Mechatronics 21 (2011) 1234–1238

Contents lists available at SciVerse ScienceDirect

Mechatronics

journal homepage: www.elsevier.com/locate/mechatronics

Improvement of valve seating performance of engine's electromagnetic valvetrain

Liang Liu, Siqin Chang *

School of Mechanical Engineering, Nanjing University of Science and Technology, 200 Xiaolingwei Street, Nanjing 210094, PR China

ARTICLE INFO

Article history:
Received 21 January 2011
Accepted 10 August 2011
Available online 31 August 2011

Keywords:
Camless
Electromagnetic valvetrain
Seating performance
Soft landing

ABSTRACT

The camless valvetrain is considered to be a promising solution to improve the engine performance. Most of the camless valvetrains suffer the problem of high impacts at valve seating, which restricts its mass production. This paper focuses on the valve seating performance of an electromagnetic valvetrain (EMVT) with moving coil linear actuator. The EMVT has inherent advantages to achieve low valve seating velocity. The seating performance of EMVT is evaluated by two indicators: seating velocity and holding force. To limit the seating velocity, the valve is controlled to track a desired trajectory based on inverse system method at seating process. The holding force is also properly controlled base on PID current control to ensure the cylinder sealed. The valve seating performance is validated on an experimental setup. The results show that excellent valve seating performance has been achieved.

1. Introduction

As the internal combustion engine (ICE) continues to be the most popular means of automobile propulsion, improvement of ICE is still the main method to comply with the stringent emission regulations. Camless valvetrain [1], which often refers to electromagnetic valve actuator (EMVA) and electrohydraulic valve actuator (EHVA), is considered to be an efficient technology to improve the engine fuel economy, emissions and torque output performance. Typical EMVA [2–7] uses two electromagnets and springs to draw the valve to the open or closed position. The EHVA [8–10] utilizes supplied hydraulic pressure to actuate the valves by electronically controlling the solenoids. Both the EMVA and EHVA have the freedom for some aspects of valve actuation. The valve event can be optimized for each operating conditions, and the engine performance will be improved radically. One of the key technical challenges of the camless valvetrain is to control the seating velocity of the valve. High seating velocity will cause high noise, excessive wear, and increased valvetrain stresses. It will also induce valve bounce, which may lead to unpredictable valve function and poor engine performance.

In a conventional engine, the intake and exhaust valves are actuated by mechanically driven camshafts. There is a closing ramp of the cam velocity profile to slow the valve before closure ensuring soft landing. The seating velocity is determined when the cam profile is designed, and changes with the engine speed proportionally. In a camless engine, the motion of the valve is controlled by the electromagnetic or electrohydraulic actuator. The seating velocity is related to the valve motion profile. To limit the seating velocity, precisely valve motion control near the closed position is necessary. Actually, the valve seating velocity of conventional engine can be significantly affected by several factors, including springs loads, vibrations and so on. But in a camless engine, the affection can be detected and effectively controlled.

The valve closing process of the EMVA is often divided into two or more stages. At the beginning of the valve closing process, the elastic energy stored in the springs accelerates the motion of the valve. At this stage, the valve motion is based on open loop control. Feedforward control is used to compensate the disturbances. When the valve is near to the closed position, feedback control is functioned to limit the valve seating velocity. The feedback control algorithms mainly include linearization based control [2], sensorless control [3], sliding mode control [4], Lyapunov function based control [5], and flatness based control [6]. And typical feedforward control algorithms include Extremum seeking control [11] and iterative learning control [12]. Instead of applying complicated control methodology, MIT [13] and UBC [14] proposed novel EMVAs with rotary actuator to solve the landing problem. A special designed nonlinear mechanical transformer was used to guarantee inherent soft landing by MIT. And in UBC's research, a rotary motor with linear behavior is employed to ensure soft landing. The valve seating control for the EHVA is often combined with the valve lift control, using adaptive control [8], and state feedback control [9] and so on. Sun [10] presented an EHVA with internal feedback mechanism to ensure precise valve motion, and therefore soft landing can be guaranteed.

Some of the investigations cited demonstrate effectiveness in valve seating velocity control. However, the EMVA or EHVA used has some limitations. The electromagnetic force of the EMVA increases rapidly when the armature is close to the core, so complicated control strategies must be used to limit the seating velocity,

* Corresponding author. Tel./fax: +86 25 84315451.
E-mail address: changsiqin@hotmail.com (S. Chang).

0957-4158/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.mechatronics.2011.08.002