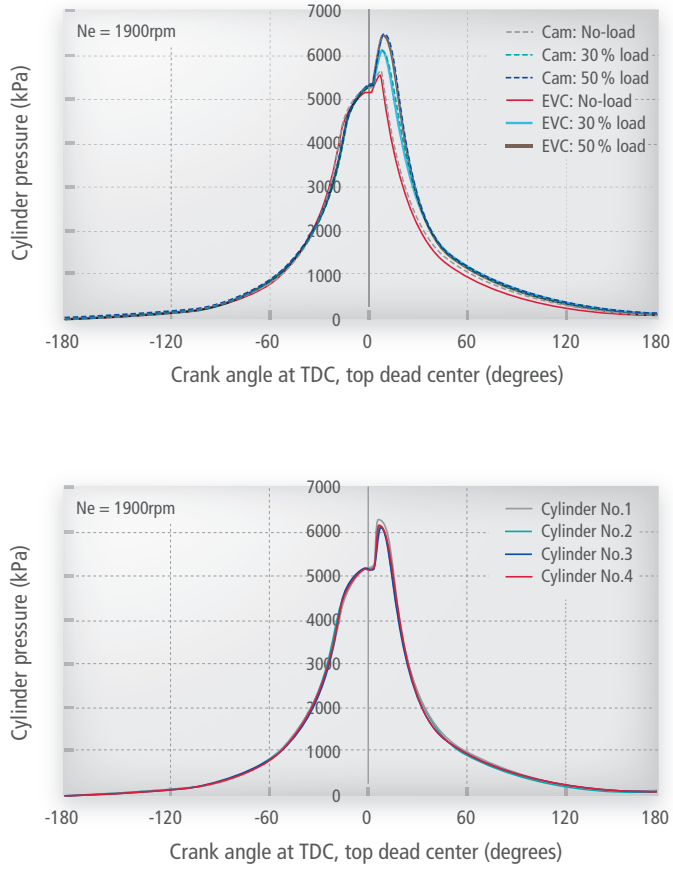


Figure 3: Comparison of cylinder pressures with mechanical camshaft control and EVC system.
Figure 4: Comparison of pressures in all 4 cylinders.

mal cam drive. In the next step, the pressures of all 4 cylinders were compared in EVC mode (figure 4). Differences between cylinders were minimal, and the ease with which the lift pattern was reproduced with the EVC system is clearly apparent. Since the EVC system constantly monitors the crank angle and controls the valve position at high speed accordingly, it is also able to follow the engine speed in transient mode, in which the engine speed is changing. Smooth operation is therefore possible in all conditions during testing, from starting with the starter motor, to stopping with fuel cutoff, to increasing and decreasing engine speeds, all without changing EVC system settings. ■

Ryuji Uehara
Mitsubishi Heavy Industries

Conclusion

Testing the multicylinder engine demonstrated that the EVC system was able to reduce variation between the cylinders, and to reproduce lift patterns to a high degree of accuracy. The application of the EVC system in research on new combustion technology illustrated its efficacy in finding conditions for improvements in combustion within a short time. The dSPACE system used as the experimental control unit offers Mitsubishi Heavy Industries a high degree of flexibility, so that changes and new ideas can be implemented quickly. The system was also convincingly easy to use and stable in operation. The dSPACE system helped Mitsubishi engineers to reduce development times and to improve the thermal efficiency of new combustion technology. Future developments include connecting the EVC system to an engine bench to automatically find optimum lift patterns in response to engine conditions.

Ryuji Uehara
Ryuji Uehara is Principal Engineer at Mitsubishi Heavy Industries, Shimonoseki Designing & Production Department Power System, in Yamaguchi, Japan.