Applied Thermal Engineering 181 (2020) 115976

Contents lists available at ScienceDirect

Applied Thermal Engineering

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

Improvement of instantaneous turbine efficiency through late intake valve phase (LIVP) in a turbocharged-gasoline direct injection (T-GDI) engine

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HIGHLIGHTS

- Late intake valve phase (LIVP) strategy.
- On engine real-time turbine efficiency evaluation.
- Instantaneous blade speed ratio.
- Instantaneous turbine efficiency.
- Instantaneous turbine mass flow parameter.

ARTICLE INFO

Keywords:
Late intake valve phase (LIVP) strategy
On engine real-time turbine efficiency evaluation
Instantaneous blade speed ratio
Instantaneous turbine efficiency
Instantaneous turbine mass flow parameter

ABSTRACT

The effects of a late intake valve phase (LIVP) strategy on crank-angle resolved real-time turbocharger efficiency were analyzed. The research is composed of experiments and simulations. In the experiments, an engine test was conducted with a downsized 2.0 L 4-cylinder turbocharged-gasoline direct injection (T-GDI) engine. In order to evaluate the effects of LIVP on the instantaneous turbocharger efficiency, the intake valve phase was retarded from its reference phase to 30 crank angle degrees (CADs) by steps of 10 CADs, while maintaining the fixed position of the other engine control parameters. Pressure in the intake and exhaust systems and turbocharger rotational speed were also measured in the experiments. In the simulation, a 1-D simulation model was built to simulate the same conditions as in the experiments. Instantaneous turbine mass flow rate as well as, temperature upstream and downstream of the turbine were extracted from the model in the units of CAD. This was done because it is inherently impossible to measure these data in the units of CAD with the existing real-world mass flow meter and thermocouples. The instantaneous blade speed ratio (BSR), turbine efficiency, and mass flow parameter were calculated by combining the results of the experiment and the 1-D simulation. In the results, the instantaneous turbine efficiency was divided into two phases and analyzed. First, in the filling phase, the effects of exhaust blow-down pulse arrival on the instantaneous turbine efficiency were analyzed. Second, in the emptying phase, the effects of exhaust gas scavenged from the cylinder on the instantaneous turbine efficiency were analyzed. The instantaneous turbine efficiency showed strong unsteady characteristics and deviated from the quasi-steady performance line. This was due to large fluctuations in the turbine inlet conditions. With the application of the LIVP strategy, the instantaneous turbine efficiency was increased. This was because of a decrease in the amount the waste-gate opened while meeting the same engine load lead to more exhaust gas energy entering the turbine, and the turbine's operating conditions were changed to more efficient conditions. Finally, correlation of the engine thermal efficiency rising according to the instantaneous turbine efficiency rising was confirmed.

1. Introduction

Global requirements for high fuel economy that are enforced on the automotive industry have pushed automakers to minimize engine size by using pressure-charging devices. In 2018, U.S. the environmental protection agency (EPA) reported that the market share of downsized

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https://doi.org/10.1016/j.applthermaleng.2020.115976
Received 22 April 2020; Received in revised form 23 July 2020; Accepted 25 August 2020
Available online 06 September 2020