Development of Gasoline Direct Injector using giant magnetostrictive materials

Article · January 2015

DOI: 10.1109/ICRERA.2014.7016476

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Development of Gasoline Direct Injector Using Giant Magnetostrictive Materials

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***Abstract*—This paper presents a conceptual design and control of a novel gasoline direct injector (GDI) using giant magnetostricitve material, Terfenol-D, as an actuation component. Electromagnetic and fluid analyses are accomplished to investigate the influence of some parameters, such as nozzle length, pressure of input fuel, and cone angle of injector's needle. Experimental results obtained from fabricated GDI show good agreement with the numerical results provided by the 3-D finite-element analysis. Furthermore, the fabricated GDI is controlled by fuzzy and PID controllers. It was shown that fuzzy controllers provide faster response with less accuracy compared to the PID controller. Consequently, there is a tradeoff between fast response and steady-state error for selecting the propoer controller.**

***Index Terms*—Finite-element method, fuzzy, gasoline direct injector (GDI), magnetostriction, Terfenol-D.**

I. Introduction

REDUCTION of fuel consumption in cars is always a hot issue for manufacturers, politicians, and environmental activists. The injector is one of the components in car's fuel system that plays a significant role in the reduction of fuel consumption. The development of four-stroke spark-ignition engines that were designed to inject gasoline directly into the combustion chamber was an important worldwide initiative of the automotive industry development of smart materials (e.g., piezoelements and magnetostrictives materials) with high-frequency bandwidth draws many researchers and companies to develop next generation of injectors by these materials. High-frequency response combined with miniaturization potential of these materials help the designer to use multiinjections in each combustion cycle. Therefore, emission of NO_x pollinations is considerably reduced. Piezoelectric fuel injectors are developed for hydrogen-fueled, diesel, and gasoline combustion engines [1]–[3]. However, a commercialized piezoelectric injector (e.g., J43Px) needs high voltage of 1000 V for a displacement of 130 μm. Furthermore, delamination in piezoelectric stack causes low life of 200 h [1] for piezoelectric injectors. Driving with low voltage and generating high strain (displacement) make giant magnetostricitve materials good candidates for these purpose. Olabi *et al.* proposed a CNG injector with magnetostrictive material without any performance test [4]. Drawbacks of piezoelectric in gasoline direct injector (GDI) were also good motivation for authors to use magnetostrictive material for developing a GDI with new nozzle configuration. Modification of the outlet nozzle comes from this fact that characteristics of outlet spray plays a significant role in efficiency of combustion. Injector's length, spray cone angle, spray width, spray penetration distance, and droplet size are considered as spray characteristics [5], [6]. Here, a conventional hollow cone nozzle is not used because of complex manufacturing process and a new tapper-shape nozzle for outlet is presented. In the presented nozzle, injector's length and cone angle (spray cone angle) are selected as effective parameters on the value of fuel consumption. The main stream of this study is feasibility study and conceptual design of a magnetostrictive GDI with new nozzle outlet. This study consists of two main parts. The first part is design, analysis, and manufacture of the GDI using Terfenol-D with modified nozzle outlet and the second part is control scheme of this developed injector. Investigations include electromagnetic and computational fluid dynamics (CFD) analysis. Due to symmetry of injector's magnetic parts, 2-D modeling is performed by Ansys12 for electromagnetic analysis. In CFD analysis, a 3-D meshed model of the gasoline flow conduit is created in GAMBIT and then simulated in FLUENT CFD software using realizable k-ε turbulent models to predict the mass flow rate of fuel to be injected. To design a controller which exerts fuel to the injector based on the needs of engine, the rate of injector needle lift must be

Manuscript received March 12, 2015; revised July 12, 2015 and September 3, 2015; accepted September 13, 2015. Date of publication September 7, 2016; date of current version January 18, 2017. Paper 2015-IACC-0145.R2, presented at the 2014 International Conference on Renewable Energy Research and Application, Milwaukee, WI, USA, Oct. 19–22, and approved for publication in the IEEE Transactions on Industry Applications by the Industrial Automation and Control Committee of the IEEE Industry Applications Society.

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Digital Object Identifier 10.1109/TIA.2016.2606591