

Development of Hydraulic- Controlled Variable Valve Lift System for Scooter Engine

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ABSTRACT

In this research, with proposed design of hydraulic-controlled variable valve lift system, a feed pump is used to supply the low-pressure oil into the hydraulic pump which will compress low-pressure oil as high-pressure oil and pumps the high-pressure oil into the hydraulic cylinder. In the meanwhile, the intake valve opened in accordance with the plunger is pushed by the hydraulic cylinder. To achieve the change of intake valve lift, a DC motor connected with the control rack that is used for controlling oil-drain time of the hydraulic pump. In addition, a solenoid valve is installed in order that the intake valve will be closed quickly without controlling the drain flow when the maximum valve lift is reached. Commonly, the throttle is not required with variable valve lift system, but the throttle is kept for engine start. Hence, except for engine cranking condition, the throttle maintains in wide open (WOT) under different test conditions. After realizing the proposed variable valve lift system, the valve profile is measured with the established bench at the beginning, and the engine experiment is executed. The experimental results show that the proposed design of hydraulic-controlled variable valve lift system can approximate the original valve operation. Furthermore, the improvement of pumping loss reaches up to 12.18%~20.75%. Finally, the chassis dynamometer experiment results show that the improvement of fuel economy reaches up about 2.96% ~ 8.35% running on the ECE-40 driving pattern.

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INTRODUCTION

Especially in the part load, the thermal efficiency of gasoline engine is much less than diesel engine because of different throttle opening that will affect pumping loss [1]. The valve timing and valve lift are important factors for fuel consumption and engine performance. Hence, the technologies of variable valve timing and lift have been designed in order to reach the demand of the engine under the different operation condition.

Currently, the variable valve systems have been widely employed to the automobiles [2], but the application for motorcycles is simply applied to heavy-duty motorcycles, such as the DVT (Desmodromic Variable Timing) designed by DUCAT [3], Honda Hyper VETC (Variable Valve Timing and Lift Electronic Control) [4], and Suzuki SR-VVT (Suzuki Racing Variable Valve Timing) [5]. At the early days, camshaft and rocker arm were revised to achieve variable valvetrain system since the technology of mechanical design and hydraulic control were not mature [6, 7, 8, 9, 10], but it can only do several simple stages for valve timing and valve lift. To overcome the above condition, hydraulic and electronic valve train concept have been widely implemented in variable valve system to progress continuous type [11, 12, 13, 14, 15, 16].

In this research, a hydraulic-controlled variable valve lift system including mechanism and control strategy are developed. In addition, the engine experiment is executed to discuss the difference between original and proposed system. Finally, the vehicle test runs on chassis dynamometer to compare the fuel consumption.

EXPERIMENTAL SETUP AND PROCEDURE

Hydraulic-Controlled Variable Valve Lift System

In this research, the original engine specification is used for realizing developed variable valve lift system referred the principle of diesel in-line injection pump is listed in Table 1, and the whole structure is shown in figure 1.

Table 1. The original engine specification

Engine type	4-stroke, air-cooled
Number of cylinder	single
Displaced volume	124.6 cc
Stroke	57.8 mm
Bore	52.4 mm
Compression ratio	11.3:1
Number of Valves	2

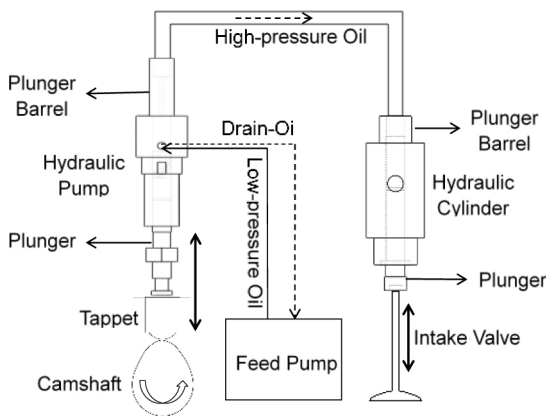


Figure 1. Configuration of the proposed hydraulic-controlled variable valve lift system

The original cylinder head is modified to assemble proposed design, and the use of tappet which is driven by camshaft is to replace rocker arm mechanism. A feed pump is used to supply the low-pressure oil into the hydraulic pump. According to the plunger reciprocating action of plunger, the low-pressure oil can be compressed as high-pressure oil in the plunger barrel. After that, intake valve will be open by supplying high-pressure oil to be driven by the plunger in the hydraulic cylinder. In addition, the excessive oil will returns to the feed pump along with end of compression stroke. Moreover, the throttle valve maintains in wide open, except for engine cranking, to reduce the pumping loss for better fuel consumption. Although the developed system can be realized from aforementioned design, intake valve cannot work like original system. The reason is intake valve will close quickly without controlling release rate of high pressure oil. Hence, a solenoid valve, which is installed on spill orifice, applied for changing drain speed with PWM signal, and drain timing is controlled by adjusting drain flow driven by control rack linked with a DC-motor. Besides, a variable resistor is set for determining the position of control rack, and PID (Proportional-Integral-Derivative) controller is used to control the position of control rack. For requirement of large intake air flow, oil drain timing delays to increase intake valve lift. On the contrary condition, timing and action are reverse. After above-mentioned, intake valve profile becomes controllable as shown in [figure 2](#).

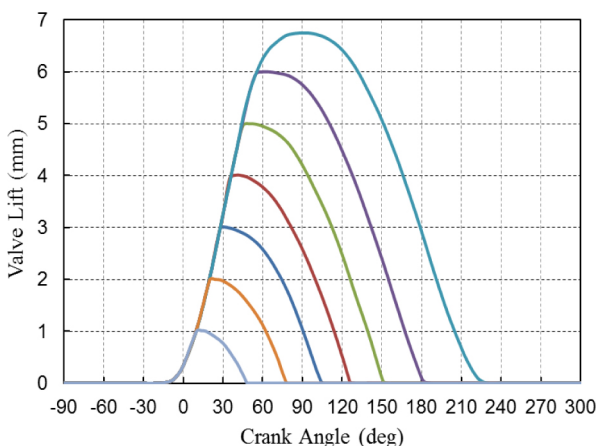


Figure 2. Intake valve lift profile of the proposed hydraulic-controlled variable valve lift system

Experimental Setup

Two experimental benches are established to obtain experimental data. One is hydraulic-controlled variable valve lift system is appeared in [figure 3](#). A hall sensor and a gear are employed to determine corresponding between cam angle and intake valve lift; a variable resistor is used to measure intake valve profile; a DC motor connected with the control rack that is used for controlling oil-drain time of the hydraulic pump. With established bench, the design of hydraulic-controlled variable valve lift system can be compared with original system under the different operation condition.

The other is for engine experiment, and whole structure is shown in [figure 4](#). An eddy-current engine dynamometer (Borghi & SaveriSrl, FE150-S) is employed to measure the engine output brake torque and speed. The gasoline flow rate is measured by the mass burette flow detector (ONO SOKKI, FX-1110). Amount of air is measured by a thermal mass flow meter. Several K-type thermocouples are installed on the engine for measuring temperatures of ambient air, intake gas, exhaust gas, cylinder head, and oil. The amplifier is used to amplify cylinder-pressure signal transmitted to combustion analyzer. Finally, the industrial computer is utilized to analyze data from engine experiment.

Since the original engine is retrofitted for hydraulic-controlled operation, engine control is replaced by using a controller (Woodward, MotoHawk ECU 555-80) to control drain-oil time and drain flow speed. The MotoHawk allows the user to automatically generate machine codes from Simulink blocks and to operate control hardware in real-time operation.

In order to confirm the effect of improvement of fuel consumption between the proposed design hydraulic-controlled variable valve system and original engine, the chassis dynamometer (Super Flow, CycleDyn) that contain the data acquisition and control system can get the data of the fuel consumption as shown in [figure 5](#).

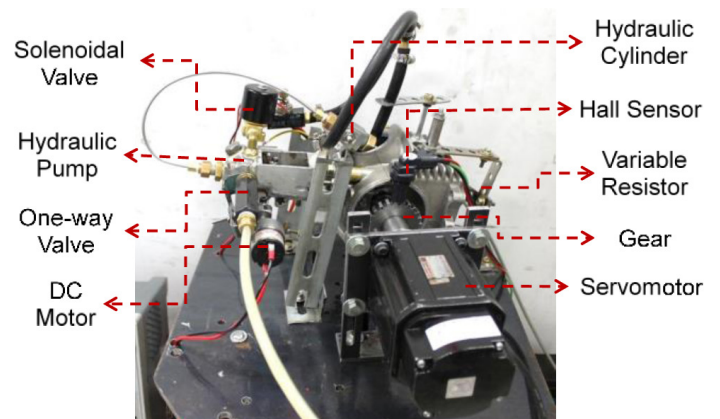


Figure 3. Hydraulic-controlled variable valve lift system measurement bench